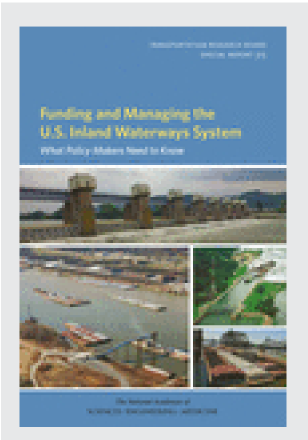

TRB Special Report 315: Funding and Managing the U.S. Inland Waterways System: What Policy Makers Need to Know

DETAILS

156 pages | 8.5 x 11 | | ISBN 978-0-309-29568-0

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TRANSPORTATION RESEARCH BOARD
SPECIAL REPORT 315

Funding and Managing the U.S. Inland Waterways System

What Policy Makers Need to Know

The National Academies of
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TRANSPORTATION RESEARCH BOARD
WASHINGTON, D.C.
2015
WWW.TRB.ORG

Transportation Research Board Special Report 315

Subscriber Categories
Economics, freight, marine policy, terminals and facilities

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Printed in the United States of America.

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the National Academy of Medicine. The members of the committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the National Academy of Medicine.

This study was sponsored by the Transportation Research Board.

Cover and page design by Beth Schlenoff, Beth Schlenoff Design
Cover photos (*clockwise from top*): Emsworth Locks and Dams, Ohio River, USACE Pittsburgh District (Chris T. Hendrickson); Starved Rock Lock and Dam, Illinois Waterway, Utica (USACE); Mississippi River Lock 15, between Rock Island, Illinois, and Davenport, Iowa (Joe Ross); and barges on the Mississippi River near St. Louis, Missouri, December 2012 (USACE).
Typesetting by Circle Graphics, Inc.

Library of Congress Cataloging-in-Publication Data

National Research Council (U.S.). Committee on Reinvesting in Inland Waterways: What Policy Makers Need to Know, author.
Funding and managing the U.S. inland waterways system : what policy makers need to know / Committee on Reinvesting in Inland Waterways: What Policy Makers Need to Know, Transportation Research Board of the National Academies of Sciences, Engineering and Medicine.
pages cm — (Transportation Research Board special report ; 315)
ISBN 978-0-309-29568-0
1. Inland water transportation—United States—Finance. 2. Inland water transportation—United States—Management. 3. Inland water transportation—Government policy—United States. 4. Federal aid to transportation—United States. I. National Research Council (U.S.). Transportation Research Board. issuing body. II. Title. III. Series: Special report (National Research Council (U.S.). Transportation Research Board) ; 315.
HE627.N38 2015
354.780973—dc23
2015024124

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Preface

This report was authored by the National Research Council (NRC) Committee on Reinvesting in Inland Waterways: What Policy Makers Need to Know. It is the culmination of an 18-month consensus study by a committee of nine diverse experts appointed by NRC to carry out the statement of task. The committee thanks the following individuals, who attended public meetings of the committee as guest presenters and helped the committee to gather the information needed to address its charge: Mark Hammond, James Hannon, Keith Hofseth, W. Jeffrey Lillycrop, Jeffrey McKee, David Moser, Mark Pointon, Burton Suedel, and Wesley Walker, U.S. Army Corps of Engineers (USACE); Rolf Schmitt and Jack Wells, U.S. Department of Transportation; Gretchen Benjamin, Nature Conservancy; Ted Coombes, Southwestern Power Resources Association; Mortimer Downey, Mort Downey Consulting, LLC; Stephen Ellis, Taxpayers for Common Sense; Robert Gallamore, Gallamore Group, LLC; John T. Gray II, Association of American Railroads; Marty Hettel, AEP River Operations; Steven M. Kramer, Association of Oil Pipe Lines; Amy W. Larson, National Waterways Conference, Inc.; Ryck Lydecker, BoatU.S.; Kristin Meira, Pacific Northwest Waterways Association; Daniel Murray, American Transportation Research Institute; Craig Phillip, Ingram Barge Company; Melissa Samet, National Wildlife Federation; Michael Steenhoek, Soy Transportation Coalition; and Michael J. Toohey, Waterways Council, Inc. The committee also thanks Christopher Dager, University of Tennessee, and Mark Sudol, USACE, for responding to requests for data and other information on inland waterways infrastructure, expenses, and funding.

The third meeting of the committee included a site visit to the Emsworth Locks and Dams facility in the USACE Pittsburgh District. The committee thanks Mark Ivanisin and Donald Zeiler for helping to arrange this visit; Richard Lockwood and John Peukert at the USACE Pittsburgh District for information concerning operations and procedures used in identifying spending priorities at the district level; and Craig Philip, Bill Porter, and Richard Kern of the Ingram Barge Company for facilitating travel to Emsworth on a company tow and providing the committee with information from the perspective of tow operators on the system.

The committee thanks Edward Carr of the University of Delaware for his assistance in analyzing public data and statistics related to inland rivers waterborne commerce, infrastructure usage, and economics and in analyzing other transportation statistics. The committee also thanks Claudia Sauls, who ably assisted with manuscript preparation, and Amelia Mathis, who assisted with meeting arrangements and logistics for committee members. The committee is grateful for the oversight and guidance of Stephen Godwin, Director of Studies and Special Programs of the Transportation Research Board. Jeffrey Jacobs, Director of the Water Science and Technology Board, provided background helpful to the study and to the committee formation process. The committee acknowledges Norman Solomon, who edited the report; Juanita Green, who managed the production; Jennifer J. Weeks, who prepared the manuscript for prepublication web posting; and Javy Awan, Director of Publications, under whose supervision the report was prepared for publication.

A draft version of the committee's report was reviewed by individuals chosen for their diverse perspectives and technical expertise in accordance with the procedures of NRC's Report Review Committee (RRC). The report review was managed by Karen Febey, Senior Report Review Officer for the Transportation Research Board, and Maureen Mellody, Senior Report Review Officer for the RRC. The purpose of this independent review is to provide candid and critical comments that will assist NRC in making its published report as sound as possible and to ensure that the report meets NRC institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. The committee thanks the following individuals for their reviews of this report: Michael Babcock, Kansas State University; Lillian C. Borrone, Port Authority of New York and New Jersey (retired); Mark Burton,

University of Tennessee; Ken Casavant, Washington State University; Gerald Galloway, University of Maryland; Michael Hanemann, University of California at Berkeley; Gerard McCullough, University of Minnesota; Craig Philip, Vanderbilt Center for Transportation Research and Ingram Barge Company (retired); Kyle Schilling, U.S. Army Corps of Engineers Institute of Water Resources (retired); and Jack Wells, U.S. Department of Transportation (retired).

Although the reviewers provided constructive comments and suggestions, they were not asked to endorse the report's conclusions, nor did they see the final draft of the report before its release. The review of this report was overseen by Charles Manski, Northwestern University, and Henry G. Schwartz, Jr., Jacobs/Sverdrup Civil, Inc. (retired). Appointed by NRC, they were responsible for making certain that an independent examination of this report was conducted in accordance with NRC institutional procedures and that all review comments received full consideration. Responsibility for the final content of this report rests entirely with the authoring committee and NRC.

Glossary

Ancillary (incidental) benefits. Benefits of a U.S. Army Corps of Engineers (USACE) project not considered or relied on to justify the investment when the project was authorized by Congress.

Contributed funds. Funds beyond any nonfederal cost contribution required by statute that may be provided voluntarily by a state or political subdivision for any project purposes, including navigation. (For example, states and private entities such as waterways users can voluntarily contribute funds for any water resource project or study beyond the required cost share, according to the Water Resources Reform and Development Act of 2014.)

Cost allocation. A process for assigning specific costs and then a share of joint costs to each beneficiary.

Cost-effective. Receipt of the greatest possible benefit for the amount paid.

Cost recovery. A requirement that all costs for construction, operation, maintenance, and repair incurred over a period of time be matched by general tax revenues and receipts from user fees in dedicated taxes. Since benefits are realized over time, payments toward cost recovery may be received over several years. Up-front costs will typically require sale of bonds; repayment of bond debt would be spread over some period of project life.

Cost sharing. A legally mandated sharing of the costs between the federal government and a nonfederal entity.

Cross-subsidy. The charging of higher prices to one group of consumers relative to the benefit received to charge (or that results in) lower prices to another consumer group relative to that group's benefit.

Dedicated tax. A required payment to a government entity to pay for a specific benefit.

Economic efficiency. Attainment of the most highly valued use of resources (or of maximal benefit relative to cost).

Financing. The advancement of funds from a public, quasi-public, or private entity to an entity initially responsible for the costs; the responsible entity then uses a combination of general revenues, user fees, and dedicated taxes to repay the incurred debt.

Freight corridor. A pathway of freight transportation used heavily by one or more modes.

General revenues. Funds received by governments from taxes or other sources of revenue that may be used for any purpose.

Inland waterways commercial navigation. Vessel movements for freight transport.

Inland waterways navigation. Vessel movements for freight transport.

Inland waterways navigation budget. Funds appropriated by Congress to USACE to provide for commercial navigation service on the inland waterways.

Project (USACE project). A USACE Civil Works infrastructure installation or activity whose scope is defined in the authorizing legislation that approves the project and that may include one or more installations or activities in one or more waterway locations. The project has passed through a feasibility study and has been approved by the Secretary of the Army before being authorized as a federal project by Congress. A USACE project has a defined purpose (or possibly more than one purpose) specified in authorizing legislation and is eligible for funding during the normal federal appropriations process.

Revolving trust fund. An account established and managed by government that is used for accumulating the revenues from user charges dedicated by law for a specific purpose and for tracking receipts and spending.

River segment. A portion of a river that may be bounded by geographic features, population centers, or trade flows.

Subsidy. A payment made or benefit provided by the federal government where the benefit exceeds the cost for the beneficiary; subsidies are designed to support the conduct of an economic enterprise or activity.

Tax. A required payment imposed to pay for a government service. (Unlike a user fee, taxes arise from the government's sovereign power to raise revenue and need not be related to receipt of a specific benefit. Unlike a fee, the tax is enforced by threats of sanction for nonpayment rather than by denial of use, as is the case for a user fee.)

Tow. A barge or group of barges (as many as 60 on the Lower Mississippi River) lashed together and propelled by a push boat (commonly called a tow boat).

User-based funding. An approach in which each beneficiary pays an amount for a good or a service equal to the benefit received.

User charge. A payment in the form of fees or taxes based on benefits received from the federal government or that in some way compensates for costs imposed on society or its resources.

User fee. A charge assessed to users of goods or services provided by the federal government normally related to the cost of the goods or services provided. The degree to which fees can be considered voluntary depends on the availability of reasonable substitutes; user fees may also be collected through a tax such as an excise tax.

Contents

Summary

The inland waterways system provides for the domestic barge shipping component of the nation's freight transportation system. The system infrastructure is managed by the U.S. Army Corps of Engineers (USACE) and funded by Congress through the USACE civil appropriations for the inland navigation budget. The Executive Committee of the Transportation Research Board initiated this consensus study of the inland waterways system because of reports of deteriorating and aged infrastructure combined with perceived inadequate capital investment, a growing backlog of capital needs, and declining federal appropriations[1] for inland navigation. The study committee was charged with addressing (a) the transportation role and importance of the federally funded inland waterways system, (b) its costs and benefits, (c) estimated levels of investment required to achieve an efficient inland waterways system and options for funding, and (d) who should pay for the required investment. (The complete charge appears in Chapter 1.)

This report describes issues relevant to policy makers in considering decisions about funding for the inland waterways system. The committee's major conclusions are as follows.

The inland waterways system is a small but important component of the national freight system.

[1] Federal appropriations for inland navigation include federal general revenues and revenues from shippers disbursed via the Inland Waterways Trust Fund.

The inland waterways system moves 6 to 7 percent of all domestic cargo in terms of total ton-miles, mostly coal, petroleum and petroleum products, food and farm products, chemicals and related products, and crude materials. The primary expense in providing for barge service is maintaining locks and other infrastructure that enables cargo movements. While many locks are more than 50 years old, age is not a useful indicator of their condition. Many locks have been rehabilitated, and lock performance correlates poorly with age. The large backlog of capital projects also is not a reliable indicator of funding required for maintaining reliable freight service. The navigation share of these projects is modest, maintenance costs are not included in the backlog, and Congress has authorized more projects than can be funded.

The most critical need for the inland waterways system is a sustainable and well-executed plan for maintaining system reliability and performance that ensures efficient use of limited navigation resources.

Time lost due to delays at locks and locks out of commission for repairs is a cost to shippers and an important consideration in deciding on future investments to maintain reliable freight service. Systemwide, about 20 percent of time lost in transportation is caused by scheduled and unscheduled outages. A more targeted operations and maintenance (O&M) budget would prioritize facilities that are most in need of maintenance and for which the economic cost of disruption would be highest. USACE has begun a process of prioritizing O&M spending along these lines, but it is not fully developed.

In contrast to the need to focus on system reliability, much of the policy discussion about the inland waterways system centers on the user charges to support the Inland Waterways Trust Fund, which is dedicated to capital improvement projects. Users, through a tax on barge fuel, and the federal government, through general tax revenues, share the cost of capital projects on a 50-50 basis. The passage of an increase in the barge fuel tax by the 113th Congress only heightens the urgency of settling on a plan for maintenance, since under federal law any new revenues from the barge fuel tax can be used only for construction and not for O&M, for which the federal government pays the full cost. Because funds for capital projects raised by the barge fuel tax must be matched by the federal government, O&M competes directly with construction for federal general revenues. O&M now accounts for about three-quarters of the requested inland navigation budget (roughly $650 million annually). Without a new funding strategy that prioritizes O&M and repairs, repairs may continue to be deferred until reaching $20 million (the point at which they become classified as a capital expenditure), which would result in further deterioration and in an inefficient and less reliable system.

More reliance on a "user-pays" funding strategy for the commercial navigation system is feasible, would generate new revenues for maintenance, and would promote economic efficiency.

In a climate of constrained federal funds and with O&M becoming a greater part of the inland navigation budget, it is reasonable to examine whether beneficiaries could help pay for the system to increase revenues for the system and improve economic efficiency. Indeed, Congress, in the 2014 Water Resources Reform and Development Act (Section 2004, Inland Waterways Revenue Studies), called for a study of whether and how the various beneficiaries of the waterways might be charged.

A reconceived system of user charges would focus policy attention on a sustainable plan for system performance and efficiency. Since users are not responsible for the cost of O&M, strong incentives exist to overcapitalize the system. Dedicating revenues from users to O&M instead of only capital expenditures would focus maintenance spending on the assets that users most value and result in a system that is more cost-effective and efficient.

Commercial navigation is the primary beneficiary of the inland waterways, and commercial carriers impose significant marginal costs on the system. Charging commercial navigation beneficiaries for the costs associated with their use of the system is feasible. User charges may be restructured in a variety of ways. There is no single best option; the preferred choice for achieving a policy goal may be to combine one or more of the options, such as an increase in the barge fuel tax with user fees. Charging user fees on the basis of facility and segment usage would identify the parts of the waterways most valued by shippers and warranting maintenance. Multiple criteria would apply in choosing among the user charge options: ease of administration, revenue potential, distribution of burden across user groups, and design components that would reinforce the efficient use of resources and cost-effective expenditures. A trust fund for maintenance would ensure that all new funds collected are dedicated to inland navigation while providing greater latitude for USACE to disburse funds for maintaining the system according to criteria approved by Congress and with the involvement of the Inland Waterways Users Board, whose current advisory role is limited to capital spending.

A special case arises for segments on which freight traffic has waned but other beneficiaries remain dependent on the pools originally created for commercial navigation service. Alternative plans and mechanisms exist under which these beneficiaries could pay for any maintenance that might be required for them to continue receiving benefits.

Deciding the amount beneficiaries would need to pay for the commercial navigation system and how to allocate the costs among beneficiaries would be a complex task. The economic value of parts of the system to commercial navigation beneficiaries would need to be identified, and a systemwide assessment of the assets required to achieve a reliable level of freight service would need to be made (see the next conclusion).

Asset management can help prioritize maintenance and ascertain the level of funding required for the system.

A standard process for assessing the ability of the inland waterways system to meet demand for commercial navigation service and for prioritizing spending for maintenance and repairs is lacking. For reasons explained in this report, the capital projects backlog and age of inland waterways infrastructure are not reliable indicators of the needs of the system or the amount of investment required. Regardless of who pays for the system, a program of economically efficient asset management (EEAM), fully implemented and linked to the budgeting process, would prioritize maintenance spending and ascertain the funding levels required for reliable freight service. USACE has adopted a generally appropriate framework for asset management that is mostly consistent with EEAM, but it is not yet fully developed or deployed across USACE districts. The framework recognizes the importance of economic consequences for strategic investment instead of assuming that all navigation infrastructure needs to be maintained at its original condition. The approach appropriately includes assessment of three main elements that follow from EEAM: the probability of failure of the infrastructure; infrastructure usage (demand), defined as whether the waterway has low, moderate, or high levels of freight traffic; and the economic consequences of failure to shippers and carriers.

A fully developed and applied asset management approach could be used to prioritize allocation of resources for O&M to the waterways with economic value to shippers and carriers and indicate areas where major rehabilitation or other capital spending should be considered. The committee offers suggestions for implementing an asset management approach in Chapter 4 (summarized in Chapter 6).

1

Introduction

The inland waterways system provides for the domestic barge shipping component of the nation's freight transportation system. The system infrastructure is managed by the U.S. Army Corps of Engineers (USACE) and funded through the USACE inland navigation budget. The United States established and funded the federal inland waterways system early in the nation's history to promote commercial shipping and the U.S. economy. Commercial shipping continues to drive federal economic interest in the system.

Reason for This Report

The Executive Committee of the Transportation Research Board (TRB) initiated this consensus study of the inland waterways system because of reports of deteriorating and aged infrastructure combined with inadequate capital investment, a growing backlog of capital needs, and declining federal funding for inland navigation. This report describes issues relevant to policy makers in considering investments for the inland waterways system.

TRB convened the Committee on Reinvesting in Inland Waterways: What Policy Makers Need to Know. Its task was to examine the role of the inland waterways in the nation's freight transportation network and, in that context, to assess issues requiring policy attention to determine the level of funding required for the system, who should pay for the system, and how system users and other beneficiaries could be charged.

Box 1-1 presents the complete statement of task that guided the work of this committee and locations in the report (italicized) that respond to each part of the task.

BOX 1-1

Statement of Task

This study will address (*a*) the transportation role and importance of the federally funded Inland Waterways System (IWS); (*b*) its costs and benefits; (*c*) estimated levels of investment required to achieve an efficient inland waterways system and options for funding; and (*d*) who should pay for the required investment.

1. The committee will assess the role of the IWS in the national freight system by examining specific corridors where commodity shipments by waterways are particularly important. [*Chapter 2.*] For a subset of these corridors, the committee will consider the implications for shippers, alternate modes, and the general public of lost or significantly degraded water transportation both now and at projected future levels of freight demand. [*Chapter 2; Appendix B.*] In corridors where the IWS competes with other modes, the committee will consider how public investments could impact the efficiency of freight movements in that corridor, regardless of mode or funding mechanism. [*Chapter 5.*]

2. At a conceptual level, the committee will describe the full range of benefits and costs of maintaining rivers and coastal channels for inland water transportation, the issues and challenges associated with characterizing as well as quantifying these costs and benefits, and the extent to which they are captured in benefit–cost analyses of the U.S. Army Corps of Engineers. [*Chapter 3.*]

3. The committee will examine alternate estimates of the level of investment required for an efficient inland waterways navigation system, taking into consideration the difference in peak demand (and therefore capital requirements) that nonstructural alternatives, such as tolls and lock scheduling, could make and the potential for disinvesting in lightly used sections of the IWS. [*Chapter 3 describes nonstructural alternatives; Chapter 4 describes an approach to achieving estimates of the level of investment required.*]

4. The committee will assess how IWS costs are currently shared among users, the public, and other beneficiaries. [*Chapter 3.*] It will also assess whether (*a*) general fund subsidies to inland waterways appear to be commensurate with public benefits; (*b*) user fees reflect costs imposed; and (*c*) a full accounting of benefits and costs (including those that can only be

(continued on next page)

BOX 1-1 *(continued)* **Statement of Task**

described qualitatively) offers insight into how capital and operating costs of the inland waterways system should be apportioned between users and the public. In examining beneficiaries of navigation investments, the committee will assess whether there are grounds and mechanisms for the nontransportation beneficiaries of the IWS to be charged for the benefits they derive from public investments in the system. [*Chapter 3; Chapter 5.*]

The study will provide answers to the questions posed above to the extent possible with existing information and identify gaps in information and knowledge required to answer these questions, including uncertainties surrounding external benefits and costs associated with the IWS and freight system more generally.

Committee's Approach

BOUNDS FOR THE SCOPE

To address its charge, the committee set judicious bounds for its work and identified certain topics as beyond its scope.

Inland Waterways System

The primary concern of this report is funding for lock and dam infrastructure on rivers or river systems. Locks and dams are the main mechanism for enabling cargo movements and the most expensive component in maintaining the inland waterways for barge transportation, although other activities such as dredging are necessary and can be costly. The Great Lakes and the Saint Lawrence River are part of the larger inland marine transportation system but not a focus of this report because of the small number of locks and dams they contain. Furthermore, these segments face issues different from those of the inland waterways system. The Saint Lawrence is a joint Canadian–U.S. system with parallel authorities for maintaining locks and traffic management, but Canada funds, manages, and maintains those segments. Most of the vessels on the Great Lakes are bulk carriers in a largely self-contained system in which vessels too large to fit through the locks on the Saint Lawrence travel back and forth as they move ore from mines and coal to utilities. Domestic offshore navigation routes, such as transportation to and from Alaska, are also excluded.

Guidance for Policy

The committee offers conceptual frameworks and practical illustrations to aid policy makers in their deliberations related to inland waterways system funding. The report identifies the main policy issues, relevant sources of data, facts to consider, and other concerns that can affect policy judgments about the inland waterways system. The statement of task did not require recommendations; in responding to the charge, the committee drew a number of conclusions on the basis of the information it analyzed, which are summarized in the Summary and in Chapter 6.

Topics Beyond the Scope

Issues related to ports and harbors are beyond the scope. USACE is responsible for deep draft harbor dredging to ensure that harbor channels can accommodate flows of freight carried on large vessels for international commerce. However, ports and harbors are managed and funded differently from the inland waterways and are not a focus of this report. Panama Canal expansion also is not addressed in this report except to the extent that it relates to arguments for the building of larger locks on parts of the inland waterways system.

Broader water resource management and funding challenges and opportunities for the nation are beyond the scope of this report. USACE has three primary mission areas: navigation for freight transportation, flood control and damage reduction, and ecosystem restoration. Other activities performed by USACE include safety and disaster relief, hurricane and storm damage reduction, water supply, hydroelectric power generation, and waterborne recreation. This report focuses on funding for the inland waterways system with regard to the freight transportation mission; it recognizes that decisions concerning shipping affect other users of water resources in the system. The National Research Council (NRC) has prepared a more general overview of issues related to the nation's water resources (NRC 2012 in Box 1-2).

In discussing its charge, the committee determined that the TRB Executive Committee, which initiated this study and oversaw development of the statement of task, was overly optimistic about what the committee could achieve in an analysis of corridors. Detailed public origin–destination data are scarce, and a full analysis of the corridors that make up the system is a study in itself and would exceed the study timeline and resources. The committee has instead provided an overview of commodity flows in major river corridors that will enable policy makers to become generally familiar with the system and understand the main issues pertaining to decisions about funding. Some readers may be concerned about the possibility for mode shifts if certain waterways are affected by deferred maintenance. However, the committee determined that generalizations or speculation about hypothetical scenarios and possible mode shifts on specific subcorridors based on a general description of the system would be inappropriate; this issue is discussed in Chapter 2, Box 2-1, p. 41.

In discussing its charge, the committee further determined that accurate forecasting of barge traffic and demand would not be prudent or feasible. As noted in the report, forecasts for traffic growth on the inland waterways system in recent years have been proven wrong by static or declining traffic. Several factors may at some point affect the demand for barge service. Among them are changes in modal access (such as new pipelines), energy prices, policy, and production that may affect the movement of coal, crude oil, and related petroleum and petrochemical products on inland waterways, pipeline, and rail; changing weather patterns that may affect water depth and flows or the production of agricultural products; and changes in the size or technology of vessels. Such factors are important to track over time, but they are beyond accurate prediction by this committee. The report includes a descriptive overview of the current system and discussions about prioritization and funding for system reliability. The discussions pertain to the present challenge of funding the existing system so that it can be responsive to fluctuations in traffic.

INFORMATION GATHERED

The committee held six meetings. Three were public with the purposes of understanding the available data and gathering various perspectives concerning system needs, management, and funding (see the Preface for a list of attendees); three consisted of deliberations and preparation of the committee's report. Five meetings were held at the National Academies buildings in Washington, D.C. The third public meeting was held at Carnegie Mellon University in Pittsburgh, Pennsylvania, with a site visit to the Emsworth Locks and Dams facility in the USACE Pittsburgh district. The site visit was planned to aid the committee in understanding operations at the USACE district level and the procedures used in identifying priorities for spending at facilities in the navigation system. The site visit included travel to Emsworth on a tow of the Ingram Barge Company, which provided the committee with further information from the perspective of tow operators on the system.

This report draws on a number of past NRC reports related to the nation's water resource and freight transportation system (Box 1-2).

BOX 1-2

Related NRC and TRB Reports

NRC. 2001. *Inland Navigation System Planning: The Upper Mississippi River–Illinois Waterway.* National Academy Press, Washington, D.C.

NRC. 2004. *Analytical Methods and Approaches for Water Resources Project Planning.* National Academies Press, Washington, D.C.

NRC. 2004. *Review of the U.S. Army Corps of Engineers Restructured Upper Mississippi–Illinois River Waterway Feasibility Study.* National Academies Press, Washington, D.C.

NRC. 2005. *Water Resources Planning for the Upper Mississippi River and Illinois Waterway.* National Academies Press, Washington, D.C.

NRC. 2012. *Corps of Engineers Water Resources Infrastructure: Deterioration, Investment, or Divestment?* National Academies Press, Washington, D.C.

TRB. 2003. *Special Report 271: Freight Capacity for the 21st Century.* Transportation Research Board of the National Academies, Washington, D.C.

TRB. 2006. *Special Report 285: The Fuel Tax and Alternatives for Transportation Funding.* Transportation Research Board of the National Academies, Washington, D.C.

TRB. 2012. *NCFRP Report 15: Dedicated Revenue Mechanisms for Freight Transportation Investment.* Transportation Research Board of the National Academies, Washington, D.C.

The current report differs from and extends previous NRC and TRB reports in that it focuses on strategies for investing in the inland waterways system and does so with consideration of the role of the system in the nation's freight transportation network. The report also is informed by a number of key reports of the Congressional Research Service, the U.S. Government Accountability Office, and the Congressional Budget Office. Primary sources of data for analyses in the report include USACE Waterborne Commerce Statistics and the U.S. Department of Transportation Freight Analysis Framework.

Organization of the Report

This report is organized into six chapters. Chapter 2 describes the role of the inland waterways system in national freight transportation. It includes discussion of major corridors and commodities shipped. Indicators of the condition and functioning of lock and dam infrastructure are described, some of which could be used to prioritize maintenance spending for commercial navigation.

Chapter 3 describes federal involvement in the management and funding of the inland waterways and the federal role relative to other transportation modes. It presents considerations to take into account in deciding on the federal role in funding the inland waterways, including grounds and mechanisms for charging users of the system.

Chapter 4 describes a strategy for prioritizing navigation expenditures on the basis of the concept of economically efficient asset management. It also describes a framework that USACE is developing for asset management and that could be advanced to prioritize spending.

Chapter 5 presents a user-based approach to funding the system with user charges both to increase revenues for system maintenance and to promote economic efficiency by targeting limited navigation resources to parts of the system most valued for freight transportation. It describes the various user payment options and criteria for evaluating them. Alternative plans are considered for parts of the system that have minimal freight traffic but that may have benefits other than commercial shipping.

Findings and conclusions are summarized at the end of each chapter. Chapter 6 summarizes major conclusions and findings from the report. The chapters are followed by appendixes, which provide more detailed technical data and explanation related to issues raised in the chapters.

A glossary of terms used in the report appears after the Preface.

Intended Audiences

The primary audience for this report is policy makers at the federal level who are responsible for decisions about inland waterways system funding and who may have varying familiarity with the system and the issues and arguments related to its support. Secondary audiences include state and local governments, users and beneficiaries of the waterways, and private organizations and individuals with an interest in the management and funding of freight transportation and the nation's water resources.

2

Role of the Inland Waterways System in National Freight Transportation

This chapter describes the inland waterways, with a focus on those parts used to transport freight and an eye toward describing certain aspects of the system that warrant consideration in decisions about funding. The first section below describes the physical characteristics and history of the system. The next describes the major corridors, the commodities shipped, and the contribution of the inland waterways system to national freight transportation relative to other modes. The condition and performance of the system, including reliability (delays and unavailabilities), usage, and age of the infrastructure, are then discussed. An alternative approach for assessing the age of infrastructure is considered, and a model and possible metrics for understanding the impact of delays across the system are offered. The final section summarizes findings and conclusions from the chapter.

Overview of U.S. Inland Waterways

CHARACTERISTICS

The inland waterways navigation system is part of the U.S. marine transportation system (MTS), which provides for both passenger transport and domestic freight transportation infrastructure and coastal gateways for global trade (TRB 2004). The MTS includes navigable waterways and public and private ports on three coasts (Atlantic, Pacific, and Gulf) and the Great Lakes as well as a network of inland waterways (CMTS 2008). It includes, by extension, inland highway and rail connections between ports and inland markets that ensure access to the water for shippers and customers in all 50 states (AASHTO 2013; CMTS 2008).

The inland and intracoastal waterways directly serve 41 states[1] (Clark et al. 2012).

The inland waterways system comprises navigable rivers linked by a series of major canals. Lock and dam infrastructure is the chief mechanism in enabling the upstream and downstream movement of cargo, and its installation is the most expensive component in providing for navigation service (McCartney et al. 1998).[2] Waterways are categorized as deep draft, shallow draft, both (allowing both shallow and deep draft vessels), or nonnavigable, as shown in Table 2-1, which reports the average control depths in the U.S. Army Corps of Engineers (USACE) geographic information system (GIS) data. Because of shallow drafts and seasonal changes in navigable depths, fixed infrastructure is required in many parts of the river system to maintain open navigation for commerce.

The nation's inland waterways include more than 36,000 miles of rivers, waterways, channels, and canals, with 241 locks managed by USACE at 195 sites.[3] [Kruse et al. 2007; USACE Navigation Data

[1] The U.S. Army Corps of Engineers geographic information system viewer data can mostly confirm this. The committee counts 39 states (40 including the District of Columbia) if the focus is on shallow draft or both shallow and deep draft and if nonnavigable and deep draft (only) and unknown segments are eliminated. Some of the inland and intracoastal waterways are access routes for deep draft vessels; with those included, the committee counts 41 (43 including the District of Columbia and Puerto Rico). Some are coastal states (e.g., California, Delaware, New Jersey, Maryland) with minor inland or intracoastal waterways outside of the committee's charter. For example, 12 states, ranked by ton-miles, account for 80 percent of ton-miles and 74 percent of tons moved by inland waterway. Conversely, an overlapping but not identical 12 states ranked by tons account for 80 percent of the tons and 75 percent of the ton-miles moved by inland waterway.

[2] The U.S. Army Corps of Engineers Navigation Data Center provides data on the national waterways network with defined geographic classes that include ocean, Great Lakes, and inland rivers (http://www.navigationdatacenter.us/data/dictionary/ddnwn.htm).

[3] The USACE GIS viewer data identify some 250 locks in the USACE Navigation Data Center GIS data. Nineteen are listed as seasonal. The analysis in this chapter eliminated those identified as caretaker, closed, or inoperable.

Included in the 36,000 miles are the Erie Canal, a portion of the Saint Lawrence Seaway (the 101.2-mile stretch that borders New York from Lake Ontario), and other border connections such as Lake of the Woods to Lake Superior and the Saint Marys River connecting Lakes Superior and Huron. The full extents of the Gulf Intracoastal and Atlantic Intracoastal Waterways are also included.

Navigable waterways are defined in terms of the USACE link data dictionary (http://www.navigationdatacenter.us/data/dictionary/ddnwn.htm) in the GIS data set nwn.zip available at http://www.navigationdatacenter.us/db/gisviewer/, with GEO = I, inland, for the contiguous United States.

[*Footnote continues on next page.*]

TABLE 2-1 Summary Characteristics of the Inland Waterways of the National Waterways Network

Inland Geographic Class	Length of Waterway (miles)	Average Control Depth (feet)
Deep draft navigation	1,901	35
Shallow draft navigation	21,218	10
Both (deep and shallow draft)	13,205	28
Total	**36,324**	

NOTE: Shallow draft navigation includes all waterway segments with navigable depths; not all of these waterways carry substantial cargo. About 11,000 of the 36,000 inland waterway miles are part of the fuel-taxed inland waterways navigation system specified in legislation and subject to a barge fuel tax used to pay 50 percent of the costs of inland waterways system infrastructure construction (see Appendix A for a list of fuel-taxed inland waterways).

SOURCE: USACE Navigation Data Center GIS Viewer (http://www.navigationdatacenter.us/db/gisviewer, file ndcgis13shp.zip, updated May 16, 2013; accessed July 2014).

Center GIS Viewer files (http://www.navigationdatacenter.us/db/gisviewer, accessed July 2014)]. As shown in Figure 2-1, most of the navigable channels are rivers located in the central and eastern half of the country. The largest river system is the Mississippi, which is navigable for about 1,800 miles from New Orleans, Louisiana, to Minneapolis, Minnesota, and has a large tributary system. In the western part of the country the largest inland waterway is the Columbia–Snake River system. As described in Chapter 1, this report covers the inland waterways, excluding the Saint Lawrence Seaway system and the Great Lakes.

HISTORICAL CONTEXT

At the time of the American Revolution (1775–1783), a shipper had to pay as much to move a ton of freight 30 miles inland as to move it across the Atlantic (AASHTO 2013). As the new nation

USACE has responsibility for enabling commercial navigation on approximately 25,000 of these miles. [See the nwn.zip (http://www.navigationdatacenter.us/db/gisviewer/) data set filtered by GEO = I, inland; FUNC = S, D, B; WTYPE = 2, 6–9, 12 for all states in the contiguous United States; see the USACE link data dictionary (http://www.navigationdatacenter.us/data/dictionary/ddnwn.htm) for a complete description of the codes used. All data sets were accessed in September 2014.]

FIGURE 2-1 Inland and intracoastal waterways system.

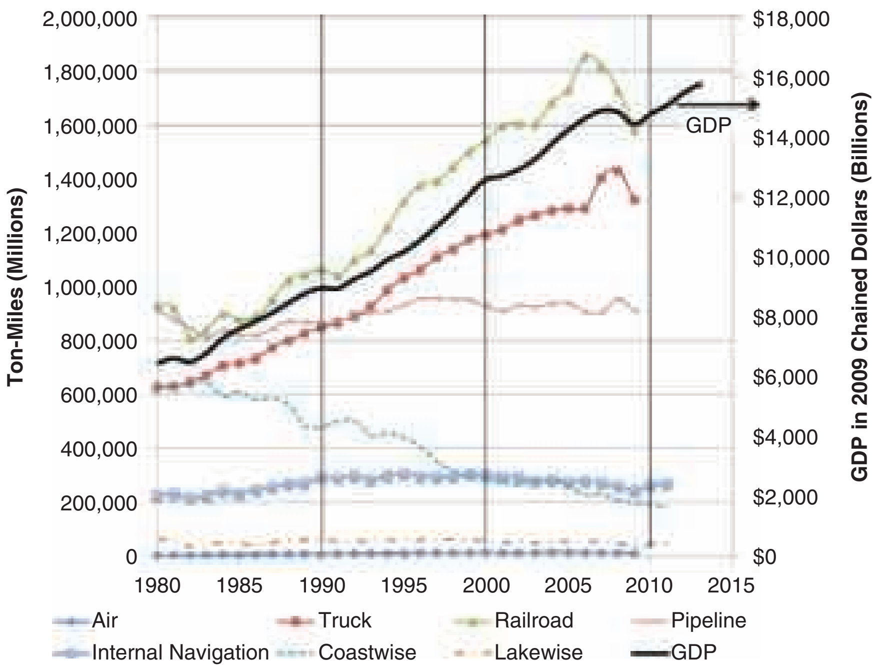
SOURCE: USACE Navigation Data Center GIS Viewer (http://www.navigationdatacenter.us/db/gisviewer, file ndcgis13shp.zip, updated May 16, 2013; accessed July 2014).

began building, leaders understood that a good transportation system would be essential in opening the country's vast interior and increasing national wealth. In view of the availability of easily navigable waterways, waterborne commerce was the primary viable option for transporting freight over significant distances. The inland waterways carried grain, lumber, and coal to the eastern ports and finished goods and immigrants to the rapidly developing Northwest Territory (National Park Service 2013).

The emergence and rapid expansion of railroads complemented the north–south river system with an east–west alignment. Railroads allowed waterways to become even more productive as they carried goods to river ports, where they were consolidated and moved by barge to seaports for export (AASHTO 2013). Later, rail became a direct substitute for slower canal transport. In the early 20th century, the development of technologies related to automobiles, trucks, and highways spurred a new age of industrial development in the United States (AASHTO 2013). Trucking emerged as the most viable mode for serving local and regional freight markets. Trucks carried water and rail freight to and from the interior communities and functioned as a faster door-to-door mode for higher-value cargoes. The federal Interstate and state highway networks made trucking competitive with rail serving long-haul markets for time-sensitive, high-value commodities with speedy, reliable service (AASHTO 2013). Intermodal freight systems became the standard for nonbulk products with the introduction of containerization, unitized cargo configurations that could be transferred among truck, rail, and water modes without repackaging. Associated technologies made their tracking and reliable delivery more transparent to shippers.

NATIONAL ECONOMY

The inland waterways freight system makes a relatively small but stable contribution to the overall economy. Since 2000, it has carried about half of domestic U.S. waterborne commerce, measured in ton-miles, and 6 to 7 percent of all ton-miles (Figure 2-2).

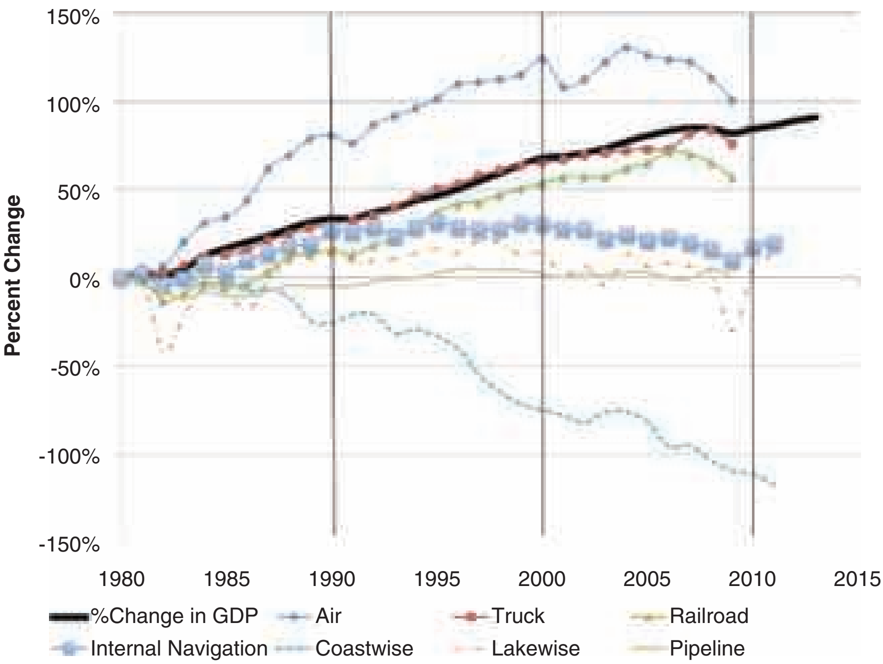


(a)

FIGURE 2-2 Trends for various modes in terms of (*a*) ton-miles and (*b, next page*) U.S. GDP. These data do not include trends in foreign imports of cargo delivered to U.S. ports. That is, imports become domestic after processing through U.S. Customs at ports of entry; therefore, trucking volumes and some rail volumes increase over time because of growth in imported freight flows, whereas U.S. pipeline transport and domestic waterway transport primarily serve domestic-only freight flows (with the notable exception of grain exports).

(continued on next page)

SOURCE: GDP is from the Bureau of Economic Analysis, current-dollar and "real" GDP (http://www.bea.gov/national/xls/gdplev.xls, accessed May 29, 2014), where GDP is in billions of chained 2009 dollars; ton-miles data were compiled from the National Transportation Statistics of the Bureau of Transportation Statistics, various years (http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_50.html and http://www.rita.dot.gov/bts/node/81022, accessed May 2014).



(b)

FIGURE 2-2 *(continued)* Trends for various modes in terms of (*b*) U.S. GDP.

Some modes of transportation are correlated with the economy measured in terms of gross domestic product (GDP), especially truck and rail, which deliver goods for final consumption. Other modes are less correlated with economic growth, such as waterborne commerce and pipeline transportation of energy products. Pipelines and barge are more specialized modes that carry a narrower range of products than trucking or rail and may be correlated with the output of the industries whose goods they carry. These modes provide essential transportation services that underpin the ability of trucking and rail to deliver consumer products.

The following will help put in perspective the contribution of waterborne commerce to the U.S. economy. The transportation sector overall contributes approximately 3 percent of U.S. GDP, according to the Bureau of Economic Analysis (http://www.bea.gov/iTable

/index_industry_gdpIndy.cfm). Water transportation contributes nearly $15 billion in value added to U.S. GDP, compared with nearly $120 billion from truck transportation, more than $60 billion from air transportation, more than $30 billion from rail transportation, and $15 billion from pipeline transportation (Table 1 in http://www.bea.gov/scb/pdf/2012/05%20May/0512_industry.pdf and Table 1-2 in the North American Transportation Statistics, http://nats.sct.gob.mx/en/). Water transportation represents about 0.1 percent of total GDP. This amount includes all water transportation for passengers and freight, since data are not available specific to the inland waterways and freight. As shown in Figure 2-3, the transport sector contribution to GDP is declining (slightly), whereas water transport is about constant.

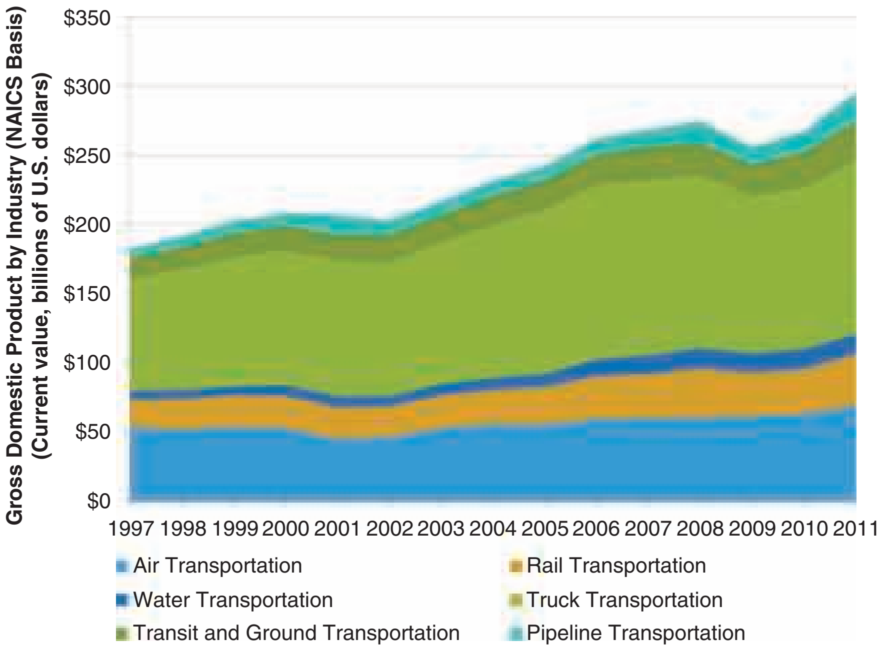
Similarly, the inland water transportation labor force has been constant for a number of years at about 20,000 (2007 census data, http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk, and 2012 data from U.S. Census Bureau, 2012 County Business Patterns, accessed June 2014).

Inland Waterways Traffic

Freight traffic is highly variable across the inland waterways system, as shown in Figure 2-4. For the purpose of illustration, river segments are categorized in Figure 2-4 as high use, moderate use, or low use according to the number of ton-miles carried.[4] Notably, the high-use parts of the inland waterways represent 22 percent of the total inland waterway miles and account for 76 percent of the cargo ton-miles transported[5] (USACE 2013 and USACE Navigation Data Center, http://www.navigationdatacenter.us/db/gisviewer/, file linktons11.zip, updated August 14, 2013, and accessed July 2014).

[4] These category definitions for usage also form part of the guidance that USACE follows for spending priorities (USACE 2013, Appendix F, Table F-1 and Section F-12). The guidance allows for categorizing usage according to both number of ton-miles and number of lockages.

[5] These percentages were computed by adding the ton-miles reported by the USACE Navigation Data Center within each illustrative usage category used by USACE and specified in the guidance (USACE 2013).

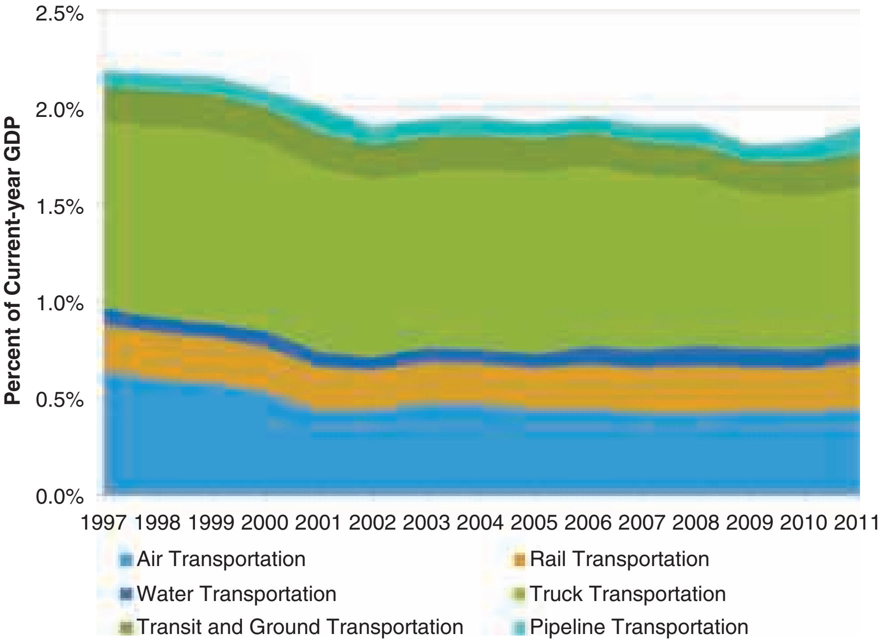


(a)

FIGURE 2-3 Summary of transportation contribution to U.S. GDP trends (*a*) in billions of dollars and (*b, page 23*) as a percentage of the total economy. Data show real dollars indexed to 2009. The data encompass all of water transportation, including passenger transportation; data are not available specific to the inland waterways and freight. Figures indicate the North American Industry Classification System categories. For further details, see http://nats.sct.gob.mx/english/go-to-tables/table-2-transportation-and-the-economy/table-2-1-gross-domestic-product-gdp-attributed-to-transportation-related-final-demand/#sthash.EenJZ015.dpuf.

(continued)

SOURCE: NATS 2012, Table 2-1: Gross Domestic Product (GDP) Attributed to Transportation-Related Final Demand (http://nats.sct.gob.mx/english/go-to-tables/table-2-transportation-and-the-economy/table-2-1-gross-domestic-product-gdp-attributed-to-transportation-related-final-demand/, accessed July 2014).



(b)

FIGURE 2-3 *(continued)* Summary of transportation contribution to U.S. GDP trends (*b*) as a percentage of the total economy.

Figure 2-4 also illustrates one of the thorny issues of inland waterways system funding. While some of the low-use tributaries appear to be less important, they may contribute shipments that join other commerce on the downstream moderate- and high-use segments. Since the shipments from individual low-use tributaries are a small contribution to total system flows, their marginal value added is also low, although their collective contribution is greater, and some individual segments may be important for moving cargo. When proponents of the inland waterways system refer to the need to preserve the network, they often are referring to these low-use tributaries and their contribution to total system freight flows. In many cases shippers have organized their operations to take advantage of low-cost water transportation of bulk commodities on these segments, and some would have few or no practical alternatives for shipping or receiving their bulk materials if the low-use segment were to be closed to commercial navigation.

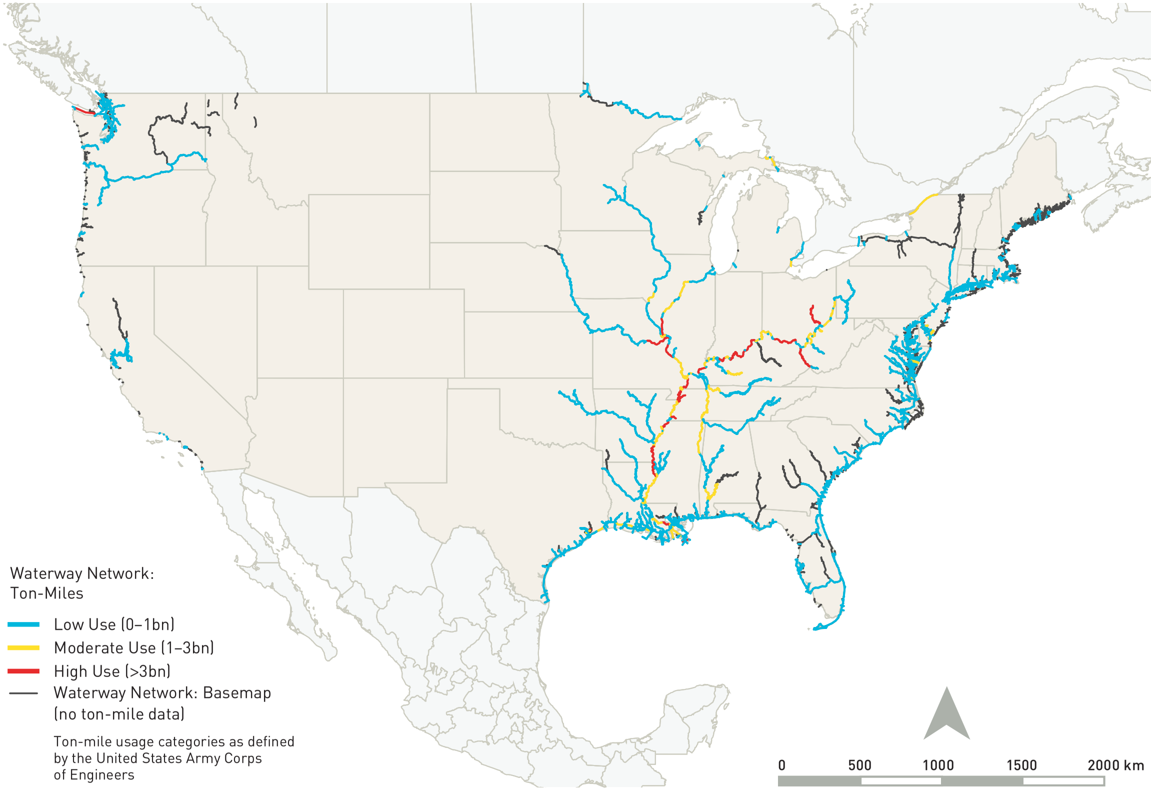


FIGURE 2-4 Inland waterways network with high-, moderate-, and low-use river segments in 2011.

SOURCE: USACE, Navigation Data Center, http://www.navigationdatacenter.us/db/gisviewer/, file linktons11.zip; updated August 14, 2013; accessed July 2014.

MAJOR INLAND WATERWAYS CORRIDORS

In 2012, inland waterways (internal) barge traffic accounted for 57 percent of U.S. domestic waterborne tonnage and about 70 percent of all domestic barge traffic (USACE 2013), as shown in Table 2-2.

Table 2-3 and the sections that follow summarize the features of the six major corridors that move substantial tonnages of waterborne commerce: the Upper Mississippi River, the Lower Mississippi River, the Ohio River, the Gulf Intracoastal Waterway (GIWW), the Illinois River, and the Columbia River system. This chapter focuses mainly on these six river corridors because they represent 80 percent of the commercial lockages, as shown later in Figure 2-13.[6] For perspective, the miles of waterway on the six corridors represent about 16 percent of the total 36,000 inland river miles (as described in Table 2-1). These six rivers carry about 50 percent of the cargo transported (in ton-miles) on the inland waterways.[7] While these six major corridors carry most of the freight, other river systems may transport regionally important commodities and may provide subcorridor routes for critically important freight movement at regional or national scales.[8] (See Appendix B for a map representation and listing of major commodity-specific corridors generated from USACE Waterborne Commerce Statistics.)

Upper Mississippi River

The Upper Mississippi River flows south from Minneapolis, Minnesota, 858 miles to the mouth of the Ohio River at Cairo, Illinois. The navigation channel above Saint Louis, Missouri, is maintained at a minimum depth of 9 feet by a system of 27 locks and dams. As Table 2-3 indicates, agriculture-related products dominate the commodity flows on this river. Farm products, primarily grain shipped downbound for export through

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[6] USACE Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/lpms/lpms.htm, Locks by Waterway, Lock Usage, Calendar Years 1993–2013, accessed July 2014.

[7] This statistic is derived from USACE commodity and usage statistics. Commodity statistics are at http://www.navigationdatacenter.us/lpms/cy2013comweb.htm. Usage statistics are at http://www.navigationdatacenter.us/lpms/lock2013web.htm.

[8] Furthermore, the waterway freight tonnage data alone cannot fully characterize the economic value of the corridors because these freight flows necessarily involve drayage or long-haul trucking and can complement rail transport serving the commodities. For example, the heavy flow of coal by rail from the Powder River Basin to the Midwest is economically tied to the heavy waterway flows on the Mississippi and Ohio Rivers.

TABLE 2-2 Barge Freight Traffic Summary for 2012, by Commodity and Waterway Type

Commodity	Total Barge	Coastwise or Lakewise	Inland (internal)	Intraport or Intra-territory	All Traffic (barge and nonbarge)	Barge (%)	Percent of All Domestic Traffic That Is Inland Barge (internal)	Percent of Barge Traffic That Is Inland Barge (internal)
Total	737.6	101.1	557.6	79.1	884.8	83	63	76
Coal	182.7	4.0	169.0	9.7	200.0	91	85	93
Petroleum and petroleum products	252.4	55.5	149.2	47.7	311.1	81	48	59
Chemicals and related products	70.4	8.7	50.7	11.0	72.8	97	70	72
Crude materials	111.5	16.9	85.9	8.7	165.7	67	52	77
Primary manufactured goods	31.0	3.9	26.2	0.9	32.4	96	81	85
Food and farm products	76.1	1.9	73.7	0.5	79.1	96	93	97
All manufactured equipment	12.2	10.0	1.8	0.4	22.3	55	8	15
Other	1.3	0.0	1.0	0.3	1.5	100	67	77

NOTE: Except for percentages, figures are in millions of tons. "Intraport" refers to movement of freight within the confines of a port whether the port has one or several arms or channels included in the port definition. This traffic type will not include car ferries and general ferries moving within a port. "Intraterritory" refers to traffic between ports in Puerto Rico and the Virgin Islands, which are considered a single unit.

SOURCE: Table 2-3 of Part 5, National Summaries, Waterborne Commerce of the United States, 2012, published November 2013, http://www.navigationdatacenter.us/wcsc/wcsc.htm. (Values rounded to nearest 100,000 tons; therefore, percentages may differ because of rounding.)

TABLE 2-3 Freight Traffic for Six Major U.S. Inland Waterways, 2012

Waterway Description	Commodities	Short Tons (millions)	Percent of Total
Upper Mississippi River (Minneapolis, Minnesota, to mouth of Ohio River)	**Total**	**110.1**	**100**
	Coal	24.1	21.9
	Petroleum and petroleum products	12.8	11.6
	Chemicals and related products	11.4	10.3
	Crude materials	16.7	15.2
	Primary manufactured goods	9.8	8.9
	Food and farm products	35	31.7
	All manufactured equipment	0.3	0.3
	Other	0	0
Lower Mississippi River (mouth of Ohio River to Baton Rouge, Louisiana)	**Total**	**186.3**	**100**
	Coal	37.3	20
	Petroleum and petroleum products	20.1	10.8
	Chemicals and related products	22.3	11.9
	Crude materials	31	16.6
	Primary manufactured goods	12.8	6.9
	Food and farm products	62.5	33.6
	All manufactured equipment	0.4	0.22
	Other	0	0
Ohio River system	**Total**	**239.1**	**100**
	Coal	140.2	58.5
	Petroleum and petroleum products	14.4	6
	Chemicals and related products	10.5	4.4
	Crude materials	51.9	21.7
	Primary manufactured goods	8.7	3.6
	Food and farm products	13.4	5.6
	All manufactured equipment	0.1	0.04
	Other	0	0

(continued on next page)

TABLE 2-3 *(continued)* Freight Traffic for Six Major Inland Waterways, 2012

Waterway Description	Commodities	Short Tons (millions)	Percent of Total
Gulf Intracoastal Waterway (from Florida to Texas)	**Total**	**113.7**	**100**
	Coal	2.5	2.2
	Petroleum and petroleum products	65.8	57.8
	Chemicals and related products	21.2	18.7
	Crude materials	16.7	14.7
	Primary manufactured goods	4.6	4.1
	Food and farm products	1.4	1.3
	All manufactured equipment	0.8	0.7
	Other	0.6	0.5
Illinois River	**Total**	**31**	**100**
	Coal	2.7	8.5
	Petroleum and petroleum products	5.7	18.4
	Chemicals and related products	5.2	16.7
	Crude materials	3.2	10.4
	Primary manufactured goods	3.6	11.6
	Food and farm products	10.6	34.1
	All manufactured equipment	0.1	0.24
	Other	0	0
Columbia River system (including Columbia, Willamette, and Snake Rivers)	**Total**	**57.3**	**100**
	Coal	0	0
	Petroleum and petroleum products	4.9	8.5
	Chemicals and related products	6.1	10.6

(continued)

TABLE 2-3 *(continued)* Freight Traffic for Six Major Inland Waterways, 2012

Waterway Description	Commodities	Short Tons (millions)	Percent of Total
Columbia River system (*continued*)	Crude materials	11.8	20.7
	Primary manufactured goods	2.6	4.5
	Food and farm products	30.3	52.9
	All manufactured equipment	0.9	1.7
	Other	0.6	1.1

NOTE: These totals cannot be summed to compare with Table 2-2 because the same tonnages often move on connected rivers within commodity corridors; national summaries avoid duplicative reporting of total tonnages.

SOURCE: USACE, Waterborne Commerce of the United States, Calendar Year 2012, Waterborne Commerce Statistics Center, New Orleans, Louisiana, November 2013, Parts 2 and 4.

the Gulf Coast deepwater ports, account for 32 percent of the tonnage. The Upper Mississippi also is the top regional source for corn and soybean exports. The second-ranked commodity is coal, which accounts for 22 percent of the tonnage. Much of the chemical tonnage (10 percent of the total) consists of fertilizers shipped upbound back to the farm belt.

The dominant flows on the Upper Mississippi illustrate the modal competition and cooperation aspects of much waterborne commerce. For example, much of the grain is shipped by truck or rail to waterside grain elevators for transloading to barges, which then transload again to deepwater vessels in southern Louisiana for export to world grain markets. Trains also bring grain to the Gulf Coast, so for some farms there is at times a genuine modal choice between rail and water transport. However, grain transactions turn on margins as low as cents per bushel, so most shippers are essentially heavily dependent on one mode or the other. During the height of the harvest season, the capacities of both the rail and the inland waterways systems are stretched to keep up with shipping demand. The coal traffic on the system consists largely of low-sulfur coal that is shipped by unit train from the western coal fields to large transloading facilities at places like Cora and Metropolis, Illinois, where it is loaded onto barges for movement to waterside electric power plants on the Ohio and Mississippi Rivers. Usually, competition among transport modes to serve a major shipper facility occurs when the facility site is being selected. Once the decision is made to locate a facility on a particular mode (e.g., a grain elevator or power plant is located on a river), goods movement tends to depend on that mode.

Lower Mississippi River

The Lower Mississippi River flows 956 miles from the mouth of the Ohio River at Cairo, Illinois, to the Mouth of Passes in the Gulf of Mexico. There are no navigation locks on this portion of the inland waterways system. Navigation depth is maintained by river training works such as groins and revetments and by periodic maintenance dredging of shoals. Operations on this segment typically feature large tows, since the size of tows is not constrained by lock sizes. Table 2-3 shows the commodity tonnages on the 720-mile stretch from Cairo to Baton Rouge, Louisiana. The commodity mix there is similar to that on the Upper Mississippi, but the quantities are 50 to 100 percent greater.

Ohio River System

The Ohio River begins at the junction of the Allegheny and Monongahela Rivers at Pittsburgh, Pennsylvania, and flows in a southwesterly direction 981 miles to its mouth at Cairo, Illinois, where it empties into the Mississippi River. Navigation is maintained at a minimum 9-foot channel depth by 20 locks and dams on the Ohio River (Olmsted Lock will replace two older locks near the lower end of the river). Table 2-3 shows the commodity flow on the entire Ohio River system, which includes the Ohio mainstem and its tributaries. The Monongahela, Kanawha, and Tennessee Rivers contribute significant flow to the Ohio.

Coal is the dominant commodity on the system, making up 59 percent of the tonnage in 2012. Most is steam coal, which moves both inbound and outbound on the system. Coal mines in Appalachia send coal to the river via conveyor belt, truck, and rail for shipment to river-located electric power generation plants. Those power plants also receive upbound coal from other sources, and there is still considerable movement of metallurgical coal on the Ohio and its tributaries. The second-ranked commodity group, crude materials (nearly 22 percent of the total), consists primarily of sand, gravel, and limestone.

While rail lines run parallel along most of the Ohio, they are primarily part of the nation's extensive east–west manufactured products and foodstuffs distribution system. As a practical matter, the large quantities of coal and crude materials moving on the Ohio could not easily be diverted to rail. Coal alone would require the railroads to handle more than 1 million additional carloads annually and to provide in excess of 26 more train movements per day (Kruse et al. 2012). Furthermore, most of the shipping and receiving facilities for this traffic are designed and operated specifically to handle barge shipments. Thus, as was the case for the Upper Mississippi, rail, truck, pipeline, and conveyor belts are complementary to water transport.

Gulf Intracoastal Waterway

The GIWW provides a protected route along the Gulf Coast from Saint Marks, Florida, to the Mexican border at Brownsville, Texas. The total distance is 1,109 miles, and the maintained minimum channel depth is 12 feet. The system includes 10 locks, which serve a variety of purposes. The Inner Harbor Navigation Canal lock at New Orleans connects the Mississippi River to the GIWW and overcomes elevation differences between the river and the canal. The lock is currently one of the most congested on the entire inland waterways system.

As would be expected in view of the GIWW's location in the largest petrochemical region of the United States, petroleum and chemicals dominate the system's commodity flow. Together they made up 76.5 percent of the tonnage in 2012. Crude materials ranked third, at nearly 15 percent. Within these broad groups a wide variety of specific commodities are moved, in keeping with the region's complex industrial base. Pipelines are the main competing and complementary mode, but the circumstances of individual plant locations and outputs defy any easy generalizations.

Illinois River

The Illinois extends 292 miles from Lockport, Illinois, to its mouth at the Mississippi River at Grafton, Illinois, just above Saint Louis. Above Lockport, various channels connect the Illinois River and the Mississippi River system to Lake Michigan at Chicago, Illinois. The

Illinois has a minimum maintained channel depth of 9 feet and seven lock sites with single chambers 600 feet long by 110 feet wide. These dimensions require the typical tow of 15 jumbo barges to double lock, and the lack of auxiliary chambers means that any lock outage will shut down navigation. The Illinois is a typical moderate-use waterway. It moved 31 million tons in 2012. The commodity mix was similar to that on the Mississippi, but with a smaller proportion of coal and a greater proportion of petroleum and chemicals.

Columbia River System

The Columbia River has the longest inland navigation channel on the U.S. West Coast. The Columbia provides a shallow draft waterway (14-foot depth) from Kennewick, Washington, to Vancouver, Washington, and Portland, Oregon, a distance of approximately 225 miles. Below Portland, a deep draft channel (40 feet) extends approximately 100 miles to the river's mouth at the Pacific Ocean. There are four navigation dams on the shallow draft section. Above Kennewick, the Snake River allows navigation for 140 miles upstream to Lewiston, Idaho. The Willamette River drains northwestern Oregon and flows into the Columbia near Portland, where it forms part of that city's deep draft harbor.

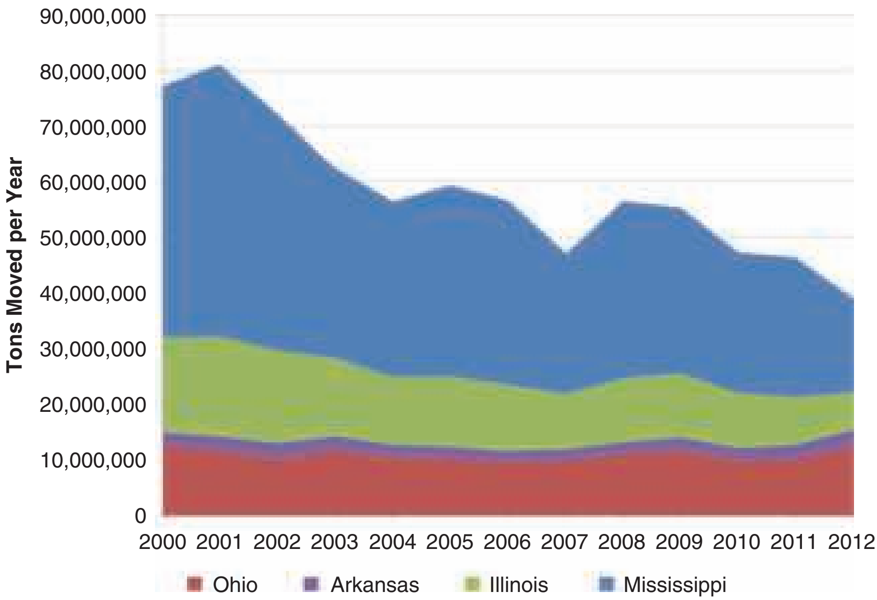
Agriculture dominates flows on the Columbia. Food and farm products constituted 53 percent of the tonnage in 2012. About 76 percent of these agricultural products were grain and soybeans shipped for export. The Columbia River is the top gateway for U.S. wheat exports. It accounts for about 16 percent of all food and farm products moved on the inland waterways and about 3 percent of all food and farm imports and exports. Crude materials, largely forest products and sand and gravel, made up another 20 percent of the tonnage. The river also plays an important role in distribution of petroleum products throughout the region. There are rail lines along both the north and the south shores of the Columbia River. They are running at or near capacity, with much of that capacity devoted to serving the intermodal container trade.

COMMODITY TRENDS BY CORRIDOR

As shown in Table 2-3, the principal commodities carried on inland waterways system corridors are coal, petroleum and petroleum products, food and farm products, chemicals and related products, crude materials, manufactured goods, and manufactured equipment. Examination of annual commodity trends for several of the chief commodities on most of the primary corridors during the period 2000 to 2013 indicates adequate capacity in the system. Aside from petroleum products moving on the Lower Mississippi, commodity movement appears to be stable or declining for more than a decade for most corridor segments (Figure 2-5 and Figure 2-6).

MULTIMODAL COMPARISONS

Concern over maintaining the inland waterways system extends to the consequences for other modes if large shifts in freight from water to rail or highway occur because of steadily declining investment in the waterways. However, comparison of freight transport across modes in the con-



(a)

FIGURE 2-5 Annual trends by river in (*a*) midnation food and farm products.

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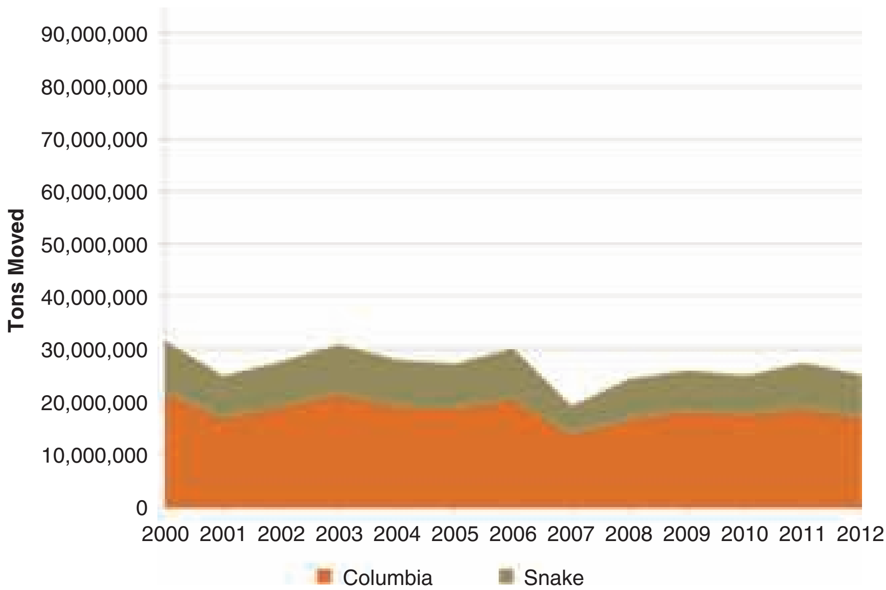

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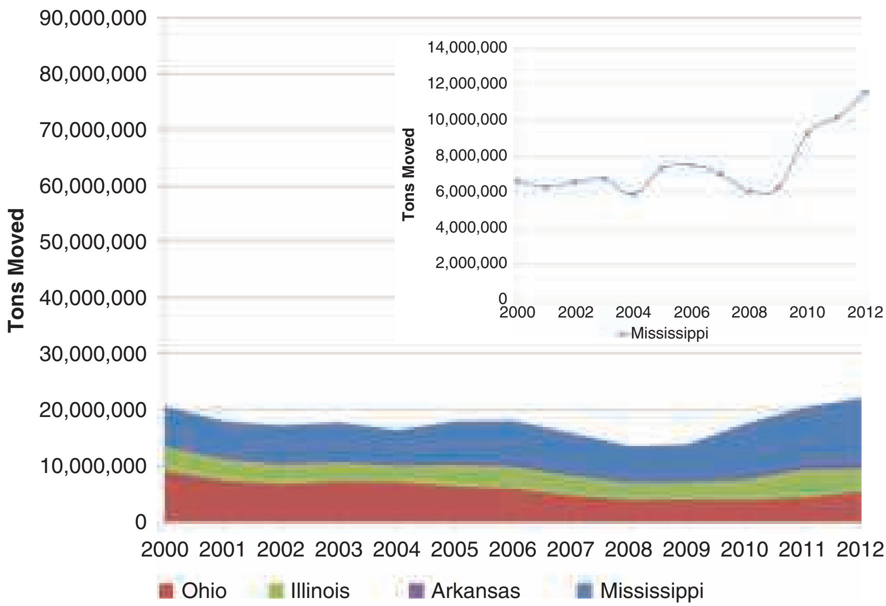
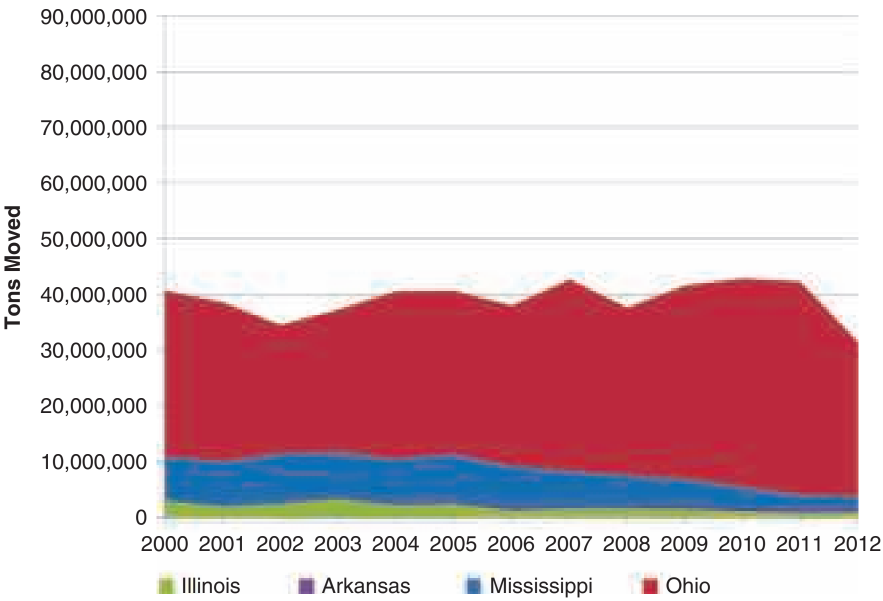


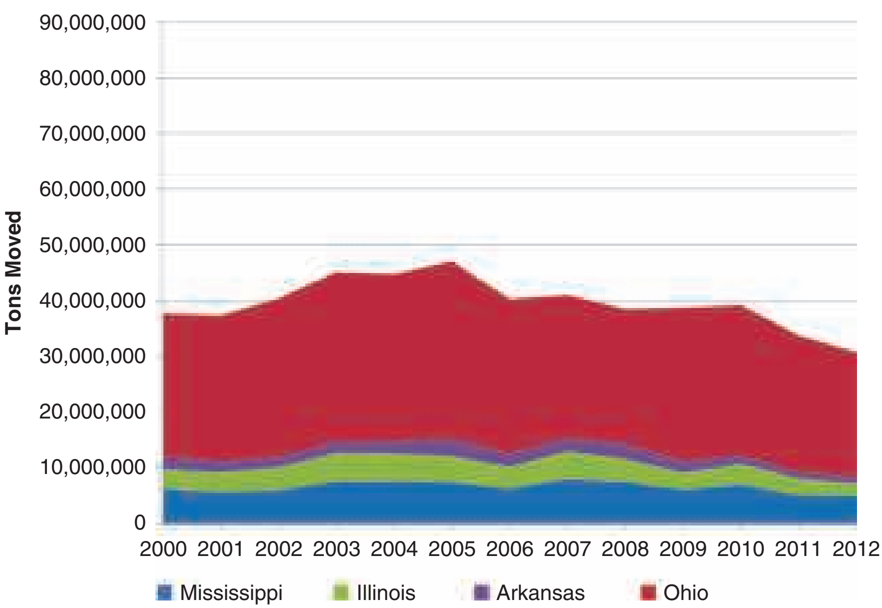
(c)

FIGURE 2-5 *(continued)* Annual trends by river in (*b*) northwestern food and farm products and (*c*) midnation petroleum and petroleum products (with inset showing a doubling of volumes on the Mississippi).

SOURCE: USACE Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/lpms/lpms.htm, Locks by Waterway, Tons Locked by Commodity Group, Calendar Years 1993–2013. Accessed July 2014.



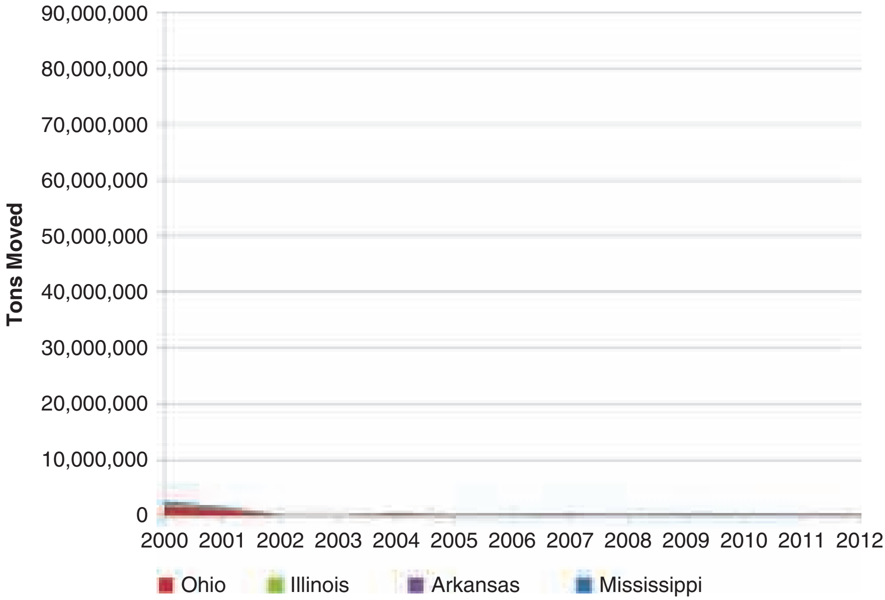
(a)



(b)

FIGURE 2-6 Annual trends by river in (*a*) midnation coal, lignite, and coal coke; (*b*) midnation crude materials.

(continued on next page)



(c)

FIGURE 2-6 *(continued)* Annual trends by river in (*c*) midnation manufactured equipment and machinery.

SOURCE: USACE Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/lpms/lpms.htm, Locks by Waterway, Tons Locked by Commodity Group, Calendar Years 1993–2013. Accessed July 2014.

text of potential mode shift is difficult because the modes are so different in their evolution, ownership, and funding. Furthermore, the ability of bulk cargoes to shift from one mode to another can depend on the availability of large-scale facilities to transfer cargo; thus, the potential for mode shift in the short run may vary from the potential in the long run.

Quantitative comparisons of freight movements across modes for a single cargo between a specific origin and destination are not considered here because they depend on such fluctuating factors as market conditions and the price of fuel and so are valid only for a short period of time. The more enduring observations on freight flows and mode shares can be useful in considering the impact of other modes on use of the inland waterways system.

Freight Flows

Examination of freight flows by mode shows the different character and magnitudes of cargoes moved. Figure 2-7 shows estimated U.S. freight flows by highway, rail, and waterway (http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/tonhwyrrww2010.htm). At an overview level the figure indicates that the modes are mainly complementary to one another instead of competing, although intense competition between rail and water occurs when facilities are being located and diminishes once a shipper or receiver has invested in facilities to support the preferred mode. One striking image is the heavy flow of coal by rail from the Powder River Basin to the Midwest, which complements the heavy waterway flows on the Mississippi and Ohio Rivers. Significant rail flows are notably absent parallel to the six waterway corridors studied, which may reflect the unwillingness or inability of railroads to compete in the short run for bulk cargoes that have ready access to water transportation. Truck traffic is heavy along the six waterway corridors, but trucks are a poor substitute for long-distance inland waterways transport because barges can carry more weight at a far lower cost than can trucks.

Modal Shares and Potential for Modal Shift

According to the U.S. Department of Transportation Freight Analysis Framework, Version 3 (FAF3),[9] the relative modal shares of domestic tons and ton-miles of freight shipments remained similar across 1997, 2002, 2007, and 2012. As shown in Table 2-4, waterborne transport (which includes inland, lakewise, and coastwise movements) moves nearly 10 percent of all ton-miles in the national freight system. Comparable data are reported in Table 1-50 of the National Transportation

[9] The FAF category for "water" shown in Table 2-4 includes more than cargo moved on the inland waterways system—it also includes deep sea, coastal waters, and Great Lakes cargo movements. Furthermore, information included in the FAF differs from that available from the USACE Waterborne Commerce Statistics Center partly because of differences in statistical sourcing (such as in commodity classifications) and aggregation. However, the FAF is useful for an overview of the relative modal share values even though some of the absolute values that make up this general picture might differ from other sources.

FIGURE 2-7 Freight flows by highway, railroad, and waterway, 2010, according to the Freight Analysis Framework, Version 3.

SOURCE: Freight Analysis Framework, Version 3, Freight Facts and Figures 2013 (http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/13factsfigures/figure3_01.htm, accessed September 2014). (Highways, U.S. Department of Transportation, Federal Highway Administration, Freight Analysis Framework, Version 3.4, 2013; rail, based on Surface Transportation Board, Annual Carload Waybill Sample and rail freight flow assignments done by Oak Ridge National Laboratory; inland waterways, USACE, Institute of Water Resources, Annual Vessel Operating Activity and Lock Performance Monitoring System data, 2013.)

TABLE 2-4 Mode Share by Value, Freight Tons Moved, and Ton-Miles of Freight for 1997, 2002, 2007, and 2012 According to FAF3

	1997	2002	2007	2012
Mode Share by Value				
Truck	63	70	63	63
Rail	6	5	6	6
Water	0.7	0.7	1.2	1.3
Air (including truck–air)	10	4	4	5
Multiple modes and mail	16	15	20	19
Pipeline	2	2	4	4
Other and unknown	2	2	2	2
Total	100	100	100	100
Mode Share by Freight Tons Moved				
Truck	48	50	46	46
Rail	22	25	27	27
Water	7	7	6	6
Air (including truck–air)	0.1	0.1	0.1	0.1
Multiple modes and mail	5	5	7	7
Pipeline	16	12	12	13
Other and unknown	2	1	1	1
Total	100	100	100	100
Mode Share by Ton-Miles of Freight				
Truck	30	34	32	32
Rail	24	29	31	32
Water	9	8	9	10
Air (including truck–air)	0.3	0.1	0.2	0.2
Multiple modes and mail	11	10	10	10
Pipeline	23	17	17	15
Other and unknown	2	2	1	1
Total	100	100	100	100

NOTE: Mode shares are expressed as percentages.

Statistics, 2013, where the ton-miles accounted for by multiple-mode shipments are redistributed to the individual modes.

Choice of mode and intermodal combinations is affected by such factors as access to an alternative mode (DiPietro et al. 2014), time to delivery, cost, transparency of tracking, flexibility if rerouting may be required (Simmons et al. 2013), and payload per shipment (Kruse et al. 2012). Inland waterborne commerce requires more time to delivery than other modes for similar transport distances because (*a*) shallow water navigation speeds with heavy payloads are slower than road or rail speeds and (*b*) routes can be longer because waterways are circuitous. Longer distances and transit times do not necessarily preclude use of a modal shift to barge, particularly as energy prices, freight rates, and other drivers favoring larger payloads on intermodal networks may emerge. Judgments about modal trade-offs, including those related to concerns about shifts from barge as described in Box 2-1, need to be informed by transparent and rigorous analyses beyond the scope of this report.

Condition and Performance of Inland Waterways Infrastructure

OVERVIEW

The availability of multiple measures of system reliability and performance is useful for assessing system functioning. Delays, lock unavailabilities, and usage of the system are important components in the assessment of system functioning and are the focus of this section. USACE maintains multiple measures of performance as part of a Lock Performance Monitoring System (http://www.navigationdatacenter.us/lpms/lpms.htm) used here to describe the performance of lock infrastructure. Lock performance metrics derived from these measures could be useful in a systemwide assessment of locks for asset management and setting of maintenance priorities (see Chapter 4).[10] Data enhancements

[10] The USACE Lock Performance Monitoring System contains 10 measures of cargo transported through the locks, nine commodity groups and one total tons metric. Sixteen metrics describe facility use intensity and performance for commercial, noncommercial, and recreational navigation. They include hours of processing and delay time; vessel, barge, and tow counts; and numbers of lockages. Six metrics describe lock closure statistics, including unscheduled and scheduled unavailabilities in terms of both number (frequency) and annual hours closed.

BOX 2-1

Modal Shift to Road or Rail Resulting from Loss of Waterway Corridor

The Transportation Research Board's Executive Committee wanted this study to cover possible impacts of a major diversion of freight from water on highway systems should a waterway fail because of deferred maintenance. In view of the volume that can be moved by one barge being equal to the payloads of many trucks, state officials have expressed concern about the consequences of massive numbers of heavy trucks replacing shipments that had moved by water for highway congestion and pavement and bridge infrastructure.

Long-duration (more than 6 months) closures of waterways have been rare. Few year-long navigation closures of major lock and dam installations have occurred in the past 20 years, and only four locks on high-use waterways have been out of service for more than 180 days in any year since 1993.[a] USACE uses scheduled closures, intermittent closures during phased construction, and other design and construction strategies to minimize the impact of long-duration construction and repair, similar to current practices for highway repair and construction that balance long-duration full closures with partial closures or intermittent closure periods.

When a section of infrastructure is out of service for months or longer, shippers have multiple choices, including rerouting, postponing, or canceling shipments; selling goods in different markets; and, if the loss is sufficiently disruptive and alternative modes too costly, closing (DiPietro et al. 2014). For barge transportation, the simplifying assumption is usually made that in the event of a waterway closure, most freight that could shift would shift to rail and relatively little to truck, because of the substantially greater cost of movement by truck (Kruse et al. 2011). Modeling and analysis of what might happen to soybean shipments if various locks closed on the Upper Mississippi, Illinois, or Ohio Rivers indicated that total shipments of soybeans would decrease, but the rail mode share would increase and the truck share decrease (Kruse et al. 2011). However, the outcomes in specific corridors depend on circumstances, and some modal shift to truck cannot be ruled out. Furthermore, substantial drayage transport may be needed in a water-to-rail shift (i.e., short-distance

(continued on next page)

[a]These statistics are derived from the committee's analysis of USACE unavailability data collected for the USACE Lock Performance Monitoring System, http://www.navigationdatacenter.us/lpms/data/lock2013webunavail-021914.htm.

BOX 2-1 *(continued)* **Modal Shift to Road or Rail Resulting from Loss of Waterway Corridor**

trucking to connect the origin with rail via partial waterway movement or to connect the origin directly with rail access).

Impacts from such an event would vary widely by corridor, commodity, and the nature of freight flows in the corridor. Because a loss of transportation access can shift markets and shipper behavior in complex ways, accurate predictions concerning modal shifts cannot be made without a detailed analysis and model applied to a suite of case studies.

that could improve understanding of traffic flows and be used to set priorities to maintain reliable freight service are noted as part of this discussion and are elaborated on further in Chapter 4. Options for metrics are discussed in Appendix E of this report and in Chapter 4.

USACE also maintains statistics on the original construction of locks (construction year, gate type, safety, and so on), which are publicly available (http://www.navigationdatacenter.us/index.htm). The statistics describe the design details of lock and dam infrastructure and so could be useful in determining the condition of locks as part of a systemwide assessment. Other important information for assessing condition, such as records on major rehabilitations and seasonal navigation closures, is not available for all lock and dam facilities in an identifiable location that is accessible to the public but would be desirable for system assessment.

Lock age does not measure performance and is not included in the USACE Lock Performance Monitoring System. It is included in this discussion because the age of locks is widely used to communicate the condition of the inland waterways system and needs for funding.

AGE OF LOCKS

Figure 2-8 shows a map of inland waterways lock infrastructure by original construction date. Figure 2-9 shows the average age of lock and dam infrastructure in comparison with other federal and state infrastructure and transportation assets. The average age of the locks in 1940 was less than 10 years; in 1980 the average age of the locks was about 30 years (whether or not major rehabilitation work was considered); in 2014 the average age was 59 years.

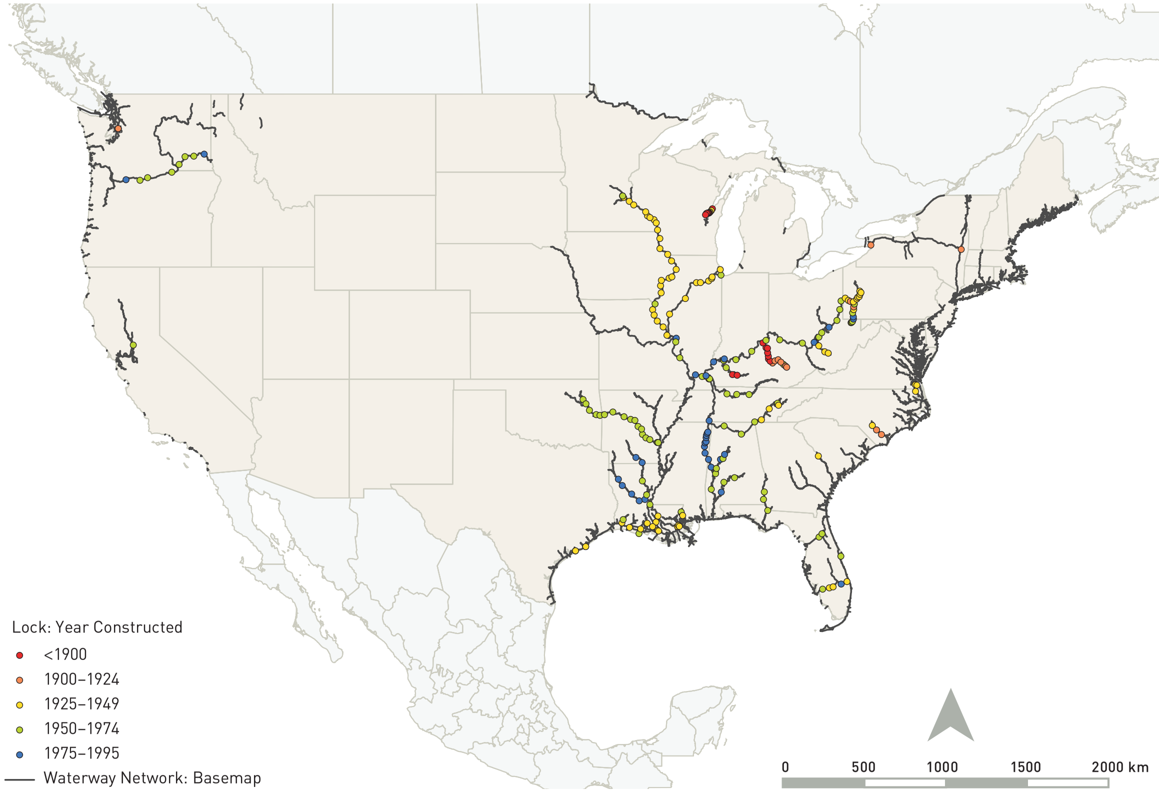


FIGURE 2-8 Summary map of inland waterways navigation lock and dam infrastructure, by year of construction.

SOURCE: USACE Navigation Data Center GIS Viewer files (http://www.navigationdatacenter.us/db/gisviewer/) and Lock Use, Performance, and Characteristics (http://www.navigationdatacenter.us/lpms/lpms.htm). Accessed July 2014.

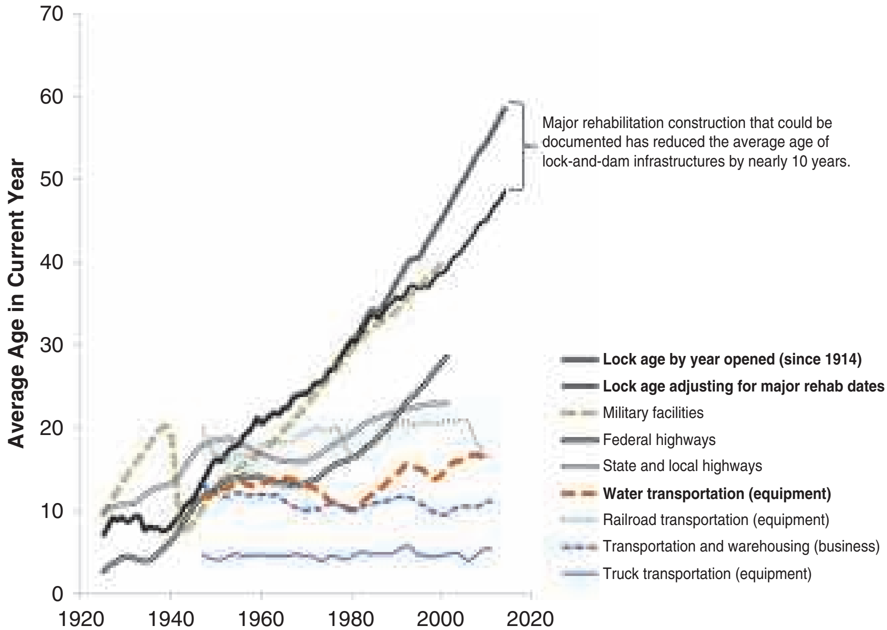


FIGURE 2-9 Comparison of age of infrastructure showing inland navigation lock age (with and without consideration of rehabilitation construction).

Source: USACE Navigation Data Center: Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/data/datalck.htm, accessed July 2014.

A substantial number of locks have been rehabilitated, which would be expected to restore performance to its original condition if not better and effectively reduce the age of the locks. To illustrate the impact, for this report, the effective age of locks was updated (assumed to return to zero) for locks on the Illinois, Mississippi, and Ohio River system where major rehabilitation was documented. This approach is similar to that used for documenting the current age of highways, bridges, and military infrastructure and is a more accurate method of communicating the age of inland waterways infrastructure.

In 2014, the average age of locks computed from the date of last known major rehabilitation was 49 years, nearly 10 years younger than the age assessed from the original construction date (Figure 2-9;

see Appendix C for documented dates of original construction and last known major rehabilitation; see Appendix D for age detail for each major river system.)[11] After rehabilitation is accounted for, in 2014 more than 50 percent of the locks were more than 50 years old (Figure 2-10*a*). However, rehabilitated age varies substantially by river system. For example, the Ohio River corridor is about 6 years (10 percent) younger than the original construction age when age is adjusted for major rehabilitation construction (Figure 2-10*b*), while locks on the Upper Mississippi and Illinois River (Figure 2-10*c*) have an age adjusted from construction of about 36 years, less than half of the age reckoned from original construction.

USAGE

Usage of navigation locks can be computed in several ways, such as by transported commerce (tonnage) or by number of cycles (lockages). Consideration of lock tonnage (Figure 2-11) and the number of lockages (Figure 2-12) together is useful because it provides insight into the importance of locks in the waterway. The highest-use locks by lock tonnage are found along high- and moderate-use waterways, primarily the Upper Mississippi and Ohio River corridors (Figure 2-11).[12] High-use cargo locks frequently have a large number of lockages, which is understandable given the large number of barges that travel through them. An exception is small locks that require multiple lockages for typical barge tows. The eight river systems with the most average lockages per lock are shown in Figure 2-13: the Ohio (including Monongahela and Allegheny), the GIWW, the Upper Mississippi, the Arkansas, the Illinois, the Tennessee, the Tennessee–Tombigbee, and the Columbia (including the Snake) systems. They account for more than 77 percent of all lockages in the inland waterways.

Some locks that experience periods of high use are on waterways designated as low or moderate use on the basis of average annual ton-miles, which has implications for the allocation of resources needed

[11] See Chapter 4 for further discussion of age of infrastructure in the context of asset management and prioritization of maintenance spending.

[12] As described earlier, high-use waterways are defined by USACE as those carrying more than 3 billion ton-miles of freight annually. Medium-use waterways carry 1 billion to 3 billion ton-miles of freight annually, and low-use waterways carry less than 1 billion ton-miles annually.

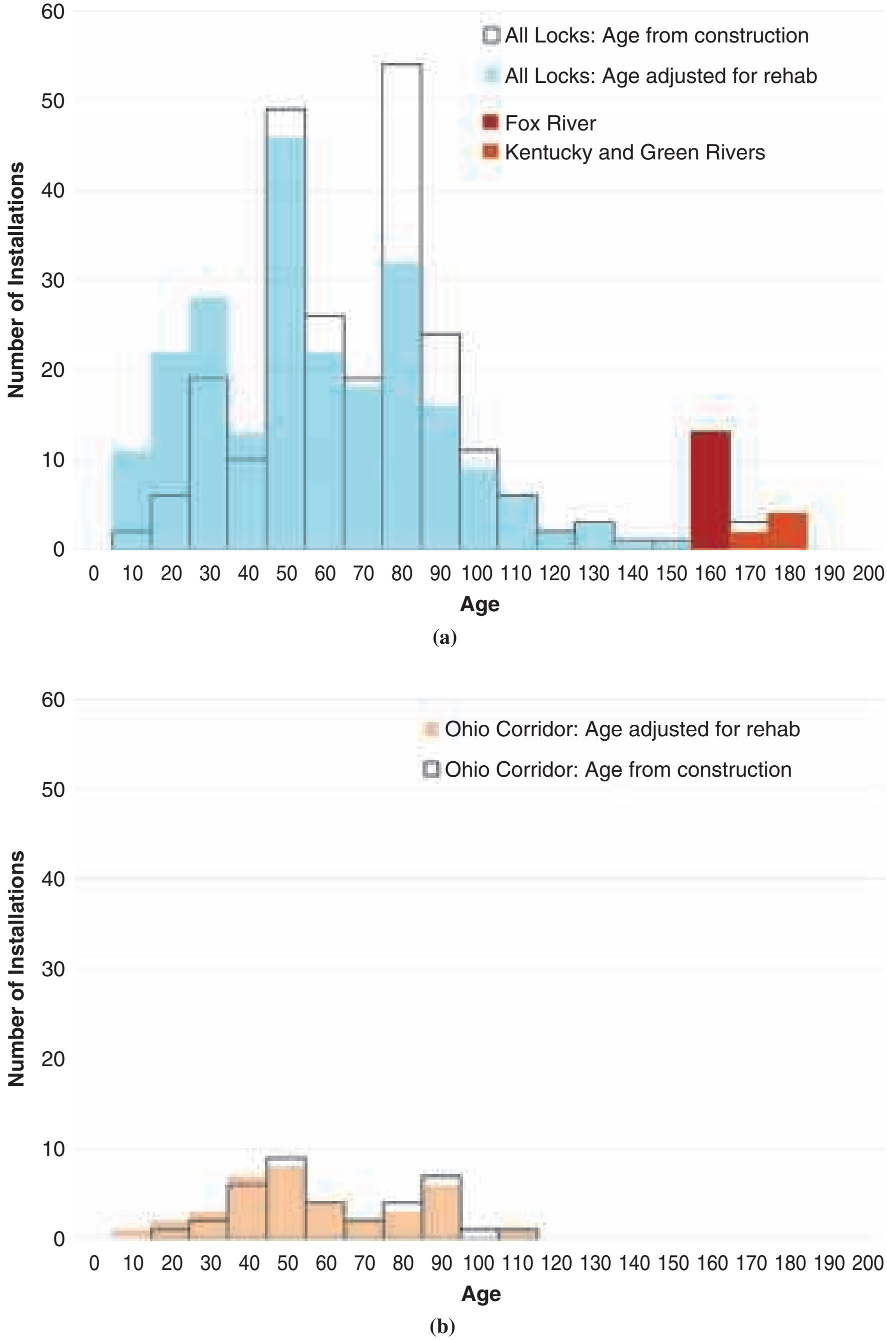
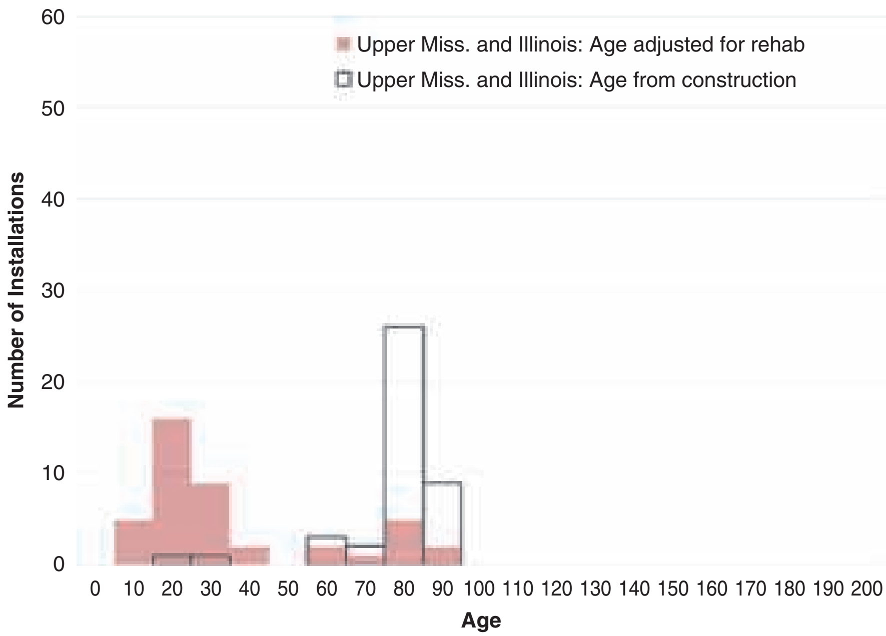


FIGURE 2-10 Histogram of effective age of infrastructure on the inland waterways network including rehabilitation for (*a*) all locks using available data, (*b*) the Ohio River corridor.

(continued)



(c)

FIGURE 2-10 *(continued)* Histogram of effective age of infrastructure on the inland waterways network including rehabilitation for (*c*) the Upper Mississippi and Illinois River corridors.

Source: USACE Navigation Data Center: Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/data/datalck.htm, accessed July 2014.

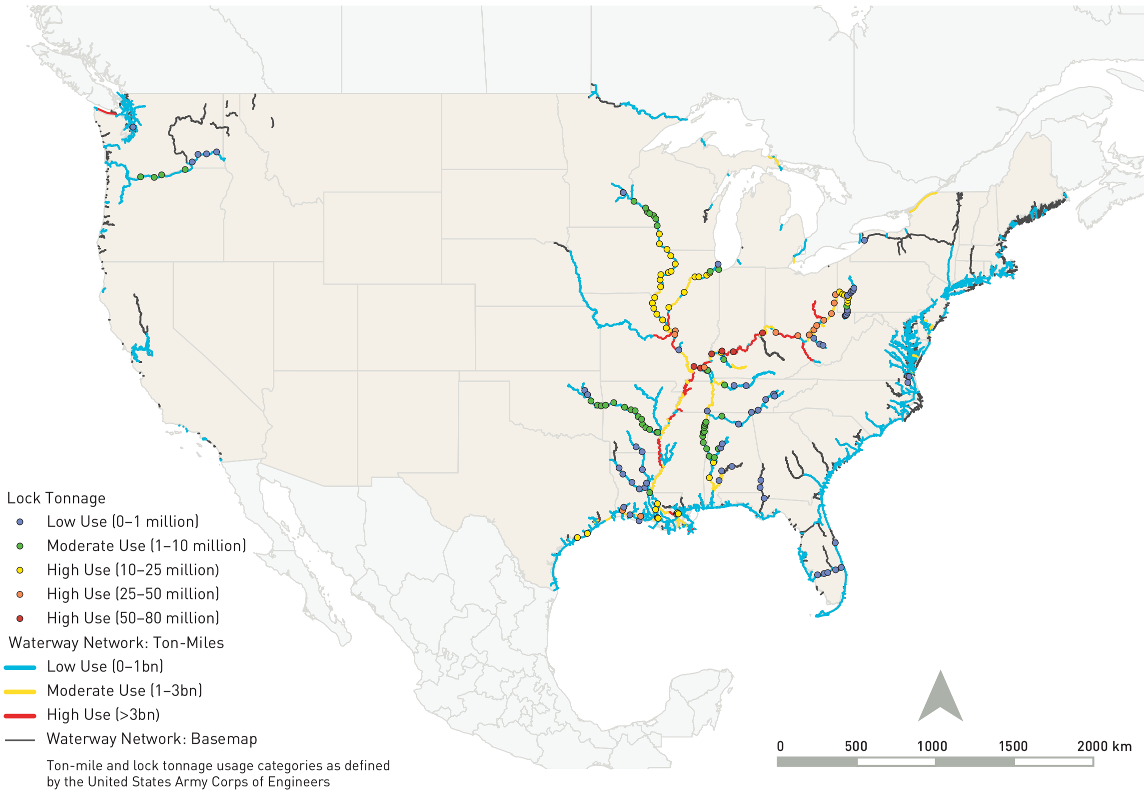


FIGURE 2-11 Summary of number of tons of cargo passing through inland waterway navigation lock and dam infrastructure, with waterways identified according to ton-mile usage category and locks identified by ton usage category.

SOURCE: USACE Navigation Data Center, GIS Viewer files, http://www.navigationdatacenter.us/db/gisviewer/; Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/lpms/lpms.htm. Accessed July 2014. Usage definitions based on USACE 2013, Table F-1 and Section F-12.

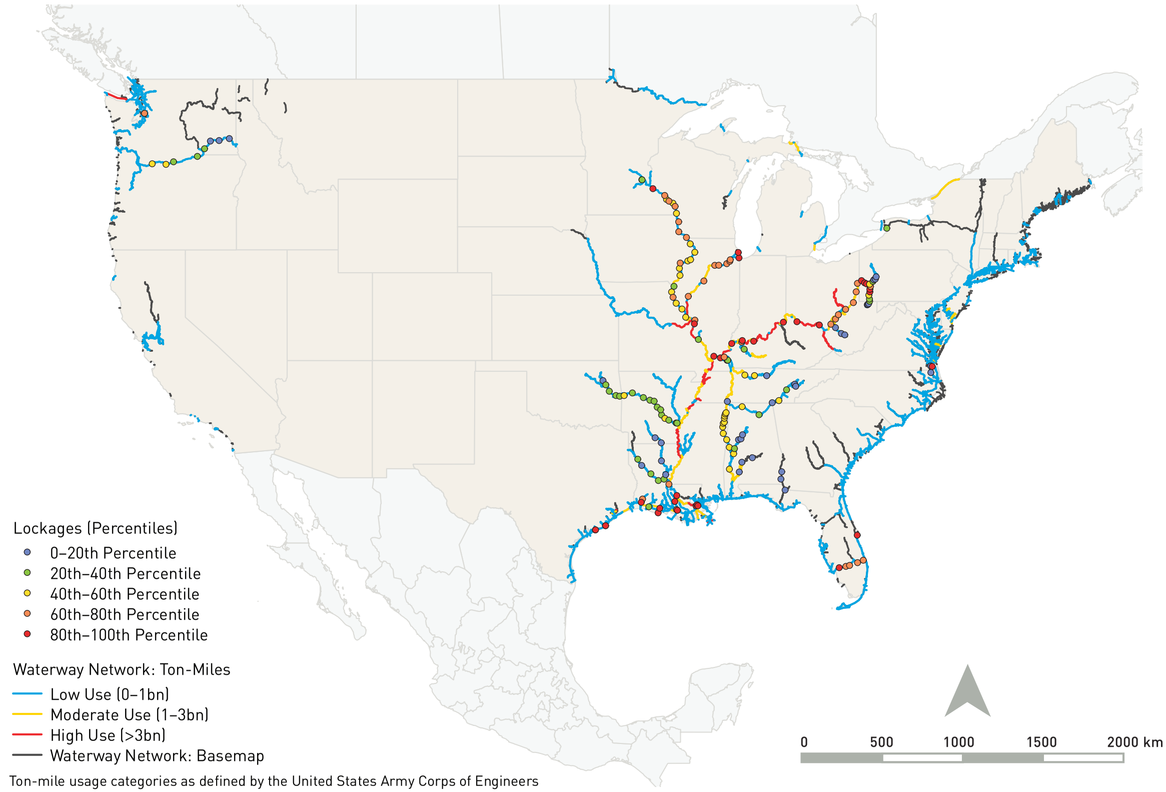
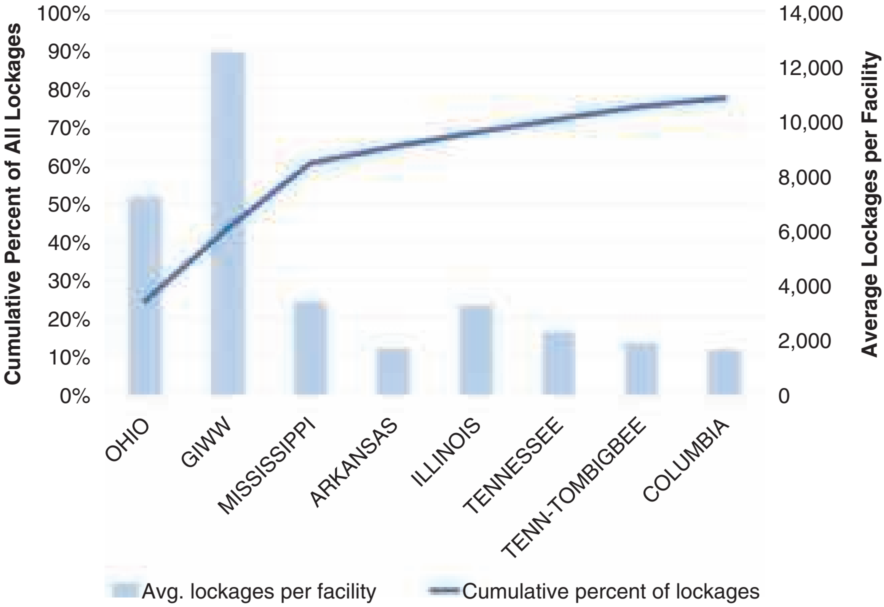
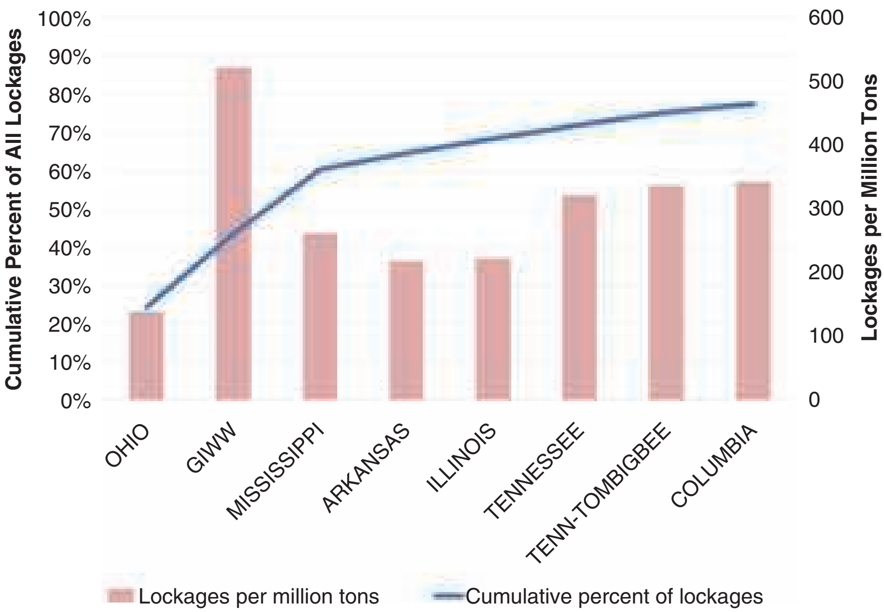


FIGURE 2-12 Summary of inland waterways navigation lock and dam usage, by percentage of lockages in the inland navigation system (2013 data).

SOURCE: USACE Navigation Data Center, GIS Viewer files, http://www.navigationdatacenter.us/db/gisviewer/; Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/lpms/lpms.htm. Accessed July 2014.



(a)



(b)

FIGURE 2-13 Summary of top eight rivers by lockages and cumulative percent of lockages by (*a*) lockages per facility on the river and (*b*) lockages per million tons transported. These eight rivers account for about 80 percent of all lockages in the inland waterways system.

SOURCE: USACE Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/lpms/lpms.htm, Locks by Waterway, Lock Usage, Calendar Years 1993–2013. Accessed July 2014.

to maintain the system. For example, whereas the entire Arkansas and Tennessee Rivers are low use, the Upper Mississippi, Illinois, and Tennessee–Tombigbee Rivers and the GIWW have high-use locks in waterway sections that would be classified as moderate or low use. This situation can occur because of seasonal peaks in the movement of certain commodities such as harvested food and farm products or because of navigation closures due to annually recurring weather conditions such as ice or flooding. For prioritization, the tonnage moved through each lock during peak demand periods, as well as the type and value of the cargo, needs to be considered; usage should not be assessed merely on the basis of average annual waterway ton-miles. Likewise, some rivers and waterborne corridors may on a seasonal basis move as much or more tonnage as rivers classified as high use but receive low-use classification on the basis of annual ton-miles of transport rather than seasonal peak ton-miles.

River systems have sharply different patterns with regard to the direction and balance of freight flows, which has implications for the economic importance of low-use tributaries to the system. These patterns are shown in Figure 2-11 for tonnage and in Figure 2-12 for lockages. To illustrate, the Ohio system, which mainly carries coal, is self-contained, with balanced flows back and forth; low-use tributaries make little contribution to overall system flows. However, the Upper Mississippi and Missouri Rivers are part of an export-based system in which low-use tributaries contribute to increases in the tonnages of food and farm products and other types of freight carried as barges move downstream.

Some busy locks on low-use waterways near major population centers do not move freight but provide service for recreational navigation. For example, the Okeechobee Waterway and the Albemarle and Chesapeake Canal have low-tonnage locks that experience a large number of recreational lockages. Such facilities might be candidates for charging recreational users for lockage.

DELAYS AND UNAVAILABILITIES

The definitions and measures used in this section are consistent with terminology and performance measures included in the USACE Lock Performance Monitoring System (http://www.navigationdatacenter

.us/lpms/lpms.htm). Lost transportation time is the average time lost by vessel tows to unproductive transportation. It is the sum of delay and unavailability. Lost transportation time due to delays and lock unavailability is a cost to shippers and an important consideration in deciding on future investments to maintain reliable freight service. A delay is defined by USACE as the time a tow must wait to move through a lock once it is at the lock and ready to transit (i.e., to be processed through the lock). Lock unavailability is a closure or outage usually due to failure or repair.

Some delays and unavailabilities are expected in any transportation network. As cargo moves up- and downriver, delays can occur if the barge tow is too large and must be towed through in sections; if there is a backlog of barges waiting to be towed through the lock; or if the lock experiences an outage for routine maintenance, weather, accident, equipment failure, or other unforeseen reasons. Operators may be waiting for shippers to bring cargo to the waterfront; cargoes must be safely loaded into vessels and barges; lockages require processing time to prepare chambers and gates, which can result in delays for other vessels; and queuing (congestion) may occur during peak usage times.

The number and duration of some delays and unavailabilities may indicate declining performance of navigation locks because of aging machinery or infrastructure (unreliability) or a mismatch between lock sizes and demand for vessels and cargoes (undercapacity). Delays also can occur on river segments without lock and dam infrastructure because of flood conditions or low-water periods; a summary of waterway locations where noninfrastructure delays may occur is not included in USACE performance statistics.[13]

USACE maintains public statistics on annual delays for each lock and dam, scheduled unavailabilities, and unscheduled unavailabilities.[14] *Delay* is reported by using average time delayed per delayed vessel and the percentage of vessels delayed. *Annual delay* is estimated

[13] USACE could address this gap in performance data by providing information in future data releases on delays for river segments without lock and dam infrastructure beyond the data already available on delays due to dredging.

[14] Unavailability statistics are at http://www.navigationdatacenter.us/lpms/data/lock2013webunavail-021914.htm; commodity statistics are at http://www.navigationdatacenter.us/lpms/cy2013comweb.htm; usage statistics are at http://www.navigationdatacenter.us/lpms/lock2013web.htm.

by multiplying the total vessels transiting a lock by average delay time per vessel. These statistics can be organized by river or aggregated to represent the potential lost service in hours for the waterways system as a whole. Lock processing time is not included in the USACE definition and measure of delay and is instead a separate measure in the USACE Lock Performance Monitoring System. Lock processing time is the time required for a vessel to approach, to break down the tow into subtows (if needed for large tows to pass through the lock), to enter the lock chamber, for the water level to rise or fall, for the vessel to exist and clear the lock, and to reassemble the tow (if needed).[15] The description of the system that follows maintains this distinction and examines lock processing time separately from delay because (*a*) such a procedure is consistent with USACE's performance metrics, (*b*) the underlying causes and mitigation of these occurrences may differ, and (*c*) stakeholders informed the committee during public meetings that outages (unscheduled unavailabilities) are a primary concern for the reliability of shipping service.

Figure 2-14 shows the percentage of vessels delayed on low-, moderate-, and high-use segments of the system. On average, 49 percent of tows in 2013 were delayed across the 10 highest-tonnage locks, with an average length of tow delay of 3.8 hours. USACE's Lock Performance Monitoring System does not include the reasons for delay.[16] Delays might be attributable to seasonal peak volumes due to weather, harvest, undercapacity, or other causes. However, the observation that delays are typically larger at locks with greater demand for agriculture-related transport during the harvest period suggests that the delays are largely a result of seasonal congestion.

Unavailabilities are reported by using the number of outages and the total hours unavailable per year.[17] For 2000 through 2013 the

[15] USACE's measure of lock processing time does not distinguish processing times specific to the locking through of tows larger than the lock. However, the extra waiting time imposed on other tows because of lockage reconfiguration activities is captured in the lock delay time.

[16] Collecting information about the reasons for delay would be useful for prioritization, as discussed in Chapter 4.

[17] The time that the lock is unavailable due to scheduled or unscheduled maintenance is not considered delay in the USACE Lock Performance Monitoring System statistics but is tracked separately. (Delay presumes that the lock is open, whereas if a lock is unavailable it is scheduled as closed or experiencing an unanticipated outage.) Figure 2-16*b* illustrates the importance of the distinction.

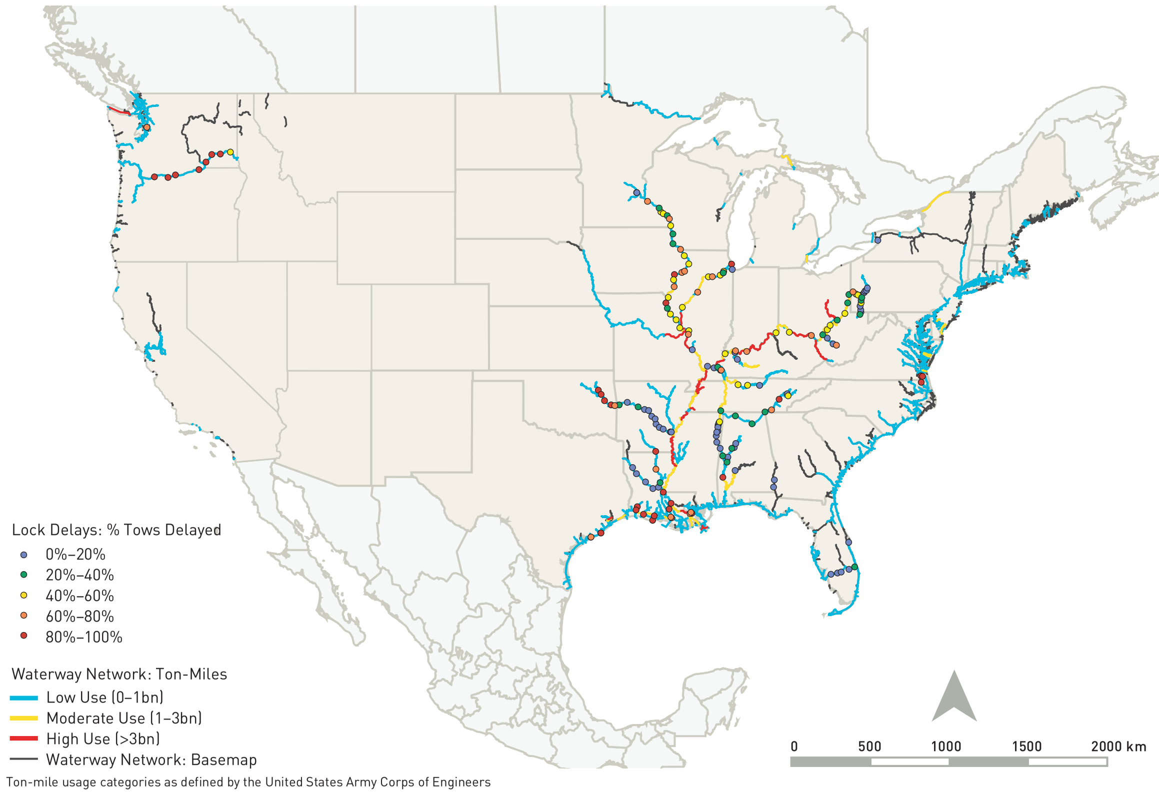


FIGURE 2-14 Summary of inland waterways navigation lock and dam delay statistics, by percent of vessels delayed (2013 data).

SOURCE: USACE Navigation Data Center, GIS Viewer files, http://www.navigationdatacenter.us/db/gisviewer/; Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/lpms/lpms.htm. Accessed July 2014.

estimated lost transportation hours due to delays accounted for nearly 80 percent of the total hours in lost service (Figure 2-15). More hours of lost transportation time are attributable to scheduled unavailability than to unscheduled outages. As discussed below, a method is needed for understanding the impact of delay and unavailabilities across the system to determine proper approaches for mitigating delay.

MODEL FOR UNDERSTANDING THE POTENTIAL IMPACT OF DELAY AND UNAVAILABILITY

To improve understanding of the impact that delay and unavailability can have on service, the transportation hours lost because of scheduled

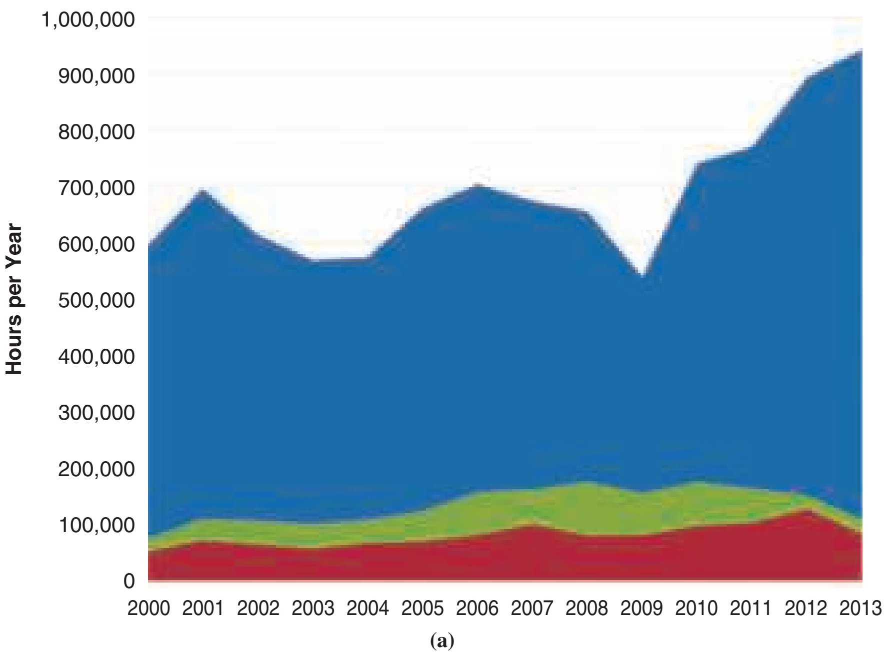
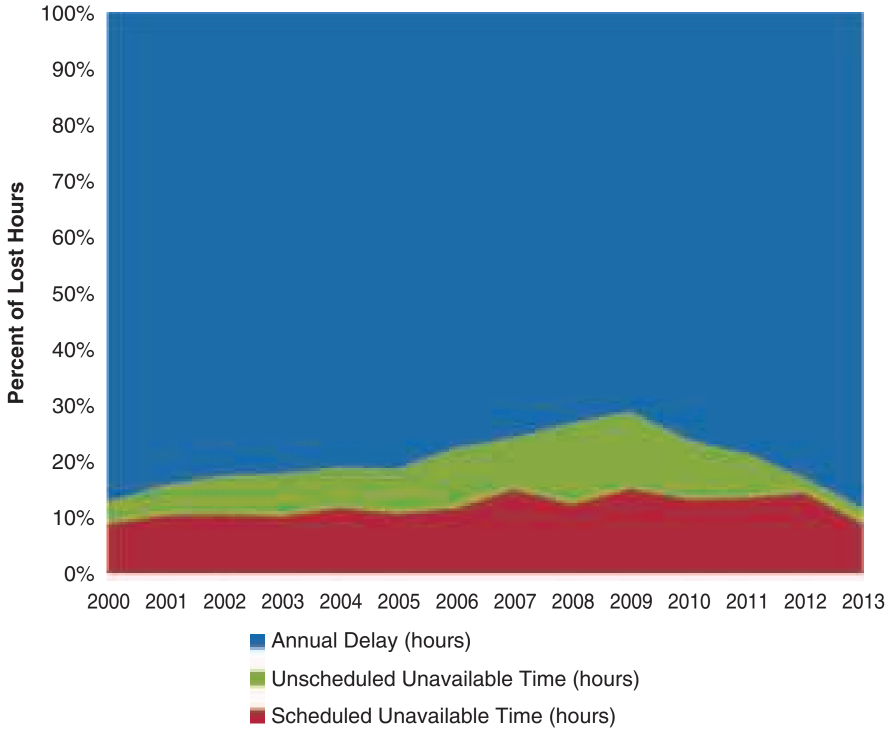


FIGURE 2-15 Summary of trends in total lost transportation time (delays and unavailabilities): (*a*) in hours per year for all locks and dams.

(continued on next page)

SOURCE: USACE Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/lpms/lpms.htm, Locks by Waterway, Lock Usage, Calendar Years 1993–2013, and Locks by Waterway, Locks Unavailability, Calendar Years 1993–2013. Accessed July 2014.



(b)

FIGURE 2-15 *(continued)* Summary of trends in total lost transportation time (delays and unavailabilities): (*b*) as percents of lost hours for all locks and dams.

and unscheduled delay can be evaluated for specific locks and dams and considered in the light of navigation demand. Demand can be observed in terms of (*a*) tonnage of cargo transported, (*b*) number of vessels requiring passage through locks, and (*c*) the number of lockages (i.e., use of navigation infrastructure). Lock infrastructure for a river system can be compared with regard to long-run demand (cargo transported, vessels, and lockages) and chronic lost service (hours of delay and hours unavailable). By averaging these data over a number of years, periodic influences such as short-term economic downturns can be minimized. (See Appendix E for an illustration for several sets of locks and dams grouped by major river system.) A derived metric, such as average lost transportation hours per million tons of cargo, could be a useful way of identifying and prioritizing facilities for investment consideration.[18]

To illustrate, Figure 2-16*a* shows the average percentage of lock transit time accounted for by lock processing time versus lost transportation hours, which comprises delay and unavailability. Systemwide, the inland waterways had an annual average of 272 lost transportation hours per million tons of commerce from 2000 through 2013, according to data obtained from USACE. A detailed examination of lost transportation hours shows that lost transportation time was dominated by delay, as illustrated in Figure 2-16*b*. Each river and corridor may have its unique characteristic metric, which would be a function of the commodities served, seasonality, and performance of the lock and dam infrastructure. Identifying major facilities where the lost transportation time due to delay or repairs is significantly higher than the river average could improve investment decisions to preserve or upgrade navigation performance.

Several options exist for mitigating hours of lost transportation service. Among them are the following:

- An effective system for scheduling lock usage to reduce queuing congestion (discussed further in Chapter 3); this may require users to invest in increased storage for waterborne commodities during peak demand periods such as the harvest;
- Localized reprioritization of lock throughput design that could consider seasonal peak demand (often driven by late spring ice melts, summer flooding, or early winter freezes); this may involve realigning the USACE construction investment framework away from annualized benefits in regions where infrastructure is critical to peak seasonal usage (e.g., Illinois River food and farm products); and
- Continued attention to managing unavailabilities and pursuit of opportunities for avoiding such closures (scheduled or unscheduled); investment in more operations and maintenance (O&M)

[18] The average accounts for the elements of delay that occur as more tonnage is moved through the waterway network.

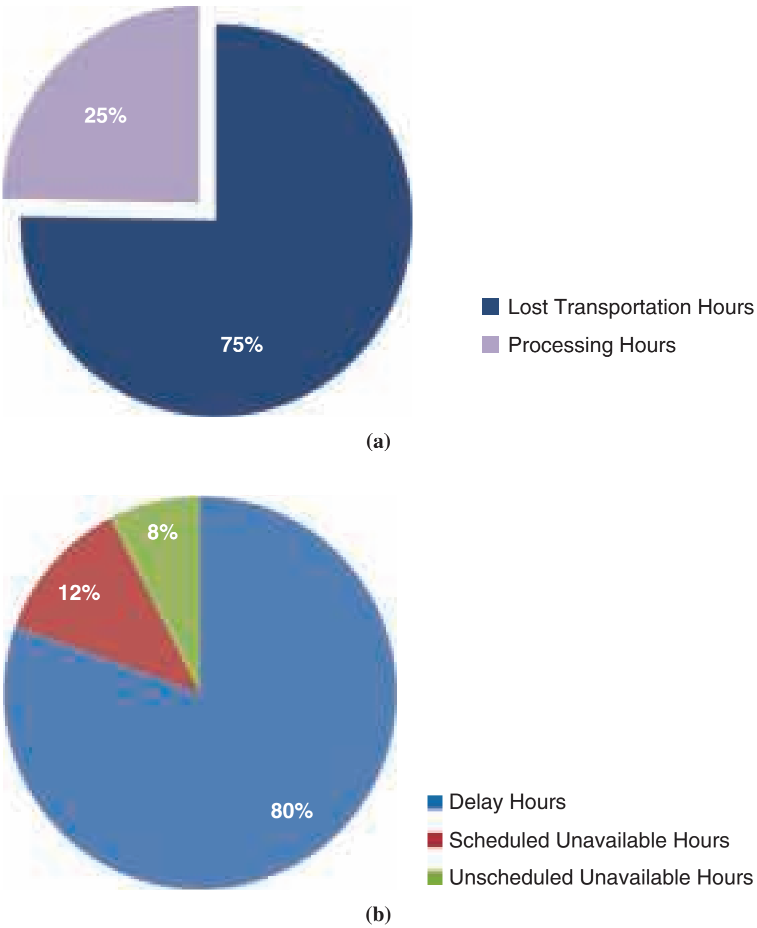


FIGURE 2-16 (*a*) Summary of lock transit time: processing hours versus lost transportation hours and (*b*) detailed breakdown of lost transportation hours as delay and scheduled or unscheduled unavailability. Lost transportation hours are reported in terms of hours per million tons of commerce for 2000–2013.

SOURCE: USACE Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/lpms/lpms.htm, Locks by Waterway, Lock Usage, Calendar Years 1993–2013, and Locks by Waterway, Locks Unavailability, Calendar Years 1993–2013. Accessed July 2014.

activities to reduce lost transportation time due to outages may be economically more beneficial than capital investments to expand the size of locks.

Data are not available to explain the causes of delay at locks, which makes up 80 percent of lost transportation hours. Delay might be attributable to seasonal peak volumes due to weather, harvest, undercapacity, or other causes. Collection of data and development of performance metrics would enhance understanding of whether delay problems could be most efficiently addressed by more targeted O&M, traffic management, capacity enhancement, or some combination of these measures (see Chapter 4). Such an index would be superior to the proxy of age, which is an inconsistent indicator of lock infrastructure failure. As shown in Table 2-5, measures of lock performance are for the most part not correlated with age of locks.

Findings and Conclusions

The role of the inland waterways system in freight transportation has changed significantly since the system was built to promote the early economic development of the nation. Today, barges carry a relatively small but steady portion of freight, mainly bulk commodities that include coal, petroleum and petroleum products, food and farm products, chemicals and related products, crude materials, manufactured goods, and manufactured equipment. Annual trends in inland waterways shipments show that freight traffic is static or declining on some waterways. Overall demand for the inland waterways system is static relative to the growing demand for rail and truck. In recent years, the inland waterways system has transported 6 to 7 percent of all domestic cargo (measured in ton-miles). Truck has carried the greatest share of freight, followed by rail, pipeline, and water.

Seventy-six percent of barge cargo (in ton-miles) moves on just 22 percent of the 36,000 inland waterway miles. About 50 percent of the inland waterway ton-miles moves on six major corridors

TABLE 2-5 Summary of Correlations Between Lock Performance and Lock Age in 2014 Calculated from the Date of Last Known Major Rehabilitation

		Level of Correlation Between Lock Performance and Effective Age on a River System						
River System	**Average Age of Locks**	**Lockages**	**Percent of Vessels Delayed**	**Percent of Tows Delayed**	**Average Vessel Delay**	**Average Tow Delay**	**Average Closure Duration**	**Closure Frequency**
All inland river locks	**61**	Low	Low	Low	Low	Low	Low	Low
Ohio River	**35**	Low	Low	Low	Low	Low	Low	Low
Mississippi River	**25**	Low	Low	Low	Low	Low	**Medium**	Low
Illinois River	**22**	**Medium**	Low	Low	Low	Low	**Medium**	**Medium**
Columbia–Snake Rivers	**45**	Low	Low	Low	Low	Low	**High**	Low
GIWW	**72**	Low	Low	Low	Low	Low	Low	Low
Arkansas River	**45**	Low	**Medium**	**Medium**	**Medium**	Low	Low	Low

(continued)

TABLE 2-5 *(continued)* Summary of Correlations Between Lock Performance and Lock Age in 2014 Calculated from the Date of Last Known Major Rehabilitation

		Level of Correlation Between Lock Performance and Effective Age on a River System						
River System	**Average Age of Locks**	**Lockages**	**Percent of Vessels Delayed**	**Percent of Tows Delayed**	**Average Vessel Delay**	**Average Tow Delay**	**Average Closure Duration**	**Closure Frequency**
Black Warrior, Tennessee, Tennessee–Tombigbee, Tombigbee	**42**	Low	**Medium**	**Medium**	Low	Low	Low	**Medium**
Monongahela River	**57**	**Medium**	**High**	**High**	**Medium**	Low	Gaps in data	**Medium**
Allegheny River	**62**	Low	Low	Low	Low	Low	Gaps in data	Low

Negative Correlation Positive Correlation

NOTE: Delay and closure (includes scheduled and unscheduled unavailability) data used to compute correlations were obtained from the USACE Lock Performance Monitoring System. High positive correlation (blue text, blue shading) is defined as greater than 75 percent correlation. Medium positive correlation (blue text, light blue shading) is defined as between 50 and 75 percent correlation. Medium negative correlation (red text, light pink shading) is defined as between –50 and –75 percent correlation. Low correlation (white background) is defined as within 450 percent correlation. Some rivers indicate "negative correlations" because the correlations are affected by traffic level and rehabilitation; that is, some of the older locks have less traffic and so fewer traffic-related problems, or they may be rehabilitated and so experience fewer closures and delays. (See Appendix F data detail.)

SOURCE: USACE Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/lpms/lpms.htm: Locks by Waterway, Tons Locked by Commodity Group, Calendar Years 1993–2013; Locks by Waterway, Lock Usage, Calendar Years 1993–2013; and Locks by Waterway, Locks Unavailability, Calendar Years 1993–2013. Accessed July 2014.

that represent 16 percent of the inland waterway miles—the Upper Mississippi River, the Illinois River, the Ohio River, the Lower Mississippi River, the Columbia River system, and the GIWW. Some inland waterways segments have minimal or no freight traffic. With shrinking resources for the system and growing demands on the USACE O&M budget, targeting commercial navigation investments mainly to portions of the system important for moving freight would be prudent.

Lost transportation time due to delays and lock unavailability (outages) is a cost to shippers and an important consideration in deciding on future investments. Systemwide, about 80 percent of lost transportation time is attributable to delays. On average, 49 percent of tows in 2013 were delayed across the 10 highest-tonnage locks, with an average length of tow delay of 3.8 hours. Some delay is expected for routine maintenance, weather, accidents, and other reasons, but delays can be affected by maintenance outages caused by decreases in the reliability of aging machinery or infrastructure. About 12 percent of lost time on the inland waterways system is due to scheduled closures and about 8 percent is due to unscheduled closures, which indicates that up to 20 percent of lost time could be addressed with more targeted O&M resources. Targeting O&M resources toward major facilities with frequent lockages and high volumes and where the lost time due to delay is significantly higher than the river average could improve navigation performance.

Most lost service due to delay occurs at high-demand locks used for agricultural exports and so may be caused by congestion related to peaks in seasonal shipping. Chapter 4 describes debates about how to mitigate congestion delays. Data are not available to explain the causes of delay at locks, which makes up 80 percent of lost transportation hours. Delays might be attributable to seasonal peak volumes due to weather, harvest, undercapacity, or other causes. Collection of data and development of performance metrics would enhance understanding of whether delay problems could be most efficiently addressed by more targeted O&M, traffic management, capacity enhancement, or some combination of these measures.

Some high-use locks are located on waterways designated as low or moderate use, which has implications for how to allocate funds across parts of the system. This situation can occur because of seasonal peaks in the movement of certain commodities, such as harvested food and farm products, or from navigation closures caused by annually recurring weather conditions, such as ice or flooding. The tonnage moved through each lock during peak demand periods, as well as the type and value of the cargo, could be considered in funding allocations instead of considering only average annual waterway ton-miles. Likewise, some rivers and waterborne corridors may move as much or more tonnage on a seasonal basis as rivers classified as high use but receive low-use classification on the basis of annual ton-miles of transport rather than seasonal peak ton-miles.[19]

The advanced age of lock and dam infrastructure is often used to communicate funding needs for the system. Age is not a good indicator of lock condition. A substantial number of locks have been rehabilitated, which would be expected to restore performance to its original condition if not better. Dating the age of assets from the time of the last major rehabilitation, as is done for highway infrastructure such as bridges, would be more accurate. Furthermore, with some exceptions, little correlation exists between the age of locks and their performance as measured by delay experienced by system users. A more useful approach for targeting funds to improve system performance than focusing on age as a proxy for lock functioning would be to identify waterway segments and facilities where the lost time due to delay (based on millions of tons delayed) is substantially higher than the system average.

[19] An approach to prioritization focusing on economic risk, such as that discussed in Chapter 4, would address whether an outage during a seasonal peak could be more costly than an outage occurring on a segment with fairly level year-round traffic.

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ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
CMTS	Committee on the Marine Transportation System
TRB	Transportation Research Board
USACE	U.S. Army Corps of Engineers

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3

Federal Role in the Inland Waterways System

The inland waterways infrastructure is managed by the U.S. Army Corps of Engineers (USACE) and funded from the USACE budget. The first section below describes USACE missions and activities, a major component of which is providing for commercially navigable inland waterways. The next section gives an overview of the authorization, planning, and budgeting process for the inland waterways system and how spending is prioritized. Recent trends in funding levels for the inland waterways system and who pays for the system according to the cost-sharing rules specified in current federal legislation are discussed. The greater involvement of the federal government in the inland waterways relative to other modes is described. Considerations with regard to the federal role in funding the inland waterways are explained, including reasons and mechanisms for assessing payments from those who benefit from the system. The final section summarizes findings and conclusions from the chapter.

USACE Missions and Activities

With the authorization of Congress, USACE, under its Civil Works Program headed by the Assistant Secretary for Civil Works, plans, constructs, operates, and maintains a large water resources infrastructure that includes locks and dams for inland navigation; maintenance of harbor channel depths; dams, levees, and coastal barriers for flood risk management; hydropower generation facilities; and recreation. The primary USACE Civil Works mission areas are support of navigation for freight transportation and public safety; reduction of flood and storm damage; and protection and restoration of aquatic ecosystems, such as the rebuilding of wetlands and the performance of environmental mitigation for USACE facilities. Hydropower generation is an important activity of USACE, although it has not been considered a primary mission. Other USACE responsibilities include recreation, maintenance of water supply infrastructure (municipal water and wastewater facilitates), and disaster relief and remediation beyond flood disaster relief (e.g., remediation of formerly used nuclear sites). Some infrastructure projects are authorized as multiple-use projects for navigation and other purposes (e.g., hydropower, municipal water supply, recreation), with the costs being allocated among the various users, but most projects are authorized for a single purpose. Navigation projects are authorized, and the federal share of costs paid, with funds from the USACE navigation budget. Hence, with the exception of a few multipurpose projects, USACE's navigation mission, its costs, and its benefits are separable from USACE's other missions.

Overview of the USACE Water Resources Authorization, Planning, and Budgeting Process

CAPITAL PROJECTS: NEW CONSTRUCTION AND MAJOR REHABILITATION

The inland waterways system is both part of a larger national freight transportation system and part of the nation's watershed system (system of rivers and canals). This dual role complicates decisions about management and funding of the inland waterways. Whereas some federal agencies have broad authorities, Congress authorizes each capital investment for capacity expansion, facility replacement, or major rehabilitation of USACE water infrastructure projects. A construction project generally originates with a request to a congressional office from communities, businesses or other organizations, and state and local governments for federal assistance.[1] Since 1974, the process for authorizing federal water resources projects, including infrastructure for freight transportation, has been the omnibus bill typically

[1] At this early stage, USACE typically engages in an advisory role to answer technical questions or to assess the level of interest in possible projects and the support of nonfederal entities (state, tribal, county, or local agencies and governments) that may become sponsors.

called the Water Resources Development Act (WRDA).[2] On the basis of this legislation, Congress authorizes individual capital projects and numerous other USACE activities and provides policy direction in areas such as project delivery, revenue generation, and cost-sharing requirements. Benefit–cost analysis is the primary criterion used in selecting capital expenditures projects for funding. Projects that pass a minimum threshold for determining that the benefit exceeds the cost are eligible for congressional authorization and funding.

Two types of congressional authorizations are required for a construction project—one for investigation and one for project implementation.[3] First, authority is provided for a feasibility study in which the local USACE district investigates engineering feasibility, formulates alternative plans, conducts benefit–cost analysis, and assesses environmental impacts under the National Environmental Policy Act.[4] The study results are conveyed to Congress through a Chief of Engineers Report (Chief's Report) that contains either a favorable or an unfavorable recommendation for each project. Study results also are submitted to the executive office of the Office of Management and Budget (OMB), which applies its own fiscal, benefit–cost, and other criteria to assess whether projects warrant funding according to executive branch objectives. Congress considers USACE study results, recommendations of OMB, and other factors in choosing projects to authorize. Thus, both the projects selected for initial study and the project authorizations are at the discretion of Congress.[5]

After Congress authorizes a project, it becomes eligible to receive implementation funding in annual Energy and Water Development appropriations acts. The appropriations process begins with the submission of the annual President's budget. To be included in the President's budget, authorized projects must compete within the overall

[2] The 2014 authorizing legislation is titled the Water Resources Reform and Development Act (WRRDA).
[3] If the geographic area was investigated in previous studies, the study may be authorized by a resolution of either the House Transportation and Infrastructure Committee or the Senate Environment and Public Works Committee.
[4] According to WRRDA 2014, at any point during a feasibility study, the Secretary of the Army may terminate the study when it is clear that a project in the public interest is not possible for technical, legal, or financial reasons.
[5] After a project is authorized, modifications beyond a certain cost and scope require additional congressional authorization.

USACE program ceiling not only for initial funding but also for continued annual funding throughout the project's life cycle. Once Congress receives the President's budget request, it is "marked up" by the House and Senate Appropriations Committees, where project funding levels are adjusted in response to congressional priorities. Even if an authorized project has received initial construction funding, there is no assurance that it will receive sufficient appropriations each year to provide for an efficient construction schedule. The actual funding for the project over its life cycle may be much less suitable.

A previous National Research Council (NRC) report (2012) encouraged less reliance on WRDA as the main vehicle for authorizing projects for USACE infrastructure. The traditional focus on WRDA for authorizing large new construction projects in particular is less relevant to a system that is mostly "built out" and for which the main concern is a sustainable source of funding for ongoing operations and maintenance (O&M) and major repairs.

Although WRDA drives capital funding for freight transportation on the inland waterways, it is largely disconnected from federal legislative processes and efforts related to other freight modes. Similarly, the goal of the USACE planning process is to determine whether a navigation project is eligible for funding, not to assess whether the project will be the most efficient option for meeting national freight transportation needs and economic interests given the availability of other modes. (The benefit–cost analyses required for the authorization of navigation projects must consider other modes to a degree, as described later in this chapter.) The inland waterways system is not unique in this regard; a national freight system perspective on the efficiency of the nation's freight network is generally lacking, and no mechanism exists for prioritizing spending across modes.

OPERATIONS AND MAINTENANCE

O&M projects can be authorized under WRDA, but it has not often been used for this purpose (see NRC 2012, Table 2-2, for exceptions in WRDA 2007). USACE headquarters sets priorities for O&M

investments as part of the budgeting process on the basis of information gathered from USACE districts and divisions. Eight USACE divisions coordinate projects and budgets in 38 district offices across the United States. Districts develop plans, priorities, and rankings for investigations, construction, and O&M and submit them to USACE divisions. Divisions prioritize projects across their districts and provide divisionwide rankings of projects to USACE headquarters. USACE headquarters considers division priorities and rankings, administration budget priorities, and other factors in ranking requests.[6] The number of projects funded each year depends on the annual budget appropriation by Congress.

The local assessment of assets and maintenance needs follows general guidelines, but it has many local variations. For example, districts may develop their own asset management systems for assessing and communicating the condition of infrastructure and level of service being provided for navigation and O&M and repair needs. According to a past NRC report, with respect to water resources funding, "neither the Congress nor the administration provides clear guiding principles and concepts that the USACE might use in prioritizing OMR [operations, maintenance, and repair] needs and investments" (NRC 2012, 11). Full benefit–cost analysis is applied only to construction and not to O&M,[7] which is appropriate given the costs of conducting benefit–cost analysis relative to the cost of O&M projects. USACE is developing an approach to asset management that could be applied systemwide to improve identification and prioritization of maintenance and repair needs and spending (see Chapter 4).

DISTINCTIONS AMONG O&M, MAJOR REHABILITATION, AND CONSTRUCTION

USACE separates projects labeled as "major rehabilitation" from its O&M budget. Major rehabilitation projects meet the following criteria

[6] The USACE budget submitted as part of the President's budget request is not commensurate with all local requests given the lack of available funds and competing priorities within and across USACE programs (e.g., hydropower, recreation).

[7] As discussed in the next section and Chapter 4, rehabilitation projects of more than $20 million are classified arbitrarily as a capital cost.

established in a series of Water Resources Development Acts from 1986 to 2014.[8]

- Requires approval by the Secretary of the Army and construction is funded out of the Construction General Civil Works appropriation for USACE.
- Includes economically justified structural work for restoration of a major project feature that extends the life of the feature significantly or enhances operational efficiency.
- Requires a minimum of 2 fiscal years to complete.
- Costs more than $20 million in capital outlays for reliability improvement projects or more than $2 million in capital outlays for efficiency improvement projects. These thresholds are adjusted annually by regulation and are subject to negotiation.

Major rehabilitation projects are treated as capital projects for new construction in the budgeting process instead of being considered an expense of maintaining the system. The decision to classify major rehabilitations as a capital expenditure instead of as an O&M expense is arbitrary.[9]

Funding for the Inland Waterways Navigation System

COST-SHARING RULES

Before 1978, the inland navigation system was funded almost entirely through general revenues collected from taxpayers. Congress transformed funding for the inland waterways by passing two pieces of legislation: the Inland Waterways Revenue Act of 1978 and the Water Resources Development Act of 1986, which created the funding framework followed today. This legislation established a tax on diesel fuel for commercial vessels paid by the barge industry and an Inland

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[8] The $8 million ceiling for O&M was set in WRDA 1986 (P.L. 99-662). WRDA 1992 (P.L. 102-580) established a statutory definition for "rehabilitation" of inland waterways projects. WRRDA 2014 (P.L. 113-121) increased the ceiling from $8 million to $20 million for rehabilitation projects that can still be considered O&M. (With the escalation that accompanied the $8 million ceiling set in WRDA 1986, the ceiling for federal spending on rehabilitation projects was already at $16.5 million by 2014.)

[9] The Federal Highway Administration, for example, more clearly distinguishes between projects for maintenance and capital projects that significantly alter the function or expand the physical capacity of an asset.

Waterways Trust Fund (IWTF) to pay for construction with fuel tax revenues. It also increased the nonfederal cost-sharing requirements for inland navigation construction projects.[10]

The required cost share depends on whether the navigation project is classified as a capital cost or as O&M. For single-purpose navigation projects and multiple-purpose projects assigned to the navigation budget, the federal government pays 100 percent of O&M costs, 50 percent of capital costs (including capacity expansion, replacement, and major rehabilitation), and 100 percent of rehabilitation costs up to $20 million (costs for a single repair or set of repairs that exceed this amount are considered major rehabilitation and a capital cost). The waiving or adjustment of cost-sharing requirements for individual projects is infrequent and typically requires authorization by Congress.

The federal share for commercial navigation is paid via general revenues. The commercial users' share is paid for with a diesel fuel tax per gallon via the IWTF; the tax is collected by the Internal Revenue Service. The fuel tax was initially set at $0.04 per gallon and is not indexed to inflation. In 1986 legislation, the tax was set to rise to its current level of $0.20 per gallon, where it has remained until 2014, when the 113th Congress approved an increase in the barge fuel tax to $0.29 per gallon.

In contrast to the cost share for navigation, the O&M costs for non-navigation projects are paid for partly by sponsors. The federal share depends on the type of water resource project (see Table 3-1). For many project types (e.g., levees), the nonfederal sponsor is responsible for O&M once construction is complete. Furthermore, inland waterways feasibility studies to determine the eligibility of a navigation project

[10] The IWTF does not apply to ports and harbors. A separate Harbor Maintenance Trust Fund (HMTF) was established in 1986. The HMTF is designated only for O&M of federally authorized channels for commercial navigation in deep draft harbors and shallow draft waterways that are not subject to the IWTF fuel tax (Frittelli 2013). The HMTF is based on a 0.125 percent ad valorem tax imposed on imports, domestic shipments, and cruise line passenger tickets at designated ports (collected by U.S. Customs). Major port construction traditionally has been financed with existing reserves, cash from operations, government grants, and loans. Often port districts are set up to operate the port and borrow from capital markets, with bonds being paid off via user fees or property taxes. More recently, ports have begun examining joint venture financing, in which their customers assume most of the debt associated with a capital project, and third-party financing, in which an entity invests in project design and construction but may not operate the facility (see http://www.aapa-ports.org).

TABLE 3-1 Standard Construction and O&M Cost-Sharing Requirement for USACE Projects

Project Purpose	Maximum Federal Share of Construction (%)	Maximum Federal Share of O&M (%)
Navigation		
Coastal ports—		
<20-ft harbor	80[a]	100[b]
20- to 50-ft harbor	65[a]	100[b]
>50-ft harbor	40[a]	50[b]
Inland waterways	100[c]	100
Flood and hurricane damage reduction		
Inland flood control	65	0
Coastal hurricane and storm damage reduction except periodic beach renourishment	65	0
Repair of damaged flood and coastal storm projects	50	0
Locally constructed flood projects	NA	80[d]
Federally constructed flood and coastal projects	NA	100[d]
Aquatic ecosystem restoration	65	0
Multipurpose project components		
Hydroelectric power	0[e]	0
Municipal and industrial water supply storage	0	0
Agricultural water supply storage	65[f]	0
Recreation at Corps facilities	50	0
Aquatic invasive species control and prevention	NA	30
Environmental infrastructure (typically municipal water and wastewater infrastructure)	75[g]	0

NOTE: Information comes from 33 USC §§2211–2215 unless otherwise specified in footnotes *a* through *g*. NA = not applicable.

[a] These percentages reflect that the nonfederal sponsors pay 10, 25, or 30 percent during construction and an additional 10 percent over a period not to exceed 30 years.

[b] Appropriations from the HMTF, which is funded by collections on commercial cargo imports at federally maintained ports, are used for 100 percent of these costs.

[c] Appropriations from the IWTF, which is funded by a fuel tax on vessels engaged in commercial transport on designated waterways, are used for 50 percent of these costs.

[d] 33 USC §701n. Repair assistance is restricted to projects eligible for and participating in the USACE Rehabilitation and Inspection Program and to fixing damage caused by natural events.

[e] Capital costs initially are federally funded and are repaid by fees collected from power customers.

[f] For the 17 western states where reclamation law applies, irrigation costs initially are funded by USACE but repaid by nonfederal water users.

[g] Most environmental infrastructure projects are authorized with a 75 percent federal cost share; a few have a 65 percent cost share.

SOURCE: Carter and Stern 2014.

for funding are entirely a federal expense; in contrast, for deepwater navigation and nonnavigation projects, the federal share for feasibility studies is 50 percent.[11]

ROLE OF THE INLAND WATERWAYS USERS BOARD

WRDA 1986 established a federal advisory committee subject to the Federal Advisory Committees Act, the Inland Waterways Users Board (IWUB), which represents shipping industry interests. IWUB was created to give commercial users the opportunity to inform priorities for projects funded from the IWTF. WRDA 1986 specifies that the board consist of 11 members representing shipping interests in the primary geographical areas served by inland waterways, with consideration given to tonnage shipped on the respective waterways. IWUB makes recommendations to the Secretary of the Army and Congress with regard to IWTF investments. The board is advisory only. Congress and the administration choose whether to follow the board's guidance.

WRRDA 2014 stipulates greater involvement of IWUB in project development and oversight than in previous years. According to the 2014 WRRDA, IWUB is to provide advice and recommendations to the Secretary of the Army and to Congress concerning construction and rehabilitation priorities and spending levels; feasibility reports for projects on the inland waterways system; increases in the authorized cost of project features and components; and development of a long-term, 20-year capital investment program. A representative of IWUB, appointed by the board's chair, is to serve as an adviser to project development teams for qualifying projects and for studies or designs of commercial navigation features and components for waterways and harbors. The President's 2015 budget request included $860,000 to support IWUB activity. The Secretary is to communicate with IWUB at least quarterly on the status of commercial navigation

[11] Before WRRDA 2014, a reconnaissance study to assess the need and support for a project was produced at 100 percent federal expense for navigation projects. WRRDA 2014 replaced the reconnaissance study with a preliminary study that is combined with the feasibility study as the first phase of analysis. According to the Congressional Research Service (Carter and Stern 2014), post-WRRDA 2014 cost sharing of the preliminary analysis portion of the first phase has not been clarified. WRRDA 2014 established a maximum federal cost of $3 million for most feasibility studies.

studies, designs, and construction. The board provides guidance relating only to capital investments, since current law specifies that fuel tax revenues from the shipping industry are to be used for capital expenditures and not for O&M.

PATTERNS AND TRENDS IN FUNDING FOR THE INLAND WATERWAYS SYSTEM

The FY 2015 federal budget appropriated more than $1.8 billion for USACE navigation projects,[12] with about $834 million of this amount provided for inland waterways navigation.[13] In recent years, the demand for O&M for the inland waterways has increased with the aging of infrastructure. As shown in Table 3-2, O&M has become a larger share of the administration's inland navigation budget request. It now accounts for about three-fourths of the requested budget (Table 3-2).[14]

In terms of constant dollars, funding for construction and O&M for lock and dam facilities is at its lowest point in more than 20 years and is on a downward trajectory (see Figures 3-1*a* and 3-1*b*).

The balance of the IWTF, which is used to pay 50 percent of construction costs, has declined. The fund was at its highest level, $413 million, in 2002 (see Figure 3-2). The balance fell sharply between 2005 and 2010 as expenditures for inland waterways exceeded fuel tax collections and interest on the trust fund balance. Reasons for the decline include increased appropriations, lower fuel tax revenues than in previous years, large construction costs, and construction cost overruns.

Capital projects are funded incrementally by Congress through the annual budgeting and appropriations process. Incremental federal funding, an increasingly common procedure in which only a portion of the total budget for a project is appropriated, contributes to

[12] http://www.usace.army.mil/Portals/2/docs/civilworks/budget/strongpt/fy15sp_navigation.pdf.

[13] In the past decade, USACE Civil Works appropriations (which include both general revenues and sponsor support) have ranged from $4.5 billion to $5.5 billion to support the USACE primary mission areas (navigation, flood control and prevention, ecosystem restoration) and the other services that USACE has authorities to provide (water supply; hydroelectric power; water-based recreation; and design depths for the nation's ports, harbors, and associated channels).

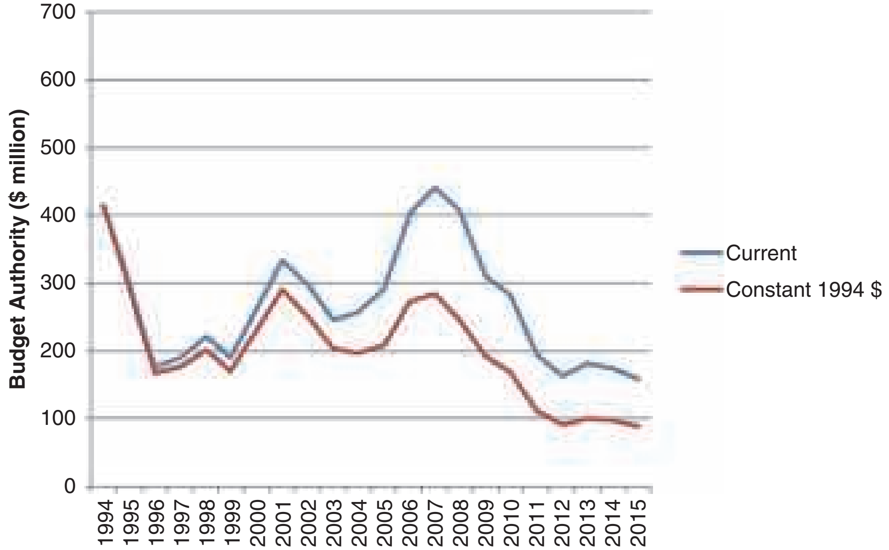
[14] Although the administration budget requests will differ from federal appropriations, this table shows requested amounts because the level of budget detail for the inland waterways needed for this report (e.g., for inland navigation O&M) is not publicly available for federal appropriations. However, federal appropriations for O&M and construction for locks and dams are available, as shown in Figures 3-1*a* and 3-1*b*.

TABLE 3-2 Administration Budgets for USACE Inland Navigation, FY 2008–FY 2015

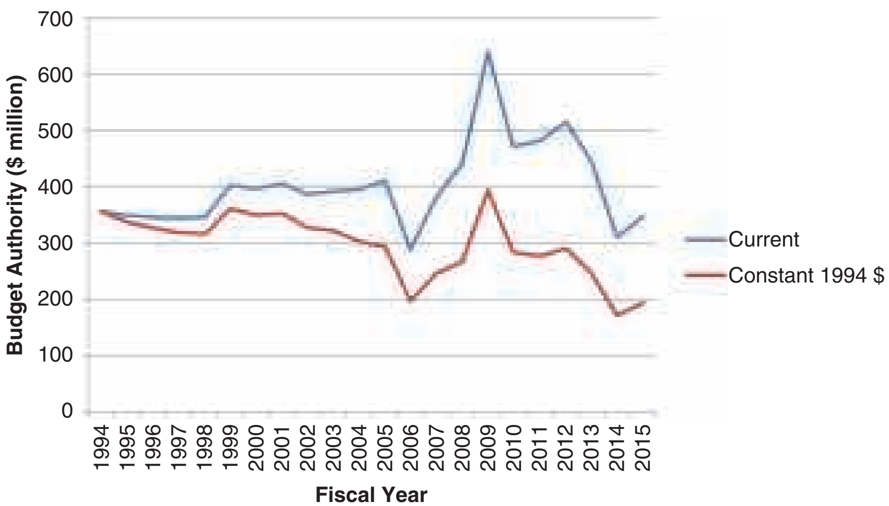
President's Budget (FY)	Investigations	Construction	Regular O&M	MR&T O&M	MR&T Investigations and Construction	Total Inland Nav	O&M Budget as % of Total Inland Nav
2015	5	180	612	29	8	834	77
2014	7	237	608	42	11	904	72
2013	8	201	529	28	14	780	71
2012	11	166	531	22	13	743	74
2011	10	176	550	28	15	779	74
2010	3	170	577	32	15	796	77
2009	3	307	586	25	10	931	66
2008	7	406	604	25	10	1,052	60

NOTE: Except for percentages, figures are dollar amounts in millions. MR&T = Mississippi River and Tributaries flood control project, which was authorized through the Flood Control Act of 1928. Nav = navigation.

SOURCE: USACE headquarters.



(a)



(b)

FIGURE 3-1 USACE budget authority, FY 1994–FY 2015, for (*a*) lock and dam construction and (*b*) lock and dam O&M. FY 2014 and FY 2015 data for both construction and O&M are estimates from the President's FY 2015 budget for the Civil Works Program, USACE. Figure 3-1*a* includes appropriations from the IWTF for construction not included in Figure 3-1*b* since the IWTF is not to be used for O&M.

SOURCE: Adapted from Kruse et al. 2012.

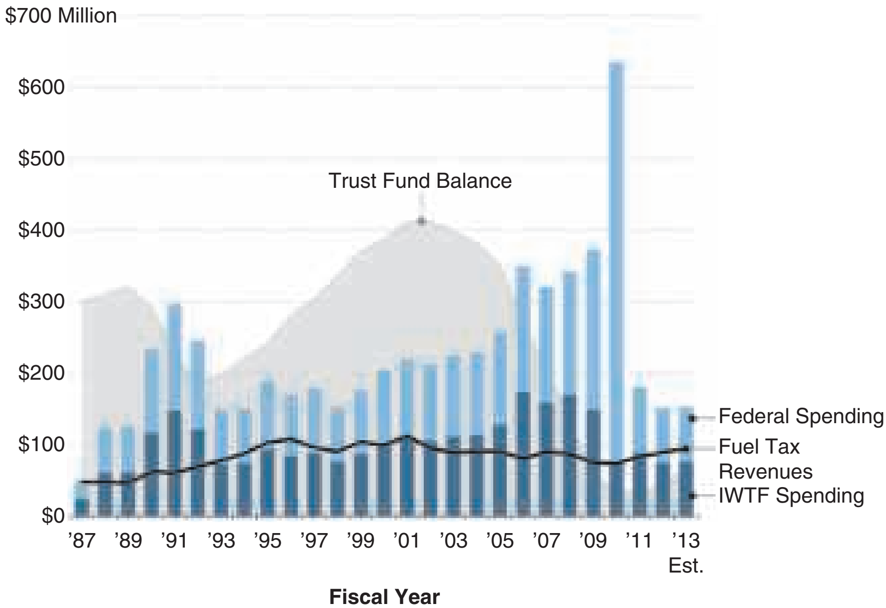


FIGURE 3-2 Inland waterways financing trends. Amounts are in nominal dollars and represent funding for construction only. Federal spending for FY 2009 and FY 2010 reflects congressional stopgap measures and supplemental funding under the American Recovery and Reinvestment Act of 2009 (P.L. 111-5). [Federal spending includes total revenues disbursed by the federal government to pay for commercial navigation on the fuel-taxed inland waterways system, including general revenues from taxpayers and fuel tax revenues from carriers. The IWTF (50 percent contributed by shippers and 50 percent contributed from general revenues) is dedicated to capital costs and is not used to pay for O&M.]

SOURCE: Stern 2014 (USACE data adapted by the Congressional Research Service).

project delivery delays and higher costs (NRC 2011; NRC 2012, 29, gives another example on the Lower Monongahela River). Between 2005 and 2010, Congress made a conscious effort to "spend down" the IWTF to accelerate project completions and reduce the size of the backlog of authorized projects.

CAPITAL PROJECTS BACKLOG

A substantial number of water resources projects that have been authorized by Congress via WRDA remain unfunded through the appropriations process. These projects are known as the backlog. WRRDA 2014 included provisions to reduce the backlog and prevent backlogs in the future; whether the provisions will achieve this purpose is unclear.[15] Congress considers the recommendations of USACE and OMB, but the selection of waterways projects for authorization has a long history of being driven largely by political and local concerns (Ferejohn 1974). In recent years, congressionally directed spending has taken the form of providing additional funding for broad categories of ongoing activities not included in the President's budget. USACE is responsible for selecting which of these activities to undertake and for prioritizing them on the basis of directions and exclusions provided in the WRRDA.

While concerns about the backlog have been expressed, its size is not a reliable indicator of the funding needed for the inland navigation system for at least three reasons. First, O&M spending is not reflected in the backlog. With the aging of the system, maintenance has become a higher priority. Second, navigation projects make up only a portion of the backlog ($4.1 billion) (Carter and Stern 2011); most of the backlog relates to waterways infrastructure serving other purposes such as flood control.

Third, not all of the projects in the navigation backlog are priorities. In contrast to its practice for other modes, Congress authorizes and appropriates funds on a project-by-project basis. Benefit–cost

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[15] The bill required the Secretary of the Army to identify a list of projects totaling $18 billion that would qualify for deauthorization. However, Congress also authorized 34 new construction projects, which added nearly $16 billion to the federal backlog. The number of authorized projects is likely to grow through allowed forms of congressionally directed spending.

analysis is used to determine whether a construction projects meets a minimum threshold of eligibility for pursuing authorization and appropriations and is generally suitable for this purpose,[16] but the lack of a prioritization process based on a formal assessment of system needs has resulted in the authorization of more projects than can be funded within the constraints of the budget. The current practice is for OMB to set a minimum benefit–cost ratio that projects must meet to be included in the President's annual budget request.[17] While benefit–cost analysis is used in determining whether a project meets a minimum threshold for authorization, there is no indication that projects are further ranked against each other during the authorization process (GAO 2010). Because more projects are authorized than can be funded, priorities are sorted out in the budgeting and appropriations process, in which both the executive branch and Congress participate. IWUB, as part of a capital projects business model, has proposed projects that might serve as a starting point for evaluating the urgency of needed repairs throughout the system (Inland Marine Transportation System Capital Investment Strategy Team 2010).

For these reasons, a method for prioritizing projects on the basis of the service needs of the system may be more useful than an attempt to estimate and seek funding for the entire backlog. As for O&M, a standard process is needed for prioritizing spending for capital projects for construction and major rehabilitation and to ascertain the level of funding required across the system to maintain reliable freight service. (Prioritization is discussed in Chapter 4.)

[16] However, USACE's implementation of benefit–cost analysis has received numerous critiques mainly related to the use of optimistic traffic projections.

[17] Although the benefit-to-cost ratio (BCR) must exceed 1.0, BCR thresholds and other criteria used by the administration vary annually. In recent years, more stringent and differentiated criteria have been used to select projects for funding. For the FY 2015 budget, a BCR of 2.5 was required for construction projects. See http://planning.usace.army.mil/toolbox/webinars/14Apr22_budgetworkplan.pdf. Furthermore, annual changes in BCR thresholds and the use of other BCR criteria have resulted in some projects qualifying for one year's budget request but not qualifying in subsequent years. For example, instead of using a traditional BCR metric for the FY 2007 budget request for incomplete projects, OMB used a remaining-benefit-to-remaining-cost metric. The rationale was that if the cost of a project has increased dramatically since it was authorized, the updated cost may have become greater than the benefits. Different BCR cutoffs have been used for projects of different types in the past. For example, the administration's FY 2010 budget request required ongoing navigation and flood control projects generally to have a BCR greater than 2.5; new projects needed to have a BCR greater than 3.2.

A number of temporary measures have been taken in an attempt to stabilize the IWTF. Beginning in 2005, the Bush administration and Congress increased annual budget appropriations for IWTF-funded construction projects. Congress also exempted the fund temporarily from the usual cost-sharing requirements, provided additional federal general revenues (through the American Recovery and Reinvestment Act of 2009, which accounted for the spike in federal spending for 2010 in Figure 3-2), and waived the IWTF cost-sharing requirements for specific projects.

Cost escalations and schedule delays have been of particular concern for one project, the Olmsted Locks and Dam on the Ohio River in Illinois. As part of WRRDA 2014, Congress altered the construction cost share for the Olmsted project, which was contributing to the depletion of the IWTF, to redress a perceived inequity to commercial users and help restore the IWTF balance. The provision for Olmsted requires the federal government to pay 85 percent of construction costs for the project (instead of the usual 50 percent). The act also specified changes in project planning and delivery, with the intent of avoiding such cost overruns in the future.

FUEL TAX REVENUES AS USER CONTRIBUTION

Federal legislation specifies the waterways subject to the collection of fuel tax revenues (Figure 3-3; see Appendix A for a more detailed description of fuel-taxed waterways). Fuel tax revenues totaled $85,754,000 in 2011, the last year for which comparable data on both fuel tax revenues and expenditures are available (Dager 2013). This amount was about 49 percent of the 2011 administration budget for construction costs. The budget for inland navigation O&M in 2011 was more than $550 million; however, fuel tax revenues are only for construction and not O&M.

The increase in the barge fuel tax passed by the 113th Congress in 2014 is consistent with the proposal of IWUB in its capital projects business model report (Inland Marine Transportation System Capital Investment Strategy Team 2010). The new rate of $0.29 per gallon is 45 percent above the current tax of $0.20 per gallon. [As with the original tax of $0.20 per gallon, the increased fuel tax would not be indexed for

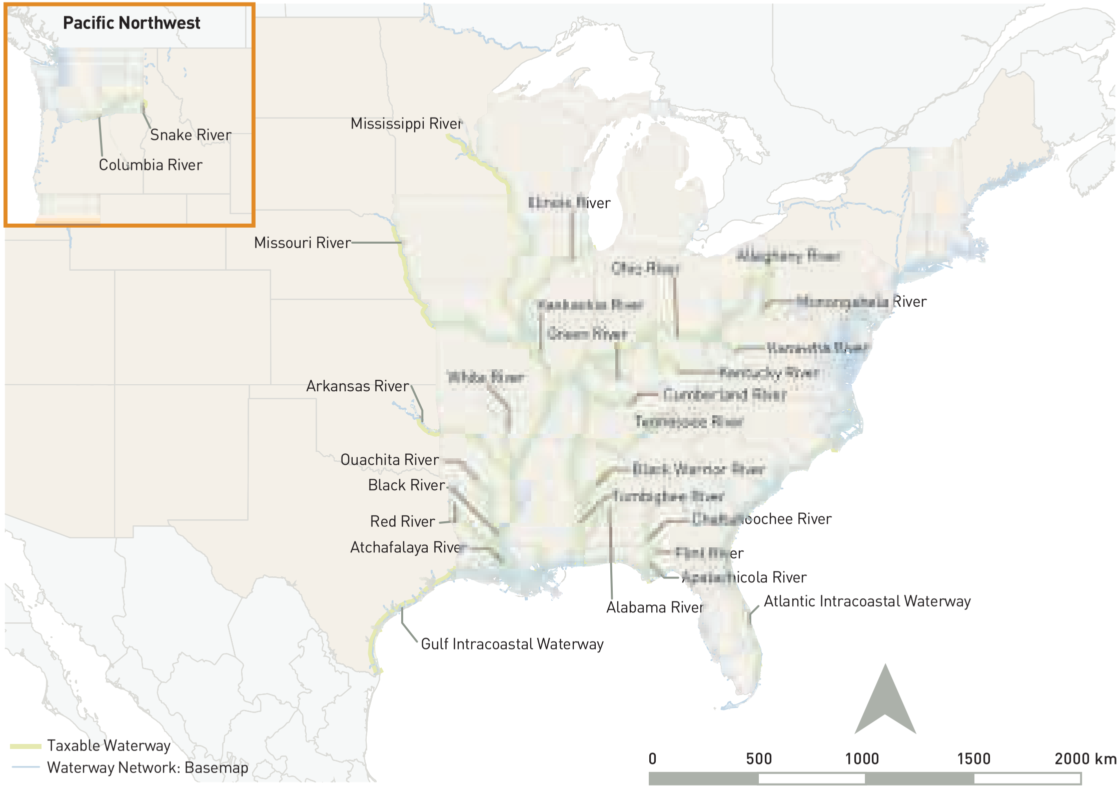

FIGURE 3-3 Map of inland waterways indicating where fuel taxes apply.

SOURCE: P.L. 95-502, October 21, 1978; P.L. 99-662, November 17, 1986.

inflation and would not include a capital recovery mechanism linking future taxes to expenditures (Stern 2014). Any action on these concerns would require separate legislation and falls under the jurisdiction of the House and Senate taxation committees.] Estimated revenue from the proposed fuel tax increase is not sufficient to pay to maintain the system, and other sources of funding are required (see Chapter 5 for details). As explained, fuel tax revenues are dedicated only to capital spending and not O&M, and the federal government must match the user contribution for capital costs while paying all of the O&M costs. Federal funding for capital projects therefore competes with federal funds for O&M. As indicated in the next section, for historical reasons, the federal cost share and general revenue spending for the system as a proportion of total costs are greater for the inland waterways system than for the other freight transportation modes.

Federal Involvement Compared with Other Transportation Modes

States and private enterprise led the initial building of inland waterways infrastructure and charged for use of the waterways. Federal involvement in the inland waterways system began in the 18th century, when the scope and scale of inland waterways projects grew beyond what any private entity or state could or would take on, especially without the ability to realize a monetary return on investment. Congress made these federal investments to promote inland waterways commerce, which was central to the economic development of the United States. This history has led to a unique federal role in the inland waterways system among all the freight transportation modes.

Today, waterborne transportation is the only freight mode for which Congress authorizes and appropriates funds (for construction and O&M) on a project-by-project basis. Federal management and decision-making responsibilities for freight transportation generally are fragmented across jurisdictional lines in Congress, multiple federal agencies, and different silos of funding. Whereas USACE and the U.S. Coast Guard (part of the Department of Homeland Security) manage the marine and inland waterways systems, the U.S. Department of Transportation has responsibilities for highway, aviation, rail, and pipeline. Various congressional committees are responsible for authorizations and appropriations for the different modes. Decisions about inland waterways investments, including ports, channels, and infrastructure, are made largely at the federal level.[18] However, most decisions about highway investments are made at the state and metropolitan levels. For ports, investment decisions are made mainly by independent private entities and sometimes by state or bi-state port authorities. As private transport industries, railroads and pipelines make their own decisions about investments.

Public and private shares of funding also differ across modes. Highways, aviation, ports (harbor and channel dredging and maintenance), and the inland waterways all receive federal aid for capital costs. In addition, the inland waterways, harbors, and channels receive federal general revenues support for O&M. Rail and pipeline, with which the inland waterways system competes to some degree, are almost entirely private enterprises, with minimal federal assistance for infrastructure.[19] For highways, the federal government pays a significant share for new construction, but O&M is a state and local financial responsibility.

The federal government, through general revenues, pays more for water transportation as a percentage of total O&M and construction costs compared with federal contributions to highways and rail. For the inland waterways system, federal support is used to cover a large shortfall between the fees paid by users and total system costs. In contrast, fees paid by the users of highway and rail modes cover a much greater share of the capital and O&M costs of those transportation systems. General federal tax revenues pay about 90 percent of total inland waterways system costs, including the construction, operations, and maintenance of barge navigation infrastructure

[18] The federal government has other important roles related to regulating and securing access to petroleum and other fuel supplies for transportation. It also sets environmental and safety standards for each mode through regulation and provides for operation of the air traffic control system and aids to navigation for ports and waterways. Highway, aviation, and rail transport both freight and passengers, which has consequences for federal involvement in passenger safety regulation for those modes.

[19] Railroads did receive land grants from federal and state governments in the 19th century and assistance in building networks through exercise of eminent domain. The Federal Energy Regulatory Commission can exercise eminent domain for siting natural gas transmission lines.

(TRB 2009).[20] This compares with virtually no federal general revenue support for rail system users and pipeline, and historically only about 25 percent federal support for highways, which are primarily derived from user fees (Federal Highway Administration, U.S. Department of Transportation, *Highway Statistics 2010*).[21] (See Box 3-1 for further discussion of federal subsidies across freight transportation modes.)

Decisions About Federal Funding and Beneficiary Payments for the Commercial Inland Waterways System

In a climate of constrained federal funds and with O&M becoming a greater part of the inland navigation budget, a pressing policy issue is how to pay to preserve the inland waterways system for commercial navigation. The structures (locks and dams) built and maintained for freight transportation have resulted in beneficiaries beyond commercial navigation. It is reasonable and, from an economic perspective, potentially efficiency enhancing to consider whether these beneficiaries could help pay for the system. Congress, in the 2014 WRRDA (Section 2004, Inland Waterways Revenue Studies), called for a study of whether and how the various beneficiaries of the waterways might be charged. The sections below assess the available evidence on benefits of the inland waterways used for freight transportation and the economic and practical considerations in charging for the benefits received.

AVAILABLE EVIDENCE ON BENEFICIARIES

Commercial navigation is the primary beneficiary of the inland waterways system. This is recognized by USACE in the primary criterion used in determining investments for the system. The framework and approach to benefit–cost analysis that USACE uses in helping

[20] This figure is based on user fee revenues that equaled 10 percent of inland waterways capital (construction and major rehabilitation) and operating expenditures (O&M) in 2006: capital expenditures, $0.5 billion; operating expenditures, $0.4 billion; user fee revenues, $0.1 billion. Commercial users are required by legislation to contribute only to capital improvement costs and are not required to pay for O&M expenditures. See TRB 2009 (99, Table 3-5).

[21] In recent years, large general fund transfers have been made to the Highway Trust Fund and the Aviation Trust Fund to maintain their solvency. These transfers have resulted from a political stalemate that has affected investments in highway, air, and waterways transportation since the 1990s by preventing the raising of user taxes, which in past decades had been increased regularly as needs arose.

BOX 3-1

Federal Subsidies for the Various Freight Transportation Modes

Federal subsidies for the various freight modes are complicated and contested among advocates for the modes, in part because of disagreements about (*a*) direct subsidies that are funded by various public sources and (*b*) indirect subsidies that result from costs imposed on the public (externalities) that are not part of market transactions between shippers and carriers. No authoritative study has estimated either direct or indirect subsidies across the various freight modes, although a previous Transportation Research Board study (TRB 1996) developed and pilot-tested a methodology for estimating freight external costs.

Assessing direct subsidies is more straightforward among the modes with which water competes (rail, pipeline, and, to a much lesser degree, trucking). Freight railroads are private entities that fund the vast bulk of their operations and capital and maintenance spending from their own funds. Limited federal funds are available for grade separation projects (to separate traffic for safety and mobility), a modest federal loan guarantee program is available (principally for short lines), and state governments occasionally provide public funding for such purposes as raising bridges or tunnels for double-stack trains or to improve rail access to state ports. Although public funding is minimal in proportion to the $20 billion to $25 billion railroads have invested in capital stock annually since 2007,[a] railroad modal competitors point out that many railroad rights-of-way were initially given in the 19th century by the federal government and states to encourage railroad development. Because pipelines are entirely private, the evaluation of subsidies is easier than for rail. Although long-distance truck–barge competition is unlikely because of the much higher cost of truck movements per ton-mile, there may be short segments in which truck and barge would compete. The trucking assessment of competitive subsidies is most complex because trucks use highways that are shared with passengers. Although both freight and passenger operators pay fuel taxes and other user

(continued)

[a] Association of American Railroads. Freight Railroad Expenditure on Infrastructure and Equipment. https://www.aar.org/Pages/Private-Rail-Investments-Power-America%27s-Economy.aspx. Accessed May 21, 2015.

BOX 3-1 *(continued)* **Federal Subsidies for the Various Freight Transportation Modes**

fees, there is continued debate about whether the largest and heaviest trucks pay their share of the costs of building and maintaining highways (GAO 2012). Moreover, after decades of relying almost exclusively on federal and state user fees to fund interstate and intercity highways, in the past decade Congress has used general funds to supplement user fee revenues to the Highway Trust Fund (HTF) for the federal share of highway capital spending (CBO 2014). (Improved fuel economy and political opposition to raising fuel taxes have resulted in insufficient user fees into the HTF to pay for the federal share of highway capital improvements.) These general fund subsidies to highway users, of course, apply to both trucks and passengers, and, as noted, truck–barge competition is fairly limited.

Indirect subsidies lack definitive estimates in the form of external costs imposed on the public, but GAO (2011) provides a high-level comparison of external costs of freight shipments by water, rail, and trucking. For air pollution in the form of particulates, for example, GAO (2011) estimates that trucking external costs are 6.7 times higher than those of rail and 10.2 times higher than those of water. While such comparisons are useful for providing a sense of national scale, they are only meaningful to the extent that one mode can substitute for another in specific origin–destination (O-D) markets. Moreover, national comparisons mask the subcorridor impacts where locally similar modal volume or intense activity by rail or inland water modes produces greater impact or provides higher benefits. As noted in Chapter 2, there are markets where truck and rail compete head-to-head and markets where rail and water compete, but trucking is involved in at least one segment of all freight moves and often two, and there are markets where the rail and water modes complement each other. Whereas trucks can serve almost all O-D pairs because of the ubiquity of roads and highways, and railroads reach many O-D pairs as well, barge transportation is limited by the availability of and access to navigable rivers and coasts. Thus, estimates of direct and indirect subsidies are meaningful in specific subcorridors for specific commodities.

Congress determine when federal spending is justified for new construction and major rehabilitation projects are based on the 1983 *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (known as the *Principles and Guidelines*).[22] The *Principles and Guidelines* prioritize the *national net economic development benefit* defined in terms of commercial navigation and operationalized as savings in shippers' transportation costs.[23]

According to the most recent and wide-ranging attempt to catalogue and estimate the benefits of the inland waterways system, benefits beyond commercial navigation may include hydropower generation, recreation, flood damage avoidance, municipal water supply, irrigation, higher property values for property owners, sewage assimilation, mosquito control, lower consumer costs because the availability of barge shipping may result in more competitive railroad pricing (referred to as water-compelled rates), and environmental benefits associated with lower fuel emissions of barge compared with other modes (Bray et al. 2011). The available evidence on nonnavigation benefits that may result locally is incomplete and inconclusive. Bray et al.'s list includes many possible local benefits and national benefits. Some of the benefits may be viewed as transfers from one part of the economy to another. For example, in cases where lower rail rates may exist because of barge competition, the resulting savings in transportation costs are classified by USACE as a transfer to shippers (and a loss to rail lines), not a net national economic benefit. (See Box 3-2 for further discussion of the available research on the issue of water-compelled rates.)

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[22] The *Principles and Guidelines* are available at http://planning.usace.army.mil/toolbox/guidance.cfm?Id=269&Option=Principles%20and%20Guidelines (accessed June 3, 2015). The *Principles and Guidelines* remain in effect. They were issued by the federal Water Resources Council, a body that no longer exists. In the Water Resources Development Act of 2007, Congress instructed the Secretary of the Army to develop a new set of *Principles and Guidelines* for USACE. However, these guidelines have long been under review and are viewed as controversial. The new guidance, if implemented, would have no effect on how the national economic development benefit is calculated for commercial navigation.

[23] Shipper savings are measured as the difference in costs between moving a volume of a commodity from an origin to a destination by using the waterway for all or part of the movement and moving the same commodity without using the waterway. Shipper savings may also be realized if the alternative results in a reduction in scheduled or unscheduled lock unavailability for moving the commodity by using the waterway for all or part of the movement. Estimation of the benefits of reducing unscheduled unavailability requires prediction of the probability of the facility being unable to pass traffic, and the estimate is a function of a condition assessment for the facility. USACE has well-developed procedures for making such benefit and cost calculations (Engineer Regulation 1105-2-100).

BOX 3-2

The Issue of Water-Compelled Rates

Analysts have built models to demonstrate how water-compelled rates should play out in theory (Anderson and Wilson 2008). Some theory and empirical evidence indicate that rail rates are lower the closer the water alternative is to the shipper (McMullen 1991; MacDonald 1987; Burton and Wilson 2006; Harbor 2009; Burton 1993; Burton 1995). However, McMullen (1991) and Burton (1993) find that intramodal competition (presence of a second railroad) may also help explain the constrained rail rates. Furthermore, Burton and Wilson (2006) find that for situations in which a segment of the rail network competes with barge and then connects to a rail monopoly segment, the rail rates on the segment with barge competition may be lower, but the rail rates on the monopoly segment are often higher than comparable rail-only monopoly segments for the same commodities. Thus, the shipper likely receives no net benefit in these cases. The evidence also indicates that shippers of bulk commodities need to be relatively close to navigable rivers to benefit from water-compelled rates. Harbor (2009) found that the further a shipment originates from water competition, the higher the rail rate. Corn shippers located 100 miles from a barge loading point pay 18.5 percent higher rail rates than those located 50 miles from water. Soybean shippers located 100 miles from water pay rail rates 13.4 percent higher than shipments originating 50 miles from a barge loading point. When shippers require movement of their commodities to the river by truck or short-line railroad, they must balance the cost of these movements and transfers with the benefit of an all-rail movement.

According to economic principles, the most efficient way to allocate resources would be for the price of the mode to be set according to its marginal cost and for the market to decide the shares of freight to be carried by each mode (see Chapter 5 for further discussion). However, shippers of bulk commodities contend that without barge transportation there is insufficient competition for transportation of their commodities to ensure efficient resource allocation. Specifically, many coal and agricultural shippers and receivers assert that they are “captive” to a single railroad that can exercise market power in the setting of rates and that a water alternative is needed to protect them from monopoly rates. Congress has been sensitive to this

(continued on next page)

BOX 3-2 *(continued)* **The Issue of Water-Compelled Rates**

argument. After deregulating the railroads in 1980, Congress directed the Interstate Commerce Commission [and later the Surface Transportation Board (STB)] to balance the interests of railroads and shippers in cases with insufficient competition. The technical and policy issues concerning the performance of STB are complex. A study in parallel with this one is under way to examine STB's performance and suggest reforms to address shipper concerns.

A possible national benefit of investing in the inland waterways is the environmental advantage that barge may have over other modes: barge's lower fuel usage per ton-mile than other transportation modes may result in lower air emissions. Whether barge or rail is the more energy-efficient mode (measured as fuel use per ton-mile) depends in large part on the water route, since the increased circuity of some rivers offsets the reduced energy required to move products by water (see Appendix G for details of the committee's assessment of the available research and its examination of data for selected major corridors). A comprehensive analysis at the subcorridor level would be needed to obtain a better understanding of the magnitude of the benefit. Challenges of such an analysis would be (*a*) the difficulty of modeling the potential for commodities to shift modes and (*b*) accounting for the comparative reliance on truck movements to and from the water and rail modes. Both rail and water can depend on trucks to move commodities from the origin to the rail or water terminal and from the rail or water line-haul movement to the ultimate destination. Since trucking involves much greater energy and emissions per ton-mile than either water or rail (GAO 2011), the distances of commodity movement by truck to the true origin and destination affects the net energy and emission benefits of movement by either mode.

A full assessment of environmental benefit would also need to account for the environmental damages associated with maintaining waterways for navigation. The mitigation of environmental costs is considered in benefit–cost analyses for construction and major rehabilitation projects for which it is classified as an aquatic ecosystem benefit, understood as restoration of some of the preproject conditions with regard to pattern and timing of river flows that may result from changes in a facility.[24]

Congestion reduction is another possible environmental benefit of barge, and one that USACE may include in benefit–cost analysis, but it is difficult to assess. A reduction in congestion may be realized if the availability of barge results in traffic shifts from an alternative mode to the waterways. The initial assumption of the investment analysis typically is that the alternative modes—rail, highway, and pipeline—have sufficient capacity to continue to move traffic at current rates without the waterway improvement and that congestion reduction could not be a benefit. For that assumption to be modified, USACE's analysis would need to show congestion on some other mode, demonstrate how the shift to waterway would reduce that congestion, and then evaluate the beneficial effects of congestion reduction. Environmental Protection Agency models might then be used to estimate the impact of such a change in highway traffic on emissions. Models are available for predicting the impact of such traffic diversions on safety. However, all of these estimates depend on the accurate prediction of traffic diversion, which requires realistic estimates of how much modal shift will take place even if costs change substantially. To monetize the impact of the investment on congestion reduction requires assigning a dollar value to time (for congestion time savings), to costs of accidents (including a value for lives saved), and to emission reduction effects on human health and ecosystems. If such effects can be identified, ranges of dollar values may be used for estimates, but there may be considerable disagreement as to the monetary size of these impacts.

In addition to possible reductions in emissions and congestion, oil spill and safety advantages may result from shipping by barge (Frittelli

[24] If the restoration was an outcome of a project investment, USACE's procedures would allow that benefit to be claimed and made part of the project cost justification, even though such river restoration benefits are not monetized. However, the more common claim is that inland waterway project investments for commercial navigation are detrimental to the aquatic ecosystem. When that is the case, the alternative must include actions to mitigate the unavoidable adverse impacts on the aquatic environment, and the costs of those actions are part of project cost. For facilities no longer operated for commercial navigation, restoration of preproject conditions would be a priority.

2014; Frittelli et al. 2014; GAO 2011). The policy question for deciding on the federal role in funding the system is not whether environmental benefits exist from moving freight by barge, but whether the size of the benefits warrants current levels of federal investment required to obtain them. On this question the evidence is uncertain because a definitive study has not been done. As noted above, a Transportation Research Board committee concluded that development of reliable estimates of the marginal costs of shipments by truck, rail, and barge would be possible and recommended a study to allow generalizations that could inform decisions about the size of federal support for surface freight transportation (TRB 1996). However, federal agencies have declined to fund the data collection and analysis that would be required to develop complete and policy-relevant conclusions.

ECONOMIC AND PRACTICAL CONSIDERATIONS IN DECIDING ON CHARGES FOR BENEFITS

In view of the constraints on federal funds and the importance of O&M in the inland navigation budget, Congress and the executive office will need to decide how to pay for the system and how to prioritize inland waterways expenditures versus other federal expenditures. Economic principles for charging system users and the practicalities of implementing charges for the benefits received are important considerations in an analysis of how to fund the system.

According to economic principles, if beneficiaries impose either marginal costs or opportunity costs, user charges will improve economic efficiency (Chapter 5 describes the economic rationale for user charges in more detail). A next step would be to determine whether efficient or practical ways exist to charge groups of users who impose significant costs for the costs associated with their use of the system. The various beneficiaries can be grouped into four classes: commercial navigation, flood control and hydropower, ancillary, and environmental.

Commercial Navigation Beneficiaries

This group is a direct beneficiary and imposes marginal costs to obtain these benefits. Chapter 5 presents options for charging users for commercial navigation and criteria for deciding among the options. User charges for the system have been proposed since the 1940s, which the shipping industry has consistently opposed. Supporters of user charges have included OMB, the Government Accountability Office, and Presidential administrations of both parties since Roosevelt, both before and after implementation of the first fuel tax approved by Congress in 1978 (see Box 3-3 for a brief history of proposals for user charges).

An increase in charges for shippers using the waterways raises concern about a resulting shift of cargo from water to rail and highway, perhaps accompanied by negative effects on highway congestion, noise, air quality, safety, and wear and tear on highways. Analysis of the possible mode shift from temporary closure of a waterway indicates, in the case examined, that, of the tonnage that would shift, most would move to rail and little to truck (Kruse et al. 2012). Moreover, after the start of the diesel fuel tax, several studies of the potential impact of the barge diesel fuel tax on barge freight were conducted in the 1980s. The consensus conclusion of these studies was that any diversion of barge freight to rail would be minimal. For example, Babcock and German (1983) found that a 100 percent cost recovery user fee would divert only 4 to 5 percent of barge tonnage to railroads. However, as noted in the discussion of the potential for mode shift in Box 2-1, the shift from one mode to another is highly dependent on commodity, distance, subcorridor infrastructure, cost, and other variables, which makes generalizations difficult. The policy question that arises in deciding the federal role is whether the emission, safety, highway congestion, and infrastructure costs are greater than the costs of preventing them.

Flood Control and Hydropower Beneficiaries

Bray et al. (2011) include flood control and hydropower as beneficiaries of inland navigation. For projects that support commercial navigation as well as other purposes such as flood control, the cost of serving that purpose is allocated as described in Table 3-1. The beneficiaries of some purposes (e.g., hydropower) pay directly for their allocated cost, and some purposes are paid for via general revenues (e.g., flood control). As a result, commercial navigation is allocated the costs attributable to that purpose, and the other purposes are allocated

BOX 3-3

Brief History of Proposals for User Charges for the Commercial Inland Waterways System[a]

The Constitution (Article 1, Section 8) gives Congress power to regulate commerce, including navigation and navigable waterways. Section 10 of the first article protects the freedom of commerce throughout the country by prohibiting the laying of "any duty of tonnage" to carry out that intent. Furthermore, Congress instituted a free waterway policy for the new Northwest Territory in the Northwest Ordinance of 1787. It declared that navigable waters leading into the Mississippi and Saint Lawrence and those of any other states that may be admitted into the Confederation "shall be common highways and forever free . . . without any tax, impost, or duty therefore." Later legislative acts from 1790 to 1803 extended these exemptions to the territory south of the Ohio River and declared that navigable rivers were public highways.

During this period, Congress limited initial federal financial investments in the inland waterways system to snagging and clearing operations. These were modest actions taken to support free use during the colonial period because of the importance of inland waterways to the early geographical and economic expansion of the nation. States undertook the expensive construction of canals, locks, and dams and made other improvements for navigation. States often charged tonnage duties and tolls for waterways use but were still unable to finance large navigation expenditures. Private enterprise also had difficulty in recovering the costs of water transport investments, especially after railroads emerged as competition.

By the 1940s, a transportation system had emerged that included both water and rail carriers. The federal policy of subsidizing commercial navigation began to be questioned (U.S. Office of the Federal Coordinator of Transportation 1939, 125). Highway transport also was emerging, but not yet for long-haul movements. The Franklin Roosevelt administration of 1940 was the first to consider seriously the idea that modifying the policy of free inland water transportation to recover the costs of providing for navigation was allowable and feasible. Since the Roosevelt administration, user

(continued)

[a] Box 3-3 draws from Ashton et al. (1976) and Shabman (1976).

BOX 3-3 *(continued)* **Brief History of Proposals for User Charges for the Commercial Inland Waterways System**

charges as a funding source for the inland waterways have been proposed or supported by presidents of both parties. The President's Water Resources Policy Commission (1950, 202–203) under President Truman was consistent with the position of the Roosevelt administration, illustrated as follows:

> Decisions as to user charges, or tolls for water commerce should be worked out as part of the whole problem of reconciling and making workable a coordinated transportation system. But with rates from all forms of transportation based on full costs, an interconnected system of modern waterways, coordinated with land transportation, should be able to sustain itself with tolls based on full costs and yield returns on the public investment, while contributing to most economic use of the Nation's resources.

In 1956, President Eisenhower submitted a report favoring some type of user charges with regard to the cost of O&M (Senate Committee on Commerce 1961, 32). In 1962, President Kennedy proposed user payment for the inland waterways and suggested a fuel tax of $0.02 per gallon. President Johnson reiterated President Kennedy's proposal in his budget messages and recommended a fuel tax that would extend to all domestic vessels with a maximum draft of 15 feet or less. The Carter administration also indicated support for some form of user charge.

In 1978 and 1986 Congress passed the two pieces of legislation that began to transform funding for the inland waterways and created the funding framework followed today. This legislation established the fuel tax on commercial barges, increased user cost-sharing requirements, and established the IWTF to fund construction with fuel taxes paid by the barge industry. The industry opposed the lockage fees to fund construction and maintenance proposed in the Inland Waterways Revenue Act of 1978; this opposition led to the current fuel tax, which is less directly tied to the usage of waterways facilities and pays for construction and not maintenance.

A number of proposals have been made more recently by both the Bush and Obama administrations to change user payments to recover the system costs associated with commercial shipping (see Chapter 5).

costs specific to their use. Hence, beneficiaries of nonnavigation purposes are expected to pay their allocated share and are not an additional source of funding for supporting the commercial navigation purpose within multipurpose projects. If the navigation function were to cease for these multipurpose projects because of minimal or no traffic, the other project purposes would be allocated the costs of the project. If the whole project was decommissioned, the federal government would be responsible for either removing the project or paying to make sure it would not fail in a weather-related or other event. In the case of hydropower, the beneficiaries already pay for the O&M costs associated with their use of the system and a share of the capital costs. For the commercial navigation projects that also provide hydropower, the hydropower beneficiaries pay 100 percent of capital costs allocated to hydropower and any allocated costs for operations. If the navigation function ceased for these waterways, hydropower beneficiaries would have to pay to maintain the dams to continue to receive this benefit.

Ancillary Beneficiaries

Groups that receive other benefits from projects authorized for commercial navigation are referred to as ancillary beneficiaries because they were incidental to the purpose for which these waterways investments were made. Municipal water supply, slack water boating, and landside recreation are possible ancillary benefits recognized by USACE. A more comprehensive assessment of these benefits and their levels could be undertaken, but even if the benefits proved to be large, the marginal and opportunity costs to navigation imposed by these users of the system are minimal. Furthermore, a practical way of charging these users does not exist, because they cannot be excluded from receiving the benefit of waterway projects maintained for commercial navigation if they do not pay. This case refers to segments used for commercial navigation; if maintenance for navigation ceased because of minimal or no commercial navigation traffic, the ancillary users would become the primary users and may be charged for their benefits. Chapter 5 provides further discussion of this case.

A possible exception is recreational boats that could be charged a fee for the operation of locks on waterways used for commercial navigation. Pools behind dams permit boating, fishing, and other water-based recreation. Lockages are required for recreational craft to pass between pools. Recreational lockages impose marginal costs on the lock and dam system. Lockage service can increase financial outlays for system operations, increase wear on the lock itself, and cause traffic delays. USACE has adopted a number of management measures to reduce commercial navigation delay cost (for example, scheduling of limited times for recreational boat passages), but financial costs are still incurred. USACE could calculate the costs of providing recreational lockages across the system, and if justified, Congress could choose to increase the inland waterways budget by that amount or authorize USACE to base a recreational user fee on that cost. This user fee is discussed further in Chapter 5.

Environmental Beneficiaries

If environmental benefits are sufficiently sizable and broadly distributed, taxpayers would be the beneficiary. As explained earlier, environmental benefits of inland navigation exist, but the magnitude of the benefit is uncertain. As a practical matter, the challenge of paying for the benefit in the context of federal budget constraints persists, leading back to a consideration of other funding options.

Findings and Conclusions

The inland waterways system infrastructure is managed by USACE and funded from the USACE budget. Funds available for inland waterways navigation are in decline in constant dollars. As the system has aged, maintenance has become a higher priority and now accounts for about three-fourths of the administration's inland navigation budget request.

Federal general revenues cover most of the cost of the inland waterways system. Users pay a share of construction costs through a barge fuel tax, but none of the cost of O&M. System users recognize that they need to pay more. The 113th Congress and the shipping industry supported a $0.09-per-gallon increase in the barge fuel tax in 2014. However, under federal legislation, fuel tax revenues can be used only to pay for construction; they cannot be used for O&M. While the amount of funding required to sustain reliable freight service is not clear, it is evident that total revenues after the increase in the fuel tax will not be sufficient to maintain the system.[25] Furthermore, increased capital funding from users would compete with available federal funding for O&M, since the federal government must both match the user contribution for capital improvements and pay all of the costs of O&M.

Because of historical precedent, the federal role in the management and funding of the inland waterways for commercial navigation is already greater than for other freight modes. The total federal share of the cost of the inland waterways system is estimated to be about 90 percent (TRB 2009). The federal share is roughly 25 percent for the highways used by motor carriers and 0 percent for pipelines and nearly so for railroads (both private industries for which the federal role is primarily one of safety and environmental regulation). Whereas federal general revenues cover all O&M expenses for the inland waterways, states pay 100 percent of the O&M expenses, mostly from user fees, for intercity highways used by motor carriers. O&M expenses for railroads and pipelines are paid for by the private industries responsible for these modes.

In a climate of constrained federal funds and with O&M becoming a greater part of the inland navigation budget, a pressing policy issue is how to pay to preserve the system. Examination of whether beneficiaries could help pay for the system is rational and would improve economic efficiency. Commercial navigation beneficiaries are a viable option, since commercial carriers impose significant marginal costs (Chapter 5 discusses options for these user charges and criteria for deciding among them).

Flood control and hydropower beneficiaries are not options for additional funding for commercial navigation projects. The cost of flood control for the few commercial navigation projects that provide a flood control benefit is allocated for that purpose and paid via

[25] It is possible, though not likely, that federal budgets will grow substantially over time with significant increases for inland navigation, but the committee assumes a more modest budget consistent with observed trends and the policy goal of efficient use of resources with or without budgetary constraints.

general revenues. For the few commercial navigation projects that also provide hydropower, hydropower beneficiaries already pay 100 percent of new capital costs and any marginal costs for operations of benefits they receive. Practical mechanisms or economic reasons do not appear to exist for charging ancillary beneficiaries of waterways projects used for commercial navigation (municipal water supply, irrigation, higher property values for property owners, sewage assimilation, mosquito control, and recreation), with the possible exception of charging for recreational boat lockages. Ancillary beneficiaries may be charged for waterways with minimal or no commercial navigation since in this case they would become the primary beneficiaries. (This case is discussed further in Chapter 5.)

Barge transportation may provide an environmental benefit to the larger public that includes lower emissions, safety, spills, and congestion, but whether the size of the benefit is in line with the current level of federal investment is uncertain. Further analysis of corridors would be needed to quantify the benefit. In the absence of definitive evidence concerning the size of inland waterways benefits and until such evidence becomes available, Congress and the executive branch will have to use their best judgment in determining the share the federal government should pay and how to prioritize these expenditures versus other federal expenditures.

Regardless of who pays for the system, a process is needed for prioritizing spending. The capital projects backlog is not a reliable indicator of the amount of funding required for the system. A modest amount of the backlog is for navigation projects. A portion of the navigation backlog includes major rehabilitation to maintain the system, but it does not include O&M. Furthermore, the navigation backlog may include projects that are a lower priority for spending. Congress has long authorized and appropriated USACE capital projects on a project-by-project basis. A benefit–cost analysis prepared by USACE is the primary source of technical information that Congress uses during the authorization process in deciding when spending is justified for capital projects. While benefit–cost analyses have been used for determining whether a project meets a minimum threshold for funding, they have not been used to rank projects, and the result has been far more projects being authorized than can be afforded within the constraints of the budget. A method for prioritizing projects on the basis of the service needs of the system would be more useful than an attempt to estimate and seek funding for the existing backlog. (Chapter 4 discusses an approach for prioritizing spending, with an emphasis on O&M.)

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ABBREVIATIONS

CBO	Congressional Budget Office
CRS	Congressional Research Service
GAO	Government Accountability Office
NRC	National Research Council
TRB	Transportation Research Board

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4

Prioritizing Maintenance for the Inland Waterways Freight System

The U.S. Army Corps of Engineers (USACE) is responsible for providing the infrastructure and operating conditions that enable freight transportation service on the inland waterways system. As described in previous chapters, a priority for USACE is operations and maintenance (O&M) of the infrastructure to provide reliable service. In view of growing maintenance needs and continuing federal budgetary constraints, an understanding of how maintenance spending for the system is prioritized and how prioritization could be improved is important.

In an environment of system expansion, relatively recent construction, and adequate funds, a structured methodology for prioritizing spending was not as high a priority. Over time USACE districts set their O&M priorities by using a variety of methodologies and procedures, which were not standardized. With increasingly constrained budgets and an aging system, a method that can be applied consistently across the system for the strategic evaluation and prioritization of maintenance expenditures is needed. In the budget development guidance for FY 2015, USACE states that it lacks a corporate maintenance management strategy; policies, practices, and terminology are inconsistent across the organization; and maintenance investments are not aligned with a desired level of performance for the system.[1] Local asset assessment and budget request processes follow general guidelines but have many variations. Districts may develop their own asset management systems for assessing and communicating the condition

[1] An initiative is under way (the Maintenance Management Improvement Plan) to establish a corporate maintenance program, but the schedule for implementation is unknown.

of infrastructure, the level of navigation service being provided, and needs for O&M and repairs. Furthermore, the asset assessments are not fully linked to the budgeting process.* The acknowledged shortcomings in the budgeting process for maintenance make it difficult for USACE headquarters to evaluate and prioritize budget requests from USACE divisions on the basis of sound criteria. A systemwide strategy is needed for prioritizing maintenance regardless of whether it is funded as an O&M expenditure or as a capital project for major rehabilitation.[2,3]

A strategic approach for comparing and ranking waterways investments for major repairs and O&M could offer advantages that supersede or complement the current budget guidance used within USACE for O&M and capital projects. The first section below describes an asset management strategy, referred to in this chapter as economically efficient asset management (EEAM), for ascertaining and communicating system needs for maintenance and for setting priorities for maintenance funding for the inland waterways system. A well-executed EEAM program is a method to consider for making rational investment decisions and directing funds where they are most needed to improve the reliability of freight transportation service. Such a data-driven approach could help to minimize the broader influences that affect the budgeting process. In effect, the method serves as a streamlined or abbreviated benefit–cost analysis. The next section describes a risk analysis framework being developed by USACE for prioritizing O&M investments and compares the USACE approach with the EEAM approach. Features that would promote the effective implementation of EEAM and its use in the budgeting process to

* Appendix H presents the USACE's description of the status of its asset management program.

[2] Major rehabilitation is further defined in the Water Resources Reform and Development Act (WRRDA) as a capital expenditure for a repair or set of repairs that maintains existing infrastructure and that does not expand capacity. It must (*a*) exceed a maximum cost, set at $20 million in WRRDA 2014; (*b*) require a minimum of 2 fiscal years to complete; and (*c*) extend the life of the feature significantly or enhance operational efficiency. As a capital expenditure, 50 percent of major rehabilitation costs are paid by shippers via the Inland Waterways Trust Fund and 50 percent are paid by the federal government via general revenues. Repairs that do not meet the budgetary definition of rehabilitation are considered O&M; 100 percent of O&M costs, which include repairs up to $20 million, are paid via general revenues.

[3] The funding of ongoing maintenance as part of O&M to prevent deferred maintenance, which results in greater costs, is more cost-effective, however.

establish maintenance budget priorities are then discussed. The final section summarizes the chapter's findings and conclusions.

Economically Efficient Asset Management

OVERVIEW

In this chapter, EEAM refers to a conceptual tool for deciding how to prioritize investments to maintain a transportation system's functionality. The EEAM approach includes three steps: (*a*) assessing demand for a service, (*b*) determining the condition of the asset and the risk of failure, and (*c*) estimating the economic consequences of failure. (Box 4-1 provides examples of EEAM implementation and sources for further information.) The approach can be developed to account for how parts of the system function within a larger national freight transportation network. EEAM is a method for establishing system priorities, not a budgeting tool. However, when it is linked to the budgeting process, information gathered from EEAM could be used to identify and rank system needs for maintenance to inform budget requests and to prioritize the spending of appropriated funds. This approach is similar to that endorsed by the Inland Waterways Users Board in its capital projects business model (Inland Marine Transportation System Capital Investment Strategy Team 2010) for capital expenditures. However, it can also apply to maintenance and rehabilitation projects to improve the reliability and performance of the system.[4]

BLENDING OF ENGINEERING AND ECONOMIC CONCEPTS

The EEAM approach incorporates both engineering and economic concepts into system assessment. The EEAM process begins with collecting the following engineering data on asset performance: the availability of the asset (its capacity to perform service), reliability (the likelihood that it will remain in service at any given time), and the overall quality of the service that the asset provides. The reason

[4] A recent report sponsored by the National Waterways Foundation concentrates on capital projects paid for out of the Inland Waterways Trust Fund and not the need for prioritizing and funding O&M and repair expenditures (Grossardt et al. 2014).

BOX 4-1
Examples of EEAM

The Moving Ahead for Progress in the 21st Century Act is requiring states to develop a risk-based asset management plan for the National Highway System. It must be a performance-driven plan.

The U.S. Coast Guard (USCG) has developed performance standards for shore infrastructure assets based on their intended uses. This process was successfully used to support prioritization of all asset management projects associated with the six largest USCG installations in USCG's Pacific Area.[a]

Ports around the world are implementing EEAM-type systems. For example, the Port of Rotterdam has developed a system to manage its waterfront assets that utilizes risk-based approaches to the allocation of the organization's scarce capital resources.[b] The Port of Melbourne Corporation (Australia) developed an asset management program that incorporated the following elements:[c]

- Develop asset renewal forecasts based on age, condition, level of service, and risk.
- Develop life-cycle planning processes so as to understand and predict the total cost of ownership.
- Understand asset risk exposure and its influence on maintenance and renewal forecasting.
- Develop optimized renewals decision-making processes so as to determine optimal treatments and associated timings reliably.
- Embed asset management as a core discipline within the business.

The *International Infrastructure Management Manual* describes an asset management system that focuses on level of service, asset performance, risk exposure, and multicriteria analysis. This system is used by a variety of

(continued)

[a] Strategic Asset Management: An Emerging Port Management Imperative, American Association of Port Authorities Marine Terminal Management Training Program, Philadelphia, Pennsylvania, October 6–10, 2014, Erik Stromberg, Senior Port Advisor. http://aapa.files.cms-plus.com/SeminarPresentations/2014Seminars/14MTMT/Erik%20Stromberg.pdf.

[b] Port of Rotterdam's Next Step in World-Class Asset Management, 2013 Facilities Engineering Seminar, Vancouver, British Columbia, Canada, November 8, 2013. http://aapa.files.cms-plus.com/SeminarPresentations/2013Seminars/13FacEng/Voogth_Henk.pdf.

[c] http://aapa.files.cms-plus.com/PDFs/Strategic%20Asset%20Management%20at%20the%20Port%20of%20Melbourne.pdf.

BOX 4-1 *(continued)* **Examples of EEAM**

organizations in the United Kingdom, the United States, and other locations around the world.[d]

More information about EEAM is available from the following sources:

National Research Council: *Predicting Outcomes of Investments in Maintenance and Repair of Federal Facilities* (2012). http://www.nap.edu/catalog/13280/predicting-outcomes-from-investments-in-maintenance-and-repair-for-federal-facilities.

AASHTO Transportation Asset Management Guide: A Focus on Implementation. http://www.fhwa.dot.gov/asset/pubs/hif13047.pdf (summary) and https://bookstore.transportation.org/item_details.aspx?id=1757 (report).

Federal Highway Administration: *Asset Management Primer.* http://www.fhwa.dot.gov/infrastructure/asstmgmt/amprimer.pdf.

Transportation Research Board: *NCHRP Report 551: Performance Measures and Targets for Transportation Asset Management.* http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_551.pdf.

Transportation Research Board: *ACRP Report 69: Asset and Infrastructure Management for Airports—Primer and Guidebook.* http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_069.pdf.

British Standards Institution's *Publicly Available Specification* for the optimized management of physical assets (PAS 55:2008). http://pas55.net/.

International Organization for Standardization (ISO):

- ISO 55000 Asset Management Standard based on PAS 55
- ISO 55000—Overview, Principles, and Terminology
- ISO 55001—Management System Requirements
- ISO 55002—Application Guidelines

International Infrastructure Management Manual, 2011. http://www.nams.org.nz/pages/273/international-infrastructure-management-manual-2011-edition.htm.

New Zealand Asset Management Steering Group: *Optimised Decision Making Guidelines*, Edition 1.0. http://www.nams.org.nz/pages/74/optimised-decision-making-guidelines.htm.

(continued on next page)

[d]Institute for Water Resources, *Best Practices in Asset Management*, 2013-R-08, October 2013. http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/2013-R-08_Best_Practices_in_Asset_Management.pdf.

BOX 4-1 *(continued)* **Examples of EEAM**

PIANC InCom Report of WG 25, April 2006: *Maintenance and Renovation of Navigation Infrastructure*. http://www.pianc.org/2872231560.php.

American Association of Port Authorities (http://www.aapa-ports.org):

- Facilities Engineering and Finance Committees
- Website: Issues and Advocacy; Best Practices; Asset Management

Transportation Research Board Standing Committee on Ports and Channels: https://www.mytrb.org/CommitteeDetails.aspx?CMTID=1105.

Waterfront Facilities Inspections and Assessments Standard Practice Manual—Waterfront Inspection Task Committee, Coasts, Oceans, Ports, and Rivers Institute Ports and Harbors Committee, American Society of Civil Engineers. http://www.asce.org/templates/membership-communities-committee-detail.aspx?committeeid=000000954571.

for rehabilitating or replacing an existing asset is to ensure that the level of service the asset provides continues or improves. If needed maintenance is deferred, which can occur when funds are limited or not readily obtainable, the availability, reliability, and service quality associated with the asset can be expected to decline.[5]

From the data on asset performance, two key pieces of information are generated: (*a*) how long the asset is expected to provide service at an acceptable level[6] and (*b*) the likelihood that a critical component will fail before it reaches the end of its expected life. In considering whether and when to replace an asset, information on how the asset helps achieve performance goals, how performance varies as the asset

[5] USACE has conducted operational condition assessments at all of its lock and dam sites. This information is not available to the public, but presentations made by USACE in public forums indicate that these assessments provide all of the engineering data needed to implement an EEAM program effectively. For example, see http://www.all-llc.com/SAME-Newsletters/SAME-09-Conf/Jose%20Sanchez%20-%20SAME%20Conference_3SEP09.pdf and http://waterways.org/wordpress1/wp-content/uploads/2014/06/LS14-Hannon.pdf. For more information on engineering assessments, see Box 4-1.

[6] For locks, an acceptable level of service consists of two parts: (*a*) lock processing time and (*b*) delays encountered during arrival at the lock before being processed through the lock. Both components require consideration in determining the traffic a lock is expected to handle within a given time frame.

ages or deteriorates, and the impact on performance if the asset failed or was removed from service is useful (Spy Pond Partners et al. 2012).

Within the EEAM framework, three approaches for collecting information about asset performance are possible: an age-based approach, a condition-based approach, and a performance-based approach. The age-based approach is used to predict the need for asset replacement or maintenance on the basis of the age of the asset or that of its critical components as a proxy for condition, performance, or reliability. The cost of replacing or maintaining the asset and the likelihood of the asset failing if it is not maintained or replaced are both considered. Failure in this context is not necessarily the inability to function but may be a condition severe enough to require immediate replacement of the asset to avoid compromising safety or the desired level of service. The weak association between age and poor lock performance (see Chapter 2) indicates that an age-based approach is the least useful for prioritizing maintenance expenditures. Of the nine river corridors analyzed in Chapter 2, the Monongahela River is the only river where age was correlated with metrics of lock performance.

The condition-based approach is used to predict the need for asset rehabilitation or replacement on the basis of the condition of the asset or that of its critical components rather than its age. Like the age-based model, it includes calculation of the cost of various actions that may be performed on an asset or its components and consideration of the likelihood of failure. Actions that should be taken to minimize owner and user costs over time are also considered. The approach takes into account the additional costs that will be incurred if actions to maintain the system are deferred.

After the engineering measures are established, economic performance measures are considered. The economic performance risks assessed may include trip (lockage) time, lost user hours, compliance, cost of alternative transportation, and safety factors.[7] Steps to

[7] EEAM cannot be used to evaluate whether a project meets legal responsibilities. A decision based on EEAM principles may violate one or more legal responsibilities for operation, safety, and environmental compliance. The following are examples: maintenance of subsistence harbors, caretaker activities, critical harbors of refuge, project condition surveys, multipurpose projects when those projects are included in the minimum programs of other business lines and are not a separable element, work required by treaties, and removal of aquatic growth. See USACE 2013, F-4.

eliminate or at least minimize the risk of asset failure on the basis of the assessment of operational condition (e.g., to take action to reduce lost transportation hours or improve lock processing times) and to ascertain the improvements to system performance to ensure the greatest net benefit to system users are desirable.[8]

Like any asset management framework, EEAM is a tool for prioritizing system needs and not an end in itself. The final decisions on prioritization must weigh uncertainties and balance multiple and often conflicting objectives, such as those relating to political requirements or environmental concerns.

LEVEL OF NAVIGATION SERVICE AND LEVEL OF ASSET PERFORMANCE

Maintenance of infrastructure at the same high level across the system regardless of demand (usage) is an inefficient use of scarce funds. With EEAM, the goal is not to maintain every asset in the system at its original condition; there is no predefined level of maintenance that should be accomplished at every lock. Instead, the objective is to prioritize maintenance expenditures on the basis of information about risk and performance. The distinction between level of navigation service and level of asset performance is helpful in establishing priorities.

In the EEAM framework, level of service takes precedence over level of asset performance. Consultation with users of the asset is assumed for setting the desired service level, but in the end the managing entity would make the final determination on the basis of the asset's effect on the overall system's level of service. Service needs generally consist of the number of movements needed in a given time frame, with a certain percentage being accomplished at or below target levels of delay. The actual level of asset performance may be either better or worse than the level of service expected to meet user demands. For example, an asset may be over- or underdesigned for

[8] Data on the condition of assets in the inland waterways system are not public information, but the information presented in Chapter 2 indicates that developing such data will most likely not obligate a significant portion of USACE's O&M budget.

its assigned level of navigation service, especially if commodities and traffic volumes have changed substantially since the asset was placed in service. A higher risk of failure or extreme delays (in terms of economic outcomes) may be more acceptable for corridors or system components that are little used for freight movement than for those that are more heavily used for that purpose.

OUTCOMES-BASED ASSESSMENT OF PERFORMANCE

The degree to which parts of the system meet goals for performance is determined by using outcomes-based assessments. Table 4-1 shows examples of possible outcomes; different weights would be assigned to outcomes on the basis of the operation and physical location of the asset. The classes of outcomes would be prioritized on the basis of the expected usage and level of service at a given facility.

TABLE 4-1 Outcomes-Based Assessment of System Investments for Maintenance and Repair

Mission-Related Outcomes	Compliance-Related Outcomes	Condition-Related Outcomes	Efficient Operations	Stakeholder-Driven Outcomes
Improved reliability	Fewer accidents and injuries	Improved condition	Less unplanned maintenance and repair	Customer satisfaction
Improved productivity	Fewer building-related outcomes	Reduced backlog of deferred maintenance and repairs	Lower operating costs	Improved public image
Functionality	Fewer insurance claims, lawsuits, and regulatory violations		Lower life-cycle costs	
Efficient space allocation			Cost avoidance	
			Reduced energy use	
			Reduced water use	
			Reduced greenhouse gas emissions	

SOURCE: NRC 2012.

TABLE 4-2 Budget Objective and Criteria for Ranking Maintenance Needs

Budget Strategy	Ranking Criteria
Maintenance—make sure projects are safe to operate (managing risk)	• Lock closures exceeding 24 hours and 1 week duration due to mechanical failures—scheduled and unscheduled • Risk reduction (or risk reduction ratio)[a] • Relative risk rating • Cumulative benefits • Cumulative O&M costs for above benefits (over set time period)

[a] In its simplest form, the risk reduction ratio is the amount of risk that will be avoided divided by the budget amount requested to achieve the reduction.

Current State of Maintenance Prioritization

OVERVIEW OF CURRENT APPROACH

USACE has examined and used three basic maintenance policies at various times: fix-as-fails, advance maintenance, and rehabilitation or reconstruction.[9] In Engineering Circular 11-2-204, USACE (2013, F-28) provides specific instructions for budgeting O&M expenses. Table F-2 of that document, Navigation Budget Performance Measures, defines the budget objective and criteria for ranking the need for maintenance expenditures, as shown in Table 4-2.

Figure 4-1 shows a simplified model of the EEAM process.

Application of an EEAM methodology would emphasize the risk aspects of this ranking approach at a system level. Risk, in this context, is the potential for unscheduled closure, decreased service level, or failure of a critical operating component. While USACE's approach

[9] Under a fix-as-fails policy, minor routine maintenance is performed and repairs are made when things "break." This would be analogous to changing a flat tire on the family car but waiting for something else to break before performing any further maintenance. An advance maintenance approach considers the asset's age and how it is used; repairs or replacements are made on the basis of the component's operating characteristics. This would be analogous to changing the timing belt on the family car—nothing has broken, but statistics indicate that at a certain point the replacement of that key component is a good idea.

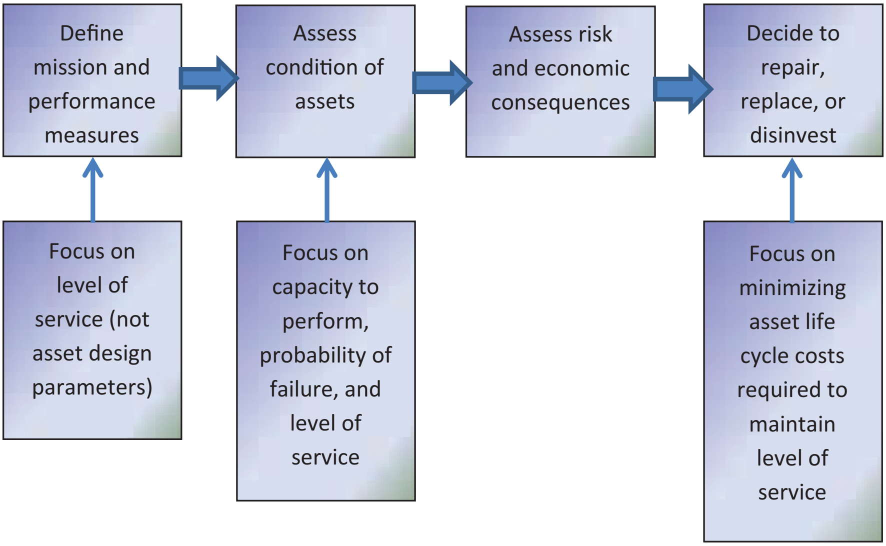

FIGURE 4-1 Simplified model of the EEAM process.

SOURCE: Study committee.

explicitly addresses certain elements of risk at a conceptual level, the process could be improved, as described later in the chapter.

Figure 4-2 illustrates USACE's conceptual approach to asset management, which tracks closely with the EEAM approach. The main difference between the two approaches is that EEAM emphasizes Activities 1, 3, and 5. Reliability-centered maintenance, Activity 2 in

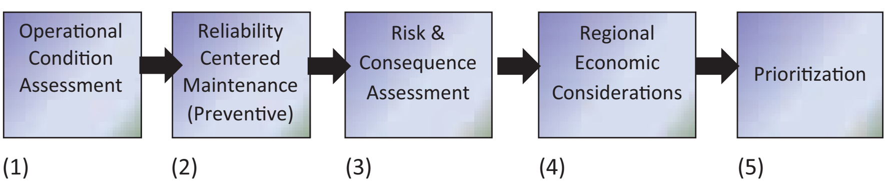

FIGURE 4-2 USACE conceptual approach to asset management for the Ohio River Region.

SOURCE: Presentation by J. R. Fisher, USACE, Program Manager, Pittsburgh District, http://www.same huntington.com/shared/content/Presentations/TB_S2_Fisher.pdf.

USACE's approach, is considered one of the objectives of EEAM and therefore is not represented as a separate step. In addition, USACE's approach takes into account economic considerations at a regional level, whereas regional considerations are not distinguished in EEAM. Regional economic considerations are typically transfers of benefits or costs from one region to another that do not affect the national economy. EEAM focuses on economic effects on the overall system rather than at specific locales. Regional considerations would only become relevant once an asset is scheduled for disinvestment; that is, the state or local interests would then have to evaluate the cost of maintaining the asset versus the benefit to be derived by their locale or region and make investment decisions accordingly. Under EEAM, this decision would not involve USACE.

As mentioned, USACE's primary mission with respect to navigation is to provide conditions that enable the passage of commercial traffic. The main cost of providing these conditions is the maintenance of lock and dam infrastructure, but the maintenance of channels and pools is part of the cost. USACE has developed a conceptual framework (described in more detail below) that considers the age of infrastructure and other elements consistent with EEAM to prioritize repairs that would cost-effectively extend the life of an asset or critical component of the asset and achieve a reliable navigation system. The elements include the probability of failure of the infrastructure; infrastructure usage (demand), defined as whether the waterway has low, moderate, or high levels of freight traffic; and the economic consequences of failure to shippers and carriers. This approach recognizes the importance of economic consequences for strategic investment instead of assuming that all navigation infrastructure needs to be maintained at its original condition. For USACE, the goal of prioritizing investments is to produce the greatest national economic development benefit, which for commercial navigation has meant maximizing reductions in the cost of cargo transported by using USACE waterway infrastructure. In practical terms, this means reducing the risk of physical failure and maintaining a target level of delays.

Although the specific procedures of the approach are just beginning to be implemented and refined and often are not clear, the framework is being applied at program, district, and headquarters levels to guide the identification of maintenance needs and funding requests. USACE intends to use the framework to implement a standardized assessment of assets across the system (outcomes-based assessment). The assessment is planned to cover all important aspects of asset management. However, further development is needed of the measures and methodology used to assess risk across all assets in the inland waterways system. Additional considerations that would need attention are described in the section of this chapter on implementation.

COMPONENTS OF CURRENT APPROACH

In the past, USACE has focused on determining the physical condition of assets. Currently, USACE considers the physical state of the asset and demand (level of traffic on a river or river segment) in prioritizing maintenance spending for budget requests and allocating the appropriated funds. However, these factors are not made explicit in USACE assessments of level of risk or the desired level of navigation service. USACE is beginning to develop a more comprehensive risk-informed asset management program with the components described below. These components have not been fully implemented or integrated into the budget prioritization process.

Age of Assets

Age has been used as a metric by industry and to a lesser degree by USACE in assessing and communicating the need for maintenance funds. However, the definition of age and its implications for the reliable functioning of the system are not clear (see Chapter 2). The average age of the original infrastructure does not indicate the level of funding needed for the system. Reliability and processing times are not correlated with lock age, with few exceptions. Components of the system have been rehabilitated to extend the life of the assets and to enable them to perform as originally designed, if not better (see Chapter 2). The average age of the infrastructure from the date of rehabilitation is about a decade less than the age from original construction.

Navigation assets that have been rehabilitated are more appropriately dated from the time of the latest rehabilitation. The expected life of the asset also should be "reset."[10] This approach to calculating the functional or rehabilitated age of an asset is consistent with the methodology used by the U.S. Department of Transportation to describe infrastructure such as bridges.[11,12] USACE does not track rehabilitation dates for its various lock and dam assets. This is one aspect of condition assessment that needs immediate attention.[13] In view of the extensive rehabilitation of system assets, more specific information related to the condition and functioning of the asset, and not age, is clearly needed to assess, prioritize, and communicate funding needs. (See Chapter 2 for a model for measuring delays and unavailabilities and their impact that could be used for this purpose.)

Level of Navigation Service and Level of Asset Performance

Level of service is a key component of USACE's plan for allocating maintenance funds, but the definition and implementation are different from what they would be under EEAM. In USACE guidance, "level of service" refers to operational hours and staffing and not to how well the facility provides shipping service to its users. The economic impact associated with the various levels of navigation service is not considered. An EEAM approach would focus on how well the system provides a service to its users and would require an economic justification for inclusion of the facility as a priority for budgeting.

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[10] For example, if the expected life of a lock was originally 50 years dating from 1950 and a major rehabilitation of the lock was performed in 2000 to extend its life by 30 years, the age of the asset should be calculated from 2000 and the expected life should be shown as extending to 2030 instead of 2000. As an analogy, a towboat built in 1960 but rehabilitated in 2000 would not be considered to be 54 years old in 2014 from an operational perspective. In the same way, the age of a lock or dam facility should be adjusted when a major rehabilitation is performed.

[11] 2013 Report Card for America's Infrastructure. American Society of Civil Engineers. http://www.infrastructurereportcard.org/bridges/.

[12] *2010 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance Report to Congress*. U.S. Department of Transportation, Federal Highway Administration and Federal Transit Administration. http://www.fhwa.dot.gov/policy/2010cpr/pdfs/cp2010.pdf.

[13] See Appendix C for a listing of the age of assets calculated from the last known major rehabilitation date generated by the committee from public documents and documents provided to the committee by USACE. In 2013, USACE initiated an effort to establish asset rehabilitation dates and to maintain these data for the future.

TABLE 4-3 USACE Definition of Levels of Service for Locks

Level No.	Title	Description
1	Full service 24/7/365	24 hours per day, 7 days a week, 365 days a year
2	Reduced service—two shifts per day	16–20 hours per day, 7 days a week, 365 days a year (basically two shifts of either 8 or 10 hours)
3	Limited service—single shift	8–12 hours per day, 7 days a week, 365 days a year
4	Scheduled service—set times per day	Lockages (including recreational craft) at set times per day; for example, 8 a.m. and 4 p.m.
5	Weekends and holidays	Lockages on weekends and holidays only
6	Service by appointment	Commercial lockages by appointment

Table 4-3 shows that USACE has defined six levels of service for locks, ranging from full service (24 hours, 7 days a week, 365 days a year) to by appointment only. The levels have been assigned on the basis of the number of commercial lockages in a year. Districts are encouraged to consider potential impacts on economic development, seasonal adjustments, and modal shifts. Data extracted from the online Lock Performance Monitoring System indicate that 168 lock sites are owned and operated by USACE (some sites may have two or even three chambers). The data indicate that nearly all sites should be staffed at a 24/7/365 or at a two-shifts-per-day level. None of the lock sites would be categorized at the bottom three levels of navigation service; 75 percent would be assigned to the highest service level.[14] With 75 percent of the sites falling into the top category, this approach appears to have limited value in establishing priorities.

An EEAM approach would develop service levels that describe the degree to which the asset enables the systems of locks and dams to provide the access and reliability that navigation users need. Service

[14] See guidance memo from Richard C. Lockwood, Chief, Operations and Regulatory, Directorate of Civil Works (Acting), April 30, 2012. http://www.uppermon.org/Upper_Mon_Closure/Darcy-Manchin_enclosures_1-2-3-6Sept12.pdf.

levels could be assigned on the basis of information concerning lost transportation hours and lock processing times and each level associated with a level of risk of failure. For example, the hours of closure and the hours of delay per million tons transported would be the drivers affecting the level of potential economic harm (or benefit) for a given lock site. A lock that is programmed for a low level of service could be allowed a higher exposure to the risk of failure, unavailability, or high levels of delay since its usage is sporadic and would have a minimal effect on traffic. A lock programmed for the highest level of service would be expected to operate continuously and be available "24/7/365," except for programmed maintenance activities and navigation accidents, and would have the lowest level of delays. Instead of relating risk to level of service in this fashion, USACE's current objectives are to halt the trend of increasing lock outages and to maintain lock availability at least at the systemwide levels recorded for FY 2001–FY 2002.

Any definition of level of service must incorporate delay or lock processing times that are acceptable at each level. Average delays and the variance in delays affect level of service as perceived by users. Under an EEAM approach, levels of service that relate to the effects on users would be developed. A level of service would be assigned to a given lock on the basis of the economic consequences of unplanned outages, failures, or high levels of delay. The operations schedule would then be developed in such a manner as to meet the defined level of service. Table 4-4 provides a possible framework.[15] "Delays" refers to average delay times as opposed to the delay encountered by any given tow. The acceptable level of delays would have to be defined in light of what have been the best service levels historically to account for seasonal peaks and base levels of delay that cannot be eliminated in practice.

An asset's level of navigation service must be assessed as part of a system. Each lock asset in a waterway corridor depends on the other assets in that corridor, as discussed in Chapter 2. The economic

[15] The table cannot account for accidents. It is focused on expected outcomes from given levels of maintenance.

TABLE 4-4 Possible Framework for Describing Level of Service and Effects on Users

Level of Service	Effects on Users
A: Minimal delays—no unplanned outages	Delays and outages will be in line with best service levels historically; there will be minor queuing.
B: Moderate delays—no unplanned outages	Queues, delays, and outages are expected, but the average is kept within a certain variance from historical "best conditions."
C: Significant delays—possible unplanned outages	Delays and outages are unpredictable and windows of service may be constrained.
D: Severe delays—high potential for unplanned outages	Delays are expected to be lengthy and windows of service will be constrained. This category allows for an imminent risk of failure.

NOTE: The concept for this framework derives from the Transportation Research Board's *Highway Capacity Manual*.

advantages of ensuring that one lock has minimal delays are minimized if another lock in the same corridor is allowed to have frequent delays. It may be better to have all parts of a given corridor perform at a moderate level than to have some parts performing well and some poorly.[16]

Delays do not affect all shippers equally. Contractual terms and the commodity being transported will affect the absolute value. However, a high percentage of barge traffic consists of bulk commodities with a relatively low unit value. Delay times and lock processing times (as opposed to the cost of the cargo involved) thus appear to be a valid metric for assessing the role of lock performance in level of service. In a business environment where there is a shortage of mobile equipment (i.e., barges), the effect of delays becomes even more critical. The level of asset performance refers to the functioning of an asset relative to its design parameters. USACE continues to consider the

[16] Chapter 2 and Appendix E give illustrations in terms of delays at a given lock and dam facility and the hours in lost transport time per million tons transported. Delays may be addressed to some degree through changes in operational procedures such as scheduling; these nonstructural approaches need to be considered in deciding on investments, as discussed in Chapters 3 and 5.

best method of assessing the level of asset performance but typically uses unscheduled outages per lock. Another metric being considered for measuring lock performance is transit times per tow. Procedures or policies have not been established for collecting and analyzing these data. Transit times per tow would be a better indicator of lock performance than lock processing time. Lock processing time data would not account for adjustments made en route. That is, captains of vessels are aware of the acceptance rate at the lock and adjust speeds accordingly, but the increase in transit time does not appear in lock transit time statistics.

Transit time can be separated into seven components:

1. Time required for a tow to move from an arrival point to the lock chamber,
2. Time to enter the lock chamber,
3. Time to close the gates,
4. Time to fill or empty the lock,
5. Time to open the gates,
6. Time for the tow to exit from the chamber, and
7. Time required for the tow to reach a clearance point so that another tow moving in the opposite direction can start toward the lock.

While lock processing times capture the physical performance of the lock, the delays encountered by tows at each lock are important for measuring the level of service. A delay refers to the time a tow must wait to move through a lock once it is at the lock and ready to be processed through the lock. Lost transportation time may be caused by lock closures (whether scheduled or unscheduled unavailability), delays (such as those due to congestion at the lock), or problems with lock operations. A standard procedure needs to be established for recording delays across all locks in the system.

Three additional operational concerns are not captured in lock processing and delay statistics. First, in some cases the total delay time at a lock may be even more important than lock processing time per tow. For locks where minimal cargo is moved, a degradation in transit times may not have a significant effect, but for locks with high cargo volumes, even a slight degradation could have a sizable effect on total delays. Data on total delay per lock are needed to assess the level of service systemwide and at specific locks.

Second, the variance in transit times would indicate the reliability of the lock. Wide variances affect the ability of carriers to meet delivery schedules and would cause shippers and receivers to maintain larger inventories to guard against late deliveries. USACE has the data to analyze variances in lock processing times but does not do so.

Finally, the reasons for lost transportation time need to be recorded. For example, at several locks (especially on the Upper Mississippi and Tennessee Rivers), the size of the lock may require breaking apart tows (splitting the barges into lock-size groupings) to move the tow through the lock. Although the transit time per lockage may be acceptable, delays can result from the need to make two or more passes to move a tow through the lock.

In summary, the data needed for a comprehensive EEAM approach to asset management for locks are already available for the most part from USACE's Lock Performance Monitoring System. Inconsistencies in reporting need to be corrected, and procedures may need to be revised to record additional information on lost transportation hours.

Economic Metric: Rate Savings for Users

USACE uses the cost of transportation, and specifically rate savings for shippers, as the primary basis for evaluating all types of infrastructure investments for the inland waterways, whether for capacity expansion, replacement, rehabilitation, or maintenance. The primary measure used in evaluating the condition of locks is increases in transportation costs as a consequence of lock failure or closure. Since the purpose of locks is to facilitate navigation, the metric provides useful information for assessing economic risk, an important component of EEAM.

USACE's approach could be expanded to provide a more comprehensive assessment of economic consequences at the freight system level. For example, as part of its economic risk assessment, USACE could address such questions as the following: Will a lock closure eliminate a market for certain users? Is there enough capacity on alternative modes to move the cargo by land if a lock closes? Such factors are important in analyzing economic consequences at a corridor or system level as opposed to the project level.

CONSISTENCY IN APPROACH TO PRIORITIZATION ACROSS ASSETS

USACE has multiple missions and responsibilities, which result in a diverse portfolio of assets to manage. Assets vary in size and complexity, span large geographic areas, and serve diverse functions. The portfolio consists of structures for river navigation, hydropower, and flood risk management; recreation areas; fish ladders; utility systems; and laboratories. These assets range from simple boat launches to massive dams, extensive levee systems, and locks as long as four football fields. Furthermore, a few single assets have multiple functions. For example, a dam may simultaneously support power generation, water supply management, flood risk management, navigation, and recreation.[17] The ways in which asset management principles are implemented may vary by asset type, but the underlying philosophy and approach adopted for prioritizing maintenance need to be applied with consistency across the portfolio.

Decisions About Capital Investments for Capacity Expansion

This chapter focuses mainly on prioritizing maintenance spending given the growing demand for funds to maintain the existing infrastructure for a system that is no longer expanding. However, decisions about whether to invest in capacity expansion at bottlenecks will continue to arise. Chapter 2 shows a trend of static or declining traffic on the major inland waterway corridors. One scenario is that these traffic levels continue. However, forecasts of demand and traffic depend on a number of factors that are difficult to predict reliably, such as commodity prices, the price sensitivity of shippers, and external factors such as changes in the efficiency of other modes of freight transit (see Stern 2014, 19).

[17] See http://operations.usace.army.mil/asset.cfm for this description and more information about USACE assets.

Barge traffic may remain steady for the system overall while some corridors may experience an increase in traffic. As described in Chapter 2, 80 percent of lost transportation hours are due to delay, with most of the delays occurring at high-demand locks used for agricultural exports. This finding suggests that a main source of delay on the system is congestion related to peaks in seasonal shipping. However, adequate data are not available to explain the causes and timing of delay.

Delays due to congestion may result from the inefficient use of existing capacity (e.g., peak demand without scheduling) rather than from insufficient capacity. Service capacity may be expanded through alternatives to construction, such as an array of nonstructural options for reducing tow lockage time, especially that associated with double lockages.[18] More extensive proposals involve instituting a tow traffic management system, which would attempt to schedule tow arrivals at a lock so as to reduce overall congestion levels. Proponents argue that traffic management to reduce waiting times may be the most cost-effective way to smooth out spikes in barge traffic and episodes of barges arriving at a lock at the same time.

Shipping and agribusiness industry representatives counter that while some nonstructural alternatives may be feasible to improve reliability, a traffic management system would not improve delay and provide the level of service that is needed (NRC 2004). Tows typically move over long distances and are limited in their ability to arrive at a lock at an assigned time. Few productive activities can be undertaken during a delayed arrival period, which results in a cost to shippers. Slow

[18] As described by NRC 2004, some nonstructural alternatives already in use or being planned include helper boats, industry self-help, N-up/N-down servicing, deck winches, switchboats, and mooring facilities. *Helper boats* are auxiliary towboats stationed at certain locks to assist tows in making approaches to locks under adverse current conditions (outdrafts). Under *industry self-help*, a towboat waiting in the queue disengages from its own barges and assists the tow being processed. This measure is in limited use. Under *N-up/N-down servicing*, when both upriver and downriver queues exist, a lockmaster can reduce overall service time by processing several consecutive tows from each queue in turn. This reduces total approach time at the expense of increased time for turning back the lock chamber. Permanent *deck winches* on barges reduce the time required to reassemble the tow after a double-cut lockage. [One company has equipped all of its barges with deck winches, but USACE does not foresee any further adoption of this measure (Dyer et al. 2003, 13–14).] *Switchboats* could be permanently stationed at congested locks to assist with and reduce time spent on double-cut lockages. With *mooring facilities*, for some locks, the provision of tie-off facilities closer to the lock chamber could reduce approach times and therefore reduce overall servicing time.

steaming could save some fuel, but few other operational benefits are evident beyond reducing queuing times. A properly designed analysis would take into account whether locally mitigated delay reduction through scheduling might propagate delays to other parts of the system without a systemwide reduction in delays. Furthermore, traffic management proposals to handle seasonal peaks in traffic have been criticized for misunderstanding agribusiness production and shipping flexibility during the fall harvest (that is, the fall harvest cannot be rescheduled for less river traffic). A number of NRC reports (see NRC 2004, 50, for a summary) have recommended that all feasible nonstructural measures to expand the service capacity of the system be implemented and evaluated with appropriate methods to determine whether the total physical capacity of the system limits transportation options and, in turn, growth in the economy.

Decisions about whether investments in larger locks are a better investment than other expenditures for the system require more information about delays and the ability of nonstructural alternatives or smaller-scale structural alternatives to achieve the desired level of service. Collection of data and development of performance metrics would enhance understanding about whether delay problems could be most efficiently addressed by more targeted O&M, traffic management, capacity enhancement, or some combination of these.

An asset management approach could provide information that would help in assessing the type and level of investment required for maintaining the desired level of service in specific corridors. The authorization and appropriation process for navigation could then rely on an understanding of whether a facility meets freight service needs of the system and of the investments required.

Implementation

USACE has adopted an approach to asset management that is generally consistent with EEAM. The approach appropriately includes assessment of three main elements that follow from EEAM: the probability of failure of the infrastructure; infrastructure usage (demand), defined as whether the waterway has low, moderate, or high levels of freight traffic; and the economic consequences of failure to shippers and carriers. The framework prioritizes funding for inland waterways assets that are critical to USACE's primary mission areas. USACE uses a standard methodology to assess the physical condition of a lock regardless of its location or service demands. The methodology takes into account the economic importance of the lock and the consequences of its failure, which depend on the amount of traffic and the type of commodities passing through the lock. The approach should, at least theoretically, allow USACE to establish maintenance priorities at the level of the system or corridor. It could provide a basis for determining the level of performance that could be attained given a certain amount of funding and the amount of funding that would be needed to reach the desired level of service throughout important parts of the system.

The general approach is appropriate, but several areas need further attention for implementation. A level of risk tolerance needs to be defined for each asset. There is no single best measure of risk tolerance. For example, USACE could decide to accept a higher level of risk for a tributary river than a mainstem river for an asset component that would take more than 3 days to repair. Another approach to defining risk tolerance would be to have all locks undergo major rehabilitation after a certain number of years, with risk tolerance defined in terms of the number of locks not rehabilitated according to schedule.

As implied in the approach, maintenance activities that do not reduce the likelihood of failure or the consequences of an event would generally not be appropriate for budgeting—an essential tenet of the EEAM framework. Furthermore, the level of analysis performed to evaluate the need for a potential project should be commensurate with the size and importance of the project. Not all projects will require a detailed analysis of current and projected traffic flows.

The measures that USACE uses in prioritizing maintenance and rehabilitation expenditures include the 5-year average amount of tonnage moved and the number of lockages performed in a year. These measures are not used explicitly to provide for an assessment or prioritization of projects on the basis of economic considerations, as would an EEAM approach. More useful metrics for prioritizing maintenance, which would incorporate delay and other measures of system performance that have an economic effect on system users (shippers), need to be developed or refined. Under certain investment scenarios (i.e., where multiple locks are in equal level of service and risk categories but funds are insufficient to work on all of them), consideration of the economic consequences associated with the usage of individual locks may be necessary in establishing priorities. Traditionally, USACE has relied first on average annual ton-miles by river segment to assess usage and has designated waterways as high, moderate, or low use. Some locks designated as low or moderate use on the basis of annual ton-miles may service a much higher volume of traffic than annual statistics would indicate during certain periods such as the seasonal shipping of food and farm products. The ability to handle these peak periods (and the economic consequences of not being able to do so) is important to consider in addition to average annual waterway ton-miles.

For EEAM to be most effective, managers would need the ability to manage and spend O&M funds directly. In the case of the inland waterways, a direct management approach would enable USACE to have the greatest impact on the reliability of freight service given the immediate conditions (for further discussion, see the section in Chapter 5 concerning the revolving trust fund). As explained in Chapter 2, under the current budgeting process, Congress authorizes and appropriates O&M and capital funds for each project or facility. Budget requests are prepared at the USACE district level and refined and prioritized at the division level. USACE headquarters makes the final determination on project rankings across divisions and decides which requests will be submitted as part of the President's budget request to Congress. Prioritization takes into account both information from USACE divisions about local system needs and the administration's budget priorities. The number of maintenance projects funded depends on the amounts appropriated by Congress. In contrast, for highway transportation programs funded in the U.S. Department of Transportation, Congress approves funding at a program level but allows the states discretion in setting spending priorities. An analogous program for inland navigation operations, maintenance, and repair would still disburse funds through the appropriations process, but the funds would be administered by USACE in a way that allows districts discretion in setting spending priorities for O&M. Policies and procedures would be needed to ensure that district- and division-level operational condition assessments are consistent with the EEAM approach and tied to decisions about spending. This approach to budgeting could minimize deferred maintenance and the associated costs and avoid the need for forecasting maintenance investments 2 to 3 years in advance, as the current budgeting process requires.

EEAM and the data-driven initiatives under way at USACE may place significantly heavier burdens on both data management and data models traditionally used to support navigation spending decisions. Improvements for an effective EEAM approach would involve determining the data most needed and the best way to standardize the collection and recording of data across USACE districts that have commercial navigation activities.

Findings and Conclusions

A standard process is lacking for assessing the ability of the inland waterways system to meet demand for commercial navigation service and for prioritizing spending for maintenance and repairs. An asset management program focused on economic efficiency, fully implemented and linked to the budgeting process, would prioritize maintenance spending and ascertain the funding levels required for reliable freight service. A well-executed program of asset management would promote rational and data-driven investment decisions based on system needs and minimize the broader influences that affect the budgeting process.

USACE has adopted a generally appropriate framework for asset management that is mostly consistent with EEAM, but it is not yet fully developed or deployed across districts. The framework recognizes the importance of economic consequences for strategic investments and does not assume, as in the past, that all navigation infrastructure needs to be maintained at its original condition. The approach appropriately includes assessment of three main elements that follow from EEAM: the probability of failure of the infrastructure; infrastructure usage (demand), defined as whether the waterway has low, moderate, or high levels of freight traffic; and the economic consequences of failure to shippers and carriers.

Once it is fully developed, USACE's asset management framework could be applied to decisions concerning all categories of investment in USACE's infrastructure portfolio—O&M, major rehabilitation, and other capital spending. While maintenance is a priority for the system, decisions about whether to invest in construction for capacity expansion at key bottlenecks and how to prioritize these investments against other investments for the system will continue to arise. Decisions about whether investments in construction to expand capacity at the corridor level are economically justified would require more information about delays and the ability of nonstructural alternatives or smaller-scale structural alternatives to achieve the desired level of service. Collection of data and development of performance metrics would enhance understanding of whether delay problems could be addressed most efficiently by more targeted O&M, traffic management, capacity enhancement, or some combination of these. An asset management approach could provide information that would help to assess the type and level of investment that would maintain the desired level of service. The authorization and appropriation process for navigation could then rely on an understanding of whether a facility meets freight service needs of the system and of the investments required.

Age of construction is not a good indicator of lock condition. More meaningful measures of system condition derived from data such as those contained in the Lock Performance Monitoring System would more accurately communicate the condition of the system. A more accurate way of communicating the age of locks would be to date them from the time of the last major rehabilitation, as is done for highway infrastructure such as bridges (as explained in Chapter 2). USACE does not publish consistent records of rehabilitation dates for its assets. This aspect of the asset management process needs more attention.

Several elements of the USACE framework will need further attention before implementation. First, there is no single best measure of risk tolerance; a level of risk tolerance will need to be defined for each asset. Second, the approach will need to be implemented systemwide to gain the greatest level of service and economic benefits. Third, whereas the data required to apply the framework are already available for the most part from USACE's Lock Performance Monitoring System, refinements could be considered. Metrics to assess the location, timing, and reason for delays routinely could be developed and linked to data on the economic consequences of delay to prioritize investments. Under certain investment scenarios, consideration of the usage level of individual locks may be necessary in establishing maintenance priorities. For example, in some cases, the ability to handle peak periods (and the economic consequences of not being able to do so) needs to be considered rather than relying first on annual average waterway ton-miles. A consistent method of recording delays across the system would be needed, and perhaps additional information on delays recorded. Information on accidents also would be useful. Fourth, EEAM would be most effective if USACE had the ability to manage and spend O&M funds according to priorities set through the EEAM process at the district level. This would allow USACE to have the greatest impact on the reliability of freight service given the immediate conditions. Funds would still be disbursed through the appropriations process. Policies and procedures would be needed to ensure the consistent application of district- and division-level assessments under the EEAM process.

References

ABBREVIATIONS

NRC	National Research Council
USACE	U.S. Army Corps of Engineers

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5

Options for a User-Based Approach to Funding Operations, Maintenance, and Rehabilitation for Commercial Navigation

This chapter discusses funding options for the inland waterways commercial navigation system other than reliance for the most part on federal general revenues. The immediate users of the inland waterways are the companies operating the barge tows that move commercial freight. They are the focus of this chapter. However, the burden of payments by the barge industry is not borne fully by the operators, and they do not enjoy all the benefits. The industries that use barge shipping benefit from the low cost of shipping their products, mostly commodities that are low in value relative to their weight such as coal, petroleum and petroleum products, food and farm products, chemicals and related products, crude materials, and to a lesser degree manufactured goods and equipment. These commodities are sold for a price that is set by the market. If barge companies become the direct payers of a new user charge, their cost may be passed on in whole or in part in the form of increased costs to the shippers of these commodities and, in turn, to the producers and consumers of the commodities.

The first section below describes the taxes or fees that might be paid by companies operating the barge tows that move commercial freight. The options could be used alone or in various combinations. The next section describes criteria for evaluating the payment options: economic efficiency, revenue potential, distribution of burden, ease of administration, user support, and need for congressional action. These criteria were derived from the committee's review and understanding of the ongoing political discussions over who might pay for the inland waterways navigation system and were informed by reports of the Congressional Budget Office (CBO) (1992) and the U.S. Government Accountability Office (GAO) (2008). The criteria have been explicitly or implicitly used to justify various payment systems and are subject to debate. No single criterion is proposed as most important; the aim of the chapter is to inform discussions concerning the choice of one or more of the options. Policy makers may decide that one criterion should carry more weight than others. The next section of the chapter explains that a trust fund different from the current Inland Waterways Trust Fund (IWTF) would be needed for revenues collected to operate and maintain the inland waterways system, since the IWTF is designated for capital expenditures. The disposition of facilities and segments that have limited or no commercial freight is then discussed. The final section summarizes the chapter's findings and conclusions.

Options for Increasing User Payments for Commercial Navigation

User charges for the inland waterways system can take the form of a dedicated tax or user-specific fees.[1] The inland waterways barge fuel tax, a dedicated tax, involves a required payment to a government entity to be used for funding construction and other capital expenditures for the inland waterways system.[2] As discussed below, a dedicated tax on barge fuel to fund operations and maintenance (O&M) of the inland waterways system would be more in line with the concept of economic efficiency. In recent years, proposals have been made to add to or replace the inland waterways barge fuel tax with user-specific fees. In contrast to a tax, user-specific fees are direct charges paid by an identifiable user in exchange for the opportunity to pass through a lock or use a portion of the waterways. Failure to pay the fee results in being excluded from the use of a service (i.e., denial of passage through a lock, use of a particular segment, or passage

[1] Consistent with the terminology of GAO, "user-specific fee" refers to a fee for use of a specific part of a system, such as a waterway segment or facility (GAO 2008).

[2] Not all waterways are taxed, nor are fuel taxes collected on all taxable waterways. Appendix A shows waterways subject to the fuel tax and where fuel taxes are collected.

during times of peak traffic). User-specific fees have been proposed in addition to the dedicated tax user charges discussed above as a way to increase the economic efficiency of system use, as explained in more detail in the subsections under Criteria for Assessment of Options, and to secure additional revenue.

User-specific fees can take a variety of forms, including annual licensing fees (applied to towboats or barges on a segment basis or systemwide), congestion fees (a charge for passing through a lock during peak traffic periods), segment charges, and lockage fees (a charge for passing through an individual lock). Depending on goals for the fee, a user-specific fee can be combined with a fuel tax (CBO 1992).[3]

CBO, GAO, and the Congressional Research Service have prepared extensive descriptions and analyses of these alternatives.[4] A number of recent proposals for inland waterways funding have promoted movement toward a user-based funding approach. Box 5-1 summarizes recent administration proposals and the Inland Waterways Users Board's (IWUB's) proposal, the capital projects business model (Inland Marine Transportation System Capital Investment Strategy Team 2010). Although Congress passed an increase in the barge fuel tax in 2014, it has not supported user charge proposals that have included one or more user-specific fees. (See Chapter 3, Box 3-3, for a brief history of user fee proposals made by previous administrations

[3] According to GAO (2008, 4–5), a user fee is a charge assessed to users of goods or services provided by the federal government and is normally related to the cost of the goods or services provided; thus, a user fee is related to a voluntary transaction or request for government goods or services beyond what is normally available to the public. Taxes arise from the government's sovereign power to raise revenue and need not be related to benefits received but only to an individual's ability to pay. However, fees vary with the availability of reasonable substitutes in the degree to which they can be considered voluntary. User fees may also be collected through a tax such as an excise tax. As explained by GAO (2008, 4), "the legal distinction between a 'fee' and a 'tax' can be complicated and depends largely on the context of the particular assessment. Whether a particular assessment is statutorily referred to as a tax or a fee is never legally determinative. Instead, federal courts will examine the structure and the context of the assessment's application." The trade-offs in deciding between payment options often can apply to both a tax and a fee.

[4] GAO (2008) assessed how design features may influence the effectiveness of federal user fees. The report examines how the economic efficiency, equity (referred to in this report as distribution of burden), revenue adequacy, and administrative burden of fees are affected by how the fees are set, collected, used, and reviewed. CBO (1992) analyzed alternatives for funding the inland waterways system. The Congressional Research Service (Stern 2014) has summarized recent proposals for the inland waterways system.

BOX 5-1

Recent Administration and Shipping Industry Proposals[a]

In 2008, the Bush administration submitted a legislative proposal to the 110th Congress for a lock usage fee to replace the fuel tax. Charges to commercial barges of $50 to $80 for lock chambers longer than 600 feet and $30 to $48 for lock chambers less than 600 feet per lockage per barge would have been phased in through the end of calendar year 2012. IWTF balances would have been tied to this user fee at the end of 2012: lockage fees would be raised when the IWTF balance fell below $25 million and lowered when the balance exceeded $75 million. The proposal would have resulted in the industry paying considerably more than it does under the fuel tax. Congress did not support this proposal.

In 2010 and 2011, the Obama administration proposed a user fee that could either replace or supplement the fuel tax. It proposed a two-tier funding structure in which all shippers would pay the fuel tax (on both currently taxed waterways and waterway segments that would be added to the fuel-taxed waterways). In addition, an annual lockage fee would be paid by tows for passing through locks. This approach is close to one set forth by GAO (2008) for a two-part fee for users. Under the Obama administration proposals, Congress would set the fee level to reach revenue targets of the administration, which suggests that raising revenue from users was the main purpose of the proposals. The proposals were not accepted by the 111th or the 112th Congress. The administration's budget request for FY 2015 was less complex and included an unspecified user fee, but this proposal was not included in the 2014 Water Resources Reform and Development Act (WRRDA).

Industry users of the inland waterways have almost universally opposed user-fee funding. However, a proposal to increase the fuel tax to fund new construction was supported by IWUB in its capital projects business model report (Inland Marine Transportation System Capital Investment Strategy Team 2010) and passed by the 113th Congress. The annual revenue generated by the barge fuel tax is typically between $80 million and $85 million. The new rate, $0.29 per gallon, is $0.09 (45 percent) above the current tax of $0.20 per gallon and is estimated to raise $123 million annually. [This

(continued)

[a] See Stern 2014 for additional details on these proposals.

BOX 5-1 *(continued)* **Recent Administration and Shipping Industry Proposals**

projection is largely consistent with a recent estimate conducted by Dager (2013) for the U.S. Army Corps of Engineers (USACE) on the basis of 2011 towboat trip reports recorded by USACE's Waterborne Commerce Statistics Center. The analysis indicated revenue increases from $97,041,270 to $108,238,340, if it is assumed that all taxes due are collected.] Even after the $0.09 increase, the shortfall in funds for the system remains substantial: on the basis of the FY 2015 budget, the total cost of the inland waterways system was $834 million. O&M was 77 percent of the total cost and, according to authorizing legislation, cannot be paid for with revenues generated from an increase in the fuel tax. Like the original tax of $0.20 per gallon, the increased fuel tax would not be indexed for inflation and would not include a capital recovery mechanism linking future taxes to expenditures. Any action on these concerns would require separate legislation and falls under the jurisdiction of the House and Senate taxation committees.

and Box 5-1 for more recent proposals to supplement or replace the fuel tax with other user fees.)

Administration and commercial navigation industry proposals have only addressed increased revenues for the IWTF, which, according to current law, is designated only for payment of capital costs (capacity expansion, replacement, and major rehabilitation). None of the proposals has explicitly focused on the need for a reliable source of funding for operating and maintaining the system.[5] With increasing budget pressures, Congress may seriously consider proposals for users to pay more of the system costs, especially costs associated with day-to-day use and repairs to maintain reliable freight service, which now account for most of the inland navigation budget. The next section describes criteria and related considerations in choosing among user payment options.

[5] However, in its 2011 budget options report, CBO included a proposal to increase user fees on inland waterways to a level sufficient to cover the costs of construction and O&M. CBO projected that such a change would save approximately $4 billion over a 10-year horizon (CBO 2011, 105).

Criteria for Assessment of Options

The purpose of this section is to advance policy makers' understanding of the range of facts to be considered and the trade-offs to be made in deciding among options for funding, not to recommend funding alternatives. Table 5-1 presents the various payment options (see the row headings in the table) and criteria for evaluating the options: promotion of cost-effectiveness, revenue potential, distribution of burden, ease of administration, promotion of user support for cost-effective expenditures, and congressional authorization (see the column headings). The subsections that follow present key considerations in evaluating each of the payment options according to these criteria. A complete analysis of the advantages and disadvantages of a policy decision would depend on the details of how each type of fee is structured and implemented. [CBO (1992) and GAO (2008) present a more detailed analysis of the options.]

DIRECT PROMOTION OF EFFICIENT USE OF WATERWAY RESOURCES

The design of a user payment strategy can promote a waterways system that uses resources more efficiently (CBO 1992). The requirement that users of the system pay for its costs generates signals concerning the value of the system to the users and whether the benefits of the system justify the costs. In the private sector, payments by purchasers of a good or service send a clear signal concerning whether the purchasers are willing to pay the costs associated with providing it. Similarly, if users of the inland waterways system pay for the costs of navigation service on the various parts of the system (on a river segment or at a lock and dam facility), the payments show which parts of the system are cost-effective components of the national freight transportation system and should be maintained (GAO 2008). Parts of the system for which shippers are not able or willing to pay may be discontinued or justified under revenue streams other than federal navigation funding, as discussed later.

From an economic perspective, user charges should be related to use of the system and should be equal to the marginal cost that users impose. This approach enhances economic efficiency by ensuring that

TABLE 5-1 Framework for Assessing User Payment Options

Charge to Users	Direct Promotion of Efficient Use of Waterway Resources	Revenue Potential	Distribution of Burden	Ease of Administration	Promotion of User Support for Cost-Effective Expenditures	Required Congressional Authorization
Increased or redirected fuel tax[a]						
Segment license fee						
Annual license fee (fixed)						
Lockage charges						
Congestion fees						

NOTE: The table shows a framework for evaluating the user payment options. A complete analysis would entail the gathering of facts for each cell in the table and consideration of trade-offs among the criteria and any other factors that policy makers choose to consider in making a decision.
[a] Under current law, fuel tax revenues are to pay only for part of construction and not for O&M.

resources are allocated to their highest-valued use as users weigh the costs and benefits of various aspects of the system and change their behavior accordingly (GAO 2008). In the case of the inland waterways system, the facilities are already in place, so short-run marginal costs are the costs of operating and maintaining the locks and dams (associated with the passage of each vessel) and maintaining channel depths.

However, strict adherence to short-run marginal cost pricing principles may not be feasible for the inland waterways system or may not provide funds sufficient for both O&M and capital investment. New construction is characterized by large fixed capital investment costs. Fixed costs of the system (the cost of building locks and dams) are set expenses that do not vary with the amount of activity such as barge traffic. When marginal costs are low relative to the fixed costs of the system (as is the case for waterways), setting the fee at the marginal cost may not cover the fixed costs of the system. In such cases, the fees could be set above the marginal cost, or allocations from the general fund could be used to help make up the difference.

In addition, marginal costs are incurred for passing tows, such as labor to operate the locks and wear and tear on the infrastructure. Pricing a service or good on the basis of marginal cost makes practical sense in many circumstances, but implementation of such pricing is extremely complex for the inland waterways system. Marginal costs for the inland waterways system would be difficult to assess and would fluctuate significantly with traffic delays and lock unavailabilities.[6] Despite these realities, some reports have suggested complicated pricing strategies that are intended to approximate marginal cost pricing (see, for example, GAO 2008). None of these more complicated systems has received support in the executive branch or in Congress.

Another consideration is that user charges can be imposed either systemwide or at specific facilities or waterway segments with user-specific fees. If the purpose is to promote a national freight system, a nationwide fee, such as a dedicated barge fuel tax that applies to all inland waterway fuel, may be appropriate. If the purpose is to support

[6] Estimating marginal cost for the inland waterways system can be a conceptual and empirical challenge. See CBO 1992 for more extensive discussion of the problem of relying on short-run marginal costs for pricing when an industry has large fixed costs, as is the case for the inland waterways.

individual locations or if maximizing economic efficiency is considered more important than maintaining a national system, a segment or other sort of user-specific fee may be more appropriate (GAO 2008, 19.)

Although an idealized form of marginal cost pricing may not be possible, some general pricing principles that advance efficiency can be derived. First, economic efficiency is promoted whenever user charges are first applied to recover the O&M costs of the inland waterways. Under the current system, user charges are placed into a fund to be used for construction rather than O&M. The funds for O&M expenses are paid from general revenues and must be appropriated annually by Congress. As a result, sufficient funds are not always available to cover O&M, with the unintended consequence that maintenance is deferred. This leads to delays and closures that may require more construction to improve system performance. Indeed, the current arrangement encourages deferral of maintenance; instead of the system being maintained, it is allowed to deteriorate until expenditures can be reclassified as either major rehabilitation or new construction, which qualify for funding from the IWTF.[7]

Second, economic efficiency is promoted when user fees relate directly to the service provided. User fees can be linked to the costs of providing navigation service at a segment or facility level. The logic for this form of user fee is that certain facilities and segments have limited commercial freight use but have operational costs. The willingness of users to pay a fee that reflects the costs of operating that facility or segment would indicate the value of that component of the inland waterways system to the user. The identification of essential components of the system may be aided by such user fees. However, this logic does not imply that only facility- or segment-based user fees are desirable. Systemwide user fees to offset part of the cost of systemwide O&M on the components of the system deemed to be essential to the national freight transportation system might also be used. As noted above, the complicating factor for relying on segment- or facility-based pricing is that it may run counter to the desire to fund an integrated system of waterways (GAO 2008).

[7] As explained in Chapter 3, repairs that exceed $20 million under the 2014 WRRDA and meet other criteria are classified as capital costs instead of O&M.

Finally, in the long run, user payments would provide enough revenue to replace components of the system as they deteriorate. Therefore, in setting user charges, the cost of the depreciation of waterways assets would be included and placed in a dedicated fund (the IWTF) to be used when major rehabilitation is warranted.

To the extent that user charges are set according to these criteria, the system will move toward economic efficiency.

REVENUE POTENTIAL

Federal legislation specifies the fuel tax amount and the waterways subject to the collection of the tax (see Appendix A). An increase in the fuel tax of sufficient magnitude could pay for both construction and O&M of the system. However, fuel tax revenues even at the level of $0.29 per gallon passed by the 113th Congress would not be sufficient to pay for maintaining the system. They would need to be increased substantially and perhaps combined with other forms of payment. According to one recent analysis, if the fuel-taxed inland waterways system were expanded to include 40 additional waterway segments and the tax rate increased to $0.50, the total revenue generated still would be less than $190 million (Dager 2013), on the assumption that all taxes due were collected. FY 2015 budgeted amounts for construction were $180 million; O&M costs, all of which are currently a federal responsibility, were $612 million.

Projection of revenue potential, as well as revenue required, from an increase in the fuel tax requires a careful analysis that includes the effects of the tax on traffic levels and on system costs. On the one hand, at a certain level of fuel tax, some traffic may divert from the system, and revenues may be less than estimated on the assumption of no change in traffic. On the other hand, traffic diversion may allow the abandonment of some facilities with high costs relative to their use, which would reduce the cost of the system and thus the need for revenues.

The potential revenues from lockage or segment fees (for example, a segment fee based on the tonnage moved over a segment) can be calculated readily if the hypothesized fee is multiplied by a measure of current traffic. As in the case of the fuel tax, the projection of revenue potential and of the revenue that would be required from fees requires careful analysis that takes into account the intended or possible effects of the fee on traffic levels as well as on system costs. Congestion fees are often proposed as a method of raising revenue, but they may not generate large amounts if they primarily serve to discourage traffic when facilities are congested. If a specific location suffers from congestion even with congestion charges, the revenue collected would serve as both a source of funds and a market signal that capacity expansion is needed. However, as shown in Chapter 2, traffic on the inland waterways is flat or declining, and delays occur mainly at locks on waterways that experience seasonal spikes in traffic for agricultural commodities. If these trends continue, the additional revenue potential for congestion fees is likely to be small compared with that of other fees and taxes. Congestion fees, however, could still be considered as a demand management tool with the goal of reducing congestion while avoiding lock expansion and other construction.

DISTRIBUTION OF BURDEN

Cost distribution is a consideration in the design of any user payment arrangement. For the inland waterways system, most of the costs are for locks and dams located upstream; areas downstream, such as the Lower Mississippi, may require only occasional channel dredging. As a result, depending on the user charge, the potential exists for cross subsidies, in which users of low-cost facilities and segments are charged an amount that allows users of high-cost facilities and segments to pay a lower amount relative to the benefit they receive. The fuel tax creates cross subsidies because it distributes costs equally across all users of the system. While fuel taxes relate to use of the system, fuel is taxed at the same rate throughout the waterways system. Because federal spending varies substantially across waterways, the users of waterways where the cost of the system is relatively low subsidize users of waterways where the cost is high.

Conversely, user-specific fees, such as lockage and segment fees, can be assessed in direct relation to the O&M costs of specific segments and facilities. To avoid cross subsidies between users, charges could vary by facility or waterway, depending on usage, to align the distribution of payments with the distribution of incurred costs. Such a practice is consistent with the cost-effectiveness criteria described earlier in which users pay for service on parts of the waterways that are economical for them to use. The consequences for specific waterways and their users are difficult to predict (a complete analysis is beyond the scope of this report). Waterways with low freight traffic are most likely to be affected by a user-specific charge because the cost to shippers would be spread across fewer users than in waterways with more freight traffic. The cost may rise to the point that the waterway closes because shippers decide that its use is not cost-effective. Sections of waterway closures may cause shippers to shift origin–destination routes, with economic consequences to regions on abandoned routes that are not cost-effective for shipping. Shippers may switch modes, and some commodities may no longer be shipped. A cost savings to the public may result because federal general revenues may no longer be needed to maintain waterways that are not cost-effective for freight transportation.

A counterargument is that equal payment from all users, whether in the form of a fuel tax or a user fee, is the proper cost distribution for the inland waterways because users on one part of the system (such as those downstream without a high number of locks) benefit from other parts of the system (such as locks upstream that allow passage of commercial traffic to areas downstream).

A systemwide fuel tax combined with a segment or facility charge is another option that may help to increase revenues while addressing concerns about how cost burden is distributed to users of various parts of the system.

EASE OF ADMINISTRATION

Establishment and maintenance of a user-pays system are associated with a number of administrative activities and their costs. They include design of the charge, recording of revenues, and enforcement of revenue collection. Increased and redirected fuel taxes would have minimal additional administration costs since the fuel tax is the current form of user payment and a system already exists for the collection and recording of these revenues.

A lock passage fee for each tow would require costs for its design, but the necessary data are available or could be calculated with some simplifying assumptions. Costs for O&M and for capital depreciation could be calculated and the costs allocated to a time period (a year, for example) to determine the average cost during the period for the passage of each tow (average costs being easier to estimate then marginal costs). If annual costs are the basis for a lock fee, the costs in a previous year divided by the number of lockages in that year could be used to set a lock passage fee, which could be revised for changes in costs and traffic. This is only one of several ways in which the lock fee could be designed. The larger point is that data are available for the design of alternative lock fee systems. Lockage fees are moderately easy to administer and could be implemented on a systemwide basis, with lock operators keeping track of lock use. Enforcement costs would be small, since the tow using the lock could be identified and passage would require payment (or a guarantee of payment) before the lock is operated.

A segment fee requires knowledge of the tow traversing a segment, its size, and perhaps its cargo. The fee might be based on miles traversed and might vary by the value of the cargo. For example, tows with oil might pay more than tows that are empty or that haul grain. This option would focus attention on maintaining parts of the waterways used for high-value shipments. The design of segment fees can be complicated, but once design is completed, the current reporting systems for measuring traffic provide some of the necessary data for fee setting and collection. In the past a segment fee presented a logistical challenge related to tracking individual tows, but GPS technologies now allow for such tracking.

Annual license fees for each vessel can be imposed on either a systemwide or a waterway-specific basis. Systemwide charges are simple to administer but are not as closely related to actual use of the system as a fuel tax, under which payments increase with usage. The fee can be a flat rate, which might be tied to equipment (number or size of vessels, or both) used by the barge operation (towboats and barges). A segment-specific license fee is more complex to administer because most vessels operate on more than one segment.

A congestion fee would be the most difficult to implement because it would require varying the fee as a function of congestion at the lock and then making lock users aware of the fee at any time, much as high-occupancy toll (HOT) lanes vary prices on urban highways with the goal of maintaining a set level of throughput. HOT lanes provide real-time cost information concerning use of the lane to drivers. Real-time information on lock passage costs could be provided to a tow that anticipates using the lock, along with a fee schedule showing passage costs if there is no congestion (the fee might be zero). With GPS technology, the location of the tow, the location of other tows, and their direction of travel could be provided. Tow operators could use the information to time the arrival of their tows at the lock to avoid the congestion fee. During periods of seasonal increases in traffic, when lock capacity is insufficient (such as after a harvest), shippers may be willing to pay a higher fee to prioritize their movement through the lock. Slots to pass through the lock during a peak period could be allocated through an auction in which the highest bidder would move to the front of the line. (Tow operators already holding reservations could sell them to others who want to go through the lock first.) As described earlier, the congestion fee needs to be considered for cost-effective management of traffic spikes on some parts of the system during certain times of the year.

PROMOTION OF USER SUPPORT FOR COST-EFFECTIVE EXPENDITURES

The inland waterways system is operated by a federal agency requiring congressional authorizations and annual appropriations to carry out its work. Thus, system users can express their desires through the political process as well as through the market for waterway services. To manage the system, USACE needs to be responsive to pressures expressed through the political process as well as to information collected on traffic volumes and facility performance. Uniform systemwide charges such as the fuel tax or user fees that do not reflect the costs of providing service on a specific waterway segment can encourage political pressure that thwarts the cost-effective use of resources from USACE's budget. For example, regional organizations can be encouraged to lobby the executive branch and Congress to maintain unwarranted levels of service on waterways because no cost is incurred by those organizations or its members if expenditures on their waterway are increased. If a higher service level could be had only through additional direct cost to the users, greater scrutiny of the value of that service would result.

The degree to which users would advocate for a cost-effective user-payment option is included among the evaluation criteria because user advocacy through the political process is important to USACE as public agency. However, any cost-effective option, whether it results from a USACE response to political advocacy or to market forces, would result in pricing that translates into an increased cost to users.

REQUIRED CONGRESSIONAL AUTHORIZATION

Authorization by Congress would be needed to implement any of the user payment options, including an increase in the current fuel tax or a redirection of fuel tax revenues to allow them to be used for O&M. Similarly, any adjustment in the federal–nonfederal cost share for either capital costs or O&M would require congressional authorization. The ease of gaining congressional approval is a consideration for any user-pays funding strategy in view of the various committee jurisdictions involved and the dialogue and analysis that would be needed to gain the support of the shipping industry.

NECESSITY OF JUDGMENT

Use of the framework illustrated in Table 5-1 for evaluating the options requires two steps. First, an analysis of each user charge with regard to each criterion would be carried out. The analysis would result in a rating, which would be entered into the appropriate cell, even if the rating is qualitative. To a great extent, the ratings can be completed with facts already known. Second, trade-offs will need to be made among the criteria. Any substantial change in funding for the system may need to be phased in. This would allow for monitoring of the changes that occur in freight transport system costs and movements and for adjustment of the approach on the basis of such information.

This framework can be useful in helping to distinguish debates over "the facts" from those over which values or interests are being served by an argument. In the past, failure to make this distinction, combined with hope for more general revenue funding, has made the choice of a sustainable funding strategy more difficult. No single payment approach is best for all of the evaluation criteria, but a preferred approach can be selected on the basis of this framework. The preferred approach is likely to be a combination of the payment alternatives (CBO 1992).[8] While there is no perfect choice, the only alternative to selection of one or more of these options is to hope for more congressional appropriations from the federal general fund, especially for O&M, which may not materialize.

Deciding the amount beneficiaries would need to pay for the commercial navigation system and how to allocate costs among beneficiaries would be complex tasks. The economic value of parts of the system to commercial navigation beneficiaries would need to be identified, and a systemwide assessment of assets to achieve a level of reliable freight service would need to be made (see Chapter 4). Greater reliance on user payments for capital expenditures and O&M will indicate which segments or facilities have economic value to commercial navigation beneficiaries and therefore suggest which parts of the system continue to warrant funding.[9]

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[8] Public–private partnerships have been discussed as a source of financing for construction, which includes capacity expansion and major rehabilitation projects. For one proposal, see http://www.thehorinkogroup.org/wp-content/uploads/2014/04/Inland-Waterway-P3-Report.pdf. WRRDA 2014, Section 5014, authorizes a public–private partnership pilot program for funding the construction of water infrastructure. Private investments theoretically can be made in a number of ways, including up-front private financing, bond financing, or contributed funds. Such partnerships would still require revenues from user contributions or federal general revenues as described in this chapter. For example, bonds would need to be repaid, and the most efficient way of raising revenues for repayments would be through dedicated user fees for valued parts of the system. Up-front private financing with federal availability payments would require substantial and unlikely increases in USACE's budget from general revenues. While public–private partnerships have been discussed for capital investments, which can include major rehabilitation, they have not been discussed for O&M, which is a priority for the system.

[9] Previous National Research Council reports (TRB 2003; TRB 2009; NRC 2012) have come to similar conclusions about the federal role in freight transportation generally, as follows: promote economic efficiency, with investments directed to improvements that yield the greatest economic benefits; limit federal involvement to circumstances in which market-based outcomes clearly would be highly economically inefficient; limit federal subsidies and ensure that facility beneficiaries pay the costs; and rely more on user revenues and the "user-pays" principle.

The Revolving Trust Fund

User support for cost-effective expenditures is one of the criteria for consideration in deciding among the user fee options. To help ensure stakeholder support for any increased revenues from user fees, an option to consider is authorizing USACE to deposit new[10] revenues for maintenance into a revolving trust fund to be used for major rehabilitation to maintain the system and for O&M. Decisions about payments for the system would be made by USACE (as the service provider) and by the navigation industry (as the system users) and would be independent of the annual appropriations process. Direct management of the fund would protect revenues for the intended commercial navigation purpose, which would help in preserving the solvency of the trust fund and in resolving a concern of users that their contributions for navigation may be reappropriated for nonnavigation purposes. A danger of establishing such a dedicated fund from the user perspective, however, is that Congress may reduce general appropriations for the system in proportion to the revenues collected from users for this account.[11]

IWUB's advisory role concerns capital expenditure decisions affecting the current IWTF. If a revolving trust fund for rehabilitation and O&M is created, IWUB's role could be broadened to provide advice on USACE responsibilities related to O&M and major rehabilitation. For example, the 2014 WRRDA stipulates that the Secretary of the Army, in coordination with IWUB, develop a 20-year capital investment program for making investments on the basis of objective prioritization criteria for the selection of national projects. It further specifies that the program be developed with consideration of IWUB's capital projects business model (Inland Marine Transportation System Capital Investment Strategy Team 2010) and to ensure to the

[10] Creating such a fund will—under current budget rules—allow only new revenues to be dedicated to the fund. For example, the incremental revenues from any increase in the inland waterways fuel tax might be designated as above the current fuel tax receipts (baseline) and be deposited into the account.

[11] Securing this authority requires going through a congressional authorization process. If the new revenues are called a "tax," the taxing committees with broad jurisdiction would consider the legislation. If the new revenues are defined as generated from "user fees," the committees that oversee USACE may gain jurisdiction over authorization.

maximum extent practicable efficient funding of inland waterways projects. While a capital projects plan may be warranted, for IWUB to advise on how newly collected funds deposited into the trust should be allocated to O&M would be a new and important responsibility.

Rules and conditions for managing the fund could be set by Congress when the fund is authorized. This approach would be consistent with a number of other programs for which revenues are collected by federal agencies and spent at the discretion of the agencies. (For examples see GAO 2001 and GAO 2008, Chapter 12, Sections C and D.)

Direct management of the fund by USACE and the navigation users would avoid delays in receipt of funds through the appropriations process, which can affect the reliability and cost-effectiveness of the system. Funds are not always available in a timely manner to cover ongoing O&M costs, and maintenance may be deferred. Deferred maintenance can lead to infrastructure failures and facility closures and to more costly capital expenditures for rehabilitation and construction.

Segments and Facilities with Minimal or No Commercial Traffic

The analysis of inland waterways traffic in Chapter 2 can be used as a model to rate the importance of inland waterways segments and facilities to national freight transportation. Regardless of the specific changes that may occur in barge traffic and that may be difficult to forecast, three situations can be anticipated, each with implications for decisions about funding. First, some parts of the inland waterways (segments or facilities) are essential components of the national freight transportation system and, as such, warrant a new funding strategy administered by USACE to ensure their continued viability. Up to this point, Chapter 5 has been concerned with funding for parts of the inland waterways system essential for freight movement.

Chapter 2 also identifies parts of the inland waterways system with some commercial navigation traffic but where the type or volume of cargo suggests lesser significance for the freight system. Commercial freight movements in these segments might not warrant federal support, and a different funding approach may be called for. For budgetary reasons, USACE has already reduced funding to some low-priority segments and facilities, although portions of the system with lower freight traffic that now receive limited funds might receive more if additional funds were available.

The third situation emerging from the analysis is that of segments or facilities with no or a minimal amount of commercial traffic but that are being maintained with navigation funds for other uses and beneficiaries. Under a prioritization based on economic value to the shipping industry, they would not receive funding through the navigation portion of USACE's budget, but their future must still be considered as part of a new funding and management strategy.[12] Removing the cost of portions without significant freight traffic from the federal navigation budget would support better management decisions for the system and further the possibilities of shifting to a user-based funding structure for commercial navigation services. The consequences for other uses and beneficiaries of these water resources would need to be considered. For example, freight traffic on low-use segments often also passes through medium- or high-use segments, so the consequences to the latter segments of losing that traffic should be considered in the analysis.

The situations of low freight traffic and minimal or no freight traffic are discussed in the following subsections.

LOW FREIGHT TRAFFIC

Some of the payment strategies discussed earlier are available not only to the federal government but also to a nonfederal entity wishing to maintain low-use segments for shippers. If federal spending for a waterway segment or facility is no longer viable,[13] a nonfederal entity

[12] Drawing the distinction among these three situations will require technical data and analysis to support a policy judgment that surely will need to involve IWUB. Any drawing of lines for inclusion in the navigation system may be challenged. In view of this reality, one approach may be to have an appeals process under which current commercial users of a segment or a facility in a segment that has been identified as nonessential for freight movements can petition to be included in the federally supported navigation system.

[13] Federal spending includes funding from general revenues collected from taxpayers and revenues collected from shippers disbursed via the IWTF.

(a local government or port authority or perhaps a newly created entity) may use some of these payment options or take other revenue-raising actions. Some options may not be possible for nonfederal entities because of the authorities that would be required (for example, the charging of a lock fee by a nonfederal entity may not be possible), but others such as ad valorem taxes and access fees would be.

The entity raising the funds can make the receipts available to USACE in the form of contributed funds for operating, maintaining, or rehabilitating that part of the system. Contributed funds are funds beyond any nonfederal cost contribution required by statute that may be provided voluntarily by a state or political subdivision for all project purposes, including navigation. Authorizing legislation (WRRDA 2014) suggests the possibility of other mechanisms (one of which is a public–private partnership) by which the benefiting entities can collect and then dedicate funds to a waterway segment or facility.

MINIMAL OR NO FREIGHT TRAFFIC

Projects currently authorized to be maintained and operated for commercial navigation may no longer have freight traffic, may have minimal amounts of traffic that could move on other modes, or may have traffic that is not of sufficient economic value to move by waterway if shippers are required to pay more of the cost of waterway maintenance. The latter would indicate that the economic value of the navigation is below a threshold for federal investment. In this case, four situations that would need to be resolved can arise.

First, a continuing USACE navigation project could be needed to support benefits realized by nonnavigation beneficiaries, but navigation is the project's only authorized purpose. For example, over time and at no cost to the project, the pools may have come to serve as municipal water supply or to be used for water recreation. In such a situation, federal funds,[14] preferably not from the navigation budget, could be used to secure the structural integrity of the facility. This would ensure public safety and allow for the continuation of any nonnavigation uses. Ideally, USACE would turn the structure over to

[14] Federal funds for navigation include federal general revenues and revenues from shippers disbursed via the IWTF.

another entity, but the agency does not have the authority to transfer ownership of a project that no longer moves freight. Congress must authorize such a transfer. (For example, several locks and dams on Wisconsin's Fox River were transferred to the state, but only after a long process.) USACE may still need to monitor any structures to ensure their integrity. For locks and dams authorized for navigation that have low or no navigation benefits but still provide ancillary benefits, it would be possible to close the locks and retain the dam function, thereby reducing system costs but still providing ancillary benefits. Moreover, these benefits would become primary, which would enable a fresh analysis of cost sharing among users, local beneficiaries, states, and federal agencies (that may or may not include USACE).

Second, an operable lock could be used for recreational passage (or an occasional commercial freight passage). Payments to cover the costs of keeping the lock operational for recreational purposes may be provided to USACE by another entity via contributed funds. USACE could continue to operate the lock with these funds, even if recreational boats are the principal users. (See Box 5-2 for an example on the Lower Allegheny River.)

The third situation is a variation of the first. In this situation, when maintenance for freight traffic is not needed, the costs of water storage might be reallocated to other purposes such as flood damage reduction, water supply, or recreation. Federal funds, again preferably not from the navigation budget, would be used to secure the structural integrity of the facility. A study would be required to develop and evaluate such alternatives. Development of the preferred plan will require interaction with potential beneficiaries, who would be expected to pay for the new services and perhaps for the continuation of services that they received as incidental beneficiaries of a project as currently authorized. However, any costs incurred to allow the project to serve new purposes would need to be justified by a feasibility study and the cost shared according to the law governing the new purposes being served.

In the fourth situation, maintenance operations and construction for the inland waterways system have altered river hydrology, with effects on life-cycle processes of flora and fauna (e.g., disruption of fish spawning areas in rivers and floodplains and backwater habitats). For example, on segments such as the Apalachicola River, Florida,

BOX 5-2

Two Examples of Nonfederal Funding Options for Locks and Dams for Nonnavigation Purposes

Local recreation and economic benefits: In the 1920s and 1930s, eight locks and dams were built on the Lower Allegheny River to move commercial traffic 72 miles from Pittsburgh to East Brady, Pennsylvania. This corridor once was important for moving oil and timber from northwestern and central Pennsylvania to Pittsburgh and markets beyond and for supplying and moving products from metal manufacturing plants. While recreational boat traffic has increased over time, commercial traffic has decreased to levels that no longer justify substantial federal expenditures. By 2011, a total of 38,000 tons moved through Locks and Dams 6, 7, 8, and 9; there were 54 total commercial lockages versus 1,583 for recreational vessels. For comparison, in 2011 just one of the locks at Locks and Dam 2 on the Monongahela River moved 13,055,000 tons of cargo, with 2,627 commercial lockages versus 53 lockages for recreational use.

Funding for O&M and repairs for these locks has steadily declined, and hours of operation have been reduced. In 2014 the locks passed commercial traffic by appointment only and, with rare exceptions, have been closed to recreational traffic since 2012. USACE is obligated to keep the facilities operating only to the extent allowed by the available budget resources. USACE would require congressional authorization to remove the infrastructure, however.

As a result of the negative economic impact of lock closures from a loss in tourism, the nonprofit Allegheny River Development Corporation and the Upper Monongahela River Association have partnered to work with the USACE Pittsburgh District to use a provision in the newly enacted WRRDA that encourages the use of contributed funds to pay for waterway infrastructure. Section 1017 calls for the establishment of a pilot program to enable the acceptance and expenditure of funds contributed by nonfederal interests to USACE water resources projects. This approach has the support of groups that encourage the use of this new authority to maintain the Allegheny and Monongahela for recreational boating and fishing, such as the National Waterways Conference. The goal of this coalition for the Allegheny is to raise nonfederal funds from private and public sources so that USACE can continue O&M of the infrastructure, mainly for recreational use.

(continued)

BOX 5-2 *(continued)* **Two Examples of Nonfederal Funding Options for Locks and Dams for Nonnavigation Purposes**

Hydropower services: As part of an agreement among USACE, the Southwest Power Association, and its federal power customers, a system was devised whereby priority USACE facilities for power generation could be directly paid for by customers. This system was launched after power customers experienced an increase in unscheduled power outages associated with reduced and untimely appropriations for federal hydropower plant operation, maintenance, and major rehabilitation (Coombes 2013). New nonfederal development and investment also are permissible at USACE facilities. For example, as of 2010, 90 nonfederal power units were installed and maintained at operator expense at USACE dams, with a total capacity of 0.003 gigawatts. Such development requires a Federal Energy Regulatory Commission license and a Corps Section 408 permit, which authorizes the nonfederal use of a federal facility (http://fas.org/sgp/crs/misc/R42579.pdf, p. 6).

which has minimal barge traffic, continued maintenance activities are opportunities lost for the improvement and restoration of aquatic ecosystems (Box 5-3). The USACE national ecosystem restoration mission may suggest investment to remove the physical facility partially or completely or leave lock gates open to return the river to a natural flow regime. A study would be required to develop and evaluate restoration alternatives. Among the costs that would need to be recognized in such a study is the loss of benefits (for example, a water supply intake) to incidental beneficiaries, who need to be compensated for having to invest in alternative facilities. As for any other restoration, the costs incurred would need to be justified by a feasibility study and the costs shared according to the law governing the purposes served.

Findings and Conclusions

A system more reliant on user payments is feasible, would provide revenue for maintenance, and would promote economic efficiency. It also would be more consistent with the federal posture toward other freight

BOX 5-3

Apalachicola, Chattahoochee, and Flint River System: A Multiple-Purpose River System Not Reflecting Today's Economic and Environmental Values

The Apalachicola–Chattahoochee–Flint Rivers basin originates in northeast Georgia, crosses the state boundary into central Alabama, and then follows the Alabama state line south until it terminates in Apalachicola Bay, Florida. The basin covers 50 counties in Georgia, 10 in Alabama, and eight in Florida. Extending a distance of approximately 385 miles, the basin drains 19,600 square miles. The Apalachicola, Chattahoochee, and Flint River Waterway consists of a channel 9 feet deep and 100 feet wide from the mouth of the Apalachicola River to the head of navigation at Columbus, Georgia, for the Chattahoochee River and at Bainbridge, Georgia, for the Flint River. The total waterway distance is 290 miles, with a lift of 190 feet accomplished by three locks and dams. Provision of navigation services is just one of several purposes for which the system's operations are authorized; others are water supply, flood control, hydropower generation, recreation, and management of water releases for several nonfederal power generation dams.

Commercial use of the waterway has declined steadily over time and now is minimal, mainly haulage of sand and gravel. According to the Waterborne Commerce Statistics Center, no commercial traffic occurred over the 5 years from 2008 to 2012. Nevertheless, channel maintenance of the lower reaches of the waterway requires dredging and clearing, which has severe adverse impacts on the ecological health of Apalachicola Bay, one of the most economically productive water bodies in the United States. While these efforts have been strongly opposed by the state of Florida through regulatory and other measures such as not providing dredged material disposal areas, USACE has found ways to provide navigation services. In addition to the financial outlays by the federal government for navigation, operation of the upstream reservoirs to provide navigation "windows" uses releases of water that are highly valued by other users, including municipalities and lake recreationists.

(continued)

BOX 5-3 *(continued)* **Apalachicola, Chattahoochee, and Flint River System**

Because the cost of O&M assigned to navigation is borne by federal taxpayers, opposition to continued provision of navigation services comes largely from the environmental organizations and Florida. Furthermore, the lack of navigation benefits is only a small issue in the conflicts over the operation of this major multiple-purpose reservoir system. Growing demands for municipal water supply in Georgia have led to "water wars" among the states for decades, which have not been successfully addressed administratively by USACE or by Congress.

transportation modes. User charges for the inland waterways system can take the form of a dedicated tax such as the current fuel tax, a user fee, or some combination. The fuel tax can be an important source of revenue, but revenue potential alone is not sufficient for judging a funding strategy. User fees (segment- or facility-specific) instead of or in addition to the fuel tax or as a supplement to general revenues are an option to consider as part of a comprehensive funding approach. Criteria for choosing among the user payment options include the following: promotion of efficient use of waterway resources, distribution of burden, ease of administration, promotion of user support for cost-effective expenditures, and requirements for congressional authorization. No single payment alternative offers a perfect choice; for example, the preferred choice for achieving a policy goal may combine an increase in the barge fuel tax with other user fees.

Setting user charges to move the inland waterways system closer to economic efficiency would provide for more adequate maintenance of the most important parts of the system and contribute to a more efficient national freight transportation system. Economic efficiency is promoted when user charges are first used to recover the O&M costs of the inland waterways and when user fees relate directly to the service provided. In the long run, user payments structured properly to cover O&M and depreciation would also provide enough revenue to replace components of the system as they wear out.

Any additional revenues from users would need to be dedicated to the inland waterways system to ensure a source of funds for meeting system priorities and to respond to concerns that new payments intended for navigation could be reappropriated for other purposes. A revolving trust fund for maintenance would help ensure that all new funds collected are dedicated to inland navigation. Rules and conditions for managing the fund could be set by Congress if such a fund were authorized. The fund could be administered by USACE, and IWUB's advisory role, which is currently limited to capital spending for construction, could be broadened to include spending for O&M and repairs. Amounts from the IWTF are disbursed through congressional appropriations under current practice, which can result in delays in funding and deferred maintenance. Direct administration of the trust fund allows spending O&M funds as needed to provide reliable freight service and avoid the increased costs associated with deferred maintenance.

Deciding the amount beneficiaries would need to pay for the commercial navigation system and how to allocate the costs among beneficiaries would be complex tasks. The economic value of part of the system to commercial navigation beneficiaries would need to be identified and a systemwide assessment of assets required to achieve a reliable level of freight service would need to be made (see Chapter 4). Greater reliance on user payments for capital expenditures and O&M will identify which segments or facilities have economic value to the commercial navigation beneficiaries and therefore suggest which parts of the system continue to warrant funding. Because of constraints on its budget, USACE has already begun identifying waterways and facilities where commercial navigation is essential to national freight transportation or where significant commercial traffic continues. A policy and a process are needed for identifying the components of the system essential for freight transportation to fund from the navigation budget. A path to removing the cost of parts of the system not essential for freight service presently charged to the federal inland navigation budget may further the prospect of shifting to a user-based funding approach for commercial navigation service. Alternative plans and potential funding mechanisms described in this chapter are available for segments and facilities that are deemed not essential to freight transportation but that may provide other ancillary benefits.

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ABBREVIATIONS

CBO	Congressional Budget Office
GAO	U.S. Government Accountability Office
NRC	National Research Council
TRB	Transportation Research Board

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6

Conclusions

Debates about funding for the inland waterways system have long centered on the level of funding required, the roles of the federal government and users in paying for the system, and how users and other beneficiaries could be charged. These issues deserve renewed attention in light of shrinking federal budgets, declining appropriations for the inland waterways system, and increasing maintenance needs for its infrastructure. The National Research Council's Committee on Reinvesting in Inland Waterways: What Policy Makers Need to Know examined the role of the inland waterways in the nation's freight transportation network and identified issues that policy makers need to consider in decisions about funding for the system. (See Chapter 1 for the committee's statement of task.)

Summary of Major Conclusions and Findings

The policy context in which these issues were considered and the committee's conclusions are summarized below. Three main messages emerge, as follows:

- Reliability and performance of the inland waterways freight system are the priorities for funding.
- Reliability and performance will depend more on investments in operations and maintenance (O&M) than on capital expenditures for larger locks.
- More reliance on a user-pays approach to funding the inland waterways for commercial navigation is feasible, would provide additional

revenues for maintenance, and would promote economic efficiency for the system.

Policy Context

The infrastructure of the federal inland waterways system is managed by the U.S. Army Corps of Engineers (USACE) and funded through USACE's navigation budget. The nation's inland waterways include more than 36,000 miles of rivers, waterways, channels, and canals, with 241 locks managed by USACE at 195 sites.* The chief and most expensive component of providing for navigation service is the installation and maintenance of lock and dam infrastructure to enable the upstream and downstream movement of cargo.

Historically, the federal government invested in the building of the inland waterways system to aid in the physical expansion of the United States and the growth of the U.S. economy by facilitating cargo shipments. Before 1978, the federal government paid all costs associated with construction and maintenance of the inland waterways. Legislation passed in 1978 and 1986 established the current funding and cost-sharing framework. Today, 11,000 miles of the inland waterways are subject to a federal fuel tax paid by the barge industry via the Inland Waterways Trust Fund to cover up to 50 percent of the cost of construction and major rehabilitation of lock and dam infrastructure. The federal government pays 50 percent of construction costs from general revenues and 100 percent of the cost of O&M (by budgetary definition, O&M includes repairs up to $20 million; repairs that exceed $20 million and meet other criteria are considered major rehabilitation and classified as a capital expenditure). Although policy debates about funding for the inland waterways have focused on capital projects, O&M, which is paid for entirely with federal general revenues, now accounts for three-fourths of the annual budget request for inland navigation.

Because of historical precedent, the federal role in the management and funding of the inland waterways for commercial navigation is

* See Footnote 3, page 15.

already greater than for other freight modes. The total federal share of the cost of the inland waterways system is estimated to be about 90 percent. The federal share is roughly 25 percent for the highways used by motor carriers and 0 percent for pipelines and nearly so for railroads (both private industries for which the federal role is primarily one of safety and environmental regulation). Whereas federal general revenues cover all O&M expenses for the inland waterways, states pay 100 percent of the O&M expenses, mostly from user fees, for intercity highways used by motor carriers. O&M expenses for railroads and pipelines are paid for by the private industries responsible for these modes.

With the exception of a one-time infusion of funds from federal economic stimulus legislation in 2009, the funds appropriated for inland navigation have declined over the past decade in terms of constant dollars for both O&M and construction. The level of funding required to sustain a reliable inland waterways system is not clear. The level of service required from the system, and therefore the parts of the existing system that need to be maintained, has not yet been defined. USACE does not have established systemwide guidance and procedures for the assessment of inland waterways infrastructure and the prioritization of maintenance and repair spending for reliable commercial navigation. In view of stagnant federal appropriations, system users have recognized that they need to pay more and supported an increase in the barge fuel tax by the 113th Congress. However, the increase will not be sufficient to maintain the system and only heightens the urgency of settling on a plan for maintenance, since under federal law any new revenues from the barge fuel tax can be used only for construction and not for O&M. Moreover, because funds raised by the barge fuel tax for capital projects must be matched by the federal government, O&M competes directly with construction for federal general revenue funds. Without a new funding strategy that prioritizes O&M, maintenance may be deferred until it reaches $20 million (the point at which it becomes classified as a capital expenditure), which would result in further deterioration and in a less cost-effective and less reliable system.

USACE has missions and management responsibilities that extend beyond providing for commercial navigation. With the authorization of Congress, USACE, under its Civil Works Program headed by the Assistant Secretary for Civil Works, plans, constructs, operates, and maintains the following: lock and dam infrastructure for commercial shipping; channel depths required for ports and harbors; dams, levees, and coastal barriers for flood risk management; and hydropower generation facilities. Other USACE responsibilities include maintenance of water supply infrastructure (municipal water and wastewater facilitates) and provision of waterborne recreation (i.e., boating). For the most part, these missions are independent of one another, since most projects are authorized for a single purpose. However, for many navigation projects, the availability of pools behind dams has allowed others to benefit from water supply for municipal, industrial, and farming purposes and for recreation. Any decisions about funding for navigation will need to consider the implications for this broader range of beneficiaries.

Conclusions

The following considerations warrant particular attention in decisions about funding for the inland waterways system.

1. The inland waterways system is a small but important component of the national freight system.

The role of the inland waterways system in national freight transportation has changed significantly since the system was built to promote the early economic development of the nation. Today barges carry a relatively small but steady portion of freight, mainly bulk commodities that include in rough order of importance coal, petroleum and petroleum products, food and farm products, chemicals and related products, crude materials, manufactured goods, and manufactured equipment. Annual trends in inland waterways shipments show that freight traffic is static or declining. Overall demand for the inland waterways system is static, whereas demand for the rail and truck modes is growing. In recent years, the inland waterways system has transported 6 to 7 percent of all domestic cargo (measured in ton-miles). The truck mode has carried the greatest share of freight, followed by rail, pipeline, and water.

2. The most critical need for the inland waterways system is a sustainable and well-executed plan for maintaining system reliability and performance that ensures efficient use of limited navigation resources.

Lost transportation time due to delays and lock unavailability (outages) is a cost to shippers and an important consideration in deciding on future investments. Systemwide, about 80 percent of lost transportation time is attributable to delays. On average, 49 percent of tows in 2013 were delayed across the 10 highest-tonnage locks, with an average length of tow delay of 3.8 hours. While some delay is expected for routine maintenance, weather, accidents, and other reasons, lost transportation hours (delays and unavailabilities) can be affected by maintenance outages related to decreased reliability of aging machinery or infrastructure. Lost transportation hours also can be affected by capacity limitations, which may be intermittent or seasonal. About 12 percent of lost time on the inland waterways system is due to scheduled closures and about 8 percent is due to unscheduled closures. Thus, 20 percent of lost transportation time could be addressed with more targeted O&M resources. Directing O&M resources toward major facilities with frequent lockages and high volumes and where the lost time due to delay is significantly higher than the river average could improve navigation performance. Data are not available on the reasons for delay. Delays might be attributable to intermittent or seasonal peaks in volume due to weather, harvest, undercapacity, or other causes. Most lost time due to delay is at locks with periods of high demand often related to peaks in seasonal shipping, mainly for agricultural exports.

Furthermore, as described in Chapter 2, the inland waterways cover a vast geographic area, but the freight flows are highly concentrated. Seventy-six percent of barge cargo (in ton-miles) moves on just 22 percent of the 36,000 inland waterway miles. About 50 percent of the inland waterway ton-miles moves on six major corridors—the Upper Mississippi River, the Illinois River, the Ohio River, the Lower Mississippi River, the Columbia River system, and the Gulf Intracoastal

Waterway—which represent 16 percent of the total waterway miles. Some inland waterway segments have minimal or no freight traffic. The nation needs a funding strategy that targets funds to waterway segments and facilities essential to freight transportation and away from places that are not as important. This "triage" is already occurring in USACE's budgeting process.

3. More reliance on a user-pays approach to funding the commercial navigation system is feasible and could generate new revenues for maintenance while promoting economic efficiency.

In a climate of constrained federal funds, and with O&M becoming a greater part of the inland navigation budget, it is reasonable to examine whether beneficiaries could help pay for the system to increase revenues for the system and improve economic efficiency. Indeed, Congress, in the 2014 Water Resources Reform and Development Act (Section 2004, Inland Waterways Revenue Studies), called for a study of whether and how the various beneficiaries of the waterways might be charged. Federal general revenues presently cover most of the cost of the inland waterways system. Commercial navigation users, the primary identifiable beneficiaries of the system, pay a share of the construction costs through a barge fuel tax, but none of the costs of O&M.

A system more reliant on user payments would provide needed revenue for maintenance and promote economic efficiency. It also would be more consistent with the federal posture toward other freight transportation modes. Setting user charges to move the inland waterways system closer to economic efficiency would provide for more adequate maintenance for the important parts of the system and contribute to a more efficient national freight transportation system. Economic efficiency is promoted when user charges are first used to recover the O&M costs of the inland waterways and when user fees relate directly to the service provided. In the long run, user payments structured properly to include O&M and depreciation could also provide enough revenue to replace components of the system as they wear out. User charges for the inland waterways system can take the form of a dedicated tax such as the current fuel tax, a user fee, or some combination. The fuel tax can be an important source of revenue, but revenue potential alone is not sufficient for judging a funding strategy. User fees (segment- or facility-specific) instead of or in addition to the fuel tax are an option to consider as part of a comprehensive funding approach. Criteria for choosing among the user payment options include the following: promotion of efficient use of waterway resources, distribution of burden, ease of administration, promotion of user support for cost-effective expenditures, and requirements for congressional authorization. No single payment alternative offers a perfect choice; for example, the preferred option for achieving a policy goal may combine an increase in the barge fuel tax with other user fees.

To gain support from commercial navigation users, any additional revenues from users would be dedicated to the inland waterways system to ensure a source of funds for meeting system priorities and to respond to concerns of users that new payments intended for navigation could be reappropriated for other purposes. A revolving trust fund for maintenance would help ensure that all new funds collected are dedicated to inland navigation. Rules and conditions for managing the fund would be set by Congress if such a fund were authorized. The fund would be administered by USACE, and the Inland Waterways Users Board's advisory role, which is currently limited to capital spending for construction, could be broadened to include spending for O&M and repairs. Amounts from the Inland Waterways Trust Fund are disbursed through congressional appropriations under current practice, which can result in delays in funding and deferred maintenance with increased costs. Direct administration of the trust fund would allow the spending of O&M funds as needed to provide reliable freight service and avoid the increased costs associated with deferred maintenance.

Because of constraints on its budget, USACE has already begun identifying waterways and facilities where commercial navigation is essential to national freight transportation or where significant commercial traffic continues. A policy and a process for identifying the components of the system essential for freight transportation are needed.[1] A path to removing the cost of parts of the system not essential for freight service presently charged to the federal inland navigation budget may further the prospect of shifting to a user-based funding approach for commercial navigation service. Alternative plans and potential funding mechanisms (described in Chapter 5) are available for segments and facilities that are deemed not essential to freight transportation but that may provide other benefits.

Deciding the amount beneficiaries would need to pay for the commercial navigation system and how to allocate the costs among beneficiaries would be complex tasks. The economic value of parts of the system to commercial navigation beneficiaries would need to be identified, and a systemwide assessment of the assets required to achieve a reliable level of freight service would need to be made (see next conclusion).

4. Asset management can help prioritize maintenance and ascertain the level of funding required for the system.

Regardless of who pays for the system, a standard process for prioritizing spending of available funds is needed. The capital projects backlog is not a reliable indicator of the amount of funding required for the system. A modest amount of the backlog is for navigation projects. A portion of the navigation backlog includes major rehabilitation to maintain the system, but it does not include O&M. Furthermore, the navigation backlog may include projects that are a lower priority for spending. Congress has long authorized and appropriated USACE capital projects on a project-by-project basis. A benefit–cost analysis prepared by USACE is the primary source of technical information that Congress uses during the authorizations process in deciding when spending is justified for capital projects. While benefit–cost

[1] A general framework for considering which parts of the system may warrant inclusion in the navigation system given levels of freight traffic is presented in Chapter 5; however, any distinctions and decisions would require technical data and analysis to support a policy judgment that surely will need to involve the Inland Waterways Users Board. Any drawing of lines for inclusion in the navigation system may be challenged. In view of this reality, one approach may be to have an appeals process under which current commercial users of a segment or a facility in a segment that has been identified as nonessential for freight movements can petition to be included in the federally supported navigation system.

analyses have been used for determining whether a project meets a minimum threshold for funding, they have not been used to rank projects, and the result has been far more projects being authorized than can be afforded within the constraints of the budget. A method for prioritizing projects on the basis of the service needs of the system would be more useful than an attempt to estimate and seek funding for the existing backlog.

The advanced age of locks is often used to communicate funding needs for the inland waterways system. Age, however, is not a good indicator of lock condition. A substantial number of locks have been rehabilitated, which would be expected to restore performance to its original condition if not better. Furthermore, with some exceptions, little correlation exists between the age of locks and their performance as measured by delay experienced by system users. Dating the age of assets from the time of the last major rehabilitation, as is done for highway infrastructure such as bridges, would be more accurate. USACE does not publish consistent records of rehabilitation dates for its various lock and dam assets, however. Making such information available to policy makers, alongside information about the reliability and performance of the system, could improve the efficient allocation of available resources.

An asset management program focused on economic efficiency, fully implemented and linked to the budgeting process, would prioritize maintenance spending and ascertain the funding levels required for reliable freight service. A well-executed program of asset management would promote rational and data-driven investment decisions based on system needs and minimize the broader influences that affect the budgeting process.

USACE has adopted a generally appropriate framework for asset management that is mostly consistent with the economically efficient asset management (EEAM) concept described in Chapter 4, but it is not yet fully developed or deployed across USACE districts. The framework recognizes the importance of economic consequences for strategic investment instead of assuming that all navigation infrastructure needs to be maintained at its original condition. The approach appropriately includes assessment of three main elements that follow from EEAM: the probability of failure of the infrastructure; infrastructure usage (demand), defined as whether the waterway has low, moderate, or high levels of freight traffic; and the economic consequences of failure to shippers and carriers.

Whereas maintenance is a priority for the system, decisions about whether to invest in construction for capacity expansion at key bottlenecks and how to prioritize these investments against other investments for the system will continue to arise. Decisions about whether investments in construction to expand capacity at the corridor level are economically justified would require more information about delays and the ability of nonstructural alternatives or smaller-scale structural improvements (to increase processing time) to achieve the desired level of service. Collection of data and development of performance metrics would enhance understanding of whether delay problems could be most efficiently addressed by more targeted O&M, traffic management, capacity enhancement, or some combination of these. Once an asset management approach was fully developed and applied, it could be used to prioritize allocation of resources for O&M and indicate areas where major rehabilitation or other capital spending should be considered.

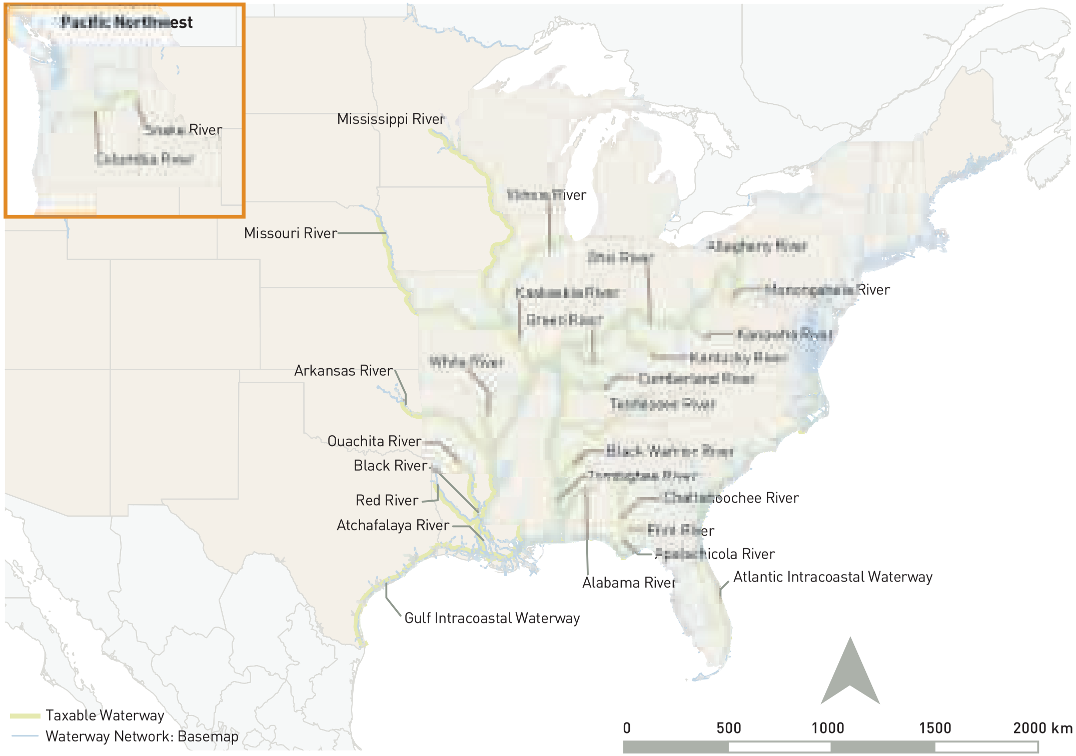
Several elements of the USACE framework would need further attention for implementation (as discussed in Chapter 4). First, there is no single best measure of risk tolerance; a level of risk tolerance will need to be defined for each asset. Second, the approach will need to be implemented systemwide to gain the greatest level of service and economic benefits. Third, whereas the data required to apply the framework are already available for the most part from USACE's Lock Performance Monitoring System, refinements could be considered. Metrics to assess the location, timing, and reason for delays routinely could be developed and linked to data on the economic consequences of delay to prioritize investments. Under certain investment scenarios it may be necessary to consider the usage level of individual locks when maintenance priorities are established. For example, in some cases, the ability to handle peak periods (and the economic consequences of not being able to do so) needs to be considered rather than relying first on annual average waterway ton-miles. A consistent method of recording delays across the system would be needed, and perhaps additional information on delays could be recorded. Information on accidents also would be useful. Fourth, EEAM would be most effective if USACE also had the ability to manage and spend O&M funds according to priorities set through the EEAM process at the district level. This would allow USACE to have the greatest impact on the reliability of freight service given the immediate conditions. Funds would still be disbursed through the appropriations process. Policies and procedures would be needed to ensure the consistent application of district- and division-level assessments under the EEAM process.

APPENDIX A

Fuel-Taxed Inland Waterways

Waterways subject to fuel taxes specified by Public Law 95-502, October 21, 1978, and Public Law 99-662, November 17, 1986 [source: Institute of Water Resources, U.S. Army Corps of Engineers (http://www.iwr.usace.army.mil/Missions/Navigation/InlandWaterwaysUsersBoard/FuelTaxedWaterways.aspx)]:

1. Alabama–Coosa Rivers: From junction with the Tombigbee River at river mile (RM) 0 to junction with Coosa River at RM 314.
2. Allegheny River: From confluence with the Monongahela River to form the Ohio River at RM 0 to the head of the existing project at East Brady, Pennsylvania, RM 72.
3. Apalachicola–Chattahoochee and Flint Rivers: Apalachicola River from mouth at Apalachicola Bay (intersection with the Gulf Intracoastal Waterway), RM 0, to junction with Chattahoochee and Flint Rivers at RM 107.8. Chattahoochee River from junction with Apalachicola and Flint Rivers at RM 0 to Columbus, Georgia, at RM 155 and Flint River, from junction with Apalachicola and Chattahoochee Rivers at RM 0 to Bainbridge, Georgia, at RM 28.
4. Arkansas River (McClellan–Kerr Arkansas River Navigation System): From junction with Mississippi River at RM 0 to Port of Catoosa, Oklahoma, at RM 448.2.
5. Atchafalaya River: From RM 0 at its intersection with the Gulf Intracoastal Waterway at Morgan City, Louisiana, upstream to junction with Red River at RM 116.8.
6. Atlantic Intracoastal Waterway: Two inland waterway routes approximately paralleling the Atlantic coast between Norfolk, Virginia, and Miami, Florida, for 1,192 miles via both the Albemarle and Chesapeake Canal and the Great Dismal Swamp Canal routes.

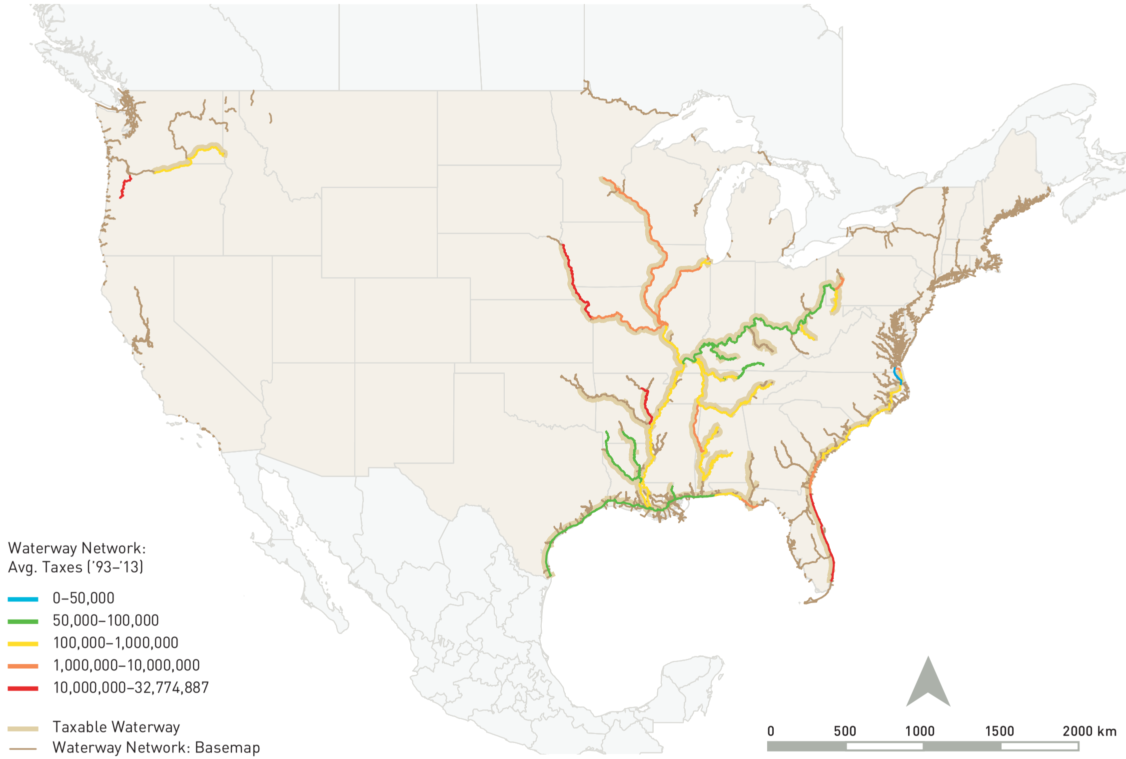


(a)

FIGURE A-1 Summary of (*a*) waterways where fuel taxes are collectible.

(continued)

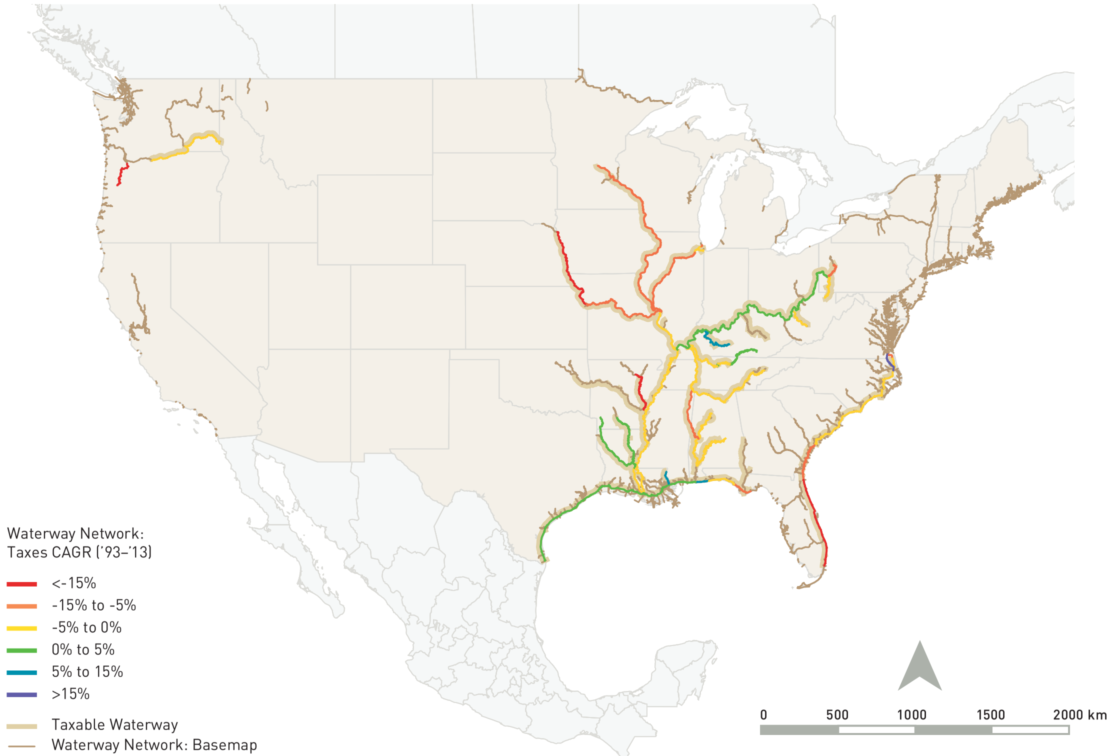
SOURCE: Dager 2013.



(b)

FIGURE A-1 *(continued)* Summary of (*b*) average fuel taxes collected.

(*continued on next page*)



(c)

FIGURE A-1 *(continued)* Summary of (*c*) compound annual growth rate over 1999–2011.

7. Black Warrior–Tombigbee–Mobile Rivers: Black Warrior River system from RM 2.9, Mobile River (at Chickasaw Creek), to confluence with Tombigbee River at RM 45. Tombigbee River (to Demopolis, Alabama, at RM 215.4) to port of Birmingham, Alabama, RMs 374 to 411 and upstream to head of navigation on Mulberry Fork (RM 429.6), Locust Fork (RM 407.8), and Sipsey Fork (RM 430.4).
8. Columbia River (Columbia–Snake Rivers Inland Waterways): From The Dalles at RM 191.5 to Pasco, Washington (McNary Pool), at RM 330; Snake River from RM 0 at the mouth to RM 231.5 at Johnson Bar Landing, Idaho.
9. Cumberland River: Junction with Ohio River at RM 0 to head of navigation, upstream to Carthage, Tennessee, at RM 313.5.
10. Green and Barren Rivers: Green River from junction with the Ohio River at RM 0 to head of navigation at RM 149.1.
11. Gulf Intracoastal Waterway: From Saint Mark's River, Florida, to Brownsville, Texas, 1,134.5 miles.
12. Illinois Waterway (Calumet–Sag Channel): From the junction of the Illinois River with the Mississippi River at RM 0 to Chicago Harbor at Lake Michigan, approximately RM 350.
13. Kanawha River: From junction with the Ohio River at RM 0 to RM 90.6 at Deep Water, West Virginia.
14. Kaskaskia River: From junction with the Mississippi River at RM 0 to RM 36.2 at Fayetteville, Illinois.
15. Kentucky River: From junction with the Ohio River at RM 0 to confluence of Middle and North Forks at RM 258.6.
16. Lower Mississippi River: From Baton Rouge, Louisiana, RM 233.9, to Cairo, Illinois, RM 953.8.
17. Upper Mississippi River: From Cairo, Illinois, RM 953.8, to Minneapolis, Minnesota, RM 1,811.4.
18. Missouri River: From junction with the Mississippi River at RM 0 to Sioux City, Iowa, at RM 734.8.
19. Monongahela River: From junction with the Allegheny River to form the Ohio River at RM 0 to junction of the Tygart and West Fork Rivers, Fairmont, West Virginia, at RM 128.7.

20. Ohio River: From junction with the Allegheny and Monongahela Rivers at Pittsburgh, Pennsylvania, at RM 0 to junction with the Mississippi River at RM 981.[1]
21. Ouachita–Black Rivers: From the mouth of the Black River at its junction with the Red River at RM 0 to RM 351 at Camden, Arkansas.
22. Pearl River: From the junction of the West Pearl River with the Rigolets at RM 0 to Bogalusa, Louisiana, RM 58.
23. Red River: From RM 0 to the mouth of the Cypress Bayou at RM 236.
24. Tennessee River: From junction with the Ohio River at RM 0 to confluence with Holston and French Broad Rivers at RM 652.
25. White River: From RM 9.8 to RM 255 at Newport, Arkansas.
26. Willamette River: From RM 21 upstream of Portland, Oregon, to Harrisburg, Oregon, at RM 194.
27. Tennessee–Tombigbee Waterway: From its confluence with the Tennessee River to the Warrior River at Demopolis, Alabama.

Reference

Dager, C. A. 2013. *Fuel Tax Report, 2011*. Center for Transportation Research, University of Tennessee, Knoxville.

[1] Public law incorrectly states that the Ohio River runs from junction with the Mississippi River at RM 0 to junction of the Allegheny and Monongahela Rivers at Pittsburgh, Pennsylvania, at RM 981; the correct information is provided here and was confirmed with Mark Pointon, U.S. Army Corps of Engineers, on January 8, 2015. Furthermore, for No. 24, public law refers incorrectly to Holstein and French Rivers, and for No. 27, public law refers incorrectly to Warrior River at Demopolis, Tennessee; both errors are corrected here.

APPENDIX B

Major Commodity Corridors

The U.S. Army Corps of Engineers Navigation Data Center provides publicly available waterborne commerce data that can be used to indicate commodity corridors. The committee's analysis indicated eight major commodity corridors with partially overlapping usage of rivers and navigation infrastructure: two food and farm corridors, one coal energy corridor, three corridors for petroleum and chemicals, one crude materials corridor, and one manufactured goods corridor. The corridors are listed below and shown in Figure B-1 and Figure B-2.

- Coal corridor: Ohio River system, including the Allegheny and Monongahela Rivers;
- Food and farm corridor: Upper Mississippi and Illinois Rivers to New Orleans, Louisiana;
- Petrochemical corridor: Mississippi River from Saint Louis, Missouri, to New Orleans;
- Manufactured goods corridor: Mississippi River from Saint Louis to New Orleans;
- Crude materials corridor: Ohio and Upper Mississippi Rivers (from Saint Louis) to New Orleans;
- Food and farm corridor: Columbia River system, including Columbia, Snake, and Willamette Rivers;
- Chemical goods corridor: Gulf Intracoastal Waterway (GIWW); and
- Petroleum goods corridor: GIWW.

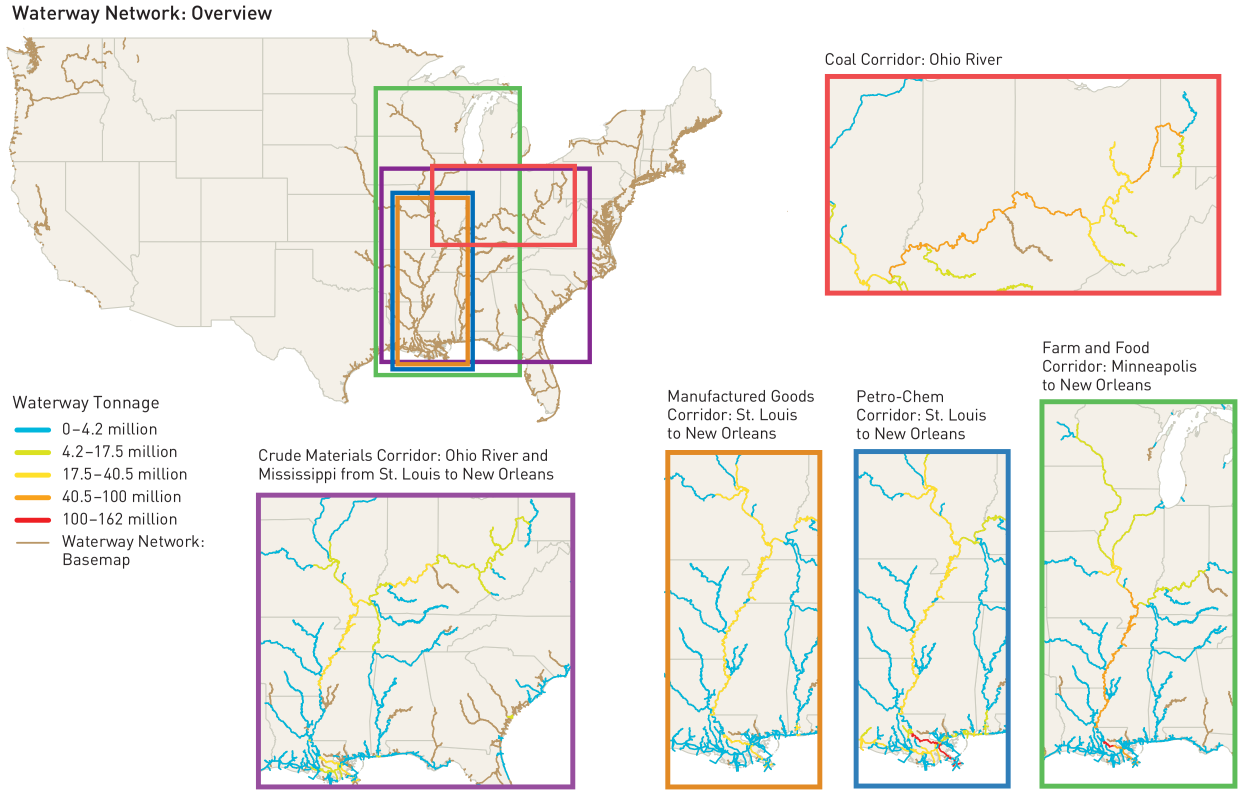


FIGURE B-1 Major commodity corridors on the inland waterways trunk (Mississippi, Illinois, and Ohio River systems), 2011. (IWWN = inland waterway network.)

SOURCE: U.S. Army Corps of Engineers Navigation Data Center GIS Viewer files (http://www.navigationdatacenter.us/db/gisviewer, file linktons11.zip, accessed July 2014).

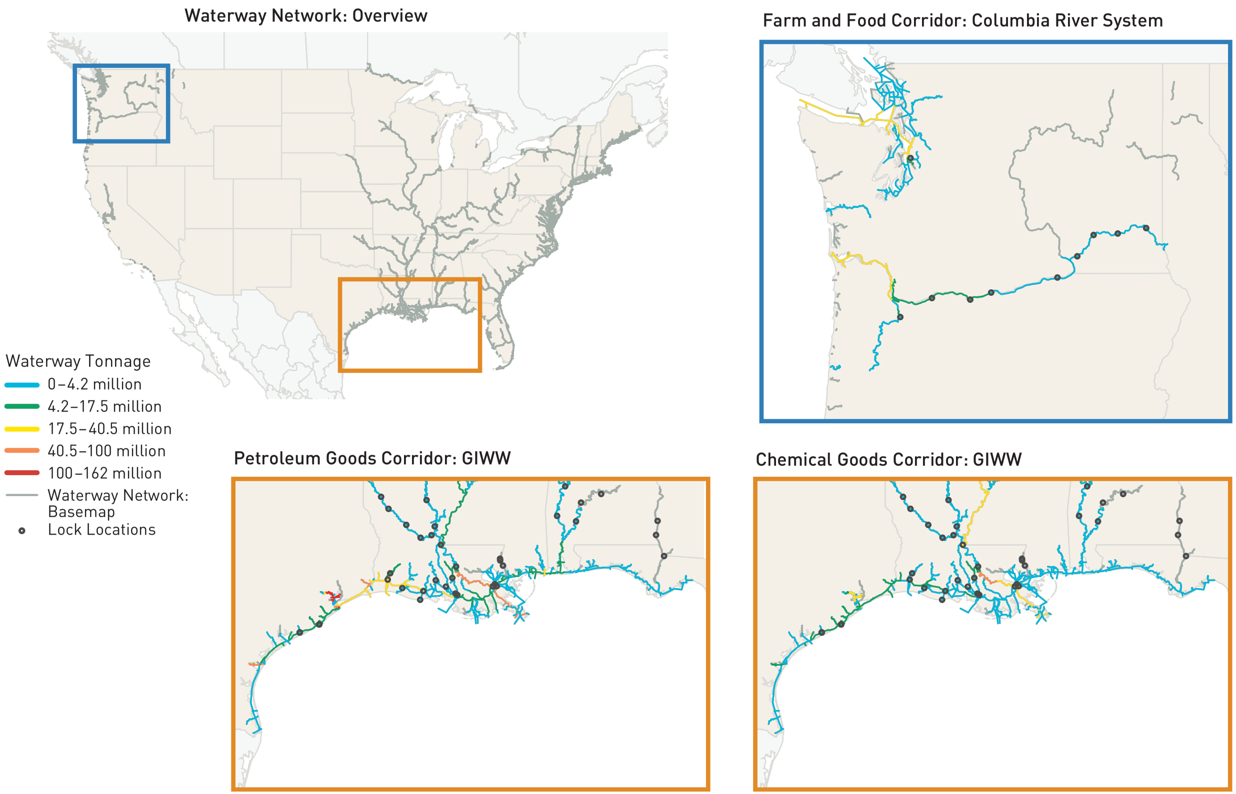


FIGURE B-2 Columbia River and GIWW corridors, 2011.

SOURCE: U.S. Army Corps of Engineers Navigation Data Center GIS Viewer files (http://www.navigationdatacenter.us/db/gisviewer, file linktons11.zip, accessed July 2014).

APPENDIX C

Documentation of Original Construction and Major Rehabilitation Dates for Mainstem Inland Waterways System Locks

River	Lock	Open Date	Rehab Date[a]	Age Based on Opening[b]	Age Based on Rehab	Data Source for Rehabilitation
Mississippi	1	1930–1932	1980	82–84	34	Mark Sudol, USACE
	2	1930	1995	84	19	Saint Paul District website: http://www.mvp.usace.army.mil/Missions/Navigation/LocksDams/LockDam2.aspx
	3	1938	1991	76	23	Saint Paul District website: http://www.mvp.usace.army.mil/Missions/Navigation/LocksDams/LockDam3.aspx
	4	1935	1994	79	20	Saint Paul District website: http://www.mvp.usace.army.mil/Missions/Navigation/LocksDams/LockDam4.aspx
	5	1935	1998	79	16	Saint Paul District website: http://www.mvp.usace.army.mil/Missions/Navigation/LocksDams/LockDam5.aspx

	5a	1936	2000	78	14	Saint Paul District website: http://www.mvp.usace.army.mil/Missions/Navigation/LocksDams/LockDam5A.aspx
	6	1936	1999	78	15	Saint Paul District website: http://www.mvp.usace.army.mil/Missions/Navigation/LocksDams/LockDam6.aspx
	7	1937	2002	77	12	Saint Paul District website: http://www.mvp.usace.army.mil/Missions/Navigation/LocksDams/LockDam7.aspx
	8	1937	2003	77	11	Saint Paul District website: http://www.mvp.usace.army.mil/Missions/Navigation/LocksDams/LockDam8.aspx
	9	1938	2005	76	9	Mark Sudol, USACE
	10	1937	2006	77	8	Mark Sudol, USACE
	11	1937	2012	77	2	Mark Sudol, USACE
	12	1939	2000	75	14	Rock Island District special compilation, May 2014
	13	1938	1996	76	18	Rock Island District special compilation, May 2014
	14	1939	1996	75	18	Rock Island District special compilation, May 2014
	15	1934	1993	80	21	Rock Island District special compilation, May 2014

(continued on next page)

River	Lock	Open Date	Rehab Date[a]	Age Based on Opening[b]	Age Based on Rehab	Data Source for Rehabilitation
	16	1937	1991	77	23	Rock Island District special compilation, May 2014
	17	1939	1988	75	26	Rock Island District special compilation, May 2014
	18	1937	1990	77	24	Rock Island District special compilation, May 2014
	19	1957	2008	57	6	Rock Island District special compilation, May 2014
	20	1936	1994	78	20	Rock Island District special compilation, May 2014
	21	1938	1990	76	24	Mark Sudol, USACE
	22	1938	1990	76	24	Mark Sudol, USACE
	24	1940	2003	74	11	Saint Louis District website: http://www.mvs.usace.army.mil/Portals/54/docs/recreation/rivers/NavFactSheets/03Dam24.pdf
	25	1939	1999	75	15	Saint Louis District website: http://www.mvr.usace.army.mil/Portals/48/docs/CC/FactSheets/Miss/LockDam25.pdf
	27	1953	2009	51	5	Mark Sudol, USACE
	Melvin Price	1990	None	24	24	N/A

Ohio	Olmsted		New construction in progress			N/A
	Belleville	1969	None	45	45	N/A
	Cannelton	1974	None	40	40	N/A
	Meldahl	1964	None	50	50	N/A
	Dashields	1929	1980	85	34	Mark Sudol, USACE
	Emsworth	1921	1986[c]	93	28	Ohio River Mainstem System Study Integrated Main Report: http://pbadupws.nrc.gov/docs/ML0810/ML081000184.pdf
	Greenup	1961	None	53	53	N/A
	Hannibal	1973	None	41	41	N/A
	Myers	1975	None	39	39	N/A
	Markland	1963	2011	51	3	Waterways Council, Inc. (2011): http://ilrdss.isws.illinois.edu/pubs/govconf2011/session1a/Rohde.pdf
	McAlpine	1965	New lock in 2009	49	5	Louisville District: http://www.lrl.usace.army.mil/Missions/CivilWorks/Navigation/LocksandDams/McAlpineLocksandDam.aspx
	Montgomery	1936	1990	78	24	Ohio River Mainstem System Study Integrated Main Report: http://pbadupws.nrc.gov/docs/ML0810/ML081000184.pdf

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River	Lock	Open Date	Rehab Date[a]	Age Based on Opening[b]	Age Based on Rehab	Data Source for Rehabilitation
	New Cumberland	1959	None	55	55	N/A
	Newburgh	1975	None	39	39	N/A
	Pike Island	1968	None	46	46	N/A
	Racine	1971	None	43	43	N/A
	Byrd	1993	2002	21	12	Huntington District website: http://www.lrh.usace.army.mil/Missions/LocksandDams/RobertCByrdLocksandDam.aspx
	Smithland	1980	None	34	34	N/A
	Willow Island	1975	None	39	39	N/A
Illinois	LaGrange	1939	1988	75	26	Rock Island District special compilation, May 2014
	Peoria	1938	1990	76	24	Mark Sudol, USACE
	O'Brien	1960	None	54	54	N/A
	Lockport	1933	1989	81	25	http://www.mvr.usace.army.mil/Portals/48/docs/CC/FactSheets/IL/Lockport_LockandDam.pdf

	Dresden Island	1933	1995	81	19	Mark Sudol, USACE
	Starved Rock	1933	1996	81	18	Mark Sudol, USACE
	Marseilles	1933	1996	81	18	Mark Sudol, USACE
	Brandon Road	1933	1988	81	26	Mark Sudol, USACE
Columbia–Snake	McNary	1953	None	61	61	N/A
	Bonneville	1993	None	21	21	N/A
	John Day	1971	None	43	43	N/A
	The Dalles	1960	None	54	54	N/A
	Ice Harbor	1962	None	52	52	N/A
	Lower Mon	1969	None	45	45	N/A
	Little Goose	1970	None	44	44	N/A
	Lower Granite	1975	None	39	39	N/A

NOTE: N/A = not applicable; mon = monumental; rehab = rehabilitation; USACE = U.S. Army Corps of Engineers.

[a] Dates are based on publicly available records that occasionally conflict with one another. There may also be discrepancies due to different dates for when the work was substantially complete and when it was officially closed out in the government accounting records. Locks with "none" did not appear in a search of public records. The lack of a rehabilitation project for the lock has not been confirmed by USACE.

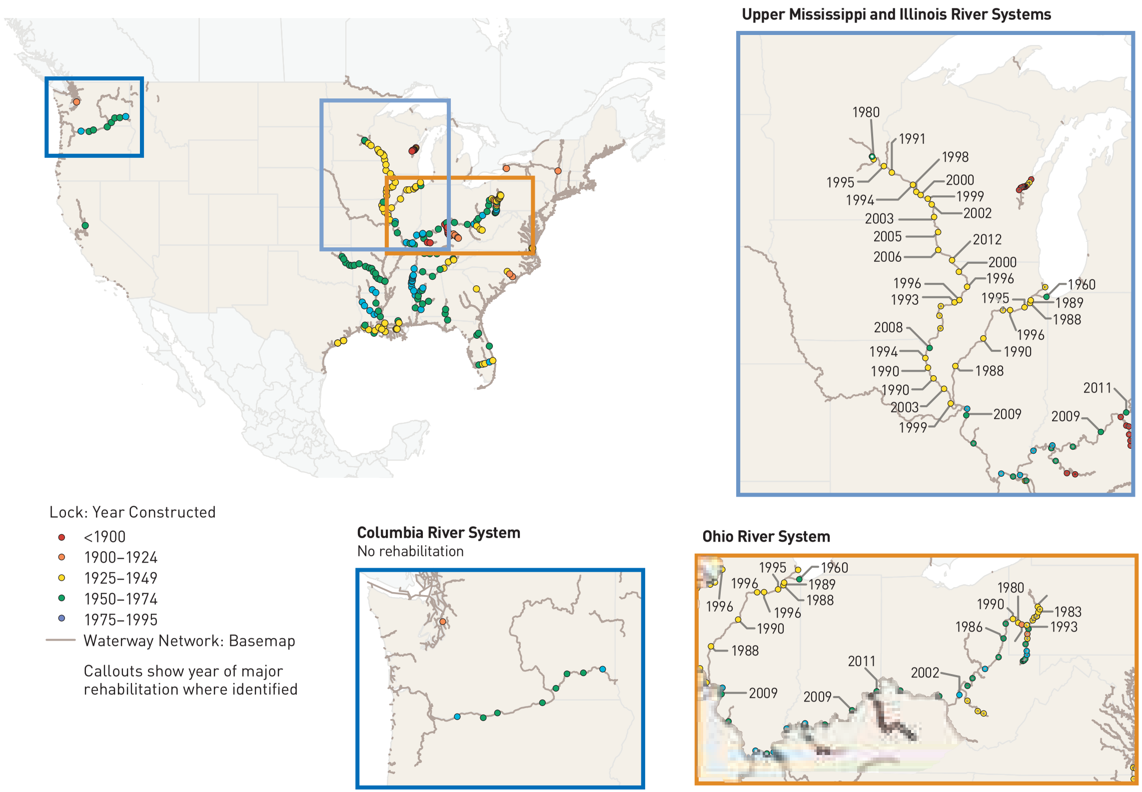
[b] As of 2014.

[c] Another rehabilitation is under way.

APPENDIX D

Age Detail for Infrastructure on Each Major River System

FIGURE D-1 Comparison of lock infrastructure construction year (indicated by colored markers) and rehabilitation year (indicated by label callout) for the Upper Mississippi, Illinois, Ohio (including Allegheny and Monongahela), and Columbia River systems.



SOURCE: U.S. Army Corps of Engineers Navigation Data Center: Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/data/datalck.htm.

APPENDIX E

Illustrations of Delay and Possible Metrics by Major River System

This appendix illustrates possible performance metrics by using data from the U.S. Army Corps of Engineers Lock Performance Monitoring System.[1] For these illustrations, the lock and dam facilities are ordered from upstream to downstream. Data from 2000 to 2013 are summarized for the Ohio River system (Ohio, Allegheny, and Monongahela locks), the Mississippi River system (where locks are on the Upper Mississippi River), the Illinois River, the Columbia River, and the Arkansas River. The figures compare lock infrastructure for a given river system with regard to long-run demand (cargo transported, vessels, and lockages) and chronic lost service (hours of delay and hours of unavailability). Because the data are averaged over 13 years, such influences as short-term economic downturns are minimized.

In Figure E-1*a*, most of the commodities are moved on the Ohio River, with less tonnage moved on the Monongahela and much less on the Allegheny. Similar traffic and lockages are seen across most locks on the Ohio River and about half the locks on the Monongahela (the lower sets of locks adjacent to the Ohio); the red and green bars indicate between 4,000 and 10,000 lockages on average. Figure E-1*a* also shows that downstream locks on the Ohio River handle more cargo than upstream locks, even though numbers of lockages are similar.

With regard to lost service, Figure E-1*b* shows that delays are correlated with tonnage handled, which suggests that larger tows and longer processing time for a given vessel transit may result in queuing delays for other vessels; this is shown as the increasing blue segments of the stacked bar chart. Three locks on the Ohio River have greater

[1] Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/lpms/lpms.htm, Locks by Waterway, Tons Locked by Commodity Group, Calendar Years 1993–2013; Locks by Waterway, Lock Usage, Calendar Years 1993–2013; and Locks by Waterway, Locks Unavailability, Calendar Years 1993–2013. Accessed July 2014.

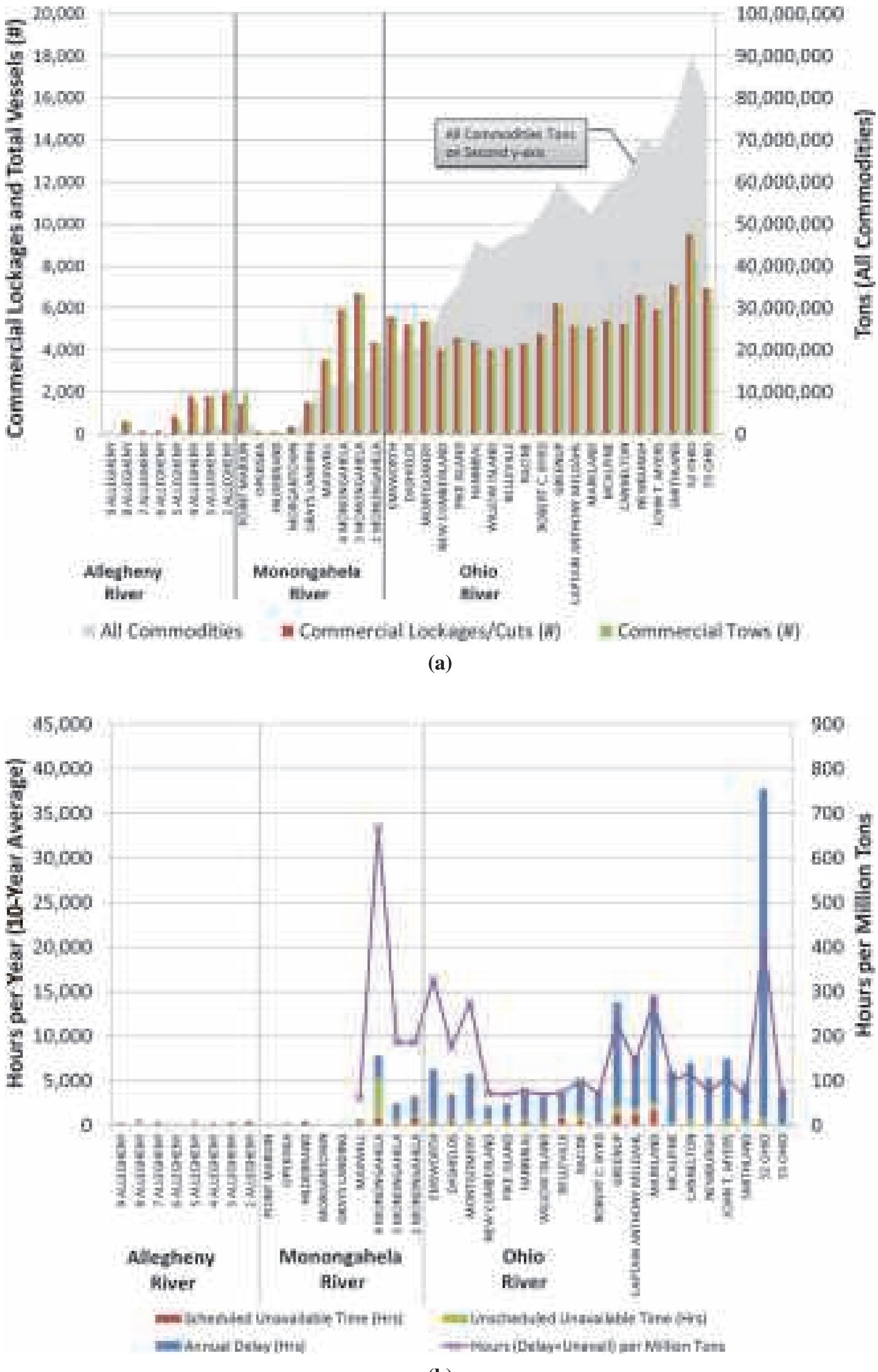


FIGURE E-1 Ohio River system comparison, by facility, of (*a*) commodities moved, commercial lockages, and vessel counts and (*b*) nonproductive time per year due to delays and unavailabilities (scheduled and unscheduled).

hours of scheduled unavailabilities (red segments of the stacked bar chart for Greenup, Captain Anthony Meldahl, and Markland). Finally, average statistics for Monongahela Lock 4 suggest that it was out of service for unscheduled unavailabilities much more than the other Ohio River locks.

To assess the impact of delay, an index can be considered, such as the long-run annual hours of lost service (sum of hours of delay and hours of unavailability) per million tons of cargo that transit a facility. This is shown in the purple line graph of Figure E-1*b*, referenced to the secondary (right-hand) axis. The weighting of the hours lost by the cargo moved (million tons) in the line graph indicates lock facilities where mitigation of delay or unavailabilities might be most helpful in terms of tonnage and thus where investment in reliability or performance may merit increased attention. The average lost service for the Ohio River system is approximately 166 hours per million tons, with about 415 hours per million tons lost at Ohio Lock 52, about 330 hours per million tons lost at Emsworth, and about 670 hours per million tons lost at Monongahela Lock 4. New construction for the Olmsted infrastructure will replace Ohio Locks 52 and 53. This should improve service for the overall river corridor, not least by reducing the approximately 415 hours per million tons lost at Ohio Lock 52.

Figure E-2*a* indicates that more vessels are operating on the upstream parts of the Mississippi and that the downstream infrastructure is handling fewer numbers of vessels (the green bars trend). Typical vessel counts at Mississippi River locks range between 3,000 and 10,000, with an average of 5,000 vessels transiting these locks. Lockages generally increase from the upstream to the downstream facilities, from approximately 1,000 lockages per year at Lock 1 to as many as 6,000 to 8,000 lockages at Lock 27 and the Melvin Price locks. As in the Ohio River system, commodity volumes moving through downstream locks are greater than those moving through upstream locks. Finally, in view of the fact that Mississippi locks are on upper river regions while the Lower Mississippi River does not have fixed lock and dam infrastructure, the figure should be interpreted as showing river cargo and vessel transits associated with the Upper Mississippi lock infrastructure rather than total Mississippi River activity.

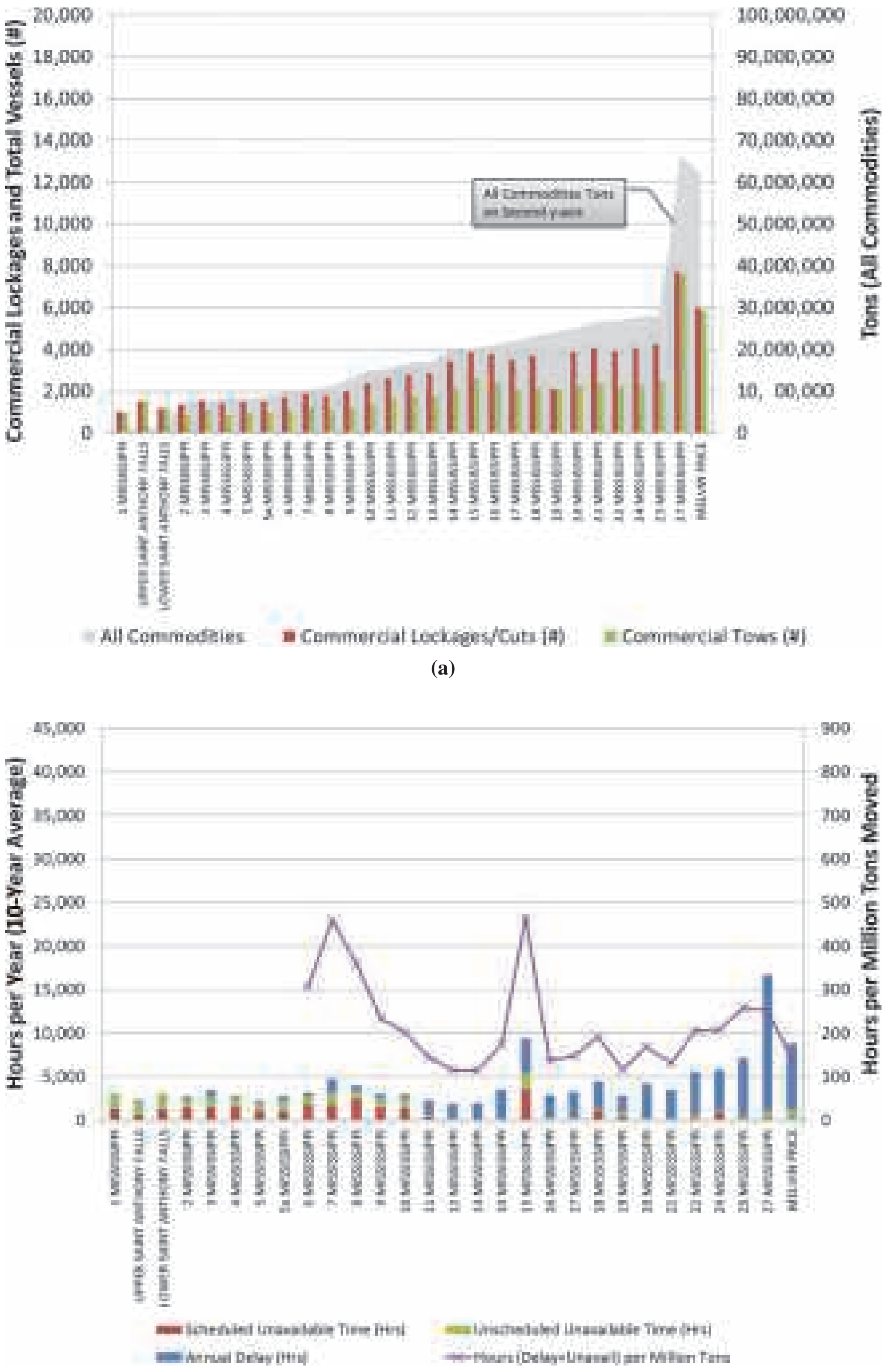


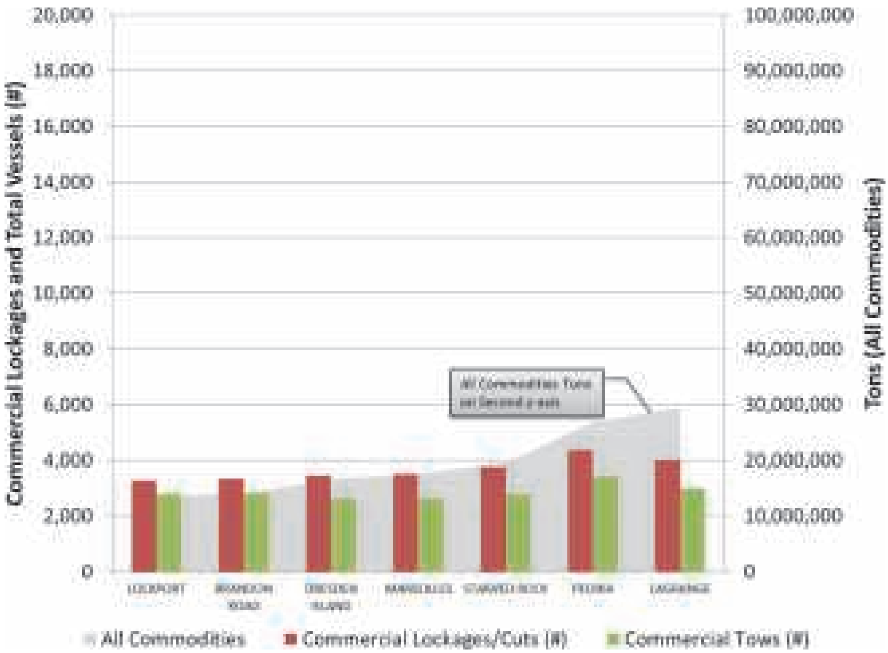
FIGURE E-2 Mississippi River comparison, by facility, of (*a*) commodities moved, commercial lockages, and vessel counts and (*b*) nonproductive time per year due to delays and unavailabilities (scheduled and unscheduled).

Figure E-2*b* illustrates a pattern of delay associated with increasing cargo volumes along downstream segments, similar to that of the Ohio River system in Figure E-1*b*. Mississippi Locks 1 through 10 and Lock 15 have longer-term patterns of scheduled downtime and are among the locks with more unscheduled unavailabilities. Lock 27 and Melvin Price also experience more hours of unscheduled unavailabilities than do other downstream locks.

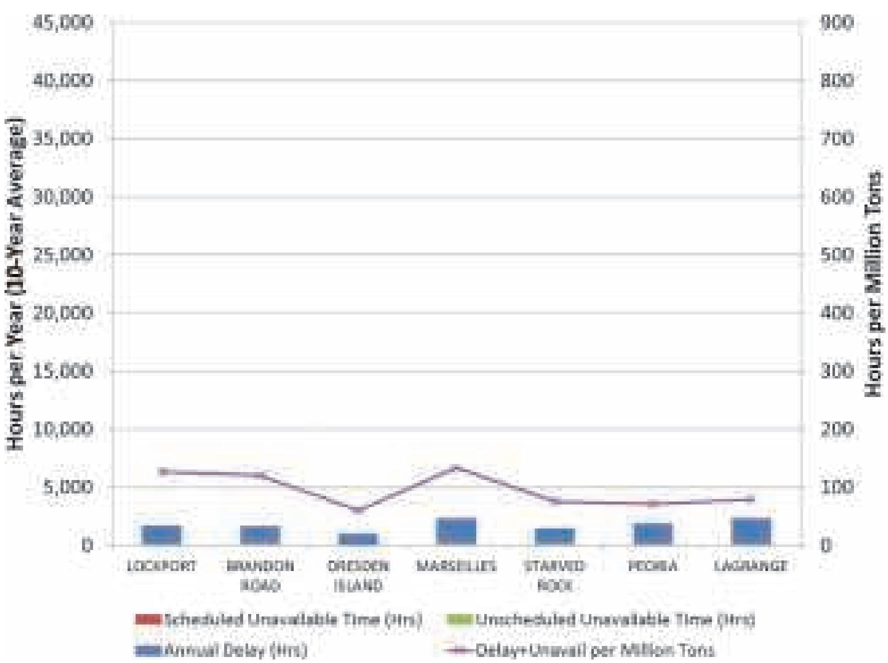
For the Illinois River, Figure E-3*a* shows similar but less dramatic increases in commodity volumes handled downriver and correlations between vessels and lockages similar to those of the Mississippi River. Lock unavailabilities across the Illinois River, both scheduled and unscheduled, are much fewer. This may be related to the lower effective age of the infrastructure; all the Illinois River locks were rehabilitated in the 1990s. (A full analysis of the relationships between lock rehabilitation and lock unavailability has not been undertaken to confirm this apparent correlation throughout the system.)

For the Columbia River system, Figure E-4*a* indicates a positive relationship between the downstream commodities moved, vessels transited, and lockages. Delays are greater at downstream locks with a notable exception at the Bonneville facility (Figure E-4*b*), where average delays are still substantial but much lower than for the Dalles and John Day locks. [This may be related to the 1993 construction that reduced the fill and empty times for Bonneville to 9 to 13 minutes from the 15 to 25 minutes associated with the original 1938 construction (see http://www.nwp.usace.army.mil/Portals/24/docs/locations/bonneville/Bonneville_FS.pdf). The John Day lock requires 39 minutes to fill and 15 minutes to empty (see http://www.nwp.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/2043/Article/492594/john-day-lock-and-dam.aspx). The Dalles requires 20 minutes to fill and empty (see http://www.nwp.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/2043/Article/492595/the-dalles-lock-and-dam.aspx).]

For the Arkansas River, the situation is somewhat different. Figure E-5*a* indicates similar commodity volumes, vessel transits, and lockages across the Arkansas River lock and dam infrastructure. However, delays are greater in the upstream facilities, as shown

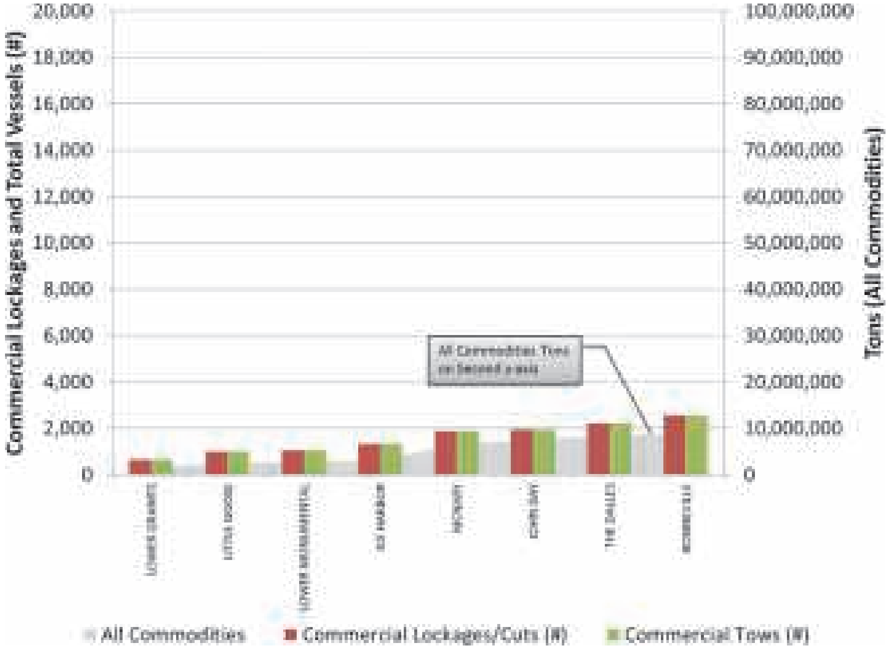


(a)

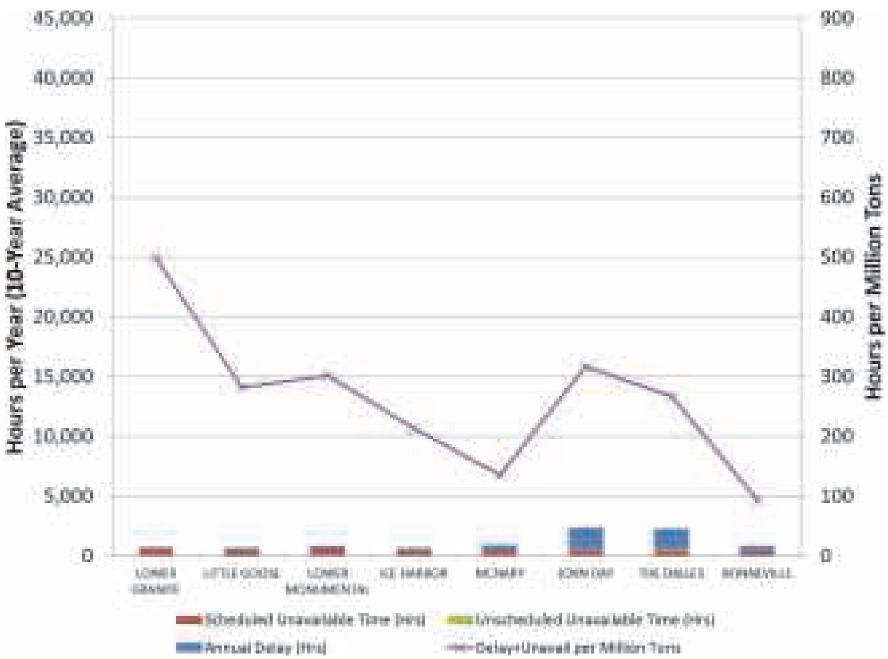


(b)

FIGURE E-3 Illinois River comparison, by facility, of (*a*) commodities moved, commercial lockages, and vessel counts and (*b*) nonproductive time per year due to delays and unavailabilities (scheduled and unscheduled).

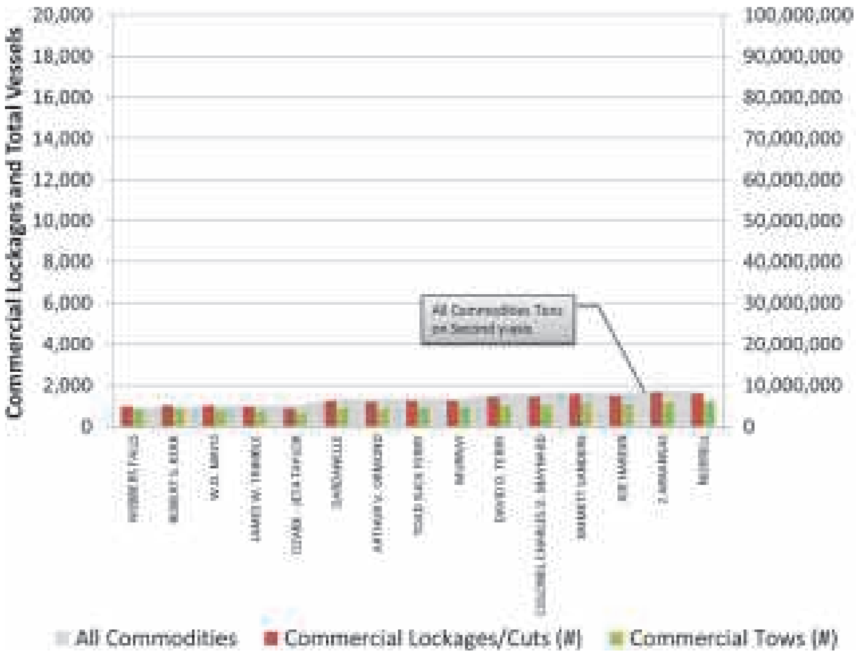


(a)

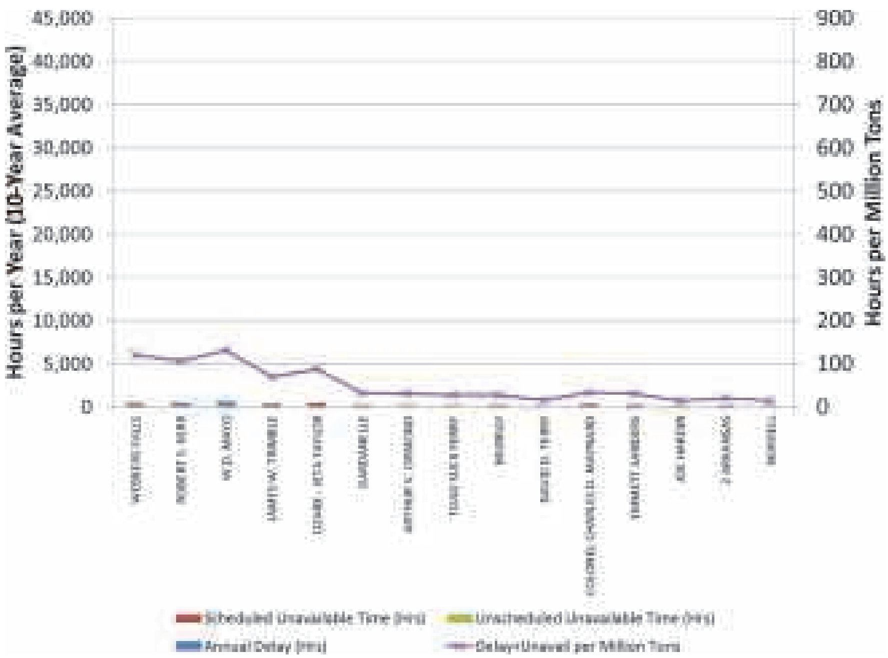


(b)

FIGURE E-4 Columbia River comparison, by facility, of (*a*) commodities moved, commercial lockages, and vessel counts and (*b*) nonproductive time per year due to delays and unavailabilities (scheduled and unscheduled).



(a)



(b)

FIGURE E-5 Arkansas River comparison, by facility, of (*a*) commodities moved, commercial lockages, and vessel counts and (*b*) nonproductive time per year due to delays and unavailabilities (scheduled and unscheduled).

in Figure E-5*b*. Scheduled unavailabilities tend to dominate the lost service time due to outages, and they are focused on five lock facilities.

[Figures E-1 through E-5 all use the same *y*-axis scales to facilitate comparison, and each is aligned from upstream to downstream location to illustrate how delay and tonnage moved (i.e., traffic congestion) are related.]

APPENDIX F

Summary of Correlations Between Lock Performance and Lock Age (in 2014) Calculated from the Date of Known Major Rehabilitation Construction

River System	Average Age of Lock Installations (years)	Correlation with Effective Age of Locks on a River System						
		Lockages	Vessels Delayed (%)	Tows Delayed (%)	Average Vessel Delay	Average Tow Delay	Average Closure Duration	Closure Frequency
All installations	61.04	0.2184	0.1404	−0.0750	0.1321	−0.1226	0.1691	0.2254
Ohio River	35.45	−0.0076	−0.0957	−0.0959	0.1081	0.0400	0.2407	−0.0477
Mississippi River	24.86	−0.3019	0.1758	−0.0103	−0.2738	−0.0463	0.6458	0.1295
Illinois River	22.28	−0.5754	0.0357	−0.2425	−0.3880	−0.2560	−0.6243	−0.5700
Columbia–Snake Rivers	44.88	−0.1953	0.1088	0.1566	0.0851	0.0677	0.8220	0.4676
Gulf Intracoastal Waterway	71.80	0.1603	0.1273	0.1050	−0.1422	−0.1403	0.2972	−0.1875
Arkansas River	45.33	0.4568	−0.7410	−0.7359	−0.7123	0.4552	−0.2562	−0.1563

Black Warrior, Tennessee, Tennessee–Tombigbee, Tombigbee	61.04	0.3474	0.5655	0.7040	0.3585	–0.1630	–0.1735	0.7485
Monongahela River	56.67	0.5545	0.7521	0.8632	0.5526	0.3800	Gaps in data	0.6358
Allegheny River	61.75	–0.0454	0.3048	–0.0426	0.1435	–0.1276	Gaps in data	0.0612

Negative Correlation Positive Correlation

NOTE: High positive correlation (dark blue shading), greater than 75 percent correlation; high negative correlation (dark pink shading), less than -75 percent correlation; medium positive correlation (light blue shading), between 50 and 75 percent correlation; low correlation (white), within 450 percent correlation. Some rivers indicate negative correlations with lock age because the correlations are affected by traffic level and rehabilitation; that is, some of the older locks have less traffic and so fewer traffic-related problems, or they may be rehabilitated and so experience fewer closures and delays.

SOURCE: U.S. Army Corps of Engineers Lock Use, Performance, and Characteristics, http://www.navigationdatacenter.us/lpms/lpms.htm, Locks by Waterway, Tons Locked by Commodity Group, Calendar Years 1993–2013; Locks by Waterway, Lock Usage, Calendar Years 1993–2013; and Locks by Waterway, Locks Unavailability, Calendar Years 1993–2013. Accessed July 2014.

APPENDIX G

Energy Intensity Comparisons for Water, Rail, and Highway

Findings from the Available Research

Research on the question of energy efficiency usually compares some measure of energy intensity rates across modes (Comer et al. 2010; Kruse et al. 2013; Sebald 1974; USDOT 1994). Historical energy intensity comparisons between railroads and barges using British thermal units (Btu) per ton-mile (Davis et al. 2014) show that the energy efficiencies of both modes have improved. Since 1970, Class I freight rail improved by about 2 percent per year, and since 2000, rail and waterborne commerce energy intensities improved by about 1.6 and 1.8 percent per year, respectively (Davis et al. 2014, Table 2-15).

Some studies show barge to be more energy efficient, while others show rail as the more energy-efficient mode. In terms of British thermal units per ton-mile, Davis et al. report that rail (294 Btu/ton-mile in 2012) is 40 percent more energy intensive than barge (210 Btu/ton-mile in 2012), nearly the same percentage difference as reported by Kruse et al. (2013).[1] These average energy intensity values represent the two-way transport average of upstream and downstream transport (upstream transport may require more energy to account for barge movement against downstream current velocities, and downstream transport energy may benefit from the river current). Alternatively, Dager (2013) reports even lower energy intensity for inland barge transport on the basis of independent data and fuel use modeling, corresponding to about 196 Btu/ton-mile, or about 60 percent better energy intensity than average rail. Moreover, commodity-specific

[1] Converting the report values in ton-miles per gallon reported by Kruse et al. (2013, Table 12) to British thermal units per ton-mile results in numbers consistent with those reported by Davis et al. (2014) for 2012, namely, 311 Btu/ton-mile and 223 Btu/ton-mile for rail and inland towing, respectively.

configurations may matter; for example, Dager reports that towboats moving on the Mississippi River between the mouth of the Missouri and Baton Rouge, Louisiana, averaged 867 ton-miles per gallon in 2011 versus the system average of 656. Baumel (2008) reported that unit grain trains moving from Iowa to New Orleans, Louisiana, had route-specific fuel efficiency of 640 ton-miles per gallon, 54 percent better than energy intensity for an average train.

Analysis of Selected Major Waterway Corridors

The committee examined route comparisons across major waterway corridors with respect to metrics important to modal performance: (*a*) distance measured geographically, (*b*) transport time using typical average speeds by mode, and (*c*) modal energy estimates per ton of cargo by multiplying the energy intensity by route distances. The analysis was conducted with data from Davis et al. (2014), Kruse et al. (2013), and Dager (2013).

Figure G-1 shows the distance and typical transport time for the Ohio River corridor (between Pittsburgh, Pennsylvania, and Saint

FIGURE G-1 Dominant modal routes and characteristic distances and travel times for transport between Pittsburgh and Saint Louis.

TABLE G-1 Comparison of Energy Use per Ton of Cargo Between Pittsburgh and Saint Louis

Mode	Distance (miles)	Energy Intensity (Btu per ton-mile)	Btu per Ton Moved	Difference Using Water Mode
Rail average value	650	294	191,100	
Water (using Davis et al. 2014 average value)	1,180	210	247,800	**30% more energy**
Water (using Dager 2013 average value)		196	231,000	**21% more energy**

Louis, Missouri) for rail, road, and river routes. The online tool WebGIFT (http://webgift.rit.edu/) was used in developing the figure. Other routes describing major corridors include the Lower Mississippi (Saint Louis to New Orleans), Upper and Lower Mississippi (Minneapolis, Minnesota, to New Orleans), and Columbia River (Pasco, Washington, to Portland, Oregon); distances and times summarized for these routes were also obtained with WebGIFT (maps not shown).

Tables G-1 through G-4 below provide a first-order comparison of energy use per ton of cargo that combines mode-related differences in geographic distances of routes with energy intensity differences. The

TABLE G-2 Comparison of Energy Use per Ton of Cargo Between Saint Louis and New Orleans

Mode	Distance (miles)	Energy Intensity (Btu per ton-mile)	Btu per Ton Moved	Difference Using Water Mode
Rail average value	710	294	208,700	
Water (using Davis et al. 2014 average value)	1,100	210	231,000	**11% more energy**
Water (using Dager 2013 average value)		196	215,000	**3% more energy**

TABLE G-3 Comparison of Energy Use per Ton of Cargo Between Minneapolis and New Orleans

Mode	Distance (miles)	Energy Intensity (Btu per ton-mile)	Btu per Ton Moved	Difference Using Water Mode
Rail average value	1,280	294	376,000	
Water (using Davis et al. 2014 average value)	1,750	210	368,000	**2% less energy**
Water (using Dager 2013 average value)		196	343,000	**9% less energy**

analysis focuses on rail since, as explained in Chapter 2, highways are not usually an option for moving the cargo shipped by barge. The comparisons account for the potentially greater circuity of rivers than railroads in some corridors. The calculations for typical corridor-scale routes show that barge movements on the Ohio River and Lower Mississippi River use more energy than rail transport for the same origin–destination pairs, if system-average energy intensities are assumed, but that typical corridor-scale routes on the Upper and Lower Mississippi River and the Columbia River corridors may be more energy efficient than rail transport.

TABLE G-4 Comparison of Energy Use per Ton of Cargo Between Pasco and Portland

Mode	Distance (miles)	Energy Intensity (Btu per ton-mile)	Btu per Ton Moved	Difference Using Water Mode
Rail average value	230	294	67,600	
Water (using Davis et al. 2014 average value)	230	210	48,300	**29% less energy**
Water (using Dager 2013 average value)		196	45,000	**33% less energy**

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ABBREVIATION

USDOT U.S. Department of Transportation

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APPENDIX H

USACE Description of the Status of Implementation of Its Asset Management Program

NOTE: This information was provided to the committee by USACE in the public interest after the public release of this report and was not reviewed for accuracy by the National Academies of Sciences, Engineering, and Medicine.

This *Status of Implementation of Asset Management* is primarily focused on inland navigation lock and dam projects consistent with the main focus of this report. The risk-informed asset management process maturity timeline for inland navigation is illustrated in the figure [on the following page], which also generally serves as the outline for this brief summary "status description."

1. Starting with the development of the FY10 budget in 2008, the Navigation Business Line initiated use of the 5×5 Relative Risk Matrix in the evaluation of O&M [operations and maintenance] work packages for both coastal and inland projects. The 5×5 risk matrix used "condition" and "consequence" descriptions at each of 5 levels, with the measure of project total commodity tonnage being a key factor in estimating consequence. The Inland Marine Transportation System (IMTS) Improvement Report identified a business process review (BPR) to "implement a standardized annual condition assessment process." As a result, the Corps began the development of what is now the Operational Condition Assessment (OCA) process. The OCA process was not yet completely implemented during the development of the 2010 Capital Projects Business Model (CPBM) so that initiative used the 5×5 condition description at the lock level.

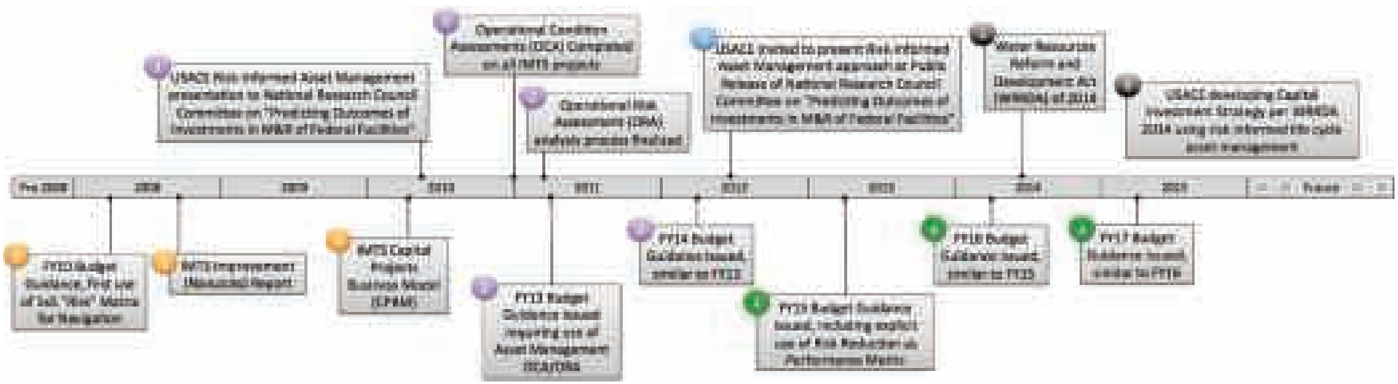

FIGURE H-1 Risk-informed asset management process maturity timeline for inland navigation.

2. As noted in Engineer Circular [EC] No. 11-2-200, "*Corps of Engineers Civil Works Direct Program Development Guidance–Fiscal Year 2013*" dated 31 March 2011, in FY10, Asset Management developed, trained and deployed the *national* Operational Condition Assessment (OCA) process in all MSCs with inland and intracoastal navigation. The EC further stated that "consequences of diminished Navigation feature performance are computed for each budget line item that could result in an *unscheduled closure . . . and will establish the initial transition from tonnage to economic consequence of unscheduled closure*. The economic consequences will be a function of the probability of failure of the components and the economic impacts as determined by the Planning Center of Expertise for Inland Navigation in the Huntington District and calculated from the OCA risk process" (now known as the Operational Risk Assessment [ORA] process). To maintain consistency with the process at that time, the "risk reduction" was correlated with the consequence levels in the 5×5 risk matrix. Concurrent with the development of the OCA and ORA processes the Corps was heavily involved in the National Research Council's Federal Facilities Council and was invited to present the processes to the Committee on Predicting Outcomes of Investments in Maintenance and Repair of Federal Facilities.
3. Upon completion of the *Predicting Outcomes of Investments in Maintenance and Repair of Federal Facilities* report, the Committee conducted a public report dissemination forum and invited two federal agencies whose maintenance budgeting processes best addressed the report's findings and recommendations—the Department of Energy was one invitee and the Corps Civil Works Asset Management the other.[1] Highlights of the Corps presentation (see link in footnote) included the focus on mission critical components (those components for which failure will result in (1) the inability to pass traffic and/or (2) maintain the naviga-

[1] Ellsworth, Douglas E, "U.S. Army Corps of Engineers–A Risk-Informed Approach to Asset Management," Public Forum for National Research Council Committee on Predicting Outcomes of Investments in Maintenance and Repair of Federal Facilities, June 19, 2012. http://sites.nationalacademies.org/cs/groups/depssite/documents/webpage/deps_081950.pdf.

tion pool to pass that traffic; the probability of failure of the many components; and the economic impact to the commercial stakeholder (commodity shippers and carriers) for varying durations of outages due to potential failures. Collectively, the Corps risk-informed approach best addresses Recommendations 2, 3, and 6 of the report, which are as follows: corporate approach to mitigating risk which focuses on linking investments to mission and objectives; use risk to inform annual maintenance and use standard methods for gathering and updating data; and focus on collecting mission critical data and information, respectively.

4. Building on the transition in 2011 from tonnage to economic impact as a consequence in the 5×5 relative risk matrix, in 2013 the Corps codified another transition in Engineering Circular No.11-2-204, the budget development guidance for Fiscal Year 2015.[2] In addition to embedding the economic impact risk reduction into the 5×5 consequence category, risk reduction visibility was elevated and explicitly added as a navigation budget performance measure. To that end, Section I.15, Budget Data Submissions for Inland Navigation, stated "condition and risk analytical tool for inland navigation . . . that develops risk buy down performance measures used to rank critical nonroutine navigation budget work packages . . . must be used to develop performance measures for inland navigation critical non-routine maintenance budget packages." Further, Section II of EC 11-2-204 introduced the strategy for maintenance, in addition to the critical non-routine, stating that "USACE Asset Management has developed an overall USACE Maintenance Management Strategy and a Maintenance Management Improvement Plan (MMIP). The MMIP and its associated implementation plan will provide that corporate maintenance management strategy; help to provide consistent maintenance management policies, processes, practices, and terminology; and begin to align maintenance investments with desired levels of performance."
5. In June 2014 the Water Resources Reform and Development Act (WRRDA) was signed into law. Section 2002 of WRRDA 2014

[2] http://www.publications.usace.army.mil/USACEPublications/EngineerCirculars.aspx.

required the Secretary of the Army to "develop and submit to Congress a report describing a 20-year program for making capital investments on the inland and intracoastal waterways based on the application of objective, national project selection prioritization criteria." The Asset Management national condition and risk processes and analytics (OCA and ORA) play a major role in the developing a capital investment strategy by enabling the identification of those projects that have the most mission critical components, that are in the worst condition, with the highest likelihood of failure, that would cause the most economic impact on our stakeholders.

Future. The Corps Asset Management continues to mature, applying lessons learned from the inland navigation processes to other business lines, as well as continuing to evolve the current navigation OCA and ORA processes. Possible future improvements may include the capability for fault-tree analysis, use of utility model theory, and other approaches to ensure investments across the life cycle and the entire portfolio of assets are focused on buying down risk to ensure the Corps continues to deliver project benefits, or value, to the nation.

Study Committee Biographical Information

Chris T. Hendrickson (NAE), *Chair*, is the Hamerschlag University Professor of Engineering, Director of the Traffic21 Institute, and Codirector of the Green Design Institute at Carnegie Mellon University. He is a member of the National Academy of Engineering and Editor-in-Chief of the American Society of Civil Engineers (ASCE) *Journal of Transportation Engineering*. His expertise is in the general area of engineering planning and management, including design for the environment, system performance, construction project management, finance, and computer applications. Dr. Hendrickson has received numerous awards, among them the Fenves Systems Research Award from the Institute of Complex Engineering Systems (2002), AT&T Industrial Ecology Fellowships (2000–2002), a Lucent–National Science Foundation Industrial Ecology Fellowship (1998), the ASCE Frank M. Masters Transportation Engineering Award (1994), the ASCE Walter L. Huber Civil Engineering Research Award (1989), and a Rhodes scholarship (1973). He is a Fellow of the American Association for the Advancement of Science (2007), a Distinguished Member of ASCE (2007), and a member of the Transportation Research Board Executive Committee. He has published numerous research articles related to computer-aided engineering, transportation systems, construction project management, and environmental systems. Central themes of this work are a systemwide perspective and a balance of engineering and management considerations. Dr. Hendrickson pioneered models of dynamic traffic equilibrium, including time-of-day departure demand models. He was an early contributor to the development of probabilistic network analysis for lifeline planning after seismic events. With others at Carnegie Mellon's Engineering Design Research Center, he developed a pioneering, experimental building design system in the early 1990s that spanned initial concept through construction scheduling and animation. Since 1994, he has concentrated on green design and exploration of the environmental life-cycle consequences of alternative product and process designs. Dr. Hendrickson received bachelor and master of science degrees from Stanford University, a master of philosophy degree in economics from Oxford University, and a PhD from the Massachusetts Institute of Technology.

Leigh B. Boske is Professor of Economics and Public Policy, Sharpe Centennial Fellow, and former Associate Dean for Academic Affairs and Research at the Lyndon B. Johnson School of Public Affairs, University of Texas at Austin. His research has focused on transportation policy, economics, and finance. He has studied national and international transport policy issues, the role of transportation and logistics in international trade, and multimodal and intermodal transport planning. He previously served as a Senior Economist at the National Transportation Policy Study Commission of the U.S. Congress and as Chief of Economic and Environmental Analysis at the Wisconsin Department of Transportation. In 1993–1994, he took a leave of absence from the university to serve as Policy Advisor to the Texas Transportation Commission and to coordinate the development of the 1994 Texas Transportation Plan. Dr. Boske is a former member of the National Research Council's Committee for the Review of the U.S. Department of Transportation's Strategic Plan for Research and Development, the Federal Advisory Committee on Impacts of Climate Change and Variability on the Gulf Coast's Transportation System and Infrastructure, the Executive Committee of the U.S.–European Transatlantic Policy Consortium, the Organization of American States' Coordinating Committee of the Inter-American Training and Research Program for Trade Corridor Development, and both the Intermodal Freight Transportation Committee and the Ports and Channels Committee of the Transportation Research Board. Dr. Boske has a PhD in economics from the University of Pittsburgh.

Michael S. Bronzini is Dewberry Chair Professor Emeritus in the Volgenau School of Engineering at George Mason University. He is principal and cofounder of 3Sigma Consultants, LLC, based in Nashville, Tennessee. Dr. Bronzini has conducted research and authored more than 250 publications on innovative solutions to complex multimodal transportation systems problems. His current work focuses on marine and intermodal transportation, freight transport, and national transportation networks and intermodal systems. He has led the development of several large inland navigation simulation and analysis models, all of which have been used for navigation feasibility studies. Most of these models or their successors are still in use by the U.S. Army Corps of Engineers. He has served as an independent technical review consultant for the Ohio River Navigation Investment Model, was an external reviewer of the Delaware River Channel Deepening Feasibility Study, and participated in two separate studies of the capacity and expansion potential of the Panama Canal. From 1990 to 1999, Dr. Bronzini was Director of the Center for Transportation Analysis at Oak Ridge National Laboratory in Oak Ridge, Tennessee, and was responsible for overseeing its interdisciplinary transportation research program. He was Professor and Head of Civil Engineering at Pennsylvania State University and Director of the Transportation Center and Professor of Civil Engineering at the University of Tennessee. Dr. Bronzini is a National Associate of the National Academies and has held numerous leadership positions in the Transportation Research Board of the National Academies, including Chair of the Inland Water Transportation Committee and Chair of the Study Committee on Landside Access to U.S. Ports. He received a bachelor of science degree in civil engineering from Stanford University and a PhD in civil engineering from Pennsylvania State University.

James J. Corbett, Jr., is Professor of Marine Science and Policy in the College of Earth, Ocean, and Environment at the University of Delaware, where he holds a joint appointment in the Department of Civil and Environmental Engineering in the College of Engineering and in the School of Public Policy and Administration in the College of Arts and Sciences. His research focuses on issues of technology policy innovation for the 21st century in the areas of freight transportation, energy and emissions, and sustainability. He has published more than 50 peer-reviewed studies on international and domestic maritime transportation and pollution policy, risk assessment and mitigation of ocean and coastal impacts from shipping, and interdisciplinary technology policy and decision making. He has provided testimony to the United States Senate Committee on Environment and Public Works. Dr. Corbett was a lead coauthor of all three reports to the International Maritime Organization (IMO) on greenhouse gas emissions, trends, and mitigation potential (IMO studies in 2000, 2009, and 2014). He received a bachelor of science degree in marine engineering technology from California Maritime Academy, master of science degrees in both mechanical engineering and engineering and public policy, and a PhD in engineering and public policy from Carnegie Mellon University. He is certified as a professional engineer (mechanical) in California.

G. Edward Dickey has been a consultant to public and private entities interested in water project development and an affiliate professor of economics at Loyola University Maryland since his retirement from federal service in 1998. Currently, he is a Senior Advisor at Dawson & Associates, a government relations firm based in Washington, D.C. He is an expert in federal water resource policy, project planning, and benefit–cost analysis as it relates to project development and management. Dr. Dickey held several positions during his 25 years with the Department of the Army's Civil Works Program, including service as U.S. Army Corps of Engineers Headquarters Chief of Planning. He was a Deputy Assistant Secretary for 11 years and Acting Principal Deputy Assistant Secretary and Acting Assistant Secretary of the Army for Civil Works during the G. H. W. Bush and Clinton administrations. He has testified before numerous congressional committees on policy and programmatic, budgetary, and project-specific issues relating to the federal role in national water and related land resources development and management. Dr. Dickey has been a member of previous National Research Council committees, including the Committee for the Study of Freight Transportation Capacity for the 21st Century (2001), the Committee on Adaptive Management for Resource Stewardship (2005), and the Committee on Climate Change and U.S. Transportation (2009). He received a PhD in economics from Northwestern University.

C. James Kruse is the Director of the Center for Ports and Waterways at the Texas A&M Transportation Institute. He is responsible for identifying research and extension needs in the port and waterways communities and mobilizing resources to meet those needs. He served in a senior executive capacity for 9 years at the Port of Brownsville, Texas (1988–1997), including 8 years as port director. Following his service at the Port of Brownsville, Mr. Kruse worked as a regional program manager for Foster Wheeler Environmental's Ports, Harbors, and Waterways Program and assisted on port-related projects across the United States. His work has focused on political, environmental, financial, and operational issues related to waterborne transportation of cargo in both inland waterway and ocean environments. He has conducted studies for the U.S. Maritime Administration, the National Waterways Foundation, American Waterways Operators, the United Soybean Board, the Port of Houston Authority, the Port of Corpus Christi Authority, the U.S. Army Corps of Engineers, and private industry. Among the topics of his research are externalities of marine transportation, marine transport of toxic inhalation hazard materials, North American marine highways, funding of waterway maintenance and infrastructure improvements, effects of lack of maintenance dredging, and waterway encroachment issues. Mr. Kruse has a master's degree in international business and human resources from Houston Baptist University and an MBA in accounting and finance from the University of Kansas.

B. Starr McMullen is Professor Emeritus of Economics at Oregon State University. Her research encompasses multiple modes of transportation, including rail, motor carrier, water for freight and transit, airline, and highway for passengers. She has studied transportation industries (in particular airline, trucking, and rail) to estimate productivity, efficiency, costs, and competitiveness. Her work in freight transportation has focused on the modal choices of wheat shippers in the Pacific Northwest (truck, rail, and barge on the Columbia River system), intermodal competition for freight transportation (especially agricultural and bulk commodities), and empirical issues involved in developing useful freight performance measures and methodologies. Her current research projects focus on problems of pricing, finance, and investment in transportation infrastructure. In 2009 Professor McMullen was awarded the Researcher of the Year Award from the Oregon Transportation Research and Education Consortium for her work on the distributional impact of changing from a gasoline tax to a vehicle miles traveled fee. She is past editor of *Research in Transportation Economics* and serves or has served on a number of editorial boards, including those of *Transportation Research Part E*, the *Journal of the Transportation Research Forum*, and *Advances in Airline Economics*. Professor McMullen is past President of the Transportation and Public Utilities Group of the American Economic Association and past President of the Transportation Research Forum (TRF). In 2013 she received TRF's Distinguished Service Award. Professor McMullen has a PhD in economics from the University of California at Berkeley with a specialization in transportation economics.

Leonard A. Shabman is a Resident Scholar at Resources for the Future. He has published on subjects including natural hazard management, wetlands and water quality management, and public investment analysis methods. He has provided advice on water and related land management policy to a wide range of nongovernmental and governmental organizations, including the U.S. Army Corps of Engineers. In 1977–1978 he served as a staff economist at the United States Water Resources Council. In 1984–1985 he was Scientific Advisor to the Assistant Secretary of the Army, Civil Works. His research relevant to corps policies and programs has focused on multicriteria decision making, benefit–cost analysis methods and applications, risk and uncertainty analysis, and project financing and cost sharing. Dr. Shabman has served on the Water Science and Technology Board of the National Research Council and has chaired or been appointed to 12 National Academies Committees covering a wide array of water resource management topics. In 2005 he was named a National Associate of the National Academies. He received a PhD in resource economics from Cornell University.

Thomas H. Wakeman III is Deputy Director of the Center for Maritime Systems and Research Professor in the Department of Civil, Environmental, and Ocean Engineering at Stevens Institute of Technology, Hoboken, New Jersey, where he conducts research studies on port and navigation infrastructure and waterborne freight logistics and teaches courses on maritime activities. Before joining Stevens in 2007, he was employed by the Port Authority of New York and New

Jersey for 14 years and led the authority's efforts in port and waterway development and construction. Earlier in his career, he worked for the U.S. Army Corps of Engineers for more than 23 years, where he focused on coastal engineering and navigation infrastructure (including coastal and river channel dredging in northern California and the San Francisco Bay region). In 2004, Dr. Wakeman was appointed as the Senior Maritime Advisor with the Coalition Provision Authority (during Operation Iraqi Freedom) and was stationed in Umm Qasr, Iraq, where he was responsible for the reopening of the Iraqi ports on the Khawr az-Zubayr and Shatt al-Arab waterways and enhancing port operations and freight movement to northern portions of Iraq. His recent research activities (2011–2013) include preparation of a resiliency plan for the Weirton Area Port Authority, West Virginia, for its operations on the Ohio River and an assessment of the impact and resiliency lessons learned in the Port of New York and New Jersey after Hurricane Sandy for the U.S. Department of Transportation University Transportation Research Center, Region 2.

In 2008, Dr. Wakeman was named ASCE's New Jersey Educator of the Year, and in 2013 he was nominated and appointed as the River Representative to the Governing Board of ASCE's Coast, Ocean, Port, and River Institute (COPRI). In 2009, he was named a Fellow in the U.S. section of the World Association for Waterborne Transport Infrastructure for contributions to the organization from 1998 to 2008, including service as International Vice President for the Western Hemisphere. In 2010, he was named a Distinguished Diplomate in both the port and the navigation engineering areas by COPRI. In 2012, he was named Marine Group chairman for the Transportation Research Board's Technical Activities Council. He has coauthored two books and published more than 100 technical papers in his areas of expertise, and he recently served as technical reviewer for *Inland Navigation*, edited by T. J. Pokrefke (ASCE Press, 2013), which describes inland waterway lock and dam engineering, design, construction, and costs and economics. Dr. Wakeman received a master of science degree in civil engineering from the University of California, Davis, a master of science degree in marine biology from San Francisco State University, and a doctorate of engineering science from Columbia University, New York.