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SELECTED NUTRIENTS AND PESTICIDES IN STREAMS OF THE EASTERN IOWA BASINS, 1970–95

Water-Resources Investigations Report 99–4028

U.S. Department of the Interior
U.S. Geological Survey
National Water-Quality Assessment Program

Selected Nutrients and Pesticides in Streams of the Eastern Iowa Basins, 1970–95

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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 a specific contamination problem; 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 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 to:

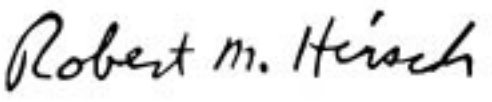
- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

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 units, 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 areas 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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Multiply	By	To obtain
	Length	
inch	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square foot (ft^2)	929.0	square centimeter ($cm^{2)}$
square inch (in^2)	6.452	square centimeter (cm^2)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Volume	
gallon (gal)	3.785	liter (L)
million gallons (Mgal)	3,785	cubic meter (m^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
	Flow	
foot per second (ft/s)	0.3048	meter per second (m/s)
foot per minute (ft/min)	0.3048	meter per minute (m/min)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Mass	
pound (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	megagram (Mg)
ton per day (ton/d)	0.9072	metric ton per day (t/d)
ton per year (ton/yr)	0.9072	megagram per year (Mg/yr)

Temperature in degrees Celsius (^oC) may be converted to degrees Fahrenheit (^oF) as follows:

$$^oF = (1.8 \times {}^oC) + 32$$

Temperature in degrees Fahrenheit (^oF) may be converted to degrees Celsius (^oC) as follows:

$$^oC = (^oF - 32) / 1.8$$

pH is the negative base-10 logarithm of the hydrogen ion activity, in moles per liter.

One metric ton is equal to 1,000 kilograms.

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Water year is the 12-month period October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the year ending in September 30, 1995, is called “water year 1995.”

These additional abbreviations are used in this report:

Abbreviation	Description
ADAPS	Automated Data Processing System data base
EIWA	Eastern Iowa Basins
HAL	Health Advisory Level
IDNR	Iowa Department of Natural Resources
LOWESS	Locally Weighted Scatterplot Smooth
MCL	Maximum Contaminant Level
MPCA	Minnesota Pollution Control Agency
NASQAN	National Stream Quality Accounting Network
NAWQA	National Water-Quality Assessment
NWIS	National Water Information System
STORET	STOrage and RETrieval data base
SAS	Statistical Analysis System
UHL	University of Iowa Hygienic Laboratory
UIIHR	University of Iowa Institute of Hydraulic Research
USCOE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
NH_3	Ammonia
NH_4^+	Ammonium
NO_3^-	Nitrate
N	Nitrogen
PO_4^{3-}	Orthophosphate
P	Phosphorus
µg/L	Micrograms per liter
mg/L	Milligrams per liter
^oC	Degrees Celsius
^oF	Degrees Fahrenheit
+	Upward trend
–	Downward trend

Selected Nutrients and Pesticides in Streams of the Eastern Iowa Basins, 1970–95

By Douglas J. Schnoebelen, Kent D. Becher, Matthew W. Bobier *and* Thomas Wilton

Abstract

Water-quality data from 17 surface-water monitoring sites were compiled for 1970 through 1995 and analyzed to determine historical water-quality conditions and possible trends in the Eastern Iowa Basins study unit as part of the U.S. Geological Survey's National Water-Quality Assessment Program. The Eastern Iowa Basins encompasses the Wapsipinicon, Cedar, Iowa, and Skunk River Basins and covers about 19,500 square miles. Seven of the monitoring sites were sampled by the Iowa Department of Natural Resources, three sites by the Minnesota Pollution Control Agency, three sites by the University of Iowa Institute for Hydraulic Research, and four sites by the U.S. Geological Survey. Water-quality analyses typically consisted of nitrate, ammonia, total nitrogen, and total phosphorus, with limited analyses available for organic nitrogen, dissolved phosphorus, dissolved orthophosphate, and water-soluble pesticides. Long-term historical nutrient and pesticide data were not available for the Wapsipinicon River Basin.

Median concentrations for total nitrogen ranged from 4.6 to 9.4 milligrams per liter, and maximum concentrations of total nitrogen ranged from 4.6 to 31 milligrams per liter. The majority of nitrogen transported in surface waters of the Eastern Iowa Basins study unit is in the form of nitrate (nitrogen). Median concentrations of total phosphorus ranged from less than 0.10 to 0.66 milligram per liter, and maximum concentrations of total phosphorus ranged from less than 0.10 to 5.4 milligrams per liter.

Nitrate varied seasonally. Median concentrations of nitrate were largest during the spring and the winter (6.0 to 7.0 milligrams per liter) compared to the summer and fall (2.0 to 4.0 milligrams per liter). Concentrations of nitrate greater than 10 milligrams per liter typically occurred during spring runoff. Median ammonia concentrations generally were highest during the winter (approximately 0.3–0.5 milligram per liter) compared to the spring and summer when ammonia concentrations were often close to the detection limit (0.01 milligram per liter). In general, the median concentrations of total phosphorus varied less than 0.1 milligram per liter between seasons.

The statistical analysis of the nutrient data typically indicated a strong positive correlation of nitrate with streamflow. Total phosphorus concentrations with streamflow showed greater variability than nitrate, perhaps reflecting the greater potential of transport of phosphorus on sediment rather than in the dissolved phase as with nitrate. Ammonia and ammonia plus organic nitrogen showed no correlation with streamflow or a weak positive correlation. Seasonal variations and the relations of nutrients and pesticides to streamflow generally corresponded with nonpoint-source loadings, although possible point sources for nutrients were indicated by the data at selected monitoring sites. Statistical trend tests for concentrations and loads were computed for nitrate, ammonia, and total phosphorus. Trend analysis indicated decreases for ammonia and total phosphorus concentrations at several sites and increases for nitrate concentrations at other sites in the study unit.

Long-term pesticide data are lacking in the study unit. Atrazine was the most commonly detected pesticide. Maximum concentrations of pesticides usually occurred after spring runoff. Large streamflows during the late summer do not have pesticide concentrations as large as do similar streamflows during the spring that occur soon after the application of pesticides.

INTRODUCTION

In 1991, the U.S. Geological Survey (USGS) began implementation of the National Water-Quality Assessment (NAWQA) Program. The long-term goals of the NAWQA Program are to describe the current water-quality conditions and trends of the Nation's water resources and to link assessment with an understanding of the natural and human factors that affect the quality of water (Gilliom and others, 1995). Through a multidisciplinary approach encompassing the sampling and analysis of water, sediment, and aquatic ecology, the program provides a nationwide assessment to aid research, water management, and policy.

Study-unit investigations and national synthesis of information are the major design features of the NAWQA Program that allow water-quality information collected at local and regional scales to be integrated into a nationwide description of water quality. Major activities of the NAWQA Program take place within a set of hydrologic systems called study units. Study units comprise diverse hydrologic systems of river basins, aquifers, or both. The 59 study units that have been identified (see cover of this report) include parts of most of the Nation's major river basins and account for approximately 60 to 70 percent of the Nation's water use and population served by public water supplies (Leahy and Wilber, 1991). The study units vary in size from less than 1,000 to more than 60,000 mi^2. The Eastern Iowa Basins (EIWA) study unit is one of 15 NAWQA study units that were selected to begin assessment in 1994. Assessment within the EIWA study unit will serve the national NAWQA goals in three respects: (1) By providing a regional description and analysis of the quality of water resources in eastern Iowa and southern Minnesota, (2) by examining the vulnerability of the water resources to natural and human factors, and (3) by providing consistent and compatible data for use in a national synthesis of information that can be used to interpret results from the many study units on a national scale. One component of the assessment process involves an analysis of historical water-quality data for surface water collected in the EIWA study unit during 1970–95. These water-quality data can provide insight into historical trends and aid in the design of NAWQA studies.

In Iowa, nutrients and pesticides are water-quality topics of concern (Goolsby and others, 1991; Goolsby and Battaglin, 1993; Kalkhoff, 1993; Iowa Department of Natural Resources, 1994a; Hallberg and others, 1996). Considerable concern in recent years has been expressed over health effects of nitrate and pesticides in drinking water (Neill, 1989; Richards and others, 1995). High levels of nitrite and nitrate have been traced to infantile methemoglobinemia (whereby the blood loses its ability to transport oxygen) and are suspected of causing the formation of carcinogenic nitrosamines and nitrosamides (Neill, 1989). Nitrogen and phosphorus compounds can occur naturally in ambient stream water but are normally at low concentrations. Concentrations of nitrogen and phosphorus in stream water can be increased by the discharge from wastewater-treatment facilities, fertilizer runoff, livestock production, soil erosion, and other sources (Hem, 1985). Increased concentrations of nitrogen and phosphorus can promote the growth of algae, which eventually die and decompose, depleting the water column of dissolved oxygen (known as hypoxia), which, in turn, may kill off fish and other aquatic life. In nutrient-poor freshwater, inorganic phosphate is often the factor limiting the growth of aquatic plants and algae. However, nitrate as nitrogen tends to become limiting when phosphate is plentiful (Allen, 1995, p. 89). Large nitrogen loads resulting from fertilizer input to the Mississippi River Basin may be a cause of concern for water quality in the Gulf of Mexico (Justic and others, 1993; Rabalais and others, 1996).

Common herbicides in use in Iowa, such as atrazine and alachor, are potential carcinogens and have Maximum Contaminant Levels (MCLs) established by the U.S. Environmental Protection Agency (USEPA) for drinking water (U.S. Environmental Protection Agency, 1986). The USEPA lists other

chemicals that have Health Advisory Levels (HALs) for drinking water or have recommended ambient water-quality criteria for the protection of aquatic organisms (Nowell and Resek, 1994). Several recent studies have raised additional concerns about potential effects of manmade chemicals in surface water on the endrocrine systems of aquatic and terrestrial organisms (Colborn and Clement, 1992; Colborn and others, 1993; Goodbred and others, 1997).

Information on water-quality conditions is necessary for water-resource management and planning purposes. Specific water-quality issues of primary concern in the EIWA study unit include degradation of aquatic ecosystems, soil erosion, and increased concentrations of nutrients and synthetic organic compounds (including pesticides) (Kalkhoff, 1994). These issues are consistent with the national objectives of the NAWQA Program described previously.

Purpose and Scope

The purposes of this report are (1) to compile and statistically summarize available data for surface water concerning nutrients and pesticides in the EIWA study unit; and (2) to describe, analyze, and assess the selected nutrient and pesticide data for possible temporal or spatial patterns. Water-quality data from seven surface-water-quality monitoring sites operated by the Iowa Department of Natural Resources (IDNR), three sites operated by the Minnesota Pollution Control Agency (MPCA), three sites operated by the University of Iowa Institute of Hydraulic Research (UIIHR), and four sites operated by the USGS were analyzed to determine concentrations and possible trends.

Acknowledgments

The authors acknowledge agencies and individuals that have collected and compiled data used in this report, which include the Iowa Department of Natural Resources, the University of Iowa Hygienic Laboratory (Iowa City), the Iowa State Department of Health, the Minnesota Pollution Control Agency, and the U.S. Army Corps of Engineers.

DESCRIPTION OF THE EASTERN IOWA BASINS

The EIWA study unit encompasses the Wapsipinicon, Cedar, Iowa, and Skunk River Basins, which cover about 19,500 mi^2 of Iowa and southeastern Minnesota (fig. 1). The four major rivers have their headwaters in the northwestern part of the study unit, flow southeastward, and discharge to the Mississippi River.

Geomorphology

The EIWA study unit is divided into three major landform regions (Des Moines Lobe, Iowan Surface, and Southern Iowa Drift Plain) (Prior, 1991) and one subregion (Iowan Karst, a subregion of the Iowan Surface) on the basis of distinct spatial differences in topography, geology, soils, and vegetation (fig. 1). These regions also broadly coincide with ecoregions and subecoregions of Iowa (Griffith and others, 1994).

The Des Moines Lobe, in the western part of the study unit, is one of the youngest landforms in Iowa and is characterized by low local relief (50–100 ft). The Des Moines Lobe was formed approximately 12,000 to 14,000 years ago (Wisconsinan age) during the last glaciation in Iowa and has been only slightly altered since that time (Prior, 1991). The topography consists of predominantly flat and slightly rolling land broken by curved bands of “knob and kettle” terrain (Buchmiller and others, 1985). Originally, ponds and wetlands from poor drainage were characteristic of the Des Moines Lobe. Extensive ditching and tiling of fields during 1900–20 have increased the surface drainage in this area. The potential natural vegetation is bluestem prairie (Griffith and others, 1994), although corn and soybean production presently dominates. Stream development is poor with many small, low-gradient streams that drain into relatively few large rivers. Surficial material consists of loamy till that has an average thickness of approximately 100 ft and alluvium in association with large streams. Surficial loess is absent.

The Iowan Surface is characterized by gently rolling topography with long slopes and low local relief (50–100 ft). Drainage is well developed, although streams generally have slight gradients. Surficial material consists of pre-Illinoian-age (500,000–700,000 years old) loamy till covered by

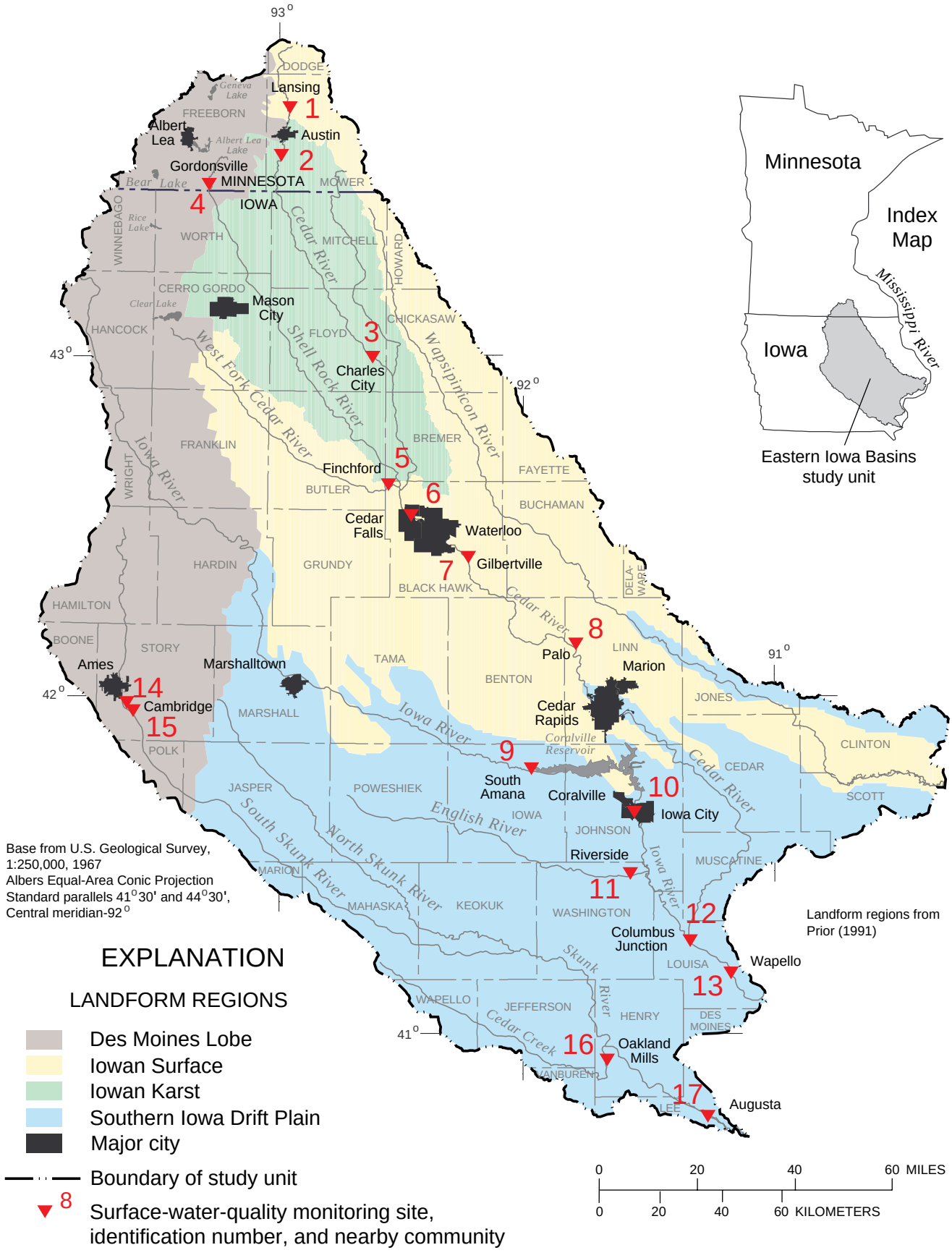


Figure 1. Location of the Eastern Iowa Basins study unit, landform regions, and selected surface-water-quality monitoring sites.

a thin veneer of windblown loess on the ridges and alluvium near the streams (Prior, 1991). Potential natural vegetation is bluestem prairie and oak-hickory forest, although corn and soybean production presently dominates (Prior, 1991; Griffith and others, 1994).

The Iowan Karst is a subregion of the Iowan Surface where dissolution of soluble limestone and dolomite under a thin or nonexistent cover of glacial drift has caused localized collapse of the land surface that resulted in a karst topography with numerous sinkholes. The surface drainage is well developed, although local infiltration to bedrock units is common. This area is extensively used for agriculture, and some fields are drained through agricultural drainage wells, which are a form of gravity-operated injection well. Field tile lines are typically connected to these drainage wells. The drainage wells can provide a conduit for surface runoff and field drainage to the underlying bedrock aquifer. Floyd County has the largest number of registered agricultural drainage wells in the EIWA study unit (Libra and others, 1996). In the EIWA study unit, sinkholes are natural features in the Iowan Karst that can affect ground-water quality in a manner similar to the agricultural drainage wells.

The Southern Iowa Drift Plain is characterized by steeply rolling terrain with moderate local relief (100–300 ft) separated by flat, tabular divides. Surficial material consists of pre-Illinoian glacial deposits mantled by loess. Soils on the lower slopes commonly are derived from till, whereas soils on the higher slopes and upland flats are derived from loess. Alluvium is present in association with streams that form a well-developed drainage pattern. Potential natural vegetation is bluestem prairie and oak-hickory forest (Griffith and others, 1994), although corn and soybean production presently predominates.

Climate

The climate in the EIWA study unit is continental, with large differences in seasonal temperatures that result in well-defined winter and summer seasons. Primary controlling factors that affect the climate in the EIWA study unit are warm, moist air from the Gulf of Mexico and surges of cold, dry air from Canada, which predominate in the summer and winter, respectively (U.S. Department of Commerce, 1959).

The mean annual temperature for the EIWA study unit is 47°F with average temperatures ranging from 71°F during the warmest months (June, July, August) to 20°F during December, January, and February (U.S. Department of Commerce, 1959). The growing season, which is approximately 127 days, is characterized by average temperatures that vary from 66°F in the southern part of the EIWA study unit to 60°F in the northern part.

Precipitation occurs mostly as rain from air that moves northward from the Gulf of Mexico. This precipitation is mainly associated with thunderstorms that occur from April through September, during which time the study unit receives approximately 70 percent of its annual rainfall (U.S. Department of Commerce, 1959). Peak precipitation occurs in June when crop-moisture demands are at their greatest and diminishes sharply during the fall harvesting season. Precipitation during the cooler months of the year generally is of long duration and of moderate or low intensity, whereas precipitation during the late spring and summer tends to be of shorter duration and of higher intensity. Snow during the colder winter months can remain on the ground until spring. The mean annual precipitation ranges from 31 inches in the northernmost part of the study unit to 38 inches in the southeastern part (U.S. Department of Commerce, 1959).

Streamflow

The Wapsipinicon, Cedar, Iowa, and Skunk Rivers flow from northwest to southeast across the study unit toward the Mississippi River at the eastern border of Iowa (figs. 1 and 2). The Wapsipinicon River originates in southeastern Minnesota and is about 225 mi long. The Wapsipinicon River Basin averages about 10 mi wide with a drainage area of 2,540 mi^2. The Cedar River originates in southern Minnesota and forms the largest basin in the study unit. The Cedar River Basin ranges from 20 to 60 mi wide. The Cedar River joins the Iowa River about 30 mi upstream from the confluence of the Iowa and Mississippi Rivers. The headwaters for the Iowa River are in north-central Iowa. The Iowa River Basin averages 20 mi wide. The Iowa and Cedar River Basins combine to cover 12,640 mi^2, more than 90 percent of which is in Iowa. The Skunk River originates in central Iowa, has a drainage basin that is about 24 mi wide, and drains approximately 4,350 mi^2. Eash (1993) has described channel and drainage-basin characteristics for many streams in the EIWA study unit.

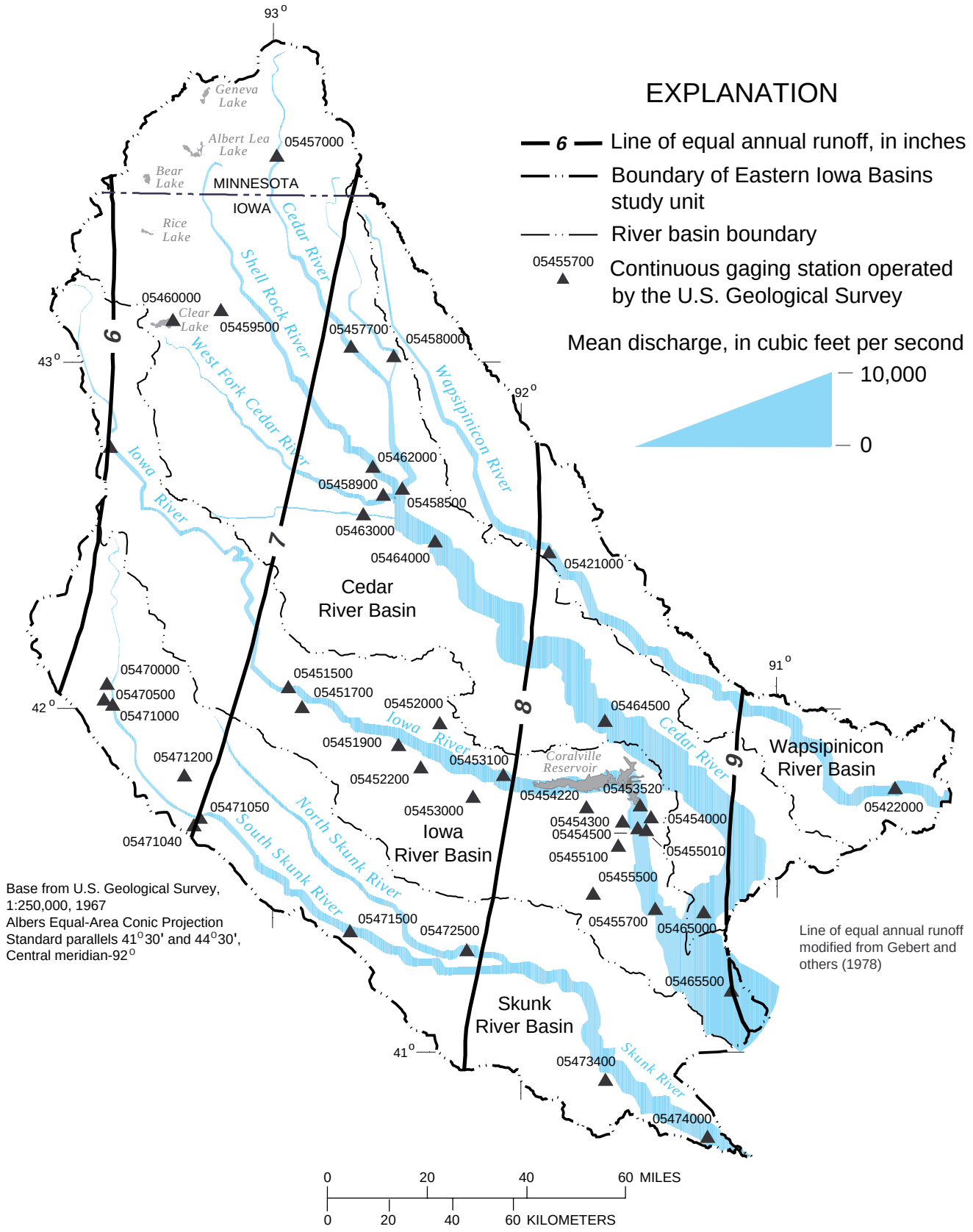


Figure 2. Mean annual streamflow (water years 1970–95), mean annual runoff (water years 1951–80), and location of continuous streamflow-gaging stations in the Eastern Iowa Basins study unit.

Overland flow (direct surface runoff) and ground-water discharge are the major sources of streamflow. Another source of flow to streams is interflow. Interflow is that part of the subsurface flow that moves at shallow depths and reaches the surface channels in a relatively short period of time and, therefore, is commonly considered part of overland flow. During a storm period, interflow is commonly characterized by slowly increasing up to the end of the storm period, followed by a gradual recession (Viessman and others, 1989). Field tile drains can enhance the subsurface drainage component of flow to streams. In the study unit, the mean annual runoff (overland flow, ground-water discharge, and interflow) to streams (water years 1951–80) averages about 25 percent of the annual precipitation and increases from less than 6 inches in the western part of the study unit to more than 9 inches in the southeastern part (fig. 2). Figure 2 also illustrates the mean annual streamflow (or surface-water discharge) of major streams (water years 1970–95) in the EIWA study unit. Total mean annual streamflow from the study unit (based on the entire period of record available) averages about 9.2 million acre-ft (Kalkhoff, 1994). The mean annual streamflow from the Wapsipinicon River Basin, the combined Iowa and Cedar River Basins, and the Skunk River Basin averages about 1.1, 6.3, and 1.8 million acre-ft, respectively. Statistical summaries of historical streamflow data for approximately 42 streamflow-gaging stations in the EIWA study unit have been compiled by Fischer and Eash (1998).

Flooding often occurs as a result of spring melting of snowpack combined with rainfall or thunderstorm activity. Droughts can result from the shift of the normal storm track by high-pressure conditions, a block or decrease in moist air flows, or lack of thunderstorm development. Soenksen and Eash (1991) describe floods and droughts that have affected streamflow in the EIWA study unit. The major floods of 1982 in the EIWA study unit were the result of thunderstorms that began in May and continued through mid-July. Water year 1993 (October 1992 through September 1993) was the wettest in 121 years of record (Southard and others, 1994). The record-breaking precipitation in Iowa during the summer of 1993 resulted in large floods in the EIWA study unit. The drought of 1974–79 was statewide and especially affected the northern half of the EIWA study unit. A drought affecting the western and central part of Iowa occurred during 1979–82 and affected mainly the southwestern parts of the study unit. The 1988–89 drought was statewide, with high temperatures and near-record minimum precipitation, and affected all of the EIWA study unit (Soenksen and Eash, 1991).

Population, Land Use, and Water Use

Total population in the EIWA study unit was approximately 1,169,000 in 1990 (U.S. Department of Commerce, 1994)—88 percent in Iowa and 12 percent in Minnesota. Thirty-nine percent of the people were located in 12 principal communities that have populations greater than 10,000. Principal communities are interspersed among small, rural communities and farms (fig. 3). Generally, the population of the principal communities in Iowa from 1980 to 1990 has been relatively stable (table 1). Five of the 12 cities with populations greater than 10,000 are located in the Cedar River Basin. In 1990, population for the entire Cedar River Basin was approximately 553,000, representing 47 percent of the total population within the EIWA study unit. The Iowa River Basin had the next largest population with approximately 231,000 people. The 1990 population for the Skunk and Wapsipinicon River Basins was about 210,000 and 175,000 respectively.

Agriculture accounts for 92.9 percent of the land use in the study unit. Other land uses are forests (4.0 percent), urban (1.8 percent), and other purposes (1.3 percent). Industries, university programs, and research in the largest cities (Cedar Rapids, Waterloo/Cedar Falls, and Iowa City/Coralville) contribute significantly to the agricultural economy. The principal crops are corn, soybeans, oats, hay, and pasture on unirrigated land. Approximately 3.95 million head of cattle were reported in Iowa in December 1995 (Sands and Holden, 1996). Hog production ranked first in the United States—14.4 million head in December 1995 (Sands and Holden, 1996). Numerous hog-production facilities began operation in the 1990's in the study unit. Figure 4 shows the location of permitted livestock facilities in the EIWA study unit, and the majority of these livestock facilities are for hog production. Confinement feeding operations must be permitted by the Iowa Department of Natural Resources before construction if the facility is designed for an animal weight capacity greater than 400,000 pound bovine or 200,000 pounds for other animal species (Iowa Department of Natural Resources, 1998a).

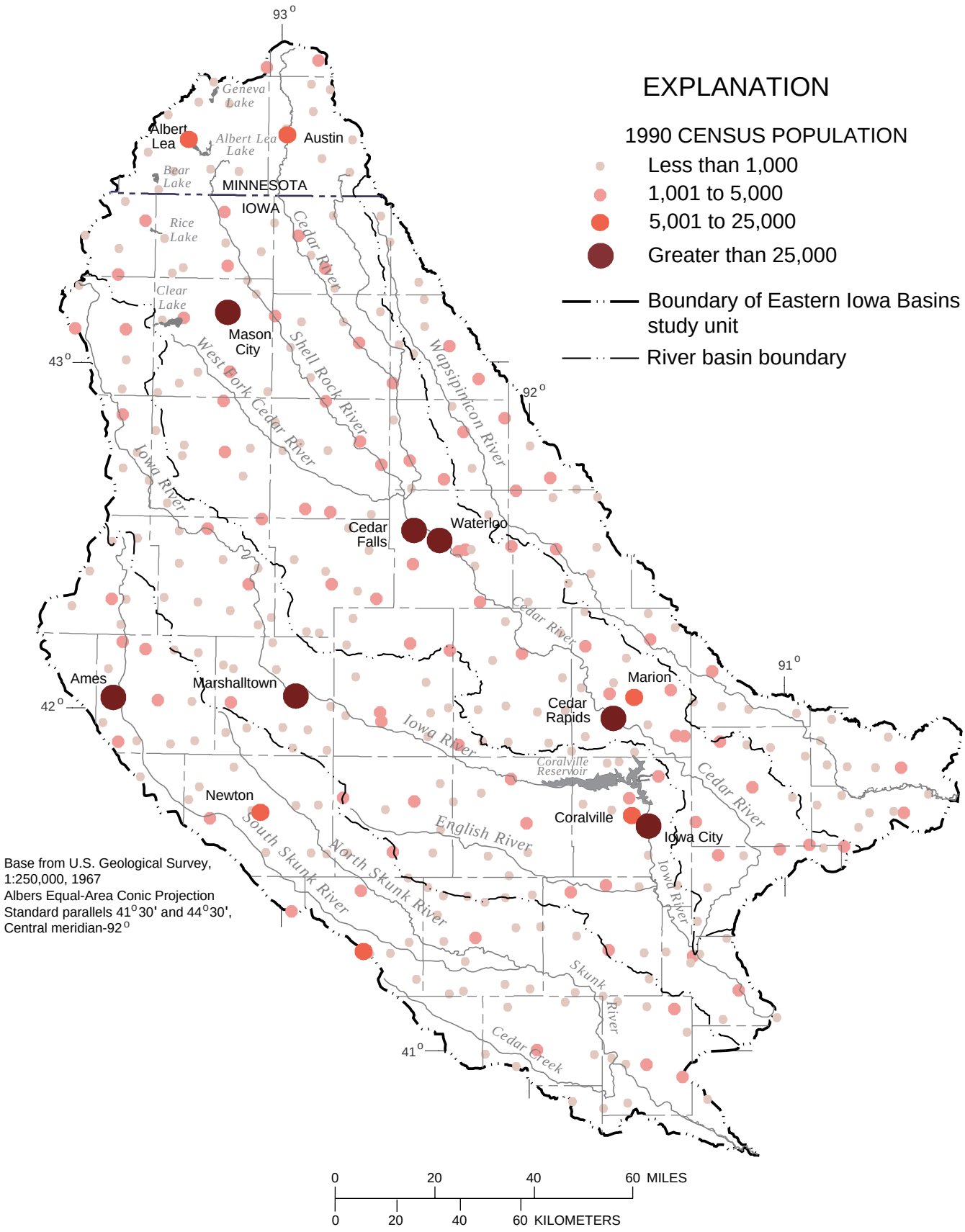


Figure 3. Population of communities in the Eastern Iowa Basins study unit, 1990.

The potential negative effects of these hog-production facilities on surface-water quality may be of concern. In particular, the upper parts of the Iowa River and Skunk River Basins have had more than double the number of hog facilities permitted during pre-1993 when compared to post-1993.

Water use in the EIWA study unit totaled about 418 Mgal/d in 1994, of which approximately 52 percent was surface water and 48 percent was ground water. The major water use in the study unit was surface water used as cooling water in power-generating plants (179 Mgal/d). Additionally, approximately 272 Mgal/d of surface water is used instream to produce 2.1 gigawatt-hours of electricity in the study unit (E.E. Fischer and L.C. Trotta, U.S. Geological Survey, written commun., 1994). Approximately 6 Mgal/d of surface water is used in the study unit to supply about 6 percent of the public water supply.

Table 1. Population of principal communities in the study unit, 1980 and 1990

[Data from U.S. Department of Commerce, 1994]

Community (fig. 3)	Population	
	1980	1990
Cedar Rapids, Iowa	110,243	108,751
Waterloo, Iowa	75,985	66,467
Iowa City, Iowa	50,508	59,738
Ames, Iowa	45,775	47,198
Cedar Falls, Iowa	26,322	34,298
Mason City, Iowa	30,144	29,040
Marshalltown, Iowa	26,938	25,178
Austin, Minnesota	23,020	21,907
Marion, Iowa	19,474	20,403
Albert Lea, Minnesota	19,200	18,310
Newton, Iowa	15,292	14,789
Coralville, Iowa	7,687	10,347

METHODS OF INVESTIGATION

Analysis of historical surface-water-quality data in the EIWA study unit often was complicated by the fact that many data-collection programs had a limited spatial or temporal extent and often were confined to a small area (for example, a single municipal site or county). Data-collection programs typically focused on a suspected source of pollution or were operated for only a year or two. These data are important for providing information on local water quality, but often may not represent typical conditions throughout a basin. Most long-term surface-water-quality information in Iowa is provided by the monitoring and assessment programs of the IDNR and supporting agencies. In addition, the USGS National Stream-Quality Accounting Network (NASQAN) provided monitoring data on the Cedar, Iowa, and Skunk Rivers. Nutrient data were available at all of the monitoring sites selected for these analyses. However, the three NASQAN sites (sites 6, 13, 17; fig. 1) were the only continuous, long-term (more than 5 years) monitoring sites in the EIWA study unit where pesticide data have been collected. The USGS monitoring site on the Cedar River at Gilbertville, Iowa (site 7; fig.1), had pesticide data for 1984–87 and also was included in the pesticide data analysis, even though the data were short term (less than 5 years) because of the scarcity of pesticide data in the EIWA study unit.

The data and analyses in this report were not intended to provide an exhaustive assessment of past conditions. Rather, data sets were selected from sites with long-term water-quality monitoring records that would indicate general patterns and possible trends in the study unit. Therefore, statistical methods that emphasized broad patterns, such as boxplots and smoothing techniques, were used for much of the data analysis.

Sources of Nutrient, Pesticide, and Streamflow Data

Three data sets were selected as having the most utility for the regional water-quality assessment: (1) the surface-water-quality monitoring programs of the IDNR and MPCA, (2) the UIIHR monitoring studies of the Iowa and Cedar Rivers, and (3) the four USGS water-quality monitoring sites.

Iowa Department of Natural Resources and Minnesota Pollution Control Agency

The data set from the IDNR had seven monitoring sites, and the MPCA data set had three monitoring sites that were selected for this report. The Environmental Protection Division of the IDNR and the University of Iowa Hygienic Laboratory (UHL) operate a network of surface-water-quality monitoring sites in the EIWA study unit on the Wapsipinicon, Cedar, Iowa, and Skunk Rivers and other major tributaries. The MPCA operates water-quality monitoring sites in the upstream part of the Cedar River Basin. Several of the monitoring sites have been operated

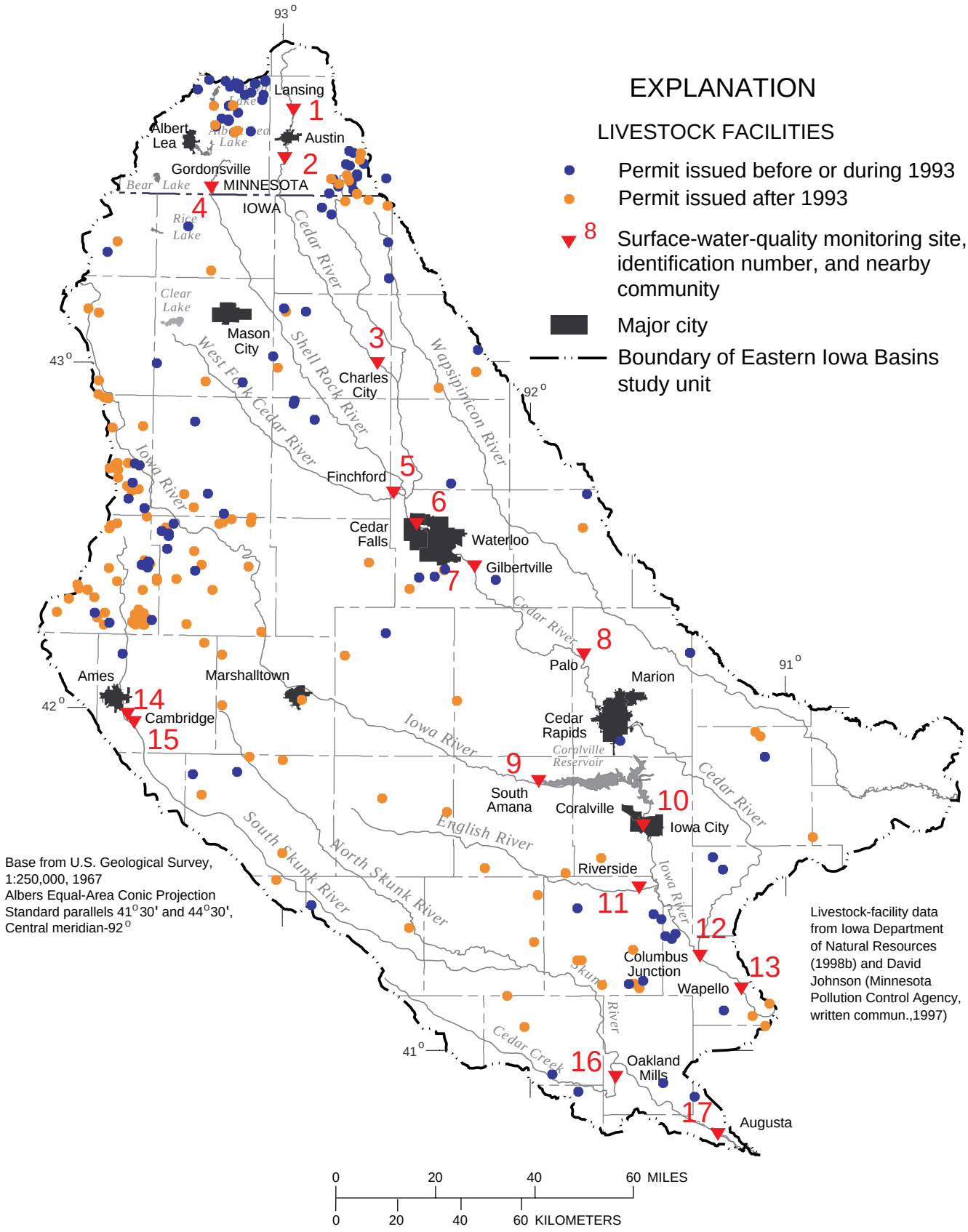


Figure 4. Location of permitted livestock facilities in the Eastern Iowa Basins study unit.

since the 1970's and have been sampled either monthly or quarterly. Pesticide monitoring is not conducted as part of the IDNR or MPCA fixed-site water-quality monitoring network.

The IDNR statewide monitoring provides basic information on water-quality trends for prospective users of surface water. Specific objectives of the program are to determine water quality during changing conditions, sources of water-quality degradation, and effects of pollution, and to compile data needed to support enforcement and pollution abatement. Data are published in biennial reports, also called Section 305(b) reports, which are transmitted by the IDNR to the USEPA. Reports have been published since 1975 and generally provide a statewide overview rather than a detailed site-specific discussion of water quality. Water-quality data are available in the USEPA's STOrage and RETrieval (STORET) data base. The water-quality period of record for the seven IDNR sites selected for this study ranged from 6 to 18 years (table 2). The South Skunk River near Ames (site 14) only had data for 1 year in STORET, and it was later moved to South Skunk River near Cambridge (site 15). The period of record for the three MPCA sites selected ranged from 19 to 24 years.

The IDNR water samples were collected from just beneath the water surface in the center of flow by a grab sample (Iowa Department of Natural Resources, 1994b). Samples were not collected within 72 hours of peak of streamflow (Iowa Department of Natural Resources, 1994b). Samples were analyzed at the UHL. The MPCA monthly samples were collected using a grab sampler at a point in the stream most likely to represent the water quality of the total instantaneous flow (Sandra Bissonnette, Minnesota Pollution Control Agency, written commun., 1998). Water samples were analyzed at the Minnesota Department of Health Laboratory. The MPCA monitoring program has been in existence in some form since 1953 and is administered and implemented by the Monitoring and Data Management Unit of the Water-Quality Division.

Streamflow data for the IDNR and MPCA sites were from the STORET data base, if available. However, streamflow data for the Cedar River near Austin, Minnesota, monitoring site (site 2, fig. 1) were not in STORET, and these data were obtained from the USGS office in Mounds View, Minnesota, for the USGS streamflow-gaging station at Cedar River near Austin, Minnesota (05457000, fig. 2).

University of Iowa Institute of Hydraulic Research

The UIIHR has conducted two long-term studies within the EIWA study unit—the Coralville Reservoir Water-Quality Study conducted from 1964 through the present and the Cedar River Baseline Ecological Study conducted from 1974 to the present. Similar methods were used and similar constituents were analyzed during both studies. The Coralville Reservoir Water-Quality Study was begun in 1964 to investigate the effects of a flood-control reservoir on the water quality and limnology of the Iowa River. The study was conducted by the UIIHR in cooperation with the U.S. Army Corps of Engineers (USCOE). Water-quality samples for the Coralville study were collected at monitoring sites located upstream from Coralville Reservoir, within Coralville Reservoir, and downstream from Coralville Reservoir. Data selected from STORET for the EIWA study unit were limited to the upstream monitoring site (site 9 near South Amana) and the downstream site (site 10 at Iowa City). These data were selected to represent ambient conditions in the Iowa River upstream and downstream from the Coralville Reservoir. Water-quality samples were collected from the Iowa City site weekly or biweekly, although data collection was occasionally interrupted at that site (table 2). Determinations of pH, water temperature, dissolved oxygen, and alkalinity were made onsite at the time of sample collection. Water samples were collected throughout the year utilizing a Kemmerer water sampler. Laboratory work was performed in the University of Iowa Water Treatment Plant (Iowa City) or the UHL. Water samples were analyzed by standard USEPA procedures (U.S. Environmental Protection Agency, 1972, 1979; American Public Health Association and others, 1976).

Streamflow data for the Iowa River at Marengo streamflow-gaging station (05453100, fig. 2) were obtained from the USGS Automated Data Processing System (ADAPS) data base and used in conjunction with the South Amana (site 9, fig. 1) water-quality data because it was the closest streamflow-gaging station to the monitoring site (located approximately 2 mi upstream from site 9). There are no major tributaries that contribute to the Iowa River streamflow between the Marengo streamflow-gaging station and the monitoring site at South Amana. Daily mean streamflow data for the monitoring site at Iowa City (site 10, fig. 1) were obtained from the USGS ADAPS data base for the streamflow-gaging station (05454500, fig. 2) at that site.

Table 2. Period of record and number of samples analyzed for selected water-quality constituents at monitoring sites in the Eastern Iowa Basins study unit

[Period of record given by month and year; for example, 07/75–05/79. The number of samples analyzed is in parentheses. *, sporadic data, either no data available or less than 20 analyses for period of record; ND, no data]

Site name and number (fig. 1)	Nitrogen, nitrite plus nitrate	Nitrogen, ammonia	Organic nitrogen or organic nitrogen plus ammonia nitrogen	Nitrogen, total (calculated)	Phosphorus, total	Phosphorus, dissolved	Ortho-phosphate, dissolved	Alachlor	Atrazine	Cyanazine	Metolachlor	Metribuzin
Iowa Department of Natural Resources												
Cedar River near Charles City (site 3)	03/78–12/96 (210)	03/78–09/79, 12/80–12/95 (197)	03/78–12/95 (208)	03/78–12/95 (208)	03/78–12/95 (198)	ND	03/78–09/79, 10/86–12/95 (133)	ND	ND	ND	ND	ND
West Fork Cedar River near Finchford (site 5)	10/86–12/95 (112)	10/86–12/95 (112)	10/86–12/95 (113)	10/86–12/95 (112)	10/87–12/95 (101)	ND	10/86–12/95 (112)	ND	ND	ND	ND	ND
English River near Riverside (site 11)	10/86–12/95 (106)	10/86–12/95 (106)	10/96–12/95 (106)	10/86–12/95 (106)	10/87–12/95 (95)	ND	10/86–12/95 (106)	ND	ND	ND	ND	ND
Iowa River at Columbus Junction (site 12)	05/88–12/95 (93)	05/88–12/95 (93)	05/88–12/95 (93)	05/88–12/95 (93)	05/88–12/95 (93)	ND	05/88–12/95 (93)	ND	ND	ND	ND	ND
South Skunk River near Ames (site 14)	03/70–12/70 (41)	03/70–12/70 (43)	ND	ND	02/70–12/70 (45)	ND	ND	ND	ND	ND	ND	ND
South Skunk River near Cambridge (site 15)	07/89–12/95 (78)	07/89–12/95 (78)	07/89–12/95 (77)	07/89–12/95 (77)	07/89–12/95 (77)	ND	07/89–12/95 (77)	ND	ND	ND	ND	ND
Cedar Creek near Oakland Mills (site 16)	10/86–12/95 (111)	10/86–12/95 (111)	10/86–12/95 (111)	10/86–12/95 (111)	10/87–12/95 (101)	ND	11/86–12/95 (110)	ND	ND	ND	ND	ND
Minnesota Pollution Control Agency												
Cedar River near Lansing (site 1)	01/70–06/76, 01/81–09/94 (196)	01/70–06/76, 01/81–09/94 (196)	01/70–06/71, 08/73–09/94 (177)	01/70–06/71, 08/73–09/94 (177)	08/70–06/71, 10/80–09/94 (189)	ND	ND	ND	ND	ND	ND	ND
Cedar River near Austin (site 2)	01/70–09/94 (246)	01/70–09/94 (246)	01/70–04/71, 08/73–09/94 (226)	01/70–04/71, 08/73–09/94 (226)	01/70–09/94 (246)	ND	ND	ND	ND	ND	ND	ND
Shell Rock River near Gordonsville (site 4)	01/70–09/94 (245)	01/70–09/94 (245)	01/70–06/71, 08/73–09/94 (226)	01/70–06/71, 08/73–09/94 (226)	01/70–09/94 (246)	ND	ND	ND	ND	ND	ND	ND

Table 2. Period of record and number of samples analyzed for selected water-quality constituents at monitoring sites in the Eastern Iowa Basins study unit—Continued

[Period of record given by month and year; for example, 07/75–05/79. The number of samples analyzed is in parentheses. *, sporadic data, either no data available or less than 20 analyses for period of record; ND, no data]

Site name and number (fig. 1)	Nitrogen, nitrite plus nitrate	Nitrogen, ammonia	Organic nitrogen or organic nitrogen plus ammonia nitrogen	Nitrogen, total (calculated)	Phosphorus, total	Phosphorus, dissolved	Ortho-phosphate, dissolved	Alachlor	Atrazine	Cyanazine	Metolachlor	Metribuzin
University of Iowa Institute of Hydraulics												
Cedar River near Palo (site 8)	04/71–09/95 (550)	04/71–09/95 (546)	ND	ND	05/71–04/73, 01/77–09/95 (477)	09/82–04/84 (31)	04/71–10/78, 09/79–08/82, 01/84–09/95 (509)	ND	ND	ND	ND	ND
Iowa River near South Amana (site 9)	02/77–09/95 (500)	02/77–09/95 (527)	05/92–06/94 (49)	05/92–09/95 (49)	ND	12/79–10/81 (102)	02/77–11/79, 11/83–09/94 (91)	ND	ND	ND	ND	ND
Iowa River at Iowa City (site 10)	01/70–12/79,* 01/79–09/95 (563)	01/70–12/79,* 01/79–09/95 (598)	01/70–08/79,* 05/92–03/95* (88)	01/70–08/79,* 05/92–03/95* (88)	01/70–08/79* (44)	01/70–08/76,* 12/79–10/81 (128)	01/70–04/70, 04/72–06/72, 01/73–04/73, 08/73–03/74, 09/76–11/79, 09/83–09/84 (141)	ND	ND	ND	ND	ND
U. S. Geological Survey												
Cedar River at Cedar Falls (site 6)	07/75–05/79, 05/84–08/95 (129)	07/75–05/79, 05/84–08/95 (114)	07/75–05/79, 05/84–08/95 (112)	07/75–05/79, 05/84–08/95 (113)	07/75–09/79, 05/84–08/95 (114)	05/84–08/95 (70)	05/84–08/95 (69)	05/84–09/85, 05/87–08/95 (68)	05/84–09/85, 05/87–08/95 (68)	05/84–09/85, 05/87–08/95 (68)	05/84–09/85, 05/87–08/95 (68)	05/84–09/85, 05/87–08/95 (55)
Cedar River at Gilbertville (site 7)	07/75–09/81, 05/84–11/85 01/87 (79)	07/75–09/81, 05/84–11/85 01/87 (79)	07/75–09/81, 05/84–11/85, 01/87 (77)	07/75–09/81, 05/84–11/85, 01/87 (77)	07/75–09/81, 05/84–01/87 (79)	05/84–11/85 (18)	05/84–11/85 (21)	05/84–11/85, 01/87 (17)	05/84–11/85, 01/87 (18)	05/84–11/85, 01/87 (17)	05/84–11/85, 01/87 (17)	05/84–11/85, 01/87 (17)
Iowa River at Wapello (site 13)	11/77–08/95 (117)	11/77–08/95 (115)	11/77–08/95 (116)	11/77–08/95 (116)	11/77–08/95 (116)	11/77–08/95 (114)	11/81–08/95 (82)	10/85–08/95 (39)	10/85–08/95 (39)	10/85–08/95 (39)	10/85–08/95 (39)	10/85–08/95 (38)
Skunk River at Augusta (site 17)	11/77–08/95 (123)	11/77–08/95 (117)	11/77–08/95 (113)	11/77–08/95 (113)	11/77–08/95 (115)	11/77–08/95 (115)	11/81–08/95 (83)	05/87–08/95 (39)	05/87–08/95 (39)	05/87–08/95 (39)	05/87–08/95 (39)	05/87–08/95 (38)

The Cedar River Baseline Ecological Study was begun in 1974 to investigate the effects of the operation of the Duane Arnold Energy Center near Palo, Iowa, on the ecology and water quality of the Cedar River. The Duane Arnold Energy Center is a nuclear-fuel electrical-generating plant located about 2.5 mi north-northeast of Palo. The study was conducted by the UIIHR in cooperation with the Duane Arnold Energy Center. Water-quality samples were collected at five separate sites on the Cedar River. The data for monitoring site 8 (fig. 1), located upstream from the generating plant, were selected for use in the EIWA study unit because water quality would not be affected by the generating plant. Data were retrieved from the STORET data set. The data set includes nutrient data from 1971–95 (site 8, table 2). Streamflow data for the Cedar Rapids streamflow-gaging station (05464500, fig. 2) were obtained from the USGS ADAPS data base and used in conjunction with the Palo (site 8, fig. 1) water-quality data, as it was the closest streamflow-gaging station to the monitoring site. The Cedar Rapids streamflow-gaging station is approximately 10–12 mi downstream of the Palo monitoring site. There are no large tributaries that flow into the Cedar River between Palo and Cedar Rapids.

U.S. Geological Survey

The USGS has collected and analyzed surface-water samples as part of various programs. The water-quality data are stored in the USGS National Water Information System (NWIS) data base. The majority of the data have been published in a series of annual reports, "Water Resources Data, Iowa," compiled by the USGS in Iowa City, Iowa. The USGS water-quality data used in this report were retrieved from the NWIS data base. Data retrieved for this report include nutrient and pesticide data from three USGS sites operated as part of the NASQAN program (sites 6, 13, and 17) and one USGS site operated as part of the USGS cooperative program (site 7). The NASQAN program was begun in 1973 to provide nationally comparable information on water quality. NASQAN stations typically are sampled frequently enough to characterize variations in chemical concentrations that occur during a year, particularly variation that occurs between low and high flows during different seasons.

The water-quality period of record for the USGS sites ranged from 10 to 18 years for nutrient data and 3 to 10 years for pesticide data (table 2). The sample-collection methods and laboratory procedures for the four USGS sites were similar. Water samples for nutrients were obtained by collecting depth-integrated subsamples at equally spaced vertical sections across the stream (Ward and Harr, 1990). Pesticide samples were collected in precleaned glass bottles from the centroid of streamflow. All samples were preserved by chilling on ice. Pesticide samples were sent to the University of Iowa Hygienic Laboratory, and other samples were shipped to the USGS National Water-Quality Laboratory by air express. Streamflow data for the USGS monitoring sites were from the USGS ADAPS or NWIS data bases.

Data Compilation and Statistical Methods

The data sets contained various combinations of nutrient data; the USGS data also contained pesticide data. Quality-control replicate samples were deleted from the data sets to avoid biasing the number of samples in the data set. The STORET data were examined for erroneous values by comparison with published data when possible and corrected according to the published data. No attempt was made to correct or delete outlier values in the data sets if published records were not available. However, in three cases, concentrations that were apparent typographical errors were deleted from the data sets. The Statistical Analysis System (SAS) software package was used to identify and compile nutrient data for statistical analysis from all three data sets.

The majority of the nutrient and pesticide data within these data sets were reported as dissolved constituents. It is important to distinguish between the terms "dissolved" and "total." The terms "dissolved" and "total" distinguish between filtered and nonfiltered concentrations, respectively. The dissolved-nutrient and dissolved-pesticide concentrations were used unless total constituent values were the only values available. Total values then were used with the assumption that most of the constituents were in the dissolved phase. Typically, the nitrogen-containing compounds were reported as dissolved concentrations in the data sets, although ammonia concentrations for the IDNR and UHL sites were mostly reported as total (unfiltered) ammonia. All nitrogen-containing compounds described in this report are reported as equivalent amounts of elemental

nitrogen (mg/L as N). The terms "dissolved" or "total" were not used as descriptors for ammonia, organic nitrogen, nitrite plus nitrate, or nitrate when presenting these nitrogen species in the tables or figures in this report; however, they are used in the text when it is necessary to refer to specific types of laboratory analyses. All phosphorus species described in the assessment are reported as equivalent amounts of elemental phosphorus (mg/L as P). The majority of data for phosphorus concentrations were as "total phosphorus," which refers to all the phosphorus species present. Occasionally, data on dissolved phosphorus and dissolved orthophosphate were present in the data sets. In the cases where dissolved phosphorus and dissolved orthophosphate data were available, the descriptor "dissolved" is retained when discussing these phosphorus compounds in the text and all tables and figures. "Total" or "dissolved" are not used as descriptors for the pesticide compounds in this report.

"Total nitrogen" (total N), as used in this report, refers to the summation of all the nitrogen species. Total nitrogen concentrations were obtained by using three different methods. The first method calculated total nitrogen by summing the three nitrogen-species concentrations (if all species were present)—nitrite plus nitrate as nitrogen, organic nitrogen as nitrogen, and ammonia as nitrogen. The second method calculated total nitrogen by summing nitrite plus nitrate as nitrogen and ammonia plus organic nitrogen as nitrogen. The third method used total nitrogen as given by the laboratory if that was the only species reported in the data set. The Palo site (site 8, fig. 2) had only 4 years of data with ammonia nitrogen plus organic nitrogen as nitrogen concentrations, so total nitrogen concentration was not calculated for this site.

There was some variation in the minimum analytical reporting levels [concentrations reported as "less than" (<) a particular value] for the various nutrient species and pesticides in the data sets. In general, the minimum analytical reporting levels for the MPCA organic nitrogen and ammonia data were more variable than the IDNR, UIIHR, and USGS data sets. The MPCA minimum analytical reporting levels for organic nitrogen and ammonia ranged from <0.1 to <0.3 mg/L. The lowest common analytical reporting level for each nutrient and pesticide compound was selected in the data sets. Concentrations reported as "less than the reporting level" (for example, <0.1 mg/L) in the data sets were replaced with a concentration that was one-half of the lowest common analytical reporting level for statistical calculations of the data. For example, if nitrate as nitrogen was reported as <0.1 mg/L in the data set, it would be set to 0.05 mg/L for statistical calculation of the data. The lowest common analytical reporting level selected for nutrients was 0.1 mg/L, for all data sets. The exception was ammonia nitrogen, for which the lower reporting level (0.01 mg/L) available from the USGS data was used. For pesticides, the lowest common analytical level (0.1 mg/L) was selected, with the exception of cyanazine (0.2 mg/L).

Three different measures of nitrate-related species were retrieved from the different data bases: total nitrite plus nitrate, total nitrate, and dissolved nitrite plus nitrate. Data for these three constituents were combined and will be referred to in the figures and tables as "nitrite plus nitrate" and simply as "nitrate" in the text to reduce wordage. This is reasonable because the concentrations of nitrite are small when compared to nitrate concentrations. Typically, nitrate concentrations often are two orders of magnitude greater than the concentration of nitrite in oxygenated water, and the nitrite in surface water typically does not exceed 0.5 mg/L (National Research Council, 1978). At pH values less than 9.3, most of the ammonia dissolved in water is generally ionized ammonium (NH_4^+) (Hem, 1985, p. 126). In this report, "ammonia" is used to refer to both ammonia and ammonium nitrogen (NH_3–N and NH_4–N, respectively).

Nutrient and pesticide data were analyzed using a variety of graphical and statistical methods. The median and variability of data are shown using boxplots (fig. 5). In this plot, a box is drawn from the 25th to the 75th quartile (interquartile range), and the median is shown as a horizontal line in the box. "Whiskers" are drawn from the ends of the box to the most extreme data values within or equal to 1.5 times the interquartile range outside the quartile. Outlier values can be shown above or below the "whiskers" on the boxplot. The univariate procedure of SAS was used to calculate the statistical summaries for the chemical data, such as mean, median, minimum and maximum concentrations, standard error, and percentiles (SAS Institute Inc., 1989). Spearman's rho is a nonparametric measure of the strength of association between two variables and was used to quantify the relation between concentrations and streamflow (Ott, 1993).

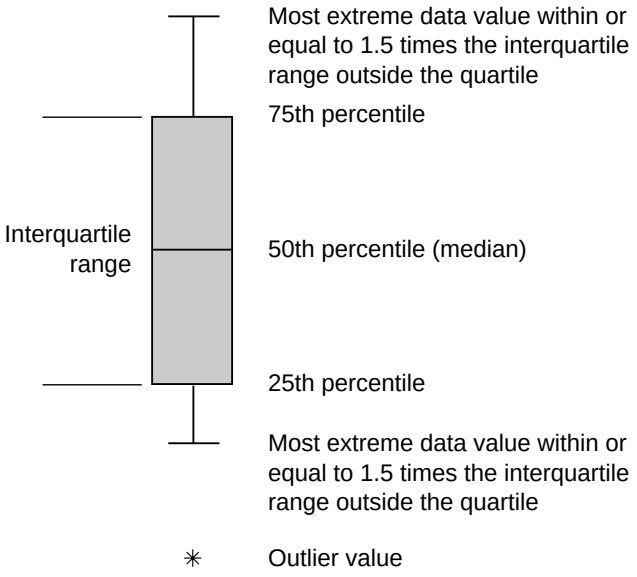


Figure 5. Example boxplot showing central tendency and variability of data.

To better visualize nonlinear trends in the concentration and streamflow data, a LOWESS (LOcally WEighted Scatterplot Smoothing) trend line (Cleveland, 1979; Helsel and Hirsch, 1992) was calculated and plotted for each scatterplot presented in this report. The LOWESS trend lines illustrate relations between concentrations and streamflow that are difficult to discern in a simple scatterplot. The LOWESS trend line is computed by fitting a weighted least-squares equation to the concentration and streamflow data (Helsel and Hirsch, 1992, p. 288–291). The "smoothing" used to calculate the LOWESS trend line is a particularly useful technique because no assumptions about linearity of the data are required. The smoothing algorithm uses nearby data points to calculate a "smoothed value" for every data point. Each nearby data point is weighted so that the more distant points affect the smoothed value less than points that are closer. A line then is drawn through the smoothed values. The number of nearby points used to calculate a smoothed value is controlled by the smoothness factor. A smoothness factor of 0.5 was used for all LOWESS trend lines in this report. This means that the closest 50 percent of all the data points were used to calculate each smoothed value.

Time-series constituent concentration plots for nutrients at all the monitoring sites were compared visually and by using a statistical test called the seasonal Kendall tau test to detect trends (Hirsch and others, 1982; Smith and others, 1982). The seasonal Kendall tau was computed for nitrate, ammonia, and total phosphorus for all monitoring sites for which a complete data set was available. The seasonal Kendall tau trend test can indicate long-term improvement or deterioration in stream quality. The seasonal Kendall tau test is based on the nonparametric Kendall's tau test (Kendall, 1975), which compares the relative values of all possible pairs of data values in a time series. In the seasonal Kendall tau test, comparisons between data values are restricted to pairs of data values that are from the same time period annually; this period is defined as a "season." Instantaneous loads were calculated for nitrate, ammonia, and total phosphorus by multiplying the nutrient concentration by the streamflow at the time of the sample. The seasonal Kendall tau tests then were computed for these instantaneous loads.

The seasonal Kendall tau test also was used for testing a null hypothesis of no trend (the constituent concentration and its time of observation are independent). A statistically significant trend is indicated when the null hypothesis obtained from the seasonal Kendall tau test has a probability level (p-value) of 0.05 or less. For example, a p-value of 0.05 means that there is a 5-percent chance of making an error when rejecting the null hypothesis. In this report, p-values less than or equal to 0.05 were considered statistically significant in indicating upward or downward trends in constituent concentrations.

Spatial and Temporal Records

The majority of the selected monitoring sites with water-quality data were located on the largest rivers in the EIWA study unit—the Cedar, Iowa, and Skunk Rivers (fig. 1). The Wapsipinicon River did not have monthly, long-term (5 years or greater) monitoring data available. Data from several monitoring sites on tributaries also were included. Characteristics of the monitoring sites, such as drainage area, source of streamflow data, sampling agency, and locations, are shown in table 3. The monitoring site number is a sequential number arranged in downstream order. Drainage areas for the monitoring sites range from approximately 180 to 12,500 mi^2. Water-quality samples generally were collected monthly at all of the monitoring sites. The USGS-NASQAN sites generally had quarterly data. Typically, data on nitrate, ammonia, and total phosphorus concentrations were the most complete for all the data sets throughout the assessment period (table 2).

Table 3. Description of selected surface-water-quality monitoring sites in the Eastern Iowa Basins study unit, 1970–95

Monitoring site number (fig. 1)	Monitoring site name	Approximate drainage area (square miles)	Stream-flow data[1]	Sampling agency[2]	Location and comments
		Cedar River Basin			
1	Cedar River near Lansing, Minnesota	250	--	MPCA	County-State Highway 2, 0.5 mile east of Lansing
2	Cedar River near Austin, Minnesota	425	G, S	MPCA	County-State Highway 4, 3 miles south of Austin (station 0545700)
3	Cedar River near Charles City, Iowa	1,080	G, S	IDNR/UHL	About 4 miles southeast of Charles City (station 05457700)
4	Shell Rock River near Gordonsville, Minnesota	180	--	MPCA	County-State Highway 1, 1 mile west of Gordonsville
5	West Fork Cedar River near Finchford, Iowa	846	--	IDNR/UHL	County road T71 near Finchford
6	Cedar River at Cedar Falls, Iowa	4,730	G	USGS	Highway 20 bridge at Cedar Falls (gage is located downstream at Waterloo, station 05464000)
7	Cedar River at Gilbertville, Iowa	5,230	N	USGS	County highway D38 bridge at Gilbertville (station 05464020 discontinued)
8	Cedar River near Palo, Iowa	6,340	E	UIIHR/DAEC	Lewis access, about 6.5 miles north of Palo
		Iowa River Basin			
9	Iowa River near South Amana, Iowa	2,860	E	UIIHR/USCOE	Highway 220 bridge, about 1 mile north of South Amana
10	Iowa River at Iowa City, Iowa	3,270	G	UIIHR	Burlington Street Bridge (station 05454500)
11	English River near Riverside, Iowa	626	E, S	IDNR/UHL	W61 bridge near Riverside
12	Iowa River at Columbus Junction, Iowa	12,300	S	IDNR/UHL	Highway 92 bridge at Columbus Junction
13	Iowa River at Wapello, Iowa	12,500	G	USGS	Highway 99 bridge at Wapello (station 05465500)
		Skunk River Basin			
14	South Skunk River near Ames, Iowa	556	--	IDNR/UHL	Downstream from Ames water-treatment plant
15	South Skunk River near Cambridge, Iowa	585	--	IDNR/UHL	E55 bridge near Cambridge downstream from new Ames water-treatment plant
16	Cedar Creek near Oakland Mills, Iowa	530	G	IDNR/UHL	County highway H46, 3 miles northwest of Oakland Mills (station 05473400)
17	Skunk River at Augusta, Iowa	4,300	G	USGS	Highway 394 at Augusta (station 05474000)

[1]G, streamflow-gaging station at site; S, streamflow data in STORET data base; E, streamflow data estimated from streamflow-gaging station near monitoring site; N, streamflow data in U.S. Geological Survey National Water Information System (NWIS) data base; --, not available.

[2]DAEC, Duane Arnold Energy Center near Palo, Iowa; IDNR, Iowa Department of Natural Resources; MPCA, Minnesota Pollution Control Agency; UHL, University of Iowa Hygienic Laboratory; UIIHR, University of Iowa Institute of Hydraulic Research; USCOE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey.

SELECTED NUTRIENTS AND PESTICIDES IN STREAMS

The variety of agencies collecting water-quality data often results in diverse data sets. The various sample-collection protocols, analytical methods, and sampling frequencies can make comparisons between data sets difficult. Water-quality data used in the EIWA study unit have been collected for many specific purposes and programs. State and local regulatory agencies collect data to develop and determine compliance with operating permits and drinking-water regulations. State and Federal natural-resource agencies collect water-quality data to provide information for water managers to make decisions on resource planning and use. Municipalities and industries collect data on the quality and quantity of their wastewater discharges to streams. Universities often collect water data to support basic and applied research. Interpretations between data sets certainly are possible but should be treated with more caution than interpretations within a particular data set.

Nutrients

Nitrogen species are a water-quality concern primarily because they contribute to aquatic plant growth (in particular algae), eutrophication, and toxicity. Algae generally prefer ammonia over nitrate for growth (Brezonik, 1973, p. 11), but both the reduced species of nitrogen (ammonia and organic nitrogen) and the oxidized species (nitrite and nitrate) can be used as nutrients for algal growth. The excessive growth of algae can promote eutrophication in surface water. Some nitrogen species also are potentially toxic. Freshwater fish are very sensitive to un-ionized ammonia (NH_3), which increases with increasing pH and temperature, and to the total ammonia-nitrogen concentration (NH_4 as N). At a pH of 9.3 and a temperature of 25°C, about one-half of the ammonia is in the un-ionized form (NH_3) (Hem, 1985, p. 126). Generally, most water analyses only report the total ammonia concentration (the sum of the ammonium ion concentration and the un-ionized or solvated ammonia); the un-ionized ammonia fraction typically is not reported separately. This report does not consider the un-ionized species of ammonia separately. Total ammonia concentrations in surface water can be of concern, especially during low-flow conditions. Volatilization and loss of ammonia to the atmosphere can be a significant process in streams during the summer months, particularly with increasing pH and temperature. The USEPA has tabulated toxic concentrations of total ammonia-nitrogen (NH_4 as N) as a function of pH and temperature (U.S. Environmental Protection Agency, 1986). Nitrite and nitrate can be a health concern, particularly for pregnant women and children. Nitrate is converted to nitrite in the digestive tract of warm-blooded animals. The nitrite then interferes with respiration by inhibiting the ability of hemoglobin to transport oxygen. Nitrite concentrations exceeding 1.0 mg/L as nitrogen may be particularly harmful to infants and unborn babies. The USEPA MCL for nitrate in drinking water is 10 mg/L as nitrogen (U.S. Environmental Protection Agency, 1986). Wastewater-treatment-plant effluent, manure, and commercial fertilizers are common sources of ammonia, organic nitrogen, nitrite, and nitrate.

Phosphorus, like nitrogen, is an essential nutrient for plant growth, and high concentrations of phosphorus in streams promote aquatic plant growth and eutrophication. To prevent the excessive growth of aquatic plants in streams, the USEPA recommends that total phosphorus concentrations not exceed 0.1 mg/L as P (U.S. Environmental Protection Agency, 1986). Orthophosphate (PO_4^{3-}) is the most stable form of phosphorus in natural water, and forms such as H_3PO_4, $H_2PO_4^-$, and HPO_4^{2-} are the other common phosphorus-containing compounds (Hem, 1985, p. 126). The majority of the total phosphorus in streams is associated with suspended particles as phosphorus readily adsorbs to soils and sediment. About 95 percent of the phosphorus transported by rivers is adsorbed on sediment (Meybeck, 1982). Dissolved phosphorus in water typically is no more than a few tenths of milligrams per liter (Hem, 1985, p. 126). However, the soluble or dissolved form of phosphorus is the most readily used by algae and other aquatic plants. Most dissolved phosphorus is present as orthophosphate (often called dissolved inorganic phosphorus or dissolved reactive phosphorus); lesser amounts are present as phosphate esters or polyphosphates (often called organic phosphates) or associated with colloids (Wetzel, 1983). Total phosphorus was the most commonly reported phosphorus species in

the data sets for the EIWA study unit. Sources of phosphorus include wastewater-treatment-plant effluent, detergents, fertilizers, and sediment from surface runoff.

Concentrations

Nutrient data were statistically summarized for all monitoring sites from the IDNR, MPCA, UIIHR, and USGS data sets (table 4). Statistical summary concentrations for each monitoring site are presented as a minimum, 25th percentile, 50th percentile (median), 75th percentile, maximum, and mean.

Nutrient concentrations were variable at the monitoring sites. Ammonia concentrations ranged from <0.10 to 28 mg/L. However, the 28 mg/L ammonia concentration for one sample is unusually high and unexplained. The median ammonia concentrations ranged from <0.10 to 0.77 mg/L (table 4). Nitrate concentrations ranged from <0.10 to 26 mg/L. The median nitrate concentrations were 2.2 to 8.8 mg/L with 12 of the 17 monitoring sites having median nitrate concentrations ranging from 4.0 to 6.0 mg/L. Total phosphorus concentrations ranged from <0.10 to 5.4 mg/L. Median concentrations of total phosphorus ranged from <0.10 to 0.66 mg/L (table 4).

Relations Between Concentrations and Streamflow

The concentration of nutrients associated with nonpoint-source inputs generally increases as streamflow increases because of runoff and (or) agricultural tile drain flow, which result in a positive relation between concentration and streamflow. The opposite effect typically is observed for point-source concentrations. Concentrations of constituents associated with point-source locations decrease in the stream due to dilution as streamflow increases, resulting in a negative relation between concentration and streamflow. Point sources often have higher concentrations at the lowest streamflows as the point-source concentrations input to the stream are not being diluted during periods of low streamflow. These relations are complex and are affected by antecedent soil conditions, timing of fertilizer application, land cover, and the location, duration, and intensity of precipitation. A mixture of point and nonpoint sources can obscure any relation between concentration and streamflow.

The ideal situation is to collect water-quality samples over a range of flow conditions to limit bias in the data. Water-quality samples collected over a long period of time may tend to include results from a range of flow conditions. In addition, larger streams generally have a better distribution of samples in the data sets when compared to small streams. High flow in the larger streams is generally of longer duration, resulting in an increased likelihood of obtaining samples at peak streamflows when compared to collecting samples at high flow in small streams. Small streams have streamflows that peak quickly (within a few hours) during runoff, making runoff samples more difficult to obtain. The monitoring sites selected for this report were on larger streams and had long-term water-quality records.

Nutrient concentration and streamflow were plotted for all the IDNR, MPCA, UIIHR, and USGS monitoring sites with the exception of three sites. At two of the three unused monitoring sites, streamflow data were not available (site 1, Cedar River near Lansing, Minnesota, and site 4, Shell Rock River near Gordonsville, Minnesota), and at the third monitoring site (site 14, South Skunk River near Ames, Iowa), long-term nutrient data were lacking. In addition, for the plots of ammonia plus organic nitrogen concentrations versus streamflow, site 8 (Cedar River near Palo, Iowa) was not included because of a lack of ammonia plus organic nitrogen data for this site. Plots of total phosphorus versus streamflow were not prepared for site 2 (Cedar River near Austin, Minnesota) and site 9 (Iowa River near South Amana, Iowa) because of the lack of phosphorus data at these sites.

The most typical relations observed between nutrients and streamflow at selected monitoring sites on the Cedar, Iowa, and Skunk Rivers are illustrated in LOWESS plots (figs. 6–9). The LOWESS plots for the remaining monitoring sites are shown in figures 10–13. In general, nutrient concentrations were not linearly related to streamflow. In other words, as streamflow increased, there was not always a corresponding increase in nutrient concentrations, especially at the highest rates of flow. There may be a "dilution effect" of nutrient concentrations at the highest flows as more water originates directly from precipitation. Another explanation is that there is simply a lack of representative water-quality samples at the highest flows. Also, concentrations tend to be higher for most nutrient constituents on the rising limb of the hydrograph than on the falling limb.

Table 4. Statistical summary of nutrient concentrations in samples from surface-water-quality monitoring sites in the Eastern Iowa Basins study unit, 1970–95

[mg/L, milligrams per liter; <, less than; --, no data]

Constituent	Number of samples	Minimum concentration measured (mg/L)	Percentile			Maximum concentration measured (mg/L)	Mean concentration measured (mg/L)
			25	50 (median) (mg/L)	75		
Cedar River near Lansing, Minn. (site 1, fig. 1)							
Total nitrogen, as N	177	1.3	3.5	5.4	7.9	18	5.9
Ammonia, as N	196	<.10	<.10	.14	.32	3.9	.28
Organic nitrogen, as N	177	<.10	.49	.69	1.0	3.7	.81
Nitrite plus nitrate, as N	196	.08	2.0	4.0	7.0	17	4.6
Orthophosphate, dissolved, as P	--	--	--	--	--	--	--
Total phosphorus, as P	189	<.10	.12	.17	.27	.97	.22
Dissolved phosphorus, as P	--	--	--	--	--	--	--
Cedar River near Austin, Minn. (site 2, fig. 1)							
Total nitrogen, as N	226	1.5	4.9	6.4	8.6	14	6.8
Ammonia, as N	246	<.10	.25	.59	1.4	4.9	1.0
Organic nitrogen, as N	226	<.10	.78	1.1	1.5	6.9	1.2
Nitrite plus nitrate, as N	246	<.10	2.7	3.9	6.3	12	4.5
Orthophosphate, dissolved, as P	--	--	--	--	--	--	--
Total phosphorus, as P	246	<.10	.35	.53	.82	2.6	.43
Dissolved phosphorus, as P	2	.26	--	--	--	.57	.42
Cedar River near Charles City, Iowa (site 3, fig. 1)							
Total nitrogen, as N	208	1.6	5.0	6.3	8.1	13	6.4
Ammonia, as N	197	<.10	<.10	<.10	.20	1.7	.17
Organic nitrogen, as N	18	.19	.51	.82	1.0	2.5	.84
Nitrite plus nitrate, as N	210	<.10	3.8	5.6	7.2	11	5.5
Orthophosphate, dissolved, as P	133	<.10	<.10	.11	.20	.70	.16
Total phosphorus, as P	198	<.10	.19	.22	.30	1.2	.27
Dissolved phosphorus, as P	--	--	--	--	--	--	--
Shell Rock River near Gordonsville, Minn. (site 4, fig. 1)							
Total nitrogen, as N	226	.39	5.0	6.8	8.6	31	7.4
Ammonia, as N	245	<.10	.10	.29	1.0	28	1.2
Organic nitrogen, as N	226	<.10	1.8	2.7	3.6	13	2.9
Nitrite plus nitrate, as N	245	<.10	.68	2.2	4.5	26	3.2
Orthophosphate, dissolved, as P	--	--	--	--	--	--	--
Total phosphorus, as P	246	<.10	.40	.66	1.2	5.4	.97
Dissolved phosphorus, as P	--	--	--	--	--	--	--
West Fork Cedar River near Finchford, Iowa (site 5, fig. 1)							
Total nitrogen, as N	112	.15	4.4	5.9	8.4	14	6.0
Ammonia, as N	112	<.10	<.10	<.10	<.10	1.2	.10
Organic nitrogen, as N	1	.35	--	--	--	.35	.35
Nitrite plus nitrate, as N	112	<.10	3.4	5.4	7.8	13	5.4

Table 4. Statistical summary of nutrient concentrations in samples from surface-water-quality monitoring sites in the Eastern Iowa Basins study unit, 1970–95—Continued

[mg/L, milligrams per liter; <, less than; --, no data]

Constituent	Number of samples	Minimum concentration measured (mg/L)	Percentile			Maximum concentration measured (mg/L)	Mean concentration measured (mg/L)
			25	50 (median) (mg/L)	75		
West Fork Cedar River near Finchford, Iowa (site 5, fig. 1)—Continued							
Orthophosphate, dissolved, as P	112	<.10	<.10	<.10	.10	.60	.10
Total phosphorus, as P	101	<.10	<.10	.12	.20	.70	.18
Dissolved phosphorus, as P	--	--	--	--	--	--	--
Cedar River at Cedar Falls, Iowa (site 6, fig. 1)							
Total nitrogen, as N	113	0.24	3.8	5.6	7.4	17	5.9
Ammonia, as N	114	<.01	.01	.04	.17	1.30	.15
Organic nitrogen, as N	112	.15	.62	.98	1.6	12	1.2
Nitrite plus nitrate, as N	129	<.10	2.0	4.1	6.2	16	4.2
Orthophosphate, dissolved, as P	69	<.10	<.10	<.10	.15	.46	.11
Total phosphorus, as P	114	<.10	.14	.19	.28	.76	.22
Dissolved phosphorus, as P	70	<.10	<.10	.10	.18	.48	.12
Cedar River at Gilbertville, Iowa (site 7, fig. 1)							
Total nitrogen, as N	77	.66	3.9	5.6	7.2	10	5.7
Ammonia, as N	79	<.01	.01	.06	.21	1.8	.24
Organic nitrogen, as N	77	.02	.62	1.4	1.7	4.6	1.3
Nitrite plus nitrate, as N	79	<.10	2.3	4.1	6.0	8.8	4.2
Orthophosphate, dissolved, as P	21	<.10	<.10	.12	.17	.42	.12
Total phosphorus, as P	79	<.10	.25	.31	.44	.86	.35
Dissolved phosphorus, as P	18	<.10	<.10	.16	.23	.48	.18
Cedar River near Palo, Iowa (site 8, fig. 1)							
Total nitrogen, as N	--	--	--	--	--	--	--
Ammonia, as N	546	<.10	<.10	<.10	.28	1.6	.23
Organic nitrogen, as N	--	--	--	--	--	--	-
Nitrite plus nitrate, as N	550	<.10	2.1	5.0	7.0	24	4.9
Orthophosphate, dissolved, as P	509	<.10	<.10	.10	.20	1.8	.15
Total phosphorus, as P	477	<.10	.20	.30	.44	3.1	.41
Dissolved phosphorus, as P	31	<.10	<.10	<.10	<.10	<.10	<.10
Iowa River near South Amana, Iowa (site 9, fig. 1)							
Total nitrogen, as N	49	3.6	5.6	6.2	8.6	15	6.8
Ammonia, as N	527	<.10	<.10	<.10	.20	3.7	.20
Organic nitrogen, as N	3	.49	--	--	--	.83	.60
Nitrite plus nitrate, as N	500	<.10	2.7	4.9	7.8	20	5.3
Orthophosphate, dissolved, as P	91	<.10	<.10	<.10	.13	1.1	.11
Total phosphorus, as P	7	<.10	--	--	--	.50	.15
Dissolved phosphorus, as P	102	<.10	<.10	<.10	.12	1.0	.10
Iowa River at Iowa City, Iowa (site 10, fig. 1)							
Total nitrogen, as N	88	.55	3.4	4.6	6.1	14	4.9
Ammonia, as N	598	<.10	<.10	.13	.30	4.1	.28
Organic nitrogen, as N	40	<.10	.56	.86	1.2	5.0	1.0
Nitrite plus nitrate, as N	563	<.10	2.0	4.2	6.7	15	4.5

Table 4. Statistical summary of nutrient concentrations in samples from surface-water-quality monitoring sites in the Eastern Iowa Basins study unit, 1970–95—Continued

[mg/L, milligrams per liter; <, less than; --, no data]

Constituent	Number of samples	Minimum concentration measured (mg/L)	Percentile			Maximum concentration measured (mg/L)	Mean concentration measured (mg/L)
			25	50 (median) (mg/L)	75		
Iowa River at Iowa City, Iowa (site 10, fig. 1)—Continued							
Orthophosphate, dissolved, as P	141	<.10	<.10	<.10	.12	1.1	.11
Total phosphorus, as P	44	<.10	<.10	<.10	.19	1.4	.14
Dissolved phosphorus, as P	128	<.10	<.10	<.10	<.10	.72	<.10
English River near Riverside, Iowa (site 11, fig. 1)							
Total nitrogen, as N	106	0.45	2.4	6.0	8.3	19	6.0
Ammonia, as N	106	<.10	<.10	.08	.30	2.7	.28
Organic nitrogen, as N	--	--	--	--	--	--	--
Nitrite plus nitrate, as N	106	<.10	1.4	4.3	6.9	16	4.7
Orthophosphate, dissolved, as P	106	<.10	<.10	<.10	.15	.80	.12
Total phosphorus, as P	95	<.10	.10	.20	.40	2.3	.38
Dissolved phosphorus, as P	--	--	--	--	--	--	--
Iowa River at Columbus Junction, Iowa (site 12, fig. 1)							
Total nitrogen, as N	93	1.8	4.4	6.2	8.2	13	6.4
Ammonia, as N	93	<.10	<.10	.20	.50	2.2	.40
Organic nitrogen, as N	1	3.0	--	--	--	3.0	--
Nitrite plus nitrate, as N	93	<.10	2.2	4.7	6.6	12	4.6
Orthophosphate, dissolved, as P	93	<.10	.10	.20	.20	.60	.18
Total phosphorus, as P	93	<.10	.30	.40	.60	1.1	.42
Dissolved phosphorus, as P	--	--	--	--	--	--	--
Iowa River at Wapello, Iowa (site 13, fig. 1)							
Total nitrogen, as N	116	1.2	5.2	6.6	8.6	15	6.8
Ammonia, as N	115	<.01	.02	.06	.16	1.6	.16
Organic nitrogen, as N	114	.35	.90	1.5	1.9	5.3	1.5
Nitrite plus nitrate, as N	117	<.10	3.5	5.3	7.0	15	5.2
Orthophosphate, dissolved, as P	82	<.10	<.10	.11	.15	.29	.11
Total phosphorus, as P	116	<.10	.20	.27	.38	1.0	.31
Dissolved phosphorus, as P	114	<.10	<.10	.14	.19	.39	.14
South Skunk River near Ames, Iowa (site 14, fig. 1)							
Total nitrogen, as N	2	3.8	--	--	--	4.6	4.2
Ammonia, as N	43	.41	.61	.77	1.0	7.2	1.1
Organic nitrogen, as N	2	.89	--	--	--	.97	.93
Nitrite plus nitrate, as N	41	.17	.99	2.4	4.0	9.2	2.9
Orthophosphate, dissolved, as P	2	1.2	--	--	--	1.9	1.6
Total phosphorus, as P	45	.19	.29	.37	.64	4.0	.62
Dissolved phosphorus, as P	--	--	--	--	--	--	--
South Skunk River near Cambridge, Iowa (site 15, fig. 1)							
Total nitrogen, as N	77	2.2	7.4	9.4	13	23	10
Ammonia, as N	78	<.10	<.10	<.10	.10	1.7	.15
Organic nitrogen, as N	--	--	--	--	--	--	--
Nitrite plus nitrate, as N	78	1.4	6.8	8.8	12	22	9.5

Table 4. Statistical summary of nutrient concentrations in samples from surface-water-quality monitoring sites in the Eastern Iowa Basins study unit, 1970–95—Continued

[mg/L, milligrams per liter; <, less than; --, no data]

Constituent	Number of samples	Minimum concentration measured (mg/L)	Percentile			Maximum concentration measured (mg/L)	Mean concentration measured (mg/L)
			25	50 (median) (mg/L)	75		
South Skunk River near Cambridge, Iowa (site 15, fig. 1)—Continued							
Orthophosphate, dissolved, as P	78	<.10	.20	.30	.70	4.2	.65
Total phosphorus, as P	77	.10	.30	.40	.90	4.5	.79
Dissolved phosphorus, as P	--	--	--	--	--	--	--
Cedar Creek near Oakland Mills, Iowa (site 16, fig. 1)							
Total nitrogen, as N	111	0.60	2.3	4.9	8.2	16	5.5
Ammonia as N	111	<.10	<.10	<.10	.10	2.2	.16
Organic nitrogen, as N	--	--	--	--	--	--	--
Nitrite plus nitrate, as N	111	<.10	1.0	3.7	7.6	13	4.4
Orthophosphate, dissolved, as P	110	<.10	<.10	.10	.20	.90	.14
Total phosphorus, as P	101	<.10	.20	.20	.40	1.9	.32
Dissolved phosphorus, as P	--	--	--	--	--	--	--
Skunk River at Augusta, Iowa (site 17, fig. 1)							
Total nitrogen, as N	115	.55	3.4	5.7	8.1	13	5.8
Ammonia, as N	117	<.01	.02	.06	.17	1.5	.17
Organic nitrogen, as N	113	.09	.71	1.0	1.6	5.7	1.3
Nitrite plus nitrate, as N	123	<.10	1.8	4.1	6.8	12	4.4
Orthophosphate, dissolved, as P	83	<.10	<.10	<.10	.13	.24	<.10
Total phosphorus, as P	115	<.10	.15	.23	.35	1.7	.29
Dissolved phosphorus, as P	115	<.10	<.10	.12	.16	.25	.11

One of the trends observed was a positive correlation of nitrate concentrations with streamflow. The LOWESS plots of nitrate versus streamflow (fig. 6) show nitrate concentrations increasing with higher rates of streamflow until extreme streamflows where nitrate concentrations tend to "level off" and even decrease. During storms, nitrate that has accumulated on the land surface and in the soil is transported to streams by water flowing overland and through soils and by shallow ground water. Typically, the LOWESS plots for nitrate concentrations show a steep positive increase in concentration as streamflow begins to increase. The decrease in concentration at the highest rate of streamflow indicates that after extended periods of runoff, nitrate available for transport to streams becomes depleted, and further rainfall and runoff dilute the nitrate concentrations.

The ammonia and ammonia plus organic nitrogen LOWESS plots do not show a correlation with streamflow (figs. 7, 8, 11, and 12). This may be expected as ammonia is oxidized rather quickly to nitrate during surface-water runoff. Typically, nitrate is the dominant nitrogen species at the surface-water monitoring sites rather than ammonia or ammonia plus organic nitrogen. Approximately 60 to 94 percent of the median concentrations of total nitrogen consisted of nitrate (table 4). The one exception was the Shell Rock River near Gordonsville, Minnesota (site 4), which had a median nitrate of only 32 percent of the total nitrogen.

Typically, phosphorus shows a slight positive correlation with increasing streamflow. However, the positive correlation for increasing phosphorus concentrations with increasing streamflow differs from and is not as strong as the positive correlation of nitrate concentrations that increase with streamflow.

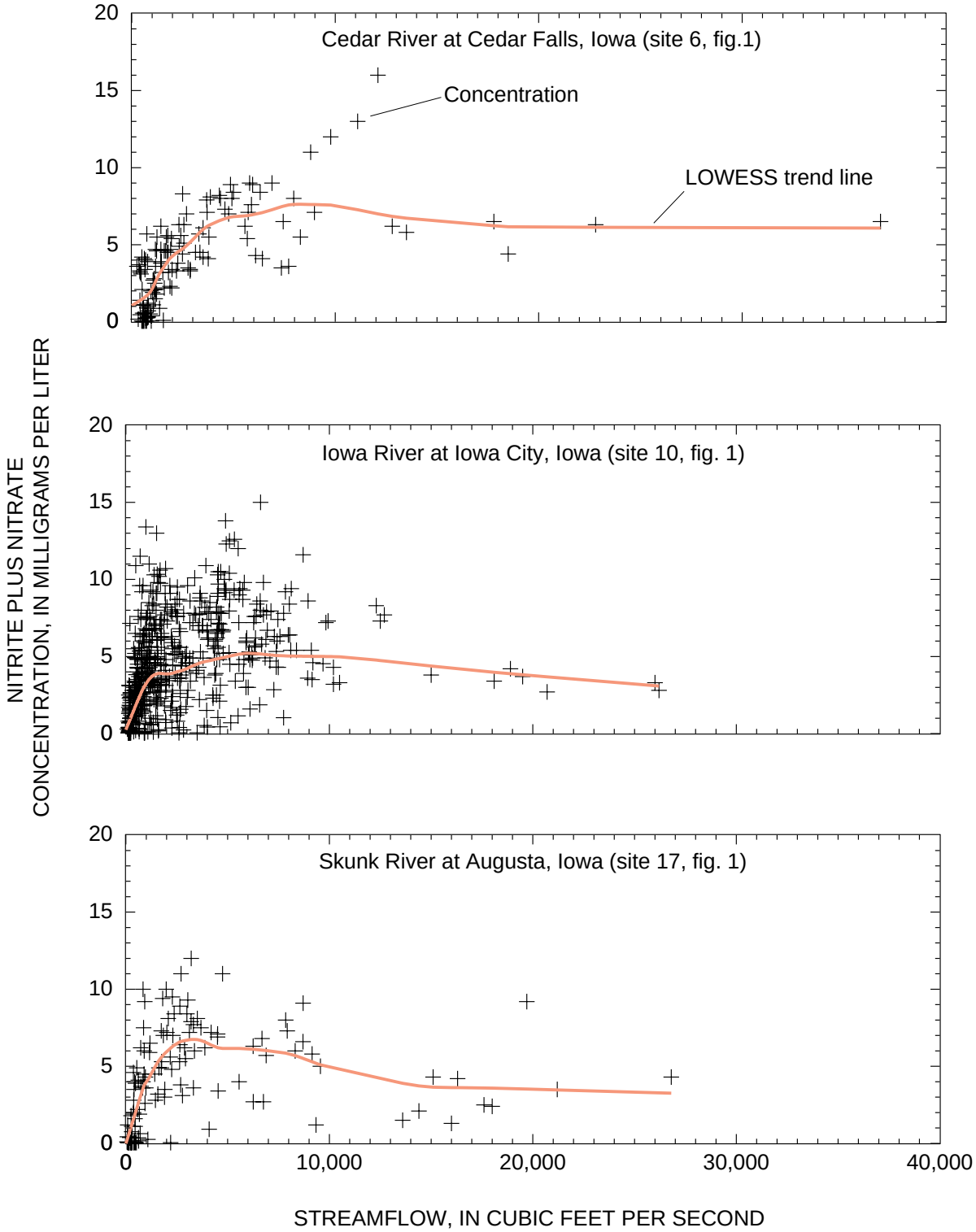


Figure 6. Relation of nitrite plus nitrate concentrations to streamflow at selected surface-water-quality sites in the Eastern Iowa Basins study unit, 1970–95.

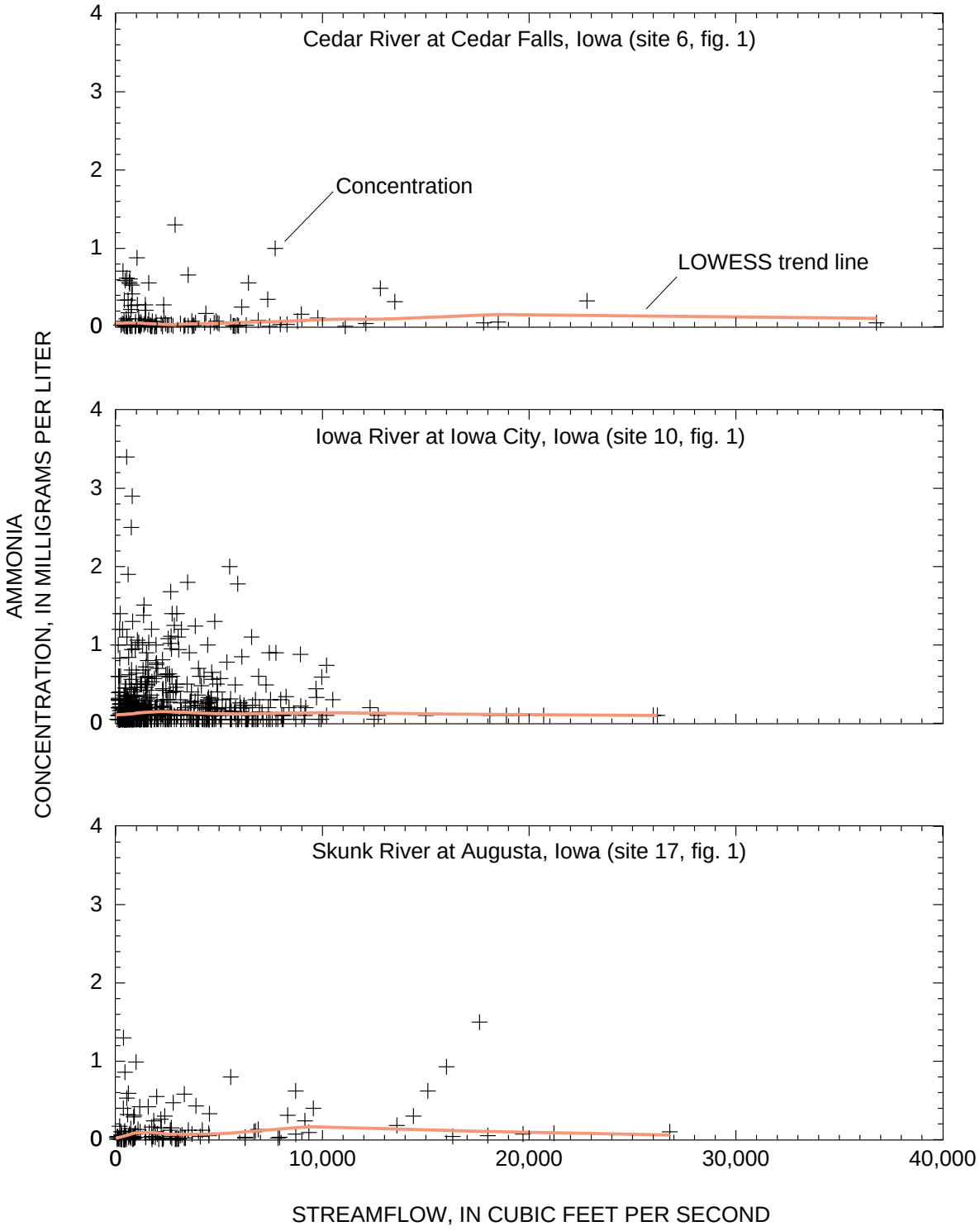


Figure 7. Relation of ammonia concentrations to streamflow at selected surface-water-quality monitoring sites in the Eastern Iowa Basins study unit, 1970–95.

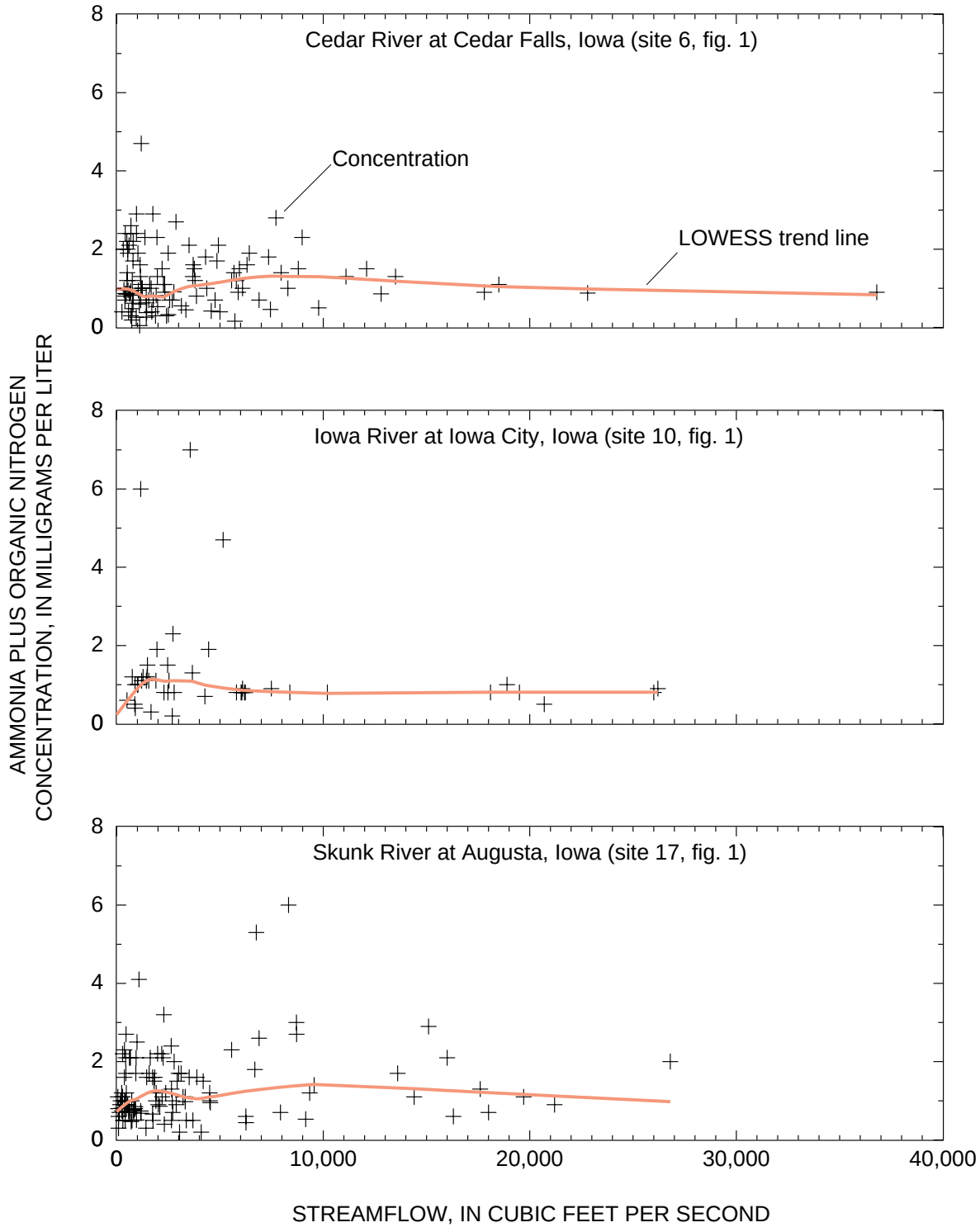
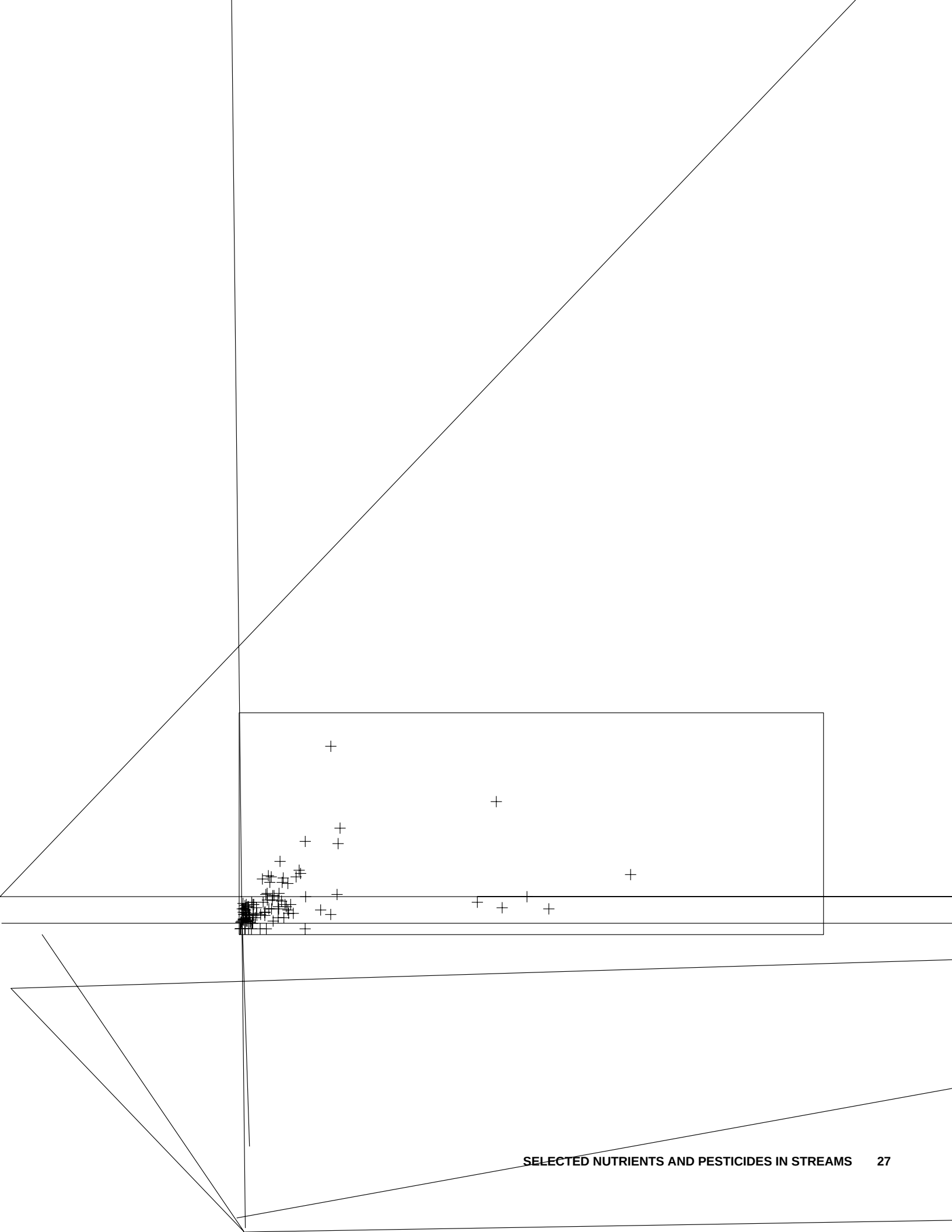


Figure 8. Relation of ammonia plus organic nitrogen to streamflow at selected surface-water-quality monitoring sites in the Eastern Iowa Basins study unit, 1970–95.



and Skunk River Basins have had more than twice the number of hog facilities permitted from 1993–96 compared to 1987–93. The potential negative effects of these hog-production facilities on surface-water quality may be of concern.

Surface-water samples are needed to characterize water-quality variations associated with changes in season and streamflow. Typically, monthly samples are needed to measure the effects of seasonal fluctuations. Monthly samples at monitoring sites used in this report would provide extremely valuable data to determine seasonal trends in water quality and streamflow. Monthly samples also are important for understanding long-term trends. Sampling that targets storm runoff would measure the effects of nonpoint-source pollution from urban and agricultural areas and improve constituent load estimates. Substantial loads of nutrients and herbicides can be carried by streams during runoff (Schottler and others, 1994; Larson and others, 1997).

The Cedar River had the most extensive surface-water-quality data set in the study unit. However, monthly long-term data for the Wapsipinicon River were lacking. The Wapsipinicon River is one of the major rivers in eastern Iowa, but very little historical data are available. Preliminary data indicate that the Wapsipinicon River may have a larger riparian zone than other large rivers in the study unit. A larger riparian zone may help to reduce the transport of nutrients and pesticides to the river. Data on the Wapsipinicon River would be valuable for a comparison with the Cedar River or other large rivers.

Long-term monitoring data for pesticides are lacking in the EIWA study unit. Pesticide concentrations fluctuate annually, depending on a variety of factors including application rates, rainfall, runoff rates, and timing of runoff after application. Long-term monitoring is important in determining if pesticide concentrations are increasing. It was not possible to analyze long-term temporal or spatial pesticide trends due to the lack of data available. In addition, pesticide metabolites (degradation products of pesticides) may persist at higher concentrations than the parent compounds (Kalkhoff and others, 1998). Data to monitor trends in pesticide and pesticide metabolite concentrations are basic to determining the occurrence and fate of these compounds.

SUMMARY

In 1991, the U.S. Geological Survey (USGS) began implementation of the National Water-Quality Assessment (NAWQA) Program. The Eastern Iowa Basins (EIWA) study unit was selected as one of the units that began work in 1994. The Eastern Iowa Basins study unit encompasses 19,500 mi^2 and is divided into four main subbasins—the Wapsipinicon, Cedar, Iowa, and Skunk. This report compiled selected nutrient and pesticide data in the Eastern Iowa Basins study unit from the period 1970–95 and described, to the extent possible, patterns and trends.

Seventeen surface-water-quality monitoring sites were selected where monthly sampling data were available with a long-term record (5 years or greater). Water-quality data were compiled for seven monitoring sites sampled by the Iowa Department of Natural Resources, three sampled by the Minnesota Pollution Control Agency, three sampled by the University of Iowa Institute for Hydraulic Research, and four sampled by the U.S. Geological Survey. Streamflow data were available or estimated from nearby stream gages for 12 of the 17 surface-water-quality monitoring sites. The water-quality analyses typically consisted of nitrate, ammonia, total nitrogen, and total phosphorus, with limited analyses available for organic nitrogen, dissolved phosphorus, dissolved orthophosphate, and water-soluble pesticides. The Cedar River and two of its tributaries had the most monitoring sites (eight), including some with the longest periods of record available (20 years). In contrast, monthly water-quality data for the Wapsipinicon River were scant or not available. Long-term pesticide data were lacking for most monitoring sites in the Eastern Iowa Basins study unit.

A statistical analysis of the nutrient data was summarized for each monitoring site. The median concentrations for total nitrogen ranged from 4.6 to 9.4 mg/L, and maximum concentrations of total nitrogen ranged from 4.6 to 31 mg/L. Median concentrations of total phosphorus ranged from less than 0.10 to 0.66 mg/L, and maximum concentrations of total phosphrous ranged from less than 0.10 to 5.4 mg/L. Median concentrations of nitrate were largest during the spring and winter (6.0 to 7.0 mg/L) and smallest in the summer and fall (2.0 to 4.0 mg/L).

Concentrations of nitrate greater than 10 mg/L typically occurred during spring runoff. The largest nitrate concentration was 26 milligrams per liter nitrate as nitrogen in the Shell Rock River near Gordonsville, Minnesota. Median ammonia concentrations generally were greatest during the winter (approximately 0.3 to 0.5 mg/L) compared to the spring and summer when ammonia concentrations often were close to the detection limit (0.01 mg/L). In general, the median concentrations of total phosphorus varied less than 0.1 mg/L between seasons.

Nitrate concentrations were strongly correlated with streamflow. Total phosphorus showed a weak positive correlation with streamflow with more variability than nitrate concentrations. The trend line for nitrate concentration with increasing streamflow was steeper than the trend line for total phosphorus at low and moderate streamflows. Nitrate is generally transported in the dissolved phase by overland flow, tile drains, interflow, and ground-water discharge. In contrast, the transport of phosphorus often is associated with sediment and not in the dissolved phase.

The ammonia and ammonia plus organic nitrogen concentrations were not correlated with streamflow or indicated a weak positive correlation. This is expected as the concentrations of these nitrogen species are small to begin with and are oxidized rather quickly by instream processes. The trend lines showed differences between point and nonpoint sources. Nitrate and phosphorus concentrations increased with decreasing streamflow during low-flow conditions.

Seasonal Kendall statistical trend analysis of nutrient concentrations generally indicated decreases for ammonia and total phosphorus concentrations with increases for nitrate concentrations for other sites in the study unit. Ammonia nitrogen reductions are most likely the result of improvements to wastewater-treatment plants in the late 1980's. In general, the median concentrations of total phosphorus varied less than 0.1 mg/L between seasons. Total phosphorus concentrations did not show a strong seasonal variation when compared to nitrate concentrations. An increase in nitrate concentration across the study unit was apparent after the 1988–89 drought because of leaching and subsequent transport of nitrogen that had accumulated in the soil.

The seasonal Kendall statistical trend analysis for instantaneous loads (concentration multiplied by streamflow at the time of sample) also were completed for sites where streamflow data were available or could be estimated from nearby stream gages. Instantaneous load trends for total phosphorus showed three sites with upward trends (Cedar River at Cedar Falls, Cedar River at Gilbertville, and Cedar Creek near Oakland Mills) and two sites with downward trends (Cedar River near Austin, Minnesota, and Cedar River near Palo, Iowa). Instantaneous load trends for ammonia were noted at two sites (English River near Riverside and Cedar Creek near Oakland Mills) with downward trends at three sites (Cedar River near Austin, Cedar River near Charles City, and Cedar River near Palo). Nitrate instantaneous load trends showed increases at five sites (Cedar River near Austin, Cedar River at Cedar Falls, Cedar River at Gilbertville, Iowa River at Iowa City, and Iowa River at Columbus Junction) and a decrease at one site (Cedar River near Palo). Numerous factors such as soil conditions, increased soil "loading" of nitrate or phosphorus, livestock facilities, and wastewater-treatment plants can affect long-term trends.

Data on water-soluble pesticides were not as complete as the nutrient data sets. Long-term pesticide data are lacking in the study unit. Statistical summaries were completed for the most commonly detected pesticides—alachlor, atrazine, cyanazine, metolachlor, and metribuzin. Other pesticides in the data sets had concentrations that were not detected or had values at or less than the analytical method detection level. Atrazine was the most commonly detected pesticide. Maximum concentrations of pesticides usually occurred after spring runoff. The largest pesticide concentration was 31 micrograms per liter for cyanazine in a sample from the Skunk River at Augusta. However, mean concentrations of pesticides were typically less than the maximum contaminant levels. Large streamflows during the late summer do not have pesticide concentrations as large as do the streamflows during the spring that occur soon after the application of pesticides.

In general, when analyzing the seasonal variations of nutrients and pesticides concentrations and the relations of nutrients and pesticides concentrations to streamflow, the available information generally corresponded with nonpoint-source loadings. However, possible point sources for nutrients were indicated by at selected monitoring sites, particularly those downstream from wastewater-treatment plants.

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