THE NATIONAL WATER-QUALITY ASSESSMENT PROGRAM AND THE MISSISSIPPI EMBAYMENT STUDY UNIT

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INTRODUCTION

This paper presents an overview of the National Water-Quality Assessment (NAWQA) Program, the Mississippi Embayment study unit in relation to the national program, and the environmental setting and major water-quality issues in the Mississippi Embayment study unit. The Nation's water resources are composed of many interrelated ground- and surface-water systems. The response of each of these systems to natural and anthropogenic factors manifests itself in a corresponding set of hydrologic, chemical, and biological characteristics that reflect the effects these factors have on water quality. Many national water-quality concerns arise from the recognition of recurring local and regional problems related to managing and protecting water quality.

THE NATIONAL WATER QUALITY ASSESSMENT PROGRAM

To address complex water-quality concerns and related issues, in 1985 the U.S. Geological Survey (USGS) proposed a NAWQA Program to:

(1) provide a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources;

(2) define long-term trends (or identify the lack of trends) in water quality; and

(3) identify, describe, and explain the major natural and anthropogenic factors that affect observed water-quality conditions and trends.

In 1991, the USGS began the full-scale implementation of a NAWQA Program after the successful completion of a pilot phase with field investigations in seven areas throughout the Nation (Hirsch et al. 1988). Congress appropriated $18 million in Fiscal Year 1991 to begin the full-scale program; funding is planned to increase to about $60 million annually in Fiscal Year 1995. The program integrates information about water quality at several spatial scales, from local to national, and focuses on water-quality conditions that affect large areas of the nation or occur frequently within small areas. Meeting the goals of the program will produce a wealth of water-quality information that will be useful to policy makers and managers at the national, state, and local levels. Detailed background information on the objectives, design, and plan of implementation for the program is provided by Leahy et al. (1990).

The NAWQA Program consists of two major elements – study unit investigations and regional and national syntheses of study unit investigation results. Study unit investigations, the basic building blocks of the NAWQA Program, are designed to address study unit and local water-quality issues and to provide the information upon which regional and national water-quality assessments can be made.

The program's 60 study unit investigations address hydrologic systems that include the principal river basins, aquifer systems, and ecosystems throughout the nation. These study units cover areas from 1,200 to more than 65,000 square miles and incorporate about 60 to 70 percent of the Nation's water use and population served by public water supply. The distribution of study units will allow the most important regional and national water-quality issues to be addressed by comparative studies among study units.

Regional and national synthesis investigations combine results of study unit investigations with existing information from other programs, USGS studies, other agencies, and researchers to produce regional and national-scale assessments for priority water-quality issues. Comparative studies among study units and regional or national aggregations of data for national synthesis require comparable data on factors that affect sources and behavior of contaminants and other factors that determine water-quality conditions. Natural and anthropogenic factors, such as geology and land use, provide an environmental framework for assessing influences on water quality in different hydrologic systems.

The first water-quality issues to be focused on for national synthesis are nutrients, suspended sediment, and pesticides. An example of a specific water-quality issue is the presence of atrazine, one of the most heavily applied herbicides in the United States. Most of the usage of atrazine is concentrated in agricultural areas in the Midwest, along the Mid-Atlantic coast, and in specific regions of many other States. Thus, a "regional" analysis of the relation of the presence of atrazine to natural and anthropogenic factors would focus on several large, noncontiguous geographical areas of the nation. Synthesis of study unit investigation results in different parts of the country will provide a unique opportunity to examine the presence of atrazine and identify the distinct differences or similarities in climate, hydrology, and agricultural practices.

Major activities to be performed as part of the study unit investigations include the compilation and retrospective analysis of existing water-quality information, sampling and analysis of water quality for a large array of physical, chemical, and biological properties, and the interpretation and reporting of results. Study unit investigations consist of intensive assessment activity for 5 years, followed by 5 years of less intensive low-level monitoring, with the cycle repeated (Leahy et al. 1990). The first year of the project will be devoted to study design, assembly of project personnel, and preliminary familiarization with the study unit. The second year of intensive assessment activity is composed of retrospective data analysis where an effort will be made to identify, obtain, and analyze data from existing sources. These initial activities are followed by 3 years of intensive field-data collection. During the intensive assessment, as many as 10 project members having expertise in ground- and surface-water hydrology, water quality, geochemistry, ecology, geomorphology, statistics, and other scientific disciplines will be involved in a study unit investigation. The water resource to be emphasized in each study unit investigation will depend on water use in the study unit and the nature and importance of the ground- or surface-water-quality problems. During the less intensive activity period of each study unit investigation, a project chief and one or two support project members will be needed to continue low-level monitoring activities.

Twenty study units will be in an intensive assessment phase during each year, and the first complete cycle of intensive investigations of all 60 study units is scheduled to be completed in 2002. The first set of 20 study units was begun in 1991; those 20 are currently in their second year of intensive field-data collection. The second set of 20 study units was begun in October 1993, and the chiefs of those 20 projects are currently developing study designs and work plans, as well as setting up liaison committees. Study unit liaison committees consist of representatives of federal, state, local, and private organizations with interest and active programs in water-quality evaluation and management. These committees are an important element of the NAWQA Program and help ensure that significant water-quality problems of local concern are addressed by the program. In the second project year of the study units which began in 1994, a retrospective analysis of existing data will be performed. This retrospective analysis will attempt to identify and analyze all federal, state, local and academic sources of comparable data. In the third through fifth years of these studies, intensive field data collection will be performed.

THE MISSISSIPPI EMBAYMENT STUDY UNIT

The Mississippi Embayment study unit was among the second set of 20 NAWQA study units selected for study beginning in 1994 under the phased implementation plan. A general description of the study unit, identification of major water-quality issues to be addressed, and communication, coordination, and reports are presented in the following section.

Study Unit Description

The Mississippi Embayment water-quality study unit (Figure 1) covers an area of approximately 48,500 square miles and includes parts of Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee. An overview of the physiography, climate, surface water, geology and geomorphology, aquifers, and land use of the study unit follows.

Physiography. The study unit lies entirely in the Mississippi Embayment sub-province of the Gulf Coastal Plain Physiographic Province and is approximately bisected by the Mississippi River. The western and central part of the study unit lies in the Mississippi River Alluvial Plain, an area of little topographic relief with an average gulfward slope of about 0.5 foot per mile. In the northern and southern thirds of the alluvial plain, the Mississippi River meanders along the eastern edge of the plain, whereas in the middle third, the river lies approximately in the center of the plain. The width of the alluvial plain ranges from about 40 to 110 miles and is largest in the middle third of the study unit. A major topographic feature in the alluvial plain is Crowleys Ridge, a narrow, segmented ridge about 200 miles long extending northward from the Mississippi River in extreme east-central Arkansas into southeastern Missouri. The ridge, an erosional remnant underlain by rocks ranging in age from Paleozoic to late Tertiary, is as much as 250 feet higher than the surrounding alluvial plain.

The Loess Hills form the eastern physiographic boundary of the alluvial plain and extend the length of the study unit. The windblown material forming the Loess Hills belt rises several hundred feet above the plain and averages about 15 miles in width. The western boundary of the alluvial plain is the uplands of the Interior Highlands physiographic province which also defines the western limit of the study unit.

The eastern part of the study unit lies in the Gulf Coastal Plain uplands and generally is rolling to hilly with little to moderate topographic relief. The land surface generally slopes inward toward the Mississippi River from both the eastern and western sides of the study unit and to the south towards the Gulf of Mexico. Fenneman (1938) defines five physiographic subdivisions of the Coastal Plain uplands: the Fall Line Hills, Black Belt, Ripley Cuesta, Flatwoods, and Red Hills Belt. Locally in Mississippi, the Black Belt is known as the Black Prairies, and the Red Hills Belt is known as the North Central Hills.

The Coastal Plain uplands are the result of uplift and erosion of the generally unconsolidated coastal sediments. The arcuate pattern of these subdivisions reflects closely the outcrops of geologic units in the area. The Fall Line, where unconsolidated Coastal Plain sediments meet consolidated rocks of Paleozoic age, forms the northeastern boundary of the study unit. The Fall Line Hills, a broad belt which is up to 50 miles in width, is underlain by the Upper Cretaceous sediments including clay, sand, gravel, and chalk. The sandy and poorly consolidated material of these formations characteristically supports steep slopes, with as much as 250 feet of relief within a half mile being common near the larger streams. Altitudes of hilltops range from over 600 feet in eastern Alcorn County, Mississippi, to about 400 feet in the southern parts of the Fall Line Hills belt. The area of the belt underlain by the thinly bedded sands of the Eutaw Formation generally is somewhat higher and more deeply dissected than the area underlain by the more irregularly bedded sands and gravels of the Tuscaloosa Group to the east and north.

West and south of the Fall Line Hills lies the Black Belt, a lowland formed on the outcrop of chalk in the Selma Group. This belt of subdued topography is as much as 25 miles wide and is topographically lower than either the Fall Line Hills to the north and east, or the Ripley Cuesta to the south and west. Average altitudes between streams in the Black Belt are about 500 feet in northern Mississippi. South and west of the Black Belt, the more resistant and occasionally indurated sandy clay of the Ripley Formation supports a cuesta that rises as much as 300 feet above the adjacent Black Belt. In Mississippi, the cuesta, locally known as the Pontotoc Ridge, narrows from a width of about 12 miles at the Tennessee boundary to a point about 90 miles south, where the cuesta disappears and the lowlands of the Black Belt are contiguous with the lowlands of the Flatwoods. Farther to the southwest, the Red Hills Belt underlies Tertiary sediments of the Midway Group, Wilcox Formation, and Claiborne Group.

Climate. The study unit has a humid subtropical to temperate climate. Climatic variations are largely governed by the presence of the extensive land mass to the north and the Gulf of Mexico to the south, which produce alternating flows of cold air moving southward and warm, moist air moving northward. Mean annual air temperature ranges from about 58° in the northern part of the study unit to about 66° in the southern part. Mean annual precipitation ranges from about 48 inches near Little Rock, Arkansas, to about 56 inches in Richland Parish, Louisiana, in the southern part of the area. Precipitation is unevenly distributed throughout the year. The greatest mean precipitation occurs in the winter and early spring, and the least occurs in fall. Droughts are common during summer and fall.

Surface Water. The drainage area of the study unit extends downstream from the confluence of the Mississippi and Ohio Rivers to a point on the Mississippi River south of Vicksburg, Mississippi, and includes, in order of drainage area in the study unit, the drainage basins of the Yazoo, Hatchie-Obion, St. Francis, and Boeuf-Tensas Rivers.

Yazoo River Basin: The Yazoo River basin drains about 14,000 square miles in northwestern Mississippi. Recreational use of Arkabutla, Sardis, Enid, and Grenada Lakes - large flood-control reservoirs constructed on the four headwater tributaries in the 1940s and 1950s - is the principal use of surface water in the hilly uplands of the headwaters of the basin. Small amounts of surface water also are used for livestock watering and irrigation. Principal uses of surface water in the Delta include transportation of agricultural products (on the Yazoo and the Mississippi Rivers), cooling at thermoelectric powerplants, and irrigation. Surface-water withdrawals for thermoelectric-power generation at sites along the Mississippi River and the Sunflower River, principal tributary to the Yazoo River in the Delta, averaged about 370 million gallons per day or 572 cubic feet per second in 1983. Surface-water withdrawals for irrigation, which accounted for less than 15 percent of total irrigation withdrawals, averaged about 100 million gallons per day or 155 cubic feet per second in 1983. Despite the many levees, drainage ditches, channel improvements, and other flood control measures, flooding in the Delta, either from excessive rainfall in the area or backwater flooding from the Mississippi River at Vicksburg, continues to be a principal concern of farmers. Surface waters in the Yazoo River basin generally are low in dissolved mineral content and are suitable for most uses; however, in the heavily farmed areas, particularly in the lower part of the basin, streams receive large amounts of sediment and agricultural chemicals.

Hatchie River Basin and Mississippi River Main Stem: The Mississippi River is an important navigation route. Major use of water from the mainstem and its tributaries, other than navigation, is recreation; little water is withdrawn for irrigation. Use of the water for industrial, municipal, and rural-domestic supplies is constrained by sediment loads and by waste disposal at upstream sources. At these locations, adequate supplies of ground water are available for most uses. Generally, low stream gradient contributes to the frequency and severity of flooding, which has been and continues to be a concern in communities along the river and its tributaries.

The quality of surface water in the Hatchie River basin has been degraded by sedimentation from farmland, by discharge of wastewater, and by agricultural chemicals. Locally, sediment transport from farmland and nutrient enrichment resulting from crop-production activities adversely affect stream water for municipal and industrial uses. The effects of municipal and industrial discharges on surface-water quality are also a concern. Overall, water quality is improving owing to efforts by state and federal agencies to decrease the effects of municipal and industrial wastes.

St. Francis River Basin: The St. Francis River originates in the hills of Missouri where it flows rapidly until it enters the flatlands and gradually becomes sluggish and meandering. The river enters the alluvial valley of the Mississippi River and flows into the Mississippi River near Helena, Arkansas. The St. Francis River is 475 miles long and has a drainage area of 8,416 square miles at its mouth. Originally, the stream channel was poorly defined as it flowed on the marshy and swampy flood plain of the alluvial valley for a distance of about 100 miles. During the past 150 years, many anthropogenic changes have occurred in the St. Francis River Basin. Swamps have been drained, levees built, and millions of acres of land cleared for cultivation. Much of the fertile farmland is in the St. Francis River flood plain and is protected from flooding by levees. Accumulation of pesticides in bottom sediments of streams, lakes, and ponds, and the effects of these compounds on the food chain is a concern in the St. Francis River Basin. Some regulation in Missouri has occurred since 1941.

Arkansas River Basin: The Arkansas River flows south-eastward across Arkansas before emptying into the Mississippi River. The total drainage area at the mouth is 160,576 square miles. The Arkansas River is regulated by many locks, dams, and reservoirs. The primary purpose of the locks and dams is for navigation. The locks and dams also help control low-magnitude floods; however, they have little effect in reducing peaks of large magnitude floods. Most of the tributaries that flow into the Arkansas River go dry during dry periods. The Arkansas River is being considered as a source of water for public supply and irrigation. Seepage from natural salt deposits in upstream areas increases the salinity of the river, which may make the river unsuitable for some uses during low flow. Municipal and industrial discharges to the river may contribute wastes and other chemicals that affect the river's potability. Impoundment of water by the Arkansas River Navigation System and tributary dams has moderated the effects of salinity and inflowing pollutants by maintaining larger volumes of water in the river thus diluting the concentration of contaminants.

Generalized Geology and Geomorphology. Geologic units exposed in the study unit range in age from Cretaceous to Holocene. At the eastern edge of the study unit in Mississippi and Tennessee, a small area of Cretaceous sediments crop out. Tertiary sediments composed predominantly of unconsolidated to slightly consolidated beds of sand and clay and some interbedded gravel, silt, lignite, chalk, and limestone crop out in a broad band in north-central Mississippi and western Tennessee and subcrop the surficial Mississippi River alluvial deposits. Mississippi River alluvial deposits of Quaternary age occupy the western part of the study unit, including most of the study unit in Louisiana, Arkansas, and Missouri, and part of northwestern Mississippi. Pre-Holocene strata generally dip toward the axis of the Mississippi Embayment syncline, which generally is coincident with the present-day course of the Mississippi River.

The structural setting for the deposition of sediments that comprise the aquifer systems of the Mississippi Embayment consisted of broad, subsiding depressions of the Gulf Coast geosyncline and the southward plunging syncline of the Mississippi Embayment (Mallory 1993). Initial subsidence of these features may have occurred as early as the end of the Paleozoic era. Subsidence continued throughout the Cretaceous period, and transgressive seas reached as far north as Cairo, Illinois, during Late Cretaceous time. Thick wedges of sediments that now make up the southeastern Coastal Plain and Mississippi embayment aquifer systems were deposited in the subsiding structural trough. The nature of the sediments was determined by the depositional environment which, in turn, was governed by the fluctuations of relative sea level and the shifting location of the shoreline of this ancient sea.

The Cretaceous sediments include gravel, sand, clay, chalk, and marls of fluvial and marine origin. Some reef-type limestones are present locally. The trough-like shape of the embayment results in the older rock units cropping out in an arcuate pattern approximately parallel with the periphery of the embayment. Progressively younger units occur to the south and toward the Mississippi Embayment and Gulf of Mexico. The dip of these beds generally is toward the axis of the Mississippi Embayment. Thickness of sediments increases greatly downdip; in the south near the embayment axis (outside the area of the current study) the total thickness of post-Paleozoic deposits is about 18,000 feet. Upper Cretaceous units include, in ascending order, the Tuscaloosa Group, composed of the Coker and Gordo Formations; the Eutaw and McShan Formations; and the Selma Group, composed of the Mooreville Chalk, Coffee Sand, Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk.

Subsidence accompanied by cyclic invasions of the sea continued through the Tertiary Period. Each invasion stopped successively farther to the south during the Tertiary Period. Tertiary units include, in ascending order, the Midway Group, Wilcox Group, and Jackson Group.

Pleistocene glaciation caused a lowering of sea level and subsequent changes in drainage. Among these changes was the entrenchment of the Mississippi River valley into sediments of Cretaceous and Tertiary age. Melting glaciers produced tremendous volumes of water flowing southward to the Gulf of Mexico. Water eroded the ancestral Mississippi River valley more than 100 feet deeper than the present-day surface of the Mississippi Alluvial Plain. As sea level rose following the melting of the glaciers, stream gradients decreased and the entrenched valley was filled with sediments to its present level, forming the Mississippi Alluvial Plain.

Aquifers. The Southeastern Coastal Plain aquifer system is composed of five aquifers in sediments of Cretaceous age in the Tuscaloosa, Eutaw, and Selma Groups (Mallory 1993). These Cretaceous aquifers rest on consolidated Paleozoic rocks in the northern part of the study unit and on Lower Cretaceous deposits which are often water-bearing in the southern part of the study unit. The aquifers of Cretaceous age are, in descending order, the Ripley, Coffee, Eutaw-McShan, Coker, and Gordo aquifers.

The Mississippi Embayment aquifer system is composed of six regional aquifers; the oldest five consist of sediments of Tertiary age in the Wilcox and Claiborne Groups and the youngest is the Mississippi River alluvial aquifer in sediments of Pleistocene and Holocene age (Arthur and Taylor 1991). These Tertiary aquifers are separated from underlying aquifers in deposits of Cretaceous age by thick marine clay of the Midway confining unit and are hydraulically connected to the younger Mississippi River alluvial aquifer where they subcrop that aquifer. The five major aquifers in sediments of Tertiary age are, in descending order, the Cockfield aquifer, Sparta aquifer, lower Claiborne-upper Wilcox aquifer, middle Wilcox aquifer, and the lower Wilcox aquifer.

Land Use. More than three fourths of the total study unit area consists of cropland with interspersed pasture, forest, and woodland (Paulson et al. 1993). The area of the Mississippi River alluvium, in the central and eastern part of the study unit, produces large amounts of cotton, soybeans, and rice. Aquaculture, specifically the farming of catfish in Mississippi and crayfish in Louisiana, is also widespread in the area. The second largest category of land use consists of woodlands with interspersed croplands and pasture. Today (1994), about 5 percent of the area consists of forested wetlands of the Mississippi River, whereas in the mid 1900s, probably half of the area consisted of forested wetlands (Dahle 1990).

The conversion of these forested wetlands to cropland over the past century has been, perhaps, the most dramatic ecological change in the study unit. The loss of wetlands has implications for water quality; wetlands act as traps for sediment and nutrient deposition and provide flood-water retention, which reduces suspended sediment load. Loss of wetlands has also caused profound changes in the habitat and fauna assemblages of the area (Nature Conservancy 1992).

Major Water-Quality Issues

Surface-water quality issues are related to point and non-point sources of contamination. The primary non-point-source activities are irrigated and non-irrigated agriculture, grazing, streamflow regulation from dams and diversions, and recreation. Primary point-source activities are agricultural-related industry, aquaculture, municipal wastewater-treatment facilities, and landfills. Water-quality effects on lakes and reservoirs in the study unit primarily are due to agricultural- and aquacultural-related activities and generally are related to intense cultivation and the use of agricultural chemicals in the area.

Ground-water contamination from point sources generally is localized and limited to releases from areas between a few acres to several square miles. Common point sources of contamination are petroleum storage tanks, industrial chemical spills, leaks from underground storage tanks, and application of wastewater to the land. Ground-water contamination from non-point sources has not been extensively investigated.

Specific water-quality issues include:

- Potential ground-water contamination by pesticides and nutrients associated with agricultural activities in intensively irrigated areas;
- Elevated concentrations of sediments and nutrients and the occurrence of low dissolved-oxygen concentrations in surface water associated with agriculture and aquaculture (Rebich 1993); and
- Susceptibility of water supplies to encroachment or upwelling of saline ground water in areas of heavy ground-water withdrawals for agricultural use.

Communication and Coordination

Communication and coordination between USGS personnel and other scientists and water-management organizations are critical components of the NAWQA Program. Each of the study unit investigations will have a local liaison committee consisting of representatives from federal, state, and local agencies, universities, and the private sector, who have water-resources responsibilities. Specific activities of each liaison committee will include the exchange of information about water-quality issues of regional and local interest; the identification of sources of data; assistance in the design and scope of project products; and the review of project planning documents and reports. A liaison committee for the Mississippi Embayment NAWQA study unit will be formed in 1994.

Reports

Results of each study unit investigation will be presented in several reports during each period of intensive assessment activity. Early in each investigation, the project team will prepare a work plan. This work plan will present refined boundaries of the study unit, describe the hydrogeologic setting of the study unit, identify major water-quality issues, and define specific objectives and approaches that will be used. Briefing materials on planned water-quality investigations will be prepared and released to the public to aid in coordinating and ensuring that local interests are addressed by the program. The public will be informed about activities in each study unit through participation in public meetings. Addressing local water-quality concerns will be an important component of the study unit investigations.

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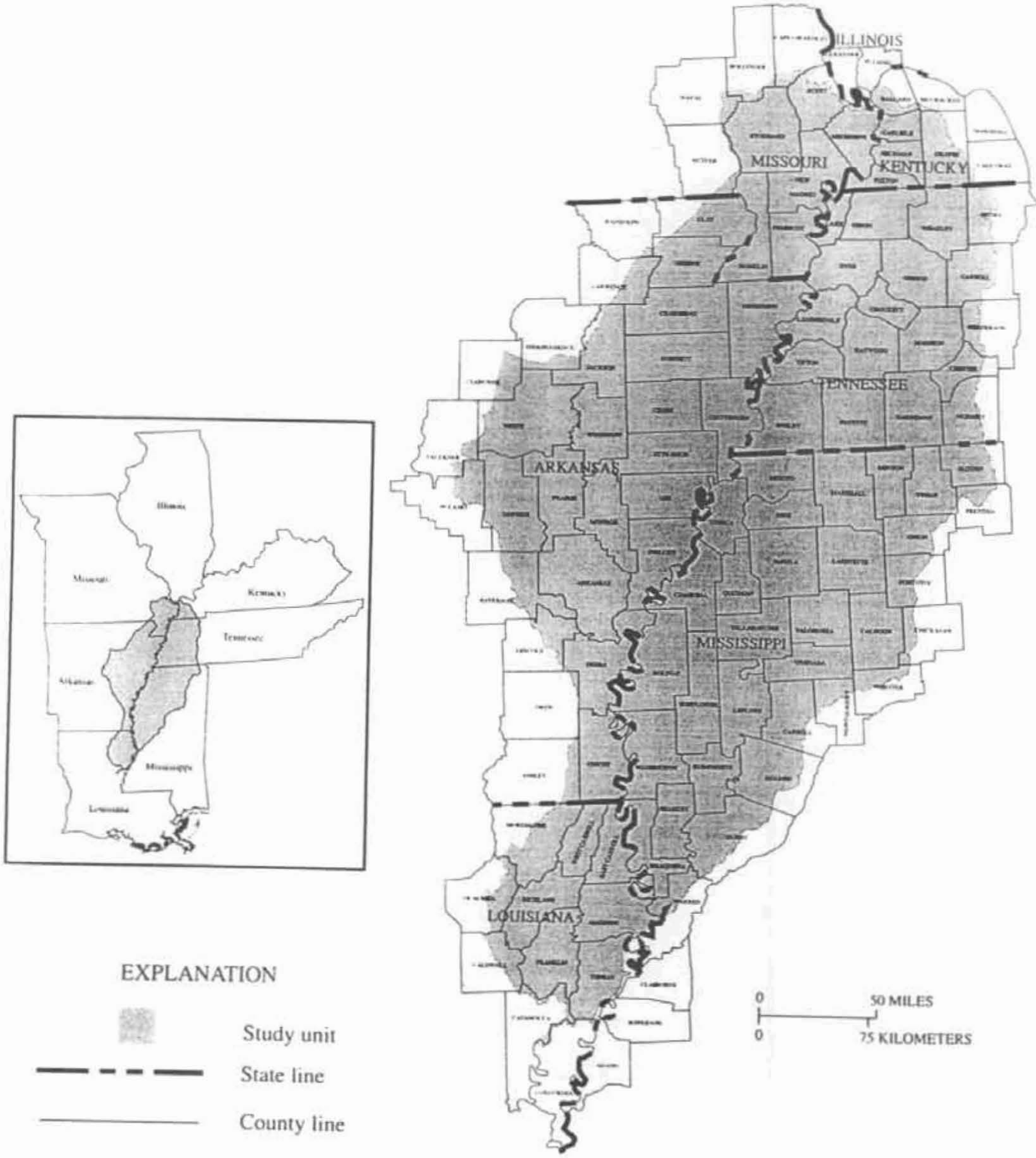

Figure 1.-- Mississippi Embayment National Water-Quality Assessment study unit.