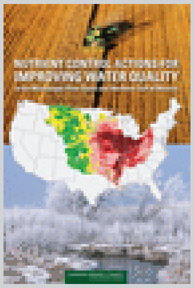

Nutrient Control Actions for Improving Water Quality in the Mississippi River Basin and Northern Gulf of Mexico

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NUTRIENT CONTROL ACTIONS FOR IMPROVING WATER QUALITY in the Mississippi River Basin and Northern Gulf of Mexico

Committee on the Mississippi River and the Clean Water Act: Scientific, Modeling, and Technical Aspects of Nutrient Pollutant Load Allocation and Implementation

Water Science and Technology Board

Division on Earth and Life Studies

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COMMITTEE ON THE MISSISSIPPI RIVER AND THE CLEAN WATER ACT: SCIENTIFIC, MODELING, AND TECHNICAL ASPECTS OF NUTRIENT POLLUTANT LOAD REDUCTION ALLOCATION AND IMPLEMENTATION

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Acknowledgment of Reviewers

This report was reviewed in draft form 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 thank the following for their review of this report: James Baker, Iowa State University; Norman Fausey, U.S. Department of Agriculture-ARS, Midwest Area; Cathy Kling, Iowa State University; Kenneth Potter, University of Wisconsin; Donald Scavia, University of Michigan; Jerry Schnoor, University of Iowa; Holly Stoerker (retired), Upper Mississippi River Basin Authority; Edward Thackston (emeritus), Vanderbilt University; Alan Vicory, Ohio River Valley Water Sanitation Commission.

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 Dr. Frank Stillinger, Princeton University, who was appointed by the NRC Report Review Committee, and Dr. Patrick Brezonik, University of Minnesota, who was appointed by the NRC Division on Earth and Life Studies. They were responsible for ensuring that an independent examination of this report was conducted in accordance with NRC institutional procedures and that all review comments were carefully considered. Responsibility for this report's final contents rests entirely with the authoring committee and the NRC.

Contents

Summary

A large area of coastal waters in the northern Gulf of Mexico experiences seasonal conditions of low levels of dissolved oxygen, a condition known as hypoxia. This zone of hypoxia has been persistent since consistent data collection on its distribution and dynamics was begun in 1985. Excess discharge of nutrients—especially nitrogen and phosphorus—into the Gulf of Mexico from the Mississippi and Atchafalaya rivers causes nutrient overenrichment in the gulf's coastal waters and stimulates the growth of large algae blooms. When these algae die, the process of decomposition depletes dissolved oxygen from the water column and creates hypoxic conditions.

The nitrogen and phosphorus nutrient discharges into the gulf's coastal waters derive from many different sources and many different watersheds across the river basin. Numerous federal and state regulatory regimes, organizations, and water quality standards govern nutrient loadings across the river basin and water quality in the Mississippi River and its tributaries. Downstream impacts from specific upstream pollutants are difficult to track precisely and require years of monitoring to detect. The large land mass of the Mississippi River basin, and the large number—31—of U.S. states in the river basin, further complicate the water quality monitoring and management challenges associated with northern Gulf of Mexico hypoxia.

In considering how to implement provisions of the Clean Water Act to strengthen nutrient reduction objectives across the Mississippi River basin, the U.S. Environmental Protection Agency (EPA) requested advice from the National Research Council (NRC) in three areas: (1) initiating nutrient pollutant control programs, (2) identifying alternatives for allocating nutrient load reductions across the river basin, and (3) documenting the effectiveness of pollutant loading reduction strategies on the gulf hypoxic zone and state designated uses (this committee's full statement of task is listed in Appendix A). Accordingly, the NRC Water Science and Technology Board (WSTB) organized a special committee for this assignment.

This report represents the results of the committee's investigations and deliberations. The committee carried out its project over the latter half of 2008, convening three meetings in the process: a first meeting in July; a second meeting in early September with several guest speakers who provided presentations at a public session; and a third meeting in late September that was

closed to the public and at which the committee worked on its draft report.

This summary presents the report's findings and recommendations, which later are discussed in greater detail in the main body of the report.

TARGETING ACTIONS IN PRIORITY WATERSHEDS

Realizing progress toward reducing the areal extent of northern Gulf of Mexico hypoxia will require an acknowledgment that there will be a considerable time lag—roughly a decade, at a minimum—between nutrient reduction actions across the river basin and ecological and water quality responses downstream in the gulf.

Purposeful targeting of nutrient control efforts toward areas of higher nutrient loadings will be essential to realize the greatest initial reductions in nutrient loadings. EPA and the U.S. Department of Agriculture (USDA) should direct conservation programs and other nutrient management resources to priority Mississippi River basin watersheds within higher levels of nutrient loadings. In addition to targeting individual watersheds, those programs should identify specific areas within watersheds where expenditures and actions are more likely to produce initial, positive results.

To improve knowledge regarding point sources' relative contribution of nutrient pollution, EPA should require major municipal and industrial point source dischargers to monitor nutrient concentrations—nitrogen and phosphorus—in effluent at their discharge point as a condition of their National Pollutant Discharge Elimination System (NPDES) permits.

GETTING STARTED:
A NUTRIENT IMPLEMENTATION CONTROL INITIATIVE

The EPA and the USDA should jointly establish a Mississippi River basin Nutrient Control Implementation Initiative (NCII). A new Mississippi River Basin Water Quality Center, discussed later in this summary and in more detail in the report, should administer the NCII.

Goals of the NCII should be to:

- Demonstrate the ability to achieve reduced nutrient loadings by implementing and testing a network of nutrient control pilot projects. These projects should be implemented in priority watersheds as part of an adaptive, nutrient control process;
- Evaluate local water quality and other benefits of nutrient control actions;
- Build an institutional model for cooperative research and nutrient control actions among federal, state, and local organizations;

- Evaluate the cost effectiveness, and strengthen the economic viability and community engagement, of various nutrient control actions;
- Compile and communicate best practices as revealed in the pilot projects.

A suite of well-designed NCII projects would represent a research-based effort that could contribute greatly to the development of more effective, cost-efficient solutions to nutrient export problems in the Mississippi River basin. In addition to their evaluative and research dimension, the NCII projects have the potential to contribute to local water quality improvements.

As part of the NCII, the EPA and USDA should identify a select group of Mississippi River basin priority watersheds for initial actions. The selection of priority watersheds should consider, but not necessarily be limited to, the following factors:

- Watersheds of higher nutrient loadings as identified by results from the U.S. Geological Survey (USGS) SPARROW modeling efforts;
- Watersheds that are sites of current and previous water quality and land use monitoring and evaluation programs and activities, and that possess inventories such as cropland and animal populations; and
- Watersheds that are focal points of conservation activity and interest to the USDA and to state and local parties.

Resources from existing USDA conservation programs—the Conservation Reserve Program (CRP), the Conservation Security Program (CSP), and the Environmental Quality Incentives Program (EQIP)—should be drawn upon to help support NCII pilot projects. Other USDA watershed-based programs, such as the Agricultural Water Enhancement Program (AWEP) and the Cooperative Conservation Partnership Initiative (CCPI), also could be used to contribute to the NCII. The agencies also should consider deploying EPA resources. Although these resources are less than those of the USDA conservation programs, the NCII could use funds from, for example, EPA's Clean Water Act Section 319 (which covers nonpoint source pollution management) grant program. The NCII also could leverage state matching funds and private sector funding in marshalling financial support for its program and projects.

The NCII projects recommended in this report would cover only a small portion of the higher nutrient yield areas in the river basin. Thus, in and of themselves, the collective reduction in nutrient loadings from NCII projects would have little effect on hypoxia. The NCII is a special, evaluative component of larger nutrient reduction allocation efforts (as described in the following section). Other nutrient control actions and programs across the river basin therefore should not pause or slow their progress in waiting for NCII project development and implementation.

ALLOCATING NUTRIENT LOAD REDUCTION TARGETS

In working toward a load reduction allocation scheme, the EPA, USDA, and the Mississippi River basin states should draw upon the experience in the Chesapeake Bay in allocating nutrient loading caps. In doing so, the following principles for allocating cap load reductions for the Mississippi River basin should be considered:

- Select an interim goal for nutrient load reductions as the first stage of an adaptive, incremental process toward subsequent reduction goals;
- Target watersheds to which load reductions are to be allocated;
- Adopt an allocation formula for distributing interim load reductions to targeted watersheds within the basin that balances equity and cost-effectiveness considerations;
- Allow credit for past progress; and
- Encourage the use of market-based approaches to allow jurisdictional flexibility in achieving allocated load reductions. It bears keeping in mind, however, that such markets do not automatically lead to satisfactory outcomes. Such markets require some regulatory caps on nutrient losses in order to operate.

MONITORING THE EFFECTIVENESS OF NUTRIENT CONTROL ACTIONS AND POLICIES

Federal and state agencies across the Mississippi River basin sponsor a variety of water quality monitoring programs. At the federal level, much of the water quality monitoring across the Mississippi River basin is overseen by the U.S. Geological Survey. The U.S. Army Corps of Engineers also supports water quality monitoring of the upper Mississippi River. Other interstate bodies, including the Upper Mississippi River Sub-basin Hypoxia Nutrient Committee (UMRSHNC) and the Upper Mississippi River Basin Association (UMRBA) support communication and interstate coordination of many water quality activities. At the state level, state natural resources and water quality agencies conduct monitoring within state boundaries as part of their Clean Water Act responsibilities. There also are numerous experts in water chemistry, water quality modeling, nutrient management, agricultural economics, and water quality administration in the many land grant and other universities across the basin, and within numerous county extension programs in the basin's rural areas. Downstream in the northern Gulf of Mexico, many scientists conduct various monitoring activities within the hypoxic zone. There is a large and extensive body of water quality data for the Mississippi River basin and the northern Gulf of Mexico.

Despite this large body of information and expertise, the water quality database across the Mississippi River basin is uneven and not well coordinated.

For example, monitoring of Mississippi River water quality in the ten states along the river is inconsistent, leading to a conclusion that the river is an "orphan" from a water quality monitoring and evaluation perspective (NRC, 2008). State-level water quality efforts cover only a portion—roughly 20 percent according to a 2000 report from the (former) U.S. General Accounting Office—of intrastate rivers and streams. Downstream in the northern Gulf of Mexico, although monitoring efforts there have been very useful in many respects, challenges remain in trying to construct and support a long-term hypoxia monitoring program. The existing data base and monitoring programs across the river basin do not have the level of coordination, resources, and focus required to support the NCII program.

A Mississippi River Basin Water Quality Center

To facilitate implementation of this report's recommendations, a Mississippi River Basin Water Quality should be established. The EPA and the USDA should jointly administer the center. The center should be located in the upper Mississippi River basin because this region is the main source of nutrient loadings. The center will represent the nexus of federal interagency, federal-state, and interstate cooperation. Participation of other bodies that play important roles in water quality monitoring—such as the USGS, the U.S. Army Corps of Engineers, and state natural resources and water quality agencies—will be vital to the center's operations and functions. The center should manage a basinwide water quality monitoring, assessment, and nutrient control program and should coordinate and facilitate the following functions:

- Plan and administer the Nutrient Control Implementation Initiative (NCII) projects, including financing, evaluation, reporting, and communication of findings;
- Conduct cooperative, basinwide water quality and land use monitoring and relevant analysis and research;
- Develop a land use and land cover data base for the river basin;
- Identify additional watersheds for future actions and inclusion in the NCII;
- Provide advice on water quality variables and statistical approaches to be used in evaluating effectiveness of nutrient control actions;
- Produce periodic reports on basinwide water quality assessment and on project implementation;
- Provide technical assistance and training.

Ensuring Adequate Monitoring in the Northern Gulf of Mexico

Comprehensive and sustained water monitoring in the northern Gulf of Mexico is an essential complement to water quality data from across the river basin and is crucial to documenting the effectiveness of upstream nutrient control actions. Current funding levels and programmatic arrangements, however, do not ensure a commitment to long-term monitoring of northern Gulf of Mexico water quality and the hypoxic zone. Therefore, to augment the efforts of the Mississippi River Basin Water Quality Center, the EPA, the USGS, NOAA, and the Mississippi River basin states should strengthen their commitment to systematic, evaluation-oriented water quality monitoring for the northern Gulf of Mexico.

1
Introduction

The northern Gulf of Mexico hypoxic zone was first recorded on the continental shelf in the early 1970s and has remained persistent since sustained data collection on its distribution and dynamics was begun in 1985. Hypoxia is the term that describes conditions in a waterbody with levels of dissolved oxygen low enough to harm fish and other aquatic species. The existence of this seasonal "dead zone" derives from excess inputs of nutrients from the Mississippi and Atchafalaya rivers into the northern Gulf of Mexico. These inputs result in nutrient overenrichment in the northern gulf, which contributes to high levels of algal biomass production. When these algae die, the process of decomposition depletes dissolved oxygen from the water column and leads to these hypoxic conditions.

Efforts to remedy hypoxia are complicated by many factors, including the numerous sources and actions across the vast Mississippi River basin that generate nutrient yields, and the large time lags between nutrient inputs to the northern Gulf of Mexico and subsequent changes in the hypoxic zone. The hypoxic zone has been the subject of extensive research and many studies and initiatives, some of the more recent and prominent of which are summarized in Box 1-1. The reader interested in further details of Mississippi River water quality, nutrient loadings across the river basin, and the science of hypoxia is encouraged to consult these reports.

The U.S. Environmental Protection Agency (EPA), through its Clean Water Act authorities and responsibilities, plays a key role in the monitoring and management of northern Gulf of Mexico water quality and hypoxia. To obtain advice on Mississippi River basin nutrient control strategies, the EPA requested that the National Research Council (NRC) and its Water Science and Technology Board (WSTB) convene a committee to consider and advise in three broad topic areas. In making this request to the National Research Council, the EPA also sought to build upon an earlier, 2008 report from the NRC on Mississippi River water quality and the Clean Water Act (summarized as part of Box 1-1).

The three topic areas addressed in this report (abbreviated here and found in full in the committee statement of task in Appendix A) are:

1. Given the state of scientific knowledge and associated uncertainties applicable to reducing the hypoxic zone in the Gulf, how might existing loading estimates and targets be used to initiate pollutant control programs?

BOX 1-1
Recent Studies and Reports on Mississippi River Basin Nutrient Loadings, Water Quality, and Northern Gulf of Mexico Hypoxia

Northern Gulf of Mexico hypoxia has been the subject of extensive scientific research over the past two decades. The period of 2008 and late 2007 saw the release of many prominent reports on these topics. This box summarizes four of these reports.

2008 Gulf Hypoxia Action Plan

This 2008 report from the federal interagency Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (MS River/Gulf of Mexico Watershed Nutrient Task Force, 2008) follows up and builds upon a 2001 report from the task force, which was the first "action plan" for gulf hypoxia. That 2001 report listed a goal of reducing the 5-year running average areal extent of the hypoxic zone to less than 5,000 square kilometers by the year 2015 (MS River/ Gulf of Mexico Watershed Nutrient Task Force, 2001). This goal was restated in the 2008 task force report.

SPARROW Model Results

This 2008 paper presents results from a spatially referenced regression on watershed attributes (SPARROW) water quality model. This paper was co-authored by six scientists, most of whom are USGS staff and are affiliated with its National Water Quality Assessment program (Alexander et al., 2008). The paper presents geographic differences in nitrogen and phosphorus yields from across the Mississippi River basin as determined in the SPARROW model results. It also shows geographic differences in the percentage of stream nutrient load that eventually are delivered to the Gulf of Mexico.

NRC Study on Mississippi River Water Quality and the Clean Water Act

This 2008 report from a previous National Research Council committee addresses four broad topics: 1) Mississippi River corridor water quality problems, 2) data needs and system monitoring, 3) water quality indicators and standards, and 4) policies and implementation. The report finds that at the scale of the entire Mississippi River basin and into the gulf, nutrients and sediment are the two primary water quality problems. It concludes that as a result of limited interstate coordination, the Mississippi River is an "orphan" from a water quality monitoring and assessment perspective. It also finds that the EPA has failed to use its Clean Water Act authorities to provide adequate interstate coordination and oversight of state water quality activities. It recommends that the EPA develop water quality criteria for nutrients in the Mississippi River and the northern Gulf of Mexico; ensure that states establish water quality standards and TMDLs such that they protect water quality; and, develop a federal TMDL, or its functional equivalent, for the Mississippi River and the northern Gulf of Mexico.

Report from the EPA Science Advisory Board

This 2007 report from the EPA Science Advisory Board (SAB) Hypoxia Advisory Panel (HAP) summarizes and evaluates the most recent science on the hypoxic zone and the potential options for reducing its size. Among the report's many conclusions is an affirmation of the basic scientific understanding that contemporary changes in the hypoxic area in the northern Gulf of Mexico are related primarily to nutrient fluxes from the Mississippi and Atchafalaya rivers. The report also finds that a significant reduction in the hypoxic zone "is not likely to be achievable over the next eight years" (EPA, 2007). Finally, if the size of the hypoxic zone is to be reduced, the SAB report finds that "a dual nutrient strategy is needed that achieves at least a 45% reduction in both riverine total nitrogen flux and riverine total phosphorus flux" (USEPA, 2007).

2. What are the alternative methods to allocate load reductions to upstream tributaries, states, land uses, and other source classifications?
3. How should the effectiveness of pollutant loading reduction strategies be documented, and how much time would be required to determine if reductions in nutrient and sediment loadings are resulting in a reduction of Gulf of Mexico hypoxia?

Two topics mentioned in the full statement of task to this committee deserve elaboration at this point. They are Section 303(d) of the Clean Water Act, and the roles of nutrients and sediment in northern Gulf of Mexico hypoxia. These are mentioned here because although both topics are referred to in this committee's task statement and are important in Mississippi River and northern Gulf of Mexico water quality issues, neither topic is explored in great detail in this report.

Regarding Section 303(d), the previous 2008 NRC report on Mississippi River water quality and the Clean Water Act discusses EPA authority to act under Section 303(d) and other provisions of the act. It is explained that Section 303(d) requires states to "…identify those waters within its boundaries…" where technology-based controls are insufficient for meeting water quality standards. For each water quality segment so identified, 303(d) requires a state to establish a Total Maximum Daily Load (TMDL) for pollutants that have been identified by EPA as being appropriate.

Language within the Clean Water Act makes it clear that the TMDL process is predominantly intrastate in focus. Nevertheless, as that report importantly notes, TMDLs also must deal with cross-border effects:

> the Clean Water Act, as interpreted by EPA, imposes obligations on upstream states to protect downstream water quality through the adoption of their own water quality standards … Section 303(d) effectively requires an upstream state to adopt a TMDL at a level such that it will prevent interference by its point and nonpoint sources with attainment of downstream state water quality standards (NRC, 2008).

The report goes on to state that:

> EPA has the authority to establish TMDLs with both downstream and upstream interstate effects. … the Clean Water Act requires the EPA to set TMDLs when states fail to do so (Section 303(d)), and the federal courts have upheld the EPA's authority to set federal TMDLs even when only nonpoint source pollutants are contributing to water quality impairment (NRC, 2008).

Thus, if EPA chooses to pursue Section 303(d) authority to develop an implementation plan for the Mississippi River Basin, it apparently has the authority to do so.

However, implementation of Section 303(d) TMDLs depends upon waterways' non-compliance with state water quality standards. Most states along the Mississippi River have not set nutrient water quality standards for the river's mainstem. For states that have set such standards, they have relied primarily on narrative, rather than numeric, water quality criteria. EPA's development of recommended nutrient water quality criteria pursuant to Section 304 of the Clean Water Act, and the states' adoption of nutrient water quality standards pursuant to Section 303, are thus legal prerequisites to the use of Section 303(d) and TMDLs. Moreover, those legal prerequisites depend in turn on the development of a water quality database adequate to support numeric nutrient water quality criteria.

This report recommends some initial steps necessary to develop the information necessary for the EPA and the states to establish numeric nutrient water quality criteria. Specifically, the Nutrient Control Implementation Initiative (NCII) recommended in this report will provide basic information needed for states to set water quality standards (and which, in turn, could lead to the establishment of a basinwide TMDL, if ever it was decided to do that).

Regarding the roles of nutrients and sediment fluxes, forms of nitrogen and phosphorus are contained in excess levels in Mississippi River discharge into the Gulf of Mexico. Both nutrients contribute to overenrichment of the northern gulf's coastal waters, large algae blooms, and subsequent hypoxic conditions. It is beyond the scope of this committee's charge and report to analyze and present in detail the respective roles of these nutrients; further, these types of analyses have been performed by many other scientists and groups of scientists and a large body of literature is available to the interested reader. An excellent starting point is the 2007 report from the EPA Science Advisory Board entitled, *Hypoxia in the Northern Gulf of Mexico* (USEPA, 2007), which provides a detailed and up-to-date review of the roles of nitrogen and phosphorus in gulf hypoxia. Nevertheless, some explanation of the roles of nitrogen and phosphorus in gulf hypoxia is appropriate here.

There is scientific consensus that nitrogen (its nitrate form, more specifically) is causing the northern Gulf of Mexico hypoxic zone in the largest areas and for the longest period (USEPA, 2007). Phosphorus also is a factor, but only in localized areas in the gulf. Phosphorus also is causing impairments in the upper river basin, such as in Lake Pepin on the Mississippi River. Comprehensive nutrient control actions for water quality improvements across the Mississippi River basin and into northern Gulf of Mexico therefore will include both nitrogen and phosphorus control measures. This rationale underpins the EPA SAB recommendation for a "dual nutrient strategy" to reduce the size of the hypoxic zone (USEPA, 2007). Through the rest of this report, references to "nutrients" or "nutrient control" can be considered as referring to both nitrogen and phosphorus management unless specified otherwise.

Sediment transport affects hypoxia primarily through downstream transport of phosphorus that is attached to fine sediment particles. Sediment transport dynamics across the Mississippi River basin have changed markedly in the past two centuries; for instance, much less sediment is transported down the Missouri River system and to the Gulf of Mexico compared to 200 years ago, and sediment deprivation is a significant problem in coastal Louisiana. Soil conservation actions across the river basin could further reduce sediment loadings in some areas and thus reduce phosphorus loadings somewhat. Sediment management actions by themselves, however, would not likely have a large effect on downstream phosphorus transport or on gulf hypoxia. Although phosphorus limitation of phytoplankton production does occur closer to the delta and under high discharge conditions, the driver for this phosphorus limitation is the high nitrogen loads compared to phosphorus. Overall, nitrogen loadings to the gulf are primarily responsible for the severity and extent of hypoxia, which has changed in parallel with increasing nitrogen inputs.

This report contains five following chapters. Chapter 2 is entitled "Nutrient Inputs and Water Quality Effects." It presents and discusses the scientific understanding and nature of northern Gulf of Mexico hypoxia and various efforts to manage this water quality problem better. It is presented as fundamental background information on key water quality issues and problems as they relate to this committee's statement of task.

Chapter 3 is entitled "Getting Started: A Nutrient Control Implementation Initiative." It presents recommendations for a program to help better monitor and control nutrient yields across the Mississippi River basin. It addresses point 1 in this committee's statement of task.

Chapter 4 is entitled "Allocating Nutrient Load Reduction Targets." It discusses factors to be considered in allocating load reduction targets and provides advice to be used in making these decisions across the Mississippi River basin. It addresses point 2 in this committee's statement of task.

Chapter 5 is entitled "Monitoring the Effectiveness of Nutrient Control Actions and Policies." It offers advice for a more formal and structured program for evaluating changes in water quality across the river basin and into the northern Gulf of Mexico. It addresses point 3 in this committee's statement of task.

Chapter 6 is entitled "Overcoming Perceived Obstacles to Action." It identifies several possible objections to decisive actions for improving water quality and nutrient pollutant control, and reasons why these objections need not delay implementation of this report's recommendations.

2
Nutrient Inputs and Water Quality Effects

Adequate monitoring and proper management of Mississippi River water quality, including its effects that extend in the northern Gulf of Mexico, represent important national water management challenges. The Mississippi River basin extends over 41 percent of the area of the conterminous 48 states. It is the world's third-largest river basin (Milliman and Meade, 1983). The river basin includes all or parts of 31 U.S. states (Figure 1). Approximately 70 million people live in the basin, and water quality in the river and into the northern Gulf of Mexico is affected by urban and household activities, industry, agriculture, construction, forestry, and other sectors.

Water quality across the river basin, in the mainstem Mississippi River, and into the northern Gulf of Mexico is affected by many different sources of nutrients (Figure 2) and the river experiences varying levels and types of degradation in different reaches. As noted in the previous 2008 NRC report on Mississippi River water quality and the Clean Water Act, at the scale of the river basin, nutrients and sediment are the primary water quality problems. This chapter discusses: 1) sources of nutrient inputs, 2) water quality impacts of nutrients, 3) scientific understanding of hypoxia and key management challenges.

SOURCES OF NUTRIENT INPUTS

Since its passage in 1972 (and subsequent amendments in 1977 and other years), the Clean Water Act has achieved many successes in helping address point source effluent into the Mississippi River. Today, the more challenging water quality problems across the river basin and in the northern Gulf of Mexico derive from inputs of nonpoint source pollutants, especially nutrients.[1]

Nonpoint source pollutants derive from a variety of unconfined and unchanneled sources of water pollution, such as runoff flowing across agricultural lands, forests, and urban lawns, streets, and other paved areas. In the Mississippi River basin, the majority of nonpoint source pollution comes from agricultural applications of nitrogen and phosphorus fertilizers, primarily

[1] The specific forms of nutrient loads are crucial issues in gulf hypoxia. For nitrogen, nitrate is the prevalent form of nitrogen flux into the gulf. For phosphorus, dissolved phosphorus transported in water plays a larger role than does phosphorus that is transported with sediment.

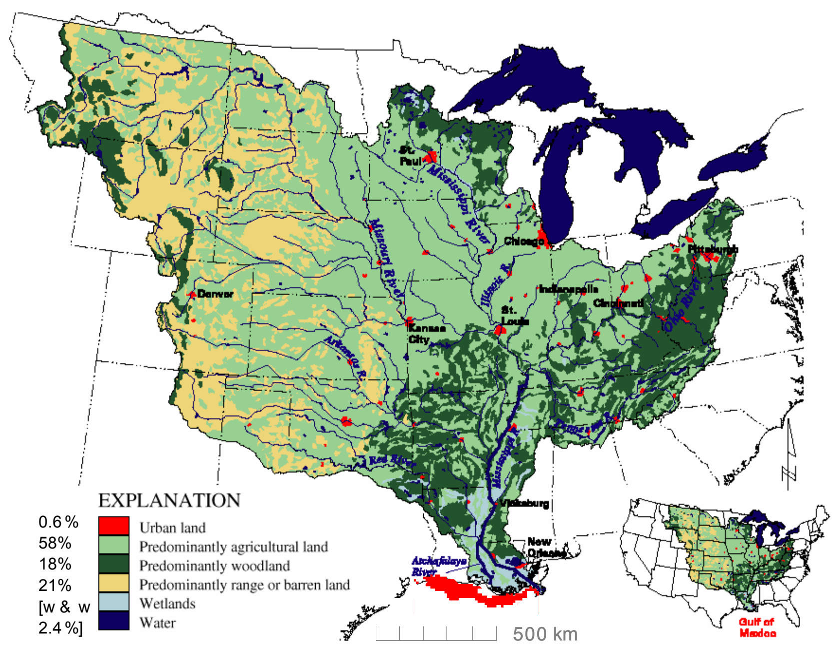

FIGURE 1. Mississippi River basin, major tributaries, land uses, and typical summertime extent of northern Gulf of Mexico hypoxia (in red). The Mississippi River basin extends over 31 U.S. states and covers 41 percent of the conterminous U.S. The size of the river basin and the diversity of land types and uses magnify the challenges associated with improving water quality in the northern gulf.
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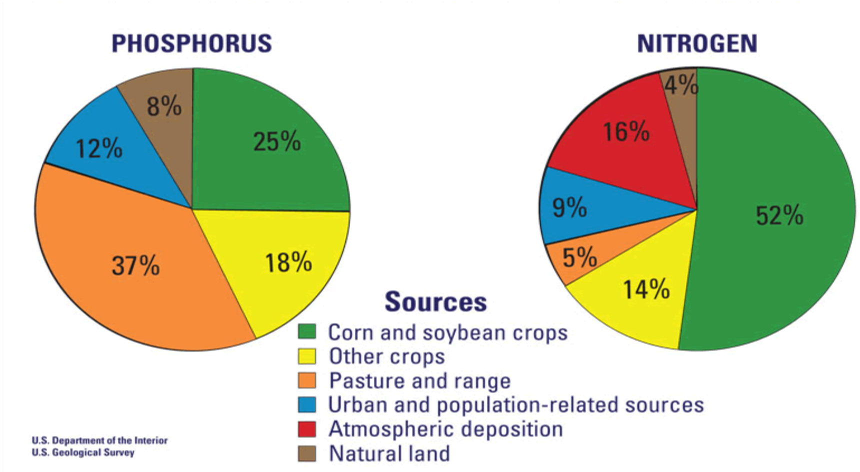

FIGURE 2. Sources of Nutrients Delivered to the Gulf of Mexico. SOURCE: Reprinted, with permission, from Alexander et al. (2008). © by the American Chemical Society.

to row crops such as corn and soybeans (Howarth et al., 1996; Bennett et al., 2001; Turner and Rabalais, 2003). The transport and delivery of nutrients across the Mississippi River basin have been affected substantially by changes in land use and related agricultural practices, including the installation of subsurface drainage systems, as well as nutrient inputs from fertilizers and manure (Baker et al., 2008).

Nutrient discharges from point sources also contribute to nutrient loadings across the river basin. For example, a data file of point sources in the Mississippi River basin created by the EPA lists more than 33,300 discharge permits in the basin (USEPA, 2006), although many of these are minor contributors. Most discharge values for nitrogen in that file are based on secondary data sources, because effluent monitoring for nitrogen (and phosphorus) in the basin is minimal. Total discharge of nitrogen from these point sources into the basin is estimated to be in excess of 210,000 metric tons per year, but the source of this data file includes no estimate of what percentage of that load reaches the Gulf of Mexico. Of the estimated total amount of nutrients discharged into the basin from point sources, 64 percent is attributed to municipal wastewater treatment plants and at least 25 percent to a variety of industrial sources. The balance is from a large array of other point sources, such as commercial and public enterprises.

Much debate has revolved around the relative importance of point sources to the total contributions of nutrients into the Gulf of Mexico. Although the estimated fraction of the current flux of nitrogen and phosphorous being delivered to the Gulf of Mexico from these point sources is roughly 10 percent of the total (Figure 2), the relative importance and actual percentage are contested by some parties. Requiring monitoring and reporting as conditions in National Pollutant Discharge Elimination System (NPDES) discharge permits for large municipal and industrial sources could substantially reduce uncertainties in estimated point source nutrient discharges. These types of permit conditions are common in states containing watersheds that drain to the Chesapeake Bay, the Great Lakes, and Long Island Sound, and in North Carolina, Florida, and California, where hypoxia problems or nutrient-related nuisance conditions have been identified. Requiring the monitoring of nutrients of these point source discharges into receiving waters would improve knowledge of the effects of nutrient discharges and provide useful data regarding relative contributions of those discharges.

Across the Mississippi River basin, farmers add large amounts of nutrients—in the form of nitrogen and phosphorus fertilizers—to supplement soil nutrients in order to increase crop yields. (Figure 3 shows the spatial distribution of phosphorus and nitrogen yields across the river basin.) Runoff and sub-surface flows end up in streams and groundwater systems. These processes result in increased nutrient loading in many streams and waterbodies across the river basin. This process of nutrient transport into the basin's stream systems is exacerbated by subsurface tile drainage systems in some areas. These tile drainage systems are networks of below-ground pipes that allow subsurface water to move out from between soil particles and into the tile line. These systems underlie many areas of row-crop agriculture and are important conduits for nitrate entering surface waters across the Mississippi River basin.

Runoff of nitrogen and phosphorus from agricultural land degrades water quality in many parts of the nation. This degradation is of particular concern across the Mississippi River basin because of the predominance of annual row-crop agriculture. Factors contributing to this region's high productivity and high acreages in row-crop agriculture include naturally rich soil, adequate annual precipitation, relatively flat to gently rolling terrain, and a hydrologically-modified landscape from which excess water drains rapidly and easily. These factors also contribute to high nitrate levels found throughout the region's streams and rivers. Numerous reports document the linkages to nutrient pollution from: prevalence of annual cropping patterns; augmentation of naturally occurring soil nutrients with nitrogen applied in commercial fertilizers and manure; animal manure from livestock operations and increasing runoff from urban development; and, nutrient leaching from failing septic systems (Kalkhoff et al., 2000; McMullen, 2001; Schilling and Spooner, 2006; Hatfield et al., 2008).

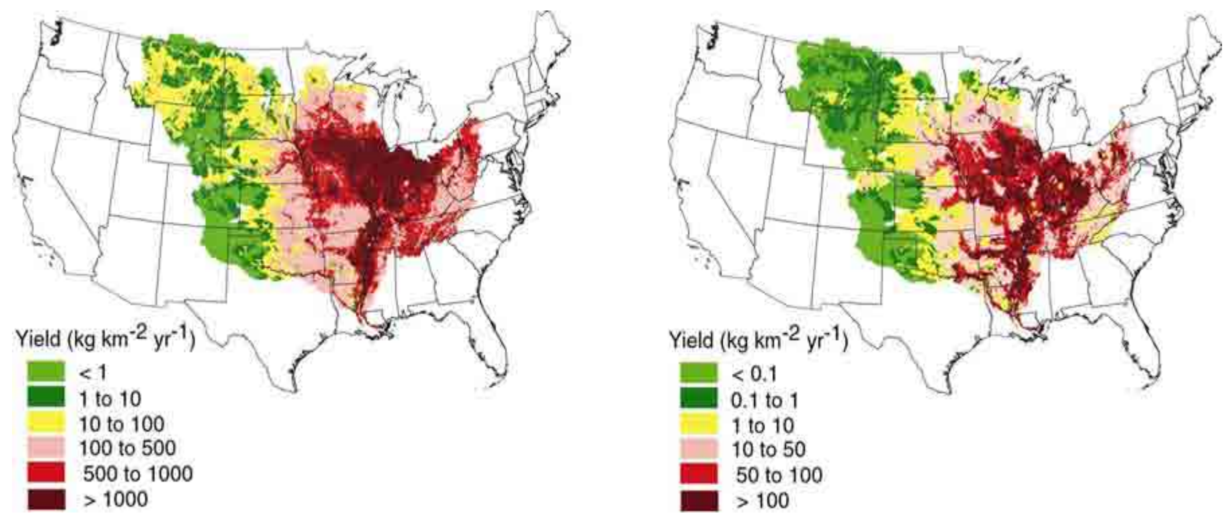

FIGURE 3. Total nutrient yield delivered to the Gulf of Mexico from sources in the Mississippi River basin. The map on the left shows total nitrogen yields, the map on the right shows total phosphorus yields. The large yields from agricultural areas are prominent on this map. These maps also show that large percentages of total nutrient yields derive from a relatively small number of watersheds across the river basin. SOURCE: Reprinted, with permission, from Alexander et al. (2008). © by the American Chemical Society.

WATER QUALITY IMPACTS OF NUTRIENTS

Just as terrestrial plants, such as corn, are synthesized from abiotic materials in the presence of sunlight, several different species of phytoplankton (some of which may be toxic to fish and humans) in waterbodies may be synthesized by similar processes. The primary abiotic building materials for phytoplankton are carbon, nitrogen, and phosphorous. Photosynthesis of phytoplankton is an oxygen-producing process. When phytoplankton die, they sink to lower levels of waterbodies, where microbiological oxidation of the organic matter depletes dissolved oxygen from the water column.

Oxygen also is exchanged between upper layers of the waterbody and the atmosphere. So long as the rate of photosynthesis, atmospheric exchange, and decomposition are within proportional ranges, oxygen remains at levels sufficient to support a rich variety of species. Excess loadings of nitrogen and phosphorus, under the right conditions of sunlight and temperature, can lead to high rates of synthesis and decomposition, reducing oxygen levels in lower parts of the water body to levels that are not sufficient to support many type of fish and shellfish. If dissolved oxygen falls below about 2 milligrams per liter, that portion of the water body is said to be hypoxic and sometimes is referred to as a "dead zone." The hypoxia zone is a seasonal but perennial feature of the coastal waters downstream from the Mississippi River discharge into the gulf and is most prevalent from late spring through late summer. Although hypoxia is mainly a bottom-water condition, oxygen-depleted waters often extend upward into the lower one-half to two-thirds of the water column. Gulf of Mexico waters are stratified for much of the year, primarily because of salinity differences. This stratification intensifies during the warmer summer months and is an important contributor to the hypoxia phenomenon (Rabalais and Turner, 2001; Rabalais et al., 2002).

Since its mapping began in 1985, the hypoxia zone in the northern Gulf of Mexico has averaged an areal extent of 13,800 square kilometers (updated from Rabalais and Turner, 2006). The size of this hypoxia zone has varied from one year to the next, depending on levels of spring nitrate loading (Turner et al., 2006). Despite these year-to-year variations, the size and duration of the hypoxia area has increased during the second half of the twentieth century. For example, in 2007 the hypoxia area was estimated to cover 20,500 km^2 (Figure 4), which represented the third largest hypoxia zone since measurements began in 1985 (LUMCON, 2007; USEPA, 2007). In 2008, the area of low oxygen measured over 20,720 km^2. This made the size of the 2008 (summer) hypoxia zone the second-largest on record (the areal extent of 2001 was roughly equal to that of 2008; LUMCON, 2008).

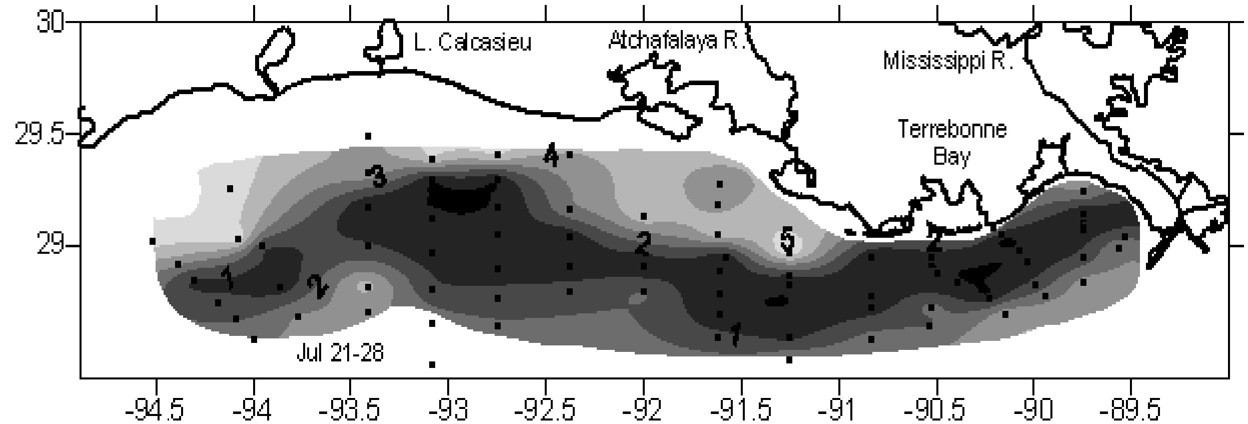

FIGURE 4. Extent of bottom-water hypoxia in the Gulf of Mexico, July 21-27, 2007. Values are milligrams/liter (mg/l) of dissolved oxygen. SOURCE: N. Rabalais, Louisiana Universities Marine Consortium.

The dynamics of the hypoxia zone also apparently have experienced some recent and important shifts, as noted in the EPA SAB report:

> the Gulf of Mexico ecosystem appears to have gone through a regime shift with hypoxia such that today the system is more sensitive to inputs of nutrients than in the past, with nutrient inputs inducing a larger response in hypoxia as shown for other coastal marine ecosystems such as the Chesapeake Bay and Danish coastal waters (USEPA, 2007).

Experience in other systems (e.g., the northwest shelf of the Black Sea; Mee, 2001), and a biological-physical model for the Louisiana shelf (Justić et al., 1997), both indicate that it may take several years or longer to detect a response of the marine system to changes in the nutrient load. Further, changes in land use, particularly with the growing demand for corn-based ethanol (and attendant increases in fertilizer applications) may further affect the hypoxic zone in yet unanticipated ways.

In addition to hypoxia, excess nutrient loadings can result in local water quality problems within the drainage basin. Locally, excess nutrient inputs can impair freshwater systems by, for example, causing blooms of algae that can be dominated by toxic cyanobacteria, such as in a summer 2008 algae bloom in the Raccoon River that threatened the drinking water supply of the city of Des Moines, Iowa. Toxic cyanobacteria can cause human health problems and in some instances can lead to fatalities (Rabalais, 2005; Lopez et al., 2008).

SCIENTIFIC UNDERSTANDING OF HYPOXIA AND IMPLICATIONS FOR MANAGEMENT ACTIONS

The scientific and management challenges in addressing the hypoxia problem have been articulated well in several publications (see Box 1-1). Good scientific knowledge of the sources of nutrient pollutants across the basin, and downstream impacts on water quality, is fundamental to creating viable nutrient pollution management programs and strategies in the Mississippi River basin. Scientific understanding of the geographic sources of nitrogen and phosphorus inputs across the basin has improved greatly over the years.

The attainment of significant reductions in nitrogen and phosphorus loadings represents a difficult goal. For example, there is only limited regulatory authority that the Clean Water Act grants to the federal government to regulate loadings from nonpoint sources of water pollutants. Many economic factors also will affect future nutrient loadings across the basin and discharges into the gulf, further complicating nutrient control measures. For example, current high commodity prices provide incentives for Midwestern farmers to maximize acreage devoted to grain production; on the other hand, higher prices of agricultural land, fertilizers, farm implements, may provide disincentives to increased commodity production.

Efforts to reduce nutrient loadings to the northern Gulf of Mexico, whether they be through improved management practices, construction of wetland areas to trap and filter pollutants, and other actions, will constitute significant management, economic, and public policy challenges. Part of this challenge relates to the long-term, temporal relations between upstream nutrient loadings and subsequent changes in downstream water quality and hypoxia. A difficulty in implementing successful nutrient management measures and programs is the long time required to determine the downstream impacts of changes in nutrient loading levels and patterns. This underscores the importance of evaluating local water quality impacts of nutrient control actions—these impacts will occur sooner and be easier to attribute to a specific course of action.

According to presentations given to this committee by USGS scientists who have worked extensively on Chesapeake Bay water quality monitoring and modeling (Blomquist, 2008; Sanford, 2008), their experience in collecting water quality data and attempting to identify trends in bay suggests that a minimum 9-year period of data is necessary to determine a trend in water quality (see also Lindsey et al., 2003; Langland et al., 2006; Raffensperger and Langland, 2007; Sanford and Pope, 2007). If a 9-year period of trend data *at a minimum* is necessary to recognize whether changes in land use practices, or changes in fertilizer applications, or other nutrient management practices can affect water quality, it may require decades for nutrient control actions in the Mississippi River basin to be reflected in changes in the areal extent of northern Gulf of Mexico hypoxia.

Box 1-1 summarizes Mississippi River water quality modeling efforts being conducted by USGS scientists. Studies being conducted within the USGS program on "SPAtially Referenced Regressions On Watershed attributes", or SPARROW, present information on geographic sources of nitrogen and phosphorus loadings from across the river basin, and the relative proportions of land use categories of these sources. Figure 5, for example, comes from the SPARROW modeling team and shows the percentage of nutrient loads exported by different watersheds that are delivered to the gulf (Alexander et al., 2008).

The nine Mississippi River states listed in Table 1 account for approximately three-fourths of the nitrogen and three-fourths of the phosphorus that reaches the Gulf of Mexico (Alexander et al., 2008). Although the remaining roughly one-quarter of nitrogen and phosphorus loads that reach the Gulf of Mexico is not insignificant, the SPARROW model results provide information that would be important in targeting nutrient control action to areas of higher nutrient yields (Alexander et al., 2008).

Figure 6 shows several watersheds from the Corn Belt region and their total nitrogen yields. Watersheds in this figure are delineated as six-digit hydrologic accounting units (HACs) as defined by federal Hydrologic Unit Codes (HUCs). Each of those watersheds can be divided into eight-digit watersheds known in the federal coding system as hydrologic cataloging units (these smaller watersheds are not shown in order to avoid excessive detail).

TABLE 1. States that contribute approximately three-fourths of the total nitrogen and phosphorus delivered to the Gulf of Mexico.

Arkansas	Iowa	Missouri
Illinois	Kentucky	Ohio
Indiana	Mississippi	Tennessee

SOURCE: Reprinted, with permission, from Alexander et al. (2008). © by the American Chemical Society.

Figure 6 shows HACs that have been overlaid with data on densities of loads (as estimated by the USGS). This figure shows that a large portion of the total Mississippi River basin nitrogen load delivered to the northern Gulf of Mexico comes from a relatively small number of HACs. There are approximately 125 HACs in the basin that drain directly to the Mississippi River mainstem (a few other HACs drain directly to the Gulf of Mexico). Of these 125, about 30 of them—which cover about 20 percent of the basin—account for substantial percentage of total nitrogen yield from the basin. This large concentration of the sources of nitrogen loadings in a relatively small number of hydrologic units/watersheds is important information for any program designed to reduce nutrient loadings to the Mississippi River and the northern Gulf of Mexico. Indeed, this information may identify opportunities for substantially reducing the areal extent of northern Gulf of Mexico hypoxia. Many groups have emphasized the importance of targeting nutrient control strategies at watersheds of higher nutrient yields. The previous 2008 NRC report, for instance, concluded that:

> Programs aimed at reducing nutrient and sediment inputs should include efforts at targeting areas of higher nutrient and sediment deliveries to surface water (NRC, 2008).

The EPA Science Advisory Board Hypoxia Advisory Panel noted that the greatest concentration of nitrogen and phosphorus in runoff comes from the upper Mississippi and Ohio-Tennessee river subbasins, both of which have extensive tile drainage systems. The SAB report recommends ". . . targeting sub regions or watersheds that have a disproportionate effect on hypoxia and local water quality" (USEPA, 2007).

In addition to targeting resources to priority watersheds, resources should be strategically targeted at specific geographic areas within a given watershed. There can be substantial variations in slope, land cover, soil type, and other features across a watershed, all of which affect runoff, erosion, and rates and levels of nutrient loadings into streams. This more exact targeting within an individual watershed promotes efficient expenditure of conservation program dollars and improvements in water quality (Sharpley et al., 2006). These more targeted actions can help identify and concentrate nutrient reduction efforts in priority watersheds on those areas where nutrient control efforts are more likely

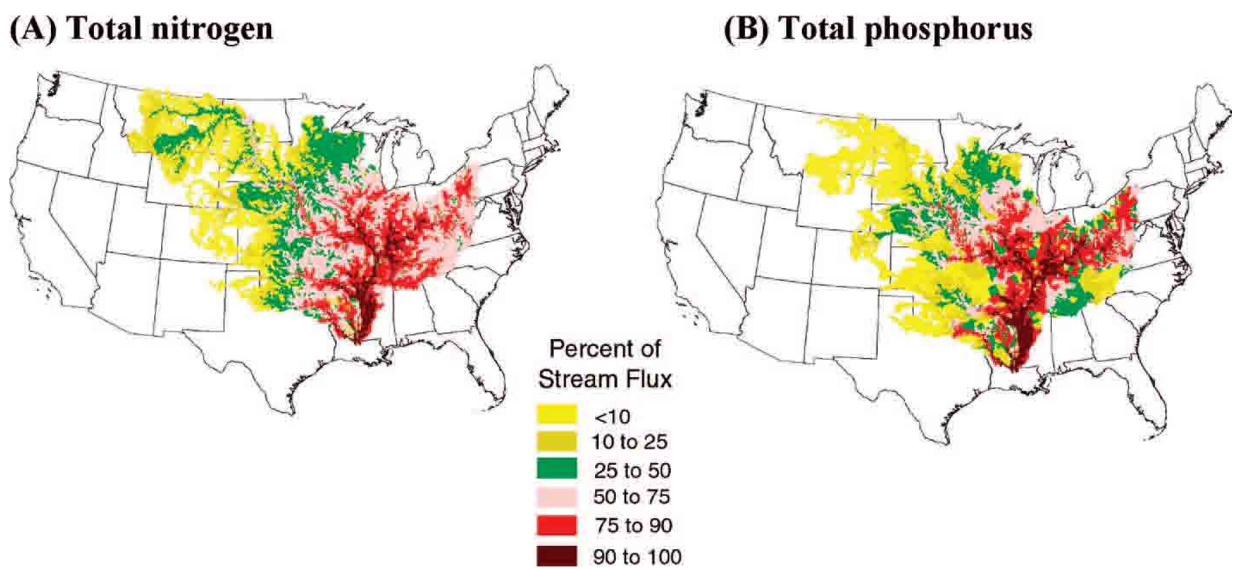

FIGURE 5. Percentage of stream nutrient load delivered to the Gulf of Mexico.
This figure illustrates the geographic differences within watersheds in percentages of nitrogen and phosphorus yields that reach the Gulf of Mexico. These maps suggest the need to focus nutrient reduction strategies on watersheds with both high total yields (as seen in Figure 3) and on high percentages of yields that reach the Gulf of Mexico. SOURCE: Reprinted, with permission, from Alexander et al. (2008). © by the American Chemical Society.

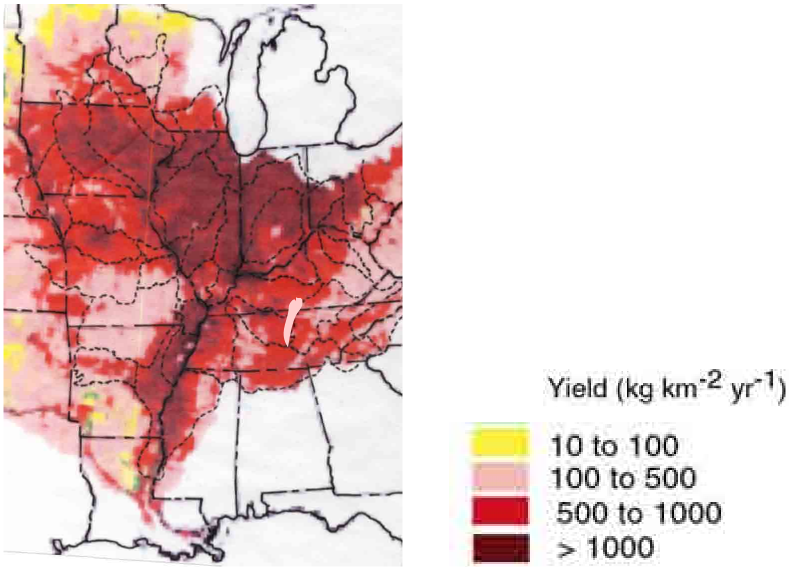

FIGURE 6. Hydrologic Accounting Units and spatial patterns of nitrogen yields in a portion of the Mississippi River basin. The figure clearly shows the high concentration of nitrogen yields from a relatively small number of watersheds. SOURCE: Reprinted, with permission, from Alexander et al. (2008). © by the American Chemical Society.

Finding/recommendation 1:

Realizing progress toward reducing the areal extent of northern Gulf of Mexico hypoxia will require an acknowledgement that there will be a considerable time lag—roughly a decade, at a minimum—between nutrient reduction actions across the river basin and ecological and water quality responses downstream in the gulf.

Finding/recommendation 2:

Purposeful targeting of nutrient control efforts toward areas of higher nutrient loadings will be essential to realize the greatest initial reductions in nutrient loadings. EPA and USDA should direct conservation programs and other nutrient management resources to priority Mississippi River basin watersheds with higher levels of nutrient loadings. In addition to targeting individual watersheds, those programs should identify specific areas within watersheds where expenditures and actions are more likely to produce initial, positive results.

Finding/recommendation 3:

To improve knowledge regarding point sources' relative contributions of nutrient pollution, EPA should require major municipal and industrial

point source dischargers to monitor nutrient concentrations—nitrogen and phosphorus—in effluent at their discharge point as a condition of their National Pollutant Discharge Elimination System (NPDES) permits.

3
Getting Started: A Nutrient Control Implementation Initiative (NCII)

This chapter discusses and presents a recommendation for a "Nutrient Control Implementation Initiative" (NCII) that could improve knowledge of best management practices, their implications for more effective nutrient control, and how they affect both local and downstream water quality. In doing so, it addresses question 1 in this committee's statement of task that asks for advice on initiating a pollutant control program.

PILOT PROJECTS AND AN ADAPTIVE, ACTION-ORIENTED APPROACH TO THE HYPOXIA PROBLEM

The targeting of specific watersheds for priority nutrient control actions can be approached in different ways. One approach could be to identify high priority watersheds within the Mississippi River basin, apply cost-effective best management agricultural and conservation practices to those watersheds, measure effects of those practices on nutrients loads, and adjust practices as necessary to satisfy a given nutrient reduction goal. Priority actions in the watersheds could be assigned using several criteria, such as the relative magnitudes of nutrient loads exported to receiving streams and estimated fractions of those loads that reach the gulf (this type of information is provided in the SPARROW model results; see Alexander et al., 2008).

Another strategy, and the one implied by language in the Clean Water Act, is to establish a goal of a specified reduction of nutrient loads at the gulf, then divide load allocation responsibilities among contributing watersheds. A nutrient control management plan within a given watershed then would be designed to satisfy that portion of the basinwide goal allocated to that watershed (criteria and methods for allocating load reductions are discussed in Chapter 4).

Either of these approaches could be initiated in the near future based on existing management programs, current information on nutrient loads within the Mississippi River basin, cost-effective management practices, and watershed-to-gulf delivery coefficients. Initial steps toward load reductions could be taken and supported by existing funding and existing scientific information. Ideally (and as recommended in this report), those actions would be supported and informed by an evaluative pilot project program aimed at improving scientific understanding of nutrient inputs and nutrient control actions, and their downstream impacts.

Regardless of the general approach taken to reduce nutrient loadings, the information and experience gained through the Nutrient Control Implementation Initiative projects recommended in this chapter will be important to initial implementation decisions and subsequent adjustments. The coordinated network of the NCII pilot projects would represent a systematic approach to better understanding and managing nutrient inputs across the basin, and evaluating their potential local benefits and downstream impacts.

The scope of the NCII described in this chapter would cover only a small portion of the river basin and, in and of itself, would not lead to substantial reductions in the areal extent of the hypoxic zone. Instead, the NCII program would represent a special, science-based initiative to provide input to guide and adapt larger nutrient control efforts—perhaps ultimately even a basinwide TMDL. This chapter presents the NCII program as an evaluative effort that will help inform larger nutrient allocation efforts for the river basin (and that are discussed in Chapter 4).

NCII RATIONALE AND GOALS

A network of nutrient control pilot projects for the river basin offers an opportunity to learn more about the relative effectiveness of various nutrient control actions with regard to water quality improvements (both locally and, over time, farther downstream), institutional viability, and social and economic benefits. Such a network would provide opportunities to strengthen interagency, interstate, and state and local coordination and cooperation in nutrient control actions and water quality monitoring and evaluation. Over time, additional pilot projects could be added to extend the network of projects and improve knowledge of land management practices (or “best management practices”) across the river basin. The pilot projects would be long-term capital investments, rather than short-term trials, and would represent initial steps toward a larger, basinwide network of land management practices aimed at protecting water quality in the Mississippi River and northern Gulf of Mexico. Because of the importance of targeting limited financial resources to areas of higher nutrient loadings, initial NCII project sites should be in areas that have the highest probability of showing results.

There is also a need for an initiative to help coordinate and synthesize “agricultural and conservation intelligence.” Farmers across the river basin are involved in many creative, innovative nutrient management efforts that represent an important source of experience and knowledge. There are many land grant and other universities across the river basin with numerous experts in soil science, agricultural engineering, agronomy, economics, and other fields with extensive knowledge of agricultural and best management practices, water quality modeling and management, and related topics. There is also a large network of county extension agents and other soil and water conservation experts in the basin's rural areas. A limitation of this knowledge base, however, is that outcomes of the many nutrient control and related conservation efforts are not systematically monitored or formally evaluated and compared across the river basin (Schempf and Cox, 2006; Cox, 2008).

The nature of the hypoxia problem suggests the need for priority actions, interim goals that can be adjusted with time, and a process that promotes learning and better management decisions as new information is gained. These program elements are captured within the rubric of adaptive management. The NCII projects will contribute to an adaptive approach to learning more about effective approaches for controlling nutrients on agricultural land in the Mississippi River basin. Several scientific bodies and experts, including the watershed nutrient task force and the EPA SAB Hypoxia Advisory Panel (both described in Box 1-1) support an adaptive management approach in addressing the challenges of better nutrient pollution control and reducing the extent of the hypoxic zone (see also Freedman et al., 2008).

The NCII initiative and its individual projects are envisioned as a special evaluative component of larger nutrient load reduction efforts across the river basin. Ideally, the NCII will strengthen research in nutrient control and best management practices, and result in local water quality improvements. The NCII is only one aspect of all basinwide efforts devoted to reduce nutrient loadings. Implementation of other research efforts or best management practices across the basin thus need not await NCII development and implementation.

A stronger commitment to performance-based, farm-level conservation actions and water quality monitoring will be necessary to reduce the extent of northern Gulf of Mexico hypoxia. Most current nutrient control efforts, which are made possible by USDA land and water conservation programs that promote use of best management practices (BMPs), are not closely monitored, if at all. Further, a basinwide system for implementing conservation and water quality practices, monitoring the results of those practices, comparing results from across different geographic regions, and applying those results to subsequent conservation efforts will be necessary. These "results" will include a wide range of outcomes, including cost effectiveness, changes in nutrient yields and water quality, and acceptability among the parties involved (e.g., farmers and relevant federal and state agencies). The NCII projects will provide a vehicle for getting started on systematically implementing and testing best management practices at the scale needed to improve water quality with respect to nutrients in the Mississippi River basin.

COMPONENTS AND SCOPE OF NCII PROJECTS

A primary goal of the Nutrient Control Implementation Initiative projects would be to evaluate effectiveness of land and water management practices to meet various performance goals. The NCII projects will be useful in identifying the level of water quality improvements feasible for agricultural watersheds having different characteristics. To help keep pilot projects focused on outcomes and to explore the limits of ultimate achievements, the pilot projects will include interim goals that are periodically gauged and adjusted. To help better understand the potential benefits of these projects, some portion of the NCII effort could be devoted to exploring the maximum benefits that a given project(s) might achieve.

The NCII projects would have the following components:

- Pre-project planning and design;
- Capital facility installation;
- Operation and maintenance;
- Water quality and land use monitoring.

Examples of the types of practices that would be implemented and tested include: erosion and sediment control; crop scheduling and nutrient management; manure storage and application management; vegetative buffers; control of confined animal feeding operations; runoff interception; constructed wetlands, and; other already established best management practices for nutrients and improving nutrient efficiency (see, for example, PADEP, 2008).

These projects would be conducted on agricultural watersheds encompassing areas sufficient to allow evaluation of land management and water quality protection practices at large scale. An area of approximately 25,000 acres is envisioned as an upper bound to the size of the individual NCII pilot projects. There may be smaller or larger projects depending on economic, administrative, and other specific conditions at a given NCII project site. There is ample precedent for conducting demonstration and evaluation projects at this scale, including several ongoing water quality and conservation projects that could be recruited into the NCII program. To the extent possible, application sites will coincide with watershed boundaries such that they will have "outlets" amenable to water quality monitoring. This is an important consideration, as it often is difficult to capture all nutrient fluxes and other impacts in a watershed when evaluating the effectiveness of best management practices.

To help realize the potential value of the NCII program, it will be important to design its pilot projects as long-term efforts. The NCII and its projects are not envisioned as short-term efforts to be terminated after one or two years. On the contrary, initial projects should be viewed as long-term endeavors that represent the start of basinwide implementation and that will serve as nuclei for the extension of additional projects to other watersheds across the river basin. Ultimately, a systematic, basinwide framework for implementing and evaluating best management practices and changes in water quality will be essential to support the NCIIs and this report's recommendations. It also will augment production goals with similarly important goals of nutrient and soil conservation and water quality protection.

Following current practices, state and local organizations would administer individual NCII pilot projects. However, a new organization would be required to plan and evaluate all NCII projects at the river basin scale. A new Mississippi River Basin Water Quality Center—which is recommended and discussed in Chapter 5–would fulfill these and other roles. The new center would include participation of other federal agencies, Mississippi River basin states, and local agricultural (e.g., organized drainage districts in tile-drained areas) and other relevant entities. Beyond the Mississippi River basin, many aspects of the Chesapeake Bay Program office can serve as a model for establishing and operating this new center (although the Mississippi River Water Quality Center will require more direct involvement by the USDA). Developing an effective institutional model for multi-agency, multi-state cooperation would be an ongoing goal of the NCII program, in addition to achieving its more science-based, technical objectives. Box 3-1 presents further examples of interagency cooperation in nutrient management and control programs.

BOX 3-1
Historic Examples of Interagency Cooperation on Nutrient Control Implementation

Two important historical examples of interagency cooperation for watershed based nutrient implementation projects are the Rural Clean Water Program (RCWP) and the Management Systems Evaluation Areas (MSEA) program.

The Rural Clean Water Program (RCWP)

The RCWP was a ten-year federally sponsored nonpoint source (NPS) pollution control program. It was initiated in 1980 as an experimental effort to address agricultural NPS pollution problems in watersheds across the country. RCWP objectives were to: 1) achieve improved water quality in the approved project area in the most cost-effective manner possible in keeping with the provision of adequate supplies of food, fiber, and a quality environment, 2) assist agricultural landowners and operators to reduce agricultural NPS water pollutants and to improve water quality in rural areas to meet water quality standards or water quality goals, and 3) develop and test programs, policies, and procedures for the control of agricultural NPS pollution.

The enabling legislation for the RCWP was the Agriculture, Rural Development, and Related Agencies Appropriations Act (P.L. 96-108). With a total appropriation of $64 million, the RCWP funded 21 experimental watershed projects across the country. The projects represented a wide range of pollution problems and impaired water uses (USEPA, 1993). The RCWP was administered by the USDA Agricultural Stabilization and Conservation Service, in consultation with EPA.

continues next page

BOX 3-1 Continued

Management Systems Evaluation Area (MSEA)

In 1989 the USDA instituted a water quality initiative as a research program entitled the Management Systems Evaluation Areas (MSEA), which had a mandate of three principles:1) protection of the Nation's ground water resources from contamination by fertilizers and pesticides without jeopardizing the economic viability of U.S. agriculture, 2) water quality programs that address the immediate need to halt contamination and the future need to alter fundamental farm practices, and 3) ultimate responsibility of farmers for changing production practices to avoid contaminating ground and surface waters.

Within USDA, the Agricultural Research Service (ARS) was a co-leader in these investigations, which were conducted in Iowa, Minnesota, Missouri, Nebraska, and Ohio. These studies were developed at the watershed scale to evaluate the effects of different farming practices on ground and surface water using nitrate-N and pesticides as the primary indicators. Leadership for these efforts was jointly provided by ARS and land grant institutions, with cooperation at each site from EPA and USGS.

The RCWP and MSEA program demonstrated utility of interagency participation and cooperation on the resource centric issue of water quality and nutrient control. The agencies involved benefited from the fact that there was dedicated funding to support their involvement while gaining valuable experience. Although the RCWP had many benefits, the program scope was limited. The RCWP was aimed more at practices in specific places, rather than taking a broader, watershed-based perspective and attempting to target the most cost effective places to invest in water quality. Input from economists and other social scientists into the program was limited. Moreover, lessons gained through the RCWP were never fully institutionalized.

With regard to the research-based MSEA program, scientists were to "assess landscapes and farming systems for their vulnerability to water contamination from farm chemicals, provide information about the behavior and effects of agrichemicals on the ecology, and identify environmentally sound farming systems that are acceptable to producers" (USDA, 1994). The concerns regarding pollutants were aimed more at pesticides rather than nutrients. One outcome was that the ARS enhanced its capability to conduct this type of integrated research, which extended into the Agricultural Systems for Environmental Quality (ASEQ) program as a follow-on to MSEA and the extension into Conservation Effects Assessment Program (CEAP). The MSEA program generated over 600 publications and reports from the various sites. Lessons learned from MSEA have been incorporated into CEAP in terms of data analysis, quality assurance/quality control, and database development (USDA, 1994; Jerry Hatfield, USDA National Soil Tilth Laboratory, Ames, Iowa, personal communication, 2008).

The initial scope of the NCII program will require detailed planning with consideration of willing partners, existing projects, and available or potentially available resources. The initial number of NCII projects should be large enough to encompass a representative range of watershed types and runoff quality, and a corresponding range of nutrient control technologies and approaches; this will allow a good sampling of nutrient control prospects in the wide variety of landscapes and geographical settings in the Mississippi River basin. The initial number of projects also should not be so large that it overwhelms the capacity of scientists, farmers, and administrators involved in the nutrient control and water quality monitoring and assessment activities. This initial number will be an administrative and policy decision not necessarily grounded in scientific evidence, and surely it will be adjusted over time. In the committee's collective judgment, however, approximately 40 NCII projects is a reasonable starting point.

These initial projects would be targeted to high priority watersheds that represent a range of cropping patterns, land types, and water quality protection challenges. These initial projects also will be located in areas of higher nutrient loadings. Table 1 lists nine states in the river basin with the largest nutrient contributions to the Mississippi River. The SPARROW model results (and which are reflected in Table 1) are useful in identifying these areas. Those results also show that areas of the highest nutrient loadings are not necessarily limited to these nine states—nutrient loadings are not based primarily on political boundaries, but are a function of watershed features, land use types, and climate and hydrology. The initial group of 40 NCII projects thus may be primarily focused in these nine states, but some of those projects could be located in other areas of high nutrient yields not in one of the nine states.

EPA AUTHORITY REGARDING PILOT PROJECTS

An important aspect of establishing nutrient pollution control demonstration projects is the Clean Water Act authorities that would enable or constrain such efforts. The EPA has multiple sources of authority under the federal Clean Water Act to authorize and implement demonstration or pilot projects designed to test methods for reducing nutrient loading into the river and the Gulf of Mexico. Most generally, in Section 101, Congress stated that the Clean Water Act's objective "is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" and then gave the EPA Administrator authority to administer the act (33 U.S.C. § 1251).

Under Section 102 of the act,

> The Administrator shall, after careful investigation, and in cooperation with other Federal agencies, State water pollution control agencies, interstate agencies, and the municipalities and industries involved, prepare or develop comprehensive programs for preventing, reducing, or eliminating the pollution of the navigable waters and ground waters and improving the sanitary condition of surface and underground waters. . . . For the purpose of this section, the Administrator is authorized to make joint investigations with any such agencies of the condition of any waters in any State or States, and of the discharges of any sewage, industrial wastes, or substances which may adversely affect such waters [33 U.S.C. § 1252(a)].

Most importantly, Section 104 gives the EPA the authority to "establish national programs for the prevention, reduction, and elimination of pollution," including, "in cooperation with other Federal, State, and local agencies," the explicit authorities to: (1) "conduct . . . research, investigations, *experiments*, training, *demonstrations*, surveys, and studies relating to the causes, effects, extent, prevention, reduction, and elimination of pollution"; and (2) to "establish, equip, and maintain a water quality surveillance system for the purpose of *monitoring* the quality of the navigable waters and ground waters and the contiguous zone and the oceans" (33 U.S.C. § 1254(a) (emphasis added)). In pursuit of the activities described in (1), moreover, the EPA is authorized to *make grants* (33 U.S.C. § 1254(b)(3)), and, explicitly, to cooperate with the Secretary of Agriculture and the states to:

> carry out a comprehensive study and research program to determine *new and improved methods and the better application of existing methods of preventing, reducing, and eliminating pollution from agriculture*, including the legal, economic, and other implications of the use of such methods [33 U.S.C. § 1254(p) (emphasis added)].

Sections 105 and 304, in turn, touch on EPA's authority with respect to projects involving both nonpoint and agricultural sources. Under Section 105, EPA "is authorized to make grants to any State or States or interstate agency to demonstrate, in river basins or portions thereof, advanced treatment and environmental enhancement techniques to control pollution from all sources, within such basins or portions thereof, including nonpoint sources" and, "in consultation with the Secretary of Agriculture, [to make] grants to persons for research and demonstration projects with respect to new and improved methods of preventing, reducing, and eliminating pollution from agriculture" (33 U.S.C. § 1255(b), (e)(1)). In turn, under Section 304, EPA has a continuing duty to provide states and the public with information regarding the best "processes, procedures, and methods to control pollution resulting from . . . agricultural and silvicultural activities, including runoff from fields and crop and forest lands" and to enter agreements with the Secretary of Agriculture "to provide for the maximum utilization of other Federal laws and programs for the purpose of achieving and maintaining water quality" through states' nonpoint source management plans (33 U.S.C. § 1314(f)(2)(A), (k)(1)).

Finding/recommendation 4:

The EPA and USDA should jointly establish a Mississippi River basin Nutrient Control Implementation Initiative (NCII). A new Mississippi River Basin Water Quality Center, which is discussed in more detail later in the report (see finding/recommendation 8), should administer the NCII.

Goals of the NCII should be to:

- **Demonstrate the ability to achieve reduced nutrient loadings by implementing and testing a network of nutrient control pilot projects.**

These projects should be implemented in priority watersheds as part of an adaptive, nutrient control process;

- **Evaluate local water quality and other benefits of nutrient control actions;**
- **Build an institutional model for cooperative research and nutrient control actions among federal, state, and local organizations;**
- **Evaluate the cost effectiveness, and strengthen the economic viability and community engagement, of various nutrient control actions;**
- **Compile and communicate best practices as revealed in the pilot projects.**

A suite of well-designed NCII projects would represent a research-based effort that could contribute greatly to the development of more effective, cost-effective solutions to nutrient export problems in the Mississippi River basin. In addition to their evaluative and research dimension, the NCII projects have the potential to contribute to local water quality improvements.

Nutrient control actions in these watersheds should be considered as pilot efforts to guide future basinwide nutrient control activities. Results from the NCII watersheds should be monitored and published in an effort to improve and share knowledge of the effectiveness of nutrient control actions. Over time, nutrient control actions should be amenable to changes and improvements, and additional watersheds can be added to the NCII as leading agencies and participants see fit.

The NCII also should be designed to identify questions for further inquiry, to enhance knowledge, and to realize land management and water quality improvements in three areas:

1) *Technical validation and program costs.* Key issues here include evaluating outcomes of conservation and best management practices, water quality monitoring, and comparing on-farm results among the pilot projects. It is crucial that monitoring results are used to evaluate costs and benefits, and the transferability of results to other NCII project sites. The process of technical validation also should include development of common guidance for NCII projects.

2) *Institutional model development.* The NCII should be jointly administered by EPA and USDA. The participation and resources of other federal agencies (e.g., the USGS) and of state agencies, along with individual farmer participation, will be crucial to its success. Participation of private sector groups, nongovernmental organizations (NGOs), and the region's land grant universities also will be important to its viability. Part of the NCII initiative should focus on enhancing and strengthening these many institutional arrangements and relations.

3) *Socioeconomic viability.* The farmers and others who work this landscape cannot be expected to implement nutrient control actions if it greatly interferes with their ability to make a living. The NCII initiative thus also will study economic and social implications of nutrient control actions, with an eye toward identifying those actions that are more cost effective and more widely embraced and implemented. The EPA SAB report recognized the importance of and links between social well-being and economic efficiency, noting that, "…preserving/enhancing social welfare will require implementing policies that target the most cost-effective sources and locations for nutrient reductions" (USEPA, 2007).

Selection of watersheds to be included in the NCII program should consider several criteria, not all of which may be fully satisfied by any particular watershed. Watersheds should be representative of the population of watersheds that are to be targeted by the load allocation process, which is discussed in Chapter 4. They should have relatively high nutrient loads and be a significant contributor to either a locally impacted waterbody or the Mississippi River and northern Gulf of Mexico. To reduce costs and obtain results in a timely manner, consideration also should be given to watersheds with existing water quality and flow data sufficient to establish baseline values of nutrient loadings. Preference should be given to watersheds with documented histories of prior land uses and tillage patterns, cropping patterns, fertilizer and manure application rates, and nutrient control activities. Preliminary results of the evaluation of effectiveness are likely to be seen earlier in watersheds that have a history of cooperative, participatory nutrient management programs. Furthermore, it is in those watersheds where evaluation of socioeconomic viability is likely to be most productive—landowners in these watersheds have developed perceptions and opinions regarding various nutrient control and conservation actions; perceived impacts of nutrient management programs are more likely to have materialized; and issues related to equity are more likely to have arisen.

IDENTIFYING NCII WATERSHEDS

Finding/recommendation 5:

As part of the NCII, the US EPA and USDA should identify a select group of Mississippi River basin priority watersheds for initial actions. The selection of priority watersheds should consider, but not necessarily be limited to, the following factors:

- **Watersheds of higher nutrient loadings as identified by SPARROW model results;**
- **Watersheds that are sites of current and previous water quality and land use monitoring and evaluation programs and activities, and that possess inventories such as cropland and animal populations; and,**
- **Watersheds that are focal points of conservation activity and interest to USDA, state, and local parties.**

The list of variables to be considered in selecting NCII priority watersheds is expected to expand and evolve over time.

FINANCING THE NCII

As agricultural sources contribute the largest share of nutrients that are delivered from the Mississippi and Atchafalaya rivers to the northern Gulf of Mexico, USDA-sponsored conservation programs and the Farm Bill[2] recently reauthorized by Congress—with billions of dollars set aside for conservation and environmental quality—will be essential to both local water quality improvements and to reducing the areal extent of the hypoxic zone.

The largest of the USDA conservation programs that provide incentives to farmers for voluntary participation are the Conservation Reserve Program (CRP) and the Environmental Quality Incentives Program (EQIP). These programs were authorized in the 1985 and 1996 Farm Bill, respectively. More recently, Congress authorized a Conservation Security Program (CSP), which complements the CSP and EQIP and is administered by the USDA Farm Services Agency (FSA) and its Natural Resources Conservation Service (NRCS). As part of the process in aligning these programs with national water quality objectives, it will be important also to align the priorities and institutional and programmatic structures of USDA conservation programs with EPA's water quality priorities and mission. In doing so, the EPA and USDA certainly will look to draw upon previous interagency coordination. One example of these efforts is the Conservation Effects Assessment Project (CEAP), which was begun in 2003 to quantify the environmental benefits of conservation practices used by private landowners participating in USDA conservation programs (NRC, 2008).

Resources available to EPA, and its state partner programs, for such water quality improvement efforts are relatively small or are largely restricted to funding hard infrastructure investments for wastewater and water utilities. Innovative and non-traditional financing arrangements may need to be explored as a means for supporting water quality and nutrient management programs in the basin (Box 3-2 discusses an example of non-traditional financing arrangements). These agencies operate under a law—the Clean Water Act—that Congress did not design to effectively control or address agricultural nonpoint sources of pollutants.

Within the USDA's authorities, the recent Food Conservation and Energy Act of 2008 reauthorized flagship Working Land Conservation Programs, namely the EQIP and the Conservation Stewardship Program (CSP). These

[2] The Farm Bill is the primary legislation governing U.S. federal agricultural and food policy. It is a comprehensive omnibus bill that the U.S. Congress passes every several years and deals with agriculture and other affairs under USDA purview.

BOX 3-2
Non-traditional Financing to Support Water Quality and Nutrient Management

Because of nitrate concerns for the city of Des Moines drinking water, the Iowa Soybean Association (ISA) and the Agriculture Clean Water Alliance (ACWA) are working in cooperation with the Des Moines Water Works, the Iowa Department of Natural Resources, and other organizations to monitor water quality. This monitoring characterizes water quality trends and conditions for locations within Iowa's Raccoon River and Des Moines River watersheds Data analysis is conducted by the Des Moines Water Works laboratory. The intended use of this information is to assist communities in the watershed and other stakeholders in identifying water quality and environmental concerns; strategic decision making for planning and design of watershed management pollution abatement efforts, and; research on the short- and long-term impacts of water management efforts.

Soybean farmers collectively invest a portion of their end-of-season profits to fund research and promotion efforts. This collective investment is called the checkoff. The soybean checkoff is supported entirely by soybean farmers with individual contributions of 0.5 percent of the market price per bushel sold each season. The Iowa Soybean Checkoff has provided nearly $2,000,000 over eight years to support the Iowa Soybean Association's (ISA) Environmental Programs. These programs seek to advance agricultural leadership in achieving data-driven environmental performance at farm and watershed scales, while maintaining or improving agronomic and economic performance. A primary goal of these programs is to provide tools and systems that enable farmers to provide environmental solutions and services. These funds are leveraged with other federal, state, and private sources of funding (also see: http://www.isafarmnet.com/ep/).

The Agriculture's Clean Water Alliance is a group of 16 agricultural retailers that provide products and services to farmers in the Raccoon and Des Moines River watersheds in Iowa. The ACWA mission is to reduce nutrient loss — specifically nitrate — from farm fields and keep them from entering the Raccoon and Des Moines Rivers and their tributaries. Each ACWA member pays dues based on its respective nitrogen sales within the watershed. The funds support water sampling and remediation projects. Since 2000, the ACWA has invested over $800,000 to finance the purchase and annual operation of four automatic event based samplers, one real-time water monitoring station located in the Raccoon watershed, and support a certified sampling network that collects biweekly water samples tested for nitrate and bacteria on 128 tributary sites located throughout the watersheds (for more information on ACWA see: http://www.acwa-rrws.org/. For information on the nitrate real time reading see this web address: http://waterdata.usgs.gov/ia/nwis/uv/?site_no= 05484500&PARAmeter_cd=00065,00060).

programs provide financial assistance to individual farmers to implement conservation practices on farms. Congress has authorized funding for these programs with projected budget growth over the next five years. These two working land programs could be tapped for local NCII projects to support incentives and cost share to individual farmers. EQIP is authorized at $1.2 billion in FY2008; $1.337 billion in FY2009; $1.45 billion in FY2010; $1.588 billion in FY2011; $1.588 billion in FY2011; and $1.75 billion in FY2012. The Clean Water Act (and EPA) Section 319 (nonpoint source management program) contains resources that also could be drawn upon to help finance the NCII, and the 319 program has seen some successes in helping manage nonpoint source pollutants (see: http://www.epa.gov/nps/Section319III/). The level of resources in the 319 program, however, is very modest compared to USDA's EQIP and CSP programs.

In addition to EQIP and CSP programs, two other key programs that USDA could use to target support for nutrient reduction water quality enhancement projects (beyond individual farmer operations) in the Mississippi River basin are the Agriculture Water Enhancement Program (AWEP) and Cooperative Conservation Partnership Initiative (CCPI).

Agricultural Water Enhancement Program (AWEP)

Congress created the Agricultural Water Enhancement Program (AWEP) in 2008 as part of the Food, Conservation, and Energy Act (Section 2510) to provide additional assistance to farmers to help them undertake measures to specifically preserve and protect regional water resources. Farmers can participate in the AWEP as a means to address water quality and water quantity challenges that attend agricultural operations. The new program allows USDA's Natural Resources Conservation Service to contract with producers, especially those producers who are part of a local regional partnership agreement, who have proposed identifiable projects to address water quality or water quantity issues. Partners in these projects are expected to leverage federal funds. The Secretary of Agriculture *may* prioritize applications that contain higher percentages of agricultural land and producers in a region (Section 1240I(e)(2)(A)); result in high levels of applied agricultural water quality and water conservation activities (Section 1240i(e)(2)(B)); significantly enhance agricultural activity (Section 1240i(e)(2)(C)); allow for monitoring and evaluation (Section 1240i(e)(2)(D), or assist producers in meeting a regulatory requirement that reduces the producer's economic scope (Section 1240i(e)(2)(E). Eligible partners include producer associations, state or local governments, and tribes. Authorization for AWEP is $73 million for FY2009 and 2010; $74 million for FY 2011; and $60 million for FY2012 and each year thereafter.

Cooperative Conservation Partnership Initiative (CCPI)

The Cooperative Conservation Partnership Initiative (CCPI) also was created as part of the Food, Conservation, and Energy Act of 2008 (Section 2707) and is designed to use existing authorities and leverage resources from outside the USDA to assist producers in coordinated efforts to address specific environmental challenges in particular areas. The vision of CCPI is to encourage the USDA Natural Resources Conservation Service to work with eligible partners to assist producers in participating in one or more of the covered programs to enhance conservation outcomes on agricultural and nonindustrial private forestland. Eligible partners include state and local governments, tribes, producer associations, farmer cooperatives, institutions of higher education, non-profit groups with a history of working with producers to address conservation priorities. The Secretary of Agriculture is required to select projects through a competitive process from applications submitted by eligible partners. These projects will be implemented through multi-year agreements with partners. Agreements are not to last longer than five years.

A particular partnership established under the initiative can have any of the following purposes (section 1243a): addressing local, state, multi-state or regional conservation priorities; encouraging producers to cooperate in meeting federal, state, and local regulatory requirements; encouraging producers to work together to install and maintain conservation practices that affect multiple operations; or promoting the development and demonstration of innovative conservation practices and delivery methods. In selecting applications, the Secretary of Agriculture must prioritize projects (section 1243f(2)) that: involve a high percentage of the producers and/or forest landowners in the area covered by the project; will leverage non-federal funding and technical resources and coordinate with other local, state, or federal conservation efforts; will result in a high level of conservation effort in the project area to address water quality, water conservation, or further other state, regional, or national conservation initiatives; will use innovative conservation methods, including outcome-based measures of success; or meet other requirements that the USDA may establish.

Funding for CCPI is 6 percent of the funds made available each year to carry out selected farm bill conservation programs. Most of the funding for the initiative will come from the working land conservation programs, the Environmental Quality Incentive Program, Conservation Stewardship Program, and Wildlife Habitat Incentive Program, because they are the largest of the covered programs. Ninety percent of the funding reserved for CCPI is to be for projects chosen by the NRCS state conservationist, with input from state technical committees. Ten percent of the total funds will support projects to be selected by the Secretary through a national competition.

Finding/recommendation 6:

Resources from existing USDA conservation programs—the Conservation Reserve Program (CRP), the Conservation Security Program (CSP), and the Environmental Quality Incentives Program (EQIP)—should be drawn upon to help support NCII pilot projects. Other USDA watershed-based programs, such as the Agricultural Water Enhancement Program (AWEP) and the Cooperative Conservation Partnership Initiative (CCPI), also could be used to contribute to the NCII. The agencies also should consider deploying EPA resources. Although these resources are less than those of the USDA conservation programs, the NCII could use funds from, for example, EPA's Clean Water Act Section 319 (which covers nonpoint source pollution management) grant program. The NCII also could leverage state matching funds and private sector funding in marshalling financial support for its program and projects.

4
Allocating Nutrient Load Reduction Targets

Decisions and policies for reducing nutrient loadings in watersheds and tributaries across the Mississippi River basin are complicated by numerous geographic, economic, legal, historical, and political factors. This section addresses question 2 in this committee's statement of task to discuss "alternate methods to allocate load reductions." It identifies several factors to be considered in setting allocations and discuses two fundamental considerations in these decisions: equity and cost effectiveness. As explained below, there is a good rationale for considering both factors in load reduction plans.

ESTIMATING LOADS, REDUCTION TARGETS, AND SPATIAL DISTRIBUTION OF SOURCES

Two key decisions need to be made before nutrient load reductions can be allocated. The first is to determine a target for the reduction of aggregate loads reaching the Gulf of Mexico. The second is to determine the spatial units to which load reductions are to be allocated. In other words, it is necessary to establish a target as to how much reduction is to be achieved, then to decide how the aggregate reduction will be divided among spatial units within the basin.

Targets and Spatial Units

Given the uncertainty regarding the amount of nutrient load reduction that may be necessary to reduce the areal extent of hypoxia, it may be prudent to set a series of interim targets over time in an adaptive, incremental approach to load reduction allocation. The need to proceed adaptively in addressing the nutrient loadings-Gulf of Mexico hypoxia challenge was explained in the 2007 EPA SAB report on hypoxia:

> Accordingly, it is even more important to proceed in a directionally correct fashion to manage the factors affecting hypoxia than to wait for greater precision in setting the goal for the size of the zone. Much can be learned by implementing

> management plans, documenting practices, and measuring their effects with appropriate monitoring programs (USEPA, 2007, p. 2).

Once load reduction targets are set, those reductions must be allocated among spatial units. The two main types of spatial units for allocating reductions are states, or watersheds within states. Because the Clean Water Act encourages states to assume the primary responsibility to address water quality, state boundaries are logical political boundaries for dividing responsibilities for load reductions. However, the amounts of loads delivered to the gulf differ greatly among the Mississippi River basin states, and also differ greatly in different watersheds in the same state (Figure 3). Therefore, allocation of load reductions to highest priority watersheds will result in a very different spatial pattern of allocations from one based solely on states.

If federal funds are intended to be targeted to watersheds likely to have the most cost-effective impact on reducing nutrient loads delivered to the northern Gulf of Mexico, load reduction allocations based on watersheds are essential. Allocations to states then would be determined by summing allocations to watersheds within states. Any allocation to an interstate watershed would have to be apportioned among states based on the watershed area within each state.

Point and Nonpoint Sources

Nutrient loads in the Mississippi River basin are dominated by nonpoint sources. This dominance of nonpoint source loadings is very different from some other river basins where interstate initiatives have been taken to reduce nutrient loads. For example, in-basin nonpoint source loads in the Connecticut River Basin delivered to Long Island Sound were only 33 percent of the total pollutant loadings (NY State Dept of Env. Protection and CT Dept of Env Protection, 2000). The high percentage of nutrient loadings contributed by nonpoint agricultural sources across the Mississippi River basin presents a special challenge for administering water quality improvements actions pursuant to the Clean Water Act, because those nonpoint sources cannot be regulated directly at the federal level by a permitting process.

FACTORS IN LOAD REDUCTION ALLOCATION DECISIONS

Once load reduction targets for nitrogen and phosphorus for the northern Gulf of Mexico have been established, those reductions must be allocated among priority watersheds across the Mississippi River basin. There is previous experience in making similar decisions in two large U.S. watersheds—the Chesapeake Bay and North Carolina's Neuse River. One useful guide is a formal analysis of alternative approaches to reducing nonpoint nitrogen loads delivered to the hypoxia-plagued Neuse River estuary by 30 percent (Schwabe, 2001). A structural model was used to compare costs of a uniform rollback strategy with a cost-minimization strategy, taking into account heterogeneity of biochemical and physical factors across subareas within the basin and fate and transport of nitrogen in streams that deliver loads to the estuary. The uniform rollback policy places greater weight or considerations of equity, while the cost-minimization policy places greater weight on considerations of cost-effectiveness. Of course, issues of equity versus efficient use of limited financial resources abound in all types of public decisions (further discussion of this topic as it relates to water resources decisions is in Druzrik and Theriaque, 1996).

Balancing Equity and Cost Effectiveness

Equity

Decisions upon tradeoffs among the several aspects of equity and cost-effectiveness are central to the process of allocating nutrient load reductions. A simple model may help in illustrating the concept of equity. Let the basinwide target reduction be represented by T tons per year, and let the number of watersheds to which T is allocated be N. Then, T must be divided among the N units included in the management program, taking into account the percentages of loads from those sources that are delivered to the Gulf of Mexico.

Let L_i be the load in tons per year generated in watershed i;
d_i is the fraction of L_i that is delivered to the Gulf ; and
p_i is the fraction of L_i that is to be reduced.

Then, the load reduction equation can be written:

$$p_1d_1L_1 + p_2d_2L_2 + p_3d_3L_3 + \ldots + p_Nd_NL_N = T$$

The allocation problem is one of selecting the set of load reduction factors, p_i, $i = 1,2,3\ldots N$.

For nonpoint sources, a simple formula for allocating load reductions that has been used in the Chesapeake Bay Program and was actually adopted for the Neuse River Basin, is the uniform rollback strategy ($p_1 = p_2 = \ldots = p_N$).

That concept of equity is accepted by many stakeholders, state land and water managers, elected officials, and other parties. It may be equitable only in a limited sense, however, because it does not account for large variations in percentages of loads within watersheds that are delivered to the Gulf of Mexico (see Figure 3). Uniform reductions of loads delivered to the Gulf of Mexico would require that reduction percentages assigned to watersheds be weighted by delivery factors, namely $p_i d_i = p_j d_j$ or $p_i = p_j(d_j/d_i)$ for all pairs of spatial units.

Equity considerations also extend to methods for financing control strategies. If the costs to one group (call them Group A) are borne by owners in that group, and costs to a second group (call them Group B) are covered from general tax revenues, Group A will not consider the result to be equitable. That condition is a real one—many point source dischargers currently are paying for construction, operation and maintenance largely from their own source revenues, while costs of management practices for nonpoint sources (e.g., buffer strips, water controls, tillage practices, nutrient control actions, etc.) are subsidized to a significant extent from state and federal tax revenues.

Yet another equity consideration is ability-to-pay. There are significant differences in per capita income among the Mississippi River basin states, the lower basin states generally having lower incomes than in the upper basin. Such differences among landowners and producers who would be affected by load reductions requirements also enter into these decisions and policies.

Another consideration is past actions taken to reduce pollutant discharges. Setting load allocation targets conceivably will affect the discharges of many different sources and parties. Invariably, some of these parties will have taken few past measures to reduce nutrient yields, while other parties will have made stronger efforts to reduce nutrient yields. It is important that these past efforts be recognized in setting future allocation targets. In setting future allocation regimes, parties who have implemented past nutrient reduction measures should receive some credit for these actions.

Cost Effectiveness

Cost effectiveness of load reductions also is an important consideration. Analysis clearly has shown that heterogeneity of soils, slopes management practices, characteristics of tributary streams, and unit costs can have significant effects on costs of reducing loads to downstream water bodies subject to severe hypoxia (Schwabe, 2001). These important geographic differences—which can be substantial in adjoining sections of the same watershed—point to the importance and value of "precision agriculture" practices (Cox, 2008).

If a cost-effectiveness approach is to be pursued, actions or policies that distribute financial assistance uniformly across all watersheds or across all municipalities will be counter-productive. Targeting requires that funds be disproportionately—and more efficiently—distributed to watersheds and municipalities with higher nutrient loads and high delivery coefficients.

Development of a credible, formal least cost model for the entire Mississippi River Basin (or portions of the basin subject to significant nutrient loads) is not likely to be completed in the near future. At least one study is underway to construct a least cost model for the upper portion of the basin (Rabotyagov et al., 2007), and where other credible results are available they may be used to guide allocation decisions. Even in the absence of formal optimization models of least cost approaches and policies, guiding principles can be derived from existing studies of watersheds and regions within the basin. Among the important guiding principles are: 1) some management practices are generally more cost effective than others in particular settings and, more specifically, 2) management practices on watersheds with higher loading densities and higher delivery coefficients are likely to be more cost-effective than on watersheds with lower densities and lower delivery coefficients.

There is also interest in the prospects of market-based approaches, such as tradable permits or allowances, to manage water quality across a watershed. Interest in market-based approaches to water quality management stems, in part, from the extensive use of tradable permits to manage air pollution. There has been less experience in water quality trading than in air quality, especially in watersheds where nutrient loads are dominated by nonpoint sources. Most examples of trading in water quality have been among point sources or where point sources have been allowed to purchase offsets from nonpoint sources. Nevertheless, there is potential for market-based approaches to manage water quality more cost effectively and these should be encouraged. As was observed in the previous 2008 NRC report, ". . .water quality trading regimes could become more useful and widespread over time as monitoring improves and as stricter water quality criteria are adopted" (NRC, 2008, p. 181-182).

SETTING LOAD ALLOCATIONS FOR THE MISSISSIPPI RIVER BASIN

As the preceding section has explained, there are alternative methods and multiple factors to consider in allocating load reductions. Furthermore, final decisions about load reduction targets are not based fully on scientific and engineering factors and also must consider social, economic, and political issues.

In developing a load reduction allocation scheme for the Mississippi River basin, the experience in allocation of load reductions for the Chesapeake Bay merits careful consideration (Box 4-1). There is no standard formula or practice for setting these targets, and practices in one watershed may not transfer perfectly to another. Important differences between the Chesapeake Bay system and the Mississippi River/Gulf of Mexico system must be kept in mind. In particular, the Mississippi River basin is much larger and extends over 31 U.S. states and six different EPA regions.

Nevertheless, there are important parallels between these two systems: both are affected by downstream water quality problems of nutrient overenrichment, large percentages of these nutrients derive from agriculture in both systems, and both systems extend over many different states and thus necessitate interstate approaches and cooperation for effective water quality administration. The experience of addressing Chesapeake Bay watershed nutrient yields and

BOX 4-1
The Chesapeake Bay Program:
An Example of Interstate Water Quality Monitoring and Nutrient Control Actions

In considering approaches to reducing northern Gulf of Mexico hypoxia, water quality experts and decision makers often look to modeling, monitoring, load reduction allocation, and related efforts that have been undertaken for the Chesapeake Bay. Efforts to reduce nutrient loadings to the bay and to develop a basinwide, nutrient management program date back to the 1980s. The Chesapeake Bay Program was founded in 1983 as a regional partnership to direct bay restoration. Program members include Maryland, Pennsylvania, and Virginia; the District of Columbia; the Chesapeake Bay Commission (a tri-state legislative body); the US EPA, and citizen advisory groups (for more information visit: http://www.chesapeakebay.net/overview.aspx; accessed September 11, 2008; also see NRC, 2008 for more discussion of the program). The program today encompasses a range of scientific and nutrient management components and includes: a coordinated water quality monitoring program; interstate information management arrangements; consistent water quality standards; and tributary watershed cap load allocations.

Many aspects of the Chesapeake Bay experience are relevant to creating a similar science-based nutrient control program for the Mississippi River basin and northern Gulf of Mexico. Scientifically, that program includes an interstate information management system, basinwide water quality monitoring, and integrated water quality modeling and data analysis. Regarding nutrient control efforts, participants in the program agreed to annual nitrogen load and sediment load reductions and to a basinwide permitting strategy. The process by which nutrient load caps were allocated is particularly relevant to this report. As explained in the previous 2008 NRC report:

> Final basinwide nutrient cap loads were allocated to the nine major tributary basins. Basin allocations were further divided and assigned to each of the six watershed states and the District of Columbia based on principles of fairness and equity. . . Individual states have the option to further sub-divide their major tributary basin cap load allocations into 44 state-defined tributary strategy sub-basins (NRC, 2008).

Finally, the time requirements to establish, develop, and extend the various components of the Chesapeake Bay Program should be kept in mind. As mentioned, the monitoring and nutrient control efforts in the Chesapeake Bay date back to the early 1980s, and it has taken decades for the program to develop into its current state. The development of a similar program for the Mississippi River basin and northern Gulf of Mexico clearly will require a similar amount of time—if not longer, given the greater size of the Mississippi River basin. If the Mississippi River basin states and the federal government are to establish a similar program of water quality monitoring and modeling (some of which are reflected in this report's recommendation for the "NCII") and nutrient control actions some time in the foreseeable future, it will be important to initiate soon similar monitoring, evaluative, and nutrient control actions.

downstream water quality impacts represents a significant effort that the federal government and Mississippi River basin states should look to in considering a future allocation scheme and process. In particular, Chesapeake Bay program components that should be considered in establishing a similar process for the Mississippi River basin are:

- The extensive water quality monitoring system;
- The use of water quality models to inform a host of administrative decisions;
- The process of agreeing to cap nutrient loads;
- Dividing allocations by major river sub-basin; and,
- Further dividing allocations on successively smaller watersheds.

Regardless of the method chosen for allocation, however, the allocators should also consider the potential need for future adjustments to the overall goal. Given the recommended use of interim goals, allocators need to be sensitive to the possibility that early investments in "hard" technologies could limit future choices in adaptive management. In other words, allocators should consider the possibility that early commitments to certain technologies may commit the overall adaptive management strategy to limited paths.

Finding/recommendation 7:

In working toward a load reduction allocation scheme, the EPA, USDA, and the Mississippi River basin states should draw upon the experience in the Chesapeake Bay in allocating nutrient loading caps.

In doing so, the following principles for allocating cap load reductions should be considered:

- **Select an interim goal for nutrient load reductions as the first stage of an adaptive, incremental process toward subsequent reduction goals;**
- **Target watersheds to which load reductions are to be allocated;**
- **Adopt an allocation formula for distributing interim load reductions to targeted watersheds within the basin that balances equity and cost-effectiveness considerations;**
- **Allow credit for past progress; and**
- **Encourage the use of market-based approaches to allow jurisdictional flexibility in achieving nutrient load reductions. It bears keeping in mind, however, that such markets do not automatically lead to satisfactory outcomes. Such markets require some regulatory caps on nutrient losses in order to operate.**

5
Monitoring the Effectiveness of Nutrient Control Actions and Strategies

A crucial aspect of effective nutrient control programs and load allocation processes is adequate monitoring and understanding of the downstream effects of nutrient load reductions. This section addresses question 3 in this committee's statement of task, which asks "How should the effectiveness of pollutant loading reduction strategies on the gulf hypoxic zone and state-designated uses, be documented?"

WATER QUALITY MONITORING FOR THE MISSISSIPPI RIVER BASIN AND THE NORTHERN GULF OF MEXICO

Mississippi River Mainstem and River Basin

Federal and state agencies across the Mississippi River basin support many different water quality monitoring programs. At the federal level, much of the water quality monitoring across the river basin is overseen by the U.S. Geological Survey (USGS), especially through its National Stream Quality Assessment Network (NASQAN) and its National Water Quality Assessment program (NAWQA). The major impetus for establishing the NASQAN program in 1974 was to develop a baseline water chemistry data set that was long-term and systematically collected throughout the nation (USGS, 2008a). In 1991, the USGS implemented the NAWQA Program, just as much of the NASQAN assessment network was being eliminated (USGS, 2008b). The NAWQA program was seen as more comprehensive than NASQAN and aimed to develop long-term consistent and comparable information on streams, rivers, groundwater, and aquatic systems in support of national, regional, state, and local information needs and decisions related to water-quality management and policy (USGS, 2008b). At the state level, states conduct water quality monitoring within their state boundaries as part of their Clean Water Act responsibilities.

The previous 2008 NRC report focused on water quality issues along the ten-state Mississippi River corridor and discussed water quality standards and monitoring for the river corridor. That report described past and ongoing efforts to monitor water quality of the river's mainstem. These efforts include a Long Term Resource Monitoring Program (LTRMP) for the upper portion of the Mississippi River. The LTRMP, an element of the U.S. Army Corps of Engineers Environmental Management Program (EMP), is administered by the USGS Upper Midwest Environmental Sciences Center, with participation of the Corps of Engineers, the U.S. Fish and Wildlife Service, and the five upper Mississippi River basin states of Iowa, Illinois, Minnesota, Missouri, and Wisconsin (USGS, 2008c; see also USGS, 1999 for a report of ecological status and trends on the upper river). The USGS has maintained some NASQAN stations on the river, but "today only a few mainstem water quality sites remain in the USGS network downstream of Lake Pepin" (NRC, 2008). The previous NRC 2008 report also discussed two landmark Mississippi River water quality assessments conducted in the 1990s. These studies were led by, respectively, Robert Meade (1995) and Donald Goolsby (1999), both of whom were USGS scientists at the time of these surveys. More recently, the SPARROW study by the USGS scientists has provided quantitative and detailed information regarding the sources of nutrient loadings across the river basin (Alexander et al., 2008).

As called for in the 2001 task force action plan, an Upper Mississippi River Sub-Basin Hypoxia Nutrient Committee (UMRSHNC) has been established to help promote regional research and interstate coordination. Its members are state agricultural and natural resources agencies from the five upper Mississippi River basin states. The UMRSHNC role to date has been primarily to solicit and facilitate stakeholder input and to sponsor workshops. The Upper Mississippi River Basin Association (UMRBA) is important entity for promoting interstate cooperation and education on a variety of Mississippi River water quality and related river issues (e.g., navigation, hydropower relicensing). Established in 1981, the UMRBA has its headquarters in St. Paul, MN and employs five full-time staff, including a water quality program coordinator. Neither UMRSHNC nor UMRBA have the extent of resources or staff necessary to administer the NCIIs and conduct the associated water quality coordination and evaluation responsibilities. Both organizations, however, have important and relevant experience in the region that would represent useful input to future nutrient control and water quality efforts.

The multiple water quality programs across the Mississippi River basin have improved scientific understanding, communication, and cooperation on Mississippi River water quality issues; however, none of them are conducted specifically with regard to Clean Water Act reporting requirements. The previous NRC report also noted that "Although the LTRMP has collected data from thousands of locations along the river for more than 15 years, these efforts have tended to be seasonal and limited to five river reaches. There has been no mechanism to extrapolate these data to intervening portions of the river or to other periods of time" (NRC, 2008). That 2008 report also noted that water quality monitoring of the Mississippi River by the ten states along the river is very limited in many areas, inconsistent among states, and is not well coordinated (ibid.). This state of water quality monitoring efforts led to a conclusion that the river is an "orphan" from a monitoring and evaluation perspective (NRC, 2008). The report concluded that there is "a clear need for federal leadership in system-wide monitoring of the Mississippi River." It recommended that "[t]he EPA administrator should ensure coordination among the four EPA regions along the Mississippi River corridor so that the regional offices act consistently with regard to water quality issues along the Mississippi River and in the northern Gulf of Mexico." It further recommended that ". . . the EPA should encourage and support the efforts of all ten Mississippi River states to effect regional coordination on water quality monitoring and planning and should facilitate stronger integration of state-level programs."

The previous 2008 NRC report noted that "Monitoring of Mississippi River water quality has not been performed in a system-wide manner for extended periods . . . and at intervals of time. . . or space . . . that would support rigorous assessment of water quality and ecology for the river" (NRC, 2008). A similar point could be made about water quality monitoring for the entire river basin. For example, there is no formal water quality monitoring program at the river basin scale that attempts to link water quality changes with land use practices and changes. At the level of state water quality monitoring, in 2000 the U.S. General Accounting Office (today the U.S. Government Accountability Office) reported that as of 1996, states assessed only 19 percent of their rivers and streams (GAO, 2000). There is also an acknowledged weakness of federal conservation programs in monitoring and evaluating the effectiveness (e.g., local water quality improvements) of these programs. Few goals are set for these conservation programs and there is no formal network to help track, for instance, water quality impacts. The existing water quality database and monitoring infrastructure is too diffuse and inconsistent to provide adequate support for a more comprehensive nutrient control program—such as the NCII—for the Mississippi River basin and northern Gulf of Mexico.

Northern Gulf of Mexico

Downstream in the northern Gulf of Mexico, current monitoring efforts of hypoxic zone dynamics are supported by the National Oceanic and Atmospheric Administration (NOAA) Coastal Ocean Program, Center for Sponsored Coastal Ocean Research (CSCOR), through a competitive research program. Since 1985, a group of Louisiana scientists, through various competitive research programs funded primarily by NOAA, have conducted measurements of the northern Gulf of Mexico hypoxic area. The observations expanded in 1989 with the development of offshore instrumented observing sites, in 2000 with the addition of a transect off the Atchafalaya River delta, and in 2003 with additional ocean observing systems and limited surveys from additional research cruises. Although a long-term data set has been developed, there is no plan from the NOAA CSCOR competitive research programs to support routine measurements of hypoxia on the continental shelf.

Although the need for monitoring Gulf of Mexico hypoxia is identified in several documents—the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998, the 2001 *Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico*, the EPA Science Advisory Board Hypoxia Assessment Panel Report, and the 2008 *Action Plan*—there is no dedicated Gulf of Hypoxia Monitoring Plan. A *Summit on Long-Term Monitoring of the Gulf of Mexico Hypoxic Zone: Developing the Implementation Plan for an Operational Observation System* was held in 2007 and an implementation plan is under development. That plan seeks to develop a comprehensive, integrative, sustainable monitoring program for the gulf hypoxic zone, with financial plans for a cooperative monitoring program with long-term funding. Near-term needs were identified for a fiscal year 2009 budget submission, but no action was taken. Modeling and research programs may be able to conduct some basic observational measurements, but there is no long-term commitment for hypoxia monitoring. The 2001 task force Action Plan (see Box 1) cited a need to expand monitoring efforts to better characterize the impact of nutrient loading from the Mississippi River watershed and other factors on hypoxic zone dynamics. Such improvements have not been made, however, as emphasized in the USGS 2004 report, *A Science Strategy to Support Management Decisions Related to Hypoxia in the Northern Gulf of Mexico and Excess Nutrients in the Mississippi River Basin*. If progress from the NCIIs is to be adequately measured, thorough monitoring of water quality changes in the northern Gulf of Mexico will be essential.

A MISSISSIPPI RIVER BASIN WATER QUALITY CENTER

Consistent and adequate funding and support for water quality monitoring and assessment programs, and evaluation of agricultural conservation programs, historically have not been high priorities of the U.S. federal government. Just as the previous 2008 NRC report called for stronger federal leadership for Mississippi River water quality monitoring, stronger federal leadership will be necessary to implement and administer the NCII and to support processes of nutrient load reductions allocations.

As mentioned in this report and as documented in the previous, NRC 2008 report on Mississippi River water quality and elsewhere, the existing water quality database and monitoring infrastructure across the river basin is diffuse, spotty, and inadequate to support a systematic nutrient control effort such as the NCII. Sustained and systematic efforts at reducing nutrient loadings across the river basin will require, for example, consistency in the parameters and methods used to track changes in nutrient loadings and water quality. A more focused water quality data collection and assessment effort will be necessary to ensure support of the NCII program and, ultimately, efficient allocation and expenditure of taxpayer dollars.

This improved monitoring and research effort might be accomplished through a variety of changes in expenditures or organizational responsibilities and missions. This committee did not have the resources or expertise to evaluate all possible water quality monitoring and assessment options that might be required to support the NCII. Nevertheless, this committee did consider several crucial functions to be carried out via a strengthened water quality monitoring effort and how they might be most effectively achieved. Those functions include: a capacity to support sustained, consistent collection of water quality data across the river basin; a capacity to support and promote cooperative monitoring and research among USDA, EPA, other relevant federal agencies, state agencies, local experts and officials, and university and other experts; and the capacity and resources to administer the NCII program.

One alternative would be to continue essentially with the status quo of water quality monitoring programs, an option explained earlier as being inadequate to support the NCII initiative and other water quality monitoring needs. A variant of the status quo would be to establish a type of "virtual" office or program. This virtual arrangement could include representatives from federal, state, and local agencies, and local farmers and other stakeholders in a new organization, but not employ full-time staff and offices, or require substantial resources. One advantage of this option is that it could be developed and established relatively quickly and with minimal costs. This body, however, would not have the capacity or resources to administer the NCII and conduct the supporting water quality monitoring and research functions.

Another alternative would be to delegate NCII administration and related water quality monitoring and research duties to an existing organization with expertise in Mississippi River water quality monitoring activities. Examples of these organizations have been described in this report: the U.S. Geological Survey; the Upper Midwest Environmental Sciences Center (which is a USGS center); the Upper Mississippi River Basin Association; or, the Upper Mississippi River Sub-basin Hypoxia Nutrient Committee. All of these organizations employ competent and highly regarded water quality experts, and they all have mandates and staff knowledge that are relevant to the NCII. None of them, however, have the combination of resources, expertise, and mandate to adequately support the NCII program and its goals.

The committee considered these various options carefully, and also considered the large water quality monitoring and assessment requirements to administer a NCII program, and the needs to efficiently allocate nutrient load reduction responsibilities in an effective and satisfactory manner. In the end, it was concluded that a new organization, with a physical organization, located in the upper river basin and full-time staff, is necessary to accomplish this ambitious, and essential, water quality monitoring, evaluation, and administration challenge. It thus is recommended that the EPA and the USDA establish and jointly administer a new Mississippi River Basin Water Quality Center.

The previous NRC 2008 report stated that, "The Mississippi River, with its extensive interstate commerce, its ecosystems that cross state boundaries, and its effects that extend into the northern Gulf of Mexico, clearly is a river of federal interest." Strong federal leadership on coordinating Mississippi River basinwide water quality monitoring and evaluations is essential and justifiable. This interstate river and river basin system require a stronger scientific and institutional framework for sustained, cooperative water quality monitoring, planning, and improvements. There have been and are many water quality monitoring programs across the river basin, and the center should draw upon these efforts and databases, such as the USGS NASQAN and NAWQA, and the monitoring data and reports of the Upper Midwest Environmental Sciences Center. The initial level of funding to establish the center and appoint full-time staff could be relatively modest; as the NCII projects come online, additional center resources will be required.

Data collected and evaluated by the center will be useful in informing the process of achieving numeric water quality criteria and the need for TMDLs designed to reduce northern Gulf of Mexico hypoxia to varying degrees. Data and research from the center also could examine the implications of setting instream numeric water quality criteria for nutrients at different levels. The center's efforts also will be useful in helping identify key variables and statistical approaches to be used in evaluating the local and downstream water quality effects of nutrient control actions.

Finding/recommendation 8:

To facilitate implementation of this report's recommendations, a Mississippi River Basin Water Quality Center should be established. The EPA and the USDA should jointly administer the center. The center should be located in the upper Mississippi River basin because this region is the main source of nutrient loadings. The center will represent the nexus of federal interagency, federal-state, and interstate cooperation. The participation of other bodies that play important roles in water quality monitoring—such as the USGS, the U.S. Army Corps of Engineers, and state natural resources and water quality agencies—will be vital to the center's operations and functions. The center should manage a basinwide water quality monitoring, assessment, and nutrient control program and should coordinate and facilitate the following functions:

- **Plan and administer nutrient control implementation initiative (NCII) projects, including financing, evaluation, reporting, and communication of findings;**
- **Conduct cooperative, basinwide water quality and land use monitoring and relevant analysis and research;**
- **Develop a land use and land cover data base for the river basin;**
- **Identify additional watersheds for future actions and inclusion in the NCII;**
- **Provide advice on water quality variables and statistical**

approaches to be used in evaluating effectiveness of nutrient control actions;

- **Produce periodic reports on basinwide water quality assessment and on project implementation;**
- **Provide technical assistance and training.**

STRENGTHENED MONITORING FOR THE NORTHERN GULF OF MEXICO

Adequate downstream water monitoring in the northern Gulf of Mexico is an essential complement to water quality data gathered upstream and is crucial to documenting the effectiveness of upstream nutrient control actions. Current funding levels and commitments and institutional arrangements, however, do not ensure that this monitoring will be conducted in the future.

Finding/recommendation 9:

To augment the efforts of the Mississippi River Basin Water Quality Center, the EPA, the USGS, NOAA, and the Mississippi River basin states should strengthen their commitment to systematic, evaluation-oriented water quality monitoring for the northern Gulf of Mexico.

6
Overcoming Perceived Obstacles to Action

This report's authoring committee was charged to offer advice on initiating pollutant control programs, load reduction allocation options, and on documenting the effectiveness of loading reduction strategies. In an effort to both stimulate initial actions and define a viable longer-term strategy toward progress on nutrient control and water quality improvements, this report identifies several scientific and institutional recommendations. Those recommendations aim to create a more systematic framework for nutrient control actions, improve and better coordinate the knowledge base of conservation intelligence, and to eventually realize local and downstream water quality improvements.

Action and progress on reducing nutrient loads to the Mississippi River basin and reducing northern Gulf of Mexico hypoxia have been stalled for years. Many obstacles to progress on these issues derive in large part to policy, institutional, and historical inertia. Many of this report's recommendations call for decisive, immediate actions to help overcome some of this inertia. These recommendations are likely to raise objections that they are infeasible, impractical, or legally unsupported. In anticipation of these objections, this brief closing section identifies some common objections and obstacles that have affected past progress, along with explanations of why these are not defensible reasons not to move forward with implementing this report's recommendations. These objections fall into a number of categories. Below, these common objections are grouped into the categories, along with counterpoints.

SCIENTIFIC UNDERSTANDING

Objection: the limited quantitative understanding of sources and delivery of nutrients to the gulf and the full nature of gulf hypoxia, imply that decisive actions cannot yet be taken.

The major nutrient sources and their approximate, relative importance are well known. Furthermore, as demonstrated in the results from the ongoing work of the USGS SPARROW modeling team, this knowledge is becoming more detailed. This knowledge allows identification of the largest contributors and of the geographic locations where the largest reductions in nutrient pollutants will be required and where actions can begin. Perfect knowledge of relative contributions of nutrients and their ultimate downstream impacts, in a system as large as the Mississippi River basin and northern Gulf of Mexico, will remain elusive.

In addition, the adaptive management paradigm and approach were developed in part to address exactly the type of situation that exists with nutrient loadings and water quality impacts across the Mississippi River basin and into the northern Gulf of Mexico. That is, a large complex ecosystem in which biophysical responses to human actions cannot be perfectly predicted, but in which management actions are necessary to enhance ecological benefits. Additional scientific research certainly will be valuable for many reasons but it will not change fundamental understanding of the priorities for addressing these issues. The adaptive approach embodied in the NCII is designed for decisive initial actions in order to make incremental progress in better understanding of the system, best land management practices, and water quality improvements.

Objection: we lack a reliable assessment of the percentage of nutrient loading reductions required to substantially reduce the extent of gulf hypoxia.

The existence of gulf hypoxia is a national-level water quality problem that has been persistent, has become larger over time, and will require decisive actions to remedy. The nature of this problem is such that estimates of the nutrient loadings necessary to reduce the size of the hypoxia zone—such as the 45 percent figure offered by the EPA SAB's Hypoxia Advisory Panel—will be based on some degree of judgment. The NCII approach in this report emphasizes that whatever management actions are initially taken, they will be adjusted and fine-tuned as water quality changes and improvements across the river basin are monitored. Further, the NCII initiative and a new Mississippi River Basin Water Quality Center will enhance scientific knowledge and will help improve the accuracy of the values of estimated nutrient loading reductions necessary to reduce the area of the hypoxia zone.

Regardless of whether an initial loading reduction goal is 20, 30, or 45 percent, substantial reductions in nutrient loadings will be necessary, at least initially. Data from the USGS SPARROW modeling activities and other sources (e.g., the references cited in the EPA SAB 2007 report) identify clearly the areas of higher loadings across the river basin. Focusing initial actions on these areas, with adequate resources and support, promises to produce the largest initial gains.

Objection: we do not know whether to focus on reducing nitrogen or phosphorus.

There is scientific consensus that nitrogen is causing the northern Gulf hypoxic zone in the largest areas and for the longest period. Phosphorus is also a factor, but in localized areas (especially in the upper basin) and earlier in the year. Reductions in the loadings of both nitrogen and phosphorus are needed to realize local water improvements and a reduction in the northern Gulf of Mexico hypoxic zone. These points led the EPA SAB to recommend the "dual nutrient strategy" to addressing gulf hypoxia.

Objection: hypoxia is affected by climate variations and is largely beyond our control to affect.

There is a connection between precipitation (climate) variability and nutrient fluxes in the river and related Gulf of Mexico hypoxia. Nutrient fluxes will be higher in wet years than in dry years. However, increased nitrate concentrations and yields across the river basin are more significant drivers of changes in Mississippi River nitrate loadings into the gulf (Justic et al., 2002). Studies have shown that, for example, only 20-25 percent of the increased nitrate loadings into the Gulf of Mexico between the mid-1960s and the mid-1990s were attributable to greater runoff and river discharge, with the remainder due to increased nitrogen concentrations in the lower river (Donner et al., 2002).

PLANNING, ALLOCATIONS, AND PAST ACTIONS

Objection: there is no comprehensive plan.

A comprehensive plan involves scientific, water quality, social, political, and economic considerations that will take years to understand better, and hence any comprehensive plan will remain a work in progress for at least several decades. This report's recommendations for the NCII program and the new Mississippi River Basin Water Quality Center would constitute a significant, important step toward establishing a more comprehensive and systematic program and plan.

Moreover, this scale of water quality problem means that any plan necessarily will be adjusted and changed over time. Any scientific and comprehensive plan expected to achieve any measure of success will require decisive action on the largest sources, and immediate actions directed toward the largest sources will be consistent with any comprehensive plan. The longer that decisive actions to address this problem are delayed, the longer it will take until effective approaches are implemented. Given that it will require years, if not decades, to see downstream responses to nutrient control actions, it is important to begin quickly and move forward decisively.

Objection: a fair allocation of needed reductions has not been determined.

Any equitable allocation will not ignore the need to focus on the larger sources. Also, fair allocation relates more to how to act on smaller sources and more expensive incremental actions, not for the larger sources and "low hanging fruit."

Objection: unless major basin wide reductions occur in all states, all watersheds, and among all sources, no benefit will be gained.

If progress is to be seen within these water quality problems, initial actions must be taken somewhere, at some time. Further, all basinwide plans will require initial targeted controls as a foundation. These initial actions are part of an adaptive approach that is essential to addressing a long-term, large-scale problem like water quality management across the Mississippi River basin and into the northern Gulf of Mexico. It makes sense to target initial actions where gains might be largest and realized more quickly. These gains can translate to both local and regional improvements in water quality and therefore would be widely beneficial.

Objection: actions have already been taken and improvements have been realized.

There is some truth to this, and credit should be given for past, positive efforts. Nevertheless, despite good past efforts toward nutrient load reductions, collectively they have not yet made a noticeable difference because loads have not been reduced substantially. Results from the SPARROW modeling exercise and other sources identify agriculture sources as the largest (but not only) source of nutrient loadings across the basin. If gulf hypoxia is to be reduced, ways must be found to reduce further the most significant loads.

LEGAL, INSTITUTIONAL, AND REGULATORY AUTHORITIES

Objection: there is a lack of institutional authority to realize large reductions in nonpoint source loadings.

As explained in this report and in the previous, 2008 NRC report on the Mississippi River and the Clean Water Act, the EPA has authority and responsibility to investigate, promote interagency and interstate coordination, while the USDA has authority to direct its conservation funds to areas of high priority with respect to land and water quality goals. There is authority to direct resources, target programs, develop plans, develop standards, and engage in cooperative efforts for ecological improvements, including water quality.

Objection: there is no federal regulatory authority within the Clean Water Act to address nonpoint source pollutants, water quality standards and water quality criteria do not exist, and no TMDL does or can exist that will require reductions in nutrient loadings across the Mississippi River and in its tributary rivers and streams.

Some of these points are correct. The Clean Water Act does leave nonpoint source regulation primarily to the states, and numeric criteria or standards for nutrients are rare in any water quality context. Nevertheless, these shortcomings should not impede initial steps to reduce nutrient loading and to address northern

Gulf of Mexico hypoxia.

First, the EPA has fairly broad authority to address interstate water pollution. In an interstate water quality context such as that presented by the Mississippi River and the Gulf of Mexico, the EPA's authority over water quality is considerable. For example, under Section 103, the EPA must: (1) "encourage cooperative activities by the States for the prevention, reduction, and elimination of pollution"; (2) "encourage the enactment of improved and, so far as is practicable, uniform State laws relating to the prevention, reduction, and elimination of pollution"; and (3) "encourage compacts between States for the prevention and control of pollution" (NRC, 2008).

With respect to water quality-impaired water bodies, the EPA may set TMDLs when the relevant state fails to do so (Section 303(d)), and the federal courts have upheld the EPA's authority to set these TMDLs even when the water's impairment derives solely from nonpoint source pollution. Moreover, as a practical matter, the EPA is already establishing TMDLs that must have interstate regulatory effects, such as in the mercury TMDL for the Ochlockonee River in Georgia and the fish-tissue mercury TMDL for Louisiana's Gulf of Mexico waters (NRC, 2008).

Second, even in the absence of *numeric* water quality criteria and standards, narrative standards that apply to water quality management *do* exist, and most if not all states have listed certain waterbodies as impaired for nutrients.

Third, as noted above, there is no question that nutrient loadings in the Mississippi River basin are causing water quality problems and gulf hypoxia. Therefore, even though the development of numeric water quality standards and a TMDL will take years, more precise standards are not needed to begin making improvements. The absence of precise quantitative goals does not change the fact that the major sources of nutrient loading can be readily identified and that progressive reductions of those loadings can begin now, regardless how the final goal is eventually defined. Moreover, these initial actions, such as those outlined in this report, will provide useful information for development of a TMDL.

FINANCIAL AND ECONOMIC

Objection: there is a lack of funding to realize all improvements and actions necessary to fully address the problem.

There are substantial resources in the USDA conservation programs described in this report. Some of these programs allow discretion in deploying resources more effectively to areas of higher nutrient yields. There are also modest EPA resources available for nonpoint source programs that could be drawn upon. In addition, new funding may be attainable through leveraging of state, local, and private resources consistent with existing programs.

LEADERSHIP

Objection: there is a lack of leadership to comprehensively address the many different factors underlying these nutrient loading-water quality issues.

Stronger leadership and better cooperation among governmental bodies and key players certainly is necessary for improving management practices and water quality improvements. Historically, USDA has made commodity production a top priority for agriculture, while EPA's regional office structure has four regional offices overseeing various portions of the river corridor—an arrangement that, in part, led the conclusion in the 2008 NRC report that the river is an "orphan" from a water quality and monitoring perspective.

USDA and EPA will have to synchronize better their production, conservation, and water quality monitoring and administration programs to make significant progress on the hypoxia problem. The creation of a Mississippi River Basin Water Quality Center would offer the agencies the opportunity to demonstrate leadership on these issues and to productively engage state governments, the private sector, NGOs, and citizens in the collective NCII effort to better manage nutrient loadings in the river basin and improve local and national water quality.

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Appendixes

Appendix A
Statement of Task

The purpose of this task order is to engage the National Academy of Sciences' expertise to help the EPA conceive and implement Section 303(d) of the Clean Water Act (CWA) across the Mississippi River basin and the Gulf of Mexico in order to meet nutrient and sediment reduction objectives.

A report will be prepared that addresses the following three questions:

1. Given the state of scientific knowledge, and associated uncertainties, about phosphorous, nitrogen, and sediment reduction applicable to reducing the hypoxic zone in the Gulf and meet the designated uses for Mississippi basin States, how might existing loading estimates and targets be used to initiate pollutant control programs? In addressing this question, the implications of inevitable future improvements in precision and accuracy of monitoring and modeling will be considered.
2. What are the alternative methods to allocate load reductions to the relevant upstream tributaries, states, land uses, and other source classifications? What are the implications of these different allocation approaches on the geographic and sectoral distribution of pollutant load reduction responsibilities?
3. How should the effectiveness of pollutant loading reduction strategies on the gulf hypoxic zone and the states designated uses be documented? In addition, how much time would be required to determine if future reductions in nutrient and sediment loadings are resulting in a reduction in Gulf of Mexico hypoxia?

A public workshop will inform the committee in the preparation of its consensus report.

1. Papers and presentations from the workshop will be compiled along with any distilled summary statements and placed in the public access file;
2. Materials presented and discussions at the workshop will help inform the committee in the preparation of its report that addresses the three questions above, and that uses illustrative case examples, to suggest useful alternative strategies for allocating reductions in upstream nutrient loadings that hold promise for achieving both local water quality improvements and improvements in Mississippi River and northern Gulf of Mexico water quality, and;
3. The committee will identify key future issues and challenges regarding scientific and administrative aspects of the Clean Water Act's TMDL program in the Mississippi River Basin, including nutrient management and load limit allocations.

Appendix B
Guest Speakers at Committee Meetings

Federal Agencies

Richard Alexander, U.S. Geological Survey, Reston, Virginia
Richard Batiuk, U.S. Environmental Protection Agency, Annapolis, Maryland
Joel Blomquist, U.S. Geological Survey, Baltimore, Maryland
Roger Claassen, U.S. Department of Agriculture, Economic Research Service, Washington, D.C.
John Goodin, U.S. Environmental Protection Agency, Washington, D.C.
Marc Ribaudo, U.S. Department of Agriculture, Economic Research Service, Washington, D.C.
Ward Sanford, U.S. Geological Survey, Reston, Virginia
Ellen Tarquinio, U.S. Environmental Protection Agency, Washington, D.C.

Nonprofit Organizations and Trade Associations

Craig Cox, Environmental Working Group, Ames, Iowa
Jon Devine, Natural Resources Defense Council, Washington, D.C.
Jeffrey Jacobs, National Research Council, Washington, D.C.
Keith Jones, National Association of Clean Water Agencies, Washington, D.C.
Cathy Kling, Iowa State University, Ames, Iowa
Matt Rota, Gulf Restoration Network, New Orleans, Louisiana
Leonard Shabman, Resources for the Future, Washington, D.C.
Tom Simpson, University of Maryland, College Park
Rod Snyder, National Corn Growers Association, Washington, D.C.

Appendix C
Committee Biographical Information

DAVID H. MOREAU, *Chairman*, is a professor in the Departments of City and Regional Planning and Environmental Sciences and Engineering at the University of North Carolina at Chapel Hill. Dr. Moreau teaches water resources planning and regional environmental planning. His research interests include analysis, planning, financing, and evaluation of water resource and related environmental programs. He is engaged in water resources planning at the local, state, and national levels. He has chaired or served on several NRC committees, most recently as a member of the Committee on New Orleans Regional Hurricane Protection Projects. Dr. Moreau serves as chairman of the North Carolina Environmental Management Commission, the state's regulatory commission for water quality, air quality, and water allocation. Dr. Moreau received his B.S. and M.S. degrees from Mississippi State University and North Carolina State University, respectively, and his Ph.D. degree from Harvard University.

ROBIN K. CRAIG is a professor of law at the Florida State University College of Law. Prior to that she was a professor at Indiana University School of Law and an associate professor of law at Western New England College of Law in Springfield, Massachusetts. She was a judicial clerk to Judge Robert E. Jones, U.S. District Court for the District of Oregon from 1996-1998, and was also a law clerk at the Oregon Department of Justice in the Natural Resources Section. She was a visiting professor of law at Lewis & Clark School of Law during the 1998-1999 academic year, and a summer professor of law in June 2002, teaching a seminar on the Clean Water Act. Dr. Craig has authored two books, The Clean Water Act and the Constitution (ELI, 2004) and an environmental law textbook, Environmental Law in Context (West, 2005). She has also written numerous law articles on environmental law, ocean and coastal law, and law and science, as well as the "Oceans and Estuaries" chapter of Stumbling Toward Sustainability (ELI, 2002). She is a former member of the NRC committee that reviewed the effectiveness of the Clean Water Act in protecting and restoring water quality in the Mississippi River. Dr. Craig received her B.A. degree from Pomona College, her M.A. degree from Johns Hopkins University, her Ph.D. degree from the University of California, and her J.D. degree from Lewis & Clark School of Law.

MISGANAW DEMISSIE is a principal scientist and director of the Center for Watershed Science at the Illinois State Water Survey in Champaign, 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 towards 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, the American Geophysical Union, the International Water Resources Association, and the International Association of Hydrological Sciences. Dr. Demissie received his B.S. degree in civil engineering from the University of Iowa, and his M.S. and Ph.D. degrees in civil engineering from the University of Illinois.

OTTO C. DOERING III is a professor in the department of agricultural economics at Purdue University. He is a public policy specialist and has served the U.S. Department of Agriculture working on the 1977 and 1990 Farm Bills. In 1997, he was the Principal Advisor to USDA's Natural Resources Conservation Service for implementing the 1996 Farm Bill. In 1999, he was team leader for the economic analysis of the White House's National Hypoxia Assessment looking at the dead zone in the Gulf of Mexico. He has been a Director of the American Agricultural Economics Association and Chairman of the National Public Policy Education Committee. He has twice received the AAEA's Distinguished Policy Contribution Award as well as its Extension Economics Teaching Award. His recent publications include a book on the 1996 Farm Bill and a book on the effects of climate change and variability on agricultural production systems. His recent publications focus on economic linkages to nitrogen over-enrichment, the rationale for U. S. agricultural policy, and integrating biomass energy into existing energy systems. He is a former member of the NRC committee that reviewed the effectiveness of the Clean Water Act in protecting and restoring water quality in the Mississippi River. Dr. Doering received his M.S. degree in economics from the London School of Economics and his Ph.D. degree from Cornell University.

DAVID A. DZOMBAK is the Walter J. Blenko, Sr. professor of environmental engineering at Carnegie Mellon University. He teaches and conducts research in the fields of water and soil quality engineering and science. His research focuses on physical-chemical processes governing contaminant fate, transport, and treatment in the subsurface environment, in surface waters and sediments, and in industrial wastes. Dr. Dzombak has published numerous articles in environmental engineering and science journals, book chapters, articles for the popular press, and a book on modeling adsorption of inorganic chemicals on mineral particles. He is faculty director of Carnegie Mellon's Steinbrenner Institute for Environmental Education and Research. He 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 previous NRC Committee that reviewed the effectiveness of the Clean Water Act in protecting and restoring water quality in the Mississippi River. Dr. Dzombak received his B.S. and M.S. degrees in civil engineering from Carnegie Mellon University and his Ph.D. degree in civil engineering from Massachusetts Institute of Technology.

PAUL L. FREEDMAN is the founder and president of LimnoTech, a national water science and engineering firm. His research and consulting have focused primarily on water quality including modeling; lake and watershed management; stream restoration; contaminated sediments and groundwater, wet weather issues including stormwater CSO and SSO, TMDL, permitting, sustainability, and many other environmental issues. Mr. Freedman has worked on hundreds of projects in over three dozen states for clients including federal agencies, municipalities and industries. He is the current vice president of the Water Environment Federation. Throughout his career, he has served in multiple committees and task force on various issues involving environmental regulations and legislation. He is a licensed Professional Engineer in several states and a Board Certified Environmental Engineer of the American Academy of Environmental Engineers. He received his B.S. degree in engineering and his M.S. degree in water resources-civil Engineering from the University of Michigan.

G. TRACY MEHAN III is a principal with the Cadmus Group in Arlington, VA. He previously served as Assistant Administrator for Water at the U.S. Environmental Protection Agency from 2001-2003; Director of the Michigan Office of the Great Lakes and a member of the governor's cabinet from 1993-2001; and as Associate Deputy Administrator of EPA in 1992. Prior to that, he served as director of the Missouri Department of Natural Resources. At EPA, he was a leader on ambient water quality monitoring, the watershed approach, and strategies for dealing with aging infrastructure. Mr. Mehan is the recipient of the 2004 Environment Award from the Association of Metropolitan Sewerage Agencies and the 2003 Elizabeth Jester Fellows Environmental Partnership Award from the Association of State and Interstate Water Pollution Control Administrators. He also served as a member of the NRC committee that reviewed the effectiveness of the Clean Water Act in protecting and restoring water quality in the Mississippi River. Mr. Mehan received his B.S. degree in history from St. Louis University and his J.D. degree from St. Louis University.

NANCY N. RABALAIS is a professor at the Louisiana Universities Marine Consortium. Dr. Rabalais' research interests include the dynamics of hypoxic environments, interactions of large rivers with the coastal ocean, estuarine and coastal eutrophication, benthic ecology, and environmental effects of habitat alterations and contaminants. Dr. Rabalais is an AAAS Fellow, an Aldo Leopold Leadership Program Fellow, a Past President of the Estuarine Research Federation, a National Associate of the National Academies of Science, a member of the Scientific Steering Committee of LOICZ/IGBP, is a past chair of the Ocean Studies Board, and served as a member of the previous NRC committee that reviewed the effectiveness of the Clean Water Act in protecting and restoring water quality of the Mississippi River. She received the 2002 Bostwick H. Ketchum Award for coastal research from the Woods Hole Oceanographic Institution and was the Ian Morris Scholar in Residence at the University of Maryland Center for Environmental Studies. Her work on the causes and consequences of Gulf hypoxia has garnered several citations—the Blasker award (shared with R.E. Turner) and a NOAA Environmental Hero, Clean Water Act Hero, and Gulf Guardian award. She received her B.S and M.S. degrees in biology from Texas A&I University, Kingsville and her Ph.D. degree in zoology from the University of Texas at Austin.

THOMAS W. SIMPSON is the Coordinator, Chesapeake Bay Agricultural Programs, College of Agriculture and Natural Resources at the University of Maryland. From 1980 to 1992, he was professor of soil-environmental quality at Virginia Tech, focusing on organic waste management and agricultural water quality issues. Dr Simpson's early research efforts focused on beneficial use of organic waste, composting and agricultural impacts on water quality. In the last decade, his work has focused on Best Management Practice efficiencies for agricultural sources of nutrient pollution and opportunities for innovation agricultural conservation programs, practices and policies. Since 1992, Dr. Simpson has coordinated science activities regarding nonpoint sources of pollution and the Chesapeake Bay. He currently chairs the Chesapeake Bay Program's Nutrient Subcommittee, which oversees nutrient and sediment reduction efforts from all sources throughout the watershed. Dr. Simpson also leads the Mid-Atlantic Water Quality Program, a ten university research and outreach effort, and is a member of the USDA-land grant National Committee on Shared Leadership for Water Quality. He received his B.S. degree in soil science from Virginia Polytechnic Institute & State University and his M.S. and Ph.D. degrees, also in soil science, from Pennsylvania State University.

ROGER WOLF directs the environmental programs at the Iowa Soybean Association (ISA) in Urbandale, Iowa. At the ISA heleads the creation, development, and oversight of environmental projects designed to advance environmental performance at farm and watershed scale, while maintaining or improving agronomic and economic performance. Mr. Wolf has led the development of the Certified Environmental Management Systems for Agriculture (CEMSA) program, a voluntary program that provides farmers with metrics for monitoring, measuring, and validating a farm's environmental performance. He is also currently the executive director of Agriculture's Clean Water Alliance, a non-profit organization for agribusiness retailers in Des Moines, IA, and director-at-large for the Iowa Environmental Council. Prior to his post with ISA he worked with stakeholders in developing plans for Iowa watersheds (1994-2000) and was an environmental specialist at the Iowa Division of Soil Conservation (1989-1994). He has served on a number of local, state, and national task forces, coalitions, and boards on topics ranging from agricultural sustainability to water quality improvement. He received his B.S. degree in geography from the University of Iowa.

NRC Staff

JEFFREY JACOBS is a scholar with the NRC Water Science and Technology Board. Dr. Jacobs' research interests include policy and organizational arrangements for water resources management and the use of scientific information in water resources decision making. He has studied these issues extensively both in the United States and in mainland Southeast Asia. Prior to joining the NRC he was a faculty member at the National University of Singapore and at Texas A&M University. Since joining the NRC in 1997, Dr. Jacobs has served as the study director for over twenty NRC reports. He received his B.S. degree from Texas A&M University, his M.A. degree from the University of California, Riverside, and his Ph.D. degree from the University of Colorado.

ELLEN A. DE GUZMAN is a research associate at the NRC's Water Science and Technology Board. She received her B.A. degree from the University of the Philippines and an M.A. in international development from American University. She has worked with a number of studies including *Stormwater Management in the United States, Drinking Water Distribution Systems,* and *Hydrologic Effects of a Changing Forest Landscape.*