*In* **Water quality assessments in the Mississippi Delta: Regional solutions, national scope. M.T. Nett, M.A. Locke, and D.A. Pennington, eds., ACS Symposium Ser. 877, pp. 1-15.**

# Mississippi Delta Management Systems Evaluation Area – Overview of Water Quality Issues on a Watershed Scale

**Martin A. Locke**

**USDA-ARS, NSL, Water Quality & Ecological Processes Research Unit, P.O. Box 1157, Oxford, MS 38655, 662-232-2908, mlocke@ars.usda.gov.**

The Mississippi Delta Management Systems Evaluation Area (MDMSEA) Project was initiated as a regional effort to evaluate best management practices that might minimize non-point source pollution of water in the lower Mississippi Delta. The context of Mid-South agriculture was a unique setting to expand on environmental issues previously addressed by the Midwestern MSEA projects. The MDMSEA project is comprised of a consortium of nearly twenty private, state and federal organizations. Evaluating the combined effects of management practices on lake water quality was the primary focus of the first five years. Three oxbow lakes and their respective surrounding watersheds provided systems that were compact and manageable, and essentially hydrologically isolated with regard to extraneous surface water. Thighman Lake watershed was originally protocolled as a control watershed with conventional farm practices; at Beasley Lake watershed, edge-of-field practices (e.g., vegetative strips, slotted board risers) were implemented with conventional practices; and Deep Hollow Lake watershed was established with a combination of agronomic conservation practices such as winter cover crops and conservation tillage, as well as edge-of-field structural mitigations. Sediment, nutrients and pesticides were identified as the primary lake pollutants of concern, and lakes were monitored for changes in water quality, microbial communities, and fish populations. Other aspects under investigation included: runoff from fields, soil resource management, ground water quality, insect and weed control, agricultural production, and socioeconomics. Results from the first five years of research have demonstrated the capability of these management practices to reduce the transport of nonpoint source pollutants to the oxbow lakes monitored.

Centuries of meandering by the Mississippi River carved out the region of the United States known today as the Mississippi Delta, an area that includes sections of present day states of Mississippi, Louisiana, Arkansas, Missouri, and Tennessee (Figure 1). Untold quantities of sediment eroded from the center of what would later be named the North American Continent and were redeposited during annual spring floods. Sediment loss from the more northern uplands was gain for the Mississippi Delta as rich alluvial soils formed underneath vast areas of cypress swamps and white pine forests. Native Americans established small settlements that developed into the Mound Culture along the many tributaries, streams, and rivers throughout the region. They were the ones who gave the rivers along the Mississippi Basin names such as “Mississippi” or “Great Water” and “Yazoo” that we still use and recognize today. The first European explorers such as DeSoto arrived in the Mississippi Delta region in the 1500s, and it was not long before others followed and began to settle the land. The great cypress and bottomland hardwood forests were cleared, giving way to livestock and row crops. An intricate system of levees and ditches was built during the first part of the 20th Century, diverting excess water from farms and residential areas to natural streams and bayous.

With the discovery that climate and growth conditions were favorable, cotton was introduced as a key economic crop in the Delta. Great demand for cloth fabric by the textile mills of Europe and the Eastern United States fueled the economy of the Mississippi Delta Region for decades, and “King Cotton” flourished. During the 100 years that followed the U.S. Civil War, farm practices gradually changed from labor intensive, largely African American, to highly mechanized operations. Mechanization enabled farmers to work more land area in a given day. Tilling the earth with heavy equipment, however, took its toll, leaving the soil more vulnerable to the erosive forces of nature which sometimes resulted in annual sediment losses of up to 16 tons $ha^{-1}$ (*1*, *2*).

As in the Mississippi Delta, other regions of the United States have experienced large quantities of soil loss as sediment runoff. The US Environmental Protection Agency (USEPA) reported in 1986 that nonpoint pollution was the major cause of the Nation’s water quality problems, and that agriculture was a major nonpoint source, primarily pinpointing sediment, nutrient, and pesticide losses resulting from soil erosion (*3*). Efforts on a national scale have been made to address issues of nonpoint pollution from agriculture, but often, progress has been impeded by agricultural and environmental policies that moved in opposite directions (*4*).

## Management Systems Evaluation Areas – A National Initiative

### Establishment of MDMSEA

The need to improve and conserve America's water resources was recognized at the highest level with the Presidential Initiative on Water Quality in 1989. The Presidential Initiative established the objectives of (i) protecting ground water resources from contamination; (ii) developing water quality programs to address contamination; and (iii) providing the basis to alter practices contributing to contamination (*5*). One underlying premise of this initiative was the notion of "volunteerism": that it was the ultimate responsibility of America's farmers to change practices to avoid contaminating water resources. The US Department of Agriculture (USDA) responded to the Presidential Initiative by establishing a Water Quality Program. A national research and assessment effort called the Management Systems Evaluation Areas (MSEA) emerged from the USDA Water Quality Program (*6*). The National MSEA project was to be a multi-agency effort involving the USDA Agricultural Research Service (USDA-ARS) and the USDA Cooperative State Research, Education, and Extension Service (USDA-CSREES) in cooperation with state agricultural experiment stations; the USDA Natural Resources Conservation Service (USDA-NRCS); the USDA Economic Research Service (USDA-ERS), the US Geological Survey (USGS), and the USEPA. For a more comprehensive review of the history and establishment of the National MSEA program, other sources are available (e.g., *7*, Romkens chapter, this volume).

The original objectives of the MSEA Program were to evaluate the effects of agrichemicals on ground water in the Midwest in various "at-risk" geographic areas and to develop protocols of best management practices (BMPs) to safeguard ground water resources, while satisfying the economic, environmental, and social needs of the region. Initial research efforts focused on five states: Iowa, Minnesota, Missouri, Nebraska, and Ohio (the Midwest Initiative), beginning in 1990 (*8*). After the Midwest Initiative was well underway, additional regions were explored to expand the national MSEA

Program.  One of the areas considered for expansion of MSEA was the Mississippi Delta Region.

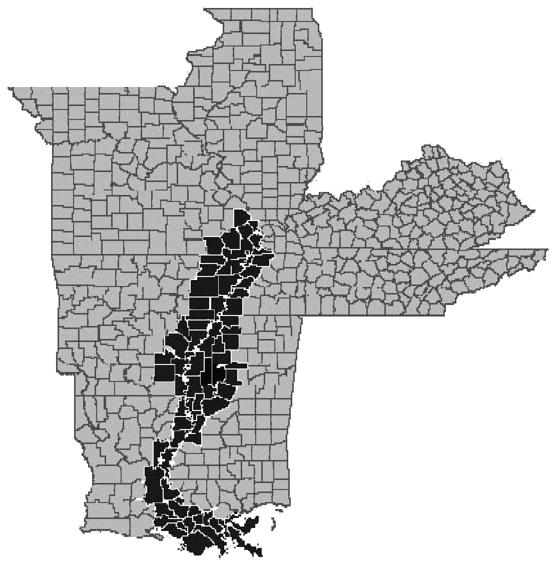

*Figure 1. Map of the Mississippi Delta Region.*

Several key factors came together in the decision to expand the National MSEA to include the Mississippi Delta Region.  The Mississippi Delta is a distinct region that comprises the southern portion of the Mississippi River Alluvial Plain, approximately 11 million hectares (Figure 1).  The region extends over 1100 kilometers from southeastern Missouri to the Gulf of Mexico and widens to over 160 kilometers in some places.  The Mississippi Delta is an intensively agricultural, rural region.  Row crops, rice fields, and catfish farms stretch for miles across the fertile alluvial plain, yielding bountiful agricultural produce.  During the last two decades, however, several issues related to agricultural management have raised some environmental concerns.

The humid subtropical climate (average annual rainfall 114 to 152 cm, average temperature 18$^{o}$C) typically produces periods of heavy rainfall, especially in the spring and fall months.  Although the topography averages less than 1% slope, significant quantities of sediment are removed during intense rain events.

Traditional row crop management in the Mississippi Delta involves multiple cultivations during a growing season. Tillage prior to heavy precipitation results in high sediment loss, and findings from earlier research efforts underscored the need to address this issue in the central Delta region. Insect and weed pressures in the humid climate of the south central United States necessitate the use of agrichemicals for effective control. Intense row cropping requires the use of fertilizer, especially nitrogen in non-legume crops such as corn and cotton. Both fertilizers and pesticides are considered as potential contaminants of Mississippi Delta surface and ground water resources (*9*; *10*). Irrigation is a major use of water in the Mississippi Delta, totalling 184,500 ha m per year. The quality and quantity of water used for irrigation is a major factor in assessing the environmental issues in this region.

The Mississippi Delta possessed other distinctions that strengthened its position as a candidate for inclusion within the national MSEA Program. Most of the research in the Midwest Initiative involved cropping systems of corn and soybeans. Corn and soybeans were grown in the Mississippi Delta, but cotton, rice, and catfish were also important components of the agricultural landscape. Agricultural systems that included these latter commodities were not part of the environmental assessments in the Midwest. Additionally, region-specific Delta characteristics, such as being “downriver” on the Mississippi implied that all of the sediment and other pollutants from the Midwest flowed through this region en route to the Gulf of Mexico. Adding the lower portion of the Mississippi alluvial basin to the national MSEA program would complement the Midwest Initiative research in the upper Mississippi basin.

At the same time that national attention was focusing on the need to evaluate nonpoint source pollution in the Mid-South region, the Beaver Creek Watershed Project, a USGS regional effort in water quality assessment in West Tennessee, was nearing completion. In 1993, USGS representatives met with members of several other Delta-based state and federal agencies to evaluate the feasibility of a new environmental project in the Mississippi Delta region to be modeled after the Beaver Creek Watershed Project. It was suggested that USGS coordinate efforts in this regard with other groups, particularly USDA-ARS and Mississippi State University (MSU). Late in 1993, representatives from USGS, USDA-ARS, and MSU determined that the national MSEA was the best vehicle for this regional project, thus the Mississippi Delta MSEA (MDMSEA) was born.

# Mississippi Delta MSEA Project: Purpose and Organization

## Scope and Purpose

The MDMSEA program was established as a watershed-based project to assess the effects of best management agronomic or conservation practices on water and soil quality within the Mississippi Delta. Specific objectives were to:

1. Increase the knowledge base needed to design and evaluate BMPs that address specific Delta water quality issues
2. Assess how agricultural activities affect surface and ground water quality
3. Quantify and evaluate improvements in soil and water resources resulting from use of combinations of BMPs

## Organization

The MDMSEA project is comprised of a consortium of public and private agencies and institutions, with the USDA-ARS, MSU, and USGS taking the lead in funding and scientific staffing for the research efforts. Other state and Federal organizations include the Mississippi Department of Environmental Quality, the USDA-NRCS, the Mississippi Soil and Water Conservation Commission, and the USDA-Farm Service Agency. Participants from the private sector include the Delta Council, the Mississippi Farm Bureau, the Yazoo Mississippi Delta Joint Water Management District (YMD), the Delta Wildlife Foundation, and the Pyrethroid Working Group, a crop protection industry task force.

Early in 1994, the MDMSEA Technical Steering Committee was formed with representatives from USGS, USDA-ARS, and MSU serving as co-chairs. A draft copy of MDMSEA project framework was developed and presented to scientists from the various agencies. Proposals were solicited from the USDA-ARS, USGS, and MSU scientists on potential research projects, and these were used as the basis for finalizing the project framework. A site selection committee was formed to identify and select oxbow lake sites, and the USDA-NRCS was enlisted to advise on lake selection and to serve as a liaison with farmers. An Advisory Committee was established in May, 1994, consisting of farmers and interest groups. Three oxbow lake sites were selected in August, 1994, in Mississippi's LeFlore and Sunflower counties (Figure 2). The following month, a BMP Selection Committee began to evaluate which BMPs to focus on in the project. Core funding was secured for USDA-ARS

($450,000) and USGS ($400,000, half of which was matched funds through the Mississippi DEQ). Funds and support also came from the Delta Wildlife Foundation, the Department of Interior, the U.S. Fish and Wildlife Service, the Mississippi Department of Wildlife Fisheries and Parks, and a Section 319 (1987 Water Quality Act) grant through the Mississippi Soil Water Conservation Commission Model Farm Program.

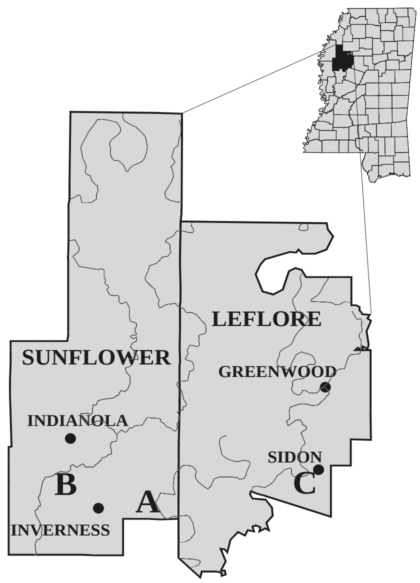


*Figure 2. Map showing the locations of MDMSEA watershed sites in Sunflower and LeFlore Counties. The watershed locations are designated as (A) Thighman;(B) Beasley; and (C) Deep Hollow.*

**Basic Premise for Study**

A watershed-based, systems approach was used to assess the effects of best management practices on water and soil quality in three oxbow lake watersheds in the Mississippi Delta. This approach allowed researchers to evaluate a number of factors within the context of a single system and an overall objective. It also allowed the use of a variety of scientific disciplines, each addressing various aspects of the whole, rather than limiting the multi-year program to individual projects without a common endpoint or focus.  The experimental approach used real farming systems, which made it easier to translate into practical recommendations for addressing soil and water conservation issues.  A primary disadvantage in using a systems approach was that it was difficult to assess the role that individual BMPs played in improving water and soil resources.  Within the umbrella of the MDMSEA project, however, there was latitude to evaluate individual BMPs both within and outside of the selected watershed sites.

The MDMSEA Project derived an initial benefit from the planning and organizational experiences of the Midwest Initiative.  In the Midwest MSEA, the research watersheds were large and involved many farming operations and management practices. Determining the effects of individual management practices or combinations of practices on water quality was complicated.  It was recognized that a simpler, more manageable system was needed.

Meandering rivers and streams in the Mississippi Delta generated numerous oxbow lakes.  Many of them represent unique and relatively compact watershed systems.  Since oxbow lakes are commonly found adjacent to areas of intense agricultural activity, the decision was made to take advantage of this feature in the landscape.  The oxbow lake watersheds are essentially closed systems, with all surface water draining to the lake.  Changes in lake water quality therefore became one of the major focal points of MDMSEA evaluations.  As well, it was recognized that associated riparian areas were integral components of the oxbow lake systems, and management of these areas was deemed critical to watershed ecology and lake health.

Budget constraints limited the project to three oxbow lake watersheds.  In order to maintain the watershed system framework and still address different kinds of practices, the project was designed so that each oxbow lake watershed was cropped and managed using a different set of BMPs, in a hierarchy ranging from no BMPs to a combination of edge-of-field and agronomic measures for conserving and improving soil and water resources (Table 1).

**Table I.  Installation of BMPs in the MSEA Oxbow Lake Watersheds**

| *BMP* | *Thighman* | *Beasley* | *Deep Hollow* |
|---|---|---|---|
| **Edge-of-Field** | | | |
| Grass Filter Strip | | X | X |
| Grass Turn Row | | X | X |
| Slotted Board Riser | | X | X |
| Slotted Inlet Pipe | | X | X |
| **Agronomic** | | | |
| Reduced Tillage | | | X |
| Wheat Cover | | | X |
| Precision Application | | | X |

Thighman Lake watershed (Figure 3) was designated as the program control, with all management decisions made by the farmers and no improvements implemented by the MDMSEA researchers.

Only edge-of-field practices (Table I) were installed in the Beasley Lake watershed (Figure 4). Edge-of-field measures included structural and vegetative practices. Examples of structural practices included slotted board risers and slotted inlet pipes. Drainage pipes were positioned at low points in the field where surface runoff converges. During periods of high rainfall, wooden boards were placed in slots at the pipe inlet to impede the flow of water through the pipe. Sediment settled out at the pipe entrance as the runoff water slowly drained through the pipe.

One vegetative practice used in the Beasley Lake watershed was the establishment of grass filter strips to serve as a buffer between the field and drainage ditches or the lake itself. Grassed turn rows were another vegetative practice employed at Beasley Lake. Turn rows were areas at the end of a crop row where farm machinery maneuvered into position for a pass down another row. Vegetation in the filter strips and turn rows slowed the rate of runoff and helped trap chemicals and sediment as the water flowed through.

Deep Hollow Lake watershed (Figure 5) received a combination of agronomic and edge-of-field practices (Table I). Agronomic practices at Deep Hollow included cover crops, reduced tillage, and precision application of herbicides. The same edge-of-field practices used in the Beasley Lake watershed were also used at Deep Hollow.

Although each watershed was managed differently, several common parameters were established so that comparisons could be made among the watersheds. Unlike the Midwest region, cotton was a major crop in the Mississippi Delta region. Maintaining cotton as a component of the management system in all watersheds was therefore desirable. Sediment, nutrients, and pesticides were the primary pollutants of concern, and efforts were made to ensure that certain pesticides were used in all three watersheds. One of those pesticides, fluometuron, is a major herbicide applied to the soil in cotton management and was chosen as a key analyte in lake water samples. In areas of the watersheds where cotton or corn was grown, nitrogen fertilizer was applied and evaluated in surface- and ground water samples.

**Implementation of MDMSEA Research**

Instrumentation for focal sampling points in MDMSEA watersheds was installed during the period from 1994 to 1995, and watershed BMPs were established from 1994 to 1996. A mix of bluegill (*Lepomis macrochirus*),

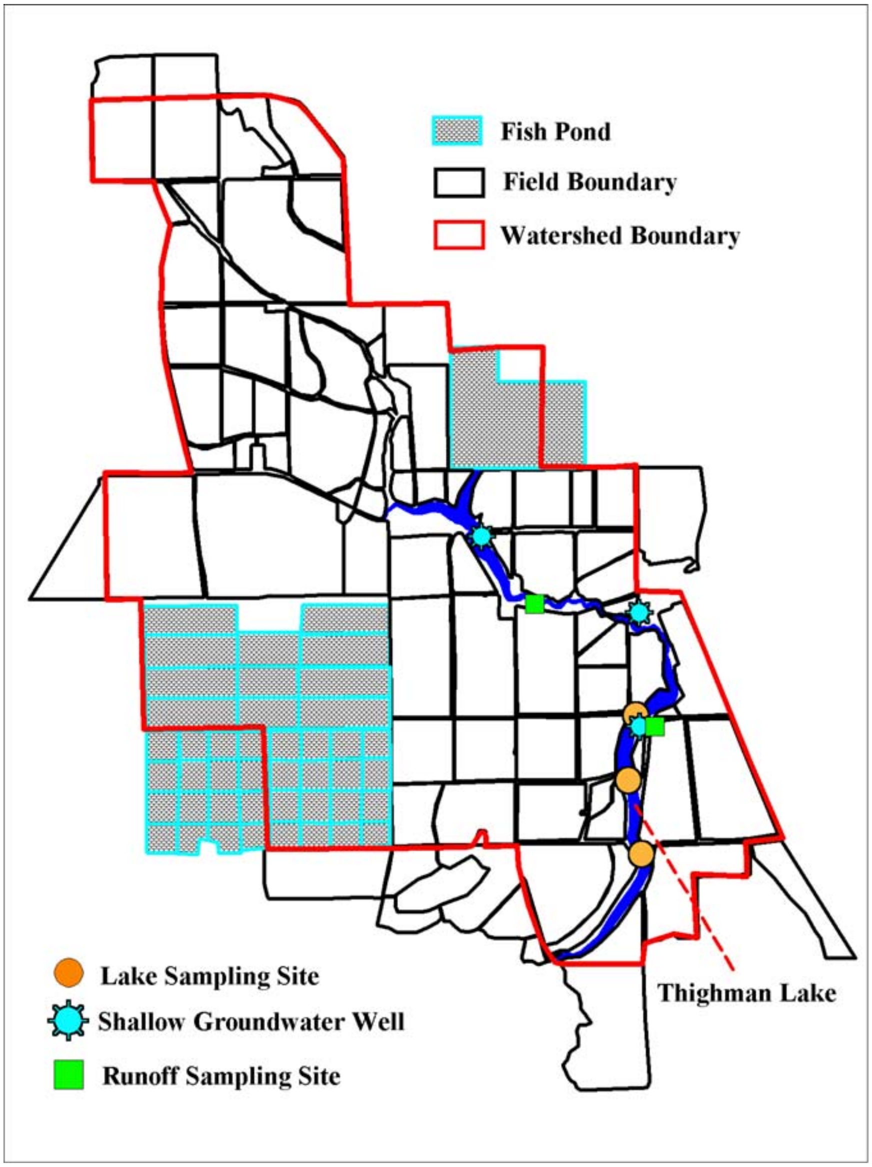


*Figure 3. Map of the Thighman Lake watershed.*

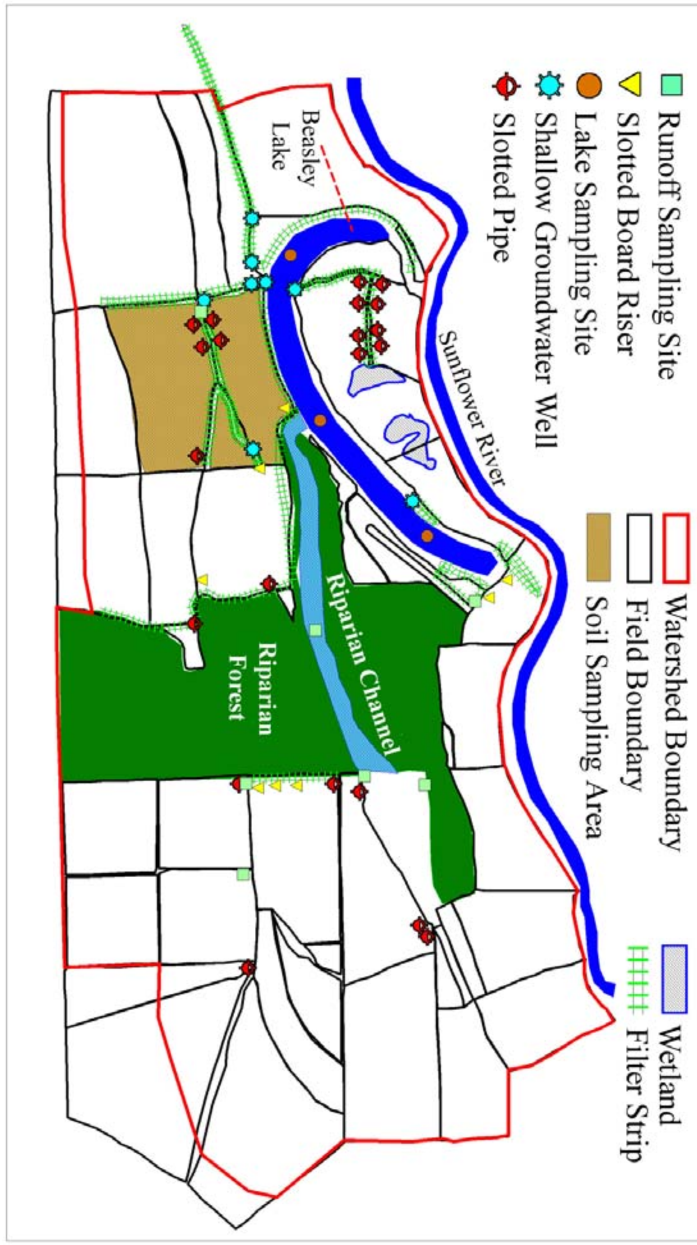


*Figure 4. Map of the Beasley Lake watershed.*

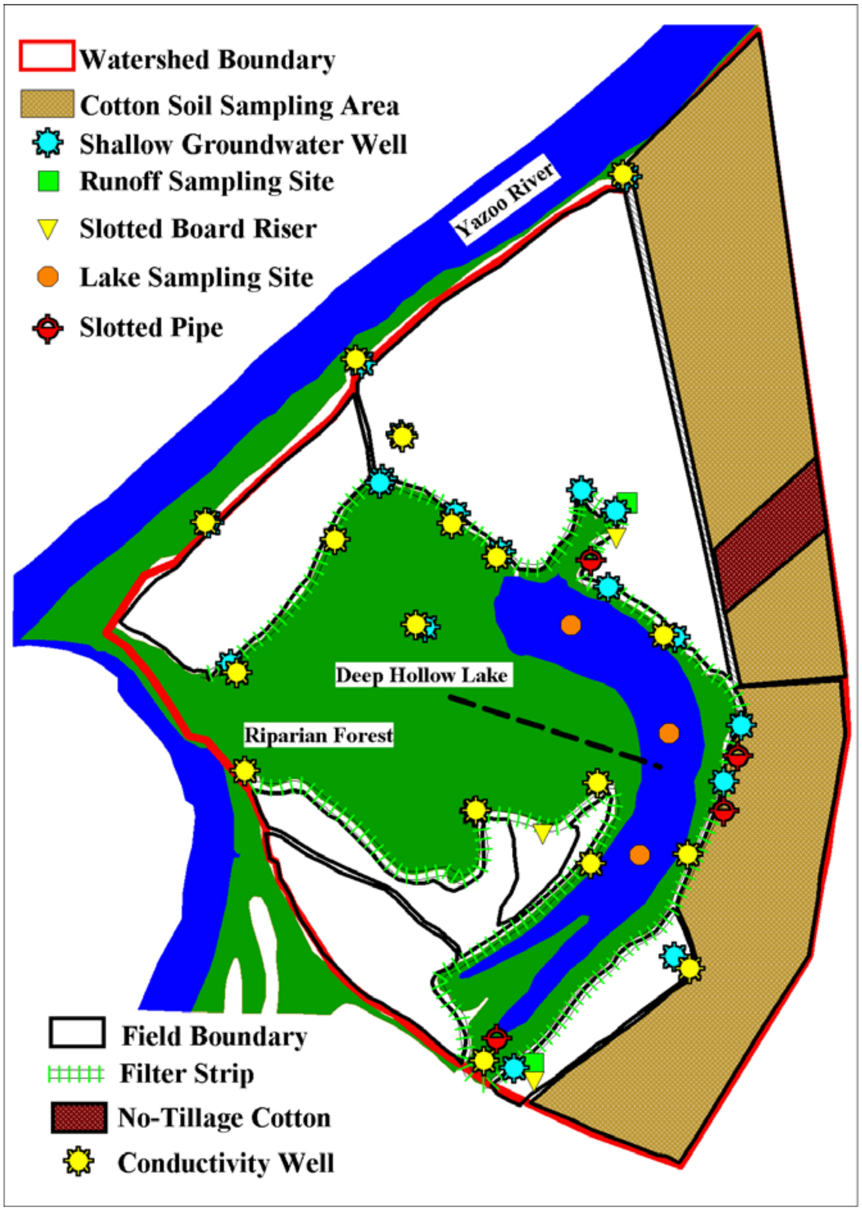


*Figure 5. Map of the Deep Hollow Lake watershed.*

redear sunfish (*Lepomis microlophus*) and channel catfish (*Ictalurus punctatus*) were introduced in the fall of 1996 followed by largemouth bass (*Micropterus salmoides*) in the spring of 1997. Lake water quality sampling began in the spring of 1995 and has continued through the present.

Thighman Lake watershed (Figure 3), the largest study area, was located in Sunflower County, Mississippi. The lake was 8.9-ha, and total watershed area was 1497 ha. Crops grown in Thighman watershed were soybean, corn, rice, catfish, and cotton. As the control watershed, the approach taken for Thighman Lake was for farmers to manage their land in the way that was most appropriate for them, with no input from the project. However, in some portions of the watershed, farmers voluntarily implemented conservation practices.

Beasley Lake watershed, Sunflower County, Mississippi, was 850 hectares with a 25-ha lake (Figure 4). Cotton, soybean, and corn were major crops in the Beasley watershed. As with Thighman Lake watershed, farmers made the decisions in the way that their crops were managed. Farmer practices in this watershed generally included disking the soil in the fall and preparing seedbeds just prior to planting. Only edge-of-field improvements were made in Beasley watershed. Grass filter strips were established along the edges of the lake at key locations, and grass was planted in some of the turn rows. Slotted board risers also were installed throughout the watershed as needed.

Deep Hollow Lake watershed in Leflore County, Mississippi, was comprised of 202 ha total area and an 8.1-ha lake (Figure 5). Crops grown in the Deep Hollow watershed included cotton and soybean. MDMSEA-introduced management practices for Deep Hollow included both edge-of-field and agronomic measures. A wheat cover crop was planted in the fall and desiccated in the spring prior to planting soybean or cotton. Cotton acreage was managed as reduced tillage, with a fall subsoiling as the only soil tillage operation. Soybeans were managed with no soil tillage. Sensor sprayer technology was used to spot-apply glyphosate for weed control, thereby reducing the amount of herbicides used in the watershed. As with Beasley Lake, grass filter strips, grassed turn rows, and slotted board risers were installed where necessary.

USDA-ARS, USGS, and MSU provided the primary pool of approximately 25 participating scientists and funding for MDMSEA research activities. USGS had the responsibility for instrumentation to evaluate storm events and stream flow rate. Samples were collected to assess quality of surface water runoff and sediment. MSU scientists from Starkville, MS evaluated socio-economic impacts of BMP systems, assessed herbicide dissipation in riparian soils and in vegetative filter strips, and provided support through Mississippi State Extension. National Science Foundation funding was obtained by MSU for a program called Student and Teacher Research Institute – Delta Experience (STRIDE). The goal of STRIDE was to foster interest in middle school students and teachers in environmental issues. USDA-ARS scientists were located at

Oxford and Stoneville, MS, and Baton Rouge, LA.  Research activities by USDA-ARS scientists included:

- Shallow ground water quality assessment (pesticides, nutrients)
- Lake water quality assessment (sediment, pesticides, nutrients)
- Assessment of fishery ecology in study lakes
- Evaluation of changes in lake ecology due to BMP implementation
- Assessment of microbial ecology in lakes
- Wetlands assessments
- Pesticide, nutrient, and sediment analyses of runoff water
- Precision application of herbicides
- Characterization of the spatial variability of soil properties
- Evaluation of weed population shifts due to management
- Assessment of agronomic management practices
- Assessment of edge-of-field practices buffer strips, drainage ditches
- Modeling on a watershed scale

Several groups provided support in ways other than research.  YMD provided GIS and mapping support.  USDA-NRCS provided guidance on BMP establishment, particularly with respect to edge-of-field management practices.

## Future Direction of MDMSEA

The MDMSEA project completed its first five years and research results are presented in this book and other publications (*11*).  Now that the first phase is completed, the Technical Steering Committee has addressed the questions of future direction.  Several issues will determine that direction, and funding is anticipated at least through 2006.

The three oxbow lake watersheds will continue to be at the core of the MDMSEA project.  Expansion to other locations will be considered, especially for studies addressing individual BMPs.  Changes in research emphasis have occurred since project inception.  Because no major problems were found in ground water, it may receive less attention.  Surface water quality issues remain as a high priority.  Research into and demonstration of individual BMPs were recognized as information gaps, and a matrix of management inputs and outcomes is seen as a potential product of the next phase.  Comprehensive economic analyses need to be completed; not only of production management, but also of impacts and benefits to the environment.  Section 303(d) of the 1972 Clean Water Act authorizes USEPA or individual states to develop lists of waters impaired by pollutants based on water quality standards.  For a water body to be removed from the list, it must not exceed a total maximum daily load of specified pollutant (TMDL). Currently, many surface waters of the Mississippi Delta Region are listed as impaired by pollutants such as sediments, nutrients, and pesticides (*12*). The relatively recent implementation of TMDL policy is a significant concern for farmers and the regulatory community and will continue to serve as a catalyst for future research. A major point for the Technical Steering Committee is to ensure synchronization of national and regional environmental issues with MDMSEA objectives.

## References


1. Dendy, F.E. *J.Environ. Qual.* **1981**, *10*, 482-486.
2. Murphree, C.E., and K.C. McGregor. *Trans. ASAE* **1991,** *34*, 407-411.
3. USEPA. 1986. National water quality inventory, 1986 report to Congress. EPA-440/4-87-008. Office of Water, US EPA, Washington, D.C., 185 pp.
4. Council Agricultural Science Technology, Report 120. Water Quality: Agriculture's Role. 1992.
5. Bush, G.W. *Building a better America.* **1989,** Message to Joint Session of Congress, Feb. 9. Washington, D.C., pp. 92-93.
6. USDA. *Water Quality Research Plan for Management Systems Evaluation Areas (MSEA's): An Ecosystems Management Program*; Agricultural Research Service Bulletin, ARS-123, Washington, DC, 1994, 45 p.
7. Onstad, C.A.; Burkart, M.R.; Bubenzer, G.D. *J. Soil Water Cons.* **1991,** *46*, 184-188.
8. Hatfield, J.L.; Bucks, D.A.; Horton, M.L. In *Agrochemical Fate and Movement: Perspective and Scale of Study*. Steinheimer, T.R., Ross, L.J., Spittler, T.D., Eds. American Chemical Society: Washington, DC, 2000, pp. 232-247.
9. McDowell, L.L., G.H. Willis, and C.E. Murphree. 1984. Plant nutrient yields in runoff from a Mississippi Delta watershed. Trans. Am. Soc. Agric. Eng. 27:1059-1066.
10. Willis, G.H., L.L. McDowell, C.E. Murphree, L.M. Southwick, and S.S. Smith. 1983. Pesticide concentrations and yields in runoff from silty soils in the Lower Mississippi Valley. J. Agric. Food Chem. 31:1171-1177.
11. Rebich, R.A., Knight, S.S. The Mississippi Delta Management Systems Evaluation Areas project, 1995-1999. 2002. Mississippi Agricultural and Forestry Experiment Station Information Bulletin 377.
12. USEPA. 2000. Total maximum daily load program. Http://www.epa.gov/owow/tmdl/intro.html.