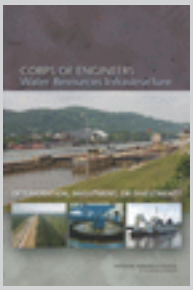

Corps of Engineers Water Resources Infrastructure: Deterioration, Investment, or Divestment?

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CORPS OF ENGINEERS
Water Resources Infrastructure

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Acknowledgments

This report was authored by the National Research Council Committee on *U.S. Army Corps of Engineers Water Resources Science, Engineering, and Planning*. 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 approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the 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.

We wish to thank the following individuals for their reviews of this report: John J. Boland, Johns Hopkins University; Adrian Chamberlain, consultant, Stephen W. Fuller, Texas A&M University; Jerome B. Gilbert, consultant; David Goldston, Natural Resources Defense Council; Allen W. Marr, Jr., Geocomp Corporation; Doug Plasencia, Michael Baker, Jr. Inc.; Leonard A. Shabman, Resources for the Future; Robert R. Twilley, Louisiana State University; and James W. Ziglar, Van Ness Feldman.

Although these reviewers provided constructive comments and suggestions, they were not asked to endorse the report's conclusions and recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Michael F. Goodchild, University of California, Santa Barbara, who was appointed by the National Research

Council. Dr. Goodchild was responsible for ensuring that an independent examination of this report was conducted in accordance with NRC institutional procedures and that all review comments received full consideration.

This report was being coordinated by Dr. Leo Eisel, who passed away during the review process. Leo was a widely regarded, highly respected member of the U.S. water policy and science community. Leo served with distinction on several Water Science and Technology Board committees, and also was a valued Coordinator for many NRC reports. Leo's friendly manner and superb judgment made him a favorite of the NRC staff, and he leaves behind a countless number of friends and many good memories.

Responsibility for this report's final contents rests entirely with the authoring committee and the NRC.

Contents

Summary

The U.S. Army Corps of Engineers (Corps) has major federal responsibilities for supporting flood risk management activities in communities across the nation, ensuring navigable channels on the nation's waterways, and restoring aquatic ecosystems. The Corps also has authorities to provide water supply, protect and maintain beaches, generate hydroelectric power, support water-based recreation, and ensure design depths in the nation's ports, harbors, and associated channels. The Corps is the federal government's largest producer of hydropower and a leading provider of outdoor recreation areas and facilities. The Corps of Engineers also regulates alteration of wetlands.

To meet its responsibilities in these various sectors, the Corps of Engineers has built incrementally what now comprises an extensive water resources management infrastructure that includes approximately 700 dams, 14,000 miles of levees in the federal levee system, and 12,000 miles of river navigation channel and control structures. This infrastructure has been developed over the course of more than a century, most of it on an individual project basis, within varying contexts of system planning. From a macroscale perspective, the water resources infrastructure of the nation is largely "built out." New water projects of course will be constructed in the future, but given that most of the nation's major river and coastal systems have been developed, there are reduced opportunities for new water resources infrastructure construction. Ecosystem restoration was added as a primary mis-

sions area for the Corps in 1996 and has been the main focus of new construction.

Large portions of the Corps' water resources infrastructure were built in the first half of the twentieth century and are experiencing various stages of decay and disrepair. Project maintenance and rehabilitation are thus high priority needs for Corps water infrastructure. Funding streams in the U.S. federal budget over the past 20 years consistently have been inadequate to maintain all of this infrastructure at acceptable levels of performance and efficiency. In instances where the Corps shares maintenance responsibilities with a nonfederal partner (e.g., many of the flood risk management projects built by the Corps), local or state funds are less available than in recent past years. The water resources infrastructure of the Corps of Engineers thus is wearing out faster than it is being replaced or rehabilitated. Estimated to have a value of $237 billion in the 1980s, the estimated value of that infrastructure today is approximately $164 billion (Calvert, 2012).

These systemic modern challenges regarding the funding and maintenance of the Corps water infrastructure led the agency to request advice from the National Research Council (NRC) and its Water Science and Technology Board (WSTB). This report is from the NRC *Committee on U.S. Army Corps of Engineers Water Resources Science, Engineering, and Planning*. It is the second in a series of five reports from this committee. The committee issued its first report in 2011, providing an overview of the scope of the national water resources challenges facing the Corps, and it will issue three future reports on topics to be determined by the Corps and the NRC (NRC, 2011).

This report provides observations and advice in three broad areas related to Corps water resources infrastructure: (1) the federal Water Resources Development Act (WRDA) process, (2) determining priorities for operation, maintenance, and rehabilitation (OMR), and (3) options for improving OMR. Current approaches for budgeting and prioritizing OMR projects are presented and discussed, and the report examines the capacity of the annual budget processes of the WRDA and the Corps to address water resources infrastructure challenges.

In considering future priorities and directions for the Corps of Engineers, it is important to note that the Corps operates at the behest of the U.S. Congress and the executive branch. Many of this report's findings and

recommendations therefore are directed to the U.S. Congress and executive branch, as well as to the Corps of Engineers.

STATUS OF CORPS OF ENGINEERS WATER RESOURCES INFRASTRUCTURE

The national water infrastructure is largely "built out." Compared to an earlier era, there are fewer opportunities and only a limited number of undeveloped or appropriate sites for new water resources infrastructure. New water projects will be constructed in the future, but the nation's water resources infrastructure needs increasingly are in the areas of existing project OMR. In some instances, full project replacement may be needed. As new construction has declined since 1980, so too has the Corps civil works budget and hence funds available for OMR. Trends in funding for the Corps over the past three decades make clear this reality.

THE FEDERAL WATER RESOURCES DEVELOPMENT ACT PROCESS

Efficient investment in Corps water infrastructure OMR requires setting of priorities, but existing legislative processes for Corps funding and authorizations do not generally provide such guidance. The Congress and the Office of Management and Budget (OMB) of the executive branch undertake many water resources planning responsibilities for new projects, but there exists no systematic process or guidelines for setting OMR priorities exist.

The U.S. Congress and the executive branch Office of Management and Budget are the *de facto* national water resources planners. There is no defined distribution of responsibility between Congress and the executive branch, including the Corps and OMB, for national-level prioritization of OMR needs for existing water infrastructure. Further, neither Congress nor the administration provides clear guiding principles and concepts that the Corps might use in prioritizing OMR needs and investments.

Federal water resources projects are authorized through federal Water Resources Development Act (WRDA) legislation. The WRDA and its processes were established by Congress in the 1970s and served to replace processes established under the Flood Control Act and Rivers and Harbors Acts. WRDA serves as a vehicle to authorize a collection of new water resources projects. The process for identifying, authorizing, funding, and implementing water resources projects embodied in WRDA is rooted in an era when the nation was expanding into undeveloped areas and building new water resources infrastructure. Corps civil works activities and needs today are less focused on new project construction and more focused on OMR of existing infrastructure.

The federal WRDA process was developed in a previous era of water management during which new water project construction was of high priority. The WRDA is a familiar process to Congress and will continue to be used as a means for authorizing new federal water projects. WRDA was not designed to identify and establish OMR priority actions and investments for existing Corps of Engineers water infrastructure. The process of individual project appropriations thus represents a *de facto* process for national water project prioritization. Higher congressional and administration priority on OMR issues for Corps infrastructure will entail some reorientation away from the present strong focus on WRDA.

CORPS MISSION AREAS AND INFRASTRUCTURE ASSETS

The Corps' primary civil works mission areas are navigation, flood risk management, and ecosystem restoration. The Corps also has authorities, responsibilities, and programs for hydropower generation, harbors and ports, recreation, and coastal and beach protection. For each mission area, there are generally separate annual budgets for operation and maintenance (O&M), and for construction. Most minor and routine rehabilitation is funded through O&M budgets, whereas major rehabilitation and replacement generally are funded through annual construction budgets. The process of prioritization for the annual O&M budget takes place generally at the division and district level and follows general guidelines, but it has many variations, depending on local needs.

The Corps' original involvement in national water resources planning dates back to the nineteenth century and its work in ensuring navigable rivers. In the twentieth century, and after 1927 Mississippi River flooding and resulting damages, the Corps became involved in flood damage reduction (this report, like the Corps of Engineers, uses the term "flood risk management"). The Corps's third primary mission area is ecosystem restoration, which was formally established in 1996. In an earlier era, it was easier to integrate a smaller number of missions and to share expertise and experience among them. Today, however, the larger number of responsibilities makes agency-wide integration more difficult.

In carrying out its duties in these areas, the Corps is guided by numerous federal laws and authorizations, a wide mix of clients with different goals, and different modes of taxation and sources of revenue. Its distinctive and diverse water infrastructure, its specific roles in the national economy, and its clientele and history make the Corps a unique organization. This makes many of the potential approaches and solutions to Corps OMR challenges specific to the Corps.

Corps of Engineers water resources infrastructure responsibilities, including navigation, flood risk management, and hydropower generation, differ significantly in terms of enabling legislation, taxation and revenue sources, clients, and relations with the private sector. The Corps faces challenges in its OMR duties given that its roles, partnerships, and successes in addressing OMR in one mission area often are not transferred easily to other areas or activities.

Greater private sector involvement is often raised as one option for increasing revenues for public agencies or works, and this report identifies some ways in which private-sector participation in Corps OMR activities might be enhanced.

Opportunities for greater private-sector involvement in Corps infrastructure operations and maintenance activities will vary by Corps mission area, and by economic sector. In general, these opportunities are greater in the areas of flood risk management, port and harbor maintenance, and hydropower generation, and less for inland navigation.

Inland Navigation

The inland navigation system presents an especially formidable challenge and a set of difficult choices. There are limited options and stark realities, including:

- Funding from Congress for project construction and rehabilitation has been declining steadily.
- Lockage fees on users/direct beneficiaries could be implemented. These are resisted by users and others.
- Parts of the system could be decommissioned or divested and the extent of the system decreased.
- The status quo is a likely future path, but it will entail continued deterioration of the system and eventual, significant disruptions in service. It also implies that the system will be modified by deterioration, rather than by plan.

Flood Risk Management

Reductions in resources available for construction of federal flood control works present opportunities for expanded implementation of nonstructural flood risk management options that are more efficient, less costly, and provide greater environmental benefits. Many of these strategies have been used successfully for years, in many parts of the country. They have not always received full consideration, however, because of a historical emphasis on large engineered civil works for flood protection. Today's fiscal realities present the Corps of Engineers opportunities to collaborate more closely with local communities in providing technical information and other types of support.

Hydropower Generation

Hydropower revenues could be increased by improving the efficiency of the turbine systems used in Corps hydropower projects, as has been

demonstrated by the Tennessee Valley Authority. Total generation from Corps hydropower projects decreased by 16 percent from 2000 to 2008. By contrast, the TVA increased hydropower generation 34 percent with the same water availability through efficiency improvements in the 1980s and early 1990s (Sale, 2010). This suggests that at least a 20 percent improvement with current water flows is achievable and would provide significant new revenues. Because of its revenue-generating potential, hydropower is in an especially good position to accommodate public-private investments required to increase capacity and reliability. Some modification of operating regulations by the U.S. Congress will be needed to realize this potential.

Systematic Asset Management

An up-to-date, accessible water resources infrastructure inventory, including infrastructure conditions, benefits, and risks, would be useful in helping set priorities among competing Corps water infrastructure OMR needs. The Corps has made progress on implementing a more systematic approach to infrastructure asset management over the past decade, but progress has been slow. There are various asset inventories at the district and division level, and some at the national level, but they are not well coordinated within each mission area.

Increasing strains placed on the Corps today by decaying infrastructure and associated fiscal challenges demand a systematic approach to asset management. To its credit, the Corps has begun an asset management initiative. To further promote these efforts, the Corps should continue to develop more comprehensive, and publicly accessible, inventories of infrastructure assets for each of its core mission areas.

ECONOMIC PRINCIPLES AND FUTURE INVESTMENTS

Future OMR investments should be guided by a more coherent set of principles that include strong reliance on economics of infrastructure investment. A 2003 NRC committee that studied national freight transport

offered the following set of investment and economic principles that merit careful consideration. Those principles can be summarized as:

- **Promote economic efficiency, with investments directed to improvements that yield greatest economic benefits.**
- **Limit government involvement to circumstances in which market-based outcomes clearly would be highly inefficient. Government also is responsible for managing facilities where it has important historical responsibilities that would not be easily altered, and where institutional complexity necessitates government leadership.**
- **Limit government subsidies and ensure that facility beneficiaries pay the costs.**
- **Rely more on user revenues, and the 'user pays' principle, along with matching funds and stronger public-private relationships.**

Along with economic development principles, broader social and environmental goals for Corps projects, including public safety purposes, of course need to be considered when prioritizing OMR investments for Corps projects (the complete listing of these principles is on pages 54 and 55.)

OPTIONS FOR CORPS WATER RESOURCES INFRASTRUCTURE

In order to identify viable paths for sustainable management of Corps of Engineers water infrastructure, it is useful to consider the range of options available to the Corps, the U.S. Congress, and Corps project beneficiaries. Possible future paths that might be taken with regard to Corps of Engineers infrastructure are as follows:

1. Business as usual. Accept degraded performance, and the consequences of gradual or sudden failure of infrastructure components.
2. Increase federal funding for operations, maintenance, and rehabilitation.
3. Divest or decommission parts of Corps infrastructure to reduce OMR obligations.
4. Increase revenue from Corps project beneficiaries.

5. Expand opportunities for partnerships in operating and maintaining portions of existing infrastructure.
6. Adopt some combination of these options.

Option 1: Business as Usual

Resources from the Corps annual budget (i.e., the general fund of the U.S. Treasury) for new construction and rehabilitation of existing water infrastructure have been declining steadily and are inadequate to cover all OMR needs. Other possible sources of funding have been inadequate to cover all costs, leading to an unsustainable situation for maintenance of existing infrastructure. This scenario entails increased frequency of infrastructure failure and negative social, economic, and public safety consequences. The potential extent of these negative consequences is not well understood.

Option 2: Increase Federal Funding for Operations, Maintenance, and Rehabilitation

There has been a long-term declining trend in funding for Corps water resources infrastructure construction and rehabilitation across numerous federal budgets. The future viability of this option is unclear.

Option 3: Divest or Decommission Parts of the Corps Infrastructure

The inability of the Corps to divest and decommission infrastructure is an obstacle to focusing available funding on highest-priority OMR needs. Financial stresses placed on the Corps to provide safe and efficient operation of all infrastructure leads to partial investments across many facilities, rather than larger investments in more critical facilities. Decommissioning and divestment of some components of the Corps water infrastructure would reduce OMR obligations, but such decisions are matters of public policy and would require action by Congress or the administration.

Option 4: Increase Revenues from Corps Project Beneficiaries

Opportunities exist for expansion of revenue capture from water resources infrastructure, especially for inland navigation and hydropower projects. However, legal and other barriers will necessitate congressional action to expand such revenue streams.

Option 5: Expand Partnerships

Although some components of the Corps water infrastructure entail shared responsibilities and activities with private entities, public-private partnerships are utilized only in a limited manner to support operations for much of Corps water resources infrastructure. Greater private- sector participation in Corps water infrastructure OMR will not be merited or desirable in all circumstances. Nevertheless, public-private partnerships offer a range of possibilities for bringing new resources and potentially more efficient methods to OMR of Corps water resources infrastructure. Given the many complexities and uncertainties surrounding partnership prospects, with private sector entities as well as state and local governments, a credible evaluation of promising opportunities would be useful for identifying the most immediate, promising prospects.

This evaluation ideally would be conducted by an independent and credible organization with good knowledge of Corps of Engineers functions, policies, and activities.

The U.S. Congress and/or the administration should commission an investigation of opportunities for additional and different kinds of partnerships for operation and maintenance of Corps water resources infrastructure. Partnerships investigated should include both those with private entities, and partnerships with state and local governments. The investigation should be conducted by an entity independent of the Corps of Engineers.

Option 6: Some Combination of Options 2-5

THE NEED FOR FEDERAL LEADERSHIP AND ACTION

The Corps of Engineers clearly faces many challenges in setting OMR priorities and in procuring resources for OMR needs. Many of these challenges are rooted in political issues and decisions, and may require changes in federal legislation. Their successful resolution therefore will require stronger leadership from the U.S Congress and executive branch. In some instances, a willingness to make a break with past traditions and practices will be needed.

The process of federal water resources planning by the U.S. Congress and administration is reflected in new project authorizations through WRDAs and appropriations for new and ongoing projects. These familiar processes focus far more on new water project construction than on OMR of existing infrastructure. Neither the U.S. Congress nor the administration has established a process or program for setting OMR priorities for existing Corps water projects. During an earlier era of expansion of national water infrastructure, there was little need for such a process. Today, in a setting of deteriorating Corps water infrastructure and increasing importance of OMR, this type of process increasingly is necessary to identify high-priority investments. The lack of a process for high-level OMR prioritization represents an impediment to more efficient investments in critical Corps infrastructure, and it inhibits the ability to divest or decommission water resources infrastructure projects. The Corps effectively makes decisions about priorities within its allotted annual budgets. The agency, however, lacks broader authority for higher level, policy-based prioritizations, such as those that would lead to infrastructure divestiture or decommissioning.

More specific direction from the U.S. Congress regarding priority OMR investments for Corps water infrastructure will be crucial to sustaining the agency's high priority and most valuable infrastructure. The executive branch also could play a more aggressive role in promoting dialogue between the Corps and the Congress on existing infrastructure investment needs and priorities.

1

Introduction

The Corps of Engineers has constructed, operates, and maintains a vast national water resources infrastructure, with various facilities in all 50 U.S. states. The traditional mission areas of the Corps were flood control and navigation enhancement, and the agency has constructed tens of thousands of miles of levees, hundreds of locks and dams for navigation, and dams for multiple purposes, including hydroelectric power generation. The Corps has constructed channel control structures along hundreds of miles of rivers and along the intracoastal waterways of the southern and eastern United States. The Corps also has important responsibilities in ensuring navigable depths in the nation's ports and harbors. Corps water resources infrastructure affects river flows and levels on many of the nation's large river systems, including the Columbia, Missouri, Mississippi, and Ohio Rivers.

Much of the Corps of Engineers water resources infrastructure was constructed many decades ago. Approximately 95 percent of the dams managed by the Corps are more than 30 years old, and 52 percent have reached or exceeded their 50-year project lives (USACE, 2012a). Similar statistics can be cited for Corps levees, hydropower, and other facilities. This deterioration of Corps water resources infrastructure is a microcosm of larger national trends in the deteriorating condition of major infrastructure, including highways, bridges, roads, airports, and drinking water and wastewater treatment facilities. Degradation of U.S. infrastructure has been discussed in many fora, such as the well-known annual infrastructure 'report cards'

issued by the American Society of Civil Engineers (e.g., ASCE, 2012a). In addition to aging Corps water infrastructure, in particular, federal resources for major rehabilitation have decreased. Since the mid-1980s, the constant dollar value estimate of the net capital stock civil works projects of the Corps has decreased from roughly $237 billion to about $164 billion (Calvert, 2012).

The water resources infrastructure of the United States is in most senses complete, or "built out." New water resources projects of course will continue to be constructed in the future, but most of the nation's major river and coastal systems have been developed, and national water infrastructure investment needs increasingly are centered on maintenance and rehabilitation needs. However, many of the processes developed over the years, and still in use, by the U.S. Congress to ensure viable national water resources infrastructure revolve around planning, authorizing, and in some cases providing appropriations for new water project construction. These processes are reflected in occasional federal Water Resources Development Acts, or WRDAs. The WRDA process historically was not developed or used as a primary vehicle for water project maintenance and rehabilitation, but these issues today are increasingly important national water investment priorities.

It is in this context that the National Research Council (NRC) *Committee on U.S. Army Corps of Engineers Water Resources Science, Engineering, and Planning* produced its second report. This committee is scheduled to release five reports during the course of its tenure of approximately five years, on a series of different water resources issues of importance to the Corps of Engineers. The committee issued its first report in 2011 (NRC, 2011), with a focus on national water resources challenges and roles for the U.S. Army Corps of Engineers. Topics for this committee's third, fourth, and fifth reports will be developed and agreed upon by the Corps and the National Research Council in the future.

This report investigates existing Corps water resources infrastructure, including its navigation, flood management, and hydropower generating infrastructure (Box 1-1). The report focuses on 'hard' infrastructure assets such as locks, dams, levees, and hydropower facilities, and not on related resources that are affected by Corps facilities and their operations, such as wetlands, endangered species, sediment, or water quality.

BOX 1-1
STATEMENT OF TASK

This committee will provide advice to the Corps of Engineers on a range of scientific, engineering, and water resources planning issues through periodic reports. Through its reports, the committee will provide advice to the Corps on agency practices that are valid or that should be revised, and it will help the Corps anticipate and prepare for emerging water resources planning challenges. Meetings between this committee and the Corps will allow for the identification of important and emerging water resources planning and policy issues of high priority to the agency and upon which they are seeking external advice. In addition to speaking with the Corps of Engineers, the committee often will engage invited speakers from other federal agencies, U.S. congressional staff, state governments, the private sector, and relevant stakeholders. The committee also may serve as a forum for occasional workshops on thematic issues, such as flood risk management, sustainable river system planning, hydroecosystem restoration, or implications to water management of climate change and variability.

This committee's first report (NRC, 2011) identified emerging national water resources challenges and their implications for Corps of Engineers strategies and programs. The committee's second report will focus on the future of Corps of Engineers water resources infrastructure.

Part of the committee's work plan for this second report will include a meeting with several invited speakers to discuss the purposes, condition, investment levels and projected needs, funding alternatives, and decision-making processes relevant to operations, maintenance, and improvements (recapitalization, rehabilitation, repurposing, decommissioning, etc.) of Corps of Engineers water resources infrastructure.

The committee's report will seek to identify alternatives and opportunities for improved decision making and prioritization in regard to maintenance, upgrades, and modernization of the navigation, flood risk management, hydropower, and related ecosystem infrastructure managed by the Corps.

The report also will consider potential opportunities and innovations for managing Corps water resources infrastructure in a modern context of more intergovernmental and public/private partnerships and collaboration. The committee will not recommend changes in levels of federal water resources funding, nor will it recommend changes in Corps of Engineers organizational restructuring.

Statements of task for subsequent reports will be determined through discussions between the committee and the Corps and will be subject to approval of the Academies' Governing Board Executive Committee.

The background for the following report includes an extensive set of NRC reports that reviewed various aspects of Corps of Engineers planning processes and methods (Box 1-2). NRC committees have, for example, reviewed the Corps of Engineers planning process, analytical methods, and ecosystem restoration. The NRC also has reviewed Corps of Engineers projects and planning studies for the Florida Everglades, the Missouri River, the upper Mississippi River-Illinois Waterway, coastal Louisiana, and the New Orleans hurricane protection system. Recently, the NRC reviewed a draft of the proposed revisions to the federal Principles and Guidelines that guide planning steps of the Corps of Engineers and other federal agencies (NRC, 2010a).

The present report is distinct from previous NRC reports in that it does not focus on planning methods for new projects or on possible changes in operational regimes for better management of water and related resources. Rather, the report examines maintenance and rehabilitation of *existing* Corps water infrastructure. The setting of priorities, options for funding maintenance and rehabilitation needs, and alternatives for maintaining or decommissioning parts of that infrastructure also are discussed. Evaluation or critiques of issues such as multi-criterion decision making for new water projects, benefit-cost analysis, federal Principles and Guidelines, or adaptive management are beyond the scope of this report, although some of these topics are referred to as part of the analyses conducted.

It also should be noted that this report focuses specifically on Corps of Engineers water resources infrastructure and does not consider and evaluate specifically operational or maintenance programs of other federal water agencies, such as the U.S. Bureau of Reclamation. Further, the report does not consider other national water issues such as food security, irrigation, remediation of groundwater pollution, climatic and hydrologic nonstationarity, or provision of water supplies and drinking water. Some of these issues are closely related to Corps of Engineers water infrastructure, and some of them were discussed in the course of the committee's deliberations and preparation of its report. Ultimately, however, the committee decided to focus tightly on only those issues prescribed in its statement of task.

The Corps of Engineers is authorized to carry out projects in seven mission areas: navigation, flood damage reduction, ecosystem restoration, hurricane and storm damage reduction, water supply, hydroelectric power gen-

BOX 1-2
EXAMPLES OF NRC REPORTS REVIEWING CORPS OF ENGINEERS PLANNING

The National Research Council has issued numerous reports that have examined Corps of Engineers planning studies and methods. In some instances, these reports have focused on methods, models, and techniques. In other instances, the reports have focused on technical applications in planning studies in specific aquatic and river systems. This box presents a sampling of these reports.

Improving American River Flood Frequency Analyses. 1999. Reviewed Corps flood-frequency curve of the American River in California.

New Directions in Water Resources Planning for the U.S. Army Corps of Engineers. 1999. Reviewed Corps planning procedures and the implications of WRDA 1986 cost-sharing criteria.

Risk Analysis and Uncertainty in Flood Damage Reduction Studies. 2000. Reviewed the use of risk-based methods in Corps flood damage reduction studies.

A set of coordinated studies on various dimensions of Corps planning methods and approaches was congressionally mandated in Section 216 of the 2000 Water Resources Development Act. They have been informally referred to as "the 216 studies":

Review Procedures for Water Resources Project Planning. 2002.
Adaptive Management for Water Resources Project Planning. 2004.

eration, and recreation (USACE, 2000). The first three of these generally are referred to as the Corps' primary civil works missions.

The hard infrastructure considered in this report is facilities managed by the Corps or facilities at which the Corps is a critical partner (e.g., many ports and harbors). This infrastructure includes locks, dams (both navigation dams and multipurpose dams), hydropower generating facilities, port and harbor facilities, and levees, floodwalls, and other flood protection infrastructure. Corps hard infrastructure assets are not distributed evenly across its various mission areas. The hard infrastructure for which the Corps is responsible lies mainly within its missions for navigation, flood

Analytical Methods and Approaches for Water Resources Project Planning. 2004.

River Basins and Coastal Systems Planning Within the U.S. Army Corps of Engineers. 2004.

U.S. Army Corps of Engineers Water Resources Planning: A New Opportunity for Service. 2005.

The NRC conducted reviews of Corps studies that evaluated the economic feasibility of extensions of several locks on the lower portion of the upper Mississippi River-Illinois Waterway:

Inland Navigation System Planning: The Upper Mississippi River-Illinois Waterway. 2001.

Review of the U.S. Army Corps of Engineers Restructured Upper Mississippi River-Illinois Waterway Feasibility Study. Two 2004 reports.

Water Resources Planning for the Upper Mississippi River and Illinois Waterway. 2005.

Similarly, the NRC has performed multiple reviews of restoration plans in the Florida Everglades (e.g., NRC, 2010b).

Following Hurricane Katrina, the Department of the Army requested that the NRC and the National Academy of Engineering review successive drafts that evaluated performance of the New Orleans hurricane protection system during Hurricane Katrina. Short reports were issued in 2006 (three) and 2008. That committee's final report was *The New Orleans Hurricane Protection System: Assessing Pre-Katrina Vulnerability and Improving Mitigation and Preparedness (*2009).

damage reduction, and hydropower generation, and this report focuses on those three areas. Regarding ecosystem restoration, Corps hard infrastructure often is integral to ecosystem restoration efforts. There are important links between Corps infrastructure and aquatic ecosystems resources. In some places, hard infrastructure has been or is being removed, altered, or re-operated to help achieve restoration goals. This report does not consider the implications of maintenance, upgrades, and modernization of hard infrastructure on resources such as wetlands, fisheries, sediment, or endangered species. These latter categories encompass considerations distinct from hard infrastructure resources, financing, and prioritization. Further, evaluation of the

evaluation of the links between Corps infrastructure operations, maintenance, and rehabilitation (OMR) and ecosystems, given the breadth of the topic, would entail a separate investigation. The committee viewed this interpretation as consistent with its charge to consider "navigation, flood risk management, hydropower, and related ecosystem infrastructure managed by the Corps."

This committee held its first meeting of this phase of the project in Washington, D.C., in April 2011, where it engaged with several Corps of Engineers senior staff members, along with numerous guest speakers from outside the agency. A second meeting was held in Davenport, Iowa, in July 2011 and was hosted by Corps of Engineers staff from its Rock Island District office. That meeting featured presentations from Corps of Engineers staff, regional water experts from outside the agency, and representatives from communities affected by floods, as well as a field trip to the Mississippi River Lock and Dam 15 Corps facilities. A third meeting was held in Washington, D.C., in December 2011 that featured guest speakers mainly from outside the Corps of Engineers. A fourth and final writing meeting, which included a field trip to Hoover Dam and engagement with U.S. Bureau of Reclamation officials, was held in Las Vegas in March 2012. Guest speakers at the meetings are listed in Appendix A.

This report is organized into four chapters. Following this introductory chapter, Chapter 2 reviews and comments upon historical federal water resources planning processes, with an emphasis on the Water Resources Development Act. Chapter 3 examines the state of Corps infrastructure and related challenges in setting OMR priorities, as well as opportunities to address these issues in the Corps mission areas of navigation, flood risk management, and hydropower generation. Chapter 4 summarizes committee observations regarding the state of Corps water resources infrastructure, and presents options for paths forward in managing existing Corps water resources infrastructure.

Primary audiences for this report are the U.S. Army Corps of Engineers, the U.S. Congress, and the executive branch. Other audiences for this report include state and local elected officials and water managers, the commercial navigation sector, floodplain communities, port and harbor authorities, the energy production sector, and nongovernmental environmental organizations.

2

U.S. Federal Water Project Planning, Authorization, and Appropriations

The standard process for federal water resources project authorizations since 1974 has been via federal Water Resources Development Acts (WRDAs). The U.S. Congress has passed ten WRDAs, beginning with the first in 1974 (see Table 2-1). WRDAs are used by the U.S. Congress to authorize the Corps to perform a wide range of activities, starting with the authority to study the feasibility of a given water resources project, then on to a detailed study of the options and costs for the project if it meets the test of benefit to cost and federal interest in the feasibility study. If those studies continue to show that the project meets the required criteria, a subsequent WRDA may authorize construction. Water projects authorized by WRDAs include those for flood risk management, navigation, recreation, infrastructure maintenance and repairs, and ecological restoration. The WRDA process is used primarily for authorization of new water projects, with project appropriations decisions generally addressed in the federal budget process. Authorizations represent congressional approval for a project to begin feasibility studies, planning, and construction.

Appropriations are allotments of federal resources for actual project construction. Project authorization does not necessarily lead to project appropriations; there are many authorized water projects that are awaiting appropriations. Authorized projects that have not received appropriations often are referred to as a "backlog." The current backlog of authorized, but unfunded, projects is estimated as needing approximately $60 billion to complete (NRC,

TABLE 2-1 History of U.S. Water Resources Development Acts

Date Enacted	Public Law number	Other Acts Included
March 7, 1974	93-251	Streambank Erosion Control Evaluation and Demonstration Act; River Basin Monetary Authorization Act
October 22, 1976	94-587	Lake Ontario Protection Act; Alaska Hydroelectric Power Development Act
November 17, 1986	99-662	Harbor Development and Navigation Improvement Act; Upper Mississippi River System Management Act; Dam Safety Act
November 17, 1988	100-676	
November 12, 1990	101-640	
October 31, 1992	102-580	National Contaminated Sediment Management and Assessment Act
October 12, 1996	104-303	
August 17, 1999	106-53	
December 11, 2000	106-541	Missouri River Protection and Improvement Act; Charles M. Russell National Wildlife Refuge Enhancement Act; Missouri River Restoration Act
November 8, 2007	110-114	

2011).[1] In some instances, small amounts of money may be authorized through WRDAs for planning of specific projects. Congress also sometimes includes appropriations directly in WRDA bills for specific projects, such as post-Katrina construction on the New Orleans hurricane protection system. Only infre-

[1] There is no similar, generally accepted figure for a backlog of deferred OMR costs. Those estimates would entail diverse maintenance and rehabilitation costs and be subjected to much more judgment and expert opinion. There thus is no single credible estimate of deferred OMR costs for all Corps water infrastructure.

quently are funds for maintenance and upgrades of existing infrastructure included in WRDAs.

National water management needs increasingly are for the operations, maintenance, and rehabilitation (OMR) of existing projects, with few new water resources infrastructure project starts (NRC, 2011). A continued strong emphasis on the WRDA process may affect the ability of the Corps to cope with the stresses of maintaining existing water infrastructure in an era of declining federal funding available for new construction and major rehabilitation. This chapter reviews the WRDA process and how it might affect both the Congress and the Corps in managing water resources infrastructure and related OMR challenges.

CORPS OF ENGINEERS AUTHORITIES

The Corps of Engineers builds infrastructure for military and civilian purposes. The civilian, or civil works, arm of the Corps derives its authority from individual congressional statutes and from plans approved by the U.S. Congress and the President that authorize planning, construction, and operations of individual projects. The Corps of Engineers carries out projects and activities specified by the U.S. Congress that are approved in the federal budget passed by the Congress and signed by the President. The executive branch of the U.S. federal government plays an important role in oversight of the Corps of Engineers, especially through the Office of Management and Budget (OMB) and fiscal guidelines recommended by the President. These two branches of government play important roles in providing guidance and direction to the Corps of Engineers, and any lasting solutions to national water challenges require some degree of collaboration between them. Unlike federal agencies that have broad authorizations, such as the Bureau of Reclamation through the Reclamation Act of 1902, and the National Park Service through the Organic Act of 1916, the Corps has relied on specific legislation to authorize specific projects. For example, the Corps was given broad authority in the 1936 and 1944 Flood Control Acts to investigate possible flood control projects. However, the Chief of Engineers is required to seek separate congressional authorization for each specific project by submitting a feasibility report (except in the case of some small projects). A recent example of the limits of Corps authority and the level of con-

gressional and judicial involvement in Corps decision making is the case of water allocation in Lake Lanier, Georgia (see Box 2-1).

Congress changed its approach to water project funding in 1974 with passage of the first WRDA. Prior to 1974, Corps of Engineers projects were authorized in federal Rivers and Harbors Acts and in Flood Control Acts. Since 1974, the Corps has relied on WRDA bills to provide authorizations for specific projects. In the context of this report, it is important to note that the WRDA process and resultant legislation provide no prioritization for construction of new projects for the nation as a whole, nor does it identify project maintenance and rehabilitation priorities.

BOX 2-1
EXISTING CORPS AUTHORITIES AND CHANGING WATER DEMAND: THE CASE OF LAKE LANIER AND ATLANTA

Lake Lanier is a U.S. Army Corps of Engineers reservoir on the Chattahoochee River in north-central Georgia. It is impounded by Buford Dam, and is operated along with the four other federal projects in the Apalachicola-Chattahoochee-Flint (ACF) River system to achieve multiple purposes authorized by Congress, including flood damage reduction, hydroelectric power generation, navigation, fish and wildlife conservation, recreation, water quality, and water supply. Buford Dam and the ACF system of projects regulate flows on the Chattahoochee River that affect numerous downstream uses, including water supply and water quality in the Atlanta metropolitan area and, farther downstream, threatened and endangered species conservation in the Apalachicola River. The ACF river basin is shared by Alabama, Georgia, and Florida, and empties into Apalachicola Bay.

Disagreements among the states and other entities over the use of these waters and the Corps' operations of the federal ACF system resulted in multiple lawsuits beginning in the 1990s. Despite years of negotiations, including a congressionally-approved interstate compact, the three states have been unable to agree on an apportionment of waters that could have led to a resolution of the tri-state dispute. In the early 2000s, the region was in the midst of a multiyear drought, and the Corps of Engineers, Georgia, water supply providers, and the Southeastern Federal Power Customers (SeFPC) agreed to a settlement that could have resulted in a reallocation of water storage in Lake Lanier to accommodate water supply needs of the Atlanta metropolitan area. The settlement agreement contemplated that the Southeastern Power Administration would apply a credit to the hydropower rates

SHIFTING EMPHASIS OF CORPS ACTIVITIES

Throughout its lengthy history, the Corps of Engineers has had to operate among competing visions of water resource development. Some of the agency's pressing current challenges, including limited resources for important infrastructure OMR needs, often stem from a gap between a vision of comprehensive river basin management and the political realities regarding individual project construction. From administrations of Theodore Roosevelt to Lyndon Johnson, the idea of comprehensive, rational federal development of river basins through multiple purpose projects has been promoted by many water

charged to power customers in conjunction with the reallocation of storage from hydropower to water supply.

Alabama and Florida intervened to challenge the settlement agreement, and a 2008 court decision [SeFPC v Geren, 515F.3d 1316 (D.C. Cir. 2008)], held that the settlement exceeded the Corps' authority under the Water Supply Act, which requires congressional approval for reallocation of storage that involve "major operational changes." The reallocation constituted over 22 percent of the reservoir's conservation storage capacity, which the court noted would have been the largest reallocation undertaken by the Corps without congressional approval. Following vacatur of the settlement agreement, the SePFC case was consolidated with the other ACF litigation. A district court ruled in 2009 that the Corps' then-current operation of Lake Lanier violated the Water Supply Act because it represented a *de facto* reallocation of storage exceeding the 22 percent threshold. However, the Eleventh Circuit reversed the district court, holding that water supply was an authorized purpose of Lake Lanier, and directed the Corps of Engineers to reconsider its authority to accommodate Georgia's request for increased withdrawals from Lake Lanier and Downstream in light of the authorizing legislation, the Water Supply Act, and other applicable authority [Tri-State Water Litigation, 644 F.3rd 1160 (11th Cir. 2011)]. The Corps completed its legal and technical analysis on remand in June 2012, resulting in a legal opinion concluding that the Corps has the combined authority under the ACF authorizing legislation, a 1956 statute, and the Water Supply Act to accommodate the additional water supply withdrawals that Georgia has requested. The Corps is currently proceeding to update the water controls plans and manuals for the ACF system, taking into account the principles established in the June 2012 legal opinion.

policy experts (see White, 1957; United Nations, 1970). Although many local and state interests supported federal dam, lock, levee, and canal construction, efforts to create independent, executive authorities to develop river basins generally were resisted by both Congress and the states.

Origins of the river basin planning concept in the United States date back to observations and ideas of John Wesley Powell and his studies in the western United States, as well as President Theodore Roosevelt, who, when transmitting the Inland Waterways Commission preliminary report of 1908, stated, "Each river system from its headwaters in the forest to its mouth on the coast, is a unit and should be treated as such" (White, 1957). The concept of integrating water development plans and projects across a river system was brought to focus in basin scale for rivers such as the Allegheny and Monongahela, the Columbia, and the Missouri. The basin program that commanded the most attention in this era was for the Tennessee River. Development of the Tennessee Valley region, via the Tennessee Valley Authority established in 1933, was promoted as a model of unified river basin development, both domestically and abroad. President Roosevelt planned to apply the concept in the Missouri River basin, but the states and Congress blocked efforts to create a similar federal authority for the Missouri in the 1944 Flood Control Act and the "Pick Sloan" legislation (Ferrell, 1993; NRC, 2002). Following the New Deal era, federal support for large dam construction began to wane in the 1950s. The Eisenhower Administration (1952-1960) followed a "no-new starts" policy and stressed increased local responsibilities for smaller projects.

A new era of dam building was initiated by the Kennedy administration, and new Corps dams were built in the 1960s in the southeastern and midwestern United States. The Johnson Administration placed a high priority on river basin planning, and the Water Resources Planning Act of 1965 created seven river basin commissions coordinated by a federal Water Resources Council (WRC). However, because Congress was funding fewer dams, levees, and canals, these commissions had no clearly defined role, as noted by the National Water Commission (NWC), which operated between 1968 and 1973 (NWC, 1973). The NWC also looked ahead to the changing roles of the Corps of Engineers. The NWC 1973 report identified many of the problems with trying to adapt a new project construction model to changing water demands that the Corps was facing. For example, the commission noted that "The Corps . . . is not likely to exist as an agency specializing in the construction of great engi-

neering works; it seems virtually certain that in the future the United States will need relatively few major navigation, flood control, or water projects" (NWC, 1973).

Since the 1973 NWC report, there have been few efforts to revive the idea of strong federal water planning and development institutions. Large-scale water resources planning for both the Bureau of Reclamation and the Corps effectively ended in late 1960s. For example, the 1968 Colorado River Basin Project Act authorized both the Central Arizona Project and effectively took large-scale projects, such as interbasin transfers, off the Colorado River Basin water resources agenda. Instead, beginning in 1974, larger-scale river basin development acts (or general mission acts) such as the Flood Control Acts of 1936 and 1944 were replaced with WRDAs that contained many locally focused projects.

THE CORPS OF ENGINEERS AND THE WRDA PROCESS

Communities and local and state governments with water resources infrastructure needs often engage simultaneously with congressional representatives and the Corps to discuss potential projects. The level of Corps engagement in these preliminary discussions typically entails an advisory role to answer technical questions about potential projects.

Potential projects are initiated with a study authority, typically as part of a WRDA. This authority allows the Corps to determine whether the project warrants federal investment under the benefit-cost criteria established in the 1983 Principles and Guidelines (see Box 2-2). This study then is conveyed to Congress through a Chief of Engineers Report with either favorable or unfavorable recommendations. Results of these evaluations are submitted to the executive office of the Office of Management and Budget, which reviews the Corps evaluations. The OMB applies its own criteria that are consistent with executive branch objectives, including a benefit-cost test, to evaluate projects. Selected projects, reflecting results of the Corps and OMB evaluations (see Box 2-2), then are submitted to the relevant congressional appropriations committees as part of the President's budget for a given fiscal year. Congress then decides whether to appropriate funds to construct specific projects (for further details on the authorization and appropriation process, see Carter and Hughes, 2010).

BOX 2-2
FEDERAL PRINCIPLES AND GUIDELINES FOR WATER RESOURCES PROJECT PLANNING

The federal document, *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, was issued in 1983 by the federal Water Resources Council (WRC). That document provided a series of steps for the planning of new projects for four federal agencies: the Corps of Engineers, the Bureau of Reclamation, the Soil Conservation Service (today the Natural Resources Conservation Service), and the Tennessee Valley Authority.

The "Principles and Guidelines" (or P&G) document lays out a screening process for new project plans and is used to determine if planning for water project proposals meets a benefit-cost test, and if expected project benefits will exceed costs. The P&G and its predecessor Principles and Standards (P&S) document were designed to consider not just economic benefits but also environmental, social, and other factors.

Since the P&G document was issued in 1983, the national landscape of water project planning has changed markedly. Cost-sharing requirements for federal projects have changed, respective roles of the federal government and local beneficiaries, sponsors, and the number and influence of stakeholders have changed, and the extent of new water project construction has been reduced. Further, the P&G document never was intended to consider and compare multiple water project proposals or existing projects, or to set relative priorities or rankings. These changing circumstances prompted many entities and individuals, including National Research Council committees (e.g., NRC, 2004b) to call for the P&G document to be revised and updated.

In 2007, the U.S. Congress mandated the Army Corps of Engineers to review and update the P&G document. That mission was eventually assumed by the White House Council on Environmental Quality (CEQ). The CEQ team issued a draft revision in 2009. More recently, the 111th U.S. Congress, elected in 2010, prohibited the Corps (and effectively the administration) from spending further Fiscal Year 2012 funds to implement the 2007 WRDA congressional instructions to revise the P&G.

The WRDA process is oriented to individual project authorization, with limited considerations regarding how individual projects fit into larger, basin-wide plans or operations.[2] This focus on local projects may have been strength-

[2] The U.S. Congress still occasionally mandates basin-wide activities. For example, In P.L. 111-11, Subtitle F ("Secure Water"), Congress in 2009 directed the Secretary of the Interior to assess risks to water supply of each major reclamation river basin, analyze the extent to which changes

ened by passage of the 1986 WRDA, which created a variety of cost-sharing formulas for new projects between the federal government and its local partners. An earlier National Research Council committee that considered the effects of the 1986 WRDA on Corps planning and projects concluded (NRC, 1999):

> A general result of WRDA '86 was to increase the funding responsibilities of local sponsors. With these greater financial requirements, local sponsors requested and have received a greater voice in project planning and design considerations… The emphasis on local projects and cosponsors may be pulling the Corps in opposite directions, however. On one hand, WRDA '86 mandates the Corps to work closely with local cosponsors, effectively providing a service to local communities. On the other hand, the Corps is charged to promote the national interest in its water planning activities. Promoting this national interest may require integrating plans and programs throughout a large river basin system (especially an interstate basin), which may be incompatible with providing specific water projects tailored to local—not basinwide—interests.

Appropriated funding in any year for a particular project often is not for the entire project amount. Projects authorized in WRDA bills that do not receive timely appropriations for construction can be kept alive for long periods of time, as local governments and their congressional representatives can ensure that small amounts of money are appropriated for continued planning. This practice may not lend itself to efficient and systematic water resources planning. For example, the Congressional Research Service (CRS) has observed that "appropriated funds for an individual study or project . . . [may be] insufficient to permit the optimum programming of work by the Corps" (Carter and Hughes, 2006). This process of piecemeal funding, be-

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in water supply will impact basin resources, and consider and develop strategies to mitigate impacts of water supply changes. "Major reclamation river basins" in this case are defined to include the Columbia, Colorado, Missouri, and Sacramento/San Joaquin river basins.

low total project costs, has become an increasingly common procedure, resulting in long project schedules, inefficiency in project delivery, and higher project costs (NRC, 2011). Box 2-3 provides an example of how delays can affect the appropriations process and result in increased costs.

Projects authorized in a WRDA bill represent a wide spectrum of small to large projects, with no system for prioritizing among them. There is no formal, federal interagency task force, nor any systematic process, to determine national water resources priorities. Through the legislative process, Congress selects projects for appropriation and decides upon proper levels of appropriation. Consequently, the process of individual project appropriations represents a *de facto* process for national water project prioritization.

Although WRDAs have a strong emphasis on new project authorization, OMR projects also can be authorized within them. Table 2-2 lists some OMR projects authorized in WRDA 2007. Unlike the systematic federal-state-local cooperation on highway transportation projects, which involves a system of prioritization for determining federal support in a project (NCHRP, 2007), no similar process for water projects exists (napa, 2007).

WRDA AND WATER RESOURCES INFRASTRUCTURE OPERATIONS, MAINTENANCE, AND REHABILITATION

The focus on new water project construction was part of an earlier era of national expansion and settlement. At that time, the nation was seeking a greater degree of water control or "development" for commercial naviga tion, floodplain settlement, and hydroelectric power development. Over time, however, the need for individual project authorization, now embodied in WRDA legislation, and appropriation, became less relevant. Today, the United States is not expanding into undeveloped territory; rather, an increasingly important issue is the OMR of an extensive, existing national water infrastructure, much of which was built and is operated by the Corps of Engineers. As shown in Figure 2-1, Corps operations and maintenance budgets have in-

BOX 2-3
PROJECT AUTHORIZATION AND EXTENDED APPROPRIATION: LOWER MONONGAHELA RIVER LOCKS AND DAMS 2, 3, AND 4

The Monongahela River, which flows from West Virginia to Pittsburgh, where it joins the Allegheny River to form the Ohio River, was one of the nation's first inland waterways to have a lock and dam infrastructure installed to aid river navigation. Construction of the first locks and dams was initiated in 1837 by the Commonwealth of Pennsylvania. The federal government also constructed locks and dams in the Monongahela, and in the late nineteenth century the federal government took over the entire system. The present navigation system comprises nine locks and dams and was constructed by the Corps of Engineers beginning in 1902. Locks and Dams 2, 3, and 4 in the Lower Monongahela River, just south of Pittsburgh, are the three oldest currently operating navigation facilities on the river and experience the largest volume of commercial traffic for the river.

The Water Resources Development Act of 1992 authorized a major rehabilitation and reconstruction project involving Locks and Dams 2, 3, and 4. The project included replacement of the fixed crest dam at Locks and Dam 2 (Braddock) with a gated dam, removal of Locks and Dam 3 (Elizabeth), and construction of two larger locks at Locks and Dam 4 (Charleroi). For Locks and Dam 2, original construction was completed in 1906 and major rehabilitation was performed in 1953.

Detailed design and construction planning for the Lower Monongahela project completed in 1995 yielded a cost estimate of $750 million and an expected completion date of 2004, both of which assumed higher levels of annual project funding than were subsequently appropriated. The replacement of the Braddock Dam at Locks and Dam 2 (which employed an innovative in-the-wet construction technique) was completed in 2004. Work on the Charleroi Locks at Locks and Dam 4 was initiated in 2002. Based on expected levels of annual funding, the Charleroi Locks are scheduled to be completed in 2021. Although the Lower Monongahela project received $84 million in stimulus funding from the American Recovery and Reinvestment Act in 2009, this was a modest amount relative to the total project scope, and the completion date was not affected substantially. When one new operational lock chamber is completed at the Charleroi Locks, work on removal of Locks and Dam 3 at Elizabeth will begin. The current estimate for project completion is 2024 and the current total cost estimate is $1.5 billion. The project is cost shared 50-50 with the Inland Waterways Trust Fund and the General Treasury.

The current projected $1.5 billion cost and 2024, completion date for the Lower Monongahela project reflect estimates of future congressional funding that are uncertain. It has been estimated that if Congress provides only minimum annual funding, the project will extend into the 2030s and the cost will increase to at least $1.7 billion (Boselovic, 2012a).

TABLE 2-2 Examples of Operation, Maintenance and Rehabilitation Projects and Studies in the Water Resources Development Act of 2007

Section	Title	Description
3057	Little Wood River, Gooding, Idaho	rehabilitate the Gooding Channel project for the purposes of flood control and ecosystem restoration
3061	Chicago Sanitary and Ship Canal dispersal barriers project, Illinois	upgrade and make permanent Barrier I; construct Barrier II; operate and maintain Barrier I and Barrier II as a system to optimize effectiveness
3071	Hickman Bluff stabilization, Kentucky	repair and restore the Hickman Bluff project
3084	West bank of the Mississippi River (East of Harvey Canal), Louisiana	operation, maintenance, rehabilitation, repair, and replacement
3156	Dam remediation, Vermont	remediation of a number of dams in Vermont
3178	Upper Ohio River and Tributaries navigation system new technology pilot program	establish a pilot program to evaluate new technologies applicable to the Upper Ohio River and Tributaries navigation system.
4035	Herbert Hoover Dike supplemental major rehabilitation report, Florida	study to evaluate existing conditions at the Herbert Hoover Dike system; identification of additional risks associated with flood events at the system
4096	Elliott Bay Seawall, Seattle, Washington	primary study for rehabilitation of the Elliott Bay Seawall

creased, slightly, while construction budgets have experienced significant decreases (except for specific occasions such as appropriations for post-Katrina construction activities on the New Orleans hurricane protection system, and 'stimulus' funding in 2008-09). Decreases in construction budgets entail declining resources available for project rehabilitation. Thus, despite

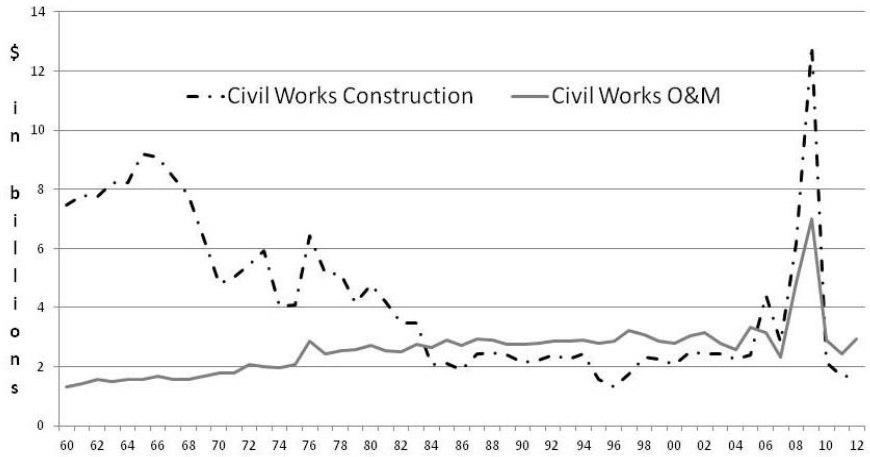

FIGURE 2-1 Corps of Engineers Appropriations 1960-2012. Prices adjusted to 2012 dollars. Spike at 2009 reflects American Recovery and Reinvestment Act.
SOURCE: U.S. Army Corps of Engineers.

modest increases in operations and maintenance funds, the level of federal resources available to the Corps has been inadequate to meet OMR needs and maintain all projects at acceptable levels of performance and efficiency. **The U.S. Congress and the executive branch Office of Management and Budget are the *de facto* national water planners. There is no defined distribution of responsibility between Congress and the Executive Branch, including the Corps and OMB, for national-level prioritization of OMR needs for existing water infrastructure. Further, neither Congress nor the administration provides clear guiding principles and concepts that the Corps might use in prioritizing OMR needs and investments.**

The WRDA process has been developed over many decades. Congress is familiar with the process and it has proven useful in authorizing numerous water projects of importance to the nation and its citizens. The process has survived challenges from administrations of both national parties (Frisch and Kelly, 2008). However, because current and future national water priorities increasingly are for water infrastructure maintenance and rehabilitation, there is a need to reorient some of the strong focus on WRDA toward a greater focus

on maintenance, rehabilitation, and even decommissioning of existing infrastructure. A revised WRDA process potentially could facilitate investment priority decisions as part of appropriations.

The federal WRDA process was developed in a previous era of water management during which new water project construction was of high priority. The WRDA is a familiar process to Congress and will continue to be used as a means for authorizing new federal water projects. WRDA was not designed to identify and establish OMR priority actions and investments for existing Corps of Engineers water infrastructure. The process of individual project appropriations thus represents a *de facto* process for national water project prioritization. Higher congressional and administration priority on OMR issues for Corps infrastructure will entail some reorientation away from the present strong focus on WRDA.

3

Corps of Engineers Water Resources Infrastructure and Mission Areas

The U.S. Army Corps of Engineers constructed, operates, and maintains a vast water resources infrastructure across the United States that includes dams, levees, and coastal barriers for flood risk management, locks and dams for inland navigation, ports and harbors, and hydropower generation facilities. Much of this infrastructure exhibits considerable maintenance and rehabilitation needs. Federal investments in civil works infrastructure for water management have been declining since the mid-1980s, and today there are considerable deferred rehabilitation and maintenance needs (NRC, 2011).

Operation, maintenance, and rehabilitation (OMR) of its existing water resources infrastructure is a primary challenge for the Corps today. These activities include repair and upgrades, carried out at many different scales, from routine to major (major projects usually require a separate construction budget). For each Corps mission area, there are generally separate annual budgets for operation and maintenance (O&M) and construction. Most minor and routine rehabilitation is funded through annual O&M budgets, while major rehabilitation and replacement generally is funded through annual construction budgets. The process of prioritization for the annual O&M budget takes place largely at the division and district level and follows general guidelines, but it has many variations, depending on local needs (for further details on budget guidance see USACE, 2011c).

Corps of Engineers maintenance responsibilities do not apply to all water infrastructure the agency has built, and maintenance duties for many portions of Corps-built water infrastructure have been turned over to state and local entities. This especially has been the case with many levees and other flood protection structures that have been built by the Corps, then subsequently turned over to levee districts or municipalities that assume OMR responsibilities. Furthermore, appropriations for operations and maintenance (and some rehabilitation) typically are not part of the project-by-project authorization process within the federal Water Resources Development Act (WRDA) process described in Chapter 2.

The needs for OMR of Corps water infrastructure are great, as funding from Congress for civil works construction and major rehabilitation has been declining for decades. Further, periodic WRDA bills are focused on new project construction and major rehabilitation, rather than more routine, but important, OMR activities. Not all aging and degraded infrastructure necessarily merits continued operation and investment, but there are legal, regulatory, and other obligations that inhibit the Corps from easily divesting, privatizing, or decommissioning existing infrastructure.

As mentioned, this report focuses on Corps of Engineers' "hard" infrastructure—locks, dams (both navigational and multipurpose), other navigation infrastructure (e.g., river control structures, federal harbor and port facilities), hydropower plants, and levees and other flood protection infrastructure. Although this chapter does not include a section on ecosystem restoration, the Corps' hard infrastructure discussed herein often is integral to restoration efforts. This report's focus is on maintenance, upgrades, and modernization of hard infrastructure, not on related ecological resources. The committee viewed this interpretation as consistent with its charge to consider "navigation, flood risk management, hydropower, and related ecosystem infrastructure managed by the Corps."

A prominent theme in this chapter is the considerable diversity across Corps mission areas in terms of enabling legislation, taxation and revenue sources, clients, and relations with the private sector. For example, inland navigation facilities are predominantly federally owned, whereas many harbor and port facilities are operated by states in partnership with private entities, with the Corps playing supporting roles. There are separate taxes and funds to provide revenue for inland navigation, and for harbor maintenance. Dams with hydropower gen-

erating facilities have a direct base of paying customers (although in most cases the revenues do not come back to the Corps). Some levees constructed with federal funds, in whole or in part, have been turned over to local levee districts that are responsible for maintenance and that raise local funds to cover repair costs.

Distinctions among Corps mission areas are rooted in the historical development, and expansion, of Corps of Engineers activities. The Flood Control Act of 1936 specified the circumstances for federal involvement in flood control and elevated the Corps' flood control activities to the same level as its navigation program. In 1996, Corps responsibilities were expanded further when ecosystem restoration was added as a formal, primary mission. Newer mission areas were not always fully consistent with the agency's original missions of navigation and flood control. Moreover, there have not been any specific congressional initiatives or activities to promote coordination and consistency across the Corps' mission areas, or any guiding principles for broad Corps responsibilities such as water resources infrastructure maintenance and rehabilitation.

NAVIGATION

The Corps has constructed, and operates and maintains, a large portion of the infrastructure that supports the nation's commercial inland waterways and its ports and harbors. Corps-maintained waterways and ports support commercial navigation in 41 U.S. states. In considering the current state of the Corps' navigation infrastructure and its options for rehabilitating and upgrading that infrastructure, it is important to recognize several distinctions between infrastructure for inland navigation and that for harbors and ports. Important differences between these systems in terms of taxation, public and private funding and facilities ownership, companies that use the facilities, and other factors will affect the direction of future infrastructure rehabilitation and upgrades.

Inland Navigation

The commercial inland navigation system includes roughly 12,000 miles of maintained river channels and 191 locks sites with 238 navigation lock

chambers. Figure 3-1 shows the scope of the Corps-maintained inland waterways system. The U.S. inland navigation system is used to ship bulk commodities such as corn and soybeans, coal, fertilizer, fuel oil, scrap metal, and aggregate (sand and gravel). Some of this cargo may transit nearly the entire length of the system. For example, corn and soybeans are shipped from across the midwestern United States down the Ohio, Illinois, and Mississippi Rivers to the Port of New Orleans, then exported. By contrast, some portions of the system are used primarily for local transport. For example, of total commodity tonnage shipped on the Missouri River between 1994 and 2006, 83 percent was estimated to originate and/or terminate in the state of Missouri, with 84 percent of the shipments consisting of sand and gravel (GAO, 2009). The Atlantic and Gulf Intracoastal water- ways also provide commercial transportation corridors. All portions of the inland navigation system also serve recreational uses, but it is commercial that primarily justifies and helps fund the system. The system is used primarily by U.S. based, domestic shipping companies. Lock and dam facilities on the inland navigation system are federally owned, operated, maintained, and rehabilitated

FIGURE 3-1 U.S. Fuel-Taxed Inland Waterway System.
SOURCE: U.S. Army Corps of Engineers.

by the Corps of Engineers. Some portions of the Atlantic and Gulf Intracoastal Waterways, however, are operated and maintained by the states they border.

There have been major changes to the U.S. economy, patterns of trade, and other cargo transportation alternatives since much of the inland navigation system was constructed several decades ago. Before the nation had its currently extensive rail and highway systems, "inland waterways were a primary means of transporting bulk goods" (Stern, 2012). Today, alternative modes for shipping inland navigation goods—namely, roads and rail—are in a more advanced state of development than during the period when the lock and dam projects were constructed. Although they remain important transportation modes for some sectors in some areas, "inland waterways are a relatively small part of the nation's overall freight transportation network" (Stern, 2012). The topics of relative costs, energy uses and efficiencies, and environmental impacts of rail, road, and barge transport make for lively debate among users of these respective modes.

Another important aspect of the inland navigation system is that its locks and dams create extensive upstream navigation pools. These navigation pools often affect river ecosystems up- and downstream for tens of miles. The inland navigation system thus affects many public resources and many private system users beyond commercial cargo carriers. There are impacts on floodplain lands overseen by federal government agencies (such as the U.S. Fish and Wildlife Service), private landowners, and recreational users, including boaters and anglers. The navigation pools are sources of both beneficial and negative effects.

Ports and Harbors

The Corps of Engineers maintains 926 coastal, Great Lakes, and inland harbors (Figure 3-2). U.S. harbors and ports operate in a setting very different from the inland navigation system. For example, U.S. harbors and ports handle a wider variety and higher volume and value of cargo than does the inland navigation system. Many more shippers use U.S. harbor and port facilities compared to the inland navigation system, and these shippers include both U.S. domestic and international companies. Docking and (un)loading facilities at

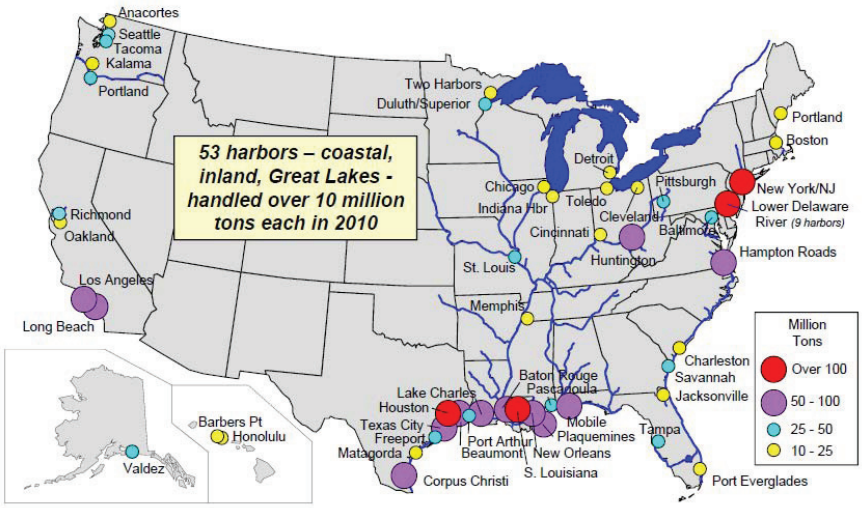

FIGURE 3-2 Major U.S. Ports and Harbors.
SOURCE: U.S. Army Corps of Engineers.

the harbors and ports generally are operated as public-private partnerships, and do not depend on direct federal resources. Corps responsibilities in ports and harbors are focused on dredging to maintain desired navigation and docking depths. The Corps also maintains wave/surge protection structures at some ports and harbors. This division of responsibilities and limited role for the federal government allows harbors and ports to pursue a broader range of partnerships and financing options. The Port of Baltimore (Box 3-1) and the Port of Miami (Box 3-2) provide good examples that involve states and private entities, with the Corps of Engineers having a limited support role.

There are generally fewer cost-effective alternatives to maritime transport for intercontinental or trans-ocean shipment for larger, heavier bulk goods such as coal and petroleum. This provides strong incentives for all port and harbor users and beneficiaries to be interested in port and harbor maintenance.

BOX 3-1
PARTNERSHIPS FOR WATER RESOURCES INFRASTRUCTURE: PORT OF BALTIMORE

The Port of Baltimore is among the busiest deep-water ports in the United States. Commerce in 2011 totaled 37.8 million tons of cargo valued at $51.4 billion (MPA, 2012a). Managed by the Maryland Port Administration (MPA) and a private sector partner, Ports America Chesapeake, the Port of Baltimore encompasses both public marine terminals and private marine terminals. The Seagirt Marine Terminal, for which a major expansion was completed in 2012, is the primary container facility at the Port. It is operated by Ports America Chesapeake under a 50-year agreement established with MPA in 2010.

The Port of Baltimore has been expanding shipping capacity in response to increasing globalization of commerce and to the Panama Canal widening scheduled for completion in 2014. When the Panama Canal widening project is completed, larger container ships from Asia will be able to access East Coast ports, including Baltimore. Accommodation of "Panamax" ships will require 50-foot berths and 50-foot deep channels. The Port of Baltimore has installed 50-foot berths and larger cranes for cargo handling at the Seagirt Marine Terminal, and, in partnership with the Corps of Engineers, has dredged 50-foot deep channels and anchorages. Changes to the Seagirt Terminal, valued at more than $200 million, are being financed and managed by Ports America Chesapeake (MPA, 2012b). In addition, MPA has worked closely with the State of Maryland and the railway company, CSX Corp., on development of an intermodal terminal facility near the Port where containers can be double-stacked on railcars, and with CSX Corp. on their National Gateway project which will raise bridges and lower tracks in 50 locations to permit rail transport of double-stacked containers from Maryland into the Midwest (MDR, 2011). The National Gateway project cost is about $850 million, of which CSX has committed $575 million (MDR, 2011).

The Corps of Engineers has had a well-defined role in the expansion of shipping capacity at the Port of Baltimore through the Baltimore Harbor Anchorages and Channels project. At the request of Congress, the Corps performed reconnaissance and feasibility studies in the 1990s for expanded commercial navigation capacity. The Water Resources Development Act of 1999 authorized construction of a 50-foot deep turning basin, deepening and widening of several anchorages in the harbor, widening of the Seagirt Marine Terminal channel and others, and construction of a new loop channel. The project was completed in 2003 at a total cost of $30.5 million, of which the federal share was $22.3 million and the MPA share was $8.2 million. Maintenance dredging is performed by the Corps annually, at a cost ranging from approximately $16 million to $18 million.

BOX 3-2
PARTNERSHIPS FOR WATER RESOURCES INFRASTRUCTURE: PORT OF MIAMI

The Port of Miami, managed by Miami-Dade County, is a man-made waterway in Biscayne Bay that was initially dredged in the early twentieth century. It was significantly expanded into a deep channel waterway and a man-made island during the 1960s and 1970s. Today the Port of Miami is the number one passenger cruise port in the world, the ninth largest cargo port in the United States and the largest cargo port in Florida. Despite the high level of activity, the port's current waterway and harbor are 42 feet deep and would not be accessible by post-Panamax megaships that require 50-foot clearance. The Corps, with responsibility for maintenance of navigation depths in the port, was authorized by Congress in 1999 to study the feasibility of deepening the port. Dredging to deepen the port was authorized by Congress in 2008 and scheduled to be completed by 2014, coincident with the scheduled completion of the Panama Canal expansion. It is the only harbor project south of Norfolk, Virginia authorized to dredge to depths that can accommodate Panamax ships.

Total costs for the Port of Miami project were estimated to be $170 million (including environmental mitigation) in 2004. The local sponsor, Miami-Dade County, has provided funding for the non-federal cost share requirement. The federal contribution has not been committed, however, because of the current Congressional moratorium on earmarks and exclusion of the project from the President's 2012 budget proposal for dredging projects (Clark, 2011).

In response to the lack of federal funding to proceed with the project, Florida Governor Scott redirected $77 million in state transportation funds to cover the federal share (Wright, 2011). Dredging for the port was initiated in summer 2012. This project coincides with additional infrastructure investments that state and local governments have initiated to expand overall capacity at the port. A public-private partnership was established in 2009 to build a $1 billion tunnel beneath the harbor that will connect the port's inner roadways to a nearby interstate highway (Port of Miami, 2010). Short-term funding for completion by 2014 will be provided by the private concessionaire, MAT Concessionaire, LLC, which will also maintain the tunnel and roadways for 30 years.

Distinctions Between Inland Navigation, and Harbors and Ports

The differences outlined above entail advantages and flexibility in options that harbors and ports possess in terms of financing infrastructure improve-

ments. In the past, the inland navigation system enjoyed more consistent federal support for maintenance and repair of its facilities. The decline of available federal resources increasingly represents a barrier for inland navigation in trying to raise funds for OMR. Harbors and ports have opportunities to employ new financing arrangements with numerous private-sector carriers and with state and local governments, but inland navigation generally faces more limits in its ability to employ similar options and private-sector partnerships (as discussed further below).

Taxation and Financing

Some portion of Corps infrastructure maintenance and rehabilitation activities is supported through taxes levied directly on facility users. For inland waterways, an Inland Waterways Trust Fund (IWTF) was established in 1978 and reauthorized as part of the 1986 WRDA. For harbors and ports, a Harbor Maintenance Trust Fund (HMTF) was first authorized in the 1986 WRDA. Prior to authorizations for these trust funds, waterway and harbor infrastructure and maintenance expenditures were funded almost entirely through general revenue from the U.S. Treasury (Carter and Fritelli, 2004). The IWTF is based on a commercial fuel tax of $0.20 per gallon (collected by the IRS), which has remained constant since 1995. A proposal for increasing the IWTF has been put forward by the inland waterways commercial shipping industry and is under discussion (see Box 3-3). 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).

The Inland Waterways Trust Fund is designated for *construction and major rehabilitation* of inland waterways, while the HMTF is limited to *operation and maintenance* of federally authorized channels for commercial navigation in deep-draft harbors and shallow-draft waterways that are not subject to the IWTF fuel tax (Carter and Fritelli, 2004). This is a crucial distinction between these two sources of funding and is important to understanding likely future maintenance options. Projects are undertaken under the IWTF at a 50-50 cost share between the federal government and the inland waterways shipping industry.

BOX 3-3
OPERATIONS, MAINTENANCE, CONSTRUCTION, AND MAJOR REHABILITATION COSTS ON THE INLAND WATERWAYS

Two pieces of legislation are largely responsible for the current framework of inland waterways financing: the Inland Waterways Revenue Act of 1978 and the Water Resources Development Act of 1986. These laws together established a fuel tax on commercial barges, cost-share requirements for inland waterway projects, and a trust fund to hold these revenues and fund construction (Stern, 2012). This legislation created more financial and decision-making responsibilities for commercial operators on the inland waterway system. Today, expenditures for construction and major rehabilitation projects on inland waterways are cost-shared on a 50-50 (federal-user) basis through the Inland Waterways Trust Fund (IWTF). Operations and maintenance costs for inland waterways projects typically exceed these construction costs; these O&M costs are 100 percent federal responsibility.

The IWTF currently is supported by a $0.20/gallon tax on barge fuel. The balance in the IWTF has declined significantly due to a combination of decreased appropriations, cost overruns, and decreased revenues from previous years (see Figure 3-3). To help offset this declining balance, both the Bush and Obama administrations recommended replacing the IWTF with one or more user fees. Both the U.S. Congress and the navigation industry have rejected these proposals.

In 2010, the Inland Waterways Users Board (IWUB), a federal advisory committee that advises the Corps on inland waterways, endorsed an alternative proposal that called for increase in the fuel tax of $0.06-08/gallon. The proposal also called for the federal government and taxpayer to pay the full cost of some projects that now are cost-shared. Inland navigation shippers argue that changes are necessary to shore up the trust fund, improve infrastructure, and distribute costs more equally among those that benefit from the system. Other groups, such as Taxpayers for Common Sense, argue that an increased share of waterway costs should be borne by the user and that routine O&M costs also should be a user responsibility.

In a letter dated December 21, 2010, Assistant Secretary of the Army for Civil Works Jo-Ellen Darcy provided some of the administration's views on the IWUB proposal. The letter noted that the IWUB "would transfer a significant responsibility from the users . . . to the general taxpayer. Such a major shifting of costs is inconsistent *with the user-pay principle that helps to guide Civil Works investment decisions*" (emphasis added).

More specifically, the letter also noted, "The Board's" recommendation to increase the revenue to the IWTF is an increase in the level of the existing diesel fuel tax of 30 percent (and potentially an increase of up to 45 percent) over the current fuel tax rate of $0.20 per gallon. This would be the first such rate increase since 1996. The Army notes that this level of revenue increase would not be sufficient to support efficient investment in the inland waterways . . ." That is, the proposed increase in fuel tax would do little to address the OMR funding shortfall that confronts the navigation system.

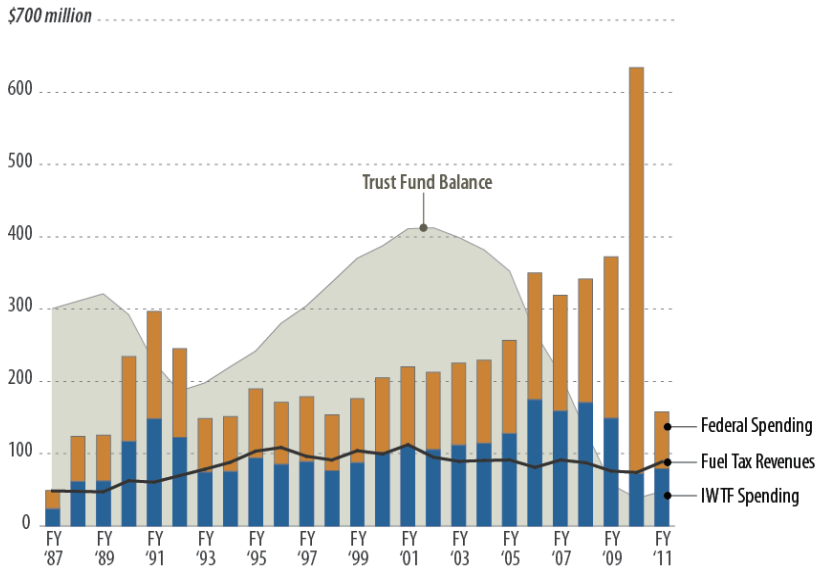

FIGURE 3-3 Federal Inland Waterway Projects: Financing Trends.
SOURCE: Stern, 2012.

In recent years, balances in the IWTF and HMTF have taken very different trajectories. In 2003, the IWTF was $412.6 million. Annually, expenditures from the IWTF exceeded revenues even though Congress appropriated funds for inland waterway modernization. Coupled with declining tax revenues due to reduced barge transport in the mid-2000s, the balance in the IWTF declined below $35 million at the end of FY 2011 (Figure 3-3). A large portion of IWTF expenditure recently has been for a single project, the Olmsted Lock and Dam Replacement on the Lower Ohio River (see Box 3-4). On the other hand, the HMTF balance has increased steadily, reaching over $5 billion at the end of FY 2010. Annual HMTF expenditures (approximately $1.0 billion) were approximately equal to revenue collected over the past decade (Fritelli, 2011).

BOX 3-4
OLMSTEAD LOCKS AND DAM

The Olmstead locks and dam project will replace 1920s-era Locks and Dams 52 and 53, the first two on the Ohio River above the confluence with the Mississippi River. These two aged facilities handle about 90 million tons of cargo annually, the highest cargo tonnage in the entire inland waterways system. Completion of the Olmsted Locks and Dam project, first authorized in the Water Resources Development Act of 1988, is the highest priority inland waterways project for the Corps of Engineers. The project is located about 20 miles upstream of the Mississippi River, near Olmsted, Illinois. The project includes two 110-foot-wide by 1,200-foot-long lock chambers, and a 2,500-foot dam with navigable pass located near the Illinois shoreline.

When the Olmsted project was authorized by Congress in 1988, the estimated cost was $775 million and the estimated completion date was 2000, but subsequent design changes, dam construction difficulties, and inadequate, start-stop funding have increased the cost estimate to $3.1 billion and extended the projected completion date to 2024 (Boselovic, 2012b). The twin 1200-foot locks were completed in 2002 at a total cost of approximately $430 million, including the costs of the cofferdam and approach walls. The contract for the dam was awarded in 2004 and construction of the dam commenced in 2005. In 2004, the total project cost estimate was revised to $1.4 billion and the completion date to 2014, by 2011, the project cost estimate was revised to $2.1 billion and the completion date to 2018; and in March 2012 budget hearings the Corps revised the cost estimate to $3.1 billion and the completion date to 2024 (Boselovic, 2012b).

The Olmsted project is being funded by the Inland Waterways Trust Fund (IWTF), which collects about $75 million to $85 million per year from a $0.20 cent per gallon tax on diesel fuel used by commercial river users, and by matching funds from the federal government. The IWTF funds plus the federal match thus provide about $150 million to $170 million per year for inland waterways rehabilitation work.

In 2011, the Olmsted project received $143 million of the IWTF funds; that is, most of the IWTF funds went to this one high-priority project (Bruggers, 2011). Even with this dominant share of the IWTF funds, plus an additional $11 million in stimulus funding from the American Reinvestment and Recovery Act in 2011, the funding for the Olmsted project was insufficient to keep the project on schedule. The IWTF funding is insufficient for even one high-priority project, and the concentration of the IWTF funding on this one project leaves essentially no funding for deployment on other rehabilitation projects in the inland waterways system.

Both the IWTF and HMTF face concerns about the need for higher revenues and expenditures in the future. In the case of the IWTF, the Inland Waterways Users Board (IWUB)[1] identified investment needs for the next 20 years totaling $18.0 billion, at an annual average of nearly $900 million, for new construction (67 percent) and major rehabilitation (33 percent; IMTS Capital Investment Strategy Team, 2010). For the HMTF, revenues have been adequate to meet annual maintenance costs for dredging to maintain congressionally authorized depth and width requirements (Fritelli, 2011). Although the HMTF generally has been adequate to meet dredging needs of current major ports, there is concern about the overall adequacy of the nation's port system in a changing international trade environment (ASCE, 2012b).

Pending completion of the new Panama Canal locks in 2014, ships transiting the canal will be larger, moving from pre-Panamax size (110 feet wide, 41-foot draft), to "post-Panamax" cargo ships (160 feet wide, 50-foot draft). East Coast and Gulf ports that wish to accommodate all types of ships from Asian harbors and markets will need to have 50-foot draft channels and harbor depths. Candidates for ports that would have to be deepened include Charleston, New York/New Jersey, Miami, and Savannah. The Port of New York and New Jersey is being deepened to post-Panamax depth as authorized by WRDA 2000. The Port of Miami is proceeding with a deepening project using funds from the State of Florida (Box 3-2). It is not clear which of the other ports, and when, might be deepened to post-Panamax depths. This issue is a major point of discussion and contention in the U.S. port and harbor community (see USACE, 2012a).

The Harbor Maintenance Fuel Tax covers only ongoing maintenance, not costs of new construction. Major port construction thus relies on some combination of congressional appropriations and local cost-sharing. In addition, many local governmental entities will incur expenditures for infrastructure improvements that are not covered by federal funding, but are dependent on continuing channel construction and maintenance by the Corps. For example, the Port Authority of New York and New Jersey is increasing vertical clearance of the Bayonne Bridge between Staten Island, NY, and Bayonne, NJ to allow for

[1] The Inland Waterway Users Board is a federal advisory committee that was established in the 1986 Water Resources Development Act.

passage of post-Panamax ships, at a cost to the port authority of $1.3 billion (PANY & NJ, 2011).

In summary, the inland navigation system relies more heavily on federal support for major maintenance than do ports and harbors, which depend more on fees from private shippers and investments from state and local governments. In an era of steady reduction of federal investments in civil works infrastructure, these distinctions may have sobering implications for prospects of future inland navigation infrastructure repairs and upgrades. The December 2010 letter from the Assistant Secretary of the Army for Civil Works to the chairman (Rep. James Oberstar) of the House Committee on Transportation and Infrastructure (also see Box 3-3) noted this distinction:

> Over the past three years, for example, receipts from the inland waterways fuel tax covered approximately 8 percent of the total costs that the Corps incurred on behalf of the companies that move goods on these waterways in these years, including costs for both capital investment and operation and maintenance. By contrast, our non-Federal partners in the coastal navigation program have paid about 80 percent of the costs of construction, operation and maintenance activities supporting coastal harbors and channels.
>
> (Darcy, 2010)

Infrastructure Status – Inland Navigation

Large portions of the inland navigation infrastructure were constructed in the first half of the twentieth century. Many dams on the Ohio River, for example, were built in the early 1900s, with some of them being constructed over one hundred years ago. The Upper Mississippi River 9-foot channel navigation project was authorized in the Rivers and Harbors Act of 1930 and completed by 1940. The Missouri River main-stem dams were authorized with passage of the 1944 Flood Control Act, and the Missouri River Bank Stabilization Project (BSNP) was authorized in the 1945 Rivers and Harbors Act. Officially completed in 1981, many revetments and other BSNP channel works were built during the 1950s and 1960s.

Much of this navigation infrastructure is nearing the end of (or has exceeded) its design life and is in various states of disrepair. Investments in routine maintenance, upgrades, and rehabilitation for the infrastructure have lagged since the mid-1980s. Portions of the navigation infrastructure, at select sites, have been repaired and rehabilitated, and the Corps undertakes maintenance activities at priority sites in greatest need of repair. To help identify priority sites and provide the basis for a systematic repair schedule, the Corps of Engineers has initiated an asset management program to identify locks and dams in greatest need of repair. For example, the Corps' Pittsburgh District has developed an infrastructure asset management system of district assets (Hawkins, 2011).

Funding Inland Navigation Maintenance, Repair, and Rehabilitation

Prospects for Divestment and Partnerships

Gradual deterioration of Corps lock and dam and other navigation facilities, combined with inadequate federal revenue streams to cover repair, presents the Corps with limited options. The Corps is not authorized, for example, to implement, unilaterally, fee increases for users of its inland navigation facilities. The Corps likewise does not have authority to privatize or otherwise divest portions of the inland navigation infrastructure. Moreover, Corps inland waterway infrastructure and its operations affect large volumes of interstate commerce, and they often have far-reaching, interstate effects on downstream aquatic resources. These conditions are especially important on large, interstate waterways like the Mississippi, Missouri, and Ohio Rivers. They are likely to affect prospects for privatization of inland navigation infrastructure, as discussed in a 2001 National Research Council report that reviewed plans for lock extensions on the Upper Mississippi River:

> [A]lmost all investment in navigation enhancement and river-training facilities is public and almost all use of the waterway is private. No federal agency would want to assume direct control over the multiple uses of inland waterways. Privatizing these facilities and services is an even less attractive option.

> A company that controlled commercial navigation would find itself making decisions that affected not only navigation, but also municipal water supply, recreation, irrigation, flood damage reduction, and environmental quality. Privatization would not work well unless the controlling firms faced the proper incentives regarding each possible use of the waterway. There are also disagreements over the goals to be achieved in managing a waterway . . .
>
> (NRC, 2001)

Divestment of inland navigation infrastructure long operated by the Corps of Engineers has been achieved in some circumstances, however. For example, the Corps of Engineers has transferred ownership of many locks and dams on Wisconsin's Fox River to the state. These transfers took place because the volume of commercial navigation traffic through these facilities had declined over time. The reduced need to provide facilities and service to support commercial navigation prompted the Corps to close some of these facilities and transfer ownership to the state (the river today is operated by Wisconsin as primarily a recreational waterway, along with some hydropower generation). Similar conditions of diminished commercial waterway traffic exist at other Corps facilities, which might offer additional divestment prospects. Ownership transfer of facilities that support large volumes of commercial traffic would be much less feasible. Additional partnerships could be explored for the operations of inland navigation infrastructure. Such public-private partnerships have worked well for some ports and harbors and for some highway systems (Istrate and Puentes, 2011). For inland navigation infrastructure, system-wide oversight, especially on large interstate rivers, likely would have to remain with the government.

Prospects for Decommissioning

Decommissioning of a dam entails full or partial removal of an existing dam and its associated facilities, or significant changes to its operations thereof. In the United States, the process of dam decommissioning includes many of the same considerations as project construction and is subject to the same federal

laws, such as the National Environmental Policy Act. Dam decommissioning is typically considered in instances where a dam's original purposes and values have diminished or greatly changed over time, and where a dam may inhibit values such as enhanced fish passage or downstream transport of sediment resources (see Box 3-5). Dam decommissioning is not a simple process, nor is it without costs. Especially for larger dams, substantial advance planning is required, including analysis of alternatives, preliminary cost estimates, permitting requirements, and consensus-building with affected parties. Economic losses due to discontinuing operation of the dam (i.e., flood control, irrigation, power generation, recreational uses) also must be considered. The Corps of Engineers has some authority for decommissioning and that differs between constructed projects, and those that have been authorized but not built. The Corps has decommissioned some projects, most of which are from the latter category.

Nearly all U.S. dams that have been decommissioned and removed or breached have been small dams; and they include many old mill dams in the northeastern United States. A prominent U.S. example of a larger dam decommissioning was removal of Edwards Dam on the Kennebec River in Maine in 1999. On the Elwha River on Olympic Peninsula in Washington State, the Elwha Dam (105 feet tall) has been removed and the Glines Canyon dam (210 feet tall) currently is being dismantled. Decommissioning of these two dams has been conducted under the 1992 Elwha River Ecosystem and Fisheries Restoration Act (P.L. 102-495). The Elwha River dams constitute the largest U.S. dam decommissioning to date.

A challenge regarding a large portion of the Corps water infrastructure is that the original, and currently authorized, purposes remain important to many parties, such as the commercial navigation sector. Although the users of and social values associated with Corps infrastructure on the nation's waterways (to a lesser extent in ports and harbors) have broadened, in locales where original project beneficiaries still rely on the infrastructure, the prospects for decommissioning are constrained. Some of the locks and dams on the lower Allegheny River in Pennsylvania provide a good example (Box 3-6). Although essentially no commercial river traffic moves through these locks and dams, this infrastructure has value to recreational boaters and river communities. Such

BOX 3-5
VALUES OF FREE-FLOWING RIVERS

In setting investment priorities for Corps infrastructure, the potential ecological benefits of removing a dam and restoring a pre-disturbance flow regime are today often integral to the necessary discussions. Hundreds of dams across the United States have been removed in the past 20-30 years. Most of these removals have been where a small dam had outlived its original purposes and where its removal offered opportunities to restore, for example, routes for migratory fish.

The benefits of free-flowing river systems accrue in two main aspects of river ecosystem function: (1) transport of sediments and maintenance of floodplains and coastal wetlands, and (2) maintenance of riverine biodiversity through provision of required flow regimes and habitat characteristics. The benefits of free-flowing rivers have become more fully understood by resource managers and ecologists alike over the past several decades, and there have been useful advances in ecological and hydrologic concepts of stream and river network function that can be applied to assess the potential benefits of dam removal. For example, the "River Continuum" concept put forward in 1980 provides a framework for understanding the impact of anthropogenic modifications of river networks, with dams and impoundments representing discontinuities in the transfer of energy to downstream river ecosystems (Vannote et al., 1980; Ward et al., 2002).

Free-flowing rivers transport and remobilize sediments, especially during high flows associated with spring snowmelt and storm events. Deposition of these sediments on flood-

Interests need to be balanced against benefits of dam removal from rivers, including elimination of O&M costs and ecological benefits. Even in instances where decommissioning may be viable, infrastructure removal could have unanticipated negative effects, such as disturbance and resuspension of toxic sediments and /or large volumes of nutrients (Gray and Ward, 1982).

Corps of Engineers dams that serve flood control purposes are among the nation's best maintained dams and are not likely candidates for decommissioning in the near future. By contrast, many Corps inland navigation dams have significant maintenance and rehabilitation needs. Without additional funding and appropriate repairs, the condition of those dams inevitably will deteriorate and decommissioning may represent a more serious alternative than in the past.

plains and coastal wetlands renews sediment lost through erosion and maintains the high productivity of these ecosystems, as de-scribed in the "flood pulse" concept. In turn, floodplain ecosystems attenuate floods, decreasing the magnitude of peak flows downstream, and coastal wetlands protect coastal communities from storm surges. In addition, riparian zones and floodplains provide critical habitats for aquatic biota and migratory birds. A controlled flood released from Glen Canyon Dam on the Colorado River in 1996 provides an example of management strategies to alleviate the impact of flow regulation on the erosion of sand bars in Grand Canyon National Park (Webb et al., 1999).

The naturally varied hydrologic regime of free-flowing rivers provides a benefit in terms of maintaining aquatic biodiversity, especially in sustaining populations of endangered fish. Flow regulation can impair the survival of native fish by causing large daily variations in downstream flow to meet power demands and by creating barriers to upstream migration of salmon and steelhead, for example. One hypothesis of the river continuum concept was that native riverine biota are adapted to both the mean and extreme conditions in flow conditions of a river system. According to this concept, restoration of more natural flow regimes by removing dams, or finding alternatives to meet peak power demands improves habitat for native fish. Other benefits to restoring free-flowing conditions by dam removal come from eliminating detrimental water quality changes associated with impoundments on river systems. For example, tailwater reaches below dams are typically cold, clear and nutrient rich, creating habitats in which nonnative species can thrive and outcompete with native fish populations, which may be adapted to turbid conditions.

Transportation Mode Alternatives

There often are alternative transport modes for the cargo that is shipped on the inland navigation system, the primary alternatives being rail and truck. For example, roughly one-third of U.S. grain exports today are shipped via rail to Portland, Oregon, where grain is transferred to ocean cargo ships (Fuller and Attanavich, 2011). U.S. freight rail carriers have in many cases upgraded and modernized their fleets in recent decades and have become more energy efficient and claim reduced environmental impacts (information about modern rail transport and technologies is available at: *http://www.csx.com*). Large portions of the inland navigation system were built before completion of the U.S. interstate highway system. There may be instances today of trucks offering viable

BOX 3-6
DEFUNDING BUT NO PATH TO DECOMMISSIONING: LOWER ALLEGHENY RIVER LOCKS AND DAMS 5-9

The locks and dams in the Lower Allegheny River provide a good example of inland waterways infrastructure for which the original commercial justification is no longer present and federal funding for major rehabilitation has declined, but for which there is no legislated authority for the Corps of Engineers to decommission and remove the infrastructure. The Lower Allegheny River once served as an important corridor for moving oil and timber from northwestern and central Pennsylvania to Pittsburgh and markets beyond and for supplying and moving product from some metal manufacturing plants. Eight locks and dams were built on the Allegheny River in the 1920s and 1930s, providing a 9-foot navigation channel for 72 miles from Pittsburgh to East Brady, Pennsylvania. The original purpose of this infrastructure was primarily to support and enhance commerce.

Since the original construction, commercial traffic on the Upper Allegheny River has decreased significantly, while at the same time use by recreational boaters has increased significantly. In 2011, for example, there were only 54 total commercial lockages at Locks and Dams 6, 7, 8, and 9, and 1,583 total recreational lockages. A total of 38,000 tons of commercial goods moved through these four locks in 2011(zero through Lock and Dam 9). By comparison, for just one of the locks at Locks and Dam 2 on the Monongahela River, 13,055,000 tons of commercial goods and 2,627 commercial vessels were locked through in 2011. Recreational vessel lockages through the same lock totaled 53 in 2011.

Due to low commercial use of the Lower Allegheny River navigation system, funding for OMR of the locks and dams has been declining steadily, with concomitant decreasing maintenance and increasing degradation. In fiscal year 2012, the budget for operation and maintenance of the Allegheny River navigation system was cut by 50 percent, to $4 million (Hayes, 2011; Thomas, 2012). That reduction caused the Corps of Engineers Pittsburgh District to cease recreational boat traffic through Locks 8 and 9 beginning in October 2011. Hours of operation were reduced for other locks in the Lower Allegheny system (Thomas, 2012). Available funding is being used for repairs as malfunctions occur. There is essentially no maintenance budget.

The Lower Allegheny River locks and dams are being removed from operation slowly through decreasing funding. There have been community meetings with the Corps to discuss the evolving conditions and concerns about impacts on municipal and industrial water supplies, marinas, and other facilities and activities. The Corps is obligated to keep the facilities running to the extent possible by allocated budget. The navigation system was established by federal legislation and the Corps was charged to build and maintain the facilities.

alternatives for shipment of commodities, fertilizer, aggregate, and other goods, especially in combination with rail infrastructure.

Economic Efficiency and Future Infrastructure Investments

The level of funding available to repair and upgrade the entire U.S. inland navigation to safe and reliable conditions will not be available in the near future. Clearly, the future U.S. inland navigation system will be different from the system of 50-plus years ago. In setting priorities for future investments, Congress and the administration will have to make choices and reach agreements about how the future system might be different. This will be challenging, but it also represents an opportunity to rethink the nation's inland navigation systems. Efficient future system investments will carefully consider economic conditions and trends, rationale for investments and account for costs and benefits associated with new construction.

In considering the viability and future of the inland navigation system, and the means for financing OMR needs, the following guiding principles for government freight programs as presented in NRC (2003) merit careful consideration:

- Economic efficiency ought to be the primary goal of government transportation policy; that is, those capital improvements and operating practices for public facilities should be selected that yield the greatest net economic benefit, considering all costs.
- Government involvement should be limited to circumstances in which market-based outcomes would be far from economically efficient. These include preventing exercise of monopoly power and dealing with non-market costs. Government also is responsible for management of facilities for which it has historically established responsibility that could not be altered in the near term, and in settings where institutional complexity necessitates government leadership. The federal government is responsible in instances where a conflict exists between nationwide and local interests and for ensuring transportation facilities for national defense.
- A government responsibility to provide facilities or leadership in developing a project does not necessarily justify government subsidy of costs.

Wherever the important benefits of a public-sector freight-related project are the direct benefits that users of the facilities receive in the form of reduced transportation and logistics costs, users should pay the costs.

- Finance provisions in public-sector programs are a major determinant of performance, affecting both the quality of investment decisions and the efficiency of operations. Reliance on revenue from users, and from local matching funds in federal grant programs will increase the likelihood that most worthwhile improvements will be carried out and facilities will be operated and maintained efficiently.

Lockage Fees for Commercial Navigation and Other System Beneficiaries

Despite funds provided through the inland waterways fuel tax, there have been concerns about the subsidy provided by the federal government for the waterways system compared to other commercial transportation modes (see NRC, 2003). One means to increase private sector revenue for the inland navigation system would be to charge fees for vessels when they pass through the locks. Such lockage fees have been proposed by administrations of both national parties, going back to the Franklin Roosevelt administration. Lockage fee proposals remain unpopular with the commercial navigation sector, without considering fees for all other users (e.g., recreational boaters).

Lockage fee proposals from recent administrations of both parties have sought to improve efficiency and equity of waterways funding. Further, the current Inland Waterways Fuel Tax policy leads to imbalances in tax revenues compared to expenditures, across different river segments (Figure 3-4). Other groups, such as a previous committee of the NRC (2001), the National Commission on Fiscal Responsibility and Reform, and the CBO (2011), have noted that increased user fees could bolster funding for system improvements (Stern, 2012).

Proposals for lockage fees as a funding source for construction and maintenance on inland waterway have a long and controversial history. Prior to the Inland Waterways Revenue Act (IWRA) of 1978 and WRDA 1986, all funding for inland waterways was from general revenues based on the precedent established by the Northwest Ordnance of 1787 (Stern, 2012). Sponsors of the IWRA proposed lockage fees to fund construction and maintenance, but barge Inland

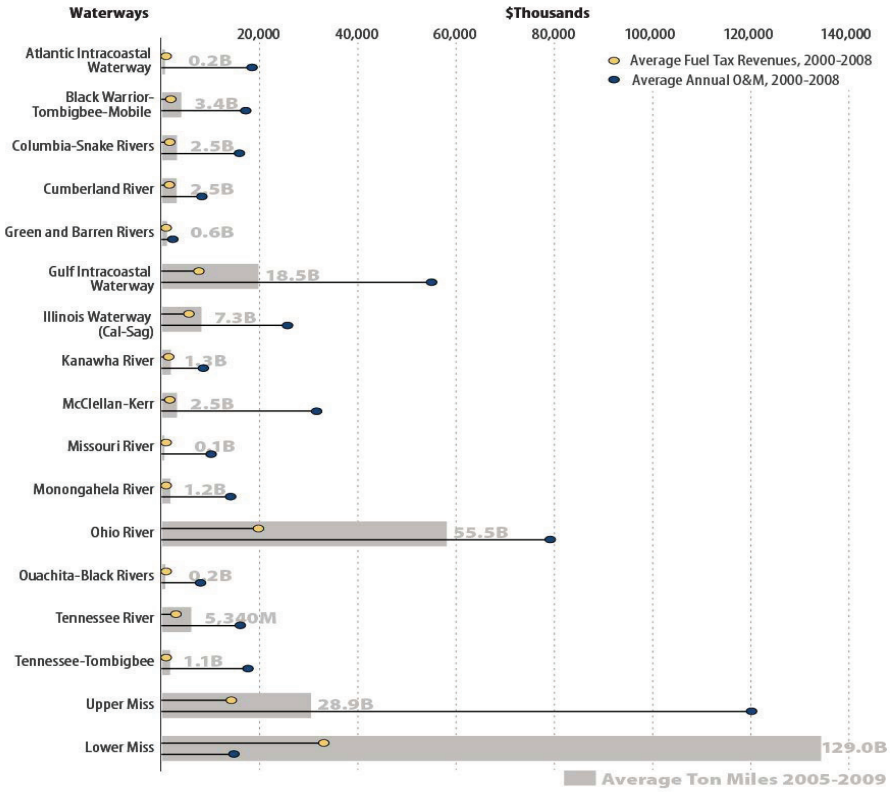

FIGURE 3-4 Fuel tax receipts relative to O&M expenditures (units in ton-miles).
SOURCE: Stern, 2012.

Waterways Revenue Act (IWRA) of 1978 and WRDA 1986, all funding for inland waterways was from general revenues based on the precedent established by the Northwest Ordnance of 1787 (Stern, 2012). Sponsors of the IWRA proposed lockage fees to fund construction and maintenance, but barge industry opposition to fees led to an alternative fuel tax that was less directly tied to usage rates of facilities within the system (Stern, 2012). Proposals for lockage fees have been opposed historically by inland navigation system users, such as the Inland Waterways Users Board. The principal concerns are that fees would

disproportionately increase the costs of barge transport and decrease the volume of barge traffic (Dunham, 2000; Stern, 2012).

There are some claims that reduced barge traffic would in turn lead to reduced exports and increased reliance on alternative modes that would be more fuel inefficient and cause more air pollution (AWO, 2009; PNWA, 2012). However, there has been little research on modal substitution for different product shipments on the inland waterways system (Fuller and Attanavich, 2011). Since construction of much of the Corps' existing water resources infrastructure in the first half of the twentieth century, the social values and beneficiaries of that infrastructure have broadened. When the Corps navigation infrastructure was constructed, especially on the Ohio and upper Mississippi Rivers, the primary beneficiaries were commercial navigation and its clients. Today, the benefits provided by these rivers—and the navigation pools created by locks and dams—are enjoyed by a wider clientele, especially for recreational purposes like boating and fishing. Declining availability of federal resources for new construction and major rehabilitation, deteriorating facilities, and a broadening base of project beneficiaries leads to discussions about which parties will finance future inland navigation system maintenance and rehabilitation. A "user pays" or "beneficiary pays," principle posits that those parties who benefit from a public good should pay for the good. It has been applied for the provision of a variety of public goods (Box 3-7 contains more detailed discussion).

The beneficiary pays principle would consider direct beneficiaries and users of Corps infrastructure as a potential source of revenue for maintenance and rehabilitation. Moreover, the Department of Army has noted the value of the "user pays" principle in guiding civil works investment decisions (Darcy, 2010; see Box 3-7). For example, locks and dams on the nation's rivers that create navigation pools for river traffic also support a recreational boating industry that enjoys considerable benefits of reliable navigation channel draft depths. Recreational boaters pay no direct fees to help maintain and repair Corps water infrastructure that supports these channel depths. Recreational boats (and kay aks, canoes, etc.) are allowed to pass through Corps lock facilities with no toll. Further, the relatively easy identification of the beneficiaries using Corps lock facilities would facilitate fee collection.

Levying new fees on system beneficiaries would involve difficult negotiations, congressional approval, and controversy. However, fundamental principles of economic efficiency, in a setting of declining funding from general reve-

BOX 3-7
BENEFICIARY PAYS PRINCIPLE

Unlike private goods that can be purchased at a market price, public goods such as national defense, highways, street lights, or a flood control dam, do not have an explicit market where prices are determined. With no market price, private suppliers would not be willing to provide the good because there is no way to recoup the costs. Samuelson (1954) was among the first to formulate the principle that the optimal output from a public good depends on consumers' marginal benefits from that output. Funding for the public good may come from general revenue, or each beneficiary could pay an amount equal to the benefits they receive. The latter approach, also known as 'a benefits tax,' 'user pays' or 'user finance,' is reflected in commonly used payments such as highway tolls for highways and parking fees in congested areas (OECD, 2002).

An important element of implementing the beneficiary pays principle (BPP) is to determine whether potential users can be prevented from receiving the benefits of a good (excludability) and whether use by one user impacts the benefits received by another (rivalry). The beneficiaries of goods that are excludable and rival (as are private goods) such as electricity and municipal water supplies, are the simplest to directly identify. The beneficiaries of goods that are nonrival but from which potential users can be excluded (sometimes referred to as "club" goods) are also easy to identify. Examples would include users of parks and highways (up to the point of congestion).

The most difficult type of good to which one can apply the BPP is 'true' public goods that are nonexcludable and nonrival. Dams, for example, provide protection to everyone in the floodplain below the dam, and one property owner's protection does not reduce that enjoyed by another. Also, wetlands provide ecosystem services such as wildlife habitat and flood control that may benefit many people but one person's enjoyment does not limit the benefits enjoyed by another. Although it may be another. Although it may be more difficult to identify the benefits and beneficiaries, it is still possible to use the BPP to provide for these goods (Pagliola & Wunder, 2008).

The BPP has been applied for the provision of a variety of public goods. A commonly used approach is to apportion the costs of a public good among the beneficiaries. Costs would include planning and design, construction, operation, maintenance, and mitigation. For example, the separable cost-remaining benefits (SCRB) method has long been advised for water project planning (Inter-Agency Committee on Water Resources, 1958) and issues related to implementation are discussed in a number of studies (e.g., U.S. Department of Interior, 2001; De Souza et al., 2011).

A common reason for adopting BPP is to encourage more efficient investment and maintenance in public projects when general revenue funding is lacking. For example, the Federal Energy Regulatory Commission (FERC) recently adopted reforms for electric

"transmission planning and cost allocation requirement for public utilities to promote more these reforms is the policy objective "that the costs of transmission solutions chosen to meet regional transmission needs are allocated fairly to those who receive the benefits from them" (FERC, 2011). Although no specific cost allocation method is required, the FERC rule creates a framework in which costs and beneficiaries are directly identified to encourage investment and maintenance planning in the future.

The central idea of the BPP that costs should be allocated to those who benefit also has to be considered in the context of other criteria. In the case of user fees for government services, for example, the Government Accountability Office (GAO) recommends that efficiency concerns should also be balanced with equity (ability-to-pay), revenue adequacy, and administrative burden (GAO, 2008). Each type of government service or project may have different weights applied to these criteria, so there is not a specific blueprint for applying the BPP. There is also no clear guidance on what portion of a project costs should be user financed or funded through general revenues.

nues, will lead to the consideration of these beneficiaries being considered as potential sources of additional revenue:

> Application of these principles (e.g., economic efficiency) frequently is controversial, and many government investment and operating decisions are not consistent with them. Controversy is especially likely when proposals are made for changing existing practices regarding users fees or funding sources…and when particular industries or local interests argue that a project's national significance justifies federal or state subsidy instead of funding through project-generated revenues. It is important to economic welfare that resources be concentrated on high-payoff capital investments that are available, rather than diverted to constructing facilities that will be high-cost or underutilized.
>
> (NRC, 2003)

Partnerships with States

There are opportunities for partnership of the federal government with states in sharing the costs of the inland waterways system. In the past, the role for state and local governments was to serve as the local sponsor for federal projects. With decreases in available federal funding, state and local governments have recognized the need to fund infrastructure improvements and maintenance. This approach has the advantage that these governmental entities have a broad range of funding mechanism options to generate revenues. These mechanisms could include user fees, fuel or sales taxes, or property taxes. Some portions of the Gulf and Atlantic Intracoastal Waterways are operated and maintained by the states they border. The Florida Inland Navigation District provides an example, as discussed in Box 3-8.

FLOOD RISK MANAGEMENT

The Corps of Engineers has constructed an extensive infrastructure designed to manage flood risks along rivers and also infrastructure to protect against surges from coastal storms. The Corps has built approximately 11,750 miles of riverine levees across the nation and provides shoreline protection for hundreds of miles of U.S. coastlines. Many of the Corps' approximately 700 dams also serve flood control purposes. Like its infrastructure for navigation activities, a large portion of Corps of Engineers levees and other protective structures were constructed in the first half of the twentieth century or earlier and face many similar maintenance, rehabilitation, upgrade—and funding—issues.

In the Corps navigation mission area, taxation and trust funds for navigation infrastructure OMR are federally governed and thus directly relevant to Corps operations. By contrast, in the Corps flood risk management mission area, taxation and financing issues for infrastructure OMR are local responsibilities and less germane to Corps programs. This section thus focuses on Corps responsibilities for flood risk management, in particular by discussing nonstructural flood management options on which the Corps can collaborate with local communities, as consistent with the shared responsibility for managing flood risk. Financial OMR responsibilities for flood pro-

BOX 3-8
FLORIDA INLAND NAVIGATION DISTRICT

An example of alternative funding mechanisms for operation and maintenance of inland waterways is the Florida Inland Navigation District (FIND). Initially created by the Florida Legislature in 1927 to serve as the local sponsor for inland waterways under the River and Harbor Act of 1927, FIND has developed into the principal state government entity with responsibility for management of the Atlantic Intracoastal Waterway in Florida. The FIND is governed by an appointed Board of Commissioners who represent each of the twelve counties along the Waterway that stretches from the Georgia border to the Florida Keys. Funding for the FIND's activities is provided through a millage assessment (currently 0.0345 mills) on *ad valorem* property within each county. These activities include dredging operations and waterway maintenance, construction and maintenance of boat marinas and ramps, and Waterway studies and educational programs. In recent years, the FIND has assumed an increasingly larger share of O&M expenses for the Waterway as federal funding has declined. For fiscal year 2011-2012, Waterway O&M amounted to 52.1 percent ($38.9 million) of the total FIND budget.

tection infrastructure differ from those in the Corps navigation support mission, as described in the previous section. Levees constructed by the Corps of Engineers that are locally maintained are eligible under emergency situations for federally funded maintenance under Public Law 84-99, the Flood Control and Coastal Emergency Act. The Act provides federal funding for emergency operations for flood control works threatened or destroyed by a flood or coastal storm, but it is not meant to cover general levee maintenance. All levee systems considered eligible for P.L. 84-99 assistance must be approved by the Corps to be in the Rehabilitation and Inspection Program before the flood event. P.L. 84-99 will repair levees to only pre-event conditions, and no improvements or enhancements are authorized. Outside of P.L. 84-99, riverine and coastal levee OMR costs for non-federal levees are not a federal responsibility. The role of the Corps of Engineers in levee OMR across the nation generally is one of technical support, including levee inspections and providing manuals and training on levee OMR.

Flood risks can be only partly mitigated by protective structures, and levees and coastal structures provide protection from some, but not all,

floods. Flood risks can be also mitigated by many 'nonstructural' factors, including measures such as building codes, flood insurance, and zoning. Generally speaking, nonstructural flood risk reduction measures are those that do not affect the flow of flood waters. Rather, they address how and where development might take place or how risks to existing development can be reduced by elevation, relocation, or other mitigation measures. Reduced availability of federal resources for large civil works projects for flood protection thus does not necessarily entail increased risks from flooding and, in some instances, may present opportunities to implement less expensive and more sustainable flood risk alternatives.

In many parts of the nation, there are large numbers of people and extensive amounts of property behind existing levees and other protective structures that have significant maintenance and rehabilitation needs. Proper maintenance and rehabilitation of these structures, especially in large urban areas, presents substantial technical, financing, and other challenges. Flood risks in these settings will not be reduced easily or quickly by implementing nonstructural measures. At the same time, given the limited availability of general funds from the federal government, and financial challenges facing nearly all U.S. state and local governments, there is a pressing need for less costly and more efficient measures to reduce risks to public safety and to reduce flood damages. Communities with substantial flood hazards surely will continue to explore financing and construction opportunities to maintain and rehabilitate traditional flood protection structures. The details of funding, financing, and taxation processes and opportunities are very site specific and typically entail complex collaborations and contracts among federal, state, and local—both public and private—entities. A number of agencies, including the Corps of Engineers, are conducting meaningful evaluations regarding these financing and fiscal opportunities and details. Although careful evaluation of the myriad financing and fiscal opportunities was beyond this project's limited scope and resources, further interagency collaboration and discussion will be useful in developing some demonstration efforts to advance the concepts.

Infrastructure Status

Dams

The Corps of Engineers today owns and operates approximately 700 dams. These dams range in size and purpose from large multipurpose projects to waterways navigation dams. Not all these dams serve flood control purposes. Navigation dams on the upper Mississippi and Ohio Rivers, for example, were not designed for flood protection and do not provide such benefits. Corps dams that provide flood risk reduction almost always support multiple purposes, such as hydroelectric power generation, water supply, and recreation. Approximately 95 percent of the dams managed by the Corps are more than 30 years old, and 52 percent have reached or exceeded nominal 50-year project lives (USACE, 2012b; USACE, 2012c). It must be emphasized, however, that a nominal project life has uncertain meaning for major components of dams, such as large earth embankments or concrete monoliths.

The Corps of Engineers has developed an extensive set of programs and activities as part of its Dam Safety Program, which includes studies and remediation construction (USACE, 2012c). Recent evaluations by the Corps find that half of the Corps' dam portfolio is actionable for rehabilitation, and that the potential requirements would exceed $20 billion (Halpin, 2009). These dams are widely spread across the nation and exhibit varying degrees of deficiency and life-safety risk. It is important to note that, from a life-safety perspective, high-hazard dams are defined as those whose failure would place one or more lives in danger (Interagency Committee on Dam Safety, 1998).

Levees

Many problems associated with levees have come into the spotlight since Hurricane Katrina and since identification of levee reliability issues in the California Bay-Delta region. These problems range from catastrophic failure of some levees and floodwalls in New Orleans, to structural integrity of levees that are owned and maintained by local authority and may be inadequately designed and/or maintained. The problems include difficult questions about how to determine the structural, hydrologic, and other

technical aspects of existing levees, to who has the authority to ensure levees are adequately designed, constructed, and maintained, to responsibilities for the consequences when levees overtop or fail. The complex levee ownership and maintenance issues in the Sacramento District provide a good example (see Box 3-9). A fundamental concern is that there is no comprehensive, easily accessible national listing of all flood-protection levees.

This would provide crucial information in informing decision makers in deciding which levees may be adequate for the areas they protect, which are not, which might be candidates for continued investment, and which are simply piles of dirt created over the years to reduce floods on farmland or other low-lying areas.

As a first step toward an inventory, Congress provided $30 million in emergency supplemental funds to the Corps in 2005 to begin an inventory of levees within the Corps portfolio (which includes federally maintained levees, plus all levees qualified to be included in the Corps rehabilitation program under Public Law 84-99). Some estimates are that the federally owned fraction may be as low as 10 percent of levees across the nation (National Committee on Levee Safety, 2009). Additional funding has been provided so that the Corps now has a listing, location, ownership, and general condition of the roughly 2,000 miles of federally owned and maintained levees, as well as the 12,000 or so miles that were federally built and locally maintained and in the federal "system" (P.L. 84-99 program). Some estimates suggest that there are perhaps another 100,000 miles of levees in the United States whose location, ownership, and condition are largely unknown. The Corps has asked states to seek data to add whatever levee information they might have to the inventory, which may add some more information to the database, but likely will be limited in nature. It is unclear what portion of the 100,000 miles even warrants inclusion in the inventory.

Funding Issues and Options

Dams

The Corps program has been undergoing significant changes in response to the National Dam Safety Act (which was passed as part of WRDA, 1996) and

BOX 3-9
SACRAMENTO-SAN JOAQUIN DELTA LEVEE SYSTEM: RISKS AND REHABILITATION

California's Central Valley, one of the nation's highly productive agricultural regions, is drained by the Sacramento River flowing from the north and the San Joaquin River flowing from the south. These rivers converge in the Sacramento-San Joaquin Delta before flowing to Suisun Bay and eventually to the San Francisco Bay and the Pacific Ocean. The Delta region comprises about 738,000 acres of land in six counties. Once dominated by islands, wetlands, and riparian forests, the Delta has been completely reconfigured for agriculture. Beginning in the 1850s, levees were constructed along the Sacramento and San Joaquin Rivers, and many of their tributaries, to make the land usable for both human settlement and agriculture (Kelley, 1989).

The Central Valley today has one of the nation's most extensive levee systems, with approximately 1600 miles of federal levees and an equal length of nonfederal levees. The Delta region includes approximately 1100 miles of levees, of which 385 levee miles are incorporated into federal flood control projects, mostly along the main-stem Sacramento and San Joaquin Rivers. The 700-plus miles of nonfederal levees, many of which line not rivers but rather channels and prevent tidal inflows, generally do not meet the same design standards as the federal levees (USACE, 2006). Unlike river levees, which experience only periodic water loading during floods, many Delta levees have constant water loading. The aging Delta levee system is fragile and undergoing failure (USACE, 2006; Mayer, 2010). Performance is

recommendations by a specially convened independent, external review panel (ASDSO, 2001). A "risk informed" management approach has been adopted and is being implemented (see USACE, 2012d). The Corps Dam Safety Program is important in the context of this report and its emphasis on setting priorities for infrastructure investments. The Corps is using a risk-based approach to assess the risk status of dams and to prioritize dam safety investments for the dams in need of life-safety risk-reduction actions.

Within its dam safety program activities, the Corps has conducted a screening of all of its nearly 700 dams to identify and classify its highest risk dams in need of urgent and compelling action (USACE, 2012c). The Corps' Dam Safety Action Classification (DSAC) program is intended to provide consistent and systematic guidelines for appropriate actions to address dam safety issues and of an urgent and compelling situation requiring immediate action for unsafe

degrading because limitations of original design, decreased capacity of flow channels from sedimentation, subsidence, sea level rise, and inadequate maintenance practices. There have been many Delta levee breaches, and there is great concern about multiple levee failures in the event of an earthquake or large storm. The City of Sacramento, now a major urban area with a population of approximately 500,000, is at substantial risk for a catastrophic flood event (Mayer, 2010).

Both federal and nonfederal levees in the Delta region are maintained by local reclamation districts with assistance from the State of California (USACE, 2006). Levee system maintenance historically has been inadequate because funding from reclamation district taxes on predominantly agricultural lands is low.

To begin to address the inadequate and failing levee infrastructure of the Delta, Congress passed the CALFED Bay-Delta Authorization Act in 2004. The CALFED Act directed the Corps to identify and prioritize potential levee stabilization projects that could be carried out with authorized federal funds ($90 million initially and supplemented with $106 million in WRDA 2007) and required matching support. In response, the Corps invited Delta stakeholders to submit project proposals along with commitments of cost sharing. Delta region reclamation districts and flood management agencies submitted 68 project proposals totaling more than $1 billion in estimated project costs (USACE, 2011a). Work has begun on the projects determined by the Corps to be of highest priority. This is just a first step to addressing Delta levee system rehabilitation and redesign needs. A long-term strategy is being developed with the State of California through the Sacramento-San Joaquin Delta Islands and Levees Feasibility Study.

deficiencies of Corps dams (ibid.). The actions range from immediate recognition dams, through normal operations and dam safety activities for safe dams.

Levees and Other Protection Infrastructure

OMR funding for flood protection levees presents its own set of financing challenges. In comparison with dams and their flood control purposes and OMR arrangements, however, levees present a clearer line of relative responsibilities. The roughly 14,000 miles of levees in the federal levee system include, for example, the large Mississippi River levees that are part of the Mississippi River and Tributaries (MRT) project. Such levees are federally owned, and their OMR costs for flood protection improvements generally are 100 percent federal

responsibility. The tens of thousands of miles of other levees across the nation are owned by and are the responsibility of local governments, member organizations (e.g., special levee districts), or private entities. Some of these levees were constructed by the Corps of Engineers and turned over to communities.

For levees constructed by the Corps, the minimum nonfederal (local) share is 35 percent. Local cost-share requirements can represent a considerable challenge to financially struggling communities that are seeking structural flood protection. As a result, many communities consider less expensive alternatives for flood risk management, which could include options such as relocations, zoning restrictions in floodplain areas, building codes, and other 'nonstructural measures' (see Box 3-10). Such flood management alternatives are not new. The late geographer Gilbert White, for example, and many other scholars and practitioners, for decades encouraged less intensive floodplain development and alternatives to large civil works structures to combat floods (see White, 1945, 1960).

Despite some successes, these types of alternatives have not always received full consideration. Federal water project planning guidance, for example, may not always have encouraged unconventional, nonstructural alternatives (see Box 3-10; also see NRC, 1999). In any event, a resource constrained environment will cause communities and others to carefully consider less expensive alternatives to flood risk management, which require fewer long-term OMR costs, and which may also enhance environmental benefits. As stated in this committee's 2011 report, "given current budget realities, the nation may have to consider more flexible, innovative, and lower cost solutions to achieving water-related objectives" (NRC, 2011).

Flood Risks, Infrastructure, and National Flood Policies

Despite billions of dollars invested in flood control structures by the Corps of Engineers, the U.S. Department of Agriculture, and the Department of the Interior, and despite a National Flood Insurance Program enacted in 1968, U.S. flood damage losses increased during the twentieth century (National Weather Service, 2012).

This trend of increasing national flood damage losses over time has continued into the twenty-first century (Figure 3-5). The late geographer Gilbert

BOX 3-10
COMMUNITY COMPREHENSIVE APPROACHES TO MANAGING FLOOD RISK

Past federal top-down approaches to manage flood risk typically promoted structural measures like levees or dams. Furthermore, prior to passage of the 1986 Water Resources Development Act and a new set of cost-sharing criteria, structural projects built by the Corps were 100 percent federally funded, which made them a favored solution for communities. The Corps approach to managing flood risks was developed by a cadre of Corps engineers trained in hydrology and hydraulics in the early twentieth century. The Corps processes estimating flood control project benefits, such benefit-cost analysis, and estimates of "damages prevented," were designed around civil works structures.

Starting in the late 1960s, some communities began questioning the strong reliance on structural solutions to flood risks. Questions were raised about the Corps' apparent inability under federal rules and procedures to identify viable nonstructural alternatives in its flood damage reduction studies. A committee of the National Research Council considered these issues and concluded that "the benefits of flood damages avoided should be explicitly accounted for in calculating project benefits" and recommended further study to determine if systematic biases existed against nonstructural solutions (NRC, 1999).

The city of Napa, California actually had to get congressional authorization for a combined solution, with a setback levee, purchase and restoration of upstream wetlands to store floodwater to lower flood levels, Department of Transportation funding to funding to raise bridges that were blocking flow, and FEMA mitigation buyout grants for some buyouts.

Grand Forks, North Dakota used FEMA buyout grants to buy out structures within a few blocks of the river, then grants from the Housing and Urban Development Authority (HUD) money to buy out a few more houses to make room for a much smaller levee way back from the river, leaving the buyout land for a recreational park that is used for camping but not permanent structures that could be damaged in floods.

Davenport, Iowa, is the largest city along the Mississippi River without a flood control levee. The city decided that it did not want a levee that would wall the city off from the Mississippi River and its aesthetic, historical, and cultural values. Over the years, the city has bought out structures to create parks and open space, limiting development in order to limit possible flood losses.

Today, Cedar Rapids, Iowa, is in the process of recovering from a disastrous 2008 flood of the Cedar River that inflicted considerable damage on structures in the floodplain. The city is working with the Corps of Engineers and is implementing a plan that includes a combination of structural works for higher-value property (some of which has been/is being constructed with private funds), relocations, and changed zoning regulations in vulnerable floodplain areas.

Nonstructural and less traditional approaches to flood risk management often present very complex administrative, real estate, financing, and social and cultural challenges. Satis-

factory policies invariably take years, or decades, to develop and thus require sustained community leadership. These approaches generally enjoy strong citizen support in the long run, as they tend to be economically viable, improve public safety, make the community more resilient in the face of disasters, reduce threats of flood losses to structures, and are compatible and beneficial to local aquatic and riverine ecosystems.

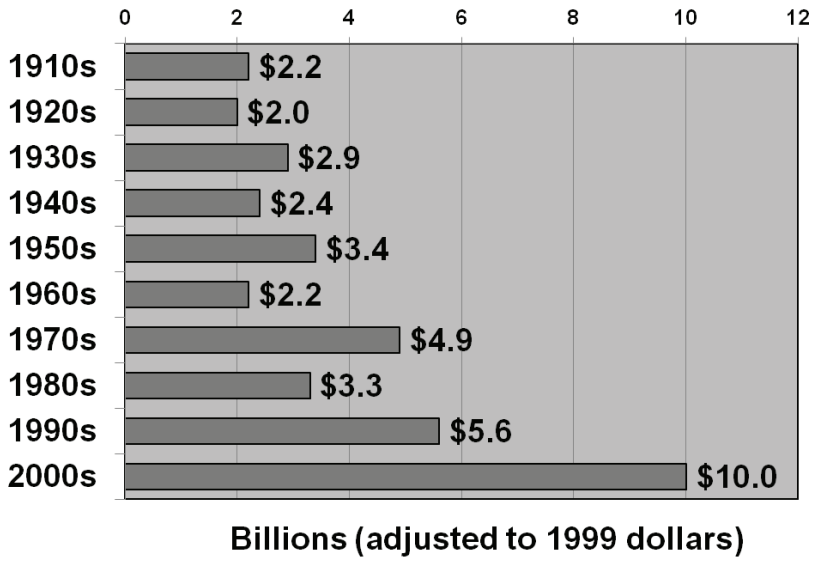

FIGURE 3-5 Average Annual U.S. Flood Damages.
SOURCE: Data from the National Weather Service, 2012.

White was a leading advocate for alternative approaches to U.S. flood risk management and floodplain development. In his doctoral dissertation, which was entitled *Human Adjustment to Floods,* he promoted the idea that, instead of various concerned entities' trying to control rivers and waterways with dams, flood-prone areas would be better left undeveloped (White, 1945). In connection with his earlier work as secretary to the Mississippi Valley Committee of the Public Works Administration, White (1939) stated that U.S. national flood policy was one of:

- Protecting floodplain occupants against floods,
- Aiding them when they suffer flood losses, and
- Then encouraging more intensive use of the nation's floodplains.

Although national floodplain development decisions have generally favored a stronger reliance on civil engineering works than Gilbert White and others might have advised, the dwindling of federal resources available for structural options will cause more states and communities to consider less expensive flood-risk management strategies. Research from White and others demonstrates that the extent and condition of physical infrastructure does not necessarily correlate with levels of protection and in some cases encourages more floodplain development, which in turn can increase flood losses.

The Corps of Engineers has more fully embraced the notion of nontraditional alternatives in flood risk management. Figure 3-6 is a chart used frequently in Corps of Engineers presentations of national flood risk management. The chart shows clearly that flood risks cannot be fully eliminated or managed by structural measures alone; rather, numerous other 'nonstructural' factors such as land use practices, zoning regulations, building codes and others affect flood risk. The chart also shows that even an optimal array of traditional and nontraditional approaches cannot fully eliminate flood risks in vulnerable areas.

The Corps often uses Figure 3-6 today to explain that adequate flood risk management cannot simply be accomplished only through civil works structures built with federal funding, but rather requires a mix of measures and actions taken at the federal, state, and local levels. The chart also reinforces the point that flood infrastructure conditions do not necessarily reflect levels of protection, and that reduced levels of federal funding for large structures need not represent a barrier to reducing risk, and in a way may represent opportunities (also see NRC, 2012).

The size, extent, and configuration of the United States and the federal levee systems, dams, and coastal protection infrastructure that serve flood control purposes defy simple categorization of overall level of protection provided and the infrastructure's condition and priority maintenance and repair needs. Congress has authorized the Corps to work with FEMA on a dam safety program and on a levee safety program. Over one-half of the dams managed by the Corps today are older than 50 years (USACE, 2012b). The Corps and FEMA have made progress on initial inventory, but more work needs to be done to

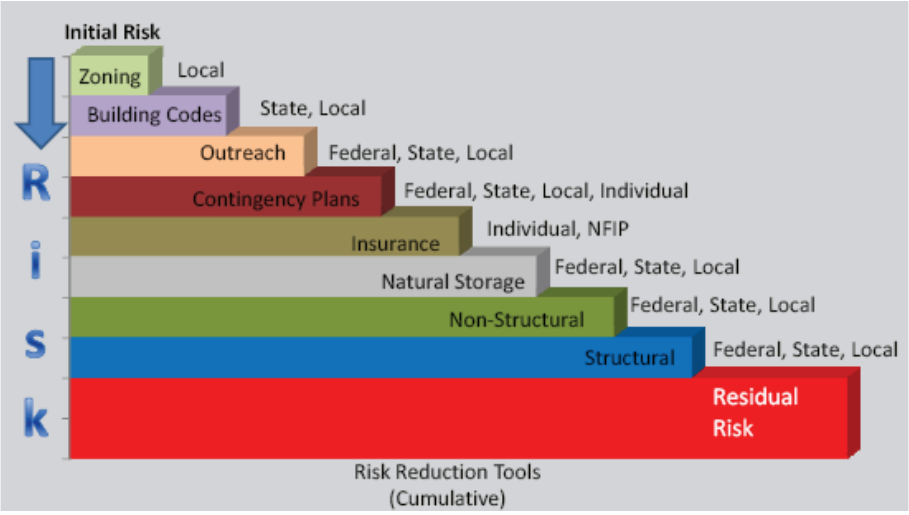

FIGURE 3-6 Shared Flood Risk Management: "Buying Down Risk."
SOURCE: Riley, 2008.

more accurately inventory, evaluate, and classify the roughly 14,000 miles of federal levees. Improved inventories of flood risk management dams and levees are critical components of asset management and portfolio planning.

Lessons from Flood Risk Infrastructure and Policy

In considering national flood protection infrastructure needs and priorities, the Corps of Engineers plays an important leadership role, but the Corps is only one of numerous federal, state, local, and other actors in national flood protection policies and activities. Levees and floodwalls protect communities, private structures, key infrastructure, and an extensive mix of public and private resources. These structures provide many benefits to tens of thousands of U.S. communities. However, despite varying levels of protection provided by these structures, even well designed and well maintained engineering structures can be overtopped by floods. Flood damage risk also involves policies such as zon-

ing, land use practices, building codes, and other "nonstructural" approaches. Federal investments in flood protection structures will be enhanced to the extent that local land use policies behind levees are designed to limit residual risks in leveed areas. Currently, there is no provision in Corps programs or sponsorship agreements that encourages or requires local sponsors to implement nonstructural measures (e.g., land use zoning) that could help reduce the consequences of structural failure or overtopping.

There will be fewer federal resources available for the Corps of Engineers to continue its leadership role in flood control via construction of large new civil works projects. The Corps also acknowledges that a wide range of community-level decisions and practices are major—perhaps the primary—factors in reducing flood risks. The future of U.S. national flood management will feature less federally centered and top-down projects with large civil works structures, and more local-driven, community-centered, and less expensive alternatives that reflect the dynamic nature of river-floodplain systems and allow rivers to move more freely into their floodplains during high flows. Recent changes in the National Flood Insurance Program under the Biggert-Waters Flood Insurance Reform Act of 2012 will increase public awareness of flood risks by strengthening requirements for flood insurance, improving flood mapping, and allow insurance premiums to reflect eventually full actuarial risk.

In the future, the Corps will be more of a flood risk management partner in providing technical advice and support to local communities. Those local communities will be expected to assume a more active role in all aspects of managing floods, including local funding for maintenance or even select relocations of structures out of hazardous flood zones. Many communities have made explicit decisions to employ less traditional, nonstructural approaches to managing floods, such as zoning regulations and flood insurance. Strategies such as allowing rivers to occasionally overflow into floodplains that have only minimal infrastructure not only reduce risks of property and financial losses of flooding but also allow floodplains to serve as storage areas to reduce downstream flood peaks. These nonstructural actions can be used to guide development in a growing community, and they can be employed in floodplain areas behind levees and other hard infrastructure that are difficult to properly maintain Moreover, these strategies generally enhance environmental and related social benefits. These types of practices, which harken back to the work of Gilbert White several decades ago, hold promise in moving the nation toward

flood risk management that is less expensive, puts fewer lives and less property at risk from floods, and provides greater environmental benefits and contributes to community resilience and sustainability. They also provide opportunities for the Corps of Engineers to transition from its previous leadership role, primarily through civil works construction, to being a leading federal partner in flood risk management via more technical support and collaboration with states and communities.

HYDROPOWER GENERATION

Hydropower generation is not among the primary missions of the Corps of Engineers, but the Corps has developed numerous hydropower projects in conjunction with its flood risk management and navigation missions and is a national leader in generating hydroelectric power. Hydropower facilities represent an important component of the Corps "hard infrastructure" that is the focus of this report. These facilities are important because of their large number and their unique role as a revenue generator for the Corps and the federal treasury. Federal hydropower resources involve projects built and operated by three agencies: the Corps, the Bureau of Reclamation, and the Tennessee Valley Authority (TVA). The national hydropower industry is approximately one-half federal and one-half nonfederal in terms of generating capacity. Of these three agencies, the Corps has the most projects. It operates 75 power plants with a total rated capacity of 20,500 megawatts (MW; Sale, 2010). In addition, there are another 90 nonfederal hydropower plants located at Corps dams with a total capacity of 2,300 MW (Sale, 2010).

Power generated at the federal projects is sold and distributed by four Power Marketing Administrations (PMAs), which are part of the Department of Energy and responsible for marketing federal hydropower. The four PMAs—Bonneville, Western, Southwestern, and Southeastern-market power to much of the continental United States. Bonneville Power Administration is the PMA with the most Corps project generating capacity, and the Corps' largest hydropower facilities are on the Columbia River.

As in its other mission areas, the Corps hydropower facilities are facing the challenges of an aging infrastructure and limited access to sources of revenue for adequate maintenance and repair. There are important legal and contractu-

al issues at play that limit the Crops' ability to access revenue generated at most of its power facilities, with those of the Bonneville Power Administration being a notable exception. The Corps hydropower program also is affected by pressures to reallocate reservoir storage to non-power uses.

This section examines the status of the Corps hydropower program, challenges it faces, and unique opportunities that it has relative to other water resources infrastructure because of inherent revenue generation in the program. A primary source of information and perspective for this section was the comprehensive and critical evaluation of the Corps hydropower program by Sale (2010).

Infrastructure Status

Through its 75 hydropower plants and installed generation capacity of 20,500 megawatts (MW), the Corps owns and operates approximately one-fourth of the nation's hydropower capacity. Most of its generating capacity is in the Federal Columbia River Power System (FCRPS), with much of the remaining capacity in its Missouri River dams. The Corps' Columbia (and Snake River) and Missouri River hydropower generation capacity combined represents about 75 percent of the Corps' national generating capacity (USACE, 2012a). Average annual energy generation from Corps projects is approximately 70 billion kWh (worth approximately $5 billion at current wholesale prices for power), and annual revenue to the U.S. Treasury from Corps hydropower sales is in the range $2 billion to $3 billion per year (Sale, 2010). This represents over half the size of the entire Corps' annual appropriation.

As of 2010, the median age of all Corps hydropower projects was 47 years, and 90 percent of the projects were 34 years old or older (Sale, 2010). Given the ages of the facilities, OMR needs and failure rates are increasing, along with associated decreases in performance. As an example, total hours of forced outages across all Corps hydropower projects have been increasing steadily since at least 1999 (Figure 3-7).

In an era of heightened interest in energy policies and sources, electricity generation from Corps hydropower projects has been decreasing steadily as a result of insufficient equipment maintenance and rehabilitation. Total electric power generation from Corps hydropower projects decreased from 73.6 TWh

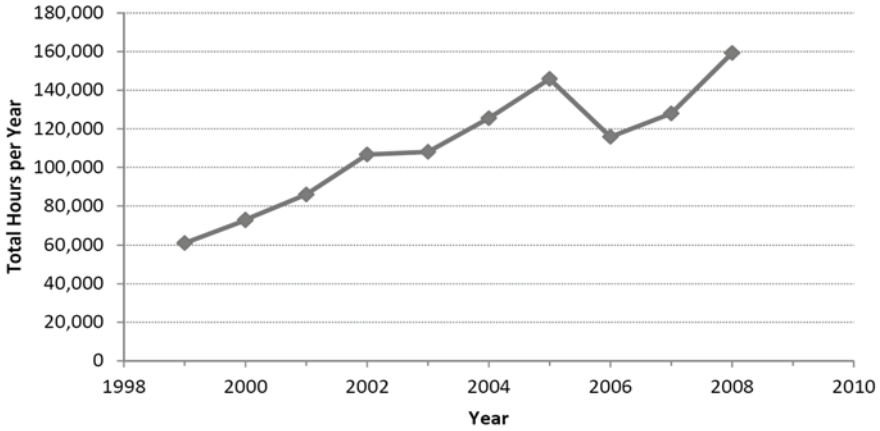

FIGURE 3-7 Total hours of forced outages over all Corps hydropower projects for 1999-2008.
SOURCE: Sale, 2010.

in 2000 to 61.7 TWh in 2008 (Sale, 2010), a decrease of 16 percent. At some Corps hydro power projects, none of the original equipment has been replaced since the facilities were constructed 30 or more years ago.

Annual budgets for repairs and upgrades of most of the Corps hydropower equipment have been inadequate for a long time (Sale, 2010). This not only has resulted in degraded infra-structure and less efficient operation, but has also meant missed opportunities for utilizing technological developments through upgrading to newer, higher-performing technology. Recent developments in hydro-power generating technologies and materials offer opportunities to upgrade to more efficient operations with less water use and less environmental impact, but fiscal constraints have largely inhibited upgrades. Developments in turbine design, runner configuration, and generator efficiency make it possible for existing dams to make modifications that can either produce 15-25 percent more with the same water flows and hydraulic heads that currently exist, or produce the same amount of power as is currently possible but with 15 to 25 percent less water flowing through the turbines. Through a hydropower generation efficiency program in the 1980s and early 1990s, the Tennessee Valley Authority (TVA) achieved a 34 percent increase in power generation with the same water availability (Sale, 2010).

In 2009, the Corps initiated a Hydropower Modernization Initiative (HMI), which is using risk assessment and net present benefit methods to identify the most pressing investment needs for hydropower rehabilitation efforts, and the potential for energy generation increases at particular facilities (Sale, 2010). From the evaluation of the first six Corps facilities, an average energy increase potential of 8 percent was identified and investments to achieve the increases were deemed cost-effective. Funding the investments will generally be difficult for facilities outside the Bonneville system, however, as discussed below.

Although there is much interest in increasing domestic hydropower production, there are challenges confronting hydropower production beyond just finding the resources to replace, rehabilitate, and upgrade equipment. The fate of hydropower is entwined with the opposition to large dams based on economic, social, and environmental factors. Dams change river flows and the fish runs that depend on them, alter water chemistry, change riverine landscapes, and inundate large areas that can include scenic canyons and valleys (Moore et al., 2010). There is growing interest in dam removal in the United States, which could affect some Corps hydropower projects in the future, although likely not the largest projects. In addition, climate change adds concerns about reliability and predictability of hydropower development. Hydropower production also faces increasing competition for use of the water and for reservoir storage space. Many Corps dams and reservoirs are part of multiple-purpose projects, so that hydropower must compete with other uses such as flood protection, irrigation, water supply, efforts to protect fish, and efforts to restore aquatic ecosystems. There is growing interest in sustainable reservoir operation (Jager and Smith, 2008). Some or all of these varied factors enter into discussions about the future of hydropower at particular project locations.

Funding Issues and Options

Hydropower is provided only modest funding in Corps budgets. In the Fiscal Year 2013 proposed Corps budget, for example, hydropower is allotted $180 million, with $178 million for operation and maintenance, and only $2 million for construction (USACE, 2012d). By contrast, the FY2013 budget includes $1.41 billion for flood risk management, $1.75 billion for navigation, $512 million for aquatic ecosystem restoration, and $252 million for recreation (USACE,

2012e). The Corps hydropower budgets in 2010, 2011, and 2012 were $230 million, $207 million, and $182 million, respectively (USACE, 2009, 2010, 2011b). These budgets are far below what is needed for adequate operation and maintenance, even before consideration of replacement and rehabilitation needs. Sale (2010) points out that the international organization Electric Utilities Cost Group has provided a best-practices estimate of $50/MWh for annual operation and maintenance costs at hydropower facilities. For Corps hydropower production of 70 TWh per year, the FY2013 budget of $180 million corresponds to $2.57/MWh. According to the Phase 2 HMI report issued in 2010, in which 54 Corps hydropower projects were evaluated, if no action is taken on modernization of these projects they will incur a combined loss of $7 billion of power revenue benefits over 20 years (Sale, 2010).

In order to realize the full potential for installed hydropower generation capacity at Corps projects, new approaches to funding OMR for hydropower must be developed and made possible through legislation. As noted in Sale (2010), PMAs are required by law to sell federal hydropower at rates that usually are significantly below market rates. These sales occur under long-term contracts that cannot easily be changed. The primary customers and beneficiaries of this power pressure the federal power producers to keep operation and maintenance costs as low as possible so as to keep power rates low.

Sale (2010) outlines three possible paths forward for Corps hydropower projects: (1) status quo, (2) privatization of more facilities, and (3) modernization.

> The **Status Quo** path would continue the current trajectory of the Hydropower Program with minimal changes in any aspect. Most importantly, Congressional budgets would most likely be flat or declining. New legislation authorizing more direct funding through PMAs would not occur, but limited agreements for direct funding from federal power customers . . . would provide some of the additional funding needed for O&M and equipment replacements. However, because total funding would not keep up with program needs, the Status Quo strategy is not sustainable in the long term.

> The **Privatization** path would focus on finding non-federal sources of funding and, where possible, transferring hydropower assets from the federal to the private sector. This strategy is . . . often suggested as the solution to shortfalls of public funding. Asset transfers and other aspects of this path are problematic for many reasons. However, the fact that there are already more than 30 non-federal hydropower plants licensed by FERC [Federal Energy Regulatory Commission] and operating at Corps dams means that joint operations are feasible. Nevertheless, some very contentious legislative and policy changes would be needed if this path were to be successful.
>
> The **Modernization** path may also require significant changes in authorities, financing, and management, but it has the best chance of long-term success. The Corps has already embarked on one modernization initiative, the HMI . . . but the HMI is only part of the Modernization path envisioned . . . Many other aspects are part of this path, ranging from finding new sources of funding to full implementation of the new Hydropower [Memorandum of Understanding] with the DOE and DOI (Sale, 2010).

A partnership on hydropower was established in March 2009 via a Memorandum of Understanding involving the Corps, the Department of Energy, and the Bureau of Reclamation. The partnership includes initiatives on resource assessments, improved regulatory processes, technology development, and other topics.

The privatization path is impractical given the need to change authorizing legislation and the complexity of the multiple-use responsibilities of the Corps. Sale (2010) notes that new legislation would be needed to de-authorize hydropower operations at many projects, long-term federal power contracts would have to be phased out, and the loss of inexpensive federal hydropower by primary customers is likely to be strongly opposed.

Modernization of the Corps hydropower program will require new legislation, new authorities, new funding, and modification and expansion of Corps partnerships. With low and declining federal support for Corps hydropower

projects, equipment replacement and rehabilitation needs will have to come from direct funding by Corps hydropower customers. New legislation will be needed to enable this, such as (Sale, 2010): (1) legislative changes that would allow all of the PMAs to fund equipment replacement/rehabilitation costs directly from their power revenues, and (2) legislation that would establish a trust fund within each PMA to provide funding for construction and rehabilitation.

The Bonneville Power Administration has the authority to fund OMR directly from power revenues, with very positive effect on operations (see Box 3-11), but other PMAs do not (Sale, 2010). Use of power revenues for direct funding of OMR will require more engagement with and support from power customers. The Corps hydropower program will need to establish expanded, diverse partnerships with federal power customers, the PMAs, and the nonfederal power industry.

BOX 3-11
THE BONNEVILLE POWER ADMINISTRATION DIRECT FUNDING AGREEMENT

The National Energy Policy Act of 1992 included a provision that allows the Bonneville Power Administration (BPA) to *direct fund* the costs of maintenance, operation, and capital projects. The BPA is the only Department of Energy Power Marketing Administration (PMA) with the authority to finance directly the OMR costs at Corps projects (Sale, 2010). This procedure eliminates the process of congressional approval, authorization, and funding, which can take years or even decades to complete. As a result, the federal assets in the Bonneville system are among the best maintained and most efficient federally owned power generating facilities in the nation. Through the direct funding agreements with its hydropower generators, BPA has been able to make a significant amount of investment across their system, where a number of the hydropower plants have been partially upgraded or scheduled to be upgraded to increase the reliability and productivity of the units and reduce the water requirements. Only a few federally owned hydropower units outside the Bonneville system have been so upgraded. Efforts to expand the direct funding agreement concept to allow other PMAs to use revenues from the generating units for capital and maintenance projects were attempted in the early 2000s, but they failed to receive congressional approval. However, some limited PMA customer funding agreements have been developed.

The Flood Control Act of 1944 specified that the Corps and the PMAs produce and sell power "at the lowest possible rates to consumers consistent with sound business practices." As discussed in Sale (2010), the Corps' responsibility to use sound business practices in managing its hydropower program provides ample justification for incorporating the funding needs for replacement of aging equipment into customer rates for federal hydropower. Interagency discussions involving the Corps, the PMAs, and DOE will be crucial in moving forward on this and other, similar modernization initiatives.

SUSTAINING CORPS OF ENGINEERS WATER RESOURCES INFRASTRUCTURE

Much of the existing water resources infrastructure of the Corps of Engineers, which is primarily in the mission areas of navigation, flood risk management and hydropower production, is quite aged and has not been adequately maintained. Funding needs for the repair and rehabilitation of this infrastructure are substantial, and it is clear from the long-term trend of declining funding from Congress for new construction and rehabilitation that new infusions of funding will not be available in the short term. Parts of the infrastructure are failing, and parts are being taken out of service because of lack of funding.

Corps of Engineers infrastructure has different OMR needs, ranging from lock repair, dam safety, levee monitoring and maintenance, port deepening, and hydropower facility maintenance and upgrades. There are different means and mechanisms for funding of infrastructure maintenance and repairs across the mission areas. It thus is difficult for the Corps to manage all water resources infrastructure as one collection of assets. In an earlier era, it was easier to integrate a smaller number of missions and to share expertise and experience among them. Today, however, the larger number of responsibilities makes agency-wide integration more difficult. The Corps is guided by numerous federal laws and authorizations, a wide mix of clients with different goals, and different modes of taxation and sources of revenue. Its distinctive and diverse water infrastructure, its specific roles in the national economy, and its clientele and history make the Corps a unique organization. Many potential approaches and solutions to Corps OMR challenges will be specific to the Corps.

Corps of Engineers water resources infrastructure responsibilities, including navigation, flood risk management, and ecosystem restoration, differ significantly in terms of enabling legislation, taxation and revenue sources, clients, and relations with the private sector. The Corps faces challenges in its OMR duties given that its roles, partnerships, and successes in addressing OMR in one mission area often are not transferred easily to other areas or activities.

Greater private sector involvement is often raised as one option for increasing revenues for public agencies or works, and this report discusses some ways in which private-sector participation in Corps OMR activities might be enhanced.

Opportunities for greater private-sector involvement in Corps infrastructure operations and maintenance activities will vary by Corps mission area, and by economic sector. In general, these opportunities are greater in the areas of flood risk management, port and harbor maintenance, and hydropower generation, and less for inland navigation.

Inland Navigation

The inland navigation system presents an especially formidable challenge and a set of difficult choices. There are stark realities and limited options, including:

- **Funding from Congress for project construction and rehabilitation has been declining steadily.**
- **Lockage fees on users/direct beneficiaries could be implemented. These are resisted by users and others.**
- **Parts of the system could be decommissioned or divested and the extent of the system decreased.**
- **The status quo is a likely future path, but it will entail continued deterioration of the system and eventual, significant disruptions in service. It also implies that the system will be modified by deterioration, rather than by plan.**

Flood Risk Management

Reductions in resources available for construction of federal flood control works present opportunities for expanded implementation of nonstructural flood risk management options that are more efficient and less costly and provide greater environmental benefits. Many of these strategies have been used successfully for years, in many parts of the country. They have not always received full consideration, however, because of a historical emphasis on large, engineered civil works for flood protection. Today's fiscal realities present the Corps of Engineers opportunities to collaborate more closely with local communities in providing technical information and other types of support.

Hydropower Generation

Future investments in hydropower generation will balance the need for reliable sources of domestic energy, relative efficiencies and flexibility of hydropower, and environmental implications of reservoir storage and release regimes. The capacity of existing Corps hydropower is not being realized, and in fact is declining.

Because of its revenue-generating potential, hydropower is in an especially good position to accommodate public-private investments required to increase capacity and reliability. Some modification of operating regulations by the U.S. Congress will be needed to realize this potential.

Systematic Asset Management

Obligations placed on the Corps for continued safe and efficient operations of the entirety of its water resources infrastructure, under modern staffing and financial conditions, heighten the need for asset management efforts within each of its mission areas. A necessary first step toward this will be comprehensive inventories of existing infrastructure. These inventories will enhance systematic planning efforts and the prioritization of OMR needs.

Increasing strains placed on the Corps today by decaying infrastructure and associated fiscal challenges demand a systematic approach to asset management. To its credit, the Corps has begun an asset management initiative. To further promote these efforts, the Corps should continue to develop more comprehensive, and publicly accessible, inventories of infrastructure assets for each of its core mission areas.

Economic Principles and Future Investments

Wise infrastructure investments will not simply repair Corps infrastructure to the same configuration that existed in the 1940s or 1950s. These investments will be made with clear recognition of the many national economic changes since much of the Corps infrastructure was constructed. One major change, for example, is the substantial expansion in international trade since the WWII era and the changing nature of the transportation infrastructure to support that growth. Other major changes include technological advances in, and easier access to, freight transport options. Today, an extensive interstate highway system provides viable freight option opportunities in some instances, and rail systems have implemented many technological advances. Regarding flood risk management, future investments in flood infrastructure will recognize lessons from relying heavily on engineered structures and the need to also develop local land use policies and zoning regulations designed to reduce vulnerability to floods. Many communities across the nation have learned, and are learning, to accommodate floods in more effective ways and reduce reliance upon large amounts of federal funding for hard-infrastructure mitigation measures. Advances in hydropower technology make possible new systems that can generate similar amounts of power, with less water.

Sound OMR investments also will be guided by principles of economic efficiency and seek to employ market-based principles when feasible. Wise investments will acknowledge declining availability of federal funding and subsidies and the need to work with the private sector and to capture revenue streams from users and beneficiaries. Paralleling conclusions from a previous report from an NRC Transportation Research Board panel of experts on investment to enhance U.S. freight capacity (NRC, 2003), Corps water infrastruc-

ture investments should be made according to a set of principles that help ensure sustained contributions to economic development.

Future OMR investments should be guided by a more coherent set of principles that include strong reliance on economics of infrastructure investment. A 2003 NRC committee that studied national freight transport offered the following set of investment and economic principles that merit careful consideration. These principles can be summarized as follows:

- **Promote economic efficiency, with investments directed to improvements that yield greatest economic benefits.**
- **Limit government involvement to circumstances in which market-based outcomes clearly would be highly inefficient. Government also is responsible for managing facilities where it has important historical responsibilities that would not be easily altered, and where institutional complexity necessitates government leadership.**
- **Limit government subsidies and ensure that facility beneficiaries pay the costs.**
- **Rely more on user revenues, and the 'user pays' principle, along with matching funds and stronger public-private relationships.**

Along with economic development principles, broader social and environmental goals for Corps projects, including public safety purposes, of course need to be considered when prioritizing OMR investments for Corps projects (the complete listing of these principles is on pages 53 and 54).

4

Options for Improving Operations, Maintenance, and Rehabilitation of Corps of Engineers Water Resources Infrastructure

Historically, construction of new infrastructure has dominated the Corps water resources budget and activities. Today, most of the favorable sites and opportunities for water project construction have been developed. National water needs thus have shifted from new project development to operation, maintenance, and rehabilitation (OMR) of existing infrastructure, as well as restoration of ecosystems associated with existing infrastructure operations. Operation and maintenance are now the largest part of the Corps budget (see Figure 2-1). Major rehabilitation and replacement projects are included in the construction budget, while smaller-scale rehabilitation and repair projects are performed under the operation and maintenance budget.

The federal Water Resources Development Act (WRDA) process has been developed and honed for new water project authorization. WRDA will continue to be important for new projects, but some reorientation in focus by the Congress and the executive branch will be required to elevate the importance of the operations, maintenance, and rehabilitation needs of Corps water resources infrastructure.

The national water infrastructure is largely "built out." Compared to an earlier era, there are fewer opportunities and only a limited number of undeveloped or appropriate sites for new water resources infrastructure. New water projects will be constructed in the future, but the nation's water resources infrastructure needs increasingly are in the areas of existing project operations, maintenance, and rehabilitation. In some instances, full project replacement may be needed. As new construction has declined since 1980, so too has the Corps civil works budget and hence funds available for OMR. Trends in funding for the Corps over the past three decades make clear this reality.

OPTIONS FOR CORPS OF ENGINEERS WATER RESOURCES INFRASTRUCTURE

Without insufficient funding to address its many OMR needs, Corps of Engineers water resources infrastructure is not being adequately maintained and rehabilitated. Its future state thus will depend on actions taken, or not taken, in the near future. There is no single, obvious path forward for alternative funding mechanisms that might be used to fully maintain and upgrade existing Corps infrastructure. The different parts of the Corps water resources infrastructure—inland navigation, flood risk management, hydropower, and ports and harbors—are governed by different laws and have different sources of revenue. Those parts of the Corps mission and infrastructure that are most reliant on federal funding and operation face the greatest challenges, while those areas that employ more extensive public-private partnerships (and entail more limited roles for the Corps, such as dredging) enjoy greater flexibility in approaches to funding OMR needs. Moreover, the original justification and purpose for some components of the Corps water infrastructure have become less relevant. Although this may make continued federal support of OMR needs for all infrastructure less viable, this will be a matter for the U.S. Congress and the executive branch to decide.

In order to identify viable paths for the future of Corps water resources infrastructure, it is useful to consider the range of options available to the Corps, the U.S. Congress, and Corps project beneficiaries. In its public meet-

ings and field visits, this committee heard a wide range of suggestions for productively moving forward. Those suggestions led the committee to identify potential future paths that might be taken with regard to Corps of Engineers infrastructure:

1. Business as usual. Accept degraded performance, and the consequences of gradual or sudden failure of infrastructure components.
2. Increase federal funding for operations, maintenance, and rehabilitation.
3. Divest or decommission parts of Corps infrastructure to reduce OMR obligations.
4. Increase revenue from direct project beneficiaries for maintenance costs.
5. Expand public-private partnerships for portions of existing infrastructure.
6. Adopt some combination of options 2-5.

The choices of which of these options, or combinations of them, represent the best path forward for the Corps, and the nation, will be public policy decisions. Further, different components of the Corps water resources infrastructure have different OMR challenges and hence different considerations with respect to the options. Evaluation of these alternatives provides insights that can help inform the needed public policy decisions.

Option 1: Business as Usual

With this option, the Corps will continue to operate the existing water resources infrastructure for inland navigation, hydropower, and flood risk management to the best of its ability with inadequate funding, with routine maintenance and repair efforts focused on keeping systems running and minimizing the rate of increase in degraded performance. Major rehabilitation projects will be directed only to the most critical facilities and will necessarily be conducted over a long period of time because of funding limitations.

Resources from the Corps annual budget (i.e., the general fund of the U.S. Treasury) for new construction and rehabilitation of existing water infrastructure have been declining steadily and are inadequate to cover all OMR needs. Available sources of funding have been inadequate to cover OMR costs, leading to an unsustainable situation for maintenance of existing infrastructure. This scenario entails increased frequency of infrastructure failure and negative social, economic, and public safety consequences. The potential extent of these negative consequences is not well understood.

Many project beneficiaries, including commercial navigation companies and shippers, and communities with dam and levee rehabilitation needs, see the business-as-usual option as unacceptable. There are projections of significant negative impacts if current approaches continue (ASCE, 2012b). Barring new direction from Congress that would enable significant changes in current business models and available federal funding, however, the status quo may be the most likely path forward.

Option 2: Increase Federal Funding for Operations, Maintenance, and Rehabilitation

Increased federal funding under Option 2 will require a renewed interest by Congress and the executive branch to provide more federal resources for rehabilitation of Corps water resources infrastructure. It is worth noting that lack of interest by the Congress to increase OMR funding to a level adequate to support existing Corps water infrastructure contributes to a growing rehabilitation and replacement backlog.

There has been a long-term declining trend in funding for Corps water resources infrastructure construction and rehabilitation across numerous federal budgets. The future viability of this option is unclear.

Option 3: Divest or Decommission Parts of the Corps Infrastructure

Current legislation governing Corps activities obligates the Corps to maintain existing infrastructure. This legislation, however, does not give the

Corps authority to decommission obsolete projects for which the original justification and project purpose are no longer relevant, or to divest itself of projects which are of marginal importance to the Corps mission and for which state/local government or private sector management is feasible. Across the Corps water resources infrastructure inventory, these conditions tend to be most pertinent to inland navigation facilities.

The inability of the Corps to divest and decommission infrastructure is an obstacle to focusing available funding on highest-priority OMR needs. Financial stresses placed on the Corps to provide for safe and efficient operation of all existing infrastructure under modern budget realities leads to partial investments in needed OMR across many facilities, rather than larger investments in more critical facilities.

Decommissioning and divestment of some components of the Corps water infrastructure would reduce OMR obligations, but such decisions are matters of public policy and would require action by Congress or the administration.

Option 4: Increase Revenues from Corps Project Operations

For several components of the Corps water resources infrastructure, mechanisms exist to capture revenue from project operation. As discussed in Chapter 3, these mechanisms include the Inland Waterways Trust Fund (IWTF) which collects monies for use in rehabilitation and construction projects on the inland navigation system through a fuel tax on commercial users of the system; the Harbor Maintenance Trust Fund which collects monies to support dredging of harbor channels to their authorized depths and widths through a cargo value tax on maritime shippers; and the allowed use of hydropower revenue by some Corps hydropower projects for OMR.

With respect to inland navigation, there is potential in higher fuel taxes for commercial shippers and for lockage fees. The IWTF, funded by the fuel tax, is far from adequately funded to meet the rehabilitation needs of the inland navigation system. Lockage fees could be implemented for commercial users, as well as for recreational boaters. For hydropower, permission for use of some power revenue to be retained for OMR could be extended to all Corps hydropower projects. Currently, only a relatively small number of

Corps hydropower projects are permitted to retain and use their own revenue. Most Corps hydropower revenue is directed to the federal treasury.

Hydropower revenues could be increased by improving efficiency of the turbine systems used in Corps hydropower projects, as has been demonstrated by the Tennessee Valley Authority (Sale, 2010). Total generation from Corps hydropower projects decreased by 16 percent from 2000 to 2008. By contrast, the TVA increased hydropower generation 34 percent with the same water availability through efficiency improvements in the 1980s and early 1990s (Sale, 2010). This suggests that at least a 20 percent improvement at Corps hydropower projects with current water flows may be obtainable and would provide significant new revenues.

Opportunities exist for expansion of revenue capture from water resources infrastructure, especially for inland navigation and hydropower projects. However, legal and other barriers will necessitate congressional action to expand such revenue streams.

Option 5: Expand Partnerships

Although some components of the Corps water infrastructure entail shared responsibilities and activities with private entities, public-private partnerships are utilized only in a limited manner to support operations for much of Corps water resources infrastructure. Broader use of public-private partnerships would offer a range of possibilities for bringing new resources and potentially more efficient methods to OMR of Corps water resources infrastructure.

As discussed in Chapter 3, there are sophisticated public-private partnerships in place at port facilities around the United States, involving partnerships between state and local governments and private entities, with the Corps having a limited but important role related to navigation dredging. Distribution of responsibilities between federal, state, and local governments in OMR of port facilities could serve as a model for other Corps water resources infrastructure.

Direct engagement of the Corps in public-private partnerships (PPP) in hydropower projects was discussed in Chapter 3. There are 90 nonfederal hydropower projects in place at Corps dams, as well as opportunities for

expanded public-private partnerships in hydropower at Corps facilities. If increased funding for OMR at Corps hydropower projects will not be feasible either through federal budgeting or allowance of more projects to capture power revenue for OMR, some of the projects could be turned over to private-sector organizations to operate and maintain. The regulatory and licensing infrastructure exists to do this, but there would be political and legal challenges that need to be addressed in order to expand such partnerships at hydropower projects.

Although the Corps consults with private sector users on OMR of the inland waterways system, and those users help to support part of OMR needs through a fuel tax directed to the IWTF, OMR of the inland navigation system is largely the responsibility of the Corps and the federal government. As discussed in Chapter 3, portions of the Gulf and Atlantic Intracoastal Waterway system are managed by the states. Through interactions with the Inland Waterways Users Board, the Corps regularly engages with the private sector users of the inland waterways system on issues of OMR prioritization and priorities for capital expenditures from the IWTF (e.g., IMTS Capital Investment Strategy Team, 2010). Greater private sector, or state government, involvement in overall management of the inland waterways system, however, likely would entail some barriers and challenges. Multiple criteria, including social and environmental considerations, for operations and maintenance will continue to be important, certainly requiring some level of Corps oversight. Nevertheless, there may be good opportunities for public-private partnerships for operation and maintenance of the inland navigation system that merit investigation. Expansion of public-private partnerships will in most instances require congressional action.

The potential public-private and other kinds of partnerships that offer the best opportunities for more efficient OMR activities are not immediately clear As this report has documented, PPP arrangements are complicated, may take years to develop, and are affected by site-specific circumstances. Moreover, greater private sector participation in Corps water infrastructure OMR will not be merited or desirable in all circumstances. Given the many complexities and uncertainties surrounding partnership prospects, with private sector entities as well as state and local governments, a credible evaluation of promising opportunities could help identify the most immediate, promising prospects.

This evaluation ideally would be conducted by independent and credible organization with good knowledge of Corps of Engineers functions, policies, and activities. If the Corps itself were to conduct such an evaluation, it could put the Corps in an awkward position and there could be questions about objectivity. An independent entity outside of the Corps of Engineers, with relevant expertise and knowledge of water infrastructure operations and financing, would be a preferred option.

The U.S. Congress and/or the administration should commission an investigation of opportunities for additional and different kinds of partnerships for operation and maintenance of Corps water resources infrastructure. Partnerships investigated should include both those with private entities and those with state and local governments. The investigation should be conducted by an entity independent of the Corps of Engineers.

Option 6: Some Combination of Options 2-5

THE NEED FOR FEDERAL LEADERSHIP AND ACTION

Moving forward with "business as usual" with respect to OMR of the aging Corps water resources infrastructure is unsustainable, as discussed under Option 1. The underfunding situation is especially critical for those parts of the Corps water resources infrastructure that are most reliant on federal funding: inland navigation, hydropower, and flood risk management. Trends in infrastructure deterioration and the limited OMR resources lead toward degraded performance, and failures, of the national water resources infrastructure. Infrastructure in all transportation, trade, communications, and other sectors eventually wears out and is either razed or replaced. If resources for adequate OMR simply are unavailable, this reality should be recognized and plans should be made accordingly. In the long run, it will be more costly to ignore these realities and allow national water infrastructure to continue to degrade, with no plans for divestment, decommissioning, or retiring old infrastructure. This path will result in unnec-

essary costs, infrastructure evolution dictated by variable degradation and failure rates, and costly negative surprises.

Wise investment of limited resources in the nation's water resources infrastructure requires that priorities be established for infrastructure OMR, as well as inevitable divestment, or decommissioning, of some portions of the existing infrastructure. More sustainable future investments, operations, and maintenance of infrastructure also will entail stronger reliance on principles of economic efficiency, including more systematic use of the 'user pays' principle. It also will entail limited government subsidies and involvement in areas in which market-based principles will guide efficient decisions.

Existing congressional processes for identifying, authorizing, funding, and implementing projects were developed when the United States was building water resources infrastructure. Today, many parts of the nation's water resources infrastructure might be considered as completed, with today's main needs in the areas of project operation, maintenance, and rehabilitation. The current water project development and oversight process is not well designed for the modern, OMR-focused era. In particular, the use of the WRDA for congressional oversight and direction of water resources management is not adequate to today's OMR challenges. WRDA provides a collection of projects, but without any prioritization. Unlike the system of federal-state-local cooperation on highway OMR, and the related criteria to determine federal interest, there is no similar arrangement between local level interests, the Congress, the administration, and the Corps for water resources projects.

Setting explicit national-level OMR priorities for federal water infrastructure—including decommissioning decisions—would represent a departure from the familiar, traditional WRDA process. As this report has explained, however, this action is today essential for sound investments in and management of a deteriorating national water infrastructure.

Neither the executive branch nor the U.S. Congress has established a comprehensive process for setting OMR priorities for Corps water project investments. During an earlier era of expansion of national water infrastructure, there was little need for such a process. Today, however, in a setting of increasing importance of OMR, this type of a process is increasingly necessary to identify high-priority investments of limited federal resources. The

lack of a process for high-level prioritization is a considerable impediment to more efficient and timely investments in critical Corps infrastructure. The lack of such a process also inhibits the ability to identify water projects that are candidates for divestment and decommissioning. The Corps effectively makes decisions about priorities within its allotted annual budgets. The agency, however, lacks broader authority for higher-level, policy-based prioritizations, such as those that would lead to infrastructure divesture or decommissioning.

More specific direction from the U.S. Congress regarding priority OMR investments for Corps water infrastructure will be crucial to sustaining the agency's high-priority and most valuable infrastructure. The executive branch also could play a more aggressive role in promoting dialogue between the Corps and the Congress on existing infrastructure investment needs and priorities.

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Appendix A

Guest Speakers at Committee Meetings

FEDERAL AGENCIES

U.S. Army Corps of Engineers

Theodore A. Brown, Planning and Policy (Chief), Washington, D.C.
Steven L. Stockton, Civil Works (Director), Washington, D.C.
Kenneth Barr, Environmental and Economic Analysis Branch, Rock Island, IL
Mike Cox, Operations Division, Rock Island, IL
Lenna Hawkins, Corps Institute for Water Resources, Alexandria, VA
Gary Meden, Programs and Project Management, Rock Island, IL
Pete Rabbon, Flood Risk Management Program, Washington, D.C.
Charles Spitzack, Navigation and Environmental Sustainability Program, Rock Island, IL
Travis Tutka, National Dam Safety Program, Washington, D.C.

U.S. Environmental Protection Agency

John McShane, National Estuary Program, Washington, D.C.

U.S. Federal Emergency Management Agency

Christopher Rolleston, Des Moines, IA

U.S. Fish and Wildlife Service

Bob Clevenstine, Moline, IL

U.S. Office of Management and Budget

Sally Ericsson, Natural Resources, Energy and Science Programs, Washington, D.C.

CITY AND MUNICIPAL GOVERMENTS

Michael Clarke, City of Davenport, IA
Dave Elgin, City of Cedar Rapids, IA

PRIVATE SECTOR AND NONPROFIT ORGANIZATIONS

Gretchen Benjamin, The Nature Conservancy Great Rivers Partnership, La Crosse, WI
Michael Brower, Mosaic Federal Affairs, LLC, Syracuse, NY
Debra Knopman, Rand Corporation, Arlington, VA
Amy Larson, National Waterways Conference, Inc., Arlington, VA
Larry Larson, Association of State Floodplain Managers, Madison, WI (NRC committee member)
Deborah Mills, Dewberry, Fairfax, VA
Barbara Naramore, Upper Mississippi River Basin Association, St. Paul, MN
Patrick Natale, American Society of Civil Engineers, Reston, VA
Michael Sale, M.J. Sale and Associates, Wartburg, TN
Leonard Shabman, Resources for the Future, Washington, D.C.

UNIVERSITY FACULTY

Linda Blum, University of Virginia, Charlottesville (NRC committee member)

Robert Dalrymple, Johns Hopkins University, Baltimore (NRC committee member)
G. Edward Dickey, Loyola University Maryland, Baltimore
Stephen Fuller, Texas A&M University, College Station
Gerald Galloway, Jr., University of Maryland, College Park

Appendix B

Biographical Information: Committee on U.S. Army Corps of Engineers Water Resources Science, Engineering, and Planning

David A. Dzombak (NAE), *Chair*, is the Walter J. Blenko, Sr. University Professor of Environmental Engineering at Carnegie Mellon University and faculty director of the Carnegie Mellon Steinbrenner Institute for Environmental Education and Research. He conducts research in water quality engineering and science, on topics pertaining to environmental restoration and the water-energy nexus. Dr. Dzombak is a member of the National Academy of Engineering, a registered professional engineer in Pennsylvania, a diplomate of the American Academy of Environmental Engineers, and a fellow of the American Society of Civil Engineers. He served as the chairman of the NRC Committee on the Mississippi River and the Clean Water Act. Dr. Dzombak holds a BA degree in mathematics from Saint Vincent College, BS and MS degrees in civil engineering from Carnegie Mellon University, and a PhD degree in civil engineering from the Massachusetts Institute of Technology.

Patrick A. Atkins is with Atkins 360, LLC, a Pittsburgh consulting firm that specializes in teaching and consulting on energy, lifecycle, and sustainability issues. Until his retirement in April 2007, Dr. Atkins was director of energy innovation at Alcoa, Inc., responsible for implementing solutions for waste heat recovery in refining, smelting, and casting, assessment of alternate (e.g., renewable) energy sources, and their applicability across Alcoa worldwide.

Dr. Atkins is a member of the American Society of Civil Engineers, the National Society of Professional Engineers, and the Engineering Society of Western Pennsylvania. He is a past member of the Science Advisory Board for the Strategic Environmental Research and Development Program, and an operating advisor at Pegasus Capital Advisors, LLC, a New York-based private equity firm. Dr. Atkins is a registered professional engineer in Pennsylvania and Texas. Dr. Atkins received a BS degree in civil engineering from the University of Kentucky and his MS and PhD degrees in environmental engineering from Stanford University.

Gregory. B. Baecher (NAE) is the G.L. Martin Institute Professor of Engineering at the University of Maryland in College Park. Dr. Baecher's principal area of work addresses the reliability of civil infrastructure and project risk management, especially in geotechnical and water resources engineering. From 1998 to 2005 he served as a member of the NRC Water Science and Technology Board. Dr. Baecher is a member of the National Academy of Engineering and has served on several NRC committees. He chaired the NRC Committee on Risk-Based Analyses for Flood Damage Reduction and the Panel on (Corps of Engineers) Methods and Techniques of Project Analysis. He holds a BS degree in civil engineering from the University of California, Berkeley, and ScM and PhD degrees from the Massachusetts Institute of Technology.

Linda K. Blum is a research associate professor in the Department of Environmental Sciences at the University of Virginia. Her current research projects include study of how living organisms modify the geomorphology of salt marshes in response to external drivers such as sea-level, precipitation, tides, and/or anthropogenic nitrogen loading; mechanisms controlling bacterial community abundance, productivity, and structure in tidal marsh creeks and soils; and rhizosphere effects on organic matter decay in anaerobic sediments. Dr. Blum served as chair of the NRC Panel to Review the Critical Ecosystem Initiative and was a member of the NRC Committee on Restoration of the Greater Everglades Ecosystem, the Committee on Independent Scientific Review of Everglades Restoration Progress, and the Committee on Challenges and Opportunities in Earth Surface Processes. She earned her BS and MS degrees in forestry from Michigan Technological

University and her PhD degree in soil science and microbial ecology from Cornell University.

Robert A. Dalrymple (NAE) is the Willard and Lillian Hackerman Professor of Civil Engineering at Johns Hopkins University in Baltimore, Maryland. His major research interests and projects are in the areas of coastal engineering, wave mechanics, fluid mechanics, littoral processes, and tidal inlets. His current interests are water wave modeling, tsunamis and their impacts on shorelines, and the interaction of water waves with the sea bed, specifically mud bottoms. *He chaired the NRC Committee on the Review of the Louisiana Coastal Protection and Restoration (LACPR) Program and currently is chairing the NRC Committee on Sea Level Rise in California, Oregon, and Washington. Dr. Dalrymple received his* AB degree in engineering sciences from Dartmouth University, his MS degree in ocean engineering from the University of Hawaii, and his PhD degree in civil and coastal engineering from the University of Florida.

Misganaw Demissie is director of the Illinois State Water Survey at the University of Illinois. His research at the Water Survey has focused on watershed science with emphasis on erosion and sedimentation and watershed hydrology. He has published more than one hundred journal articles, reports, and conference proceedings. Dr. Demissie is recipient of several awards, including The Frank Bellrose Illinois River Conservation Award from the Nature Conservancy for outstanding service and contribution toward the restoration of the Illinois River. Dr. Demissie is a registered professional engineer in Illinois. He is a fellow of the American Society of Civil Engineers, a diplomate of the American Academy of Water Resources Engineers, and a member of the International Water Resources Association and the International Association of Hydrological Sciences. Dr. Demissie received his BS degree in civil engineering from the University of Iowa and his MS and PhD degrees in civil engineering from the University of Illinois.

Terrance J. (Terry) Fulp is the Regional Director for the U.S. Bureau of Reclamation's Lower Colorado River region, headquartered in Boulder City, Nevada. Dr. Fulp is involved in numerous Colorado River issues, working with federal and state agencies and other stakeholder groups on system op-

erations decisions. Prior to his appointment as deputy regional director, he served as area manager of the Boulder Canyon Operations Office, where he managed a basin-wide effort to develop additional operational guidelines for Lake Powell and Lake Mead to minimize the effects of long-term drought. He was the principal investigator for the Department of the Interior's Watershed and River Systems Management Program. The program developed decision support tools for watershed management and resulted in development of RiverWareTM, a river operations modeling framework now used by several water management agencies—including Reclamation and the Corps of Engineers. Dr. Fulp received his BS degree in earth sciences from the University of Tulsa, his MS degree in geophysics from Stanford University, and his PhD in mathematical and computer sciences from the Colorado School of Mines.

Larry Larson is the executive director of the Association of State Floodplain Managers (ASFPM), headquartered in Madison, Wisconsin. A founding member of ASFPM in the 1970s, Larson oversees the Association's activities and communications and coordinates national flood and water resources policy development and advancement with state, local, and federal agencies; the Administration and Congress; and other policy groups and organizations. He also spent 30 years with the Wisconsin Department of Natural Resources managing flood loss reduction, dam safety, and wetlands programs, and five years with the California Department of Water Resources on design and construction of large dams, aqueducts, and water projects. An expert in developing the nation's policy on wise and sustainable use of floodplains, Larry has authored numerous position papers and articles, provides expert testimony to Congress, and frequently speaks to policy makers and flood hazard managers nationally and abroad. He is a Certified Floodplain Manager and a registered professional engineer in California and Wisconsin. Larry holds a BS degree in civil engineering from the University of Wisconsin.

Diane M. McKnight is a professor in the Department of Civil, Environmental, and Architectural Engineering, and a fellow of the Institute of Arctic and Alpine Research, at the University of Colorado. Prior to her current post she was a research scientist with the U.S. Geological Survey, Water Resources

Division. Her areas of research are biogeochemical processes, aquatic ecology, and reactive solute transport in streams and lakes in the Rocky Mountains and in polar desert areas of Antarctica. She has published numerous journal articles and book chapters and edited several books. In 1995, along with three other limnologists, she coauthored *The Freshwater Imperative: A Research Agenda*. Dr. McKnight is past president of the American Society of Limnology and Oceanography and of the biogeosciences section of the American Geophysical Union, and she was the first editor of the *Journal of Geophysical Research-Biogeosciences*. Since serving on the NRC Committee on Climate Change and Water Resources Management in 1990-1992, she has served on several other NRC committees, as well as the Polar Research Board and the Water Science and Technology Board. Dr. McKnight received her BS degree in mechanical engineering, MS degree in civil engineering, and PhD degree in environmental engineering from the Massachusetts Institute of Technology.

J. Walter Milon is the chair and Provost's Distinguished Research Professor in the Department of Economics, College of Business Administration, at the University of Central Florida. His major research interests are water resource economics, ecosystem valuation, and environmental policy. In addition to his academic research and publications, Dr. Milon has conducted research and consulting for a number of federal agencies, including the Environmental Protection Agency, the National Marine Fisheries Service, and the National Oceanic and Atmospheric Administration. Dr. Milon received his BS degree in finance and his MS and PhD degrees in economics from Florida State University.

A. Dan Tarlock is a professor at the Chicago-Kent College of Law, where he teaches courses in land use, property, energy and natural resource law, environmental policy, and international environmental law. He is an internationally recognized expert in environmental law and the law of land and water use. He has published a treatise, *Law of Water Rights and Resources*, and is a coauthor of four casebooks. Professor Tarlock is a frequent consultant to local, state, federal, and international agencies, private groups and law firms and is an elected member of the American Law Institute. From 1989 to1992, he served as chairman of the NRC Committee on Western Water

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