ENVIRONMENTAL DOCUMENTATION

CHAPTER 6-- WATERSHED NUTRIENTS MANAGEMENT ANALYSIS (PROGRAMMATIC)

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ABBREVIATIONS/ACRONYMS USED IN THIS APPENDIX

Ac	Acre	MRP	Mississippi Riverwise Partnership
ALC	American Lands Conservancy	MWRDGC	Metropolitan Water Reclamation District of Greater Chicago
AHR	American Heritage Rivers Initiative	NAWQA	National Water Quality Assessment Program
AWQMN	Ambient Water Quality Monitoring Network	NASQAN	National Stream Quality Accounting Network
BCR	Benefit-Cost Ratio	NAWQA	National Water Quality Assessment
BMPs	Best Management Practices	NGOs	Non-Governmental Organizations
CCC	Commodity Credit Corporation	NPDES	National Pollutant Discharge Elimination System
CENR	Committee on Environment and Natural Resources	NPS	Non-Point Source
CREP	Conservation Reserve Enhancement Program	NRCS	National Resources Conservation Easements
CT	Collaboration Team	NSI	National Seismic Network
DAFLOW	Diffusion Analogy Surface—Water Flow Model	NSN	National Seismic Network
DDS	Decision Support System	NSIP	National Streamflow Information Program
D&LD	Drainage & Levee District	NSTC	National Science and Technology Council
DNRs	Departments of Natural Resources	PL	Public Law
DO	Dissolved Oxygen	PPI	Potash & Phosphate Institute
DOD	Department of Defense	PWP	Pilot Watershed Program
EQIP	Environmental Quality Incentives Program	SPARROW	SPAtially Referenced Regression on Watershed Attributes
ERDC	Engineering Research & Development Center	Sq Km	Square Kilometer
FEMA	Floodplain Emergency Management Agency	SWCP	Soil & Water Conservation Program
FDR	Flood Damage Reduction	TMDL	Total Minimum Daily Load
FIP	Forestry Incentives Program	TNC	The Nature Conservancy
FSA	Farm Services Agency	TWI	The Wetlands Initiative
GIS	Geographic Information System	USEPA	US Environmental Protection Agency
GLOBEC	Global Ocean Ecosystem Dynamics	UMESC	Upper Midwest Environmental Science Center
HEL	Highly Erodible Land	UMIMRA	Upper Mississippi, Illinois and Missouri Rivers Association
IDALS	Iowa Department of Agriculture & Land Stewardship	UMR	Upper Mississippi River
IDNR	Illinois Department of Natural Resources	UMRBA	Upper Mississippi River Basin Association
IDOA	Illlinois Department of Agriculture	UMRS	Upper Mississippi River System
IEPA	Illinois Environmental Protection Agency	UMRCP	Upper Mississippi River Comprehensive Plan
IFBF	Iowa Farm Bureau Federation	USFWS	US Fish & Wildlife Service
IFCA	Illinois Fertilizer and Chemical Association	USGS	US Geological Survey
IMP	Integrated Management Plan	WDNR	Wisconsin Department of Natural Resources
KG	Kilogram	WES	Waterways Experiment Station
KM	Kilometer	WHIP	Wildlife Habitat Incentives Program
LCA	Louisiana Coastal Area	WLTP	Watershed Land Treatment
LTRMP	Long-Term Resources Management Program	WNTF	Mississippi River/Gulf of Mexico Watershed Nutrients Task Force
MADM	Multiple Attribute Decision-Making	YR	Year
MCGA	Missouri Corn Growers Association		
MMR	Monitoring, Modeling and Research		
MNRG	Midwest Natural Resources Group		
MO SEMA	Missouri State Emergency Management Agency		
MPCA	Minnesota Pollution Control Agency		
MARB	Mississippi--Atchafalaya River Basin		
MRBA	Missouri River Basin Alliance		

ENVIRONMENTAL DOCUMENTATION

CHAPTER 6-- WATERSHED NUTRIENTS MANAGEMENT ANALYSIS (PROGRAMMATIC)

1. INTRODUCTION.

1.1. Purpose and Scope.

Section 459 of the Water Resources Development Act of 1999 authorized the Upper Mississippi River Comprehensive Plan (UMRCP) study. This legislation called for the development of a plan to address water resource and related land resource problems and opportunities in the Upper Mississippi River System (UMRS), in the interest of systemic flood damage reduction. This is to be accomplished by means of structural and nonstructural flood control and floodplain management strategies, and by various other methods including habitat, watershed nutrients and sediments management. The plan is to include recommendations on management plans and actions to be carried out by the responsible Federal and non-Federal entities. The plan is to address recommendations to authorize construction of a systemic flood control project, and to include recommendations for follow-on studies for problem areas where data or current technology does not allow immediate solution. Consultation is to be conducted with the appropriate State and Federal agencies, and the study is to make maximal use of existing data and ongoing programs and efforts.

1.2. Description of the Basin.

The UMRCP study area is defined by the authorizing legislation as “the Upper Mississippi and Illinois River basins, from Cairo, Illinois, to the headwaters of the Mississippi River.” This 118 million acres region is referred to herein as the UMRS. This system includes 1,100 river miles, with a total river floodplain acreage of 2.6 million acres. The distribution of leveed floodplain as a proportion of total floodplain area is about: 3% north of Pool 13, 50% from Pool 14 through Pools 26; 80 percent in the Open River; and 60% of the lower 160 miles of the Illinois River.

For flood damage reduction purposes, that portion of the UMRS, inclusive of the 500-year floodplain, is the area of primary focus. However, due to the extensive nature of the watershed nutrients issue, the sphere of discussions will at times include the upland

regions of the UMRS watershed, the entire Mississippi--Atchafalaya River Basin (MARB), and even the Gulf of Mexico coastal zone.

While certainly outside the limits of the UMRS, and not the primary subject of this analysis, the topic of Gulf hypoxia has played a significant role in shaping the federal policy that could ultimately impact upon UMRS nutrients management. The MARB (see **Figure 1** hydrologic regions) is the source of 90 percent of the fresh water entering the Gulf, it is the source of drinking water for over 70 cities and towns, and it drains 41 percent of the contiguous U.S., and covers 55 percent of the U.S. farmlands **(PPI/PPIC, 1999)**. The Gulf of Mexico supports one of the world's most productive fisheries, with a combined commercial and recreational value of $2.4 billion per year (CENR, 2000).

1.3. Goals and Objectives.

The overall goal of the UMRCP study is to develop a comprehensive FDR plan that is supportive of the evolving long-term UMRS goal for economic and environmental sustainability. Objectives developed for the UMRCP study include: minimizing health and safety risks, reducing the damages and costs associated with flooding, and identifying environmental opportunities as part of any FDR plan.

It is the intent of this appendix to incorporate nutrients management into a holistic framework that has flood damage reduction as its primary focus. It seeks UMRS watershed nutrients management opportunities that can be effectively coupled with Flood Damage Reduction (FDR) actions. These opportunities will consider regional nutrients reduction, along with long-term data collection, trends analysis, adaptive management, and remedial actions for addressing the nutrients issue.

1.4. Constraints.

The Corps' existing guidance is that "watersheds" management is the primary domain of federal agencies other than the Corps of Engineers. This paper, while providing a complete overview of the problem of the UMRS nutrients problem, does not suggest Corps implementable features beyond the immediate UMRS floodplain. However, appropriate actions that could be taken by other federal authorities are described. Another important constraint is that the UMRCP study will utilize existing data. No new data acquisitions were proposed for the current investigation.

1.5. Communications Plan.

The communications process for this assessment was conducted consistent with the overall approach used for the study at large, i.e. interaction with the collaboration team (CT), and meetings and/or reviews by technical experts and the general public.

The CT includes mid- to upper level governmental agencies staff along with representatives from Non-Governmental Organizations (NGOs). The membership includes the Upper Mississippi River Basin Association (UMRBA, Holly Stoerker), US

Environmental Protection Agency (USEPA; Bill Franz, Region V and Larry Sheppard, Region VII); State Departments of Natural Resources (DNRs; Gary Clark and Marty Stralow, IL; Jack Riessen and Bill Cappuccio and Chuck Corell, IA; Bob Watson and Dan Baumann, WI; Charlie DuCharme, MO; Ogbazghi Sium and Tim Schlagenhaft, MN), Upper Mississippi, Illinois, and Missouri Rivers Association (UMIMRA; Heather Hampton-Knodle, Mike Klingner, Dave McMurray), US Fish and Wildlife Service (USFWS; Bob Clevenstine, Dave Ellis, Karen Westphall, Don Hultman), Mississippi River Basin Alliance (MRBA; Angela Anderson), American Heritage Rivers Initiative (AHR; Owen Dutt), Waterways Experiment Station (WES; John Barko and Jean O'Neil), Floodplain Emergency Management Agency (FEMA; Vincent Parisi, Region V; Tonya Leibold, Region VII), MO State Emergency Management Agency (MO SEMA; George Riedel), The Nature Conservancy (TNC), Maritime Administration (MA; Bob Goodwin), and the American Lands Conservancy (ALC; Jennifer Frazier). More information on the CT members can be found in the main volume of the UMRCP study report.

The CT assisted with the identification, validation, and prioritization of system-level problems, needs, and opportunities, systemic measures and plans, and recommendations related to watershed nutrients. Public meetings helped to bring a focus on regional and local viewpoints to the planning process. These meetings brought together such diverse entities as regional planning commissions, county and city government representatives, drainage commissioners, farm bureaus, farmers, refuge and conservation area managers, etc.

Groups solicited to provide expert reviews of this appendix topic included: the Mississippi River/Gulf of Mexico Watershed Nutrients Task Force (WNTF), the U.S. Geological Survey (USGS), and the U.S. Army Engineer Research and Development Center (ERDC). The WNTF was constituted via The Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 (PL 105-383) with the task of preparing a scientific assessment and plan of action for Gulf hypoxia. The USGS has been active in monitoring, modeling and research work on nutrients in the UMRS basin, and ERDC, a Department of Defense (DOD) leader in civil engineering and environmental quality research and development, has considerable expertise on coastal processes and estuaries.

2. PROBLEMS AND OPPORTUNITIES.

2.1. Nutrients Loading Problem. The main subject of this appendix is UMRS watershed nutrients loading. However, to fully appreciate the importance of this issue, it is it is necessary to look at the UMRS as a component of the much larger MARB, and its drainage into the Gulf.

Of growing concern in recent decades has been the presence of a large hypoxic (low oxygen) zone located along the north Gulf coastline. This concern eventually led to the passage of PL 105-383, which called for the development of a plan of action to reduce, mitigate, and control hypoxia. *An Integrated Assessment of Hypoxia in the Northern Gulf of Mexico* was prepared by the Committee on Environment and Natural Resources (CENR) in support of that Action Plan, and was released in May 2000. The CENR report

provided scientific information, but not recommendations for the Action Plan. It discussed the nature of Gulf hypoxia, its causes, its consequences, and describes approaches for its remediation. **Table 1** provides the reader with a brief fact sheet on Gulf hypoxia. The reader is referred to the full text of the report for a more detailed understanding of that issue. Briefly stated, the preponderance of scientific evidence (based on sediment records) shows that low DO levels in the Gulf is primarily the result of excess nutrients from the MARB in combination with stratification (CENR, 2000). These records show that algal production and deposition was lower early in the twentieth century, and that major changes occurred in the latter half of the century. Fish prey is now less plentiful in hypoxic bottom waters, and there is some evidence for a shift in the commercially significant brown shrimp catch. However, to date, economics data does not show statistically significant effects traceable to hypoxia (CENR, 2000).

In addition to being a potential contribution to gulf hypoxia, UMRS nutrients loading can degrade water quality and aquatic life along the river system itself. Most UMRS states have significant river miles impaired by high nutrient concentrations. By impairment, it is meant that these waters are not fully supporting one or more resource uses, including swimming, fish consumption, aquatic life, and/or drinking water (CENR, 2000). With or without the consideration of the Gulf hypoxia issue, the UMRCP study considers UMRS nutrients loading to be a sufficiently important to warrant further consideration.

The specific linkage between flood control and nutrient control is that floodwaters carry suspended clay and carbon sediment particles (to which adhere nutrients). Upon deposition, these sediment-adsorbed nutrients can be released, causing an excess increase in primary producers, and symptoms of eutrophication (algal blooms, changes in biological oxygen demand, and hypoxia and anoxia). Flood transported suspended material can also reduce light penetration in the water column, thus affecting the production and distribution of aquatic plants, an ecosystem component critical to the functioning of healthy river and lake ecosystems (See work by Yao Yin and Rebecca Kreiling – UMESC). In addition, flood flows can also carry large quantities of dissolved nutrients (and contaminants).

2.2. Nutrients Reduction Opportunities.

An opportunity is here defined as a study related action that provides a reasonable chance for advancement or progress in solving an identified study problem. The UMRCP study provides a unique opportunity to explore methods for nitrogen load reduction by denitrification and nitrogen retention. Measures that reduce flooding could reduce the downstream movement and adverse local and regional environmental effects of sediments and associated nutrients from upland watersheds (e.g. flood flow reductions, flood dampening via wetlands interception, conservation tillage, etc.). UMRCP nutrients reduction opportunities can be described as being of two types, primary opportunities and secondary opportunities. A primary opportunity is one in which the installation of a nutrients reduction measure, in and of itself, provides a direct FDR benefit (e.g. wetlands created in upland regions for nutrients retention and denitrification; also provide a degree

of water storage during flood events). A secondary opportunity is where the installation of an FDR measure indirectly affords an opportunity compatible with nutrients reduction (e.g. a levee raise provides for FDR at a D&LD, while a conservation easement within the D&LD provides an opportunity for limited wetlands development and the denitrification of D&LD captured tributary waters.

The UMRCP study recognizes that ultimately there is no one solution to managing nutrients, nor is solving this problem the domain of any one federal or state agency. Substantial nutrients reduction will be the combined effort of a broad spectrum of agencies and methods.

3. EXISTING CONDITIONS.

This section provides information descriptive of the "baseline" or "current" condition for the UMRS nutrients issue; relevant topics include: the regional database, nutrient sources and yield, nitrogen criterion, ongoing pollution control programs, and wetlands role in nitrogen removal.

3.1. Regional Database.

USEPA Region 5 recently contracted with the Upper Midwest Environmental Science Center (UMESC) for the preparation of a report entitled *Fate and Transport Study of the Upper Mississippi River Basin*. The study's objectives were (1) to quantify the sources of nutrient loading to the system, (2) evaluate transport patterns (trends, seasonality, flow relationships), (3) evaluate locations and magnitudes of nutrients retention within the system, (4) evaluate selected alternatives for managing sediment/nutrient movement, and (5) make data available to others.

UMESC has made major progress in compiling an Upper Mississippi Basin database. The database was constructed using nutrient and flow data obtained in a generally consistent fashion by the five states for all major tributaries. Useful information to be found on the UMESC website (www.umesc.usgs.gov.) includes background information to loading estimation and monitoring sites, nutrient monitoring locations, displayed rates of loadings and yields, and nutrient loading estimates via selected sub-areas. **Figure 2** provides a summary of the total nitrogen yield data for the UMRS.

Illinois was one of the UMR states receiving funds from USEPA. The state used its Ambient Water Quality Monitoring Network (AWQMN) for its data source **(Short, 1999)** and completed a study in 2000-2001 entitled *Baseline Loadings of Nitrogen, Phosphorous, and Sediments from Illinois Wetlands*. In addition to the baseline loadings, the effort allowed for the monitoring, assessment, and modeling of nutrient sources to support other watershed efforts. The monitoring network consisted of 209 stations monitored from 1980-1996. The strengths and weaknesses of the monitoring data were determined. The data is potentially useable for the Total Maximum Daily Load (TMDL) and other nutrient management actions in the Mississippi River Basin.

3.2. Causes of Nutrient Loading Problem.

3.2.1. Nutrients Over-Enrichment.

Natural wetlands and riparian zones reduce nitrogen loading by enhancing denitrification and by incorporating nitrogen into vegetation (CENR, 2000). Between the 1780s and the 1980s, 66 million acres of wetlands (an area the size of Illinois and Indiana combined) were lost in the Mississippi River basin **(Table 2; Hey 2002)**. Of this, approximately 26 million acres were lost from the Upper Mississippi River portion of the basin **(Hey, 2002)**. Lost with these wetlands was an enormous ability to trap organic materials and reduce aqueous nitrogen.

In addition to wetlands conversion to cropland, other significant land use changes have also occurred. Economic data exists establishing a relationship between the application rate of nitrogen and crop production. For example, an Illinois study showed that crop yield increases with increasing application of nitrogen, such that without fertilizer, a hectare of corn produces about 72 bushels/acre, and with an application of 200 pounds of nitrogen fertilizer it produces 180 bushels/acre—a 2.5-fold increase. It has been reported that nitrogen fertilizer use increased six-fold from the 1950s to the end of the 1970s, and that 89 percent of the annual total nitrogen flux to the Gulf is from non-point sources, and with the remainder coming from point sources **(Goolsby and Battaglin, 2000).**

Another major landuse change has been the installation of drain tiles throughout the UMRS. A drain tile is a tubular structure placed beneath the soil surface designed to improve drainage. Networks of tiles are installed under agricultural fields, often being connected into drainage ditches, canals, culverts, and pumps. Tiles are made out of a variety of materials including clay, concrete, and plastic. Millions of miles of drain tiles have been laid beneath the surface of most of the developed land in the basin. The economic benefits of tile drainage are well established. An acre of undrained soil may yield only 60 bushels of corn per acre. With surface and groundwater drainage improvements (e.g. use of tile lines) the same area could yield up to 120 bushels per acre. However, the use of tile lines to enhance farmland drainage also facilitates the drainage of groundwater containing nitrogen fertilizer **(Hey, 2002)**.

As presently managed, river flood control and flow control structures inhibit the natural nutrient reduction capacity of the UMR. Work in the UMR by Richardson et al 2004, Strauss et al 2004, Bartsch et al, in prep, also show that extant backwater lakes and wetlands have a significant, untapped capacity to remove nitrate through denitrification. Currently, backwaters only receive nitrate-laden flows during floods; current flow management to promote navigation forces most water to remain in the main channel and down to the Gulf of Mexico. Richardson et al 2004 estimate that the UMR system, if denitrifying at maximum potential, has the potential to remove at least another 15% of the current nitrate load in the system. They contend that a greater flow volume could be directed into backwater lakes and wetlands during the summer, thus resulting in greater N

(and P) removal from the UMR. They are currently testing the basis of this hypothesis by determining the current and potential nutrient (N & P) capacity of flow-through floodplain lakes in the UMR. These lakes are a common land form below locks and dams of UMR pools, extending from confining dikes for several kilometers downstream. They are commonly plant-filled, highly productive lakes often managed by multiple agencies for fish and wildlife benefits. They currently are evaluating a set of Finger Lakes below L&D 4 for their nutrient removal capacity. An earlier HREP at this site placed valved culverts at the upper end of each of 5 lakes, allowing the increased controlled flow of Pool 4 water into the lakes (ostensibly to promote fish populations). Preliminary data (2003) showed nitrate concentration declines along the length of these lakes, thus supporting the hypotheses about the N-removal capacity. For the next several years they plan to measure denitrification and plant uptake to determine the mechanism responsible for the longitudinal pattern. The loss of organic N associated with plant senescence following autumnal plant die back will be measured to document the role of plants in transient uptake and storage of N (and P,C) in these systems. If nitrogen is merely being removed by plants during the growing season, but lost again during fall die-back then there is no net loss of N from the system dynamics are the result of a balance between denitrification (permanent loss) and plant-algal assimilation (transient storage). After a year of process studies at current flow conditions they plan to increase flows through the lakes to determine the upper limits of nutrient removal capacity.

Wetlands Research, Inc **(Sather, 1992)** conducted intensive studies of wetland functions at a converted 550-acre wetlands restoration site along the Des Plains River in Lake County, Illinois. This study serves as a testimonial to the filtration capacity of wetlands. It was surmised that an effective reduction of nutrients could be realized with as little as 1 to 4 percent of a watershed being devoted to wetlands. Nutrient trap efficiencies on the order of 85 percent were achieved.

These results will be extrapolated to the UMR with GIS modeling to determine system-wide nutrient potential via management of flows to backwater lakes.

Based on the above, the real issue for the UMRS (and in part for the Gulf) may be the role that wetlands can play in reducing nitrogen and organic matter export.

3.2.2. Sources, Loads, and Trends of River Nutrients.

Since the early 1970s, phosphorus loads in the MARB have not changed significantly. Silica loads decreased between the 1950s and 1970s, with no change since that time. Nitrogen is the only nutrient to greatly increase in recent decades. It is present in the river in three forms: dissolved inorganic nitrogen (63%), dissolved organic nitrogen (24%), and particulate organic nitrogen (13%). However, most nitrogen analyses concentrate on the dissolved inorganic nitrogen fraction, since 61% of that fraction consists of nitrate—the most bioavailable form of nitrogen. The term total nitrogen is the sum of these three forms (CENR, 2000).

Between 1980 and 1996, the average total nitrogen flux from the MARB to the Gulf was 1.6 million metric tons per year. The total nitrogen concentration in the lower Mississippi has been estimated to have increased 1.3 fold since the early 1900s, and nitrate has increased 2.5 fold. The greatest increase in MARB inputs and outputs occurred between the 1950s and 1980s. During this period fertilizer use increased 3 fold, and crop productivity increased 2.4 fold. Nitrogen loads are highest during late winter, spring, and early summer when the runoff is the greatest (CENR, 2000).

The main source of nitrate in the MARB is the highly agricultural drainage basins of southern Minnesota, Iowa, Illinois, Indiana and Ohio. This same area is intensively farmed for corn and soybeans, and it is here that large amounts of nitrogen from fertilizer and manure are applied. Sewage plants and industrial sources also add to the nitrogen load from some basins. Fifty six percent of the nitrate to the Gulf enters the Mississippi River above Cairo, Illinois. About 90% of the nitrogen is derived from nonpoint sources and 10% from point sources (CENR, 2000).

3.3. Consequences of Nutrients Over-Enrichment

Local nutrient effects are likely large, but relatively unstudied. One obvious effect is the shading of riverine plants by suspended solids and phytoplankton. Periphyton (algae attached to plants) is also becoming more abundant in plant beds and likely results in reduced plant growth. An imbalance of nitrogen and phosphorus may also promote the development of nitrogen-fixing cyan bacteria (blue green algae). Some of the strains of cyan bacteria are toxic to aquatic life; at the very least dense populations shade desirable plants.

Another local impact is the development of high concentrations of ammonium in sediments, particularly in backwaters. The ammonium is derived from decomposition of N-rich organic matter and will dissociate from the organic matter to form highly toxic free-ammonia when sediment pH rises >8.0. The frequency of wide swings in sediment pH is not well known but our numerous measurements (>400) show high concentrations of ammonium are common in the UMR sediments. More study of this dynamic and biologic effect is needed.

Impacts to the suitability of waters for swimming and drinking can result in water quality standard violations. Most MARB states have considerable miles of river impaired by high levels of nutrients. Thus certain areas are not supporting some types of resource use, e.g. swimming, fishing, and aquatic life. Raised levels of nutrients (nitrogen and phosphorus) can result in algal blooms and other nuisance aquatic plants, that disrupt the ecological balance, clog pipes, interfere with recreation, cause foul odors, bad taste, and localized drops in DO levels. High levels of nitrate in drinking water can result in “blue baby syndrome”. Shallow groundwater contamination may be an alert to potential risks from consumption of water from deeper wells in these aquifers (CENR, 2000).

3.4. Ongoing Nutrients Control Initiatives

3.4.1. Pollution Control Programs

Water pollution (including nutrients loading) can result from both point and non-point sources. Point sources are distinct discharge points such as domestic and industrial facilities that discharge treated wastewater to surface water or land. Water quality point source programs: issue permits, monitor compliance, and enforce permit conditions. Delays in permit processing can be a problem at times, and are related to such factors as regulatory policy changes, environmental group challenges, budget reductions, and increases in the number of facilities needing permits. Strategies for correcting the problem include developing general permits for minor facilities; permit tracking tools, and improving computerization of the permits system. Enforcement can be improved with aggressive targets for compliance inspections and penalties for non-compliance.

Non-point source (NPS) pollution comes from many diffuse sources. It includes: fertilizers, herbicides, pesticides, toxic chemicals, sediment, animal waste and others. To date, NPS pollution has not been adequately addressed. This is due in part to limited regulatory authority, and in part to a lack of meaningful scientific data. In terms of regulation, only TMDLs exist, and only at some locations. In the absence of good data, it is difficult to establish, or enforce NPS controls.

In recent years, the UMRS states have been moving towards an integrated, multi-objective approach to watershed management that includes consideration of water quality, flood control, wildlife habitat, and other issues related to the human and natural environment. **Table 3** lists a number of existing federal, state, and NGO watershed management initiatives. The watershed approach allows for collaboration with stakeholders to develop an inventory of issues, and to reach a consensus on the prioritization and implementation of solutions. It utilizes a mix of tools including protection, planning, regulation, incentives, and education. Soil and Water Conservation Districts have become an integral part of the linkage between federal and local water resource management systems.

3.4.2. Nitrogen Standards

USEPA Regions 5 and 7 have been working with the UMRBA and the five UMRS states to develop a coordination framework for work on UMR water quality issues. Procedurally, each UMR state develops and adopts water quality standards (including nitrogen) under Section 303 of the Clean Water Act for waters under its jurisdiction. There is no one set of standards for the UMRS. Additionally, the standards adopted by each state may be different in regard to designated uses, pollutants covered, criteria levels, and the manner in which the standards are implemented. To date, the various parties have held meetings and phone calls to discuss this topic.

The USEPA has helped fund some recent studies that could eventually serve as a tool for the establishment of TMDLs, these include the Upper Midwest Environmental Science Center's sediment and nutrient transport study, and the Illinois EPA baseline loadings study for Illinois nitrogen, phosphorous and sediment loadings.

4. FUTURE CONDITION WITHOUT NEW MANAGEMENT ACTIONS.

Policies and practices in agriculture during the last 20 years have changed with the result being increased productivity and efficiency. The use of fertilizer has been constant since the late 1970s. At the same time, corn yield per unit of applied fertilizer has continued to climb. However, average nitrogen loads could eventually increase since the US population and the domestic and world food demand are likely to grow (CENR, 2000).

It seems reasonable that future fertilizer usage would tend to follow the future trend in crop production. For the purposes of this assessment, it is assumed that the next 50 years of UMRS crop production (based on assumptions of world trade, crop area, crop yield and crop consumption) will be the same as those conditions described for the Upper Mississippi River—Illinois Waterway System Navigation Study. **Table 5** shows the anticipated future conditions for farm product shipments along with a fertilizer usage anticipated to increase by the same percentage rates. Table 5 provides three levels of transport movement. The Central Estimate (or Scenario, as it is described in the navigation study) is intended to represent a "middle-of-the-road" U.S. export prospect. Around this Central Estimate, scenarios were developed by the navigation study that was more favorable and less favorable to U.S. agricultural trade.

Many of the **Table 3** listed UMRS federal and state watershed initiatives are anticipated to continue into the without project condition, including such critical initiatives as the CREP (**Table 4**); however, insufficient data exists to quantify such a beneficial effect. It is also anticipated that significant nutrients reduction activities will occur on the river system outside of the UMRS, e.g. the water and sediment diversion proposals of the Louisiana Coastal Area (LCA) Ecosystem Restoration Study.

5. FUTURE CONDITIONS WITH MANAGEMENT ACTIONS

Depending on the methods used to reduce nutrient loads on the UMRS, costs will result with respect to facilities and management for enhanced farm practices, loss of farm ground, and raised treatment costs for urban areas. Reducing UMRS nutrient loads could help reduce the risk of hypoxic effects in the Gulf. Within the basin it could held reduce soil erosion, reduce drinking water contamination, improve water quality for recreation, improve fishing and hunting use, and reduce flood damages. Other potential benefits include: increased efficiency in fertilizer use, lower fertilizer costs, decreased public health risk, and improved aquatic habitat (CENR, 2000).

5.1. Nutrients Reduction Measures Available.

Addressing watershed nutrients loading is a challenge. Ultimately, it requires input from a number of disciplines, including ecology, hydrology, agronomy, atmospheric science, and soil science. Candidate solutions must proceed through a gamut of social,

economic, political, regulatory, and review considerations by the government and by private stakeholders. Following a review of the available literature, the UMRCP study team identified various broad-based measures with potential application to the UMRS. These measures are described in **Table 6**.

The CENR (2000) identifies two basic approaches to reducing nitrogen loads. One is nitrogen-retention (especially nitrogen management and alternative cropping systems) and the other is denitrification (especially the creation and restoration of new wetlands and riparian bottomland hardwood forest buffers). The CENR used a macroeconomic model (U.S. Mathematical Programming Model for Agriculture (USMPM)) to evaluate some broad policy approaches. Analyses indicate that changing agricultural practices could provide the lowest cost option to society. However, there are many unanswered questions regarding how the practices would be motivated, cost-shared, and implemented across numerous state and federal programs.

Farm related practices that could be changed include: controlling the rate of application of fertilizer, changing the timing of fertilizer application, improving management of livestock manures, changing from row crop to perennial-cropping systems, cover crop plantings, reduced tillage practices, altered spacing of drainage tiles, controlling water tables to enhance denitrification, routing soil drainage through wetlands and riparian buffers.

5.2. Nutrients Reduction Measures Evaluation.

In **Tables 7 and 8**, the Table 6 described nutrients reduction measures were evaluated using the basic planning criteria of completeness, effectiveness, efficiency, and acceptability. The performance of the various measures ranged from a low value of 7 for measure 3 to a high value of 10 for measures 5.

Measure 5 represents an important opportunity for Corps involvement in nutrients reduction. It would use FDR “peak-of-flood-storage” lands for installing nutrients farm pilot projects to better assess the engineering, economic, and environmental viability of wetlands creation as a means of denitrification. If shown feasible, additional mitigation lands could be considered for use in nutrients management.

The CENR (2000) economics model (**Table 9**) predicted that edge-of-field nitrogen losses using a mix of management practices could achieve reductions at a cost of $0.88 per kg of nitrogen reduction at a 20% basin reduction level. Fertilizer reductions alone would cost $0.69 per kilogram of nitrogen reduction at the 20% level, The cost for urban point sources reduction (2% of the basins nitrogen input) is $40 per kilogram, and the costs of reducing atmospheric deposition of nitrogen is $20-100 per kilogram of nitrogen.

The estimated cost of nitrogen reduction by way of wetlands is $8.90 per kilogram of nitrogen reduction (**Table 9**). However, when the other benefits of the wetlands are

factored in (drinking-water protection, adding acres of wetlands habitat, improving the ecosystem, enhancing wildlife corridors, and FDR), the net costs of are closer $1.00 per kilogram of nitrogen reduction (CENR, 2000).

As supplemental information, **Table 10** provides a summary of the proceedings of a TWI four-day workshop to discuss various topics related to nitrogen farming using wetlands. These topics include: pilot projects and related issues of science and policy, economics, and agriculture (TWI, 2002).

It appears from the foregoing analysis, that an optimal nutrients management strategy would take appropriate advantage of the full range of possible approaches. Incentive payments, voluntary stewardship, technical assistance programs, regulatory requirements all have pros and cons in various situations and site locations. No singular approach is clearly far more economical or costly. This is also the approach advocated by CENR (2000).

5.3 UMRCP Plans Evaluation/Comparison.

Table 11 reflects the potential number of acres available for "wetlands restoration" under the various floodplain alternative plans, by river reach. Plan J was found to provide the most wetlands nutrients reduction opportunities (with 307,018 acres), followed next by Plan B, Option 3 or Plan H, Option 3 (with 66,501 acres).

6. IMPLEMENTATION.

6.1.Agencies Involvement.

Given the current state-of-the-science, the best approach (for the short-term) is to avoid excluding any of the identified options, and to proceed cautiously via adaptive management. This approach would allow for a learning curve, without committing large federal expenditures to a singular "systemic solution". Both Corps and non-Corps implementation opportunities exist. However, current policy guidance indicates that "watersheds" are the chief domain of non-Corps agencies. Accordingly, Measure 1 is best accomplished by the USEPA via the USGS and the 5 states. Measures 2, 3 and 4 by the USEPA in coordination with the 5 states and the other federal agencies. Measures 5 and 6 involve the mainstem floodplain and are appropriate for consideration by the Corps in coordination with the USEPA, the other federal agencies and the state.

6.2.Adaptive Management.

The complexity of nutrient cycling/transport processes in the MARB, make it difficult to estimate the amount of water quality improvements needed for a given reduction in nutrient inputs. Also, environmental responses to management actions occur slowly, and could take decades of data collection to show statistically. However, there are areas of

monitoring and research that can help reduce these uncertainties in future assessments, and to aid decision makers in an adaptive management framework. Adaptive management requires a process of continuous feedback between new data and improved management actions.

6.2.1. Monitoring , Modeling and Research Framework.

The adaptive framework uses models to integrate the hydrologic and ecological systems for the interpretation of systemic changes. This monitoring needs to be able to detect and partition trends, observe nutrient processes and their roles in cause-effect relationships. Monitoring should be based on a holistic approach that simulates our understanding of the overall system functions and the influence of the management actions.

Monitoring in the MARB requires environmental response measurements, and the tracking of programmatic progress indicators towards mitigating excess nutrients. Key elements of monitoring in the MARB include: the documentation of water quality changes, the monitoring of nutrients from the atmosphere, establishing an inventory of effluent through the NPDES to improve current estimates of nitrogen and phosphorus loads, and to improve measurements of soil nitrogen and nitrogen loss.

There are two categories of research needs, immediate priorities and long-term priorities. For the MARB, the immediate priorities include (1) the need for a better understanding of nitrogen transport processes from the edge-of-field to the river, and a better understanding of the distribution and design criteria for targeting wetlands creation and mixes of other nitrate reduction strategies (e.g. riparian buffers), and (2) the need to better quantify on-farm techniques between the field and groundwater and adjacent streams (including a scale up from experimental plots to watershed-farm scale studies, and monitoring the effectiveness of policies and voluntary actions on a basin scale). Long-Term priorities include (1) the need for a better understanding of nutrients processes, (2) research to more clearly reflect the effects of long-term hydrology/climate/population changes, and (3) the need for additional changes in point and urban non-point source controls.

6.2.2. UMRS Monitoring, Modeling and Research Needs.

Table 13 provides a list of monitoring parameters with application to nutrients reduction on the UMRS. This list was extracted from a larger list of nutrient reduction parameters identified by the WNTF (2003).

Within the UMRS basin, the USGS plays an important role in monitoring, modeling and research (MMR) (USGS, 2003). The agency maintains a network of water-quality monitoring sites, conducts individual studies, and provides analyses and modeling of the linkages between the watershed, the river, and the aquatic biota. It manages four national or regional long-term monitoring programs of relevance to the UMR basin (**TABLE 12**). A number of USGS models are being used to describe annual and seasonal nitrogen

sources and loads in the UMR basin. One of these is the SPAtially Referenced Regression on Watershed Attributes (SPARROW) model. The model is used to estimate large-scale transport of nitrogen by integrating landuse and landscape features, over a number of spatial scales. The National Seismic Network (NSN), National Stream Quality Accounting Network (NASQAN), and National Water-Quality Assessment (NAWQA) programs are used to calibrate and verify the model's reliability. Another model is the in-stream transport model Diffusion Analogy Surface-Water Flow Model (DAFLOW/BLTM) that simulates stream discharge and transport of nitrate. USGS research on nitrogen processing in the UMR has depended on both new innovative research and high quality nutrient-loading estimates from the Long-Term Resources Management Program (LTRMP).

UMR work efforts thus far, indicate a pressing need for models that link river hydrology to sediment biogeochemistry (Richardson 2004, pers. comm). Nitrogen cycling and nitrate removal in the UMR is tightly linked to the transport of nutrient-laden waters to environments (e.g., backwaters) known to be active biological and biogeochemical hotspots. Mechanistic, numerical models need to be developed that predict the effects of various flow regimes, pool morphologies, and sediment biogeochemical potentials to nutrient flux from the UMR and other river systems. We currently know quite a bit about extant rates of denitrification on the floodplain and pools, know that nitrate delivery rate is important, but can't predict removal of nitrate or assimilation rates for a given river stage or level of channel-backwater connectivity.

To date, the USGS and USCOE (WES) have entered into a good collaboration, but the effort is hampered by a lack of funding. For example, the work at Finger Lakes could, and should be much more extensive – including a greater number of HREP sites, and a more thorough analysis of N and P removal processes – in order to make more sound and system-wide inferences.

7. VIEWS OF OTHERS.

Table 14 provides a sampling of the kinds of concerns raised by Midwest Region stakeholders during the May 1999 review of the Gulf hypoxia science assessment. While many of these issues were subsequently resolved in the consensus agreement between the agencies in preparing the Gulf Hypoxia Action Plan, they do none-the-less help reflect the general sensitivities of the stakeholders to various nutrients related issues.

The goals of the science assessment were to document the state of knowledge regarding the magnitude, components, causes, and effects of Gulf hypoxia. As background information to that assessment, six separate but interrelated reports were prepared. The topic reports (as well as the overall assessment) can be downloaded at www.nos.noaa.gov/products/pubs_hypox.html.

A pre-draft review of the Appendix L was conducted by the CT in March 2004. Based on those comments numerous changes were made to the document. The more substantial comments included the following: UMRCP study should focus more on the

role of wetlands in UMRS nutrients transport, rather than on Gulf hypoxia; disagreements with the text references depicting the current state of the science, the administration now considers "watersheds" to be the domain of non-Corps entities, the programmatic conclusions/recommendations (utilizing existing programs, adopting a adaptive management approach, and pilot projects) were largely in line with the hypoxia Action Plan.

8. PROGRAMMATIC LEVEL CONCLUSIONS (PRELIMINARY).

The UMRCPs programmatic level conclusions regarding watershed nutrients loading are as follows:

FDR Related Nutrients Projects are Not Justified. Significant nutrients project opportunities do exist within the UMRS floodplain. However, at present there doesn't appear to be any cost-justified FDR systemic plans that would support the inclusion of ER projects.

Understanding of UMRS Nutrients Loading. Our understanding of the mechanisms of UMRS nutrients loading isn't totally complete, as is its potential relationship to Gulf hypoxia.

- Due to the current state-of-the-science, the initial years of any proposed nutrients reduction program should add greater emphasis to research and monitoring, than to construction. We should try some things, and see how effective they are.

- Any nutrients reduction effort should try to capitalize on existing institutional infrastructure for its implementation.

- Actions that could improve our understanding of the dynamics of UMRS nutrients loading include: (1) continuous and sufficient funding support for the USGS and other agencies data collection/monitoring/DDS and IMPs network, (2) continued funding support for existing pollution control programs, and (3) nutrients farming pilot projects and EPM projects.

- Pilot studies could help better establish the engineering, economic, and environmental effectiveness of wetlands development (nutrients farming and EPM) as a potential nutrients reduction measure.

Potential Improvements to Nutrients Management. Team identified potential improvements to the existing nutrients management process are as follows:

- ***Adaptive Management.*** An adaptive management approach is recommended for the reduction of UMRS nutrients loading. More specifically the UMRCP recommends the following:

- **Data Collection.** The standardization of systemic data collection methods, an expanded systemic monitoring and trends analysis program, and the development of a UMRS DSS and IMP (**Table 6, Measures 1**) at the Midwest regional level with the applicable sub-basin committees would also conduct the DSS and IMP planning efforts within its respective state boundaries. Ensuring the consistency of data collection, monitoring and analytical methods would reside with the UMESC. USEPA would provide funding and oversight for the UMRS effort.

- **Reseach/Monitoring Funding Support.** Continued funding in support of the WNTF Action Plan. This should include funding for the sub-basin workgroups and their pilot projects, and for research and monitoring of hypoxia related processes (**Table 6, Measure 2**).

- **Pollution Control Programs Funding Support.** Continued funding support for existing federal/state pollution control programs (**Table 6, Measures 3 and 4**). These programs include:

    - Nonpoint source nutrient reductions via the Farm Bill, Clean Water Act, and state cost-shared programs.

    - Grain and livestock related nutrient source reductions via implementation of EQIP.

    - Natural systems restoration/enhancements to induce nutrient reductions via implementation of WRP, CRP, and Agricultural Extension Education Programs.

    - Watershed-based approaches to water quality management (including application of TMDLs standards and National Pollutant Discharge Elimination System (NPDES) point source controls) as a furtherance of nutrients reduction.

    - Buffers establishment via public-private partnerships, e.g. the Farm Services (FSA)—Conservation Reserve Enhancement Program (CREP).

    - Voluntary incentives in support of nitrogen reductions (e.g. the NRCS Forestry Incentives Program (FIP) and NRCS Wildlife Habitat Incentives Program (WHIP).

    - Support for non-federal actions that promote nutrients removal.

- **Pilot Projects.** The implementation of nutrients reduction pilot projects (**Table 6, Measures 5 & 6**) at several scales (small, medium and large projects). These projects would be planned, designed, constructed, monitored, reassessed, and modified (as appropriate) under the purview of the UMRS--Environmental Management Program

(EMP). The performance of these projects would be reported within the program's periodic "Report to Congress". This aspect of the EMP program would include the following:

- Potential pilot project locations prioritized in collaboration with USEPA, UMESC, and states. Appropriate site prioritization criteria would include: compatibility with wetlands development opportunities afforded by the UMRCP FDR recommended plan, combinability with other related wetland projects (e.g. NGO projects), drainage location (i.e. priority being given to high nitrogen load watersheds), drainage timing, structural modifications required, cost-effectiveness, and multi-functions capability (e.g. in addition to nutrients reduction the site could yield other desirable wetland functions such as wildlife habitat and increased species diversity).

- The cost-effectiveness analysis for the projects prioritization would consider such factors as capital costs, operating costs, opportunity costs, and economies of scale, nitrogen farming income, related activities income, market area, market size, monitoring costs, certifying costs, and regional economic effects.

- Research and monitoring would be accomplished in collaboration with the UMESC, and with the affected states.

- The program would be conducted collaboratively with the states and NGOs to test the viability of "nutrients farming" as a voluntary incentives approach.

- Program would include the states and larger NGO groups as project sponsors.

- The pilot projects would be cost-shared at the rate typical of EMP projects (i.e. 65% Federal and 35% non-Federal).

- Using a strategy of adaptive management, and assuming the pilot projects prove successful, additional increments of project would be proposed to the Congress for implementation via the Report to Congress. This reporting would also take into account additional WNTF findings regarding linkage between Gulf hypoxia and river nutrients loading.

- The adaptive management process would utilize any available Decision Support System (DSS) tools available, and would also develop decisions in a manner consistent with the federal and state IMPs.

- Program would utilize the EMP outreach program to educate the public regarding nutrients reduction projects, their monitoring, research, modeling, evaluation and adaptation.

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Table 1. Gulf Hypoxia Fact Sheet

Topic	Description
Documentation	In January 2001, the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (WNTF) released an "Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico. That plan was informed by the May 2000 findings of the Committee on Environment and Natural Resources (or CENR) Integrated Assessment of Hypoxia in the Northern Gulf of Mexico, along with comments on the assessment and 6 topic reports on which it was based. The Action Plan is the major policy vehicle for addressing the hypoxia problem, and it represents a consensus agreement between the basin states and federal agencies (including the Corps).
Gulf Hypoxic Zone	Hypoxia is a condition of very low dissolved oxygen concentrations, generally less than 2 milligrams per liter, and less than the level necessary to maintain most animal life. It occurs when oxygen consumption (from decomposing organic material) exceeds oxygen production (from photosynthesis). The Northern Gulf of Mexico hypoxic zone is the largest such zone in U.S. coastal waters. The area affected is about the size of the State of New Jersey **(CENR, 2000).**
Source of Problem	Gulf hypoxia is primarily the result of algal growth and decomposition from excessive amounts of nitrogen discharged from the Mississippi-Atchafalaya River Basin combined with Gulf waters stratification **(CENR, 2000).** About 90 percent of the nitrate load to the Gulf comes from non-point sources.
Nutrients Yield	On average, the Gulf of Mexico receives 1.7 million tons of nitrogen annually, about 60 percent of which is in the form of nitrate-nitrogen **(PPI, 1999). Figure 2** reflects the estimated nitrate-nitrogen yields for the Mississippi River basin between 1980-1996. The sources of river nitrogen are both natural (from atmospheric deposition and soil depletion) and cultural (from agricultural, industrial, automotive, and numerous urban activities) **(Hey, 2002)**. Agricultural sources are believed to account for 58 percent of the river basin's nitrogen, including: commercial fertilizer (31%), manure (6%), and legumes (21%). **Bollinger (2001)** noted that estimates for phosphorous loads to the Gulf range from no statistical change in the 1970s to as high as a four times increase in the load between the 1960s and 1980s. He believes that evidence for a large increase warrants further investigation. Phosphorus is known to be easily taken up by micro-organisms, and can stimulate nitrogen fixation through the growth of blue-green algae.
Historic Presence of Zone	Sediment core samples show that algal production, deposition and oxygen stress were lower in the early 1900's, and increased greatly in the latter half of the twentieth century. Major changes occurring during this period were deforestation, farm drainage, channelization, and increased fertilizer use between the 1950s and 1980s. Total nitrogen load has increased from the 1950s due to an increase in nitrate nitrogen. Nitrate flux to the Gulf has tripled from the periods 1955-70 and 1980-96 **(CENR, 2000**).
Extent of Zone	**PPI (1999)** indicates that the hypoxic zone has been known to occur regularly since the early 1970s, and evidence of a zone goes back to the 1930s. The extent of the zone varies within years and between years, and is said to be related to Mississippi River discharge. During low flow years (e.g. 1988 and 1989) the hypoxic zone was reported to be nearly non-existent, while during the "Flood of 1993" it covered more than 7,000 square miles (or 18,130 square kilometers). The aerial extent of the mid-summer hypoxia zone for the 5-year running average, 1996 to 2000 was estimated to be 14,128 square kilometers. **Scavia et al (2003)** have been able to apply a river nitrogen load model and a simple parameterization of ocean dynamics to reproduce 17 years of observed hypoxia location and extent.
Consequences of Hypoxia in Gulf	Although economic studies haven't demonstrated a statistically significant correlation with the extent of hypoxia, the harvest of brown shrimp harvest (a commercially important species) has been trending downward over the past three decades. National concern exists over the potential impact that worsening hypoxic conditions could have on this ecologically and commercially important species **(CENR, 2000).**
State-of-the-Science	The existence of a hypoxia zone in the Gulf is not contested by the scientific community, nor is the observed relation between the aerial extent of the hypoxia and Mississippi River discharge. What has been disputed are the causal factors that lead to Gulf Hypoxia, the historical size of the hypoxic zone, and the intensity of the zone. This situation is not surprising considering the heterogeneous and highly dynamic nature of the coastal ecosystem. It is apparent from the literature that many factors contribute uncertainties to our understanding of this issue. In addition to dissolved nutrients, factors entering the equation include: climate change, land-use change, pollution, freshwater, loss of wetlands, suspended solids, fisheries harvests, storms, tidal currents, geomorphology, and terrestrial organic matter. The WNTF encourages agencies to concentrate on sub-basin areas with the highest nitrogen loads per unit area, to conduct implementation via an assessment, research, monitoring, modeling, and adaptive management process, and encourages agencies to pursue new legislative authorities and funding for implementation. Prior actions taken to implement the hypoxia plan have included: the development of an integrated federal budget proposal, establishing sub-basin committees, developing a research strategy, expanding monitoring efforts in the Gulf, and in the Mississippi River Basin. Future planned actions include: developing strategies for nutrients reduction, identification of point source nutrient discharge actions, assistance to promote beneficial wetland and buffer actions, implementation of best management practices (BMPs), and an adaptive management strategy.

Table 1. Continued.

Topic	Description
Considerations for Taking Action	The CENR recommended two primary approaches to reducing Gulf hypoxia, nitrogen retention, and denitrification. It suggested that there is no single solution to managing the problem, and a full range of methods needs to be explored using an adaptive management approach. It further suggested that such an approach could be initiated within the existing array of state and federal programs. Best management practices, point and non-point water pollution controls, increasing the acreage of wetlands and vegetated riparian buffers, and targeting high nitrogen yield watersheds would be most worthwhile. The collective benefit of these measures would be other economic and environmental benefits including restored wetlands, reduced soil erosion, reduced drinking water contamination, reduced susceptibility to floods, improved habitat and recreation, and reduced fertilizer costs.
Adaptive Management	Gulf hypoxia is an issue that will require a long-term rigorous testing of multiple working hypotheses. Responses to remedial measures may take decades to scientifically demonstrate. More research, monitoring, and modeling will be needed to reduce future uncertainties, and to improve the decision making process via adaptive management. Continual feedback of new information and interpretations will be essential to implementing the productive watershed actions. The use of environmental indices for hindcasting, nowcasting and forecasting biological productivity fluctuations have been gaining interest; however, to date these kinds of approaches have had only limited success. The reasons for this, include non-linear responses, density-dependencies, and fluctuations between limiting factors (GLOBEC, 2002). Justic et al. (2004) indicate that because of the uncertainties, model simulations for coastal eutrophication are highly variable. They have emphasized the need for adaptive management, where monitoring and modeling efforts are closely linked to provide a base for continuous policy adjustments over time. This adaptive approach has been outlined by the WNTF and includes the following parts: an action (implementing sub-basin strategies that target a reduction in nitrogen yield), education (through electronic media, workshops, etc.), monitoring (increasing scale and frequency of data collections), research and modeling (increasing our knowledge regarding the processes and impacts relating to hypoxia), and evaluation and adaptation (reviewing monitoring and research to determine the need for plan modifications). Major monitoring, modeling and research (MMR) efforts are currently underway. The USEPA, as part of its Gulf of Mexico Program, has formed a MMR workgroup to coordinate efforts cost-sharing, recommendations, and assistance on MMR issues. Referenced paper, WNTF (2003), provides the groups draft science strategy for MMR.

Table 2. Wetland Losses in Upper Mississippi River Basin and Entire Mississippi River Basin (MRB) States*

State	Area in1780 (Acres in Thousands)	Area in 1980 (Acres in Thousands)	Loss (Acres in Thousands)
Illinois	8,212	1,255	6,957
Minnesota	15,070	8,700	6,370
Wisconsin	9,800	5,331	4,469
Missouri	4,844	643	4,201
Iowa	4,000	422	3,578
UMRS States Total	41,926	16,351	25,575
Other MRB States Total *	68,409	27,857	40,552
MRB States Total	110,335	44,208	66,127

* Includes states of Louisiana, Arkansas, Mississippi, Indiana, Ohio, North Dakota, Oklahoma, Kentucky, Tennessee, Nebraska, Colorado, South Dakota, Wyoming, Kansas, and West Virginia.

Source: Hey, 2002

Table 3. Watershed Programs.

Federal Programs			Program Description
NRCS	Watershed Surveys and Planning	Watershed and Flood Prevention Act of 1954, Public Law 83-566, as amended	The purpose of this program is to assist agencies in protecting watersheds from damage caused by erosion, floodwater, and sediment, and to conserve and develop water and land resources. Resource concerns include water quality, water conservation, wetland and water storage capacity, agricultural problems, rural development, urban water needs, upstream flood damages, water needs for fish, wildlife and forests. Types of surveys and plans include watershed plans, river basin surveys and studies, flood hazard analyses, and flood plain management assistance. The focus is on plans that identify land treatment and nonstructural solutions to resource problems.
	Environmental Quality Incentives Program (EQIP) *http://cfpub.epa.gov/fedfund*	Farm Security and Rural Investment Act of 2002 (Farm Bill)	EQIP provides a voluntary conservation program for farmers that promotes agricultural production and environmental quality as compatible national goals. EQIP offers financial and technical help to assist eligible participants install or implement structural and management practices on eligible agricultural land. It offers contracts with minimum term that ends one year after the implementation of the last scheduled practices and a maximum term of ten years. These contracts provide incentive payments and cost-shares to implement conservation practices. Persons engaged in livestock or agricultural production on eligible land may participate in the program. Activities are carried out according to an environmental quality incentives program plan. The practices are subject to NRCS technical standards and the local conservation district approves the plan. EQIP may cost-share up to 75% of the costs of certain conservation practices. Incentive payments may be provided up to three years to encourage producers to carry out management practices that they might not otherwise use.
	Wetlands Reserve Program (WRP) *http://cfpub.epa.gov/fedfund*	Food Security Act of 1985, Public Law 99-198	The WRP is a voluntary program offering landowners the opportunity to protect, restore, and enhance wetlands on their property. NRCS provides technical and financial support to help landowners with their wetland restoration efforts. The NRCS goal is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. The program offers landowners an opportunity to establish long-term conservation and wildlife practices and protection.
	Forestry Incentives Program (FIP) *http://www.nal.usda.gov/wqic/funding.html*	Cooperative Forestry Assistance Act of 1978), Public Law 95-313	The FIP supports good forest management practices on privately owned, non-industrial forestlands nationwide. FIP is designed to benefit the environment while meeting future demands for wood products. Eligible practices are tree planting, timber stand improvement, site preparation for natural regeneration, and other related activities. FIP is available in counties designated by a Forest Service survey of eligible private timber acreage.
	Wildlife Habitat Incentive Program (WHIP) *http://cfpub.epa.gov/fedfund*	Federal Agriculture Improvement and Reform Act of 1996, Public Law 104-127	The WHIP is a voluntary program for people who want to develop and improve wildlife habitat on private land. Through WHIP NRCS provides technical assistance and up to 75% cost-sharing to establish and improve fish and wildlife habitat. WHIP agreements between NRCS and the participant last from 5 to 10 years. WHIP has proven to be a highly effective and widely accepted program across the country. By targeting wildlife habitat projects on all lands and aquatic areas, WHIP provides assistance to conservation minded landowners who are unable to meet the specific eligibility requirements of other USDA conservation programs.
	Conservation Reserve Program (CRP) *http://cfpub.epa.gov/fedfund*	16 U.S.C. 383-3836	The CRP provides technical and financial assistance to eligible farmers and ranchers to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial and cost-effective manner. The program provides assistance in complying with Federal/State/Tribal laws and encourages environmental enhancement. The program is funded through the Commodity Credit Corporation (CCC). CRP is administered by the FSA, with NRCS providing technical land eligibility determinations, Environmental Benefit Index scoring, and conservation planning. The CRP reduces soil erosion, protects agricultural resources, reduces sedimentation, improves water quality, establishes wildlife habitat, and enhances forest and wetland resources. It encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as native grasses, wildlife plantings, trees, filterstrips, or riparian buffers. Farmers receive an annual rental payment for the term of the multi-year contract. Cost sharing is provided to establish the vegetative cover practices.

Table 3. Watershed Programs (Continued).

Federal Programs			Program Description
	Conservation Reserve Enhancement Program (CREP) *http://www.fsa.usda.gov/dafp/cepd/crep.htm*		The Conservation Reserve Enhancement Program (CREP) is an offshoot of the country's largest private-lands environmental improvement program—the Conservation Reserve Program (CRP). The CREP is a landowner's incentives program involving a major federal/state initiative to voluntarily establish wetlands for water quality improvement in tile-drained regions. Like the CRP, USDA's Farm Service Agency (FSA) administers the CREP. **Table 4** summarizes the CREP program for the UMRS states. The Iowa partnership, as an example, consists of the USDA (Farm Services Agency and Natural Resources Conservation Service), Soil and Water Conservation Districts, Iowa Department of Agriculture and Land Stewardship, and Iowa State University **(Iowa DOA, 2001)**. The program is targeted to continue for at least 10 years, pending federal reauthorization of the CRP. Participating cropland landowners receive: an annual rent from the USDA for 15 years on enrolled acres, 100 percent cost-share for wetland restoration and adjacent buffers, and also incentives to enter into longer-term agreements. A key objective of the program is to reduce nitrate losses using a combination of in-field best management practices, and off-site landscape buffers. Eligible land must be within certain designated state counties, and must be situated such that the established wetland would not interfere with normal tile drainage. Research at Iowa State University has shown that properly located and designed, these created wetlands can remove 40-90 percent of the nitrate in tile drainage water from croplands **(Iowa DOA, 2002)**. In addition to reducing nitrate loads, the wetlands also provide valuable wildlife habitat. The ISWS is working with the USGS in developing a nutrient monitoring network in the Illinois River basin to monitor the effectiveness of the CREP.
USEPA	Section 319 Nonpoint Source (NPS) Management Program *http://www.pca.state.mn.us/water/319.html*	Clean Water Act, As Amended in 1987	Congress amended the Clean Water Act (CWA) in 1987 to establish the Section 319 Nonpoint Source (NPS) Management Program because it recognized the need for greater federal leadership to help focus state and local NPS efforts. Under Section 319, State, Territories, and Indian Tribes receive grant money which support a wide variety of activities including technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific NPS implementation projects, and monitoring to assess the success of specific NPS demonstration projects, and monitoring to assess the success of specific NPS implementation projects. Over the last few years, some section 319 funds have been dedicated to developing and implementing TMDLs (total maximum daily load).
	Clean Water State Revolving Fund (CWSRF) *http://www.epa.gov/owm/cwfinance/cwsrf/index.htm*		The Clean Water State Revolving Fund (CWSRF) programs provide about $4 billion annually in recent years to fund water quality protection projects for wastewater treatment, nonpoint source pollution control, and watershed and estuary management. CWSRFs offer low interest rates on flexible terms, significant funding for NPS control, assistance to a variety of borrowers, and partnerships with other funding sources.
	Watershed Academy Web *http://www.epa.gov/watertrain/*		The Watershed Academy Web (WAB) is a distance learning program. The program consists of an array of self-paced training modules providing an introduction to watershed management. The modules are organized by six themes: introduction/overview, watershed ecology, watershed change, analysis and planning, management practices and community/social/water low modules.
	Midwest Natural Resources Group *http://www.mnrg.gov/*		The Midwest Natural Resources Group (MNRG) is a partnership of 13 federal agencies bringing attention to federal activities supporting the vitality/sustainability of natural resources. They are committed to bringing results to the American public in the Midwest. The UMR and Illinois River watersheds are included as focus areas. Among its activities has been the holding of Environmental Round Table meetings on various topics of interest, including nutrients and sediment loading.
COE	Environmental Management Program *http://www.mvr.usace.army.mil/EMP/default.htm*		The Upper Mississippi River System Environmental Management Program (UMRS-EMP) is a Federal-State partnership to monitor the natural resources of the river system. The program was authorized by The Upper Mississippi River Management Act of 1986 (P.L. 99-662). Currently, UMRS-EMP is comprised of two elements, Habitat Rehabilitation and Enhancement Projects (HREP) and Long Term Resource Monitoring (LTRMP). Two of the larger HREP projects include uplands watershed management as project features, these are the Swan Lake and Batchtown projects.

Table 3. Watershed Programs (Continued).

State Programs			Program Description
Illinois	Interagency Pilot Watershed Program (PWP) *http://www.biodiversitypartners.org/pubs/CinAReport/Results2.shtml*		The PWP assists in providing a forum for coordinating watershed improvement. Streamlines landowner access to funding. Monitors effectiveness of watershed management practices. Showcases effective watershed management.
	Watershed Land Treatment Program (WLTP)		The WLTP is a multi-year project, providing financial assistance to land users in highly erosive land areas of selected watersheds, to install erosion control practices.
	Conservation Practices Program (CPP) *http://www.adamsswcd.org/Conservation%20Practices%20Cost.html*		Annual program provides financial assistance to land users to install erosion control practices.
	Non-Point Source Program Grants Section 319 (h) *http://www.epa.gov/OWOW/NPS/Section319/319over.html*		Activities that result in demonstrated progress in achieving Congress' goal of controlling and abating non-point source pollution.
	Conservation 2000 Program *http://www.dnr.state.il.us/orep/c2000/ecosystem*		A six-year multi-agency effort to protect and expand the states natural resources while expanding recreational opportunities and compatible economic development. Uses incentives to private landowners, easements and innovative partnerships.
Iowa	Iowa Watershed Protection Program (*http://*www.igwa.org)	Iowa Acts 1999, Chapter 204, Sec. 1 and Sec. 27	The Iowa Department of Agriculture and Land Stewardship (IDALS) has the responsibility for implementing this program. Program funding of $2.7 million was appropriated in 2001. The program advocates an integrated, multi-objective approach to watershed management that includes consideration of water quality, flood control, wildlife habitat, and other concerns related to watershed resources. The program includes three components, a watershed task force, an implementation grants program and a development grants program. The task force includes nearly 100 representatives from state, federal and local agencies, private industry, academic institutions, NGOs and private individuals. Most of the program funding is funneled through the soil and water conservation districts.
	Iowa DNR the Governor's Water Summit http://www.iowadnr.com/other/watersummit/03oct09.html		Iowa has demonstrated a very proactive approach to water quality improvement. The Governor listed water quality as one of his top priorities, and held an Iowa Water Summit at Ames (24 Nov 03) as an unprecedented commitment to address impaired waters. This summit was preceded by six Iowa DNR conducted regional meetings to seek input and ideas from the public.
Missouri	Missouri Water Pollution Control Program (*http://*www.dnr.state.mo.us/wpscd/wpcp.htm)		The Missouri Water Pollution Control Program is managed by the Missouri Department of Natural Resources (MDNR). Agriculture is the primary NPS in Missouri. The program includes a state NPS Management Plan (NPSMP), s NPS Management Prioritization, a NPS Assessment, Total Maximum Daily Loads (TMDL) Management Plans, funding, and milestones.

Table 3. Watershed Programs (Continued).

State Programs			Program Description
Missouri (Cont.)	Soil and Water Conservation Program (*http://*www.dnr.state.mo.us/wpscd/swcp.htm)		The SWCP is supported entirely by the state's parks and soils one-tenth of one percent sales tax. It provides the following services: a 75% state cost-share to landowners for putting soil conservation practices on their lands, a refund on interest for bank loans for erosion control practices and equipment such as no-till drills and planters, direct SWCD technical and financial assistance to landowners for NPS reduction within select watersheds, soil surveys, and assistance to Districts.
Minnesota	Minnesota Basins/Watersheds Program (*http://*www.pca.state.mn.us/water/basins/)		The watersheds program is the responsibility of the Minnesota Pollution Control Agency (MPCA). This program uses a GIS based approach to water quality protection and restoration. The approach focuses on the state's major river basins to identify water quality problems, work with communities to establish goals/priorities, and develop pollutant-reduction strategies. Separate plans are to be developed for each of the state's basins.
	Minnesota Governor's Clean Water Vision (http://www.governor.state.mn.us/Tpaw_View_Article.asp?artid=404)		During a Minnesota Environmental Initiative 2003 Policy Forum Series at St. Cloud, MN, the Governor of Minnesota voiced his commitment to protect the state's water quality while maintaining a balance between economic advancement and environmental protection. He indicated that he would focus in on the most attainable priorities, to recognize that watersheds differ in there problems and solutions, and that no one agency can do it alone. He appointed a member of his staff as chair of the state's Environmental Quality Board and to also head a new Clean Water Cabinet. The Clean Water Cabinet includes the state's PCA, DNR, Agriculture and Health Commissioners. He is also working on next generation of Minnesota CREP projects with a 2004 bonding proposal of $22 million to help fund such projects.
Wisconsin	Wisconsin Watershed Management Program (*http://*www.dnr.state.wi.us/)		The Wisconsin Department of Natural Resources (WDNR) has the responsibility for the states Watershed Management Program. The program manages activities that influence water quality by preventing and regulating water pollution from industries, municipal sewage treatment facilities, construction sites, farms, and urban areas. Program responsibilities include enforcing water related laws, encouraging wise use of water and land resources, setting protection and cleanup standards, monitoring and regulating resource use, and incorporating environmental, social and economic information into the decision process. This integrated management system is GIS driven.
SCF	Sand County Foundation *http://www.sandcounty.net/*		The Sand County Foundation's mission is "to advance the use of ethical and scientifically sound land management practices and partnerships for the benefit of people and the ecological landscape. The foundation is also a strong supporter of the practice of adaptive management. Its prime focus is with landowners, applying ethical principles, science and incentives. In Feb 2004, the foundation sponsored a North-South Basin Summit to address market incentives to reduce agricultural nitrogen discharge.
TWI	The Wetlands Initiative--Midwest Program *http://www.wetlands-initiative.org/*		The Wetlands Initiative (TWI) is a nonprofit corporation dedicated to restoring the wetland resources of the Midwest to reduce flood damages, improve water quality, and increase wildlife habitat and diversity. It seeks to restore wetlands such that it provides environmental and economic benefits to society and landowners. TWI has been involved with numerous projects along the Illinois River including: Spunky Bottoms, Mundinger Creek, Hennepin and Hopper Lakes, Midewin National Tallgrass Prairie, Coffee Creek and others.
TNC	The Nature Conservancy *http://nature.org/*		The Nature Conservancy's (TNC's) mission is to preserve plant, animal and natural communities representing the diversity of life on Earth by protecting the lands and waters they need to survive. TNC has developed a strategic, science-based planning process, called Conservation by Design. This process helps identify high priortity locations that if conserved promise to ensure biodiversity with long-lasting results. TNC has thousands of project sites world-wide. Land acquisition, conservation easements, land management, conservation trust funds, and partnerships (governmental, non-profit, corporate, etc.).

Table 4. Conservation Reserve Enhancement Program within UMRS States*
(As of March 2003)

State & Year Agreements Signed	Acres Approved & Contracted	Total Cost (Millions)	Incentive	Easements (Ac)/Term	Target Area	Environmental Objective and Conservation Practices
WI SCONSIN (2001)	100,000 [22,960]	$174 USDA $43 Non-Fed	USDA: *20% (75,000 ac) *70% (25,000 ac) State: •3x rental rate (75,000 ac) •6x rental rate (25,000 ac)	25,000/permanent	Upper Mississippi River Basin; Lake Michigan Basin; Grasslands	•Reduced sediment nutrient and pesticide runoff •Riparian buffers, filter strips, grassed waterway, wetland restoration, native grasses, and prairie restoration
MINNESOTA (2001)	100,000 [78,895]	$163 USDA $60 non-Fed	•20% all practices including shallow water areas and rare/declining habitat •Addendum added SIP/PIP	100,000 / >20 yr is permanent	Minnesota River	•Water quality, sediment and nutrient reduction and mitigation of flood damage •15,000 ac HEL (EI>12); 85,00 ac riparian
IOWA (2001)	9, 000 [78]	$31 USDA $7 non-Fed	•50% wetland restoration and buffers •PIP for wetland restoration	Permanent $750/acre 15 yr $350/acre	North Raccoon River Watershed (Primary water source for Des Moines)	•Reduce nitrogen loading through wetland development of drained lands. Reduce N loadings by 50% on 325,000 acres of drained lands.
MISSOURI (2000)	50,000 [11,969]	$66 USDA $17 non-Fed	•25% for filter strips, riparian. buffers, wetland restoration •15% all other practices •Addendum added SIP/PIP	N/A	Drinking water reservoirs in 36 counties	•Improve drinking water quality for 58 communities served by the reservoirs.
ILLINOIS (1998)	232,000 [109,557.1]	$262 USDA $ 60 non-Fed	•30% buffers, wetland restoration, wildlife food plots, and shallow water areas •20% all other •Addendum added SIP/PIP	100,000/15 yr or permanent	Middle Illinois River and six major tributaries watersheds.	•Reduction of sedimentation and soil erosion • 15,000 ac HEL (EI≥12); 85,000 ac riparian buffers, wetland restoration, emphasis on native species
UMRS TOTAL	491,000 [223,459]	$696 USDA $197 non-Fed				
NATIONAL TOTAL	1,393,310 [462,343]	$2,438 USDA $ 3,149 non-Fed	* Source: *http://www.fsa.usda.gov/dafp/cepd/summary.htm*			

Table 5. Estimated Future Without Project Condition for Annual Movement of Fertilizer.

Time Frame	Low Estimate	Central Estimate	High Estimate	Low Estimate	Central Estimate	High Estimate
	Total Estimated Annual UMRS Farm Products Movement (million metric tons)			Percent Change in Annual UMRS Farm Products Movement and Associated Fertilizer Usage		
2000	36.8	36.8	36.8	0	0	0
2025	26.3	52.9	60.4	-29	+44	+24
2050	12.5	64.3	71.7	-66	+75	+95

Source: USACE, 2004

Table 6. Description of Available Measures.

Measure		Key Source(s) of Measure	Measure Description
1	UMRS Watershed Nutrients Program Network	USGS, 2003; Demissie et al, 1999	This measure would further build upon the recent database work conducted by the UMESC under contract with the USEPA. This measure would provide additional funding via the USEPA to ensure the establishment, refinement and operation of a long-term framework for baseline data collection, monitoring and evaluation of UMRS nutrients reduction initiatives. The UMESC via contract funding from the USEPA would become a focal point for a UMRS regional network for a baseline/monitoring database, decision support system (DSS), and an integrated management plan (IMP). This network would function in collaboration with the USEPA and the five UMRS states. The DSS could be patterned after the Illinois DSS model (Demissie et al. 1999), the California WATER DSS (Viers et al. 2000), or similar internet-based prototype. The DSS would serve as a central repository for the regional accumulation and analysis of watershed related data. The tool would be used to evaluate the effectiveness of actions taken under a UMRS Integrated Management Plan (UMRS--IMP). Similar to the Illinois DSS, the tool would allow decision-makers to play "what-if" scenarios during the installation phase of the IMP. Scenarios assessed would include climate shifts and fluctuations, land use changes, and changes in regulation and water management practices. Each state would retain significant control over its jurisdictional portion of the DSS and IMP.
2	Funding Support for the continuation of the Mississippi River/Gulf of Mexico WNTF program	CENR, 2000; WNTF, 2001	This measure supports the future involvement of the WNTF in its efforts to implement the hypoxia Action Plan, including its Monitoring, Modeling and Research program.
3	Funding Support for Existing Point Source Pollution Control Programs	CENR, 2000; WNTF, 2001	This measure recommends continued funding support for federal and state programs involved in the upgrade of wastewater treatment facilities, and permit process improvements including: developing general permits for minor facilities, computerized permit tracking, enforcing fixed permit review/action deadlines, aggressive targets for permit compliance inspections and penalties for non-compliance.
4	Funding Support for Existing Non-Point Source Pollution Control Programs	CENR, 2000; WNTF, 2001; Mitsch, 2001; Mitsch & Day, 2001	This measure recommends continued funding support for the planning, implementation, monitoring and evaluation of existing watershed programs targeting NPS pollution. This includes funding to support state-level efforts involving sub-basin committee meetings, baseline and monitoring data collection, DSS and IMP process, grants program, and implementation of Best Management Practices (BMPs). The BMPs include such measures as fall no-till farming, grassed waterways, water detention basins, and modified cropping systems, fertilizer application controls, and drainage tile modifications.

Table 6. Description of Available Measures (Continued).

Measure		Key Source(s) of Measure	Measure Description
5	EMP Modification to Include Nutrients Farming Pilot Projects	TWI, 2002; Hey, 2002; Sather, 1992	The Wetlands Initiative (TWI) has proposed an alternative approach to nutrients reduction, one referred to as "nitrogen farming" (**Hey, 2002**). Nitrogen farms involves the inundation of lands with high levels of nutrient for a sufficient time interval to allow denitrification to occur. Such farms would be placed where enough water, hydric soils, and energy exists to manage inundation. Microorganisms at the wetlands site then consume the oxygen atoms from the nitrate molecules, thus releasing nitrogen gas into the air (denitrification). The long-term goal is to create nitrogen farms that function as an alternative crop for the local landowner. A farmer's "harvest" of nitrogen reduced would be recorded as credits. These credits would be sold to the highest bidder amongst various entities (farmers, industries, cities and towns) discharging excessive amounts of nitrogen. To offset environmental damages, producers of excess nitrogen would purchase credits from a nitrogen farmer in the affected watershed. This would establish a nitrogen trading market. Similar to corn production, the landowner would enter or exit nitrogen farming depending on the conditions of the market place (i.e. price of nitrogen credits and farm unit efficiency). Nitrogen farms would be less sensitive to flood damage impacts than the more typical bottomland agricultural land use areas. USEPA and state actions leading to the establishment of compliance standards (Total Maximum Daily Load, TMDL) and required remedial actions would activate this market driven process. TWI has suggested the establishment of three scales of pilot projects (small, moderate and large-scale projects) that would be useful in obtaining different kinds of scientific data. TWI has proposed the Spring Creek project near Macomb, Illinois as an example of a small-scale project. The project would consist of about 100 small wetlands (each 6 acres on average) in a heavily tiled watershed, on private land along highly eroded stream channels. These wetlands trap and remove nutrients and sediments from surface water drainage at an estimated cost of $1.3 million. The former Hennepin Drainage and Levee District (D&LD) (2,600 acres) is cited as an example of a moderate scale project. Formerly managed for agriculture, TWI is currently restoring the site to wetlands, prairie and a savanna, in addition to two lakes. The project will allow researchers to quantify the sources and sinks of water and nitrogen. Water can be drawn from the river at metered rates, allowing for the study of the denitrification process. TWI estimates the cost of the project to be $9 million. Located north of Quincy, Illinois, a large-scale project would be developed consisting of 13,000 leased acres. This experimental site would test the viability of a conservation organization renting land for wetlands restoration. Conceptually, it is believed that leasing the land would reduce the project's cost. If after 5-10 years, nitrogen farming proves to be ineffective--the area would be returned to agriculture. On the other hand, if the site proves to be cost-effective--the land would be acquired or the corporate owner would operate the site as a for-profit nitrogen farm. Some site modifications would be required to allow for the control of tributary and river flows into and out of the floodplain. TWI estimates the cost of the project to be $15 million. As a short-term goal this measure recommends the Corps and the NGOs work jointly to test the feasibility of the nutrients farming concept using the planning, design, construction and monitoring framework of the existing UMRS—EMP. The lands required for this experiment would be provided for by NGO, and cost-sharing credit would be given for those lands consistent with the EMP process.

Measure		Key Source(s) of Measure	Measure Description
6	EMP Inclusion of Denitrification Studies Using EPM	Baerl et al, 2003; James et al, 2003	Navigation pool drawdowns are a potentially cost-effective technique for managing and rehabilitating degraded aquatic habitats in the UMR. This drawdown concept is commonly referred to a s Environmental Pool Management or EPM. Desired outputs of drawdowns include bottom sediment consolidation, the germination of aquatic plants, reductions in sediment resuspension and improved light penetration, and changed sediment properties promoting vegetation growth upon reflooding. However, there is a need for information regarding the effects of sediment dewatering and reflooding on sediment nutrients dynamics for both modeling refinement and management of aquatic habitats. Under the purview of the EMP, two studies have been proposed to quantify the range of chemical and physical changes in sediment due to dewatering and rehydration techniques. The studies include Pools 5 and 8 (**James et al., 2003**) and Pool 25 (**Baerl et al, 2003**). Stabilized nutrient bearing soil particles and the use of excess nitrogen by plant growth could have a positive effect on the Gulf Coast hypoxia problem.

Table 7. Summary Evaluation of Nitrate-Nitrogen Reducing Measures.

Measure		Evaluation Criteria				Total Score	Ranking	Corps Implementable
		Completeness	Effectiveness	Efficiency	Acceptability			
1	UMRS Watershed Nutrients Program Network	1	3	3	2	9	2	N
2	Funding Support for the continuation of the Mississippi River/Gulf of Mexico WNTF	1	3	3	2	9	2	N
3	Funding Support for Point Source Pollution Control Programs	1	2	1	3	7	4	N
4	Funding Support for Non-Point Source Pollution Control Programs	3	2	2	1	8	3	N
5	EMP Modification to Include Nutrients Farming Pilot Projects	3	3	2	2	10	1	Y
6	EMP Inclusion of Denitrification Studies Using EPM	2	2	2	2	8	3	Y

EVALUATION CRITERIA RATINGS:

1 = Little or no contribution to evaluation attribute
2 = Moderate contribution to evaluation attribute
3 = High contribution to evaluation attribute

IMPLEMENTABILITY BY CORPS:

N = No
Y = Yes

Note: The UMRCP environmental team assigned the matrix ratings. Finalization of these values will be made after consideration of comments received from agency reviewers.

Table 8. Supporting Rationale for Table 7 Ratings.

Measure		Evaluation Criteria	Rating	Rationale for Table 7 Ratings
1	UMRS Watershed Nutrients Program Network	Completeness	1	A regional network alone does not totally address the nutrients issue. However, ensuring the consistency and comparability of the database between states, providing a more meaningful framework for making planning decisions, is a critical first step in that direction.
		Effectiveness	3	Consistent data collection is of fundamental importance to UMRS efforts to understand the status and trends in watershed nutrients. Using the Illinois DSS and IMP (or similar prototype), it should be feasible to develop an effective procedure for use at the UMRS regional level.
		Efficiency	3	The cost associated with developing a networking process would be minor compared to the potentially high dollar costs of making erroneous decisions based on inadequate data and evaluations.
		Acceptability	2	Each state has a preferred watershed planning process, but it is anticipated that all states would recognize the value of having a comparable process for making decisions at higher orders of analysis.
2	Funding Support for the continuation of the Mississippi River/Gulf of Mexico WNTF	Completeness	1	Further analysis of the Gulf hypoxia problem would help to remove scientific uncertainties. However, until properly funded, the WNTF program alone will not be able to better address the nutrients issue.
		Effectiveness	3	An enhanced understanding of the processes behind hypoxia will help us to better ascertain the need for long-term UMRS management measures directed at river nutrients reduction.
		Efficiency	3	The cost of verifying assumptions regarding the hypoxia process would be minor compared to the potential high dollar costs of making decisions based on inadequate scientific information.
		Acceptability	2	State and federal agencies would likely support efforts to develop a more scientifically sound base upon which to make future regulatory decisions. Any increased regulatory role of the government would not likely be strongly supported by the agricultural community.
3	Funding Support for Point Source Pollution Control Programs	Completeness	1	Wastewater is the major point source for nitrogen in urban areas, but it is a small percentage of the total nitrogen load.
		Effectiveness	2	Tertiary treatment using engineered wastewater treatment plants are an effective means of reducing nitrogen levels. Created or natural marshes have been used successfully as nitrogen sinks for wastewater management in urban areas.
		Efficiency	1	Engineered wastewater treatment plants are expensive, and labor intensive. Urban wetlands are lower in cost than engineered wetlands, but would be more costly than wetlands created as rurally- based nitrogen farms.
		Acceptability	3	Wastewater treatment plants are generally acceptable to agencies and the public.
4	Funding Support for Non-Point Source Pollution Control Programs	Completeness	3	Farm runoff (especially fertilizer) is believed by many to be a major contributor to nitrate-nitrogen loading. This measure makes a direct attempt to address that factor.
		Effectiveness	2	A variety of NPS BMPs can be applied with a moderate degree of effectiveness. For example, limited control of nitrogen loss can be achieved by changes in cropping system. Row crops such as corn and soybeans show higher subsurface drainage concentrations for nitrate-nitrogen than does cover crops like alfalfa or grass. As another example, applying fertilizer in the spring rather than the fall of the year would be beneficial, since fertilizer retention and plant production decreases with a fall application of fertilizer. As a final example, the amount of fertilizer needed in excess of that required for maximum crop production could be effectively cut back.
		Efficiency	2	The cost-efficiencies of this measure is mixed. For example, while less fertilizer is needed if it is applied during the spring, the price of fertilizer is generally less in the fall. As another example, while reducing excess fertilizer use is a net cost savings, a miscalculation on the fertilizer needed could have substantial impacts to individual farmers.
		Acceptability	1	Unless there is a clear cost savings, most farmers are liable to resist NPS controls. For example, some farmers may prefer to apply nitrogen in the fall since they have more time, field conditions are better, and the price of fertilizer is less.

Table 8. Continued.

Measure		Evaluation Criteria	Rating	Rationale for Table 5 Ratings
5	EMP Modification to Include Nutrients Farming Pilot Projects	Completeness	3	During the last 200 years, the river system has lost millions of acres of wetlands, along with its ability to provide a natural buffer between the river and uplands runoff. This measure directly addresses the need to restore lost wetlands function. It also address other problems, including erosion, flood control, habitat degradation, and a lack of quality open space. If stringent standards are set by the states for nitrogen reduction in response to USEPA established criteria, then the role of this UMRS measure would increase in significance.
		Effectiveness	3	Because of the high level of denitrification that occurs in hydric soils, wetlands and riparian buffers are effective nitrogen sinks. Since drainage tiles are a source of high concentrations of nitrates, the interception of such drainage with wetlands or riparian buffers can be an effective way of controlling NPS pollution. Plants in these areas either absorb the nitrate for plant growth, or provide a carbon source for the denitrification of bacteria. TWI indicates the Illinois River watershed would be particularly well suited for nitrogen farming (Table 2; Hey, 2002). While representing a small percentage of the Mississippi River basin watershed and its discharge, it makes a major contribution to Mississippi River nitrogen loading. TWI notes that a reduction of the Illinois River's contribution by 100,000 tons per year would reduce its nutrient discharge to levels occurring in the early 1900s, and that approximately 400,000 acres of wetlands restoration would be needed to accomplish such an objective.
		Efficiency	2	TWI indicates that nitrogen farms would be more economical than conventional treatment methods. TWI estimates that the cost of conventional methods for reducing nitrogen (tanks-pumps-energy) would be twice as high compared using wetlands treatment. TWI suggests the establishment of pilot projects (especially in the Illinois River watershed) to further assess the costs and efficiency of nitrogen farming.
		Acceptability	2	The farming community may be resistant to any added regulatory controls relating to nutrients runoff. However, farmers directly involved in nutrient farming are likely to find the concept acceptable, provided they are able to generate a profit.
6	EMP Inclusion of Denitrification Studies Using EPM	Completeness	2	The measure affects primarily the unprotected floodplain. Unprotected floodplain provides no additional flood storage beyond that which already exists. From a resources perspective, the measure does simultaneously addresses nutrients reduction and habitat needs.
		Effectiveness	2	EMP studies have been proposed to quantify the potential effectiveness of EPM. Considering the large acreage of main channel border habitat available for drawdown, consolidation, and plant production, it seems likely that there is a moderate potential for nutrients removal.
		Efficiency	2	Nutrients management would be a secondary purpose of EPM—the primary purpose would be aquatic habitat management. Accordingly, the costs associated with nutrients management per se would be low.
		Acceptability	2	Recreational boaters may find drawdowns unacceptable. Conservation agencies would likely support the concept.

Note: The UMRCP environmental team assigned the matrix ratings. Finalization of these values will be made a after consideration of comments received from agency reviewers.

Table 9. Summary of Economic Costs of N-Loss Reduction Actions.

Approach	Increment	N-Loss Reduction (Thousands of metric tons/yr)	Net Cost within Agricultural Sector ($/kg N loss)	Net Cost, incl. Environmental Benefits ($/kg N loss)
Edge-of-Field N-Loss Reductions	20%	941	0.88	0.80
	40%	1,882	3.37	3.25
	60%	2,822	7.48	7.37
Fertilizer Reductions	20%	503	0.69	0.67
	45%	1,027	2.85	2.81
Fertilizer Tax (500%)		1,027	14.54	14.50
Wetlands	1 M	67	6.06	-2.19
	5 M	350	8.90	1.00
Riparian buffers	27 M	692	26.03	
Tertiary Treatment of Waste Water		20	40	

Source: CENR, 2000.

Table 10. Nutrients Farming Considerations—Summary of TWI Workshop

sue Topic		Discussion Points
Science and Policy Issues.		It has been suggested that the costs of removing nitrogen from the system using wetlands as compared to conventional methods would be much lower. For example, the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) estimates that its capital costs for denitrification to meet EPA's criterion would be $500 million with annual operating costs of $500 million per year. At this expenditure level, it has been estimated that using 400,000 acres of wetlands at a rental fee of $125/acre/year), one could theoretically reduce the nitrate-nitrogen load on the entire Illinois River. The critical issues affecting wetland performance were identified as location, seasonality, wetland characteristics, and connectivity.
Regulatory Issues.		Federal and state regulations that establish water quality criteria and remediation requirements would tend to generate a market for nitrogen farming. However, for nitrogen farms to be viable, regulations would need to be flexible enough to allow nitrogen-laden waters to travel from their sources to the nitrogen farms. Varying water quality standards along the drainage way may be appropriate. Standards would also need to take into account the designated use of a reach, including its socio-economic and political factors. Regulators would also need to devise a system for monitoring outputs from nitrogen farms, and a system for crediting a farmer for reduced nitrogen outputs to the waterway. The wetlands jurisdiction process (under the Clean Water Act) will need to be flexible enough to allow nitrogen farmers to move into and out of "farming" nitrogen. Without such reversibility, farmers might be unwilling to place their land into wetlands.
Economic Issues	Permits versus Incentives.	Two alternative economic approaches to nitrogen farming have been suggested: (1) the creation of marketable permits using a cap and trade system, and (2) a government incentives system. A market-based system requires consequences to yield incentives for nitrate-nitrogen removal. The necessary institutional structure would require several components: (1) a regulatory "cap" or TMDL on the allowable level of nitrogen release; (2) a market structure of debits and credits for nitrate-nitrogen release and removal; and (3) a state agency to monitor nitrate nitrogen removal and to certify the trading system. *(a). Marketable Permits.* Assuming most of the nitrogen from the Mississippi River basin comes from agriculture, under this approach, the agricultural industry would be a large potential market for purchasing nitrate-nitrogen removal credits. Credits could be self-recorded with the state agency making spot checks for verification and to set baseline parameters. Pilot projects would be used to more clearly demonstrate the actual costs associated with nitrate-nitrogen removal. *(b). Government Incentives.* Under this approach, Federal programs would be broadened to identify wetland nitrogen farming as a recognized conservation practice. Currently, there are several programs funded by federal and state governments to pay landowners to convert cropland into wetlands. These include the USDA Wetland Reserve Program (WRP) and the Conservation Reserve Enhancement Program (CREP), the buffer programs of the US Natural Resources Conservation Service (NRCS), and the USEPA Section 319 grants for Non-Point NPS control. The landowner would receive money according to an agreed upon price per ton of nitrate-nitrogen removed. Measurements of flow and nitrogen concentrations, certified by a laboratory and reviewed by the state, could be the basis for determining the load reduction. Pilot projects could be funded to test the effectiveness of the practice, and to establish design, construction, and management guidelines.
	Economics Analysis.	Two different approaches to an economics analysis of nutrients reduction have been identified. *(a). Traditional Benefit-Cost Ratio (BCR) Analysis.* A traditional BCR analysis of nutrients farming is made difficult by the fact both the costs and benefits contain elements not normally valued in the market, e.g. clean water and wildlife habitat. Economists with the Gulf hypoxia task force preferred to look at a "cost-effectiveness" approach to accomplish a public goal (e.g. cleaner drinking water). *(b). Supply Curve Analysis.* The economics supply curve, which arrays potential areas from lowest to highest incremental cost per ton of nitrogen reduction, could also be used to determine priority sites. Such supply curves would need to be generated for all regions of the upper Mississippi River Basin. However, the supply curve approach does not consider other social and environmental values provided by wetlands. A multiple attribute decision-making (MADM) tool as a way to evaluate and rank alternatives for reducing nitrogen. Potential wetland alternatives attributes include: minimizing cost/ton of nitrogen reduction, improving aesthetics, reducing flood damages, enhancing fish and wildlife habitat, and increasing recreational opportunities.

Table 10. Continued

		Pilot projects could answer a number of important nutrients reduction questions, including: capital costs, operating costs, opportunity costs, economies of scale, nitrogen farming income, related activities income (e.g. flood control, sediment control, hunting/fishing), market area, market size, monitoring costs, certifying costs, and regional economic effects). Capital costs and operating costs would vary with location. For example, a site requiring a pump rather than gravity flow will be more costly to implement and operate. The lost income from other activities not pursued because of nitrogen farming would need to be assessed. Providing an allowance discharge market for other water quality factors could be considered; this could include such things as the removal rates for sediments, phosphorus, and other agricultural chemicals. Hunting and fishing income, established from such activities at nearby operating sites, could be offered for sale. The potential for linking nitrogen farming to mitigation required through Farm Bill Swampbuster and/or Section 404/401 needs has been suggested. The proximity of a site to high concentrations of nitrate-nitrogen may turn out to be more important than the scale of the site. The effects of nitrogen farming on the regional economy would need to be assessed through demonstration projects. In general, nutrients farming may have a lesser influence on the regional economy than does traditional farming. Fewer chemicals, little weed control, some labor, but little equipment and fuel would be needed with nitrogen farming.
Agricultural Issues		Agricultural issues that have been raised include (1) nitrogen farming would encourage the continued use of high levels of nitrogen over the landscape, and (2) international demand is increasingly being met by global competitors, thus reducing the acreage demand for U.S. corn and soybeans.
Acceptability Issues		The participants at the workshop identified several factors that would make nitrogen farming unattractive to traditional row crop farmers: (1) if the market for nitrogen credits included themselves as potential customers—they expect point source polluters to pay for any nutrient controls, (2) if farmers perceive nitrogen farming as a program that penalized farmers who already have placed acreage in wetlands (e.g. the Wetlands Reserve Program or WRP), and (3) if a permitting system was imposed that monitored how much and when farmers could discharge nitrogen from their fields.

Source: TWI, 2002

Table 11. Wetlands Nutrients Reduction Opportunities Afforded by UMRCP FDR Plans *

FDR Plan	Option	Floodplain Nutrients Farming Potential by River Reach (Acres)				
		1	2	3	4	Total
No Action		0	0	0	0	0
B	2	0	0	16,221	150	16,372
	3	0	1,903	16,888	47,710	66,501
	4	0	0	0	0	0
D	2	0	5,849	26,242	18,067	50,158
	3	0	0	11,824	35,911	49,644
	4	0	0	0	0	0
E	2	0	1,395	11,824	11,695	24,915
	3	0	0	15,969	34,909	50,612
	4	0	801	0	405	1,207
H	2	N/A	N/A	N/A	N/A	N/A
	3	0	552	16,888	47,710	66,501
	4	N/A	N/A	N/A	N/A	N/A
I	2	N/A	N/A	N/A	N/A	N/A
	3	0	552	2,280	889	3,721
	4	N/A	N/A	N/A	N/A	N/A
J	2	N/A	N/A	N/A	N/A	N/A
	3	0	43,092	194,245	69,681	307,018
	4	N/A	N/A	N/A	N/A	N/A

The Wetlands Initiative estimated that 38% of lands that it sampled from the 100-year flood zone represent existing or drained wetlands. The above analysis has applied that percentage to the acres of ER managed lands opportunities to approximate the potential acres of wetlands restoration opportunities on the UMRCP floodplain.

Table 12. Summary of USGS Monitoring Programs on Upper Mississippi River and Tributaries*.

Program	Years of Operation in UMR	Number of Sample Sites/Study Areas	Frequency of Sampling (times/year)	Physical Features Measured	Chemical Analysis	Biological and Ecological Measurements
NSN/NSIP	Some 1890s, many 1930s (ongoing)	190	Continuous	Streamflow	None	None
NASQAN	1973-95	50	1-12	Streamflow, field parameters, suspended sediment	Major ions, nutrients, carbon, dissolved and trace elements	Fecal coliform, streptococci, chlorophyll a and b
	1996-present	3	9-15	Streamflow, field parameters, suspended sediment	Carbon, major ions, nutrients, pesticides, suspended and dissolved trace elements, nitrogen and oxygen isotopes	Chlorophyll a
NAWQA Cycle I intensive study	1996-2000	38 sites in 4 study areas	15-25	Streamflow, field parameters, suspended sediment	Major ions, nutrients, pesticides, volatile organic compounds, trace elements in sediment	Community taxa for fish, invertebrates, and algae
NAWQA Long-term trends	2001-present	13 sites in 4 study areas	6-12	Streamflow, field parameters, suspended sediment	Nutrients, chloride, sulfate, and pesticides	Community taxa for fish, invertebrates, and algae
LTRMP	1988-present	120 fixed sites river-wide	13-52	Field parameters, velocity, water, ice and Secchi depth, wave depth	Nutrients and selected major ions	Chlorophyll a, vegetation cover estimates, phytoplankton
	1993-present	840 random sites within 6 study reaches	4	Field parameters, velocity, water, ice and Secchi depth, wave depth	Nutrients and selected major ions	Chlorophyll a, vegetation cover estimates, phytoplankton. Fish, vegetation, invertebrates, and land cover collected for each reach

NSN/NSIP = National Seismic Network/National Streamflow Information Program
NASQAN = National Stream Quality Accounting Network
NAWQA = National Water-Quality Assessment Program
LTRMP = Long Term Resource Monitoring Program

** Table Source: USGS (2003), Table 1*

Table 13. WNTF Monitoring Parameters with Potential Application to UMRS

CATEGORY	INDICATORS	
Environmental	1	Dissolved oxygen concentrations to reflect spatial and temporal patterns
	2	Nutrient concentrations taken seasonally and annually to reflect loadings at different watershed scales
	3	Benthos community measurements to assess diversity and abundance
Economic	4	Population
	5	Gross Domestic Product
	6	Industrial Output
	7	Net Farm Income
	8	Land Area in Crop Production
	9	Agricultural Output
	10	Fisheries
Programmatic *	11	Extent of vegetative corridors
	12	Producers/acres enrolled in CRP/WRP
	13	Acres in conservation tillage
	14	Producers/acres implementing nutrient management plans
	15	Number states with fully approved nonpoint pollution control programs
	16	Percent population served by secondary treatment
	17	Percent population served by Advanced Waste Treatment/Biological Nutrient Removal
	18	Reduction in nitrogen & phosphorus for municipalities
	19	Number of municipal stormwater programs approved
	20	Estimated/monitored reductions in nitrogen & phosphorus for industrial point sources
	21	Number of 303(d) water segments listed because of nutrient impairment
	22	Number & Percent of wetland acres restored/enhanced/created
	23	Completion of TMDLs for nutrient-impaired waters
	24	Number states/tribes within the Basin achieving Enhanced Benefits status under 319 program
	25	Number projects & dollars directed through EQIP/CRP/WRP & Sec 319 in accordance with sub-basin strategies

* Indicators tracked at various scales

Source: WNTF, 2003

TABLE 14. MIDWEST STAKEHOLDER COMMENTS ON GULF HYPOXIA ASSESSMENT *

UMRS Stakeholder	Comments
UMRBA	• Limitations in available data and models • Scientific judgments and planning evaluations should include uncertainty assessments. • There is a need for more public involvement • Need for flexibility in pursuing locally appropriate measures
Illinois Fertilizer and Chemical Association (IFCA)	• Hypoxia issue is more rooted in politics than science • Overemphasis on a single hypothesis • Certain items of factual information ignored
Iowa Farm Bureau Federation (IFBF)	• Local level is proper place to discuss nutrient strategies/policies • Need credible, scientific, conceptual framework • Fertilizer restrictions not justified • Support voluntary education and demonstration of BMPs
Missouri Corn Growers Association (MCGA)	• Negative fisheries effects not demonstrated • Quantitative estimates of nitrogen reduction ;needed are unsupported • Economic modeling methods need to be used • Nitrogen reduction methods don't exist at this time • Researchers are biased against agricultural interests
Mississippi River Basin Governors	• Support actions to reduce hypoxia • Extensive federally funded/coordinated program is needed • Support voluntary approaches to address agricultural sources of the problem (e.g CRP, EQIP) • Additional funding for wastewater treatment facilities • Support Corps & other federal agency environmental programs • Support research/monitoring in the problem and continuation of WNTF
Illinois DOA/EPA/DNR	• Concern over amount of prime farmland converted to wetlands • Concern over flooding of farm districts • Concern over sustainability of agriculture • Economic hardship to upgrade sewage treatment plants • Absence of measurable effects on Gulf fisheries • Inadequate assessment of socio-economic impacts on Midwest • More time needed to evaluate hypoxia causes prior to adopting regulatory requirements
Mississippi Riverwise Partnership (MRP)	• Excess nitrogen delivered by Mississippi River is prime cause of hypoxia • Support reducing agricultural nitrogen pollution • Support filling scientific data gaps • Support accountability for nitrogen pollution • Support monitoring agencies and policies. • Supports WNTF Action Plan and its recommended voluntary and regulatory programs • Recommend compliance with all legal obligations • Support TMDL program and its basis for a nutrients trading program • Trading program should include mechanisms for public involvement, timely implementation, fraud detection, prevention of double-counting credits, and ensure no adverse localized impacts

** Note: Many of these issues were subsequently resolved in the consensus agreement between the states and federal agencies in the Gulf Hypoxia Action Plan. However, these comments do help to highlight the sensitivity of UMRS stakeholders to various kinds of nutrients related issues.*

Table 15. Collaboration Team Members

AHR	Owen Dutt
ALC	Jennifer Frazier
FEMA, Region VII	Tonya Leibold
FEMA, Region V	Vincent Parisi
IA DNR	Bill Cappuccio
IA DNR	Chuck Corell
IA DNR	Jack Riessen
IL DNR	Gary Clark
IL DNR	Marty Stralow
MA	Bob Goodwin
MN DNR	Ogbazghi Sium
MN DNR	Tim Schlagenhaft
MO DNR	Charlie DuCharme
MO SEMA	George Riedel
MRBA	Angela Anderson
UMIMRA	Dave McMurray
UMIMRA	Heather Hampton-Knodle
UMIMRA	Mike Klingner
UMRBA	Holly Stoerker
USEPA, Region V	Bill Franz
USEPA, Region VII	Larry Shepard
USFWS	Dave Ellis
USFWS	Don Hultman
USFWS	Karen Westphall
USFWS, ES Office	Bob Clevenstine
WES	Jean O'Neil
WES	John Barko
WI DNR	Bob Watson
WI DNR	Dan Baumann

Figure 1. Hydrologic Regions of Mississippi River Basin

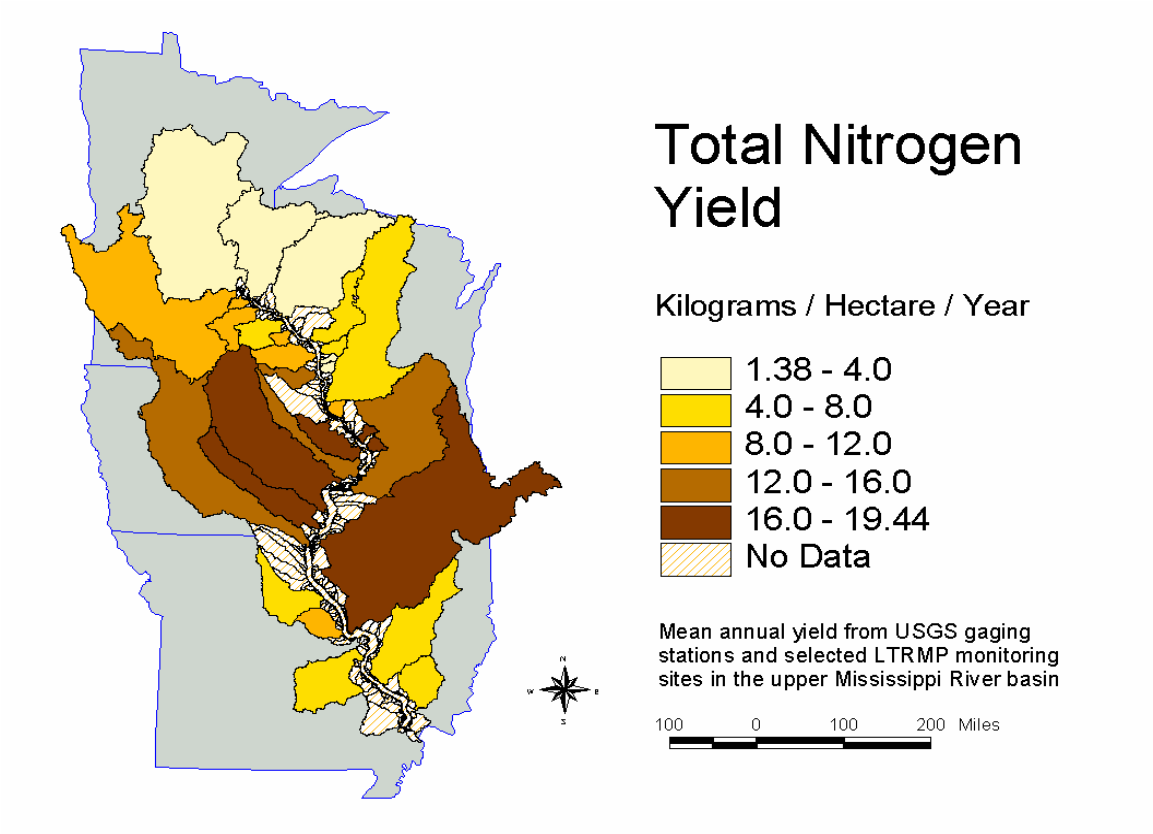
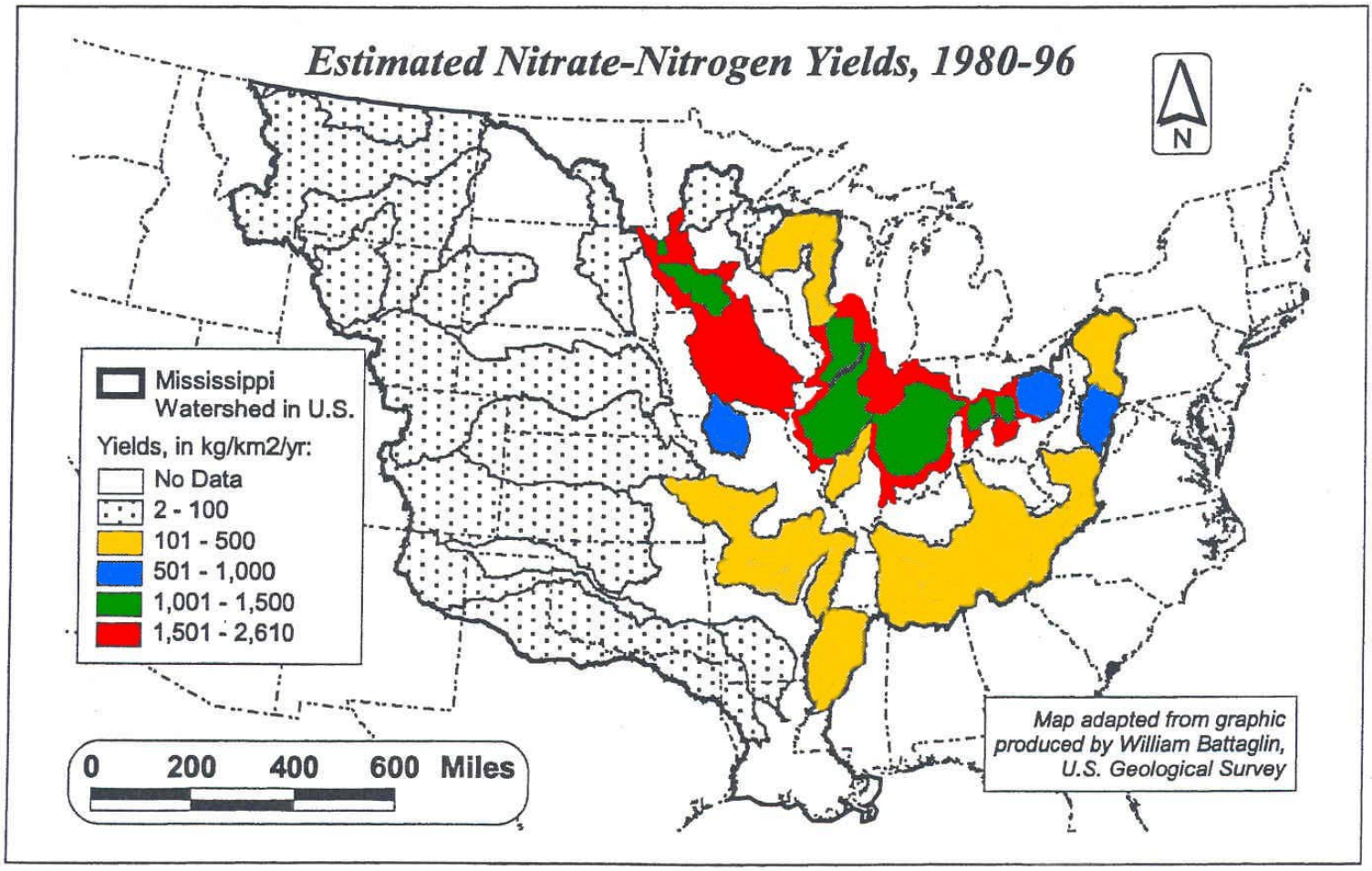


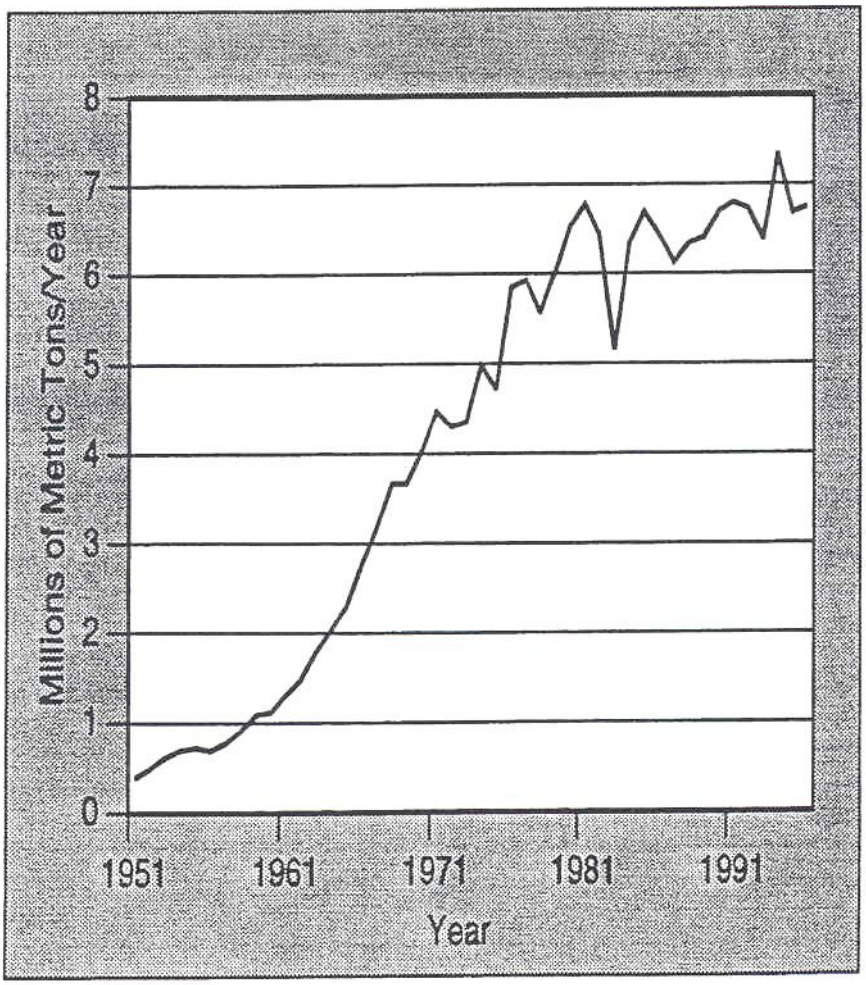
Figure 4. Total Nitrogen Yield Rates for Upper Mississippi River Basin

Figure 2. Estimated Nitrate-Nitrogen Yields (1980-1996)
For Entire Mississippi River Basin



Estimated nitrate-nitrogen yields in the Mississippi River basin, 1980-96.

Figure 3. Annual Nitrogen Input from Fertilizer, Mississippi-Atchafalaya River Basin



Annual nitrogen input from fertilizer, Mississippi-Atchafalaya River Basin. (Source: Goolsby et a., 1999)