

# Water-Quality Assessment of the Eastern Iowa Basins: Hydrologic and Biologic Data, September 1995 through September 1996

Open-File Report 99-66



U.S. Department of the Interior  
U.S. Geological Survey

# **Water-Quality Assessment of the Eastern Iowa Basins: Hydrologic and Biologic Data, September 1995 Through September 1996**

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**Open-File Report 99–66**

**NATIONAL WATER-QUALITY ASSESSMENT PROGRAM—EASTERN IOWA BASINS**

**Iowa City, Iowa  
1999**

**U.S. Department of the Interior**

Bruce Babbitt, Secretary

**U.S. Geological Survey**

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# FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.

- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 59 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 59 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study areas, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study units and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch  
Chief Hydrologist



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## CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To Obtain
<b>Length</b>		
inch (in.)	25.4	millimeter
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
<b>Area</b>		
square mile (mi <sup>2</sup> )	2.590	square kilometer
<b>Volume</b>		
gallon (gal)	3.785	liter
gallon (gal)	3,785	milliliter

Temperature, in degrees Celsius (°C), can be converted to degrees Fahrenheit (°F) by use of the following equation: °F=1.8(°C) + 32.

**Abbreviated water-quality units:** Chemical concentrations and temperature for water samples are given in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter (1,000 µg/L) is equivalent to 1 mg/L. Chemical concentrations for fish-tissue and bed-sediment samples are also given in metric units. Chemical concentrations are given in micrograms per gram (µg/g) or micrograms per kilogram (µg/kg). Micrograms per gram is a unit expressing the concentration of chemical constituent as weight (micrograms) of solute per unit mass (grams). One microgram per one thousand grams (1 µg/1,000 g) is equivalent to 1 µg/kg.

**Other abbreviations used in this report:**

EIWA	Eastern Iowa Basins
MDL	Method detection limit
MRL	Method reporting limit
NAWQA	National Water-Quality Assessment Program
NWQL	U.S. Geological Survey National Water-Quality Laboratory
UHL	University of Iowa Hygienic Laboratory
USGS	U.S. Geological Survey
cm	centimeter
g	gram
L	liter
µm	micrometer
mL	milliliter
mm	millimeter



# Water-Quality Assessment of the Eastern Iowa Basins: Hydrologic and Biologic Data, September 1995 Through September 1996

By Kimberlee K. B. Akers, Douglas J. Schnoebelen, Mark E. Savoca, Linda R. Roberts, and Kent D. Becher

## Abstract

The U.S. Geological Survey began data-collection activities in the Eastern Iowa Basins study unit of the National Water-Quality Assessment Program in September 1995 with the purpose of determining the status and trends in water quality. Surface-water data were collected, beginning in March 1996, on a monthly basis with occasional extra high- and low-flow samples. Data collected from 12 sites on rivers and streams in the study unit included determinations of the physical properties and concentrations of nutrients, major ions, organic carbon, trace elements, suspended sediment, and dissolved pesticides. Data collected at four additional sites included physical parameters and determination of the concentration of dissolved pesticides. In addition, bed-sediment and fish-tissue samples were collected at 16 sites and analyzed for trace elements and hydrophobic pesticides. There were two ground-water studies conducted in June and July 1996. The first looked at the quality of ground water in the Silurian-Devonian and Upper Carbonate aquifers and sampled 33 wells once, and the second examined the effects of agriculture on shallow ground water of the Iowa River alluvial aquifer and sampled 23 wells once. Ground-water samples were analyzed for physical properties, nutrients, major ions, organic carbon, trace elements, dissolved pesticides, and volatile organic compounds.

## INTRODUCTION

In 1991, the U.S. Geological Survey (USGS), Department of the Interior, began the National Water-Quality Assessment (NAWQA) Program. The long-term goals of this program are to describe the status of and trends in the quality of a large, representative part of the Nation's surface- and ground-water resources and to identify the major factors that affect the quality of the resources. In addressing these goals, the program provides water-quality information that can be useful to policymakers and managers at the national, State, and local levels. Studies of 59 hydrologic systems (see cover design), ranging in size from 1,200 to 62,000 mi<sup>2</sup>, include parts of most major river basins and aquifer systems (study-unit investigations) and represent from 60 to 70 percent of the Nation's water use and population served by public water supplies.

The Eastern Iowa Basins (EIWA) study unit was selected as an important hydrologic system representative of an agricultural area in the Midwest.

## Purpose and Scope

This report presents the results of data-collection activities in the Eastern Iowa Basins NAWQA study unit. These data were collected from September 1995 through September 1996 and include the results of the analysis of water samples from 16 surface-water sites and 56 ground-water wells and the analysis of bed-sediment and fish-tissue samples from 16 sites. Surface- and ground-water samples were analyzed for physical properties, nutrients, major ions, organic carbon, trace elements, and dissolved pesticides. In addition, surface-water sample analyses included sedi-

ment concentration, and ground-water sample analyses included volatile organic compounds (VOC's), radon-222, and tritium. Bed sediment and fish tissue were analyzed for trace elements and pesticides.

## Description of the Eastern Iowa Basins

The EIWA study unit covers about 19,500 mi<sup>2</sup> in eastern Iowa and southern Minnesota and includes the Wapsipinicon, Cedar, Iowa, and Skunk River Basins (fig. 1). These four major rivers generally flow in a southeasterly direction toward eventual discharge into the Mississippi River. The Wapsipinicon River originates in southern Minnesota, has a drainage area of 2,540 mi<sup>2</sup>, and is about 225 mi long. The Cedar River also originates in southern Minnesota and joins the Iowa River about 30 mi upstream from the mouth of the Iowa River. Together the Cedar River Basin and the Iowa River Basin encompass about 12,640 mi<sup>2</sup>, more than 90 percent of which is in Iowa. The Skunk River Basin originates in central Iowa and drains about 4,350 mi<sup>2</sup>.

There are three major landform regions and one subregion within the EIWA study unit: the Des Moines Lobe, the Southern Iowa Drift Plain, the Iowan Surface, and the Iowan Karst, which is a subdivision of the Iowan Surface. The Des Moines Lobe is characterized by low relief with some distinct ridges near the eastern boundary and occasional depressions that form lakes, ponds, and marshes. Glacial till is the dominant surficial material with alluvium along the streams. In the Southern Iowa Drift Plain, streams have eroded deeply into the glacial drift and the loess mantle to produce a steeply rolling terrain with broad, flat drainage divides. The Iowan Surface has gently rolling topography with long slopes, low relief, and a mature drainage pattern. The surficial material is primarily glacial drift with thin layers of windblown loess on the ridges and alluvium near the streams. In the Iowan Karst, glacial deposits are thin, and sinkholes are evidence of the shallow limestone beneath the land surface.

Land use and land cover in the EIWA study unit is primarily agricultural with about 93 percent of the total area used for cropland or pasture. The principal crops are corn, oats, hay, and soybeans. The remaining land area consists of about 4 percent forests, about 2 percent urban, and about 1 percent water and wetlands (U.S. Geological Survey, 1990).

## IMPLEMENTATION OF WATER-QUALITY STUDIES

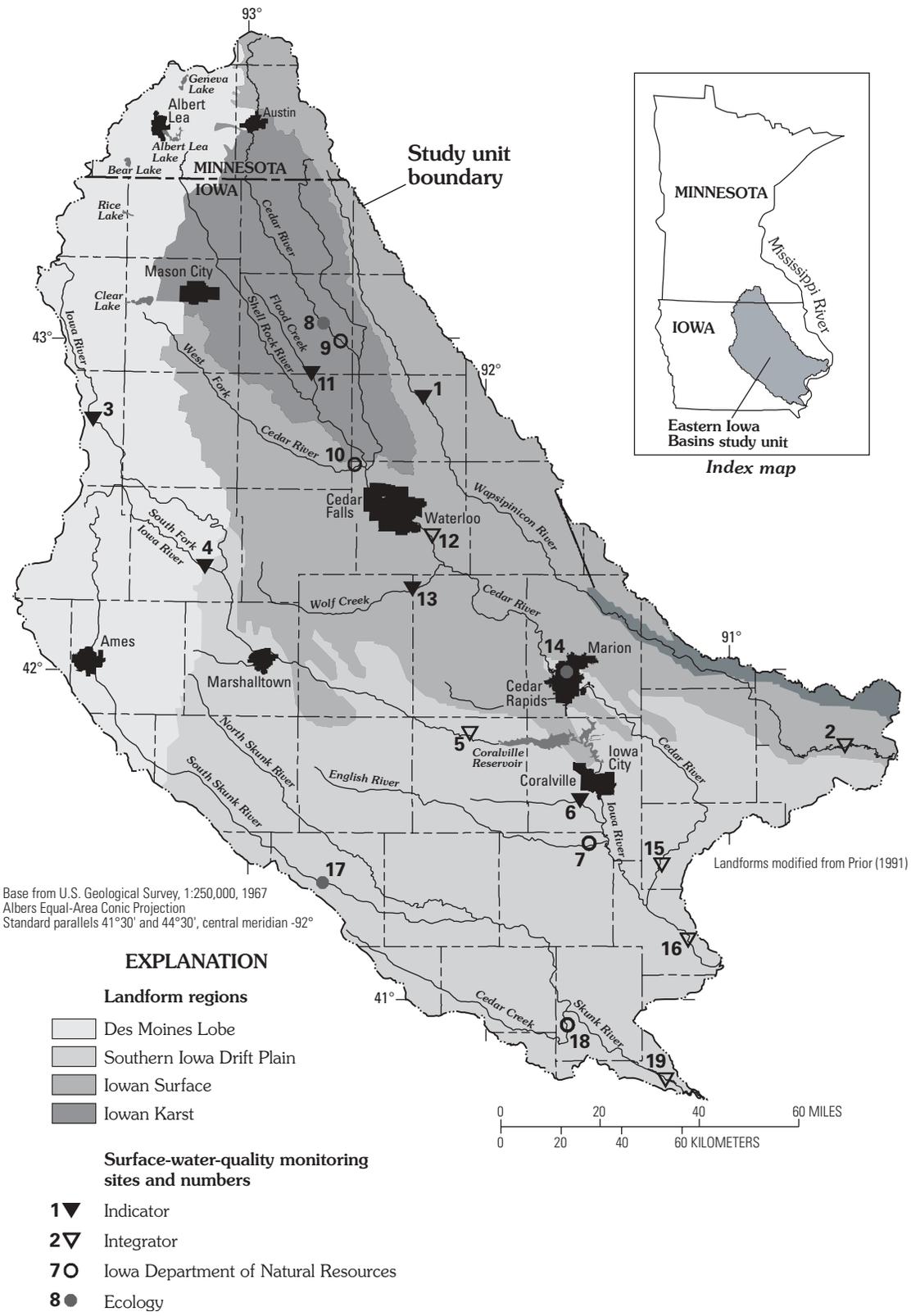
### Surface-Water-Quality Data Collection

#### Sampling Sites

The design of the surface-water-quality sampling program involved the selection of sites to increase the understanding of seasonal and spatial variability of physical and chemical characteristics in the EIWA study unit. The NAWQA network of surface-water-quality sampling sites consists of two types of basic fixed sites—integrator and indicator. Integrator basic fixed sites represent large subbasins in the study unit where the stream or river is affected by a combination of land-use types, point sources of chemical contributions, and natural factors that affect water quality. Indicator basic fixed sites are usually smaller basins and represent a specific combination of land use and physiographic condition. In the EIWA study unit, surface-water samples were collected at six integrator and six indicator sites (fig. 1 and table 1). Bed-sediment and fish-tissue samples were collected at 16 other sites, and surface-water samples were collected at 4 sites by University of Iowa Hygienic Laboratory (UHL) personnel for the Iowa Department of Natural Resources (fig. 1 and table 1).

#### Surface-Water Sample Collection

A complete discussion of the collection and processing of surface-water samples is described in Shelton (1994). All surface-water samples were obtained by collecting depth-integrated subsamples at equally spaced vertical sections across the stream (Ward and Harr, 1990). At each surface-water site, a minimum of 10 equally spaced vertical water samples were collected using cable-mounted or hand-held samplers (Shelton, 1994). Typically, a hand-held sampler is used when wading small streams, and a cable-mounted sampler is used for sampling larger streams or during high flows from a bridge. All equipment used in sampling and processing was rinsed with native water before use. For sample splitting, a Teflon cone (decaport) splitter was used. Sample water for pesticide analysis was passed through a 0.7- $\mu$ m baked-glass fiber filter by a Teflon diaphragm pump and Teflon tubing. Samples for organic carbon analysis were filtered through a 47-mm-diameter, 0.45- $\mu$ m silver



**Figure 1.** Location of surface-water-quality sampling sites in the Eastern Iowa Basins, September 1995–September 1996.

**Table 1.** Surface-water sampling sites in the Eastern Iowa Basins study unit  
[mi<sup>2</sup>, square miles; IDNR, Iowa Department of Natural Resources site]

Site (fig. 1)	Site identifica- tion number	Station name	Location (degrees, minutes, seconds)		Drainage area (mi <sup>2</sup> )	Type of data <sup>1</sup>	Site type
			Latitude	Longitude			
1	05420680	Wapsipinicon River near Tripoli, IA	42°50'10"	92°15'26"	346	F, N, B, M, P, T, S	Indicator
2	05422000	Wapsipinicon River near DeWitt, IA	41°46'01"	90°32'05"	2,340	F, C, N, B, M, P, T, S	Integrator
3	05449500	Iowa River near Rowan, IA	42°45'36"	93°37'23"	418	F, C, N, B, M, P, T, S	Indicator
4	05451210	South Fork Iowa River northeast of New Providence, IA	42°18'54"	93°09'08"	224	F, N, B, M, P, T, S	Indicator
5	05453100	Iowa River at Marengo, IA	41°48'48"	92°03'51"	2,790	F, C, N, B, M, P, T, S	Integrator
6	05455100	Old Man's Creek near Iowa City, IA	41°36'23"	91°36'56"	201	F, N, B, M, P, T, S	Indicator
7	05455570	English River at Riverside, IA	41°28'32"	91°34'49"	626	F, P	IDNR
8	05457700	Cedar River at Charles City, IA	43°03'45"	92°40'23"	1,050	B, T	Ecology
9	05457750	Cedar River near Carville, IA	43°00'23"	92°36'08"	1,075	F, P	IDNR
10	05458900	West Fork Cedar River near Finch- ford, IA	42°37'50"	92°32'24"	846	F, P	IDNR
11	05461390	Flood Creek near Powersville, IA	42°54'26"	92°43'14"	150	F, N, B, M, P, T, S	Indicator
12	05464020	Cedar River at Gilbertville, IA	42°24'57"	92°13'07"	5,240	F, C, N, B, M, P, T, S	Integrator
13	05464220	Wolf Creek near Dysart, IA	42°15'06"	92°17'55"	327	F, C, N, B, M, P, T, S	Indicator
14	05464490	McLoud Run at Cedar Rapids, IA	41°59'59"	91°39'59"	5	B, T	Ecology
15	05465000	Cedar River near Conesville, IA	41°24'36"	91°17'06"	7,790	F, C, N, B, M, P, T, S	Integrator
16	05465500	Iowa River at Wapello, IA	41°10'48"	91°10'57"	12,500	F, C, N, B, M, P, T, S	Integrator
17	05471500	South Skunk River near Oskaloosa, IA	41°21'19"	92°39'31"	1,630	B, T	Ecology
18	05473400	Cedar Creek near Oakland Mills, IA	40°55'20"	91°40'10"	530	F, B, P, T	IDNR/ Ecology
19	05474000	Skunk River at Augusta, IA	40°45'13"	91°16'40"	4,310	F, C, N, B, M, P, T, S	Integrator

<sup>1</sup>Type of data: F, physical properties; C, chlorophyll; N, nutrients; B, bed sediment; M, major ions; P, dissolved pesticides; T, fish tissue; S, suspended sediment.

membrane filter in a stainless-steel chamber pressurized by nitrogen gas. All samples were chilled and shipped by next-day air freight to the USGS National Water-Quality Laboratory (NWQL) for analysis. For chlorophyll analysis, 30 mL of sample water was filtered through a 47-mm-diameter, borosilicate glass

fiber filter. The glass fiber filter was folded into quarters, wrapped in aluminum foil, and kept on ice and stored in the laboratory freezer until analyzed.

At each vertical section in the stream, surface-water measurements of specific conductance, pH, water temperature, and dissolved oxygen were

obtained with a multiprobe instrument. The median value for each physical property was then calculated and stored in the National Water Information System (NWIS) data base. Alkalinity was determined at the time of sample collection by incremental titration (Wood, 1981; Shelton, 1994). All equipment used to collect and process samples (with the exception of carbon) was cleaned with a 0.1-percent nonphosphate detergent, rinsed with deionized water, rinsed with methanol certified by the manufacturer to be free of pesticides, air dried, wrapped in aluminum foil, and stored in a dust-free environment prior to sample collection (Shelton, 1994). Equipment used in the collection of dissolved organic carbon (DOC) and suspended organic carbon (SOC) was not rinsed with detergent or methanol but was rinsed with deionized water certified by the manufacturer to be free of both pesticides and VOC's. Water samples for fecal-coliform and fecal-streptococcal bacteria were collected and analyzed at each site using membrane filtration procedures and incubation (Myers and Wilde, 1997). All bottles and equipment used in the collection of bacteria samples were sterilized in an autoclave and wrapped in foil before sample collection.

UHL personnel collected samples for analysis of dissolved pesticides by dipping a 1-L baked glass bottle into the center of the stream. The sample was then filtered through a 0.7- $\mu$ m, baked glass fiber filter by EIWA NAWQA personnel. UHL personnel also collected physical property data that included pH, dissolved oxygen, water temperature, air temperature, gage height, and instantaneous discharge.

### **Biologic Sample Collection**

Biological studies evaluate the effects of physical and chemical characteristics of water and hydrologic conditions on aquatic biota and how biological and habitat characteristics differ among environmental settings in study units. Bed-sediment and fish-tissue samples are the primary means by which trace elements and hydrophobic organic contaminants are initially assessed. Bed-sediment and fish-tissue samples were collected at 16 sites in September 1995 and at 4 sites in September 1996.

Samples were collected and processed according to procedures outlined in Shelton and Capel (1994). Samples were collected in fine-grained sediments in nearshore depositional areas. The surficial 1 to 2 cm of bed sediment within 5 to 10 different depositional zones at each sampling site were subsampled several

times, and the subsamples were composited and sieved.

Fish were collected using electroshocking equipment carried on either a backpack, barge, or boat. Common carp (*Cyprinus carpio*) was the target taxon, although white sucker (*Catostomus commersoni*) or redbreast (*Moxostoma spp.*) were collected at sites where common carp were not sufficiently abundant. River carpsucker (*Carpionodes carpio*) or highfin carpsucker (*Carpionodes velifer*) were collected in addition to common carp at three sites in 1995. At two sites, common carp were collected in sufficient abundance to compare organic compound samples of two different size classes of fish. At one of these sites, common carp were collected in such abundance that two size-class samples were also sufficient for trace element analysis.

Each sample consisted of a composite of 8 to 12 fish of the same species and similar size. Each fish in a sample was measured, weighed, and examined for external anomalies, such as parasites, lesions, tumors, and diseases. Then scales and (or) the pectoral fin ray were collected for age determination of the fish. Powderless latex gloves were worn at all times during fish collection and processing. For analysis of organic compounds, fish were dissected with a stainless-steel scalpel blade (precleaned with methanol), examined for gender, and individually wrapped in heavy-duty aluminum foil (dull side towards fish) and then placed into a polyethylene bag. Following processing, all fish samples were placed on dry ice at the collection site in preparation for shipment to the analytical laboratory. If long-term storage was necessary, the samples were stored in a freezer.

For analysis of trace elements, the body cavity was opened with stainless-steel scissors precleaned with nitric acid. Gender was determined. The liver tissue was exposed with and excised by means of a pre-cleaned, stainless-steel scalpel blade to eliminate possible contamination from outside the body cavity. The dissected livers were placed into a plastic bag and then weighed. A sample weighing 5 g was considered minimally acceptable. The site number, date, location, species name, and the analyses to be performed were written on an index card and placed into a separate plastic bag along with the bagged liver sample. The bagged sample with identifying information was placed on dry ice at the collection site and shipped frozen to the laboratory.

## Analytical Procedures

For the analysis of major ions, nutrients, DOC, SOC, pesticides, and pesticide metabolites, surface-water samples were sent to the NWQL in Arvada, Colorado. The NWQL was also used to analyze for trace elements and organic compounds in bed sediment and fish tissue. Whole fish were composited for pesticide analysis, whereas only fish livers were composited for the trace element analysis. For analysis of bed-sediment particle size, samples were sent to the USGS sediment laboratory in Iowa City, Iowa. The analytical methods used in all sample processing can be found in tables 4-10 (at the end of this report).

Samples were analyzed for chlorophyll in the USGS office in Iowa City according to the procedure outlined in method 445.0 (Arar and Collins, 1992).

## Ground-Water-Quality Data Collection

### Geohydrology

The geology of the EIWA study unit consists mainly of bedrock that ranges in age from Pennsylvanian to Cambrian. The subcrop areas of the different bedrock units form broad, linear bands that trend northwest-southeast and regionally dip to the southeast. The units consist primarily of sandstone, shale, limestone, and dolomite. The eastern part of the Silurian-Devonian and Upper Carbonate aquifers was the focus of one study in the EIWA study unit (fig. 2) conducted in 1996.

The Silurian-Devonian aquifer underlies the central and southern parts of the study unit and consists of 200 to 400 ft of shallow marine limestone, dolomite, sandstone, shale, and evaporite deposits. These units gently dip to the southwest (fig. 2) beneath regionally confining Devonian shale of the Lime Creek Formation and Yellow Spring Group in the western part of the study unit. The aquifer forms the bedrock surface in the eastern part of the study unit where it is overlain by unconsolidated Quaternary deposits (sand, gravel, and clay), and is unconfined except in areas where fine-grained deposits produce locally confined conditions. The Silurian-Devonian aquifer is underlain by Ordovician-age rocks throughout the study unit.

The Upper Carbonate aquifer underlies the northern part of the study unit and consists of 250 to 600 ft of Ordovician and Devonian shallow marine limestone, dolomite, dolomitic limestone, and shale. The aquifer is overlain by unconsolidated Quaternary and

Cretaceous deposits (sand, gravel, and clay) and is unconfined except in areas where fine-grained deposits produce locally confined conditions. The Upper Carbonate aquifer is underlain by confining units of Ordovician age.

A second NAWQA ground-water study was begun to investigate the effects of changing land use on shallow ground-water quality in the Iowa River alluvial aquifer (fig. 3). The area of study for the Iowa River alluvial aquifer encompassed 83 mi<sup>2</sup> along a 16-mi reach of the Iowa River in east-central Iowa (Savoca and others, 1998). The river valley is underlain by alluvial clay, silt, and gravel of variable thickness (10 to 55 ft); the alluvial deposits are underlain by glacial till (Detroy and Kuzniar, 1988).

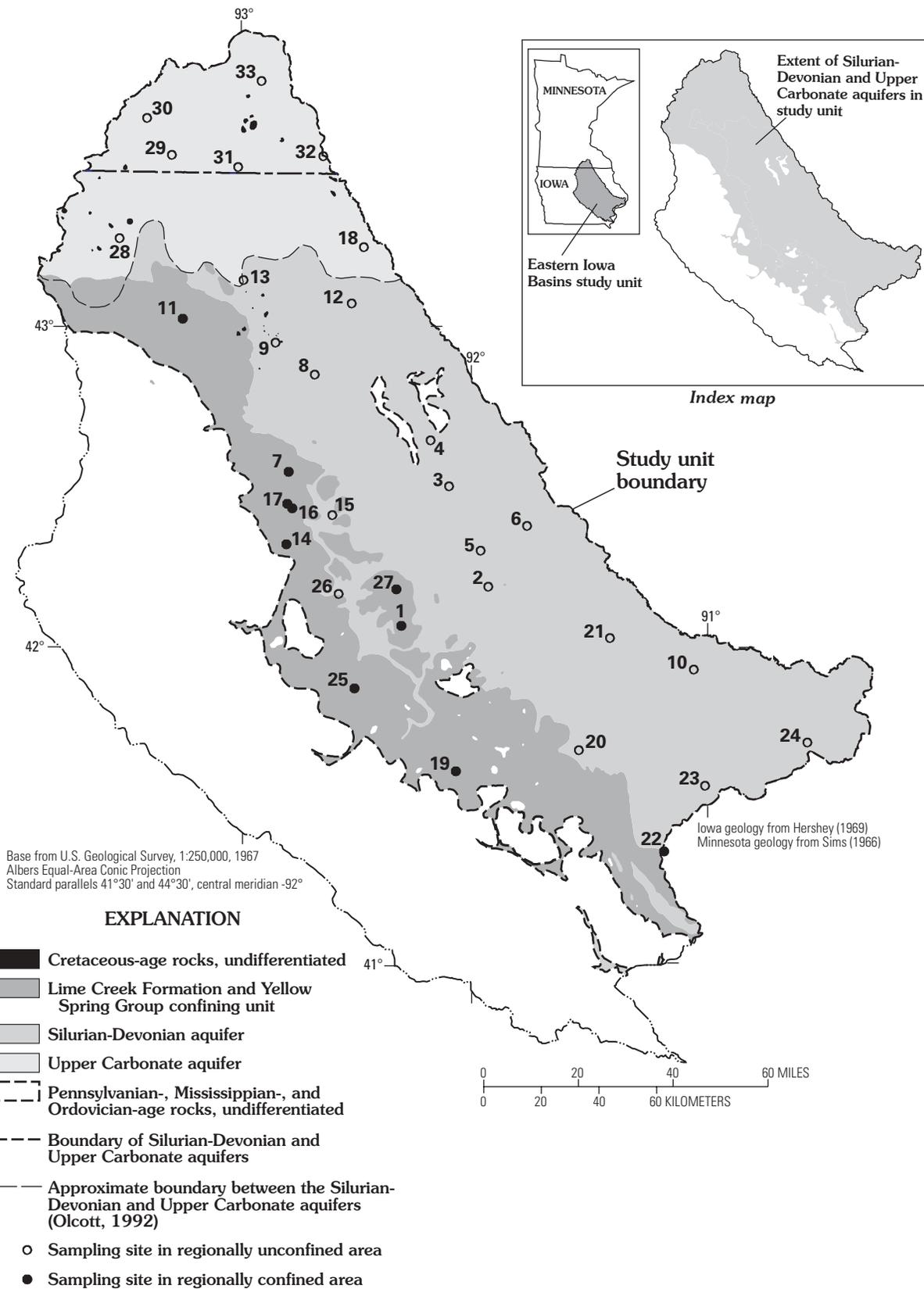
### Site Selection

Potential well locations in the study unit were identified using a stratified random selection process (Scott, 1990). An onsite reconnaissance within a 1-mi radius of each potential well location was conducted to determine if a suitable well could be found. Well-selection criteria included existing domestic well completed in the Silurian-Devonian or Upper Carbonate aquifers located within the study unit; permission to sample the well from the landowner; the depth of the well was known; the well was equipped with a submersible pump; and a sample could be obtained before a pressure tank or other treatment system. Information about the well was obtained from well-owner interviews and driller's logs. If a suitable well could not be found at the primary location, a search was initiated at the closest alternate site.

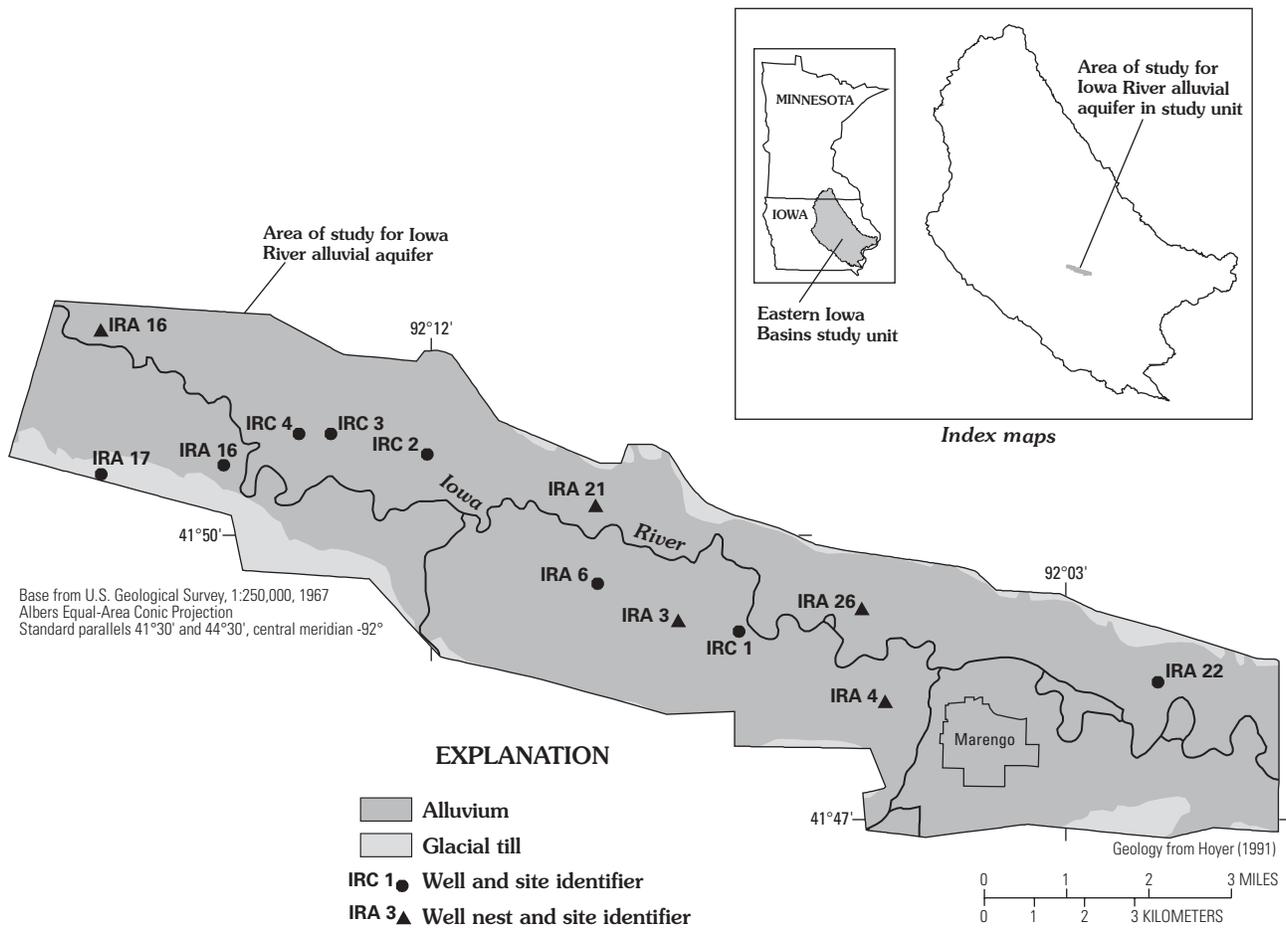
For the study of the Silurian-Devonian and Upper Carbonate aquifers, 33 wells were selected for sampling with depths ranging from 32 to 700 ft (table 2). Ground-water samples were collected during June and July 1996 and followed NAWQA protocols (Koterba and others, 1995). Twenty-three wells screened in the Iowa River alluvial aquifer were sampled during a 3-week period in 1996 (table 3).

### Ground-Water Sample Collection

The sampling procedures for ground water are described by Koterba and others (1995). Before sample collection, all sampling equipment was thoroughly cleaned. Sampling lines and hoses were cleaned by circulating a 0.1-percent nonphosphate detergent solution through the entire system with a peristaltic pump



**Figure 2.** Location of the Silurian-Devonian and Upper Carbonate aquifers and sampling sites.



**Figure 3.** Location of Iowa River alluvial aquifer and sampling sites.

for 10 minutes. The lines were then rinsed with 12 to 16 L of deionized water. All sampling and preservation chamber stands were washed with deionized water. All filter assemblies were also washed with a 0.1-percent nonphosphate detergent solution and rinsed with deionized water, with the exception of the DOC filter, which was washed with deionized water and rinsed with deionized water guaranteed by the manufacturer to be free of pesticides and VOC's. Cleaned equipment was wrapped in aluminum foil and placed in clean plastic bags.

Before sample collection, the static water level was recorded, and the wells were purged of at least three casing volumes. Pumping continued until measured values of specific conductance, pH, dissolved oxygen, and water temperature stabilized. Samples were then collected by filling containers in a sampling chamber made by placing a 6-mL polyethylene bag over a polyvinyl chloride (PVC) frame. All bottles were filled inside the sampling chamber to minimize

the potential for contamination. Holes were cut in the bag for the inflow hose, waste discharge, and access for sampling. Powderless latex gloves were worn during sampling. To begin sampling, flow valves were switched to route the water into the sampling chamber, and the sampling lines were flushed out for several minutes. For organic compound samples, all sampling lines and connections between the faucet and the sampling chamber were Teflon or stainless steel. Except for the baked glass bottles, all bottles were rinsed three times with pumped native ground water before filling. Samples were collected at each site for onsite determination of alkalinity, and laboratory analysis of VOC's, pesticides, pesticide metabolites, DOC, major ions, nutrients, tritium, radon, and stable isotopes.

Samples for pesticide analyses were filtered using a 142-mm-diameter glass fiber filter with 0.7- $\mu$ m pore openings. DOC samples were collected and filtered with a stainless-steel filter assembly and a 47-mm-

**Table 2.** Wells sampled in the Silurian-Devonian and Upper Carbonate aquifers

Site (fig. 2)	Site identification number	Local identifier	Location (degrees, minutes, seconds)		Well depth (feet)	County, State
			Latitude	Longitude		
1	420424092175101	084N 12W 19 BCC	42°04'24"	92°17'52"	560	Benton, IA
2	421157091554201	085N 09W 05 CBA	42°11'57"	91°55'45"	312	Benton, IA
3	423056092054601	089N 11W 13 CAC	42°30'56"	92°05'46"	155	Black Hawk, IA
4	423940092102801	091N 11W 29 CAC	42°39'40"	92°10'29"	120	Bremer, IA
5	421850091574001	087N 10W 25 CDC	42°18'45"	91°57'44"	218	Buchanan, IA
6	422329091455101	088N 08W 34 CAA	42°23'29"	91°45'51"	240	Buchanan, IA
7	423328092464901	090N 16W 31 DCB	42°33'28"	92°46'49"	280	Butler, IA
8	425158092402301	093N 16W 13 DAD	42°51'58"	92°40'23"	114	Butler, IA
9	425757092503001	094N 17W 10 CDD	42°57'57"	92°50'30"	240	Butler, IA
10	415600091033701	082N 02W 03 DCD	41°56'00"	91°03'37"	200	Cedar, IA
11	430216093142901	095N 20W 19 AAA	43°02'15"	93°14'30"	120	Cerro Gordo, IA
12	430532092305401	096N 14W 33 BCB	43°05'33"	92°30'54"	100	Chickasaw, IA
13	430947092590101	096N 18W 04 BCC	43°09'47"	92°58'59"	343	Floyd, IA
14	421944092471701	087N 17W 23 DDA	42°19'44"	92°47'17"	507	Grundy, IA
15	422524092353101	088N 15W 22 BCB	42°25'24"	92°35'31"	240	Grundy, IA
16	422631092454801	088N 16W 07 CDC	42°26'31"	92°45'50"	440	Grundy, IA
17	422723092470701	088N 16W 01 CCD	42°27'23"	92°47'06"	220	Grundy, IA
18	431614092275401	098N 14W 26 DCC	43°16'13"	92°27'55"	182	Howard, IA
19	413652092035801	079N 11W 36 AAA	41°36'52"	92°03'58"	700	Iowa, IA
20	414056091325201	079N 06W 04 ABD	41°40'56"	91°32'52"	225	Johnson, IA
21	420206091244901	084N 05W 34 DDC	42°02'06"	91°24'49"	291	Linn, IA
22	412030091113801	076N 03W 34 CBB	41°21'30"	91°11'38"	360	Muscatine, IA
23	413401091010901	078N 02W 12 DDD	41°34'01"	91°01'09"	240	Muscatine, IA
24	414153090350801	080N 03E 35 BBA	41°41'53"	90°35'08"	198	Scott, IA
25	415231092295301	082N 14W 32 AAB	41°52'31"	92°29'43"	320	Tama, IA
26	421030092340001	085N 15W 14 BDD	42°10'29"	92°33'51"	332	Tama, IA
27	421120092190501	085N 13W 12 BCC	42°11'21"	92°19'06"	350	Tama, IA
28	431725093310801	098N 23W 23 DAA	43°17'24"	93°31'08"	58	Winnebago, IA
29	433317093175601	101N 21W 13 BAD	43°33'16"	93°17'58"	115	Freeborn, MN
30	434012093243601	102N 22W 01 AAD	43°40'11"	93°24'35"	180	Freeborn, MN

**Table 2.** Wells sampled in the Silurian-Devonian and Upper Carbonate aquifers—Continued

Site (fig. 2)	Site identification number	Local identifier	Location (degrees, minutes, seconds)		Well depth (feet)	County, State
			Latitude	Longitude		
31	433109093004001	101N 18W 29 DAA	43°31'10"	93°00'8"	32	Mower, MN
32	433323092383201	101N 15W 16 BAB	43°33'23"	92°38'2"	160	Mower, MN
33	434732092545001	104N 17W 19 DDB	43°47'32"	92°54'50"	120	Mower, MN

**Table 3.** Wells sampled in the Iowa River alluvial aquifer

Site (fig. 3)	Site identification number	Local identifier	Location (degrees, minutes, seconds)		Well depth (feet)	County, State
			Latitude	Longitude		
IRA 16	415211092164101	082N 12W 31 DAD	41°52'11"	92°16'41"	26.0	Benton
IRA 16	415211092164102	082N 12W 31 DAD	41°52'11"	92°16'41"	15.0	Benton
IRC 4	414816092053401	081N 11W 23 DCC	41°48'16"	92°05'34"	31.0	Iowa
IRC 4	414816092053402	081N 11W 23 DCC	41°48'16"	92°05'34"	13.5	Iowa
IRC 4	414816092053403	081N 11W 23 DCC	41°48'16"	92°05'34"	11.0	Iowa
IRA 26	414818092055401	081N 11W 14 CCA	41°49'15"	92°05'54"	22.5	Iowa
IRA 26	414818092055402	081N 11W 14 CCA	41°49'15"	92°05'54"	13.5	Iowa
IRA 26	414818092055403	081N 11W 14 CCA	41°49'15"	92°05'54"	11.0	Iowa
IRA 22	414828092014201	081N 10W 20 DAC	41°48'28"	92°01'42"	25.0	Iowa
IRC 1	414900092073801	081N 11W 21 ABD	41°49'00"	92°07'38"	22.5	Iowa
IRA 3	414907092083001	081N 11W 20 AAA	41°49'07"	92°08'30"	29.0	Iowa
IRA 3	414907092083002	081N 11W 20 AAA	41°49'07"	92°08'30"	9.0	Iowa
IRA 3	414907092083003	081N 11W 20 AAA	41°49'07"	92°08'30"	15.5	Iowa
IRA 6	414930092093801	081N 11W 17 CBB	41°49'30"	92°09'38"	30.0	Iowa
IRA 21	415020092094001	081N 11W 07 DAA	41°50'20"	92°09'40"	25.0	Iowa
IRA 21	415020092094003	081N 11W 07 DAA	41°50'20"	92°09'40"	15.0	Iowa
IRA 21	415020092094004	081N 11W 07 DAA	41°50'20"	92°09'40"	12.0	Iowa
IRA 21	415020092094010	081N 11W 07 DAA	41°50'20"	92°09'40"	32.0	Iowa
IRA 17	415039092164001	081N 12W 05 CCC	41°50'39"	92°16'40"	40.0	Iowa
IRA 19	415045092145601	081N 12W 09 ABC	41°50'45"	92°14'56"	25.0	Iowa
IRC 2	415052092120301	081N 12W 11 AAD	41°50'52"	92°12'03"	27.5	Iowa
IRC 3	415105092132501	081N 12W 03 DDB	41°51'05"	92°13'25"	22.5	Iowa
IRC 4	415105092135201	081N 12W 03 CDA	41°51'05"	92°13'52"	22.5	Iowa

diameter silver filter membrane with 0.45- $\mu\text{m}$  openings. Filtration was done under pressure from nitrogen gas.

All samples were preserved and treated immediately after collection. Samples for VOC's were treated with a 1:1 hydrochloric acid solution (HCl). Samples for major ions were treated with 1 mL of nitric acid. All samples were then chilled for shipment to NWQL.

Radon-222 samples were collected by inserting a syringe through a gas-impermeable membrane in the gas-collection tube and withdrawing 15 mL of sample water. To allow the withdrawal of sample water without degassing, sufficient backpressure was created by closing a valve in the sample-collection tube. The syringe was then inverted (needle up) and voided until all air bubbles were gone and only 10 mL of sample remain in the barrel. The sample was then injected (needle down) into a vial at the base of a mineral oil layer. The vial was capped and shaken for approximately 10 seconds. Radon-222 samples were shipped (overnight delivery) the day of collection.

### **Analytical Procedures**

For the analysis of major ions, nutrients, DOC, SOC, pesticides, pesticide metabolites, VOC's, and radon, ground-water samples were sent to the NWQL in Arvada, Colorado. Ground-water samples were analyzed for tritium at the USGS Isotope Tracers Project Laboratory in Menlo Park, California, and for environmental isotopes at the USGS National Research Program Laboratory in Reston, Virginia. The analytical methods used in all sample processing are listed in tables 4-10 at the end of this report.

### **Water-Quality Analysis and Quality Control**

Analytical results were evaluated in the context of minimum reporting levels (MRL's) and method detection limits (MDL's) established by NWQL. An MRL is the minimum concentration of a constituent that can be reliably measured and reported by the laboratory using a given analytical method. MRL's are commonly reported with analytical results for common ions, nutrients, DOC, radiochemicals, and VOC's. An MDL is the minimum concentration of a substance that can be identified, measured, and reported with 99-percent confidence that the constituent concentration is greater than zero. MDL's are generally smaller and more well defined statistically than MRL's and are commonly

reported with analytical results for pesticides (Zaugg and others, 1995). MRL's and MDL's provide information about relative analytical precision and detection sensitivity but do not constitute low concentration reporting limits for conclusively identified constituents (Zaugg and others, 1995). A numerical value is reported with an "E" (estimated) code for measurements less than the MDL if a chromatograph peak is observed at the correct retention time and the qualifying information from the spectrometer conclusively identifies the constituent. Data also may be estimated when a target constituent is detected and identified, but the quantification is not completed because the resulting value is greater than the highest calibration standard for the method. Values censored with an "E" code necessarily carry a lower confidence.

### **Surface Water**

The philosophy of NAWQA surface-water quality-control design is described in detail by Mueller and others (1997). About 15 percent of the total samples collected for the EIWA NAWQA were analyzed for quality control. Quality-control samples submitted for analysis during the 1996 water year (October 1, 1995, through September 30, 1996) included equipment blanks for two sets of sampling equipment, five field blanks, six replicate samples, three spike samples, and laboratory surrogate recoveries. Equipment blank samples of deionized water guaranteed by the manufacturer to be free of pesticides and VOC's and deionized water guaranteed by the manufacturer to be free of inorganic compounds were passed through all sampling equipment at the beginning of data collection to verify the initial cleanliness of the sampling equipment. Field blank samples of the same deionized water that was used with equipment blank samples were collected by passing the deionized water through all pumps, filter plates, and filters to verify cleanliness of sampling equipment and technique. Field blank samples verified that the surface-water samples were not contaminated from either the sampling equipment, transport of the equipment, or the cleaning procedures done between sites. Blank samples (equipment and field) indicated that all constituents were less than the MDL for all samples.

The objective of the replicate samples was to estimate the precision of concentration values from sample processing and analysis. Analysis of organic constituents are generally more variable than analyses of inorganic constituents. In particular, replicate sam-

ples for pesticides were an important way to evaluate the consistency of the identifying target constituent. Each replicate sample is an aliquot of the native sample water processed through the cone splitter, that passes through the same sample equipment, and is prepared in the same way.

A spike sample is a sample to which a laboratory-certified concentration of selected constituents has been added. Spike samples were used to estimate percent recovery and possible degradation of the constituent concentration during sample processing and analysis. The spike recovery (in percent, %) is calculated as follows:

$$\text{Spike recovery \%} = [(C_{\text{spiked}} - C_{\text{unspiked}})/C_{\text{expd}}] * 100 \quad (1)$$

where  $C_{\text{spiked}}$  is the measured concentration of the spiked sample, in micrograms per liter;  $C_{\text{unspiked}}$  is the measured concentration of the unspiked sample, in micrograms per liter; and  $C_{\text{expd}}$  is the expected or theoretical concentration of the spiked sample, in micrograms per liter.  $C_{\text{expd}}$  is calculated from the concentration of the spike mixture, the amount of spike added, and volume of the sample using the following equation:

$$C_{\text{expd}} = C_{\text{soln}} * \text{Amt}/\text{SmplVol}, \quad (2)$$

where  $C_{\text{soln}}$  is the concentration of the spike solution, in micrograms per liter; Amt is the amount of spike added, in milliliters; and SmplVol is the spiked sample volume, in liters.

For the EIWA study unit, the concentration of pesticide compounds in the spike solution ( $C_{\text{soln}}$ ) for 1996 was 1.0  $\mu\text{g/L}$ , except for permethrin which was 0.3  $\mu\text{g/L}$ . The amount of spike added (Amt) for all spike samples was 0.100 mL. The sample volumes for the three spikes were 0.947, 0.948, and 0.923 L for spike samples collected at Iowa River near Rowan (site 3, fig. 1), Iowa River at Marengo (site 5, fig. 1), and Cedar River at Gilbertville (site 12, fig. 1), respectively. The spike recoveries for the pesticide compounds ranged from 33 to 301 percent.

A surrogate compound is an organic compound that has similar physical and chemical properties to the constituents being determined but is not naturally present in the sample. A surrogate compound is added to each pesticide sample that is processed at the NWQL as part of their quality-control protocols. The percent recovery of the surrogate compounds allows a quality check on amount of recovery for the pesticide sample. Surrogate recoveries were typically between 80 and 120 percent for the pesticide compounds and are listed in table 15 at the end of this report.

## Biology

A replicate bed-sediment sample and fish-tissue sample were collected at one site in 1996. These samples were analyzed for trace elements and organic compounds.

## Ground Water

Quality-control samples consisted of equipment blanks, field blanks, trip blanks, replicate samples, and laboratory surrogate recoveries. Three field blanks were analyzed for pesticides and pesticide metabolites; five for VOC's; two for major ions and nutrients; and six for DOC. Three replicate samples were analyzed for major ions, nutrients, DOC, VOC's, pesticides, pesticide metabolites, radon-222, tritium, and environmental isotopes; and one for major ions, nutrients, DOC, VOC's, and pesticides. One VOC equipment blank and two VOC trip blanks were used to investigate VOC concentrations during the sampling season.

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