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Water Quality in the Mississippi Embayment

Mississippi, Louisiana, Arkansas, Missouri, Tennessee, and Kentucky 1995–98

U.S. Department of the Interior
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Circular 1208

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Front cover: Photograph of the Black Swamp, Cache River Basin, near Gregory, Arkansas.

Back cover: Left, cotton grows on the banks of bayous in the Yazoo Basin; center, many of the rivers in the bootheel of Missouri have been channelized; right, soybeans are a major crop in the Mississippi Embayment Study Unit.

Photographs in this report were all taken by members of the MISE NAWQA Study Unit, U.S. Geological Survey.

Water Quality in the Mississippi Embayment, Mississippi, Louisiana, Arkansas, Missouri, Tennessee, and Kentucky,1995–98

By Barbara A. Kleiss, Richard H. Coupe, Gerard J. Gonthier, *and* Billy G. Justus

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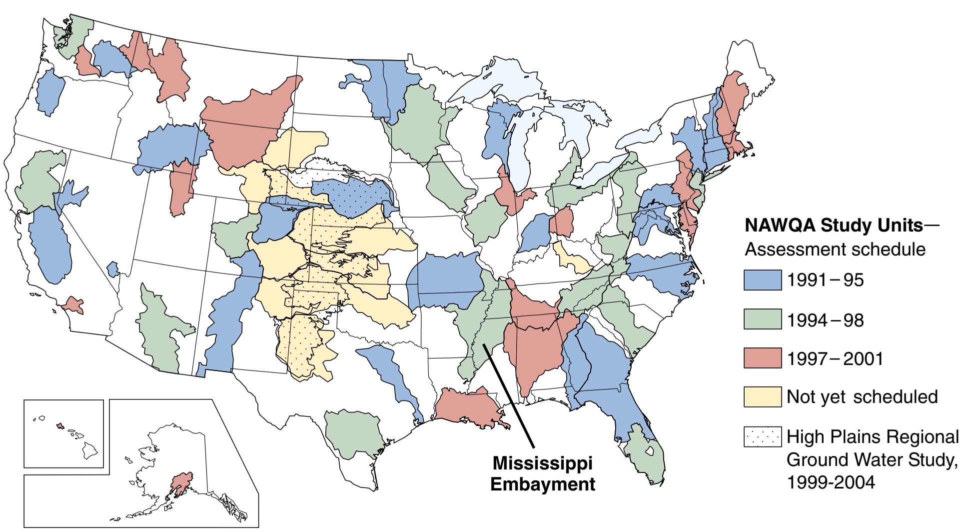
CONTENTS

THIS REPORT summarizes major findings about water quality in the Mississippi Embayment that emerged from an assessment conducted between 1995 and 1998 by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program. Water quality is discussed in terms of local and regional issues and compared to conditions found in all 36 NAWQA study areas, called Study Units, assessed to date. Findings are also explained in the context of selected national benchmarks, such as those for drinking-water quality and the protection of aquatic organisms. The NAWQA Program was not intended to assess the quality of the Nation's drinking water, such as by monitoring water from household taps. Rather, the assessments focus on the quality of the resource itself, thereby complementing many ongoing Federal, State, and local drinking-water monitoring programs. The comparisons made in this report to drinking-water standards and guidelines are only in the context of the available untreated resource. Finally, this report includes information about the status of aquatic communities and the condition of in-stream habitats as elements of a complete water-quality assessment.

Many topics covered in this report reflect the concerns of officials of State and Federal agencies, water-resource managers, and members of stakeholder groups who provided advice and input during the Mississippi Embayment assessment. Basin residents who wish to know more about water quality in the areas where they live will find this report informative as well.



THE NAWQA PROGRAM seeks to improve scientific and public understanding of water quality in the Nation's major river basins and ground-water systems. Better understanding facilitates effective resource managment, accurate identification of water-quality priorities, and successful development of strategies that protect and restore water quality. Guided by a nationally consistent study design and shaped by ongoing communication with local, State, and Federal agencies, NAWQA assessments support the investigation of local issues and trends while providing a firm foundation for understanding water quality at regional and national scales. The ability to integrate local and national scales of data collection and analysis is a unique feature of the USGS NAWQA Program.

The Mississippi Embayment is one of 51 water-quality assessments initiated since 1991, when the U.S. Congress appropriated funds for the USGS to begin the NAWQA Program. As indicated on the map, 36 assessments have been completed, and 15 more assessments will conclude in 2001. Collectively, these assessments cover about one-half of the land area of the United States and include water resources that are available to more than 60 percent of the U.S. population.

Stream and River Highlights

The climate, rainfall, soil type, and surficial geology of the Mississippi Embayment (MISE) Study Unit strongly influence land use in the basin and subsequently influence water quality. About 62 percent of the Study Unit is used for agriculture. In areas of intensive row-crop production, as much as 90 percent of the land is used for agriculture. This influence from agricultural land use, with additional contributions from urban areas, has resulted in streams that often have high turbidities, mixtures of pesticides, and degraded riparian habitat. Biological communities in the streams commonly are stressed. However, human activities on the Earth's surface seem to have a limited effect on the ground-water resources, which supply the vast majority of the region's drinking water.

- Herbicides frequently were detected in streams draining agricultural or mixed land-use basins; insecticides were detected less often. Pesticides in over 60 percent of samples collected from these streams exceeded aquatic-life guidelines. Insecticides frequently were detected in samples from the urban stream; diazinon and chlorpyrifos were detected in every sample, usually in concentrations above aquatic-life guidelines.

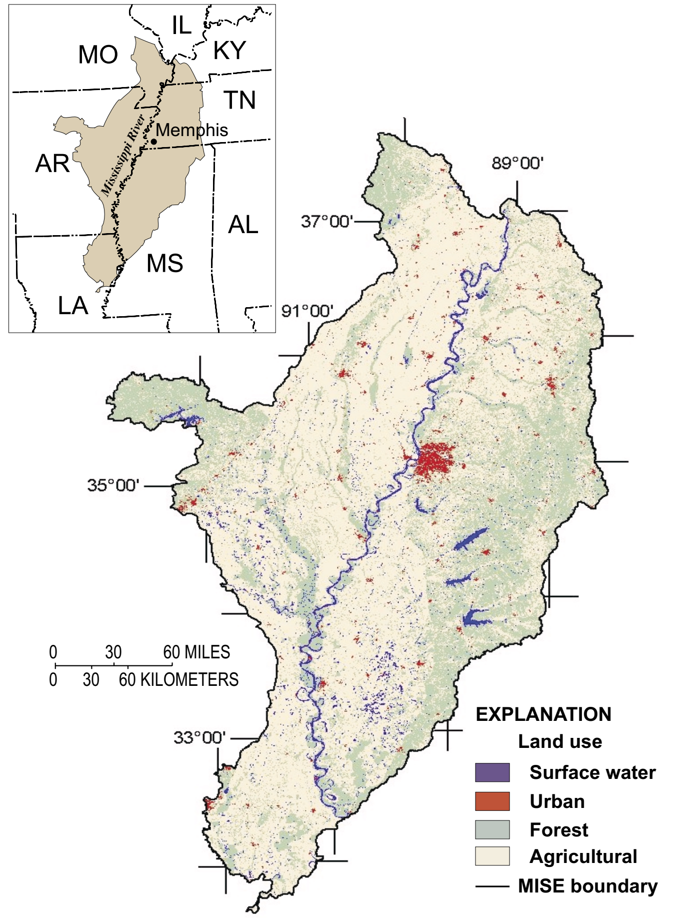
- Nitrogen concentrations in the MISE generally were in the middle range of the national data, whereas total phosphorus concentrations were in the 67th to 93d percentile. The phosphorus concentrations in the Study Unit probably were related to many factors, such as rainfall amounts, soils, and artificial drainage of agricultural fields. No sample exceeded the guidelines and standards for nitrate or ammonia, but most exceeded the U.S. Environmental Protection Agency's (USEPA) goal of 0.1 mg/L (milligram per liter) of phosphorus for the prevention of plant nuisances in streams.

- Although the sale of the organochlorine insecticide DDT was discontinued in 1972, DDT and metabolites (chemicals resulting from the breakdown of DDT) were widespread within the MISE. DDT, or one of its metabolites, was found in every fish tissue sample collected and was found in 67 percent of the streambed-sediment samples. Detectable levels of a metabolite of DDT were measured in 14 percent of surface-water samples.

- Although volatile and semivolatile organic compounds often were detected in urban stream water and in bed sediment, they were rarely at levels of concern.

- Aquatic organisms present in the MISE streams were typical of those found in impacted or degraded streams. Fish communities in most of the streams were dominated by fish tolerant of poor water quality conditions. The aquatic insects and algal communities generally were tolerant of turbid, silty conditions.

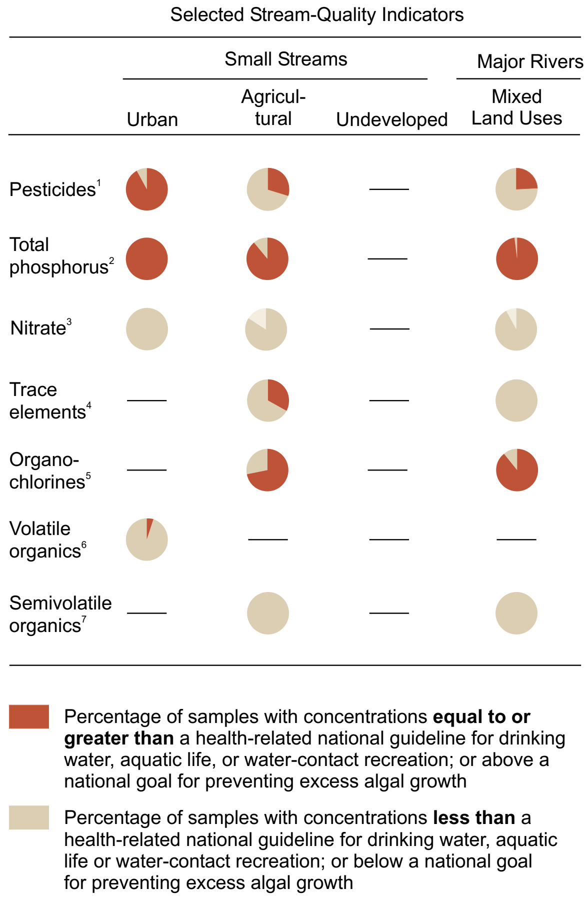
- Methyl parathion, a metabolite of DDT, and several other pesticides were detected in air and rain samples collected in an agricultural area and in the urban area of Jackson, Mississippi.



The Mississippi Embayment (MISE) Study Unit is an approximately 49,800-square-mile area in the six States of Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee. Land use in the MISE is principally agricultural. Approximately 62 percent of the study area is agricultural, 33 percent is forested, and 5 percent represents other land uses. The land use in some of the smaller drainage basins sampled is greater than 90 percent agricultural.

Major Influences on Streams and Rivers

- Runoff from agricultural and urban areas
- Drainage modifications and channelization of streams
- Modification or elimination of riparian habitat



[1] Insecticides, herbicides, and pesticide metabolites, sampled in water.
[2] Total phosphorus, sampled in water.
[3] Nitrate (as nitrogen), sampled in water.
[4] Arsenic, mercury, and metals sampled in sediment.
[5] DDT and PCBs sampled in fish tissue.
[6] Solvents, refrigerants, fumigants, and gasoline compounds sampled in water.
[7] By-products of fossil-fuel combustion; components of coal and crude oil sampled in sediment.

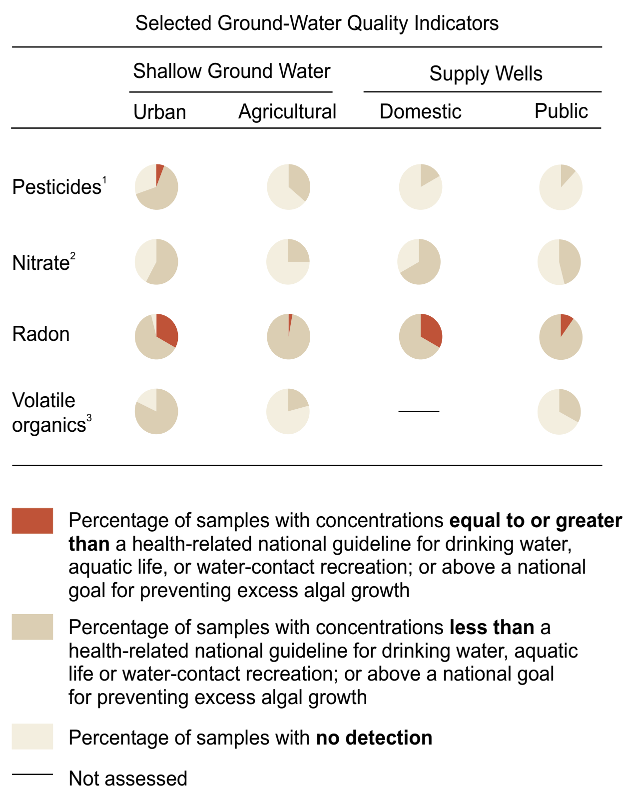
Ground-Water Highlights

Ground-water quality in the Mississippi Embayment Study Unit generally is very good. Ground water in the deep Tertiary aquifers, which supply most of the region's drinking water, generally is isolated from surface activities by thick "confining layers" of clays. Surface activities influence ground water where shallow deposits cover the hills in the eastern part of the Study Unit and in the Memphis shallow aquifers more than in the deeper aquifers. The abundant ground water in the alluvial aquifer of the Mississippi River valley is near the land surface but is covered by dense clays.

- Pesticides, such as atrazine, simazine, and metolachlor, were detected most frequently in the ground water in the shallow deposits that cover the hills in the eastern part of the Study Unit and in ground water underlying urban areas. Bentazon, molinate, and fluometuron were the pesticides most frequently detected in the alluvial aquifer. Atrazine and dieldrin were detected one time each in shallow urban wells at levels above the drinking-water standards and guidelines.
- Nutrient concentrations in the ground water in the MISE generally were low. All nitrate concentrations were below the USEPA drinking-water standard of 10 mg/L.
- Radon is naturally occurring and was detected in almost every well sampled. Concentrations above the USEPA-proposed drinking water standard of 300 picocuries per liter were found in water from only 16 of 109 wells. These levels are low, relative to levels detected in other NAWQA Study Units.
- Volatile organic compounds (VOCs) were detected in ground water throughout the Study Unit; however, concentrations were well within drinking-water standards. The most frequently detected VOCs were 1,2,4-trimethylbenzene and carbon disulfide.

Major Influences on Ground Water

- Ground water is commonly protected from surface activities by thick, regional clay layers.



[1] Insecticides, herbicides, and pesticide metabolites, sampled in water.
[2] Nitrate (as nitrogen), sampled in water.
[3] Solvents, refrigerants, fumigants, and gasoline compounds sampled in water.

In 1821, while painting a peregrine falcon, John James Audubon described the Yazoo River, the largest river wholly contained within the Mississippi Embayment Study Unit, as “a beautiful stream of transparent water, covered by thousands of geese and ducks and filled with fish” (Smith, 1954). Since that time, the bottomland hardwood forests that covered the Mississippi River Alluvial Plain have been cleared for agricultural use of the rich alluvial soils for the production of cotton, soybeans, rice, and corn. This clearing of the land has exposed the fine alluvial soils to erosion. Over time, the clays, along with nutrients and agricultural chemicals sorbed to the clay surfaces, were washed into the rivers and streams, thus greatly changing the water quality of the area.

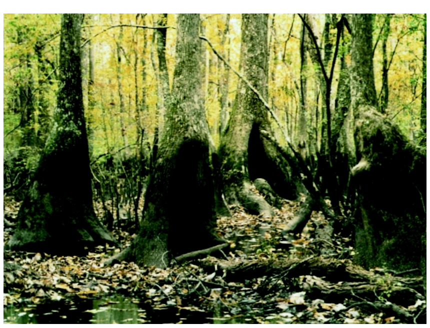
John James Audubon’s painting of the peregrine falcon that he worked on while visiting the Yazoo River area in 1821. (Reprinted courtesy of the National Audubon Society.)

Physiography and Ecoregions

Within the Mississippi Embayment (MISE) Study Unit, the surficial geology is the underlying controlling factor for the physiography, land use, biological communities, and water quality of the area. Therefore, the areas defined as physiographic regions (Fenneman, 1938) strongly correspond to the related ecoregions defined by Omernik in 1987 (fig. 1).

About 57 percent of the MISE Study Unit lies within the Mississippi Alluvial Plain physiographic province and ecoregion. This area has been dominated by the flow and flooding of the Mississippi River during the past 2 million years or more. The Mississippi Alluvial Plain is an area of little topographic relief with an average slope of about 0.5 foot per mile toward the Gulf of Mexico. One of the distinct features of the alluvial plain is the formation of natural levees along the banks of the rivers, and the associated backswamp deposits that are dominated by dense alluvial clays and historically have supported extensive wetland areas. These clays have created low permeability soils, which limit the ability of rainwater to infiltrate the ground surface and may cause runoff from agricultural fields to rapidly enter rivers and streams. These clays also seem to limit the susceptibility of the ground water to surface activities in intense agricultural areas.

Thirty-five percent of the remainder of the Study Unit lies in the Gulf Coastal Plains physiographic province, which includes the area identified as the Mississippi Valley Loess Plains and Southeastern Plains ecoregions (fig. 1). The Gulf Coastal Plains are separated from the eastern edge of the Mississippi Alluvial Plain by the Loess Hills, which extend most of the length of the Study Unit. These hills are made of windblown silts, rise a few hundred feet above the Mississippi Alluvial Plain, and average about 15 miles in width. The remaining part of the Gulf Coastal Plains uplands and Southeastern Plains ecoregion generally is rolling to hilly with low to moderate topographic relief. The soils are composed, in part, of silts and are more permeable than the alluvial clays; there are indications that this allows for the downward infiltration of precipitation. This may partly protect the streams and rivers from compounds carried in runoff but may make the ground water slightly more susceptible to surface contamination. These coarser soils on steeper slopes are more erodible than alluvial soils, and large amounts of soil from the Gulf Coastal Plains uplands have



Much of the Mississippi Embayment Study Unit was bottomland hardwood forests and wetlands well into the 20th century.

eroded into the Mississippi Alluvial Plain.

In the west, the Study Unit abuts small areas of the Ozark Highlands. Limited sampling was done in these areas during this project.

The land surface generally slopes toward the Mississippi River from both the eastern and western sides of the Study Unit and to the south toward the Gulf of Mexico. Thus, nearly all of the activities in this Study Unit that influence water quality ultimately influence the water quality of the Mississippi River and the Gulf of Mexico.

Geology

The Mississippi Alluvial Plain is in the northern part of the Mississippi Embayment, a geologic structural trough in which the underlying crust of the Earth forms a deep valley. Large rivers, such as the Mississippi, Arkansas, and Ohio Rivers, have flowed through this region, carved the surface, and deposited clay, silt, sand, and gravel, collectively called alluvium. During the past 2 million years, up to 300 feet of alluvium has filled this valley. The alluvium can be grouped into three major units: the Pleistocene Prairie Complex, Pleistocene valley trains, and the Holocene alluvium (see fig. 7 for map; Autin and others, 1991; Saucier, 1994).

The Prairie Complex is older than the Pleistocene valley trains and the Holocene alluvium. Saucier (1994) suggested that the Prairie Complex was deposited between about 120,000 years ago and the time of the greatest extent of the last glacier, about 18,000 years ago. The Pleistocene valley trains were mostly deposited during two time periods, between about 60,000 and 25,000 years ago and during the waning phase of the latest glacial period between 18,000 and 10,000 years ago. Glacial outwash (melting) flowing from north to south provided enough energy to cause a braided stream depositional environment to form in the Lower Mississippi River Valley during this time. By about 9,000 years ago, the rate of glacial outwash in the Lower Mississippi River Valley declined, and valley train deposi-

During much of the growing season, rice crops are flooded with water withdrawn from the alluvial aquifer.

Cotton is still “king” in many areas of the Mississippi Embayment. Cotton requires extensive use of agricultural chemicals for successful cultivation.

Ground water is used to maintain more than 100,000 acres of catfish ponds in the MISE Study Unit.

Figure 1. Boundaries for Fenneman’s (1938) physiographic regions are very similar to Omernik’s Level III ecoregions (1987), at least in part because the surficial geology is a controlling factor in the MISE Study Unit. The only major metropolitan area in the Study Unit is Memphis, Tennessee. The area has many rivers, as well as several large river systems, including the Yazoo and St. Francis Rivers and parts of the White and Arkansas Rivers. Major crops include soybeans, cotton, rice, and corn. Catfish farms are a major component of the landscape as well as a principal user of ground water.

tion ceased. The braided stream depositional process of the Pleistocene epoch was replaced by the lower energy meander stream depositional process of the Holocene epoch near major rivers, such as the Mississippi and Arkansas Rivers. (See fig. 2 for more explanation.) Autin and others (1991) reported that the depositional transition from Pleistocene valley trains (braided streams) to Holocene alluvium (meander streams) started near Baton Rouge, Louisiana, around 12,000 years ago and migrated northward to near Cairo, Illinois, by 9,000 years ago.

The Pleistocene valley train deposits generally have a coarser grain size than the Holocene alluvium. Also, water well drillers' logs indicate that the clay and silt layer near the surface is thicker in the Holocene alluvium, whereas the underlying sand and gravel layer (alluvial aquifer) is thicker in the Pleistocene valley train deposits.

Hydrogeology

Two principal aquifer systems provide drinking-water supplies in the Mississippi Embayment—the Tertiary and the alluvial aquifers (fig. 3).

Tertiary Aquifers

The geologic groups associated with the deep Tertiary aquifers are the Midway, Wilcox, Claiborne, and the Jackson groups. The deep Tertiary aquifers sampled in this study are thick sand deposits within the Wilcox and Claiborne groups. The names of the aquifers, from youngest to oldest, include the Cockfield, Sparta, Winona-Tallahatta, Memphis, Meridian-upper Wilcox, and Wilcox.

Figure 2. Although the photograph on the left was recently taken of a stream in the Western United States, its braided condition is representative of what streams in the Mississippi Valley may have looked like during the Pleistocene geologic period. These high-energy systems allow sand and gravel carried by the stream to be deposited in the flood plain. The photograph on the right depicts a classic meandering stream. Streams like this are low-energy systems and primarily deposit clay, silt, and fine sand in the flood plains adjacent to the streams. This depositional pattern is present today and has been the dominant form of deposition in the Lower Mississippi River Valley during the last 9,000 to 12,000 years. These differences in depositional environments appear to influence the chemistry of the ground water, the bioaccumulation of pesticides, and biological communities.

The natural regional flow of ground water in the Mississippi Embayment in the Tertiary aquifers is from the outcrop areas in the upper Gulf Coastal Plain, laterally along the aquifers toward the embayment axis, and then upward through overlying confining units and aquifers to the surface of the Mississippi Alluvial Plain (Grubb, 1986; Ackerman, 1989). Pumping in the deep Tertiary aquifers has caused recharge rates to increase in the outcrop and production areas of the aquifer (Williamson and others, 1990).

Alluvial Aquifers

The Mississippi River confining unit is composed of the upper silt and clay of the Quaternary allu-

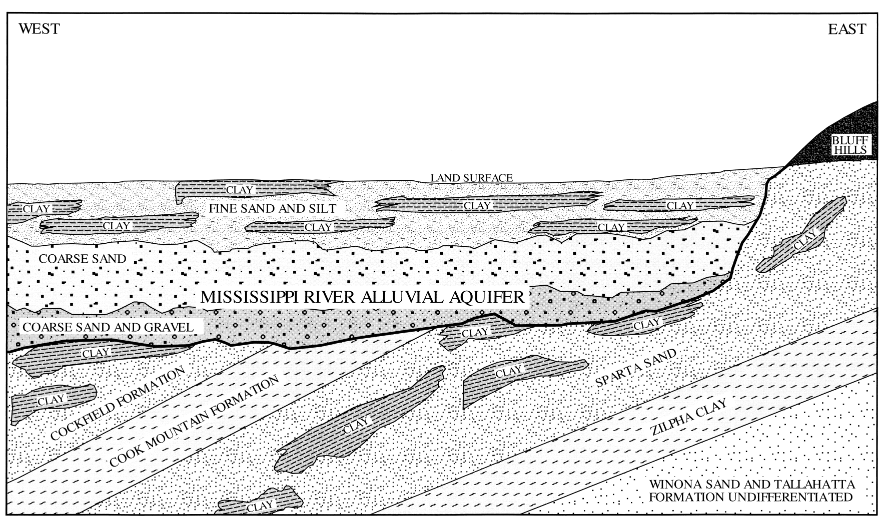


Figure 3. Generalized geohydrologic section of the Mississippi River alluvial aquifer and underlying Tertiary aquifers (from Arthur, 1994).

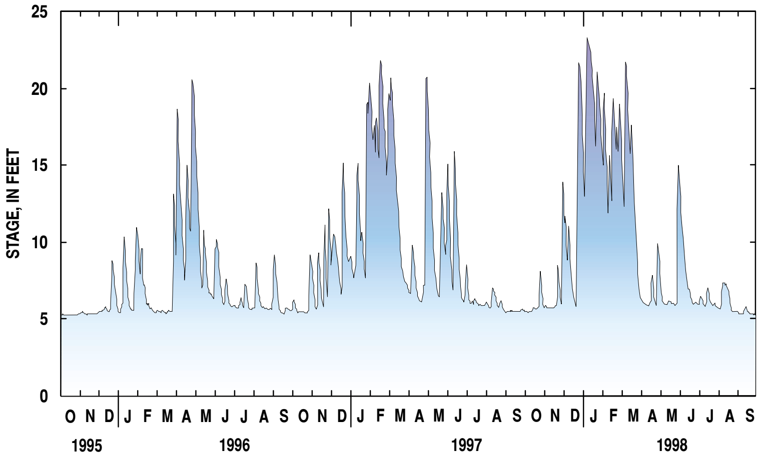


Figure 4. This hydrograph is representative of streams in the Mississippi Alluvial Plain. Often streams in this Study Unit flood rapidly, remain at high levels for long periods, and have very low streamflows in the fall. During the years of this project, 1996 was drier than usual, and 1997 and 1998 were wetter than usual.

vium, whereas the Mississippi River alluvial aquifer is composed of the lower sand and gravel of the Quaternary alluvium (Boswell and others, 1968; Ackerman, 1989). Overlying silt and clay of the confining unit impedes recharge into the alluvial aquifer. Confining unit thickness generally ranges from 10 to 50 feet and generally increases from north to south within the MISE Study Unit. The thickness of the alluvial aquifer ranges from 60 to 140 feet. Wells screened in the alluvial aquifer typically yield between 1,000 and 2,000 gallons per minute (Whitfield, 1975). Prior to development, ground-water flow is believed to have been generally from the older adjacent and underlying aquifers toward the alluvial aquifer (Williamson and others, 1990).

Climate

Climate in the MISE Study Unit varies from humid, temperate in the northern part to humid, subtropical in the southern part. This warm climate results in a long growing season and few killing frosts, which influences the types of crops that can be grown and the amount of pesticides that generally are applied. Mean annual precipitation ranges from about 48 inches per year in the northern part of the Study Unit to 56 inches per year in the southern part. Precipitation generally is greatest in April and least in October but is distributed fairly evenly throughout the year. This causes minor drought conditions to occur frequently during the summer, when the evapotranspiration rate is higher than the precipitation rate. These conditions also result in streams which flood rapidly, remain at high levels for long periods of time, and have low flows in the fall (fig. 4).

Water Use

In general, about three times as much ground water is used compared to surface water in the MISE Study Unit (fig. 5). During the summer months, both ground and surface water are used for irrigating crops. Most (in excess of 7 billion gallons per day) of the irrigation water is withdrawn from the alluvial aquifer. This aquifer is also used for domestic drinking water, aquaculture (primarily for catfish ponds), power production, and other commercial and industrial needs. Ground water, primarily from the Tertiary aquifers, is used for public supply. The principal use of surface water is for power production where it is used for cooling water for electric power generation. The second largest use of surface water is for irrigation.

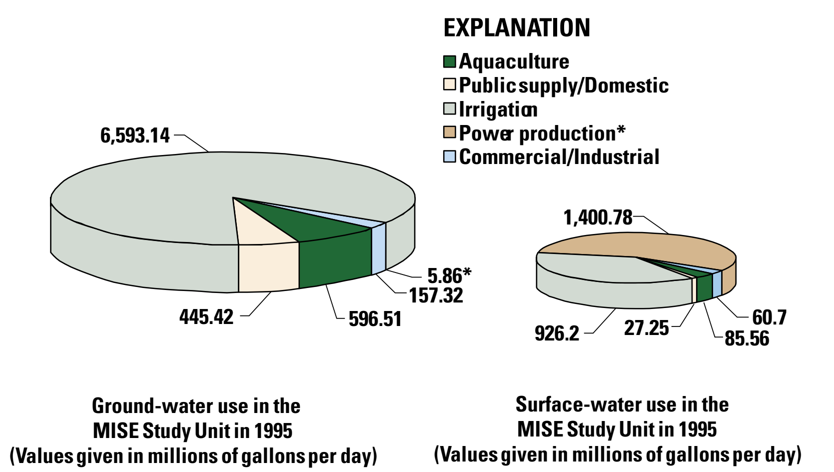


Figure 5. Ground-water use in the Mississippi Embayment (MISE) Study Unit is dominated by irrigation usage. Surface water is also used for irrigation, but more is used for cooling water for electrical power production.

Nutrient Contributions to the Mississippi River System

Although nitrogen and phosphorus, as well as silica and other nutrients, are natural and important parts of a healthy ecosystem, severe water-quality problems can arise if an ecosystem becomes enriched, or overloaded, with nutrients. In recent years, scientists have become aware of a large area of low dissolved oxygen that develops off the coast of Louisiana and Texas each summer. The extent and duration of this area of low dissolved oxygen has been related to the amount of nutrients, especially nitrogen, and freshwater flowing from the Mississippi River into the Gulf of Mexico (Goolsby and others, 1999). The proximity of the MISE Study Unit to the Gulf and the use of nitrogen fertilizer in the agricultural areas of the Study Unit, especially the Yazoo River Basin, have led to speculation that the surface waters of the Study Unit may be contributing a disproportionate amount of nitrogen and phosphorus to the Mississippi River and ultimately to the Gulf of Mexico.

In the MISE Study Unit investigations have shown that concentrations of nutrients (except total phosphorus) are higher in the Mississippi River at Vicksburg, Mississippi than near the mouth of the Yazoo River (table 1). The annual load of nitrogen and phosphorus from the Yazoo River for the 1996–97 calendar years, while significant, was only a small percentage of the load carried by the Mississippi River (Coupe, 1998).

Water-Quality Standards

Concentrations of nitrogen and phosphorus were measured from weekly to at least monthly at nine stream-sampling sites in the MISE Study Unit. Nitrate concentrations never exceeded the drinking-water standard of 10 mg/L in any sample, and ammonia concentrations did not exceed aquatic-life guidelines. However, the USEPA goal of 0.1 mg/L or less total phosphorus for streams not entering reservoirs was exceeded in every sample from the urban stream and in more than 50 percent of the samples from five streams located in the Mississippi Alluvial Plain. Samples from the streams located in the Gulf Plains exceeded the recommended goal of 0.1 mg/L or less total phosphorus in less than 50 percent of the samples.

Comparison of Nitrogen and Phosphorus in Streams in the Mississippi River Basin

The yield of nitrogen (mass per unit area), from streams in the MISE Study Unit during 1995–96 was compared to the average yield during 1980–96 from streams in

The Yazoo River, the river with the largest drainage area wholly contained in the Mississippi Embayment Study Unit, enters the Mississippi River just north of these bridges at Vicksburg, Mississippi.

Table 1. Concentrations of nutrients near the mouth of the Yazoo River compared to the Mississippi River at Vicksburg, Mississippi.

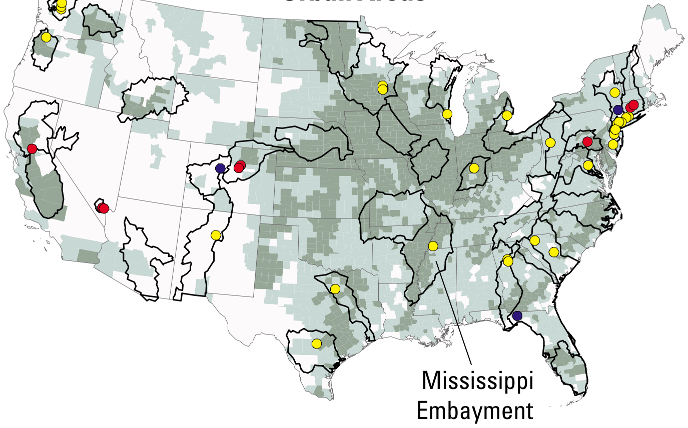
[Concentrations are in milligrams per liter]

Constituent	Site	Year	Maximum	Minimum	Mean
Total nitrogen	Yazoo River	1996–97	3.3	0.57	1.3
	Mississippi River	1984–93	3.8	1.1	2.3
Nitrate as N	Yazoo River	1996–97	1.2	0.16	0.45
	Mississippi River	1984–93	2.7	0.70	1.5
Total phosphorus	Yazoo River	1996–97	0.89	0.12	0.26
	Mississippi River	1984–93	0.38	0.04	0.16
Orthophosphate as P	Yazoo River	1996–97	0.10	0.01	0.043
	Mississippi River	1984–93	0.13	0.02	0.058

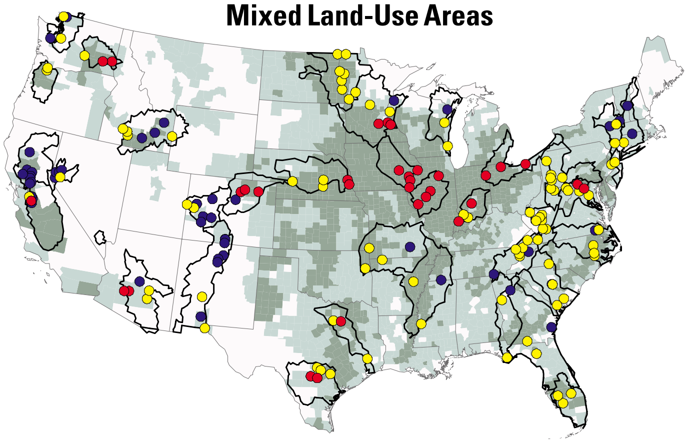
National Comparison of Total Nitrogen in Streams

TOTAL NITROGEN IN STREAMS

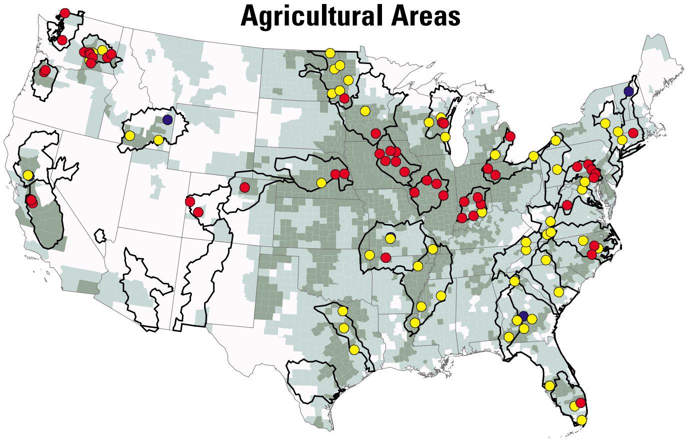
Urban Areas



Mixed Land-Use Areas



Agricultural Areas



Nitrogen is a natural and important component of a healthy stream; however, too much nitrogen can lead to degraded stream-water quality, affecting both the aquatic ecosystem and its use as a recreational or drinking-water source for humans. The sources of nitrogen in surface water are many and include atmospheric deposition, municipal and industrial wastewater, and fixation of nitrogen from the atmosphere by plants and some species of algae.

By far, the biggest source of nitrogen in an agricultural setting, such as the Mississippi Embayment (MISE) Study Unit, is from the application of fertilizer to crops. For most of the Study Unit, the average annual total nitrogen input from fertilizer, manure, and the atmosphere combined is greater than 25 pounds per acre. Most of the agriculturally productive Midwest receives the same amount.

The average annual concentration of total nitrogen from agricultural and mixed land-use streams in the MISE Study Unit is in the medium range, whereas nationally, most streams that drain areas with greater than 25 pounds per acre of nitrogen input are in the high range. The lower concentrations of total nitrogen in the MISE Study Unit may be due to the milder climate that increases microbial activity in the winter and to the increased uptake of nitrogen by vegetation during the longer growing season.

Nationally, the average annual total nitrogen concentrations in urban streams, including the one urban site in the Mississippi Embayment Study Unit, tend to fall into the “medium” classification.

EXPLANATION

Average annual concentration of total nitrogen—
in milligrams per liter

- Highest (greater than 2.9)
- Medium (0.64 to 2.9)
- Lowest (less than 0.64)

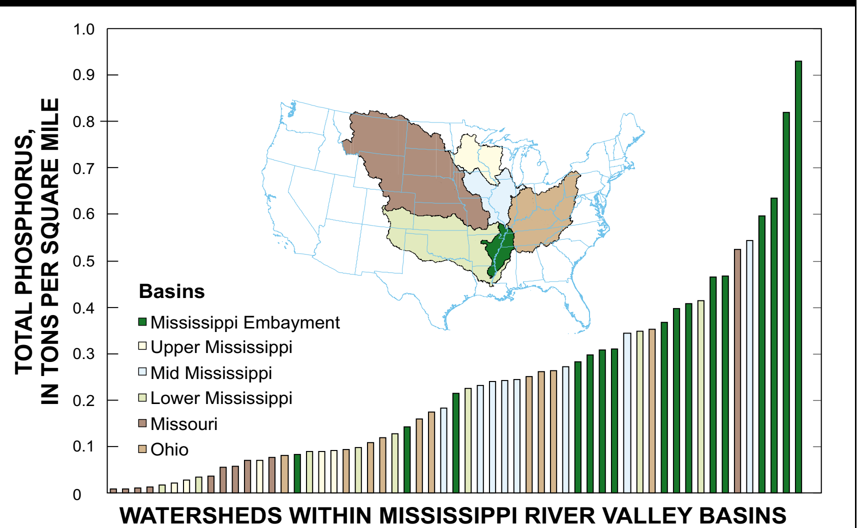
Average annual total nitrogen input—
in pounds per acre, by county, for 1995–98.
Inputs are from fertilizer, manure, and the atmosphere

- Greater than 25 pounds per acre
- 6 to 25 pounds per acre
- Less than 6 pounds per acre

the Mississippi River Basin. These data indicate that the yield of nitrogen from the MISE Study Unit was less than the average yield from streams in intensive agricultural areas of the Midwest, but more than from streams in the drier West or in the less agricultural Upper Mississippi River Basin. The flow-weighted mean total nitrogen concentrations for streams in the MISE Study Unit were generally in the 50th to 60th percentile for all data collected in the national NAWQA Program (372 steam sites). The exception was the mean nitrogen concentration at the smallest mixed land-use site which was near the 20th percentile, nationally.

The yields of total phosphorus generally were higher in the MISE Study Unit than from most other areas in the Mississippi River Basin, and the percentile ranking of the flow-weighted mean total phosphorus concentration generally was quite high (67th to 93d). Again, the exception was the smallest mixed land-use site, where the mean total phosphorus concentration was near the 40th percentile. These high phosphorus yields were somewhat unexpected, as the soils in the MISE Study Unit, while fertile, do not contain excessive amounts of phosphorus. Also, phosphorus is used less as a fertilizer in the MISE Study Unit than in many parts of the Midwest (Battaglin and Goolsby, 1995), and due to the rural nature of the MISE, there are few significant point sources. One hypothesis for the high yields and concentrations of phosphorus in the MISE involves a combination of factors, such as soils, rainfall, and agricultural drainage. The sediment in the rivers of the MISE Study Unit is composed of fine, clay-sized particles to which phosphorus can sorb. Heavy rainfalls in the Study Unit increase the potential for erosion and the movement of these fine clay-sized particles from agricultural fields into the streams. Additionally, because of the large amount of rain, the tight clays that decrease infiltration of water, and the relatively flat terrain, much of the Study Unit has artificial drainage to expedite the movement of water. Most of this artificial drainage is surface drainage, which has been shown to decrease nitrate concentrations but to increase total phosphorus concentrations.

Nutrient Yields from MISE Watersheds



Phosphorus yields from watersheds within the MISE Study Unit were the highest in the Mississippi River Basin (represented by the dark green bars). These high phosphorus yields probably are related to several factors such as soils, amounts of rainfall, and artificial drainage of agricultural fields. In contrast, total nitrogen yields in streams in the Mississippi Embayment were less than those from the agriculturally productive Midwest, but more than those in the drier western part of the basin or the cooler Upper Mississippi River Basin, and about the same as streams in the Ohio River Basin. (Data from Goolsby and others, 1999.)

The Effects of Land Use and Geology on Nutrient Concen3rations and Yields

Generally, total nitrogen and phosphorus concentrations and yields were higher in streams with predominantly agricultural land use in the Mississippi Alluvial Plain, but the highest nutrient concentrations and yields were from the urban stream. However, one stream located in the Gulf Plains in an area with no urban land use and only a moderate amount of agricultural land use had comparatively high total nitrogen and phosphorus yields. The high yields in this stream are reflective of the steep topography of the area and channelization of the stream for flood-control purposes.

More details on nutrients in the Yazoo River can be found in the report:

Coupe, R.H., 1998, Concentrations and loads of nitrogen and phosphorus in the Yazoo River, northwestern Mississippi, 1996–97: U.S. Geological Survey Water-Resources Investigations Report 98–4219, 17 p.

The report also can be downloaded at: http://ms.water.usgs.gov/misenawqa//

Pesticides Commonly Found in Mississippi Embayment Surface Water

Water samples are filtered and processed in a mobile laboratory immediately after sample collection.

The occurrence and temporal distribution of more than 80 pesticides and pesticide metabolites were determined at five stream-sampling sites from 1996 to 1998 in the MISE Study Unit. More than 230 stream samples were collected and analyzed. The five rivers sampled included three rivers with small, primarily agricultural watersheds; one river with a small, urban watershed; and one large river (the Yazoo River) with mixed land use (row-crop agriculture, forest, pasture, and a small amount of urban). Pesticides, usually herbicides, frequently were detected in water samples from all five rivers sampled. Aquatic-life guidelines were frequently exceeded in the urban stream and occasionally exceeded in all of the rivers sampled in the MISE Study Unit.

Agricultural Streams

The pesticides detected in the rivers that drain the agricultural watersheds in the MISE Study Unit showed distinct seasonal patterns that corresponded to the type of crops grown in the basin and the use of pesticides on those crops. For instance, the highest concentration of the pre-emergent herbicide atrazine frequently was found early in the growing season (April-May) corresponding to its application prior to the planting of corn and grain sorghum (fig. 6). The highest concentrations of herbicides that are used on other crops (cotton and rice) with later planting dates, or herbicides that are used after the crop has emerged from the ground, such as fluometuron and molinate, were detected later in the growing season (June–July). The concentrations of most of these herbicides were well below any acute toxicity; however, the long-term effects of chronic exposure to low levels of multiple herbicides are not well known.

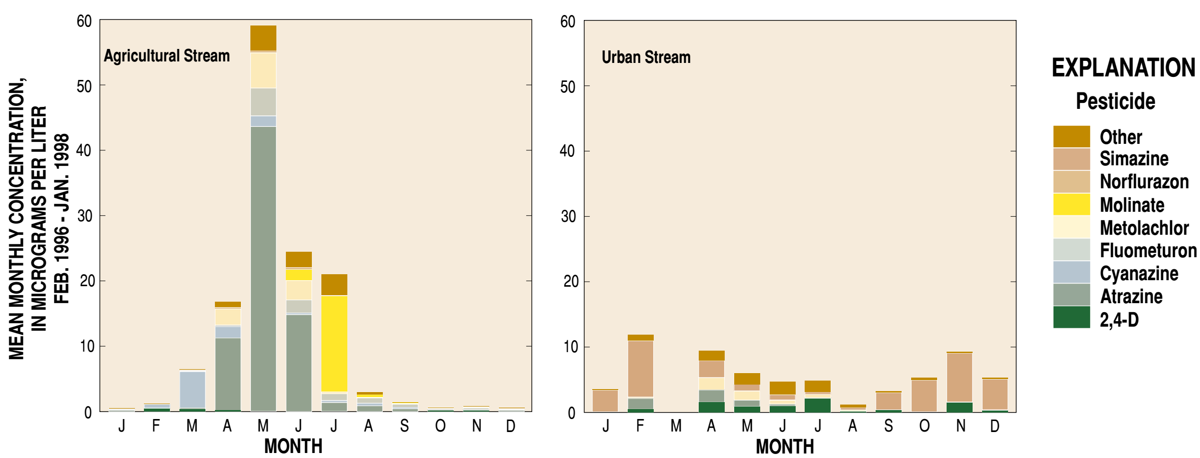
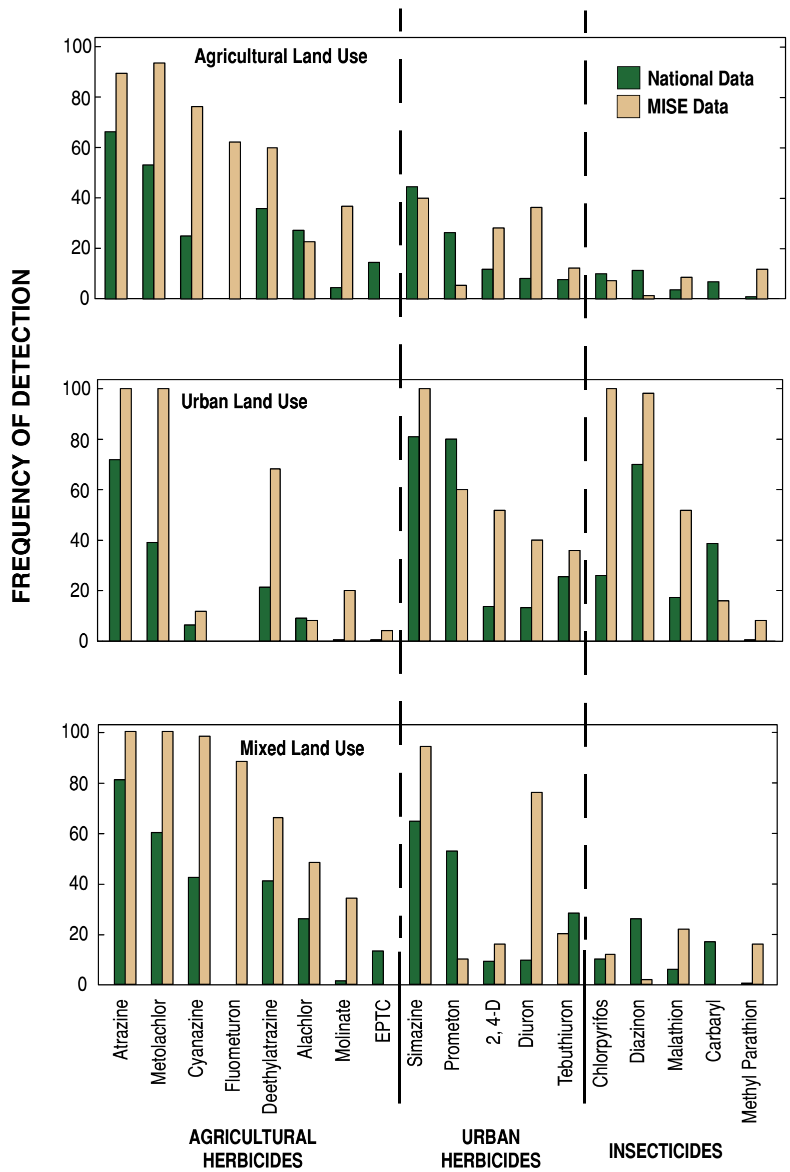


Figure 6. Herbicides in agricultural streams in the Mississippi Embayment Study Unit had higher concentrations, showed clear seasonal patterns, and contained different compounds than herbicides in urban streams. The urban stream samples were dominated by simazine, a turf grass herbicide. Concentrations of herbicides in the urban stream remained fairly constant throughout the year, whereas agricultural sites had concentrations that peaked in the spring shortly after application. Agricultural sites also were dominated by different herbicides (in this case atrazine).

Pesticides in Streams Across the United States



This diagram shows the top 15 pesticides most frequently detected in surface water at NAWQA Study Units throughout the United States and detections in surface water of the Mississippi Embayment (MISE Study Unit). Three pesticides used heavily in the Study Unit—fluometuron, methyl parathion, and molinate—but not used extensively throughout the United States, also are included for comparison. Few areas of the United States are as suited to agriculture as the Mississippi River Alluvial Plain in the MISE Study Unit. The combination of rich alluvial soils; a long, hot, growing season; flat terrain; and plentiful rainfall make agriculture the dominant economic force in the Study Unit. These same conditions also increase the weed and insect pressure and subsequently lead to an intensive use of pesticides to encourage profitable farming. In general, the frequency of detection of pesticides in surface waters of the MISE Study Unit exceed the national average.

Urban Stream

The type, amounts, and timing of the occurrence of pesticides in the stream draining an urban watershed are much different from those in the agricultural streams (fig. 6). The herbicides most frequently occurring in the urban stream such as atrazine, 2,4–D, simazine, and prometon, are those used in lawn care and in the maintenance of rights-of-way. The urban stream was also the only stream with frequent occurrences of insecticides: chlorpyrifos and diazinon were detected in every urban stream sample collected and exceeded the aquatic-life guidelines in 12 of 25 and 24 of 25 samples, respectively.

Many pesticides are applied by aircraft in the Study Unit.

DDT Metabolites in Surface Water

Although DDT strongly sorbs to sediments rather than readily dissolving in water, detectable levels of DDE, a metabolite of DDT, were found in 14 percent of the filtered stream-water samples analyzed.

More details on pesticides in streams in the MISE can be found in the report:

Coupe, R.H., 2000, Occurrence of pesticides in five rivers of the Mississippi Embayment Study Unit, 1996–98: U.S. Geological Survey Water-Resources Investigations Report 99–4159, 69 p.

The report also can be downloaded at: http://ms.water.usgs.gov/misenawqa/

Tertiary Aquifers Have High-Quality Drinking Water

During the spring of 1996, water samples were collected from 30 public-supply wells in the deep Tertiary aquifers in the MISE Study Unit. The most significant finding from this part of the study is that all of the samples analyzed from these public-supply wells met all existing drinking-water standards and guidelines. Concentrations of most of the constituents measured that could adversely affect water quality, including nutrients, pesticides, radon, and volatile organic compounds, were below drinking-water standards and guidelines.

The Deep Tertiary Aquifers

The deep Tertiary aquifers underlie about 80 percent of the MISE Study Unit. Much of the population in this part of the country depends on these aquifers for drinking water. Wells sampled range in depth from 208 to 1,460 feet below the ground surface.

Ground-water samples commonly were collected from municipal drinking-water facilities, such as the one pictured above.

Sample Results

Water from wells in the deep Tertiary aquifers had low nutrient concentrations. The highest nutrient concentration measured in a sample was 3.8 mg/L of nitrite plus nitrate nitrogen, which is less than half the drinking-water guideline of 10 mg/L. Pesticides were detected in water from only one of the wells. Water from the shallowest well sampled had a 0.16-µg/L (microgram per liter) concentration of the herbicide bromacil and a 0.004-µg/L concentration of deethylatrazine, a metabolite of the herbicide atrazine. Volatile organic compounds (VOCs) are compounds that have a high vapor pressure relative to their water solubility and include such things as components of gasoline and organic solvents. VOCs were detected frequently in the MISE, but concentrations were far below drinking-water guidelines. Samples from 26 of the 30 public-supply wells had at least one VOC detection. The VOCs most commonly detected were methylethylketone and 1,2,4-trimethylbenzene, detected in 23 and 7 percent of the wells, respectively. Nutrients, pesticides, and VOCs generally enter the ground water from surface contamination; however, public-supply wells were generally deep enough to avoid elevated levels of these compounds.

Radon in water from the public-supply wells ranged from 54 to 270 picocuries per liter; none exceeded guidelines. Radon levels found in the ground water in the MISE were the second lowest of the 16 Study Units sampled during 1996–98.

Ground-water sample preparation occurred inside plastic enclosures in order to minimize sample contamination from chemicals in the atmosphere.

Few Pesticides Detected in Memphis Shallow Aquifers

In addition to the Tertiary aquifers, 32 shallow monitoring wells (not public-supply, drinking-water wells) were sampled in the shallow aquifers near Memphis, Tennessee. Results were similar to those from the deep Tertiary aquifer study except that pesticides were more frequently detected and radon concentrations were higher. An atrazine concentration of 3.14 µg/L was measured in one well, which narrowly exceeded the drinking-water guideline of 3.0 µg/L, and dieldrin was measured above the drinking-water guideline of 0.02 µg/L in another well.

More details on ground-water quality in the deep Tertiary aquifers can be found in the report:

Gonthier, G.J., 2000, Water quality in the deep Tertiary aquifers of the Mississippi Embayment, 1996: U.S. Geological Survey Water-Resources Investigations Report 99–4131, 91 p.

The report also can be downloaded at: http://ms.water.usgs.gov/misenawqa/

Water-Quality Differences in Geological Subunits of the Alluvial Aquifer

Previous researchers have studied the alluvial aquifer as a single Quaternary feature (Grubb, 1986; Ackerman, 1989). However, during this NAWQA investigation, the results of the water-chemistry studies were examined by dividing the area into different major geologic units, two of which are the Pleistocene valley trains and the Holocene alluvium (Saucier, 1994). The data collected suggest that the differences in the geology influence the chemical makeup of the ground water in the alluvial aquifer.

The Alluvial Aquifer

The alluvial aquifer is a large, underground, water-bearing layer of sand and gravel in the Lower Mississippi River Valley (fig. 7). Water use from the alluvial aquifer is enormous; pumpage from the aquifer is about 7 billion gallons per day (Mesko and others, 1990). Most of the water pumped from the alluvial aquifer is used to irrigate crops or to maintain aquaculture, but the ground water also is used for public supply and industry.

Many of the water samples collected from the alluvial aquifer were taken from irrigation wells in agricultural areas.

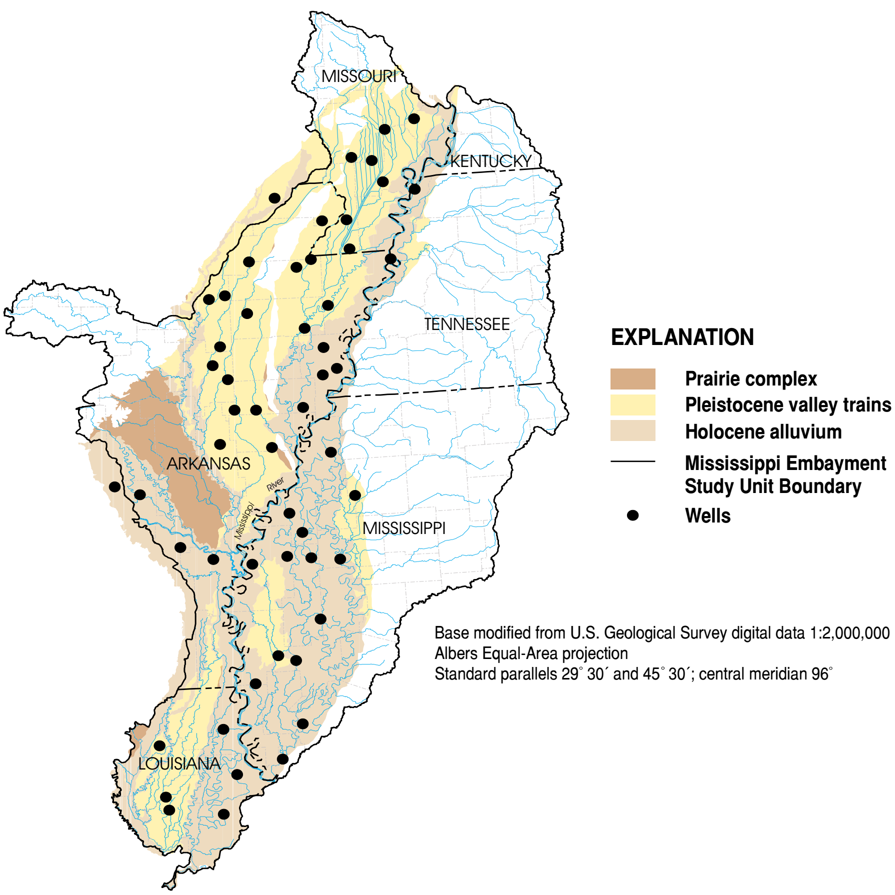


Figure 7. The colored part of this map depicts the areal extent of the three main geologic subunits of the alluvial aquifer and the location of the 54 wells that were sampled as part of this study. Statistically significant differences exist in the nutrient, carbon, and metal chemistry of the water sampled in wells located in the Pleistocene valley trains as compared to the Holocene alluvium, demonstrating the effect of geology on other components of the environment.

Water-Chemistry Analysis Results

Twenty-nine wells in the Pleistocene valley trains and 25 wells in the Holocene alluvium were sampled during the summer of 1998. At least one pesticide was detected in water from 19 of the 54 wells, but none of the concentrations were above drinking-water standards or guidelines. The most frequently detected pesticide was bentazon, an herbicide used to control weeds in soybean fields. Other pesticides detected in the alluvial aquifer in very low concentrations were molinate, fluometuron, 2,4–D, fenuron, atrazine, deethylatrazine, metolachlor, propanil, and *p,p´* DDE. At least one VOC was detected in water from 25 of 46 wells; 1,2,4-trimethylbenzene was detected most frequently. However, all of the VOC concentrations were well below drinking-water standards or guidelines.

Pleistocene Valley Trains and the Holocene Alluvium

The two subunits of the alluvial aquifer, the Pleistocene valley trains and the Holocene alluvium, have different lithological characteristics. The Pleistocene valley trains generally have coarser grain sizes than the Holocene alluvium, whereas the Holocene alluvium has a thicker clay and silt surficial unit. These characteristics indicate that ground-water flow may be more active in the Pleistocene valley trains.

Results of the ground-water chemistry showed that sulfate, pH, tritium, chloride, and radon-222 were present in higher concentrations in water from wells in the Pleistocene valley trains, whereas dissolved organic carbon, iron, ammonia, fluoride, potassium, bicarbonate, magnesium, radium-226, barium, calcium, chromium, and dissolved solids were present in higher concentrations in water from wells in the Holocene alluvium. Examples of some of these differences are shown in figure 8. Water in the Holocene alluvium tends to be older than water in the Pleistocene valley trains; that is, it has been underground longer. This increases possible contact with buried organics, resulting in less dissolved oxygen, which could influence concentrations of other chemical constituents.

Arsenic Concentrations

Arsenic, a compound that has been implicated in causing several cancers, was found at concentrations that exceeded current drinking-water guidelines in water from only one irrigation well that pumped water from the alluvial aquifer. However, concentrations at several other wells were high enough to justify additional testing if proposals to lower the standards are promulgated.

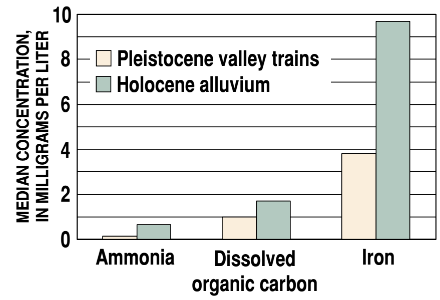
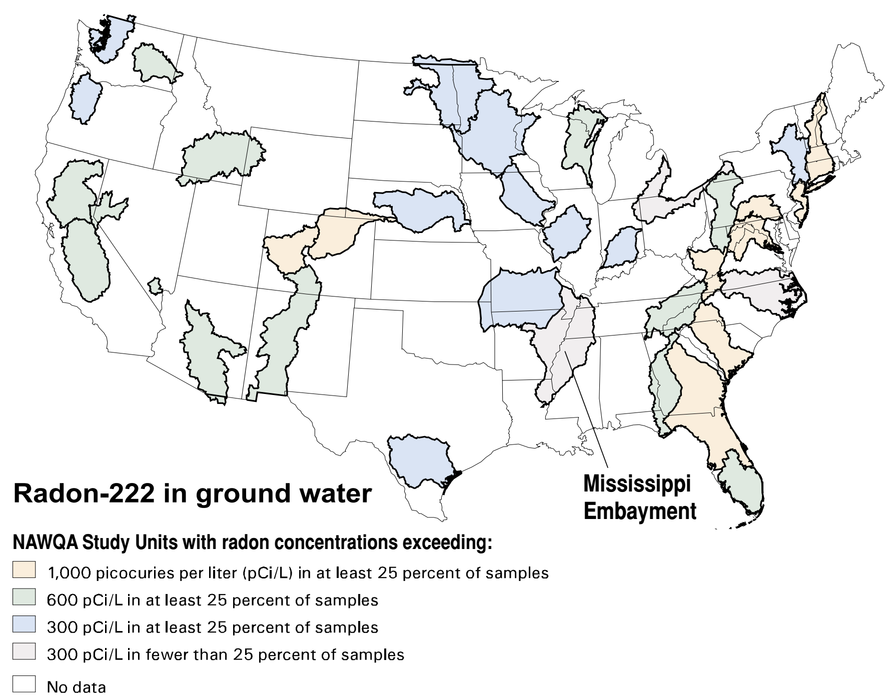


Figure 8. This graph shows some of the differences in chemistry in water from the Pleistocene valley trains and from the Holocene alluvium for a few selected constituents. Water from the wells in the Holocene deposits tended to be older and had lower oxygen levels. Low dissolved-oxygen concentrations in ground water may be associated with the presence of ammonia, dissolved organic carbon, and iron.

Radon Levels in Ground Water Low in Mississippi Embayment Study Unit

Radon is a colorless, odorless, radioactive gas that forms naturally in rocks and soils as an intermediate product in the radioactive decay of uranium-238. According to the U.S. Environmental Protection Agency, breathing radon in indoor air is the second leading cause of lung cancer in the United States. Radon can enter homes from soil or bedrock through cracks in basements or foundations, or it can be released from water during bathing, cooking, or showering.

Radon is highest in areas where there are uranium-rich metamorphic and igneous rocks. Because the MISE Study Unit is located in an area of thick alluvial soils that have few rocks, the radon levels in the ground water are some of the lowest reported by the NAWQA Program.



Aquatic Communities Show Environmental Stress

A combination of natural and anthropogenic (human-related) factors results in stream conditions that stress aquatic communities in the Mississippi Embayment Study Unit. The streams have naturally low gradients that result in sluggish flows and slow rates of reaeration (the ability of oxygen to enter the water). Also, the streams, in their natural conditions, have an abundance of streamside vegetation and swamps, resulting in an abundance of organic material in the water. This organic material is a good source of food for invertebrates (aquatic insects, crayfish, and freshwater shrimp) that inhabit the streams, but decay of the organic material and seasonally high water temperatures contribute to low dissolved-oxygen concentrations. The combination of low flow, high organic concentrations, and high temperatures results in a natural environment in which the organisms are often stressed by low dissolved-oxygen concentrations.

These natural conditions are coupled with many anthropogenic conditions in the area. These include stream channelization, which can eliminate riparian vegetation and degrade stream habitat; agricultural runoff into streams, which adds sediments, pesticides, and fertilizers to the aquatic environment; and the decline in the base flow of the streams due to ground-water withdrawal, which reduces the quantity of water available for organisms. This combination of natural and anthropogenic conditions affects each of the major biotic communities differently.

Algae

As a result of the dominant agricultural land use, fine alluvial soils, and limited vegetation in streamside or riparian areas, most of the streams in the MISE Study Unit are very turbid. Turbidity refers to the reduced clarity of surface water due to particles (usually sediment) suspended in the water. Many of the streams within the MISE also have moderately high phosphorus levels, which encourage algal growth. However, the algal growth in the streams is often more limited by the inability of light to penetrate the turbid waters, than by lack of nutrients. One indication of this can be seen in the Algal Siltation Index on page 17. This index uses the relative abundance of diatom species, which are able to move and avoid being buried under large amounts of sediment, as an indication of stream-water quality. Levels of this index are high in agricultural areas of the MISE and moderate in mixed land-use areas.

Aquatic Invertebrates

Aquatic invertebrates in the MISE are influenced by habitat quantity and quality as well as by water chemistry. Often, the loss of stream and riparian habitat in the MISE is associated with stream channelization, where streams have been cleared, ditched, and straightened to facilitate the movement of floodwaters. These activities also result in the loss of microhabitats that are essential to aquatic invertebrates for food sources and refuge. Lower numbers of invertebrate taxa were found at sites that had

Streams in the Mississippi Embayment Study Unit have small changes in elevation from their headwaters to the mouth of the stream. This makes them very slow moving and generally contributes to low oxygen concentrations in the streams. The natural streams commonly have swamps adjacent to them, resulting in water stained with organics, ample habitat, and difficult sampling conditions, as shown above. The many channelized streams in the area (see upper left photograph) have commonly lost all of their riparian vegetation, and the streams have little habitat for aquatic organisms.

Some of the samples for both algae and invertebrates were collected by scraping organisms off submerged sticks in the streams. These sticks are commonly some of the best remaining habitats in many streams and rivers in the Mississippi Embayment Study Unit.

A prime habitat for invertebrates in the Mississippi Embayment Study Unit is this “undercut bank” where insects and other organisms hide in the roots and sticks. This habitat is removed or disturbed by channelization of streams and rivers or other habitat alterations.

lower habitat quality (fig. 9). Other factors, including turbidity, low dissolved-oxygen concentrations, and the introduction of contaminants to the water, also affect invertebrate communities.

When compared to samples collected in other NAWQA Study Units across the United States (p. 17), invertebrate communities in MISE agricultural areas have low numbers of species and high proportions of tolerant organisms.

Fish

The condition of the fish communities in the MISE Study Unit was related to both water quality and land-use activities. The best quality fish communities occurred where instream variables such as turbidity, total ammonia, the average number of herbicides detected, and total DDT in fish tissue were lowest. As shown in figure 10, the number of bass, an important game fish in the MISE, was highest at the sites where the turbidity was lowest. The condition of the fish communities also was correlated to landscape-level variables such as insecticide application rates and soil permeability.

When compared to fish communities collected at NAWQA Study Units across the Nation (p. 17), the MISE had more fish that are omnivores (that is, fish that eat whatever is available and therefore are more tolerant than fish that have more restrictive diets) and more fish that are considered tolerant of poor water-quality conditions. However, there were fewer anomolies (sores, parasites and other abnormalities on the fish) and non-native fish found in the MISE than in other locations. This resulted in an overall national fish ranking of MISE agricultural streams slightly below the midpoint between the most degraded and least degraded streams in the NAWQA Program, whereas mixed land-use streams ranged from good to less than average.

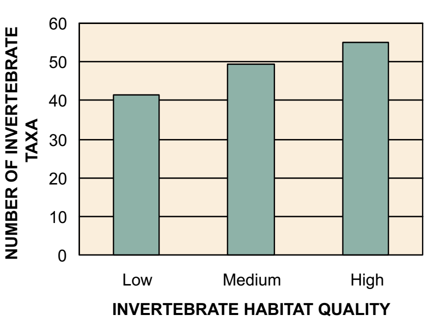


Figure 9. The number of invertebrate taxa increased as the quality of the invertebrate habitat increased in MISE streams.

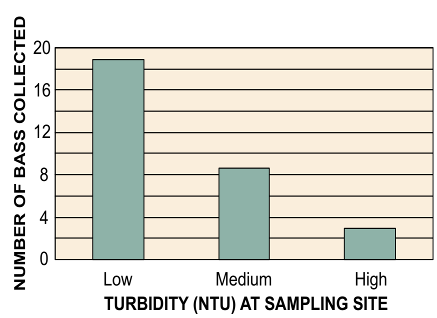
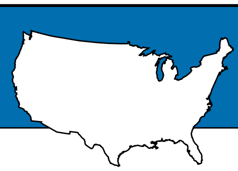


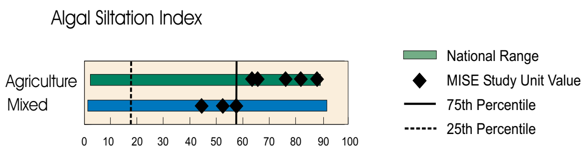
Figure 10. The number of bass collected at a stream site was highest in those streams where the turbidity was the lowest.



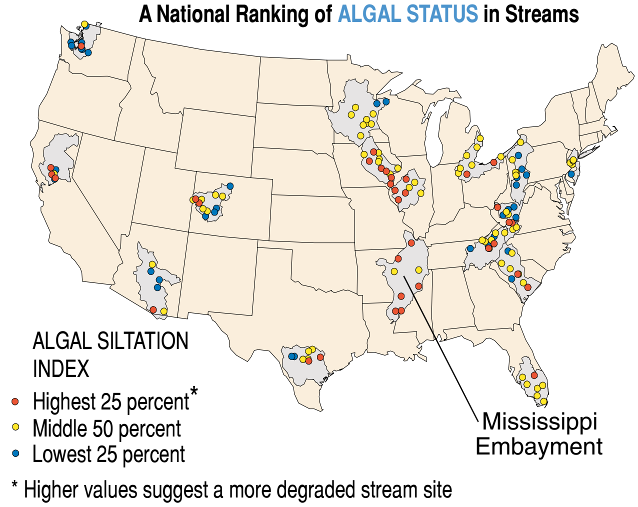
Comparison of Mississippi Embayment Aquatic Communities to National Results

Algal Siltation Index

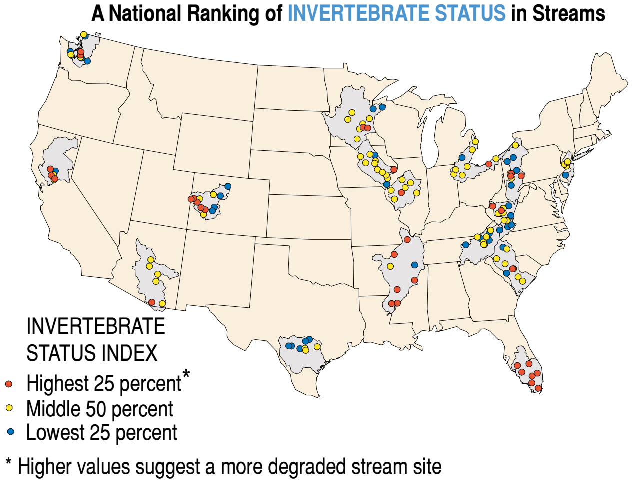
Algae collected at the 8 MISE basic fixed ecology sites were compared to algae at 140 other NAWQA sites by use of the Siltation Index (Bahls and others, 1992). This index is the relative abundance of motile diatoms, the species *Navicula*, *Nitzschia*, *Cylindrotheca*, and *Surirella* in a diatom count. These diatoms are able to move through silt particles and are associated with fine sediments. Because they are able to avoid being buried, they are considered more tolerant of sedimentation than other diatoms. Generally, this index tends to be higher for streams in agricultural basins. Relative to this index, all of the MISE agricultural sites fall into the most-degraded category for streams along with one of the mixed land-use sites, whereas the other two sites fall into the middle 50 percent.



A National Ranking of ALGAL STATUS in Streams

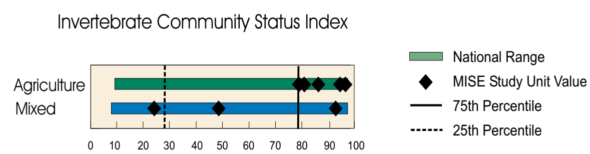


A National Ranking of INVERTEBRATE STATUS in Streams



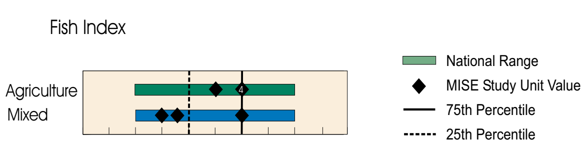
Invertebrate Community Status Index

To compare the invertebrate communities at MISE ecological basic fixed sites to national sites, a multimetric index called the Invertebrate Community Status Index was developed. The index combines 11 metrics, including ones that address taxa richness and diversity, richness of mayflies, stoneflies, and caddisflies, and tolerance metrics. Relative to this index, MISE agricultural streams are all ranked within the 25-percent most-degraded category for streams, whereas the mixed land-use streams have one site that falls into each category. Across the United States, both agricultural and urban sites tend to fall into the more degraded category.

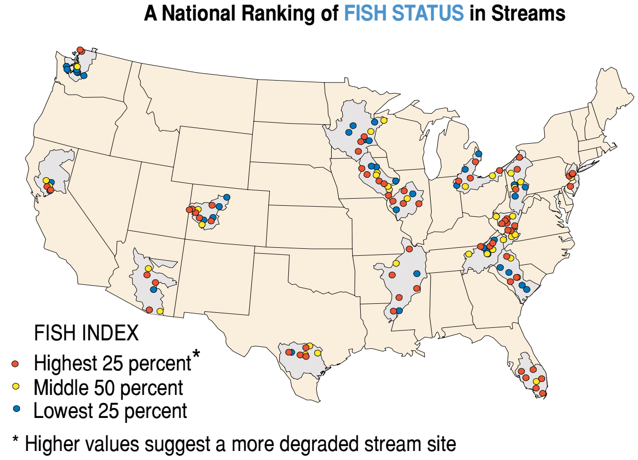


Fish Community Index

Similar in concept to the invertebrates, a multimetric fish index was developed to facilitate the comparison of fish communities across the United States. This index included four metrics: the percentage of tolerant individuals, the percentage of omnivorous individuals, the percentage of non-native individuals, and the percentage of individuals with anomalies. In all four metrics, a high percentage of individuals with the characteristic is typical of degraded sites. Agricultural sites in the MISE Study Unit generally fell at the boundary between the most-degraded category and the middle 50 percent (four sites are represented by the symbol at the 60-percent point). The mixed land-use sites ranged from the least-degraded category to the highly degraded category.



A National Ranking of FISH STATUS in Streams



Organochlorine Pesticides Persist in Fish Tissue

During the 1950s and 1960s, organochlorine pesticides were heavily used in the MISE Study Unit to control insects, particularly those associated with the cultivation of cotton. One of the most widely used organochlorine insecticides was DDT. In 1972, the sale of DDT was discontinued, and the use of most of the persistent organochlorine pesticides was discontinued during the 1970s. Nearly 30 years later, however, DDT or its metabolites were detected in fish tissue from all 41 sites sampled in the Study Unit. Thirty of these sites have total DDT levels in excess of the 0.2-mg/kg (milligram per kilogram) or 200 µg/kg (micrograms per kilogram) criterion set by the State of New York for the protection of fish-eating wildlife (Newell and others, 1987).

Although somewhat less prevalent and at lower concentrations, other organochlorine compounds also were detected in fish, including chlordane (at 33 percent of the sites), dieldrin (79 percent), heptachlor (7 percent), mirex (29 percent), and toxaphene (56 percent).

Most of the rivers in the MISE Study Unit were too deep to wade, so boat-mounted electroshocking equipment was used to collect fish (usually common carp) for tissue analysis.

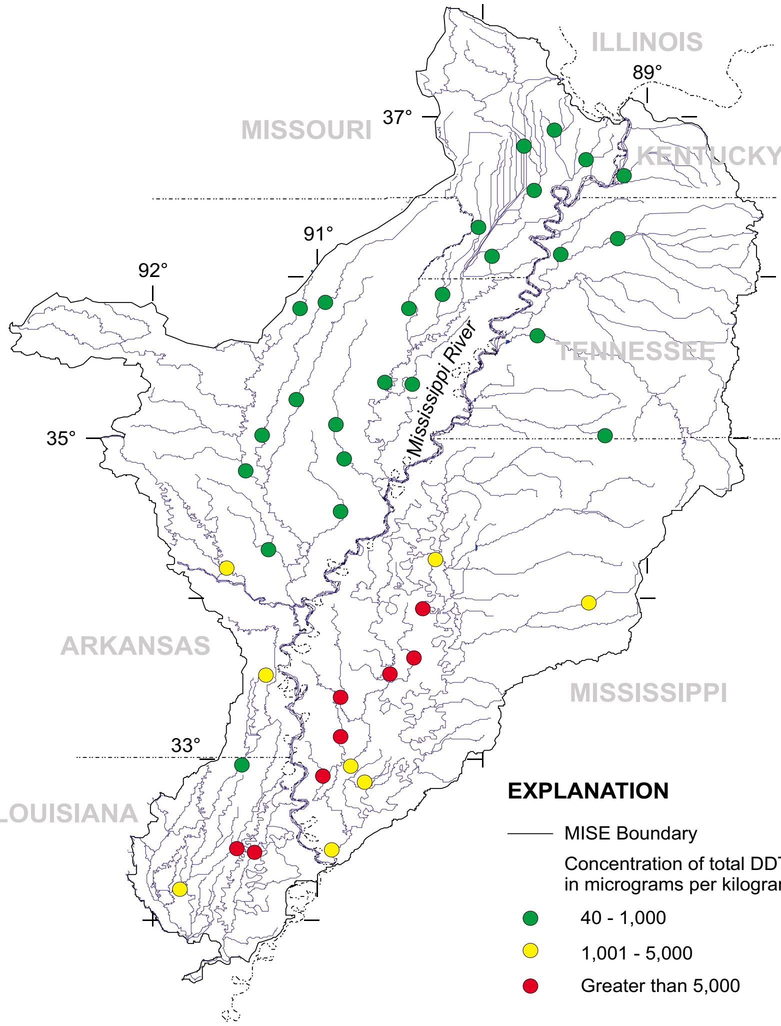


Figure 11. The concentrations of organochlorine pesticides were measured in fish tissue collected at 41 sites in the MISE Study Unit. Total DDT, an insecticide that has not been sold in the United States since 1972, was detected at all sites and occurs in concentrations that are of possible human health concern at some sites.

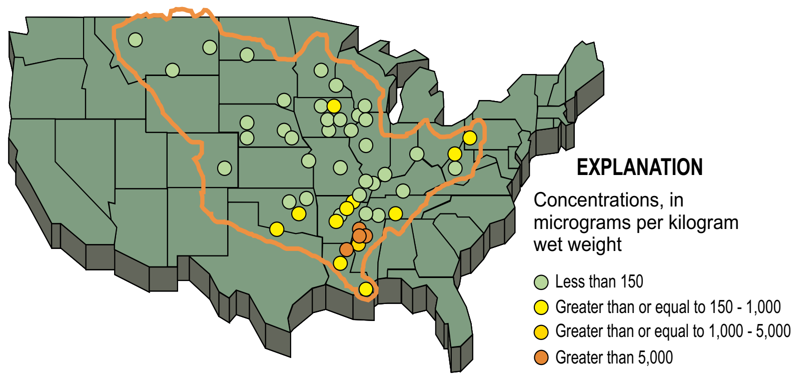
Of the 506 sites sampled thus far in the National Water-Quality Assessment Program, the highest concentrations of total DDT and toxaphene were found in fish collected in the Mississippi Embayment Study Unit (see pages 33 and 34 in Appendix A).

Distribution of Concentrations of DDT Within the Mississippi Embayment Study Unit

Although DDT was detected in fish tissue at every sampling site, tissue samples from sites in the southern part of the Study Unit (fig. 11) had much higher concentrations of total DDT. On a national scale, Nowell and others, (1999) presented a positive correlation between median total DDT concentrations in whole fish and agricultural use of DDT in 1966. In the MISE, however, there seem to be additional factors influencing the persistence of DDT in fish tissue. Fish tissue data were compared to dozens of land-use and water-chemistry variables. Good correlations can be made between total DDT concentrations and dissolved ammonia, nitrate, total phosphorus, and turbidity. The correlations with land-use variables, such as the percentage of the basin in agricultural production or the percentage of the basin in which cotton is grown, are much weaker, suggesting that factors in addition to land use and pesticide use are contributing to the distribution of DDT.

A relation exists between the concentrations of DDT in fish tissue and the geology of the area. Total DDT concentrations are much higher at sites in the Holocene alluvium than in the Pleistocene valley trains (fig. 12). The soils and geologic deposits in the Holocene alluvium are largely composed of dense clays that may cause agricultural runoff from these areas to enter the streams directly rather than infiltrate through the soils. Also, DDT tends to sorb onto clay particles and may be carried into streams attached to these particles. Once in the stream, the cohesive nature of clay tends to prevent the material from moving downstream. These combined mechanisms may cause greater amounts of DDT to be in streams and available to organisms in Holocene areas than in streams in the Pleistocene valley trains.

DDT in Fish Tissue in the Mississippi River Valley



Fish collected in 1995 during an interdisciplinary USGS study found that the highest total DDT levels in the Mississippi River Valley were measured in the MISE Study Unit. Information about study methods can be found in Schmitt and Dethloff (2000).

Total DDT concentrations were detected in streambed sediments at all 15 sites measured. However, the concentrations in the sediments were many times lower than those in fish tissue.

Human Health Considerations

Because the NAWQA sampling was designed to measure the occurrence and distribution of compounds in the environment rather than address human health issues, whole fish (usually common carp) rather than fish fillets or other edible fish parts were analyzed for organochlorine compounds. However, the high concentrations of organochlorines that were detected at some of the sites in the MISE Study Unit suggest the need for further investigation. In the years since the sale of DDT and toxaphene has been discontinued, concerns have been raised about not only the toxicity of the pesticides but also the carcinogenic nature of organochlorine compounds.

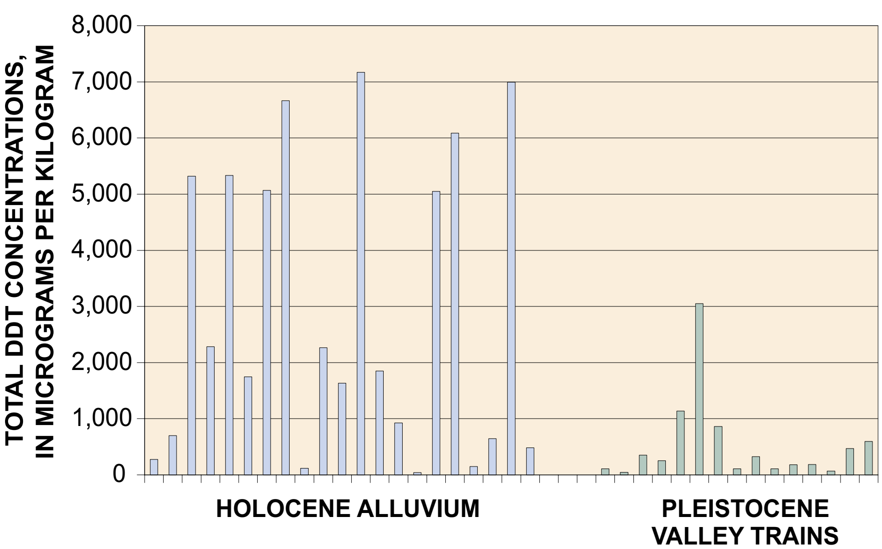


Figure 12. The concentration of total DDT in fish tissue is higher at Holocene alluvium sampling sites than at sites in the Pleistocene valley trains. The mean concentration for the Holocene sites is 2,895 micrograms per kilogram, while the mean concentration for the Pleistocene sites is 522 micrograms per kilogram.

Pesticides in Air and Rain Samples from Agricultural and Urban Sites

During the 1995 growing season, weekly air and rain samples were collected from two sites in Mississippi and analyzed for 49 pesticides and pesticide metabolites. The two sites represented an agricultural area and an urban area. Every air and rain sample had detectable levels of multiple pesticides; the pesticides detected and the frequency of detection varied between the two sites and were related to the types of pesticides used nearby. However, long-range transport appears to have an effect, as some pesticides that are not registered for use in an urban setting were found in air and rain samples at the urban site. These findings demonstrate that small amounts of pesticides can be transported through the atmosphere and deposited into aquatic and terrestrial ecosystems at a substantial distance from their point of use.

Pesticides in the Air

Pesticides can enter the atmosphere through volatilization, wind erosion of soil particles to which pesticides are attached, and direct spraying into the atmosphere during pesticide application.

Seasonal distribution of pesticides at the agricultural site is related to local application times of individual compounds. At the start of the study in April, the herbicides pendimethalin and trifluralin were the pesticides found in the highest concentrations in the air. In May, the two pesticides with the highest measured concentrations were the herbicides propanil and thiobencarb, which typically are used on rice. By August, the insecticide methyl parathion was detected in the highest concentration of any of the pesticides in the air at the agricultural site.

In contrast, diazinon was detected in the highest concentration in the air at the urban site. Chlorpyrifos also was detected frequently, and carbaryl, methyl parathion, and trifluralin were found less often. Although most of these compounds are used commonly in residential settings for such purposes as termite control, methyl parathion is used only for insect control in agricultural settings, thus suggesting the long distance atmospheric transport of this compound.

The yellow polyurethane foam plug was used to collect pesticides distributed into the gas phase of the atmosphere.

Pesticides in the Rain

Once in the atmosphere, pesticides can be degraded, transported, and (or) redeposited. Deposition can be either wet, as with rain or snow, or dry, as with gaseous sorption and particle fallout.

The urban atmospheric sampling site on the left is in a residential area in southern Jackson, Mississippi, a metropolitan area of about 400,000 people. The site is more than 10 miles from the nearest agricultural field. The agricultural site on the right is located in the center of a catfish pond complex in Sharkey County, Mississippi. This site was selected to measure pesticides in the atmosphere in an area with minimal influence of direct application of pesticides to nearby fields. The nearest agricultural field is about one-half mile away, and the major crops grown in this area are soybeans, cotton, corn, and rice.

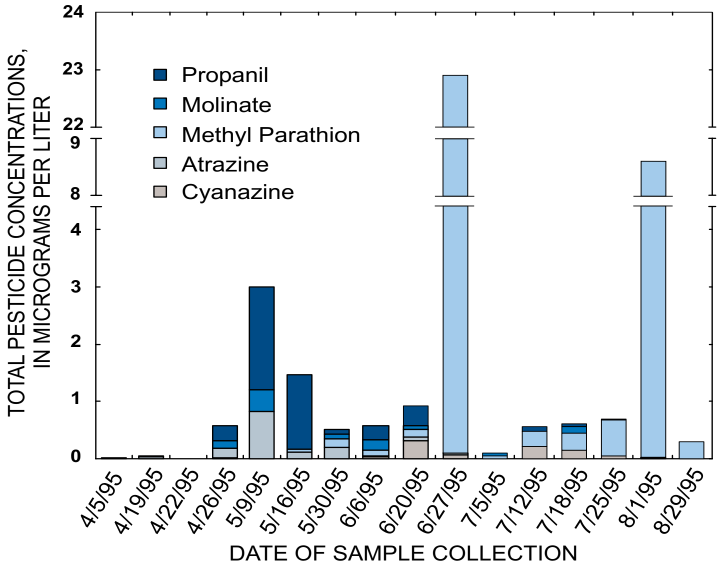


Figure 13. Pesticide concentrations in rainfall samples collected at an agricultural site in Mississippi during the 1995 growing season. In the spring, atrazine and propanil were detected in higher concentrations, but by summer the dominant pesticide measured was methyl parathion.

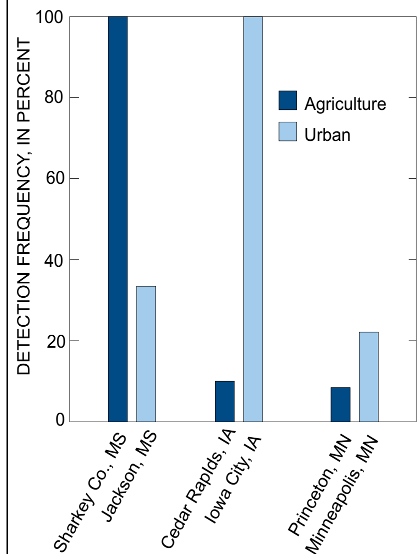
The concentrations of selected pesticides detected in rainfall samples from the agricultural site are shown in figure 13. The pesticides detected in the highest concentrations during the early part of the growing season were the herbicides atrazine, used on corn and grain sorghum, and propanil, used mainly on rice. Later in the growing season, the pesticide found in the highest concentrations was the insecticide methyl parathion.

The pesticides detected in rainfall samples from the urban site—atrazine, carbaryl, methyl parathion, and propanil—were similar to those found at the agricultural site, but the concentrations were much lower. Because methyl parathion and propanil do not have legal urban uses, it is assumed that these pesticides were transported in the atmosphere from their application areas. Methyl parathion and propanil are the first and sixth most heavily used agricultural pesticides in Mississippi.

Metabolites of DDT in the Air

In order to fully understand the fate, transport, and environmental effects of a pesticide, major metabolites of the pesticide commonly are included in the sampling program. One of the major metabolites of the organochlorine insecticide DDT is *p,p´*-DDE. In 1971, Stanley and others (1971) detected *p,p´*-DDE in the air at an agricultural site near Stoneville, Miss. (about 60 miles north of the Sharkey County site) in concentrations ranging from 2.6 to 7.1 ng/m^3 (nanograms per cubic meter). Twenty-four years later, the range of *p,p´*-DDE in air samples from the agricultural site ranged from 0.13 to 1.1 ng/m^3, lower than reported by Stanley and others (1971) but still significant considering that there is no current use of DDT in the area. These results indicate that a persistent metabolite of *p,p´*- DDT was still measurable in the air more than two decades after the sale of DDT was discontinued in the United States.

DDT Metabolites in the Air Across Mid-America



The air concentrations of *p,p´*-DDE, a metabolite of DDT, were determined at paired urban and agricultural sites in Mississippi, Iowa, and Minnesota (Foreman and others, 2000). The agricultural site in Mississippi and the urban site in Iowa had detectable levels of *p,p´*-DDE in every sample. Approximately 10 to 30 percent of the samples collected at the other sites had detectable levels of *p,p´*-DDE. It is likely that these concentrations of *p,p´*-DDE are from past local use of DDT. However, DDT is still being used in other parts of the world, and it is possible that some proportion of this *p,p´*-DDE originated elsewhere and was transported in the atmosphere.

More details on pesticides in the atmosphere can be found in the paper:
Coupe, R.H., Manning, M.A., Foreman, W.T., Goolsby, D.A., and Majewski, M.S., 2000, Occurrence of pesticides in urban and agricultural areas of Mississippi, April–September 1995: Science of the Total Environment, v. 248, no. 2–3, p. 227.

The paper also can be downloaded at:
http://ms.water.usgs.gov/misenawqa/

Integration of Biological, Geological, and Chemical Data Improves Understanding of Aquatic Systems

One of the most significant advances in the aquatic sciences during the last century is the growing understanding that aquatic systems, such as lakes and rivers, are profoundly influenced by the biological, chemical, and physical aspects of the drainage basin in which the water body is located (Wetzel, 1983). Although the conceptual framework for these ideas is decades old, scientists are still developing the technologies and accumulating the data bases necessary to more fully understand the relations between a body of water, the biotic components within it, and the chemical and physical influences of the drainage basin.

In the NAWQA Program, researchers often collect biological, geological, and chemical information from the same stream sites and analyze land use from the corresponding drainage basins. This information presents an opportunity to examine biogeochemical relations within the watersheds. This interdisciplinary approach has yielded at least three broad findings in the MISE Study Unit. Three findings, which need to be examined in more detail to guide scientific understanding and management in this region, are: (1) DDT and its metabolites remain detectable in many parts of the environment; (2) numerous interrelations exist between the biological, geological, and chemical components of the MISE Study Unit; and (3) evidence exists that the geology of the Study Unit exerts an influence on many aspects of the environment.

DDT and Its Metabolites Are Present Throughout the Environment

Nearly 30 years after the sale of DDT was discontinued, the pesticide and its metabolites were detected in all parts of the MISE Study Unit environment. While residual total DDT is found throughout the world, the concentrations in the MISE are among the highest in the United States. (See water, fish tissue, and bed sediment sections of the national comparison tables on pages 31, 33, and 34 for a comparison of MISE results to other NAWQA Study Units in the United States.) A metabolite of DDT, DDE persists in various concentrations in many different parts of the MISE environment, including the air, water, streambed sediment, and fish tissue, generating interesting questions about its transport, accumulation, and persistence.

Biological and Chemical Relations

The MISE Study Unit has numerous complex interrelations among stream biology, basin geology, stream chemistry and land use. Some of these interrelations are illustrated by a variety of linear relations among biological, geological, and chemical components of 36 stream sites and their drainage basins in the MISE Study Unit (fig. 14). Figures 14A and 14C illustrate how differences in stream chemistry can affect biological communities in the stream. Figure 14A shows that the number of insectivore fish taxa decreases as total ammonia increases, whereas figure 14C

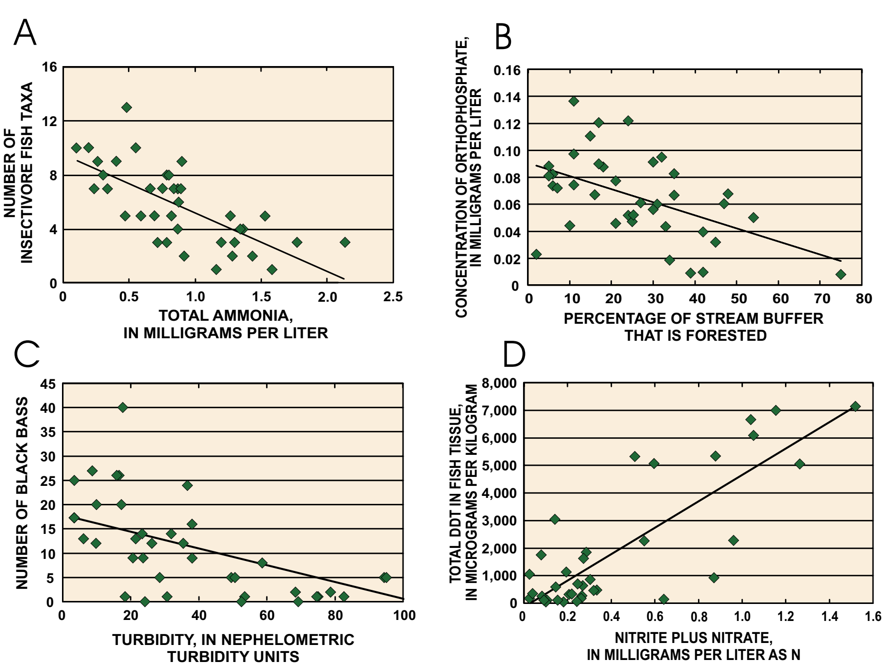


Figure 14. There are numerous interrelations among stream biology, basin geology, stream chemistry, and land use in the Mississippi Embayment Study Unit. The lines in these graphs represent linear relations between some of the variables.

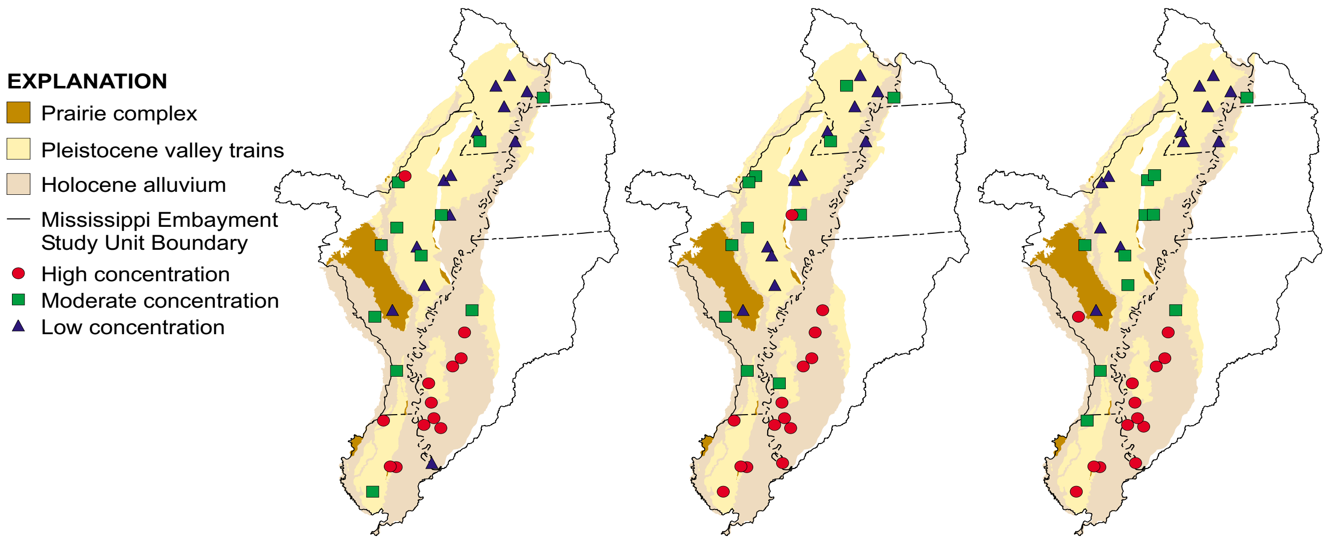


Figure 15. Several variables in the MISE Study Unit vary spatially and correspond generally to the Quaternary geology of the Mississippi Alluvial Plain. Soils formed from the Holocene alluvium tend to be dense, thick clays, whereas the Pleistocene features tend to have soils that have more silts and sands. These soils influence permeability and runoff, which in turn, appear to affect the amount and persistence of agricultural chemicals in the streams.

shows that the number of black bass decreases as turbidity increases. Figures 14B and 14D show how factors in the drainage area, but not in the stream, can influence the stream. Figure 14B shows that as the percentage of forested stream buffer (the area within 60 meters of the streams) increases, concentrations of orthophosphate in the stream decrease, indicating the value of vegetated stream buffers in minimizing the amount of runoff entering streams and rivers. Finally, figure 14D illustrates that as the concentration of dissolved nitrite plus nitrate increases, the amount of total DDT in fish tissue increases, suggesting that conditions that facilitate agricultural runoff affect nutrient levels in the streams and the long-term bioaccumulation of organochlorine pesticides in fish tissue.

The sum of these various relations shows the complexity of the system, underscores the need for multidisciplinary studies in order to thoroughly understand the Mississippi Embayment Study Unit, and discourages simplistic, one-dimensional management solutions.

Geology Influences Many Variables

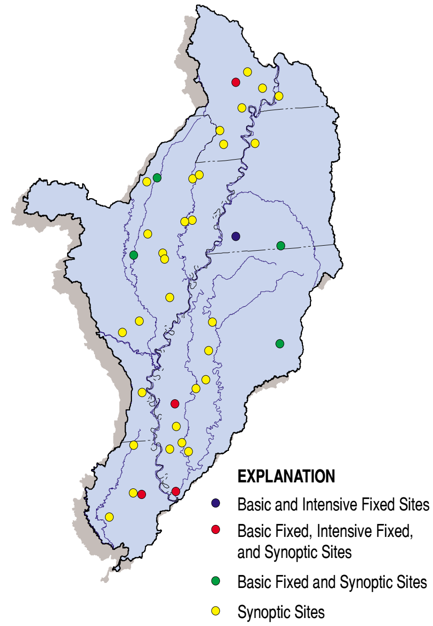
Within the Mississippi Embayment Study Unit, the geology of the land surface appears to exert an overarching influence on many components of the environment. The dense, tight clays of the Holocene alluvium dictate the types of crops grown and cause high runoff potential in the area. These factors help to determine the types of agricultural chemicals that are applied and the amounts of these chemicals that are transported into rivers and streams. Once in the streams, the clays tend to cause chemicals sorbed to sediments to remain locally in the bed sediment rather than to be washed downstream. Sites where high concentrations of ammonia were found are clustered in the Holocene alluvium (fig. 15A), whereas similar clusters occurred for the number of herbicides detected in the water (fig. 15B) and the amount of total DDT found in fish tissue (fig. 15C). In turn, many biological metrics were lower at sites located in the Holocene alluvium, and differences in ground-water chemistry were detected (pages 13 and 14).

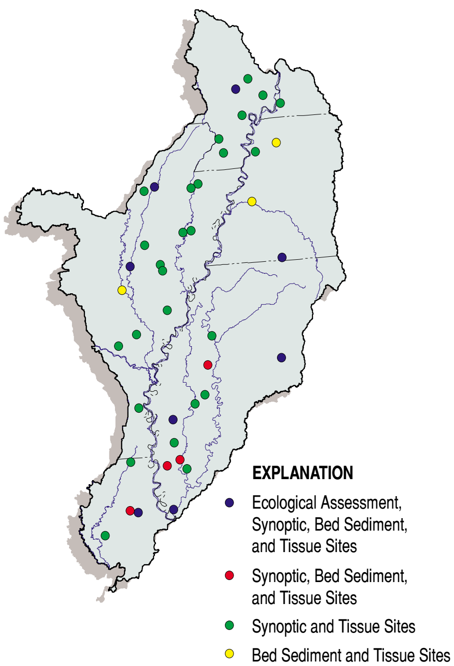
This information reaffirms that a better understanding of the underlying geology of the Earth itself is needed to fully understand the effects of human activities on the environment.

Carp used for tissue analysis.

Stream Chemistry

The stream-chemistry network was designed to measure the effects of land use (primarily cropland) on stream quality and to integrate the effects of multiple land uses and hydrogeologic settings on water quality. Data from the Basic Fixed Sites were used to examine differences in water quality from one basin to another. Data from Intensive Fixed Sites, which were sampled more often, were used to examine seasonal changes in stream quality and to calculate fluxes from the basin. Also, detailed data on pesticides dissolved in the water were collected at intensive sites. A synoptic study was conducted to measure a selected set of constituents at 38 sites in the Study Unit in order to better understand spatial differences among the basins and to compare water chemistry to biological and landscape parameters.



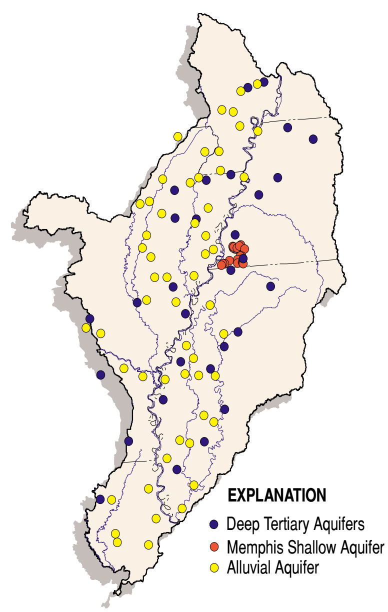


Stream Ecology

Ecological assessments were done annually at the basic and intensive stream-chemistry sites. The objective of these studies was to investigate biological, chemical, and physical data as multiple lines of evidence to assess water quality. Some of the assessments examined multiple reaches of a stream to determine spatial variations in the community structure of the aquatic organisms. Synoptic studies were designed to examine spatial variability in biological communities in the Study Unit and to relate this variability to stream chemistry and landscape variables. Early in the project, bed sediment and fish tissue were sampled at a subset of sites; later in the project, fish tissue was sampled for organochlorine concentrations at all of the synoptic sites.

Ground-Water Chemistry

Three surveys examined the effects of land use on ground water in different aquifer settings. The deep Tertiary aquifers are the deepest aquifers studied and the ones that provide drinking water to the greatest number of people in the Study Unit. The Memphis shallow aquifer survey was designed to assess the ground-water quality in commercial and residential areas. The alluvial aquifer survey examined ground-water quality from a shallow aquifer that is heavily used for agriculture.



SUMMARY OF DATA COLLECTION IN THE MISSISSIPPI EMBAYMENT STUDY UNIT, 1995–98

Study component	What data were collected and why	Types of sites sampled	Number of sites	Sampling frequency and period
Stream Chemistry				
Basic Fixed Sites	Continuous streamflow, nutrients, major ions, organic carbon, suspended sediment, and physical parameters were measured to describe concentrations and seasonal variations.	Sites were selected to represent the range of ecoregions, physiographic regions, and land uses present in the Study Unit.	9	Samples were collected monthly February 1996 – January 1998.
Intensive Fixed Sites	In addition to the above list of data collected at the Basic Fixed Sites, information on 82 dissolved pesticides was collected to determine concentrations, seasonal variations, and loads. Volatile organic compounds also were measured at the urban site.	Three of the sites were located at streams that drained intensive agricultural areas but were dominated by different crop types. One site was a large river site with mixed land use. The remaining site was located in a rapidly growing urban area.	5	Sampling frequency ranged from biweekly during the growing season to weekly throughout the remainder of the period February 1996 – January 1998.
Synoptic Sites—Water Chemistry	Nutrients, pesticides, and physical properties were measured to broaden the spatial coverage of water-quality information in the Study Unit.	Synoptic sites were selected in an effort to sample streams that drained all major crop types grown in the Study Unit.	38	Samples were collected once during May, July, and August 1997.
Stream Ecology				
Ecological Assessment Sites	Fish, macroinvertebrate, algae, and habitat data were collected to examine relations among the biological community and water chemistry, land use, and physical components of the landscape and drainage basin.	Sites were selected to represent the range of ecoregions, physiographic regions, and land uses present in the Study Unit.	8	Samples were collected once during low-flow conditions in the summers of 1996–98; at two sites, three reaches were sampled in 1996.
Synoptic Sites—Ecology	Fish, macroinvertebrate, habitat, and streamflow data were collected once at a larger number of sites to develop a better understanding of the spatial aspects of aquatic communities in the Study Unit.	Synoptic sites were selected in an effort to sample streams that drained all major crop types grown in the Study Unit.	38	Samples were collected July–September 1997 for macroinvertebrates; July–September 1998 for fish.
Contaminants in Bed Sediments	Total PCB's, organochlorine pesticides, semivolatile organic compounds, and trace elements were measured in order to determine the occurrence and distribution of contaminants in stream sediments.	Sites were selected to represent the range of ecoregions, physiographic regions, and land uses present in the Study Unit.	15	Samples were collected during August and September 1995.
Contaminants in Fish Tissue	Organochlorine pesticides were measured in whole fish, and trace elements were measured in fish liver.	Sites were selected in an effort to sample streams that drained all major crop types grown in the Study Unit.	41 (pesticides) 15 (trace elements)	Samples were collected during late summer low-flow conditions in 1995–98.
Ground-Water Chemistry				
Deep Tertiary Aquifers	Nutrients, major ions, pesticides, volatile organic compounds, radioisotopes, stable isotopes, and physical parameters were measured to determine overall water quality in a deep aquifer used for drinking water.	Public-supply wells screened in the deep Tertiary aquifers (Claiborne and Wilcox Groups) were sampled.	30	Samples were collected once during April and May 1996.
Memphis Shallow Aquifers	Nutrients, major ions, trace elements, pesticides, volatile organic compounds, radioisotopes, stable isotopes, and physical parameters were measured to determine overall water quality in shallow aquifers in a rapidly developing urban area.	Twenty-four monitoring wells screened in the shallow water-table aquifer and eight monitoring wells screened in the upper part of the Memphis aquifer were sampled.	32	Samples were collected once during April and May 1997.
Alluvial Aquifer	Nutrients, major ions, trace elements, pesticides, volatile organic compounds, radioisotopes, stable isotopes, and physical parameters were measured to determine overall water quality in an aquifer largely used for agricultural irrigation, but also for public supply and industry.	Twenty-five irrigation wells screened in the Holocene alluvium and 29 irrigation wells screened in the Pleistocene valley trains were sampled.	54	Samples were collected once during the summer of 1998.
Special Studies				
Pesticides in the Atmosphere	Pesticides were measured in the air and in the rain.	Two sites were sampled–one in an agricultural area in Sharkey County, Miss., and one in an urban area in Jackson, Miss.	2	Samples were collected April–September 1995.
Pesticides in Fish Tissue in the Mississippi River	Organochlorine pesticides in whole fish (common carp) were measured to determine if pesticides leaving the Yazoo River Basin could be detected in fish in the Mississippi River.	Four sites were selected within an area 100 miles upstream and another four sites were selected 100 miles downstream from the confluence of the Yazoo River and the Mississippi River.	8	Samples were collected once during November 1997.

GLOSSARY

Algae - Chlorophyll-bearing nonvascular, primarily aquatic species that have no true roots, stems, or leaves; most algae are microscopic, but some species can be as large as vascular plants.

Alluvial aquifer - A water-bearing deposit of unconsolidated material (sand and gravel) left behind by a river or other flowing water.

Alluvium - Deposits of clay, silt, sand, gravel or other particulate rock material left by a river in a streambed, on a flood plain, delta, or at the base of a mountain.

Aquatic-life criteria - Water-quality guidelines for protection of aquatic life. Often refers to U.S. Environmental Protection Agency water-quality criteria for protection of aquatic organisms. See also Water-quality guidelines, Water-quality criteria, and Freshwater chronic criteria.

Aquifer - A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to a well.

Atmospheric deposition - The transfer of substances from the air to the surface of the Earth, either in wet form (rain, fog, snow, dew, frost, hail) or in dry form (gases, aerosols, particles).

Basic Fixed Sites - Sites on streams at which streamflow is measured and samples are collected for temperature, salinity, suspended sediment, major ions and metals, nutrients, and organic carbon to assess the broad-scale spatial and temporal character and transport of inorganic constituents of streamwater in relation to hydrologic conditions and environmental settings.

Bed sediment - The material that temporarily is stationary in the bottom of a stream or other watercourse.

Bioaccumulation - The biological sequestering of a substance at a higher concentration than that at which it occurs in the surrounding environment or medium. Also, the process whereby a substance enters organisms through the gills, epithelia tissues, dietary, or other sources.

Biota - Living organisms.

Channelization - Modification of a stream, typically by straightening the channel, to provide more uniform flow; often done for flood control or for improved agricultural drainage or irrigation.

Community - In ecology, the species that interact in a common area.

Concentration - The amount or mass of a substance present in a given volume or mass of sample. Usually expressed as microgram per liter (water sample) or microgram per kilogram (sediment or tissue sample).

Criterion - A standard rule or test on which a judgment or decision can be based.

Degradation products - Compounds resulting from transformation of an organic substance through chemical, photochemical, and/or biochemical reactions.

Detection limit - The minimum concentration of a substance that can be identified, measured, and reported within 99 percent confidence that the analyte concentration is greater than zero; determined from analysis of a sample in a given matrix containing the analyte.

DDT - Dichloro-diphenyl-trichloroethane. An organochlorine insecticide no longer registered for use in the United States.

Dissolved solids - Amount of minerals, such as salt, that are dissolved in water; amount of dissolved solids is an indicator of salinity or hardness.

Drainage area - The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide.

Drinking-water standard or guideline - A threshold concentration in a public drinking-water supply, designed to protect human health. As defined here, standards are U.S. Environmental Protection Agency regulations that specify the maximum contamination levels for public water systems required to protect the public welfare; guidelines have no regulatory status and are issued in an advisory capacity.

Ecosystem - The interacting populations of plants, animals, and microorganisms occupying an area, plus their physical environment.

Eutrophication - The process by which water becomes enriched with plant nutrients, most commonly phosphorus and nitrogen.

Fixed Sites - NAWQA's most comprehensive monitoring sites. See also Basic Fixed Sites and Intensive Fixed Sites.

Ground water - In general, any water that exists beneath the land surface, but more commonly applied to water in fully saturated soils and geologic formations.

Habitat - The part of the physical environment where plants and animals live.

Herbicide - A chemical or other agent applied for the purpose of killing undesirable plants. See also Pesticide.

Holocene - A subdivision of geologic time which began at the end of the Pleistocene (approximately 9,000 to 11,000 years ago) and extends to the present.

Human health advisory - Guidance provided by U.S. Environmental Protection Agency, State agencies or scientific organizations, in the absence of regulatory limits, to describe acceptable contaminant levels in drinking water or edible fish.

Intensive Fixed Sites - Basic Fixed Sites with increased sampling frequency during selected seasonal periods and analysis of dissolved pesticides for 1 year. Most NAWQA Study Units have one to two integrator Intensive Fixed Sites and one to four indicator Intensive Fixed Sites.

Load - General term that refers to a material or constituent in solution, in suspension, or in transport; usually expressed in terms of mass or volume.

Loess - Homogeneous, fine-grained sediment made up primarily of silt and clay, and deposited over a wide area (probably by wind).

Maximum contaminant level (MCL) - Maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCLs are enforceable standards established by the U.S. Environmental Protection Agency.

Median - The middle or central value in a distribution of data ranked in order of magnitude. The median is also known as the 50th percentile.

Metabolite- A compound derived by chemical, biological, or physical action upon a pesticide. The breakdown is a natural process which may result in a more toxic or a less toxic compound and a more persistent or less persistent compound.

Method detection limit - The minimum concentration of a substance that can be accurately identified and measured with present laboratory technologies.

Micrograms per liter (µg/L) - A unit expressing the concentration of constituents in solution as weight (micrograms) of solute per unit volume (liter) of water; equivalent to one part per billion in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.

Minimum reporting level (MRL) - The smallest measured concentration of a constituent that may be reliably reported using a given analytical method. In many cases, the MRL is used when documentation for the method detection limit is not available.

Nitrate - An ion consisting of nitrogen and oxygen (NO3-). Nitrate is a plant nutrient and is very mobile in soils.

Nonpoint source - A pollution source that cannot be defined as originating from discrete points such as pipe discharge. Areas of fertilizer and pesticide applications, atmospheric deposition, manure, and natural inputs from plants and trees are types of nonpoint source pollution.

Nutrient - Element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium.

Organochlorine insecticide - A class of organic insecticides containing a high percentage of chlorine. Includes dichlorodiphenylethanes (such as DDT), chlorinated cyclodienes (such as chlordane), and chlorinated benzenes (such as lindane). Most organochlorine insecticides were banned because of their carcinogenicity, tendency to bioaccumulate, and toxicity to wildlife.

Periphyton - Organisms that grow on underwater surfaces; periphyton include algae, bacteria, fungi, protozoa, and other organisms.

Phosphorus - A nutrient essential for growth that can play a key role in stimulating aquatic growth in lakes and streams.

Physiography - A description of the surface features of the Earth, with an emphasis on the origin of landforms.

Pleistocene - A subdivision of geologic time which began about 2 million years ago and ended at the beginning of the Holocene epoch, approximately 9,000 to 11,000 years ago.

Quaternary - A subdivision of geologic time which began about 2 million years ago and extends to the present. The Quaternary period is further divided into two epochs, the Pleistocene and the Holocene.

Recharge - Water that infiltrates the ground and reaches the saturated zone.

Sediment quality guideline - Threshold concentration above which there is a high probability of adverse effects on aquatic life from sediment contamination, determined using modified USEPA (1996) procedures.

Semivolatile organic compound (SVOC) - Operationally defined as a group of synthetic organic compounds that are solvent-extractable and can be determined by gas chromatography/mass spectrometry. SVOCs include phenols, phthalates, and polycyclic aromatic hydrocarbons (PAHs).

Species diversity - An ecological concept that incorporates both the number of species in a particular sampling area and the evenness with which individuals are distributed among the various species.

Species (taxa) richness - The number of species (taxa) present in a defined area or sampling unit.

Stream reach - A continuous part of a stream between two specified points.

Study Unit - A major hydrologic system of the United States in which NAWQA studies are focused. Study Units are geographically defined by a combination of ground- and surface-water features and generally encompass more than 4,000 square miles of land area.

Study-Unit Survey - Broad assessment of the water-quality conditions of the major aquifer systems of each Study Unit. The Study-Unit Survey relies primarily on sampling existing wells and, wherever possible, on existing data collected by other agencies and programs. Typically, 20 to 30 wells are sampled in each of three to five aquifer subunits.

Synoptic sites - Sites sampled during a short-term investigation of specific water-quality conditions during selected seasonal or hydrologic conditions to provide improved spatial resolution for critical water-quality conditions.

Taxon (plural taxa) - Any identifiable group of taxonomically related organisms.

Total DDT - The sum of DDT and its metabolites (breakdown products), including DDD and DDE.

Trace element - An element found in only minor amounts (concentrations less than 1.0 milligram per liter) in water or sediment; includes arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.

Triazine herbicide - A class of herbicides containing a symmetrical triazine ring (a nitrogen-heterocyclic ring composed of three nitrogens and three carbons in an alternating sequence). Examples include atrazine, propazine, and simazine.

Turbidity - Reduced clarity of surface water because of suspended particles, usually sediment.

Volatile organic compounds (VOCs) - Organic chemicals that have a high vapor pressure relative to their water solubility. VOCs include components of gasoline, fuel oils, and lubricants, as well as organic solvents, fumigants, some inert ingredients in pesticides, and some by-products of chlorine disinfection.

Water-quality criteria - Specific levels of water quality which, if reached, are expected to render a body of water unsuitable for its designated use. Commonly refers to water-quality criteria established by the U.S. Environmental Protection Agency. Water-quality criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.

Water-quality guidelines - Specific levels of water quality which, if reached, may adversely affect human health or aquatic life. These are nonenforceable guidelines issued by a governmental agency or other institution.

Water-quality standards - State-adopted and U.S. Environmental Protection Agency-approved ambient standards for water bodies. Standards include the use of the water body and the water-quality criteria that must be met to protect the designated use or uses.

Water year - The continuous 12-month period, October 1 through September 30, in U.S. Geological Survey reports dealing with the surface-water supply. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1980, is referred to as the water year 1980.

Wetlands - Ecosystems whose soil is saturated for long periods seasonally or continuously, including marshes, swamps, and ephemeral ponds.

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APPENDIX—WATER-QUALITY DATA FROM THE MISSISSIPPI EMBAYMENT IN A NATIONAL CONTEXT

For a complete view of Mississippi Embayment data and for additional information about specific benchmarks used, visit our Web site at http://water.usgs.gov/nawqa/. Also visit the NAWQA Data Warehouse for access to NAWQA data sets at http://water.usgs.gov/nawqa/data.

This appendix is a summary of chemical concentrations and biological indicators assessed in the Mississippi Embayment. Selected results for this Study Unit are graphically compared to results from as many as 36 NAWQA Study Units investigated from 1991 to 1998 and to national water-quality benchmarks for human health, aquatic life, or fish-eating wildlife. The chemical and biological indicators shown were selected on the basis of frequent detection, detection at concentrations above a national benchmark, or regulatory or scientific importance. The graphs illustrate how conditions associated with each land use sampled in the Mississippi Embayment compare to results from across the Nation, and how conditions compare among the several land uses. Graphs for chemicals show only detected concentrations and, thus, care must be taken to evaluate detection frequencies in addition to concentrations when comparing study-unit and national results. For example, fluometuron concentrations in Mississippi Embayment agricultural streams were similar to the national distribution, but the detection frequency was much higher (63 percent compared to 8 percent).

CHEMICALS IN WATER

Concentrations and detection frequencies, Mississippi Embayment, 1995–98—Detection sensitivity varies among chemicals and, thus, frequencies are not directly comparable among chemicals

◆ Detected concentration in Study Unit

66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency

-- Not measured or sample size less than two

12 Study-unit sample size. For ground water, the number of samples is equal to the number of wells sampled

National ranges of detected concentrations, by land use, in 36 NAWQA Study Units, 1991–98—Ranges include only samples in which a chemical was detected

Streams in agricultural areas
Streams in urban areas
Streams and rivers draining mixed land uses
Shallow ground water in agricultural areas
Shallow ground water in urban areas
Major aquifers

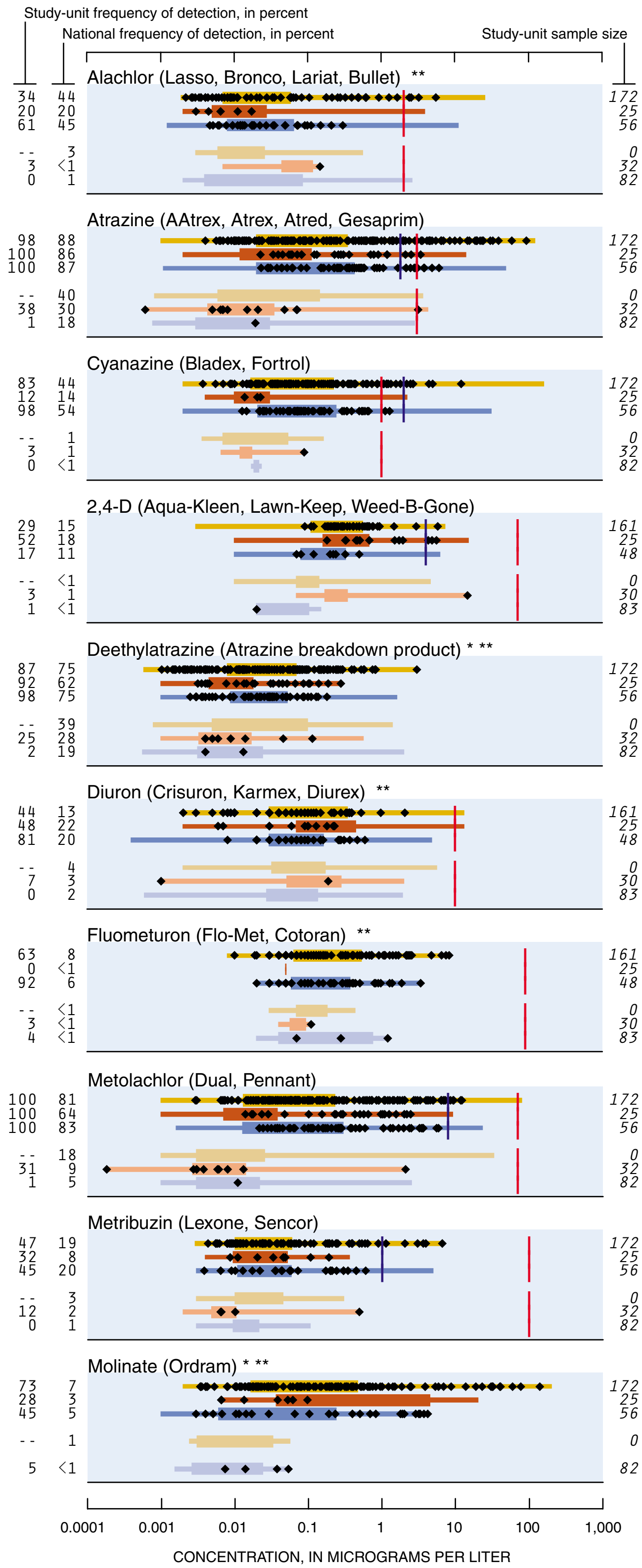
Lowest 25 percent | Middle 50 percent | Highest 25 percent

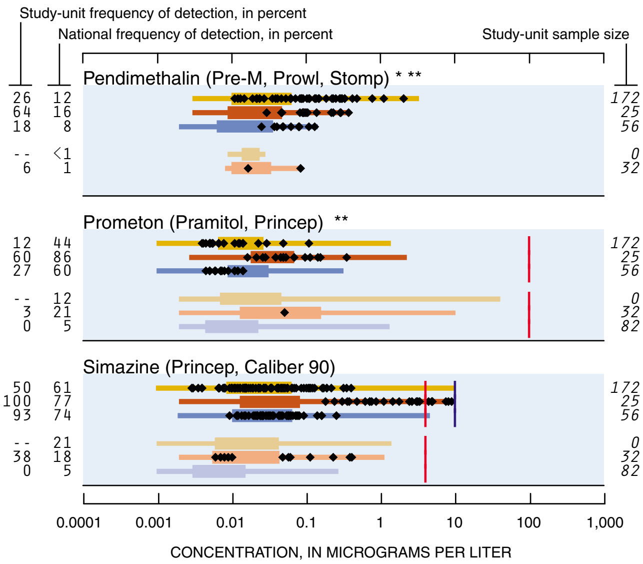
National water-quality benchmarks

National benchmarks include standards and guidelines related to drinking-water quality, criteria for protecting the health of aquatic life, and a goal for preventing stream eutrophication due to phosphorus. Sources include the U.S. Environmental Protection Agency and the Canadian Council of Ministers of the Environment

| Drinking-water quality (applies to ground water and surface water)
| Protection of aquatic life (applies to surface water only)
| Prevention of eutrophication in streams not flowing directly into lakes or impoundments
* No benchmark for drinking-water quality
** No benchmark for protection of aquatic life

Pesticides in water—Herbicides

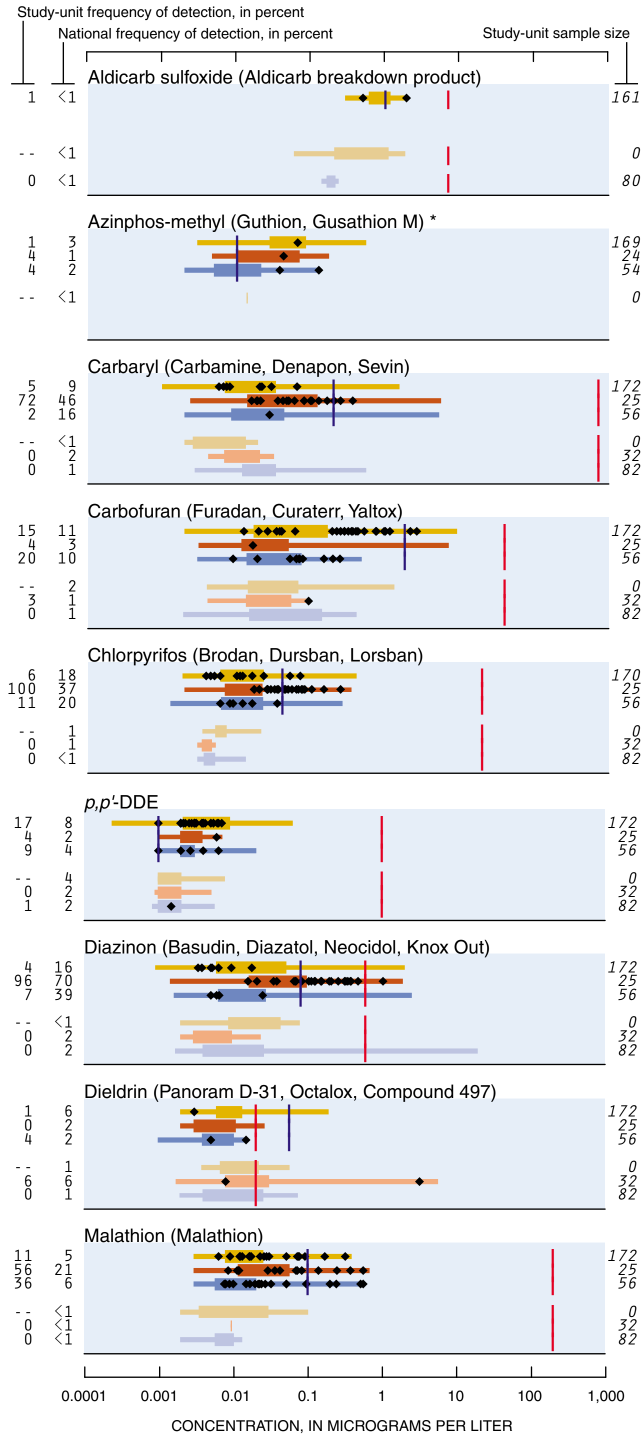




Other herbicides detected
Acetochlor (Harness Plus, Surpass) * **
Acifluorfen (Blazer, Tackle 2S) **
Benfluralin (Balan, Benefin, Bonalan) * **
Bentazon (Basagran, Bentazone) **
Bromacil (Hyvar X, Urox B, Bromax)
Bromoxynil (Buctril, Brominal) *
2,4-DB (Butyrac, Butoxone, Embutox Plus, Embutone) * **
DCPA (Dacthal, chlorthal-dimethyl) * **
Dacthal mono-acid (Dacthal breakdown product) * **
Dicamba (Banvel, Dianat, Scotts Proturf)
Dichlorprop (2,4-DP, Seritox 50, Lentemul) * **
Dinoseb (Dinosebe)
EPTC (Eptam, Farmarox, Alirox) * **
Fenuron (Fenulon, Fenidim) * **
Linuron (Lorox, Linex, Sarclex, Linurex, Afalon) *
MCPA (Rhomene, Rhonox, Chiptox)
Napropamide (Devrinol) * **
Neburon (Neburea, Neburyl, Noruben) * **
Norflurazon (Evital, Predict, Solicam, Zorial) * **
Pebulate (Tillam, PEBC) * **
Picloram (Grazon, Tordon)
Pronamide (Kerb, Propyzamid) **
Propachlor (Ramrod, Satecid) **
Propanil (Stam, Stampede, Wham) * **
Tebuthiuron (Spike, Tebusan)
Terbacil (Sinbar) **
Thiobencarb (Bolero, Saturn, Benthiocarb) * **
Triclopyr (Garlon, Grandstand, Redeem, Remedy) * **
Trifluralin (Treflan, Gowan, Tri-4, Trific)

Herbicides not detected
Butylate (Sutan +, Genate Plus, Butilate) **
Chloramben (Amiben, Amilon-WP, Vegiben) **
Clopyralid (Stinger, Lontrel, Transline) * **
2,6-Diethylaniline (Alachlor breakdown product) * **
Ethalfluralin (Sonalan, Curbit) * **
MCPB (Thistrol) * **
Oryzalin (Surflan, Dirimal) * **
Propham (Tuberite) **
2,4,5-T **
2,4,5-TP (Silvex, Fenoprop) **
0Triallate (Far-Go, Avadex BW, Tri-allate) *

Pesticides in water—Insecticides



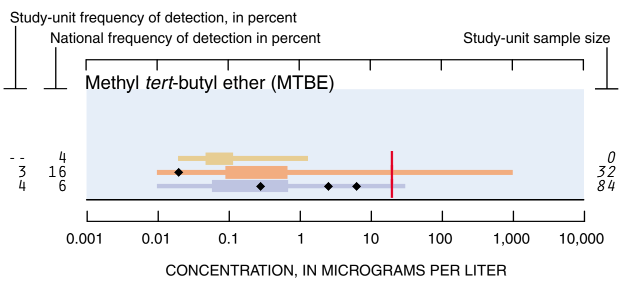
Other insecticides detected
Disulfoton (Disyston, Di-Syston) **
Methomyl (Lanox, Lannate, Acinate) **
Methyl parathion (Penncap-M, Folidol-M) **
Propargite (Comite, Omite, Ornamite) * **

Insecticides not detected
Aldicarb (Temik, Ambush, Pounce)
Aldicarb sulfone (Standak, aldoxycarb)
Ethoprop (Mocap, Ethoprophos) * **

Fonofos (Dyfonate, Capfos, Cudgel, Tycap) **
alpha-HCH (alpha-BHC, alpha-lindane) **
gamma-HCH (Lindane, gamma-BHC)
3-Hydroxycarbofuran (Carbofuran breakdown product) * **
Methiocarb (Slug-Geta, Grandslam, Mesurol) * **
Oxamyl (Vydate L, Pratt) **
Parathion (Roethyl-P, Alkron, Panthion, Phoskil) *
cis-Permethrin (Ambush, Astro, Pounce) * **
Phorate (Thimet, Granutox, Geomet, Rampart) * **
Propoxur (Baygon, Blattanex, Unden, Proprotox) * **
Terbufos (Contraven, Counter, Pilarfox) **

Volatile organic compounds (VOCs) in ground water

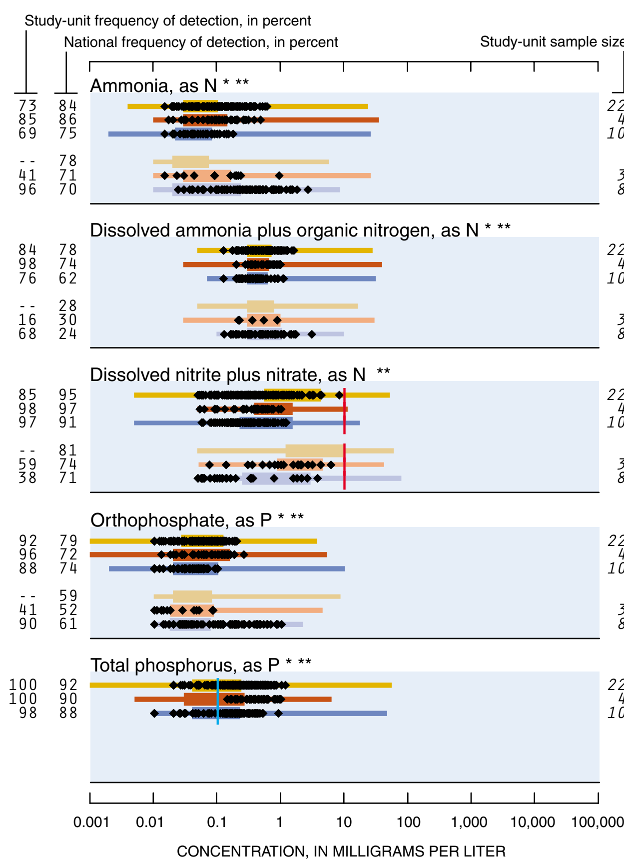
These graphs represent data from 16 Study Units, sampled from 1996 to 1998



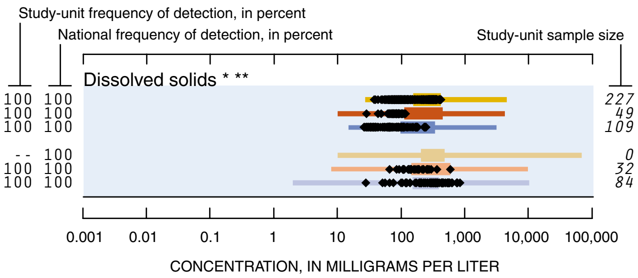
Other VOCs detected
tert-Amylmethylether (*tert*-amyl methyl ether (TAME)) *
Benzene
Bromodichloromethane (Dichlorobromomethane)
2-Butanone (Methyl ethyl ketone (MEK)) *
Carbon disulfide *
Chlorobenzene (Monochlorobenzene)
Chloroethane (Ethyl chloride) *
Chloromethane (Methyl chloride)
1,4-Dichlorobenzene (*p*-Dichlorobenzene)
Dichlorodifluoromethane (CFC 12, Freon 12)
1,2-Dichloroethane (Ethylene dichloride)
1,1-Dichloroethane (Ethylidene dichloride) *
1,1-Dichloroethene (Vinylidene chloride)
trans-1,2-Dichloroethene ((E)-1,2-Dichlorothene)
cis-1,2-Dichloroethene ((Z)-1,2-Dichloroethene)
Dichloromethane (Methylene chloride)
Diethyl ether (Ethyl ether) *
Diisopropyl ether (Diisopropylether (DIPE)) *
1,2-Dimethylbenzene (*o*-Xylene)
1,3 & 1,4-Dimethylbenzene (*m*-&*p* -Xylene)
1-4-Epoxy butane (Tetrahydrofuran, Diethylene oxide) *
Ethenylbenzene (Styrene)
1-Ethyl-2-methylbenzene (2-Ethyltoluene) *
Ethylbenzene (Phenylethane)
4-Methyl-2-pentanone (Methyl isobutyl ketone (MIBK)) *
Methylbenzene (Toluene)
2-Propanone (Acetone) *
Tetrachloroethene (Perchloroethene)
1,1,1-Trichloroethane (Methylchloroform)
Trichloroethene (TCE)
Trichlorofluoromethane (CFC 11, Freon 11)
Trichloromethane (Chloroform)
1,2,3-Trimethylbenzene (Hemimellitene) *
1,2,4-Trimethylbenzene (Pseudocumene) *
1,3,5-Trimethylbenzene (Mesitylene) *

VOCs not detected
Bromobenzene (Phenyl bromide) *
Bromochloromethane (Methylene chlorobromide)
Bromoethene (Vinyl bromide) *
Bromomethane (Methyl bromide)
n-Butylbenzene (1-Phenylbutane) *
sec-Butylbenzene *
tert-Butylbenzene *
3-Chloro-1-propene (3-Chloropropene) *
1-Chloro-2-methylbenzene (*o*-Chlorotoluene)
1-Chloro-4-methylbenzene (*p*-Chlorotoluene)
Chlorodibromomethane (Dibromochloromethane)
Chloroethene (Vinyl chloride)
1,2-Dibromo-3-chloropropane (DBCP, Nemagon)
1,2-Dibromoethane (Ethylene dibromide, EDB)
Dibromomethane (Methylene dibromide) *
trans-1,4-Dichloro-2-butene ((Z)-1,4-Dichloro-2-butene) *
1,2-Dichlorobenzene (*o*-Dichlorobenzene)
1,3-Dichlorobenzene (*m*-Dichlorobenzene)
1,2-Dichloropropane (Propylene dichloride)
2,2-Dichloropropane *
1,3-Dichloropropane (Trimethylene dichloride) *
trans-1,3-Dichloropropene ((E)-1,3-Dichloropropene)
cis-1,3-Dichloropropene ((Z)-1,3-Dichloropropene)
1,1-Dichloropropene *
Ethyl methacrylate *
Ethyl *tert*-butyl ether (Ethyl-*t*-butyl ether (ETBE)) *
Hexachlorobutadiene
1,1,1,2,2,2-Hexachloroethane (Hexachloroethane)
2-Hexanone (Methyl butyl ketone (MBK)) *
Iodomethane (Methyl iodide) *
Isopropylbenzene (Cumene) *
p-Isopropyltoluene (*p*-Cymene) *
Methyl acrylonitrile *
Methyl-2-methacrylate (Methyl methacrylate) *
Methyl-2-propenoate (Methyl acrylate) *
Naphthalene
2-Propenenitrile (Acrylonitrile)
n-Propylbenzene (Isocumene) *
1,1,2,2-Tetrachloroethane *
1,1,1,2-Tetrachloroethane
Tetrachloromethane (Carbon tetrachloride)
1,2,3,4-Tetramethylbenzene (Prehnitene) *
1,2,3,5-Tetramethylbenzene (Isodurene) *
Tribromomethane (Bromoform)
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113) *
1,2,4-Trichlorobenzene
1,2,3-Trichlorobenzene *
1,1,2-Trichloroethane (Vinyl trichloride)
1,2,3-Trichloropropane (Allyl trichloride)

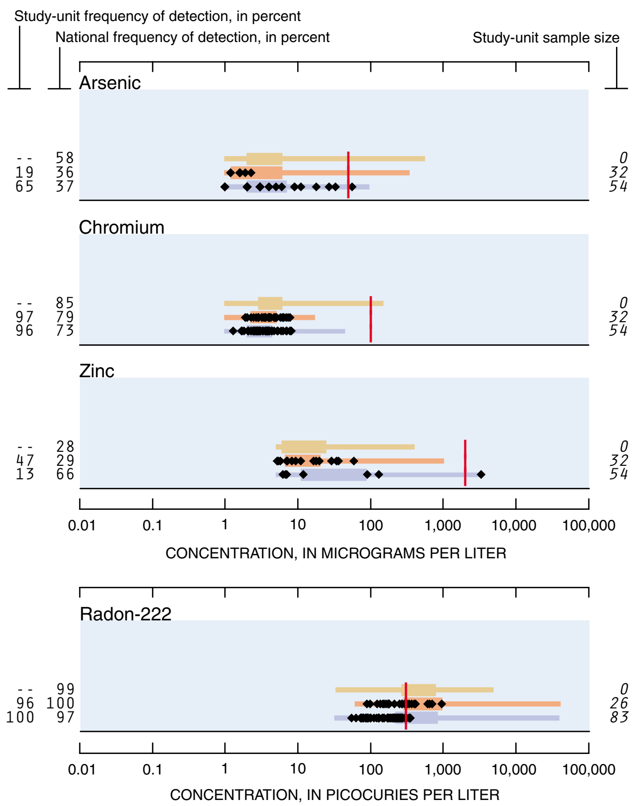
Nutrients in water



Dissolved solids in water



Trace elements in ground water



Other trace elements detected
Selenium
Uranium

Trace elements not detected
Cadmium
Lead

CHEMICALS IN FISH TISSUE AND BED SEDIMENT

Concentrations and detection frequencies, Mississippi Embayment, 1995–98—Detection sensitivity varies among chemicals and, thus, frequencies are not directly comparable among chemicals. Study-unit frequencies of detection are based on small sample sizes; the applicable sample size is specified in each graph

- ◆ Detected concentration in Study Unit
- 66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency
- -- Not measured or sample size less than two
- *12* Study-unit sample size

National ranges of concentrations detected, by land use, in 36 NAWQA Study Units, 1991–98—Ranges include only samples in which a chemical was detected

- Fish tissue from streams in agricultural areas
- Fish tissue from streams in urban areas
- Fish tissue from streams draining mixed land uses
- Sediment from streams in agricultural areas
- Sediment from streams in urban areas
- Sediment from streams draining mixed land uses

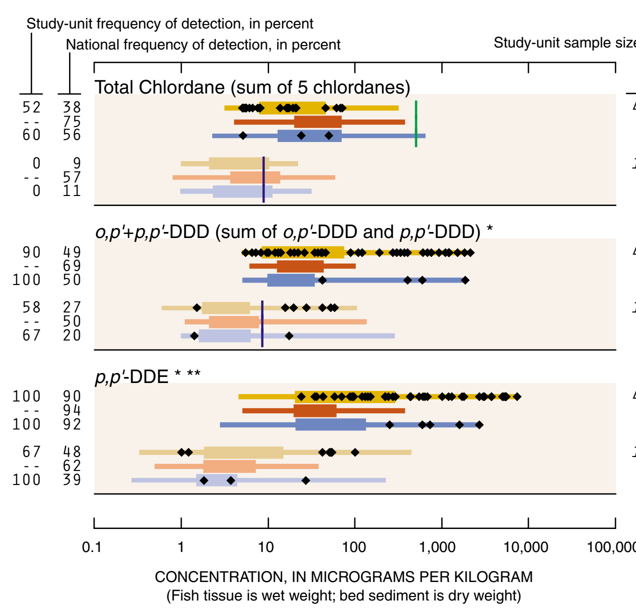
Lowest 25 percent | Middle 50 percent | Highest 25 percent

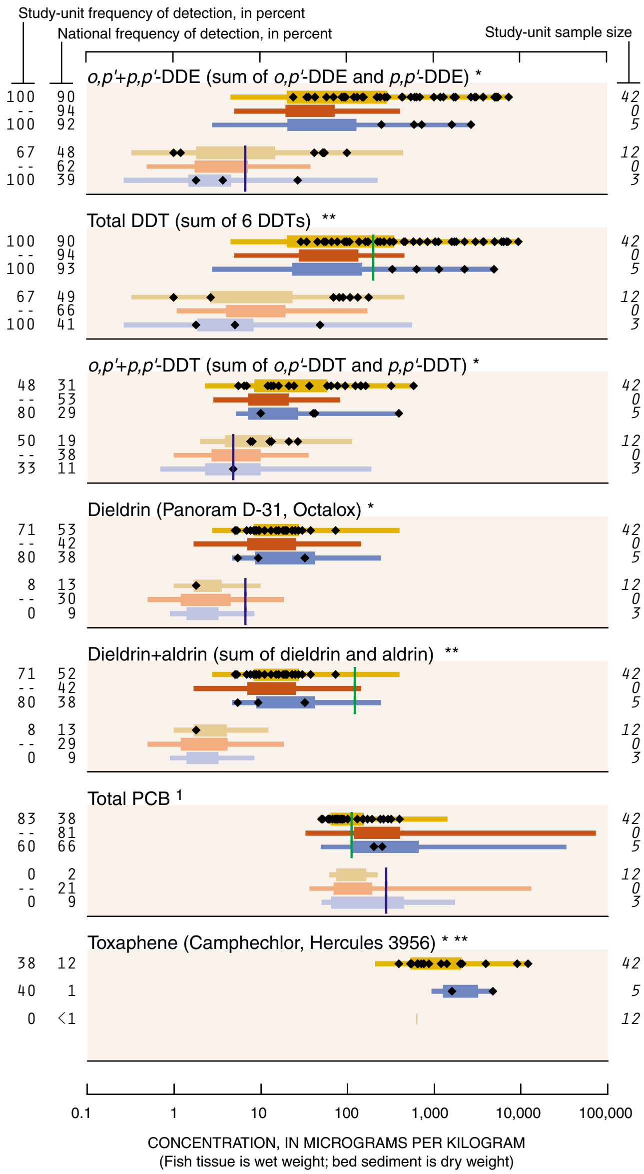
National benchmarks for fish tissue and bed sediment

National benchmarks include standards and guidelines related to criteria for protection of the health of fish-eating wildlife and aquatic organisms. Sources include the U.S. Environmental Protection Agency, other Federal and State agencies, and the Canadian Council of Ministers of the Environment

- | Protection of fish-eating wildlife (applies to fish tissue)
- | Protection of aquatic life (applies to bed sediment)
- * No benchmark for protection of fish-eating wildlife
- ** No benchmark for protection of aquatic life

Organochlorines in fish tissue (whole body) and bed sediment



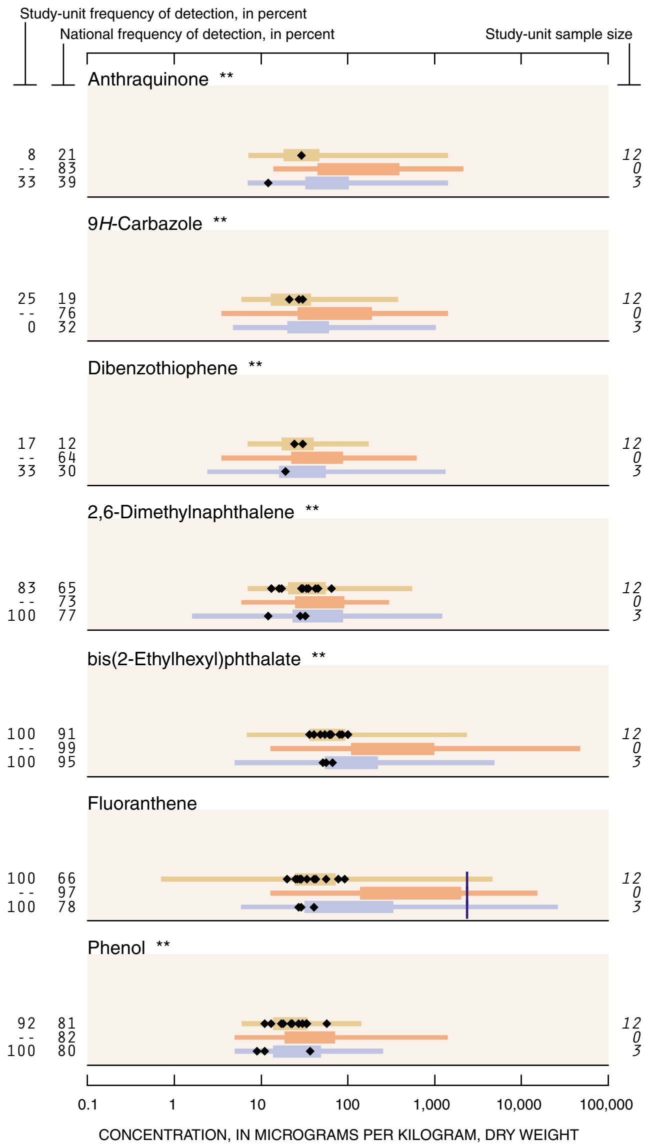


[1] The national detection frequencies for total PCB in sediment are biased low because about 30 percent of samples nationally had elevated detection levels compared to this Study Unit. See http://water.usgs.gov/nawqa/ for additional information.

Other organochlorines detected
Total-HCH (sum of alpha-HCH, beta-HCH, gamma-HCH, and delta-HCH) **
Heptachlor+heptachlor epoxide (sum of heptachlor and heptachlor epoxide) **
Hexachlorobenzene (HCB) **
Mirex (Dechlorane) **
Pentachloroanisole (PCA) * **
Toxaphene (Camphechlor, Hercules 3956) * **

Organochlorines not detected
Chloroneb (Chloronebe, Demosan) * **
DCPA (Dacthal, chlorthal-dimethyl) * **
Endosulfan I (alpha-Endosulfan, Thiodan) * **
Endrin (Endrine)
gamma-HCH (Lindane, gamma-BHC, Gammexane) *
Heptachlor epoxide (Heptachlor breakdown product) *
Isodrin (Isodrine, Compound 711) * **
p,p′-Methoxychlor (Marlate, methoxychlore) * **
o,p′-Methoxychlor * **
cis-Permethrin (Ambush, Astro, Pounce) * **
trans-Permethrin (Ambush, Astro, Pounce) * **

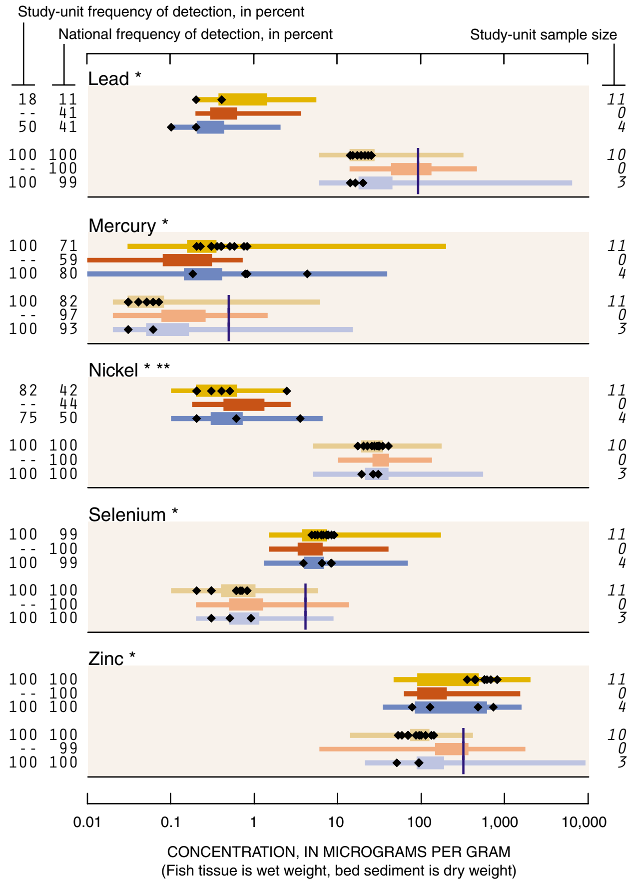
Semivolatile organic compounds (SVOCs) in bed sediment



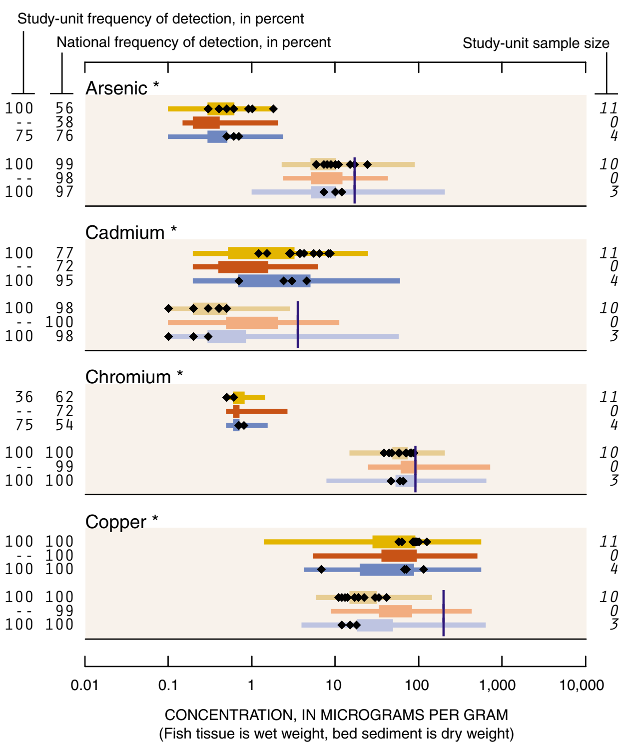
Other SVOCs detected
Acenaphthene
Acenaphthylene
Acridine **
Anthracene
Benz[*a*]anthracene
Benzo[*a*]pyrene
Benzo[*b*]fluoranthene **
Benzo[*ghi*]perylene **
Benzo[*k*]fluoranthene **
2,2-Biquinoline **
Butylbenzylphthalate **
Chrysene
p-Cresol **
Di-*n*-butylphthalate **
Di-*n*-octylphthalate **
Diethylphthalate **
1,6-Dimethylnaphthalene **
Dimethylphthalate **
9*H*-Fluorene (Fluorene)
Indeno[1,2,3-*cd*]pyrene **

Isoquinoline **
2-Methylanthracene **
4,5-Methylenephenanthrene **
1-Methylphenanthrene **
1-Methylpyrene **
Naphthalene
Phenanthrene
Pyrene

SVOCs not detected
C8-Alkylphenol **
Azobenzene **
Benzo[*c*]cinnoline **
4-Bromophenyl-phenylether **
4-Chloro-3-methylphenol **
bis(2-Chloroethoxy)methane **
2-Chloronaphthalene **
2-Chlorophenol **
4-Chlorophenyl-phenylether **
Dibenz[*a,h*]anthracene
1,2-Dichlorobenzene (*o*-Dichlorobenzene) **
1,3-Dichlorobenzene (*m*-Dichlorobenzene) **
1,4-Dichlorobenzene (*p*-Dichlorobenzene) **
1,2-Dimethylnaphthalene **
3,5-Dimethylphenol **
2,4-Dinitrotoluene **
2-Ethylnaphthalene **
Isophorone **
1-Methyl-9*H*-fluorene **
Nitrobenzene **
N-Nitrosodi-*n*-propylamine **
N-Nitrosodiphenylamine **
Pentachloronitrobenzene **
Phenanthridine **
Quinoline **
1,2,4-Trichlorobenzene **
2,3,6-Trimethylnaphthalene **



Trace elements in fish tissue (livers) and bed sediment



BIOLOGICAL INDICATORS

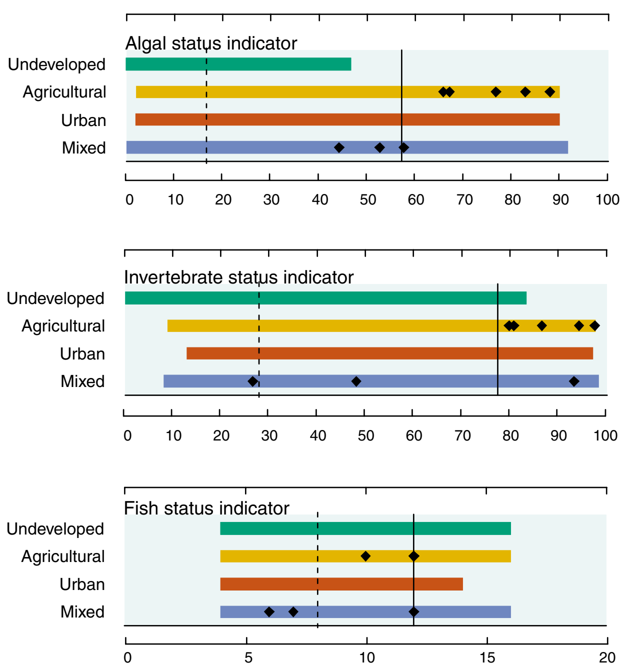
Higher national scores suggest habitat disturbance, water-quality degradation, or naturally harsh conditions. The status of algae, invertebrates (insects, worms, and clams), and fish provide a record of water-quality and stream conditions that water-chemistry indicators may not reveal. **Algal status** focuses on the changes in the percentage of certain algae in response to increasing siltation, and it often correlates with higher nutrient concentrations in some regions. **Invertebrate status** averages 11 metrics that summarize changes in richness, tolerance, trophic conditions, and dominance associated with water-quality degradation. **Fish status** sums the scores of four fish metrics (percent tolerant, omnivorous, non-native individuals, and percent individuals with external anomalies) that increase in association with water-quality degradation

Biological indicator value, Mississippi Embayment, by land use, 1995–98

◆ Biological status assessed at a site

National ranges of biological indicators, in 16 NAWQA Study Units, 1994–98

- Streams in undeveloped areas
- Streams in agricultural areas
- Streams in urban areas
- Streams in mixed-land-use areas
- 75th percentile
- 25th percentile



A COORDINATED EFFORT

Coordination with agencies and organizations in the Mississippi Embayment was integral to the success of this water-quality assessment. We thank those who served as members of our liaison committee.

Federal Agencies
U.S. Army Corps of Engineers
U.S. Department of Agriculture
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey, BRD

State Agencies
Mississippi Department of Environmental Quality
Mississippi Department of Wildlife, Fisheries, and Parks

Local Agencies
Delta Council
Yazoo-Mississippi Delta Joint Water Management District

Universities
Arkansas State University
Mississippi State University
University of Arkansas
University of Mississippi

Other public and private organizations
Wolf River Conservancy

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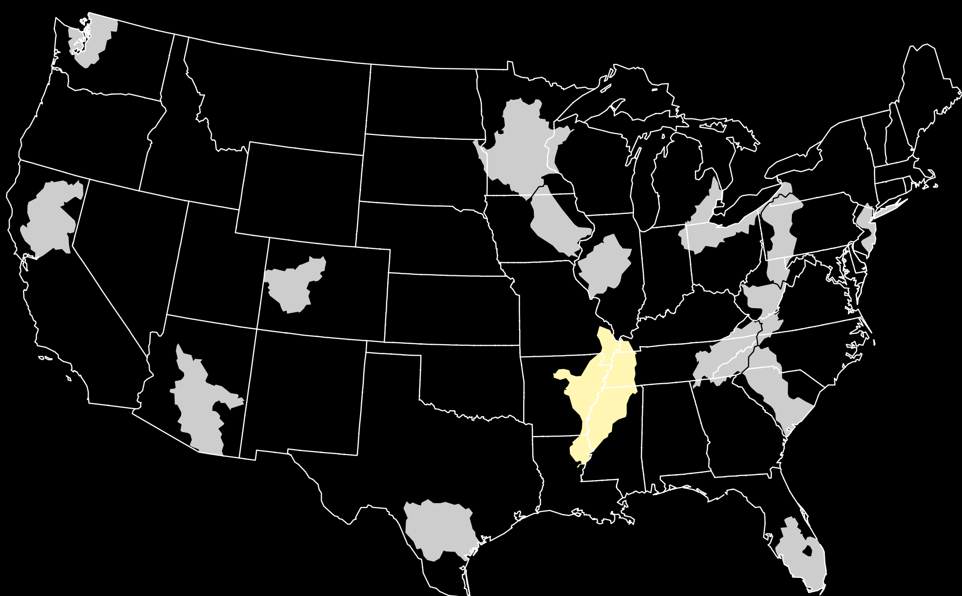
NAWQA

National Water-Quality Assessment (NAWQA) Program
Mississippi Embayment



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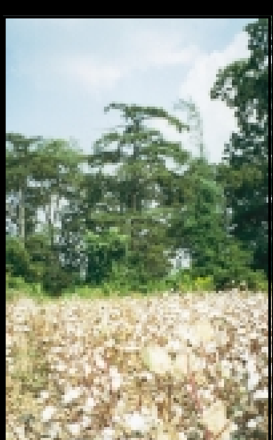

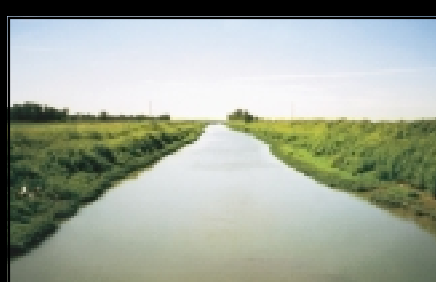

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