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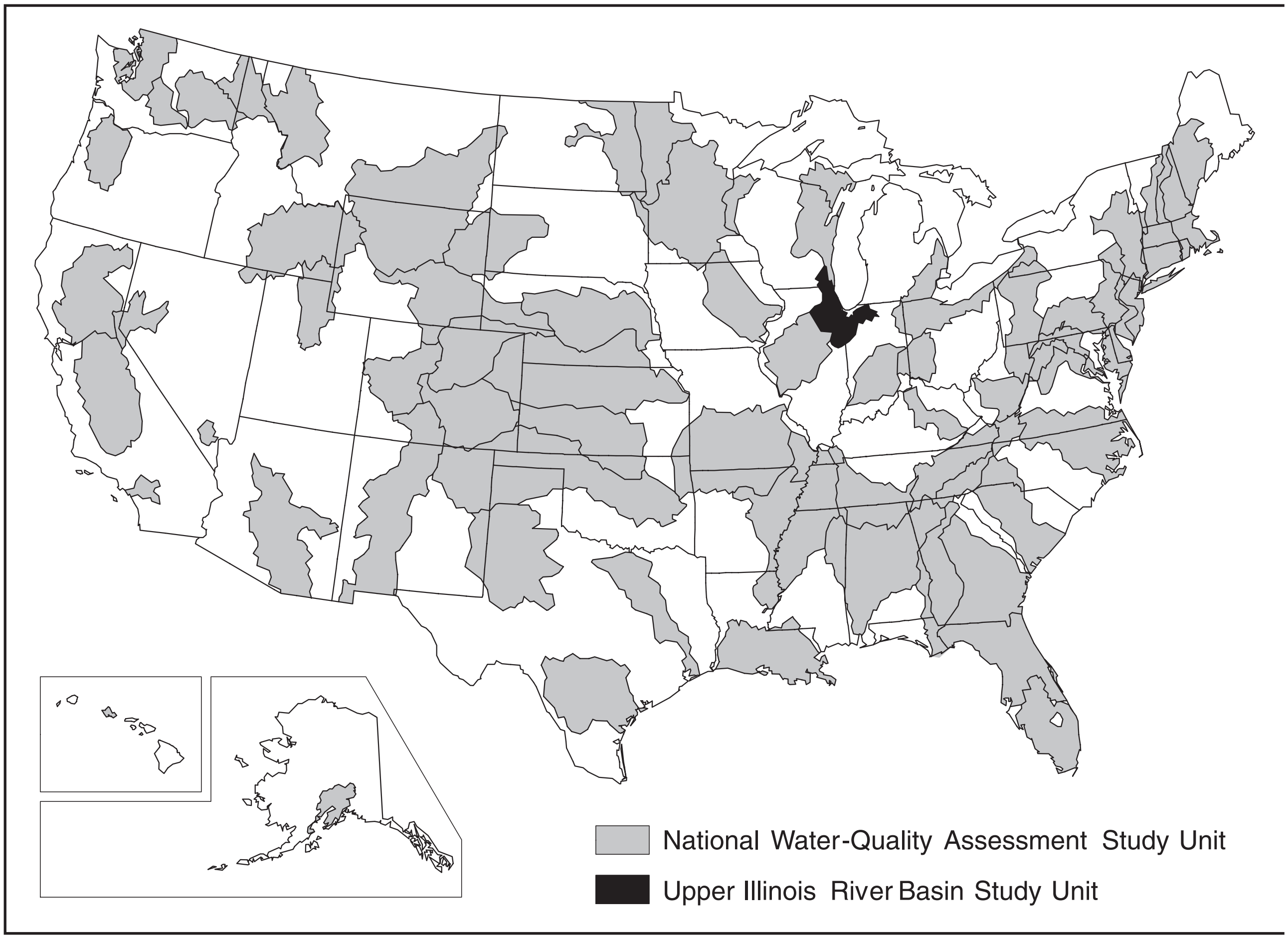
Physical, Chemical, and Biological Methods and Data from the Urban Land-Use-Gradient Study, Des Plaines and Fox River Basins, Illinois, 1999-2001

Open-File Report 01-459

UPPER ILLINOIS RIVER BASIN
National Water-Quality Assessment Program



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

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By Debbie L. Adolphson, Terri L. Arnold, Faith A. Fitzpatrick, Mitchell A. Harris, Kevin D. Richards, Barbara C. Scudder, and Jana S. Stewart

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USGS
science for a changing world

Urbana, Illinois
2002

U.S. DEPARTMENT OF THE INTERIOR

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FOREWORD

The U.S. Geological Survey (USGS) is committed to serve the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life, and facilitates effective management of water, biological, energy, and mineral resources. Information on the quality of the Nation's water resources is of critical interest to the USGS because it is so integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and that is suitable for industry, irrigation, and habitat for fish and wildlife. Escalating population growth and increasing demands for the multiple water uses make water availability, now measured in terms of quantity and quality, even more critical to the long-term sustainability of our communities and ecosystems.

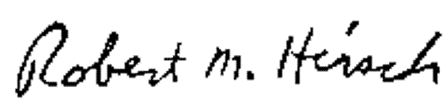
The USGS implemented the National Water-Quality Assessment (NAWQA) Program to support national, regional, and local information needs and decisions related to water-quality management and policy. Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues. NAWQA results can contribute to informed decisions that result in practical and effective water-resource management and strategies that protect and restore water quality.

Since 1991, the NAWQA Program has implemented interdisciplinary assessments in more than 50 of the Nation's most important river basins and aquifers, referred to as Study Units. Collectively, these Study Units account for more than 60 percent of the overall water use and population served by public water supply, and are representative of the Nation's major hydrologic landscapes, priority ecological resources, and agricultural, urban, and natural sources of contamination.

Each assessment is guided by a nationally consistent study design and methods of sampling and analysis. The assessments thereby build local knowledge about water-quality issues and trends in a particular stream or aquifer while providing an understanding of how and why water quality varies regionally and nationally. The consistent, multi-scale approach helps to determine if certain types of water-quality issues are isolated or pervasive, and allows direct comparisons of how human activities and natural processes affect water quality and ecological health in the Nation's diverse geographic and environmental settings. Comprehensive assessments on pesticides, nutrients, volatile organic compounds, trace metals, and aquatic ecology are developed at the national scale through comparative analysis of the Study-Unit findings.

The USGS places high value on the communication and dissemination of credible, timely, and relevant science so that the most recent and available knowledge about water resources can be applied in management and policy decisions. We hope this NAWQA publication will provide you the needed insights and information to meet your needs, and thereby foster increased awareness and involvement in the protection and restoration of our Nation's waters.

The NAWQA Program recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The Program, therefore, depends extensively on the advice, cooperation, and information from other Federal, State, interstate, Tribal, and local agencies, non-government organizations, industry, academia, and other stakeholder groups. The assistance and suggestions of all are greatly appreciated.



Robert M. Hirsch
Associate Director for Water

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Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch
millimeter (mm)	0.03937	inch
micrometer (µm)	0.00003937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
kilometer (km)	0.5400	mile, nautical
meter (m)	1.094	yard
Area		
square meter (m^2)	0.0002471	acre
square kilometer (km^2)	247.1	acre
square meter (m^2)	10.76	square foot
square kilometer (km^2)	0.3861	square mile
Volume		
milliliter (ml)	264.2	gallon
liter (L)	0.2642	gallon
Flow rate		
meter per second (m/s)	3.281	foot per second
cubic meter per second (m^3/s)	35.31	cubic foot per second
cubic meter per day (m^3/d)	35.31	cubic foot per day
Mass		
gram (g)	0.03527	ounce, avoirdupois
kilogram (kg)	2.205	pound avoirdupois
Density		
kilogram per cubic meter (kg/m^3)	0.06242	pound per cubic foot
gram per cubic centimeter (g/cm^3)	62.4220	pound per cubic foot
kilometer per square kilometer (km/km^2)	1.609	mile per square mile
Hydraulic gradient		
meter per kilometer (m/km)	5.27983	foot per mile

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F = (1.8 × °C) + 32

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

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

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ABSTRACT

Physical, chemical, and biological data were collected at 46 sites in the Fox and Des Plaines River Basins as part of the upper Illinois River Basin study of the U.S. Geological Survey's National Water-Quality Assessment Program. The data, collected from 1999 to 2001, will be used to determine the effects of urbanization on streams in the Chicago, Illinois, metropolitan area. To examine the possible effects of urbanization on stream-water quality, the sampling sites were selected to represent a gradient of land use changing from agriculture into urban. Urban land use for the selected sites ranged from less than 1 percent urban to 92 percent urban.

Data-collection methods are presented in the text portion of this report. Physical characteristics of the stream that were collected include descriptive and qualitative habitat and geomorphic measures. Water samples were analyzed for nutrients (nitrogen and phosphorus), 11 major ions, 46 wastewater indicators, pH, and specific conductance. Aquatic communities were sampled to identify and quantify populations of selected algae, benthic macroinvertebrates, and fish. There were 72 unique fish species collected at all of the sites. The number of benthic macroinvertebrate taxa collected at all the sites ranged from 15 to 48. The data and the associated data documentation are presented on a CD-ROM included with this report.

INTRODUCTION

The National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS) was designed to provide a national view of the status and trends of the Nation's water resources (Hirsch and others, 1988). On this scale, consistent monitoring of water-quality conditions over time and a nationally comparable description of water resources are provided. The NAWQA program operates on a 10-year rotational schedule (Gilliom and others, 1995). A pilot NAWQA study was done in the upper Illinois River Basin (UIRB) from 1986 to 1991, and the full study began in 1997.

As part of the current UIRB NAWQA study, physical, chemical, and biological data were collected at sites along a land-use gradient ranging from nearly 100 percent agriculture to nearly 100 percent urban. The data and methods used to collect data for the land-use-gradient study are presented in this report. Several other NAWQA study units are conducting similar land-use-gradient studies in major metropolitan areas in the United States.

Purpose and scope

The purpose of this report is to present 1) the design of the urban land-use-gradient study, 2) the methods used to collect the physical, chemical, and biological data for the study, and 3) the data resulting from the measurements and analyses of stream characteristics in the Fox and Des Plaines River Basins. The data for the urban land-use-gradient study was collected from 1999 to 2001. These data are provided as tab-delimited files on a CD-ROM at the back of this report.

Description of study area

The upper Illinois River Basin drains 28,000 km^2 and is located in parts of four States: northeastern Illinois, northwestern Indiana, southeastern Wisconsin, and southwestern Michigan (fig. 1). Three principal streams in the upper Illinois River Basin are the Kankakee, the Des Plaines, and the Fox Rivers. The Kankakee and the Des Plaines Rivers join near Morris, Illinois, to form the Illinois River. The Fox River discharges to the Illinois River at the southwestern boundary of the basin near Ottawa, Illinois (Arnold and others, 1999).

The Chicago metropolitan area, one of the largest urban areas in the United States, is within the UIRB (fig. 1). The surrounding plains contain some of the richest farmland in the world. An important water-quality issue is the conversion of agricultural land to urban land and the effects of this conversion on water quality and aquatic communities. Available literature has addressed this water-quality issue; however, the causes for resulting loss in biological integrity are not well understood. Possible causes may include space or time changes in hydrology such as increase in peak flows, increase in peak flow duration, frequency of floods, loss of baseflow, and/or increase in contaminant concentrations. Previous studies in the Chicago area by the Wisconsin Department of Natural Resources and Northern Illinois Planning Commission indicate that even though urban nonpoint sources are possible causes for urban stream impairment, effects of hydrologic changes by themselves cannot be dismissed (Dreher, 1997; Wang and others, 1997).

Study Design

The primary goal of the urban land-use-gradient study (LUG) was to understand how urbanization of the areas surrounding the Chicago metropolitan area affects the physical, chemical, and biological conditions of streams. The UIRB NAWQA land-use-gradient synoptic study focuses on the tributaries to the Des Plaines and Fox Rivers, which contain the Chicago metropolitan area and are rapidly urbanizing (fig. 1).

The objectives of the study were to develop and apply a set of conceptual models to predict changes over time for stream restoration (by identifying the optimal conditions of a stream as constrained by its geology and physiography) and/or for protection. To address this goal and objective, the study was designed to test the following hypotheses:

1) Urban development affects biological as well as chemical and physical characteristics of streams.

2) The loss of biological integrity is caused, in part, by changes in hydrologic conditions.

3) The loss of biological integrity is caused, in part, by increases in contaminant concentrations.

4) Fish, invertebrate, and algae populations respond differently to urbanization effects and have different thresholds of sensitivity.

5) Geologic setting (permeability of surficial materials and stream gradient), in part, determines the response of the biologic community to urban development.

To address these hypotheses, 46 sites (table 1) on tributaries that feed the Fox and Des Plaines Rivers were selected to obtain a range in the amount of urban land in their basins. The availability of historical streamflow or biological data was also a consideration for site selection. The land-use gradient of the sampled sites ranged from more than 99 percent agriculture (less than 1 percent urban) to about 92 percent urban (fig. 2).

The 46 sites were sampled in July 2000. Drainage basins for the sites ranged from 12 to 326 km^2. Streams without point sources of potential contaminants were to be selected, when possible; however, point sources could not be avoided in areas with a high percentage of urbanization.

The Fox and Des Plaines River Basins differ mainly in Quaternary surficial deposits (Lineback and others, 1983) (fig. 3). Streams in the upper and western Fox River Basin drain surficial deposits composed mainly of sandy glacial till and outwash with moderate to high permeability. Less permeable clay and silt deposits are confined to a narrow strip in the eastern part of the Fox River Basin. Streams in the Des Plaines River Basin drain surficial deposits mainly composed of clayey till and lacustrine deposits with low permeability. More permeable coarse-grained outwash deposits in the Des Plaines River Basin are confined to small areas along the Lake Michigan coastline. Twenty-four of the 46 sites had a clayey geologic setting and they represented a wide range of urban land cover (3-80 percent). Six sites had a mixed geologic setting of clayey and loamy deposits or outwash (3-59 percent urban land cover). The remaining 16 sites had a geologic setting with sandy/loamy deposits and/or outwash (0-24 percent urban land cover). Twenty-four of the LUG sites

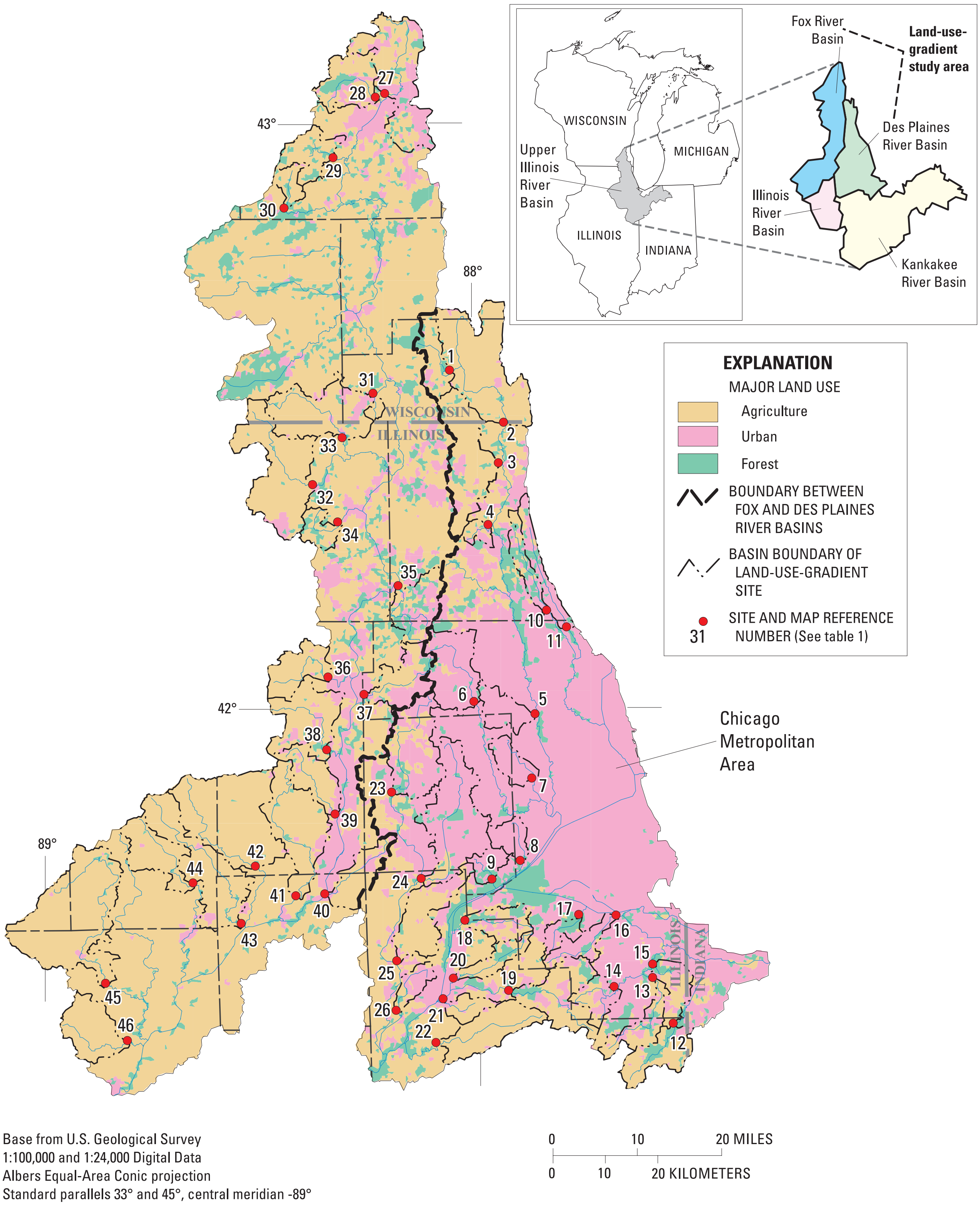

Figure **1.** Major land use in the land-use-gradient synoptic study area in the Fox and Des Plaines River Basins, Illinois (Vogelmann and others, 2001).

were at or near active USGS streamflow-gaging stations. The 46 LUG sites (table 1) were sampled once in July 2000 for habitat, geomorphic characteristics, water discharge, water chemistry (nutrients, major ions, wastewater indicators, pH, and specific conductance), and aquatic communities (algae, invertebrates, and fish). Water temperatures were collected at most sites continuously from approximately May 2000 to June 2001. Stream cross-sections were surveyed from November 2000 to May 2001. Fish were collected in August of 2000 or July of 2001 at sites that were not previously sampled by other agencies.

Table 1. Associated map reference number, site number, and site name for sampling sites in the land-use-gradient synoptic study in the Des Plaines and Fox River Basins, Illinois

[nr, near; bl, below; ab, above; Br, Branch; Cr, Creek; N, north, W, west; Rd, road; IL, Illinois; WI, Wisconsin]

Map reference number (fig. 1)	Site number	Site name
1	05527675	Brighton Creek at State Highway 45 nr Bristol, WI
2	05527800	Des Plaines River at Russell, IL
3	05527960	Mill Creek at Wadsworth, IL
4	05528032	Bull Creek bl Milwaukee Ave nr Libertyville, IL
5	05530510	Willow Creek at Des Plaines R Rd nr Rosemont, IL
6	05531045	Salt Creek at Elk Grove Village, IL
7	05532000	Addison Creek at Bellwood, IL
8	05533000	Flag Creek near Willow Springs, IL
9	05533400	Sawmill Creek near Lemont, IL
10	05534460	N Br Chicago River at Deerfield Rd at Deerfield, IL
11	05535100	Skokie River at Glencoe, IL
12	05536176	Plum Cr at Richton Rd nr Sauk Village, IL
13	05536236	Deer Creek near Glenwood, IL
14	05536248	Butterfield Cr at Country Club Rd nr Flossmoor, IL
15	05536272	North Creek Below 183rd Street near Thornton, IL
16	05536355	Midlothian Creek at Blue Island, IL
17	05536500	Tinley Creek near Palos Park, IL
18	05537550	Long Run Cr at Smith Rd nr Lemont, IL
19	05538270	Hickory Creek at Schmuhl Rd nr New Lenox, IL
20	05538490	Spring Creek near Joliet, IL
21	05539335	Sugar Run at Mills Road at Joliet, IL
22	05539632	Jackson Cr at Manhattan Rd nr Elwood, IL
23	05540032	W Br DuPage R at Garys Mill Rd nr W Chicago, IL

Table 1. Associated map reference number, site number, and site name for sampling sites in the land-use-gradient synoptic study in the Des Plaines and Fox River Basins, Illinois (Continued)

[nr, near; bl, below; ab, above; Br, Branch; Cr, Creek; N, north, W, west; Rd, road; IL, Illinois; WI, Wisconsin]

Map reference number (fig. 1)	Site number	Site name
24	05540260	East Branch Du Page River near Naperville, IL
25	05540440	Lily Cache Cr ab Caton Farm Rd nr Lily Cache, IL
26	05540660	Rock Run near Shorewood, IL
27	05543800	Fox River at Watertown Rd near Waukesha, WI
28	055438135	Pewaukee River near Pewaukee, WI
29	055438845	Genesee Creek at Saylesville, WI
30	05544080	Jericho Creek nr Jericho, WI
31	05545955	Bassett Creek nr Twin Lakes, WI
32	05548105	Nippersink Creek Above Wonder Lake, IL
33	05548200	North Branch Nippersink Creek near Richmond, IL
34	05549000	Boone Creek near Mc Henry, IL
35	05549850	Flint Creek near Fox River Grove, IL
36	05550290	Tyler Creek at Randall Road near Elgin, IL
37	05550500	Poplar Creek at Elgin, IL
38	05551200	Ferson Creek near St. Charles, IL
39	05551340	Mill Creek at Mooseheart, IL
40	05551548	Waubansee Creek at Oswego, IL
41	05551695	Blackberry Cr at Bristol Ridge Rd nr Bristol, IL
42	05551931	Big Rock Creek at Jericho Road near Sugar Grove, IL
43	05551939	Little Rock Creek at Milhurst Road near Plano, IL
44	05551985	Somonauk Creek at Somonauk Rd nr Sandwich, IL
45	05552190	Indian Creek Bl Shabbona County Park near Harding, IL
46	05552450	Buck Creek near Wedron, IL

Acknowledgments

This study was completed with the help of USGS staff, State cooperators, and landowners. In addition to the authors, the USGS staff involved in this study include: Becky Ashton, Matt Diebel, Dave Dupre, Brett Esser, Mike Friedel, Jan Fuller, Phil Gaebler, George Groschen, Dave Housner, Mindy Mathias, Morgan Schmidt, Larry Shelton, Steve Stammer, Krista Stensvold, Dan Sullivan, Sarah Tegt, Heather Whitman, and Julie Wolf. Fish-species data were

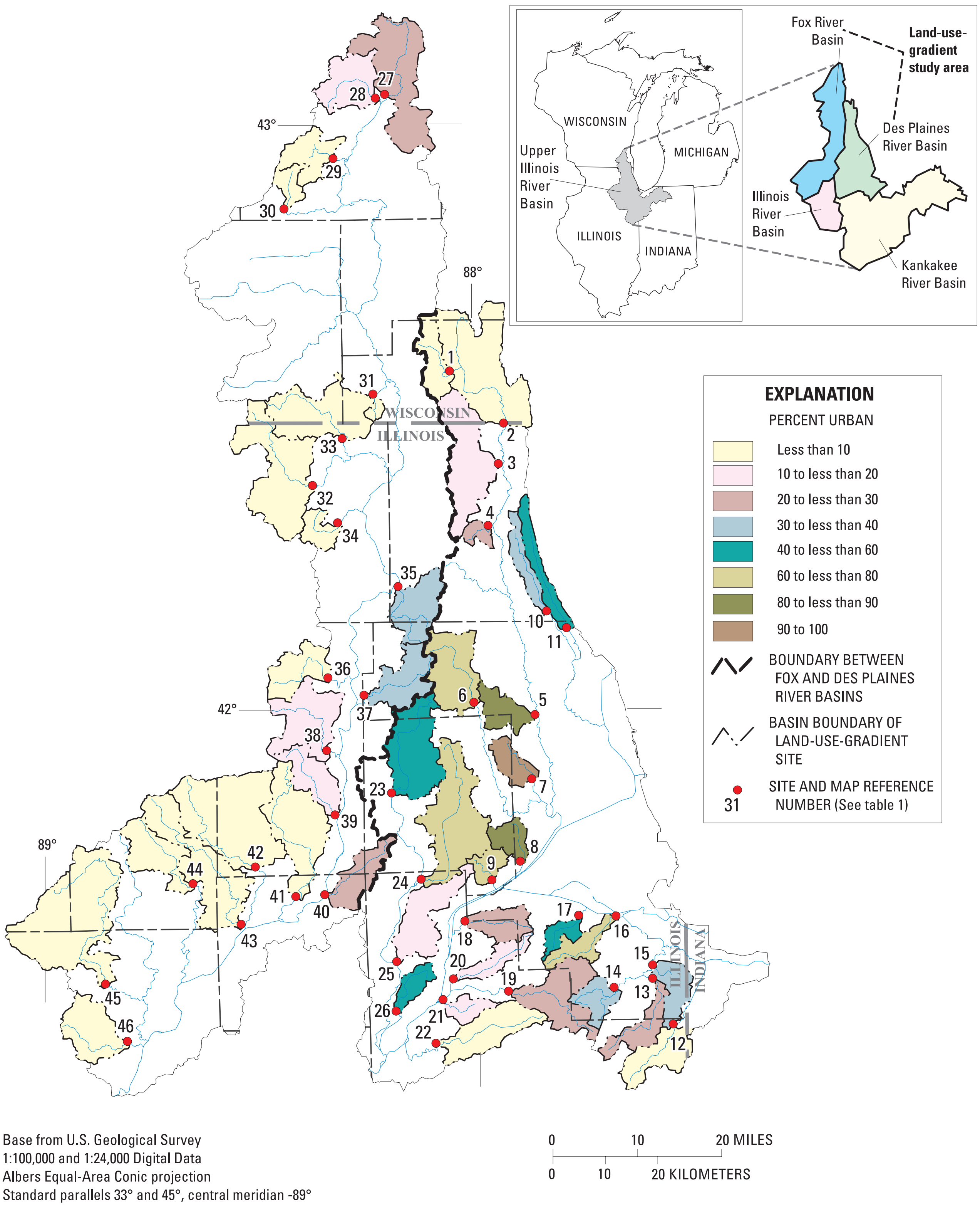

Figure **2.** Percent urban land use in basins for the land-use-gradient synoptic study in the Fox and Des Plaines River Basins, Illinois.

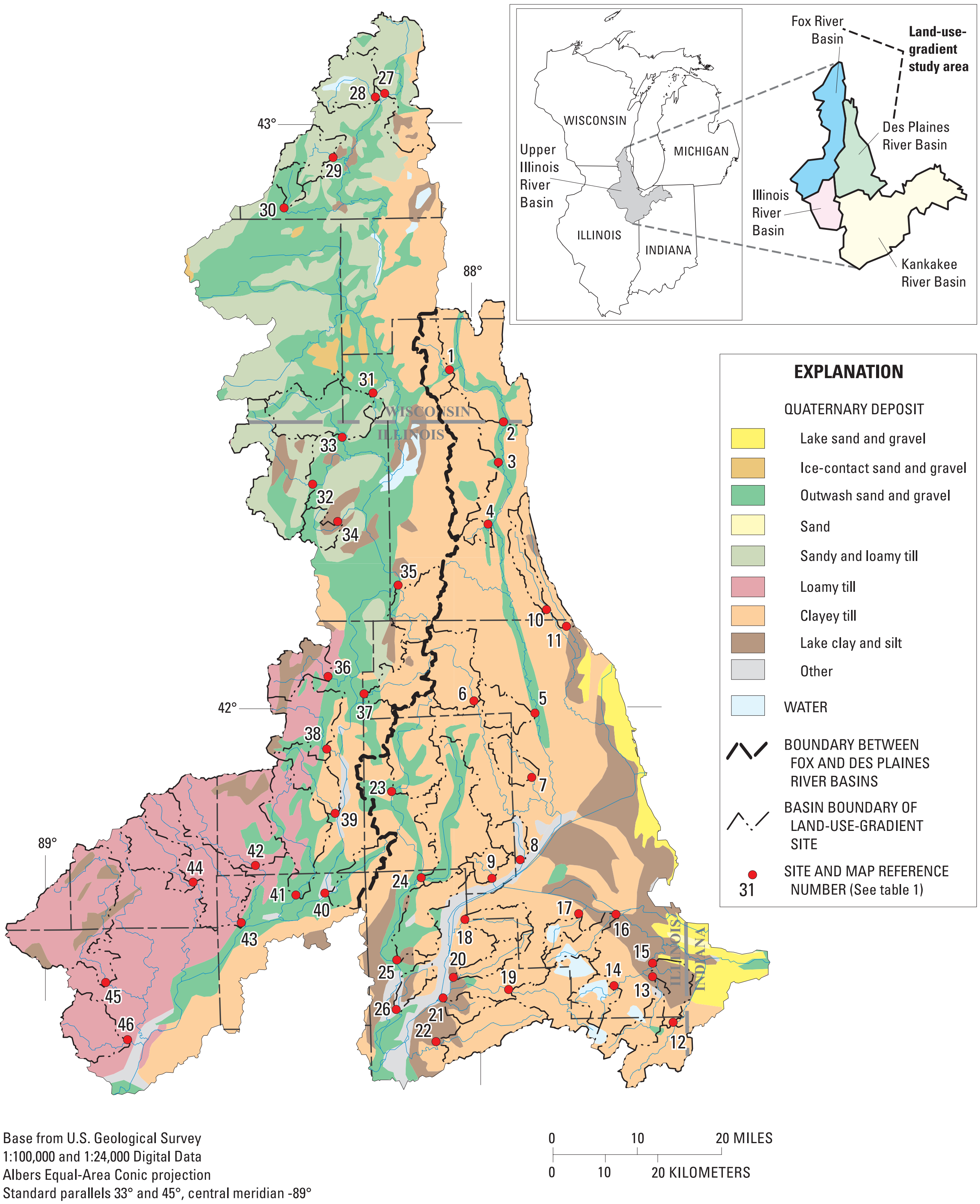

Figure **3.** Quaternary deposits in the land-use-gradient synoptic study area in the Fox and Des Plaines River Basins, Illinois.

provided by Steve Pescitelli (Illinois Department of Natural Resources) and John Lyons (Wisconsin Department of Natural Resources). Chris Taylor (Illinois Natural History Survey) provided field identification of fish collected to fill in for sites without previous data. A special thanks to Tiffany Shockey of the USGS National Water-Quality Laboratory and also to the private and public landowners that allowed us access to the sites to complete the study.

METHODS FOR DATA COLLECTION AND LABORATORY ANALYSIS

Physical Characteristics

Physical characteristics were collected and analyzed on three scales: drainage basin, segment, and reach. The drainage basin scale includes the entire land area that drains into the stream system above the site. A segment is a length of stream that is relatively homogeneous with respect to physical, chemical, and biological properties. The segment is bounded by confluences or physical or chemical discontinuities, such as major waterfalls, landform features, or appreciable changes in gradient or point-source discharges. The reach includes a length of stream that represents a uniform set of physical, chemical, and biological conditions within a segment. The reach is the principal sampling scale for collecting physical, chemical, and biological data. (Fitzpatrick and others, 1998) (fig. 4).

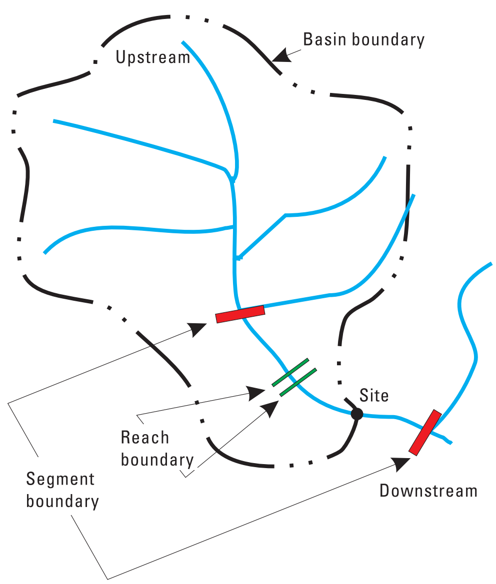

Figure **4.** Spatial hierarchy of basin, segment, and reach.

Drainage basin characteristics

A geographic information system (GIS) and various spatial data sets were used to characterize the environmental setting of each sampling site drainage basin. The spatial data represent natural and human features. The natural features represented by the data layers include: soil permeability; surficial deposits; depth to bedrock; and average annual precipitation, snowfall, and temperature. A detailed discussion of natural characteristics in the upper Illinois River Basin and spatial data sources is given in Arnold and others (1999). Human features represented by the data layers include: 1980 and 1990 demographic information from the decennial census, land use, road density, and estimates of impervious area contributed by roads. Calculations for basin characteristics were based on Fitzpatrick and others (1998) and Harvey and Eash (1996). The data are included on the CD-ROM.

The sampling sites were plotted on 1:24,000 scale topographic base maps. After sites were located on base maps, the following information was obtained: latitude and longitude, sampling site name and identification number, hydrologic unit code, State and County code, and elevation. The basin drainage boundary was drawn on the 1:24,000 topographic maps and then digitized into a GIS. These digitized basin boundaries were used to compute drainage area and basin perimeter (Harvey and Eash, 1996). Additionally, the digitized basin boundaries were combined spatially with soil permeability, surficial deposits, precipitation, snowfall, and temperature spatial data sets to calculate percent soil permeability, percent surficial deposits, and basic statistics about precipitation, snowfall, and temperature for each site.

The National Elevation Dataset (NED) (U.S. Geological Survey, 2001) was used to calculate selected basin and stream physical characteristics. The 1:24,000 NED Digital Elevation Model (DEM) was overlaid spatially with each land-use-gradient drainage basin. The NED DEM is a compilation of all the best available DEMs covering the country. Using the GIS, lines representing streams were generated from the DEM. Because of the systematic errors that occur during the creation of a DEM, the streams of some basins did not connect properly to create a continuous stream network. To represent actual streams in the basin, these disconnected streams were corrected manually. Digital stream data at the scale of 1:100,000 were used as a guide for correcting the 1:24,000 generated streams. When stream connectivity was corrected, so was stream order.

All basin characteristics except for basin relief ratio were calculated using the BasinSoft program (Harvey and Eash, 1996) and GIS. To calculate the necessary parameters for each basin, the appropriate stream and DEM spatial data layers were clipped to the basin boundary. The DEMs were used to calculate minimum and maximum elevations in the basin, basin relief, basin relief ratio, and percent of basin with a slope greater than 1 percent. Basin relief ratio was calculated using methods outlined in Fitzpatrick and others (1998).

Depth to bedrock was calculated using GIS and the unpublished UIRB hydrogeologic database that contains data from 30,000 well-driller's logs in the Upper Illinois River Basin area. Depth to bedrock point data from the database was krigged to create a spatial data layer representing the bedrock surface. The digitized basin boundary for each LUG sampling site was overlaid spatially with the depth to bedrock surface to calculate the minimum, maximum, mean, and standard deviation depth to bedrock.

Demographic data were obtained from the 1990 decennial census of population and housing characteristics (U.S. Bureau of the Census, 1991). The census reported 1990 census counts of population and housing units and estimates of 1998 and 2003 populations. Demographic data for 1990 were recorded by block group. Most basins overlapped with parts of several different block groups. The percentage of block group that overlapped the basin was multiplied by the population and housing count of the block group. This evaluation yielded an estimate of the number of people and houses each block group contributed to the basin. The population and number of houses contributed by each block group were summed by basin to obtain an estimate of the 1990 population and housing unit count in each basin.

Population data were obtained from the 1980 decennial census (U.S. Bureau of the Census, 1985) to estimate the 1980 population for all but three basins. The 1980 decennial census data were summarized by tracts; therefore, tracts were used instead of block groups. Three sites (Somonauk Creek at Somonauk Rd nr Sandwich, IL; Indian Creek Bl Shabbona County Park near Harding, IL; and Buck Creek near Wedron, IL) (table 1) did not have 1980 population information by tract or block group. Population for these sites was estimated using a similar approach but with a population count by township and range instead of by tract.

The 1999 Topologically Integrated Encoding and Referencing (TIGER) system line files (U.S. Bureau of the Census, 1999) representing roads were used to estimate road density. To estimate impervious area contributed by roads, the roads were assigned width of varying distances depending on the road type. Road widths were loosely based on suggestions from the Illinois Department of Transportation (IDOT) (Larry Piche, oral commun., 2001); however, IDOT stipulated that roads could vary in width depending on their geographic location. Road density was calculated by dividing the calculated road area (road width times road length) (table 2) by the drainage area.

Table 2. Road widths used for different road types and TIGER classifications to estimate road impervious area (modified from Piche, 2001)

Road type	TIGER classification used to assign road type	Total road width, in meters
Multi-lane interstate	A1	11.6
State and U.S. highways	A2	4.6
County	A3	3.7
Local, city, and rural	A4 or A6	4.0
Other, foot trails, bike paths	A7	1.5

Percent land use in the basins was calculated from the Multi-Resolution Land Cover (MRLC) data (Vogelmann and others, 2001). The DEM, streams, and MRLC land-use data sets were used to calculate the minimum, maximum, mean, and standard deviations of the distances of each general ("level 1") land-use classification and each detailed ("level 2") urban land-use classification to the basin outlets. These values gave a measurement of how close urban and other land-use were to the sampling site. To obtain an estimate of overall impervious area based on urban land use, calculations used U.S. Department of Agriculture (1986) estimates of percent impervious area provided by different urban land uses.

A buffered area around the streams was created by drawing a polygon with a boundary 60 m from the stream on each side. This buffered area was used to characterize the area of immediate influence on the stream and was calculated for each basin. The buffers were then overlaid spatially with soil permeability, land use, surficial deposits, and depth to bedrock. A GIS was used to calculate the percent of permeability, land use, and surficial deposits; and the minimum, maximum, mean, and standard deviation of depth to bedrock for the buffered area.

Segment-scale geomorphic characteristics

Segment characteristics include valley length, curvilinear channel length, segment curvilinear length, downstream and upstream elevations with their corresponding latitudes and longitudes, and sinuosity. The methods used to calculate these characteristics were taken from Fitzpatrick and others (1998).

Separate characteristics were calculated from the 1:24,000 NED DEM (U.S. Geological Survey, 2001) and the corrected stream network that was used to estimate basin characteristics. Valley length, curvilinear channel length, downstream and upstream segment elevations, downstream and upstream latitude and longitude, and sinuosity were calculated using measurements from the NED (U.S. Geological Survey, 2001). Latitudes and longitudes were obtained by locating the segment boundaries on the 1:24,000 scale topographic maps then digitizing the points.

Reach-scale habitat, geomorphic, and hydrologic characteristics

Reach scale (fig. 4) habitat characteristics included channel, substrate, and bank measurements. Channel features such as bars and islands were recorded as well as the geomorphic channel type (riffle, run, or pool) in each reach. Hydrologic parameters, such as measured stream discharge and estimates of bankfull flow, also were collected. Reach-scale habitat measurements were collected at each site in July 2000 using methods described in Fitzpatrick and others (1998). Reach lengths for the LUG sites ranged from 150 to 300 m.

Measurements were made at 11 equidistant transects within each reach. At each transect, channel depth and substrate measurements were made at the thalweg and at two other points equally spaced along the transect within the channel. Canopy cover and aspect of stream flow were measured from the center of the stream (fig. 5). Channel width measurements were made at the water level and at a field estimated bankfull. Bank measurements also were based on estimated bankfull. Bank stability was classified using the bank stability index described in Fitzpatrick and others (1998). The bank stability index is calculated from bank angle, vegetative cover, height, and substrate measurements.

To help quantify bank erosion and overall sedimentation, this study collected additional geomorphic measurements. In addition to noting the presence or absence of erosion at the intersection of each transect with the bank, the length of bank erosion occurring along the transect line was measured. Silt depth was measured at each transect point in addition to noting the presence or absence of silt.

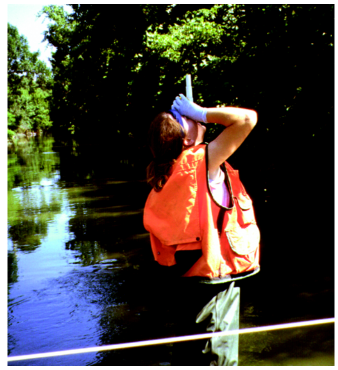

Figure **5.** Measuring canopy cover from the center of the stream at Addison Creek at Bellwood, Illinois.

To determine stream slope, channel geometry, and roughness, a Top Gun DTM-A 10LG Total Station or auto-level was used. All reaches were surveyed once during the period November 2000 through May 2001 at three cross-sections located near the top, middle, and bottom of each reach. These data were used to estimate stream power and potential shear stress. Because of the complexity of the raw surveying data only reach slope will be presented in this report.

The habitat data were summarized by site to facilitate comparisons among the sites. All of the transects or transect point data were averaged into one value to represent the site. The median diameter and standard deviation for each substrate classification category was used to calculate the mean diameter for the site. Land-use classifications for each transect were counted to determine the most common land use, and were assigned a number based on the potential effect that each land-use classification has on the site. These numbers were averaged for the whole site. The final number may not indicate the presence of a land use, but may represent the overall effect of land use on the site characteristics. The urban land-use classification, as defined by Fitzpatrick and others (1998), was split into two classifications of residential urban, and commercial urban. Habitat features recorded at transects were totaled by site for comparisons.

Hydrologic characteristics include discharge measurements, continuous streamflow data collected at gaging stations, and estimates of bankfull discharge. Of the 46 sites, 24 had USGS gaging stations at or near the site (fig. 6). The U.S. Army Corps of Engineers Hydrologic Engineering Center water-surface profile compu-

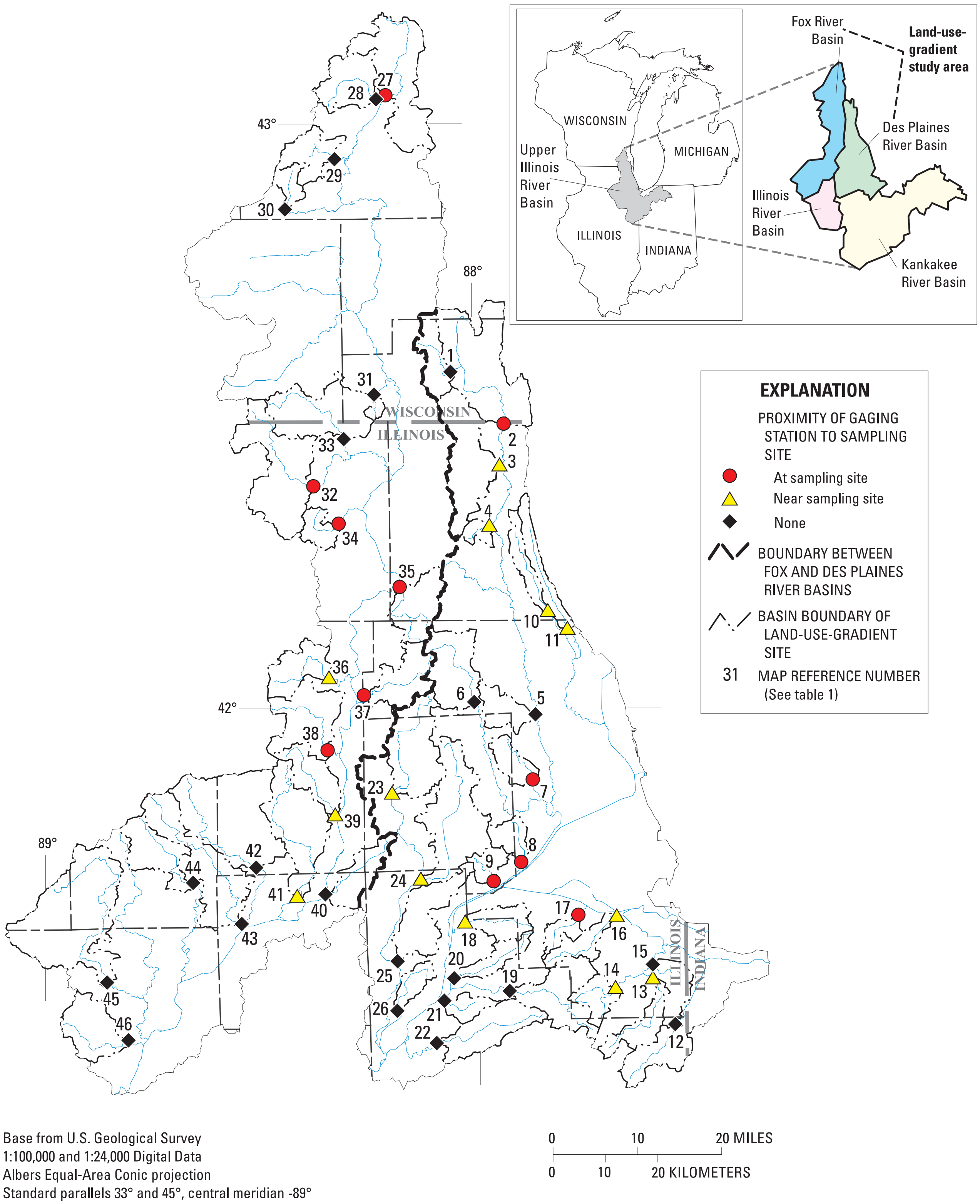

Figure **6.** Sampling sites with the proximity of nearest gaging stations for the land-use-gradient synoptic study in the Fox and Des Plaines River Basins, Illinois.

tation model HEC-RAS (Bonner, 1974) will be used to estimate bankfull streamflow through the reach. The estimated bankfull streamflow will be used in later analysis of this data and then published.

Chemical Characteristics

Water temperature

Continuous recording temperature sensors (HOBO-temp data loggers, ONSET Corporation) were installed at each of the 46 sites in the spring of 2000. Each temperature sensor was enclosed in a waterproof PVC container, submerged, and attached to a fence post. Data were collected at 2.5-hour intervals for approximately one year. Five temperature sensors were repeatedly vandalized and no data are available from those sites. In total, approximately one third of the sensors were vandalized or lost and therefore have a partial data record. A subset of the retrieved temperature sensors was checked by placing the sensors in an ice bath and verifying the temperature measurement against a lab-certified thermometer. Because the data set is incomplete, the temperature data are not included on the CD-ROM.

Water chemistry

Water chemistry samples were taken once at each of the 46 LUG sites in July 2000. All water samples were collected using standard NAWQA protocols (Shelton, 1994). Samples were analyzed for concentrations of nutrients, major ions, and for municipal wastewater-indicator constituents (tables 3 and 4). Water temperature, air temperature, pH, specific conductance, and dissolved oxygen were measured in the field at the time of sampling. Discharge was measured at sites that were not near a gaging station (fig. 7) following the procedures outlined by Rantz and others (1982).

Figure **7.** Measuring stream velocity to determine discharge at Buck Creek near Wedron, Illinois.

Specific stream-sampling equipment depended on stream conditions. At sites that were wadable and had sufficient water depths, samples were collected at equal width increments (Guy and Norman, 1970) using a DH-81. At wadable sites having insufficient water depths, dip samples were collected at the center of flow.

Samples for nutrients and major ions were analyzed at the U.S. Geological Survey's National Water-Quality Laboratory (NWQL) using methods described in Fishman and Friedman (1989) and Fishman (1993). Wastewater-indicator samples were analyzed at the NWQL using a custom method described in Brown and others (1999). Method reporting limits (MRL) for all wastewater-indicator samples are listed in table 4.

Laboratory analysis for wastewater indicators was a custom method used for this study and was not a commonly available NWQL method at the time (2001). Quality-control measures such as surrogate recovery, internal standard performance, analyte performance at concentrations above or below the NWQL calibration range, and method quality assurance/quality control (QA/QC) samples may not meet standard NWQL data quality acceptance criteria for organic analytes of 60 percent recovery with a standard deviation of 15 percent for approved methods. In this report, data for wastewater indicators are limited to detect/non-detect based on the uncertainty of these data.

Table 3. Selected stream-water properties and constituents determined in samples from urban land-use-gradient sites in the Fox and Des Plaines River Basins, Illinois

Constituent	NWQL parameter code	Laboratory method reporting limit (MRL)
Ammonia as N	00608	0.015 mg/L
Ammonia plus organic nitrogen as N	00623	0.2 mg/L
Ammonia plus organic nitrogen as N, total	00625	0.2 mg/L
Nitrite as N	00613	0.01 mg/L
Nitrite plus nitrate as N	00631	0.05 mg/L
Orthophosphate as P	00671	0.01 mg/L
Phosphorus as P, total	00665	0.01 mg/L
Phosphorus as P	00666	0.01 mg/L
Calcium	00915	0.02 mg/L
Chloride	00940	0.1 mg/L
Fluoride	00950	0.1 mg/L
Iron	01046	3.0 µg/L
Magnesium	00925	0.01 mg/L
Manganese	01056	1.0 µg/L
Potassium	00935	0.1 mg/L
Silica	00955	0.01 mg/L
Sodium	00930	0.2 mg/L
Sulfate	00945	0.1 mg/L
Dissolved solids (residue at 180 °C)	70300	1.0 mg/L

Table 4. Constituents analyzed for wastewater indicators in surface water and method reporting limit

[PAH, Polynuclear aromatic hydrocarbon; *, found frequently in lab blanks below method reporting limit]

Constituent name	Laboratory method reporting limit (MRL), in micrograms per liter	Chemical use
1,4-dichlorobenzene	0.03	Fumigant
17-beta-estradiol	0.2	Estrogen metabolite
2,6-di-tert-butylphenol	0.09	Antioxidant
2,6-di-tert-para-benzoquinone	0.07	Antioxidant
3 beta-coprostanol	0.8 *	Carnivore fecal indicator
5-methyl-1H-benzotriazole	0.1	Corrosion inhibitor
acetophenone	0.1 *	Fragrance
anthracene	0.05	PAH
benzo(a)pyrene	0.05	PAH
bis(2-ethylhexyl)-adipate	1.5 *	Plasticizer
bis(2-ethylhexyl)-phthalate	2.0 *	Plasticizer
bisphenol A	0.09	Used to manufacture polymers
Butylated hydroxy anisole (BHA)	0.12	Antioxidant
Butylated hydroxy toluene (BHT)	0.08	Antioxidant
caffeine	0.08	Stimulant
carbaryl	0.06	Pesticide
chlorpyrifos	0.02	Pesticide
cholesterol	1.5 *	Fecal indicator
cis-chlordane	0.04	Pesticide
codeine	0.1	Analgesic
cotinine	0.04	Metabolite of nicotine
diazinon	0.03	Pesticide
dieldrin	0.08	Pesticide
diethylphthalate	0.09	Plasticizer
ethanol(2-butoxy)-phosphate	0.07	Plasticizer
fluoranthene	0.03	PAH
lindane	0.05	Pesticide
methyl-parathion	0.06	Pesticide
N,N-diethyltoluamide	0.04	Insect repellent
naphthalene	0.03	PAH, fumigant
Nonylphenol monoethoxylate (NPEO1) (total)	1	Nonionic detergent metabolite
Nonylphenol diethoxylate (NPEO2) (total)	1.1	Nonionic detergent metabolite
otcylphenol, monoethoxylate (OPEO1)	0.05	Nonionic detergent metabolite
otcylphenol, diethoxylate (OPEO2)	0.1	Nonionic detergent metabolite
para-cresol	0.03	Wood preservative
para-nonylphenol (total)	0.5	Detergent, surfactant
phenanthrene	0.06	PAH
Phenol	0.08 *	General disinfectant
phthalic anhydride	0.1 *	Used to manufacture plastics
pyrene	0.03	PAH
stigmastanol	2	Hormone used to lower cholesterol
Tetrachloroethylene	0.03	Solvent, degreaser

Table 4. Constituents analyzed for wastewater indicators in surface water and method reporting limit (Continued)

[PAH, Polynuclear aromatic hydrocarbon; *, found frequently in lab blanks below method reporting limit]

Constituent name	Laboratory method reporting limit (MRL), in micrograms per liter	Chemical use
tri(2-chloroethyl) phosphate	0.04	Fire retardant
tri(dichloroisopropyl)	0.1	Fire retardant
triclosan	0.08	Disinfectant, Antimicrobial
triphenyl phosphate	0.1	Plasticizer

Sediment chemistry and particle size

Streambed sediment samples were collected for trace-element analyses at the 46 LUG sites in July 2000 using NAWQA protocols (Shelton and Capel, 1994). Five to 10 samples of fine-grained sediment were collected by hand with a Teflon scoop from each of 5 to 10 depositional zones that were submerged during low streamflow. Samples were collected from the upper 2 cm, which is the most recent, oxidized sediment layer. The sample amount that was collected depended on the relative size of the depositional zone. Depositional zones were sought out for sampling; thus, the trace element concentrations represent conditions in depositional areas, not the average concentration for sediment throughout the reach. A portion of the composited sample was homogenized and wet-sieved with native water through a 63 µm-plastic mesh (fig. 8). Trace element samples were analyzed at NWQL in Denver, Colorado (Fishman, 1993). The analyses included total digestions for 46 major and trace elements, including two forms of carbon (inorganic and organic), as well as total carbon. A second portion of the composited sample was sieved through a 2-mm screen and analyzed for particle-size distribution at the USGS Sediment Laboratory in Iowa City, Iowa.

Figure **8.** Sieving bed sediment for metal and particle size determination at Bassett Creek near Twin Lakes, Wisconsin.

Biological Characteristics

Algal pigment and biomass data

In July 2000, all 46 sites were sampled for algal pigment (chlorophyll-*a*, pheophytin-*a*) and ash-free dry-mass (AFDM) analysis to assess algal biomass of seston (phytoplankton) and benthic algae (periphyton). Methods followed established NAWQA protocols (Porter and others, 1993). Phytoplankton samples for pigment and AFDM analysis were split from the water samples that were collected for nutrient analyses. At most sites, periphyton samples were collected from submerged riffle rocks using a modified syringe sampling device (Porter and others, 1993). Each sample from riffle rocks was a composite of five subsamples collected from each of five locations in the stream reach (total sampling area about 75 cm^2). Where riffle rocks were unavailable, woody snags were used for periphyton samples. Ten woody snag sections less than or equal to 3 cm in diameter and 18 cm in length were collected from the stream reach and composited for a sample. Snag sections were scrubbed with a firm toothbrush and native water to remove algae (fig. 9). The surface area of the snag section was determined from its length and diameter.

Figure **9.** Scrubbing the algae from woody snag sections at Fox River at Watertown Road near Waukesha, Wisconsin.

For comparison, riffle rocks and woody snags were concurrently sampled for periphyton at four sites where both substrates were available: Butterfield Cr at Country Club Rd nr Flossmoor, IL; Pewaukee River near Pewaukee, WI; Basset Creek nr Twin Lakes, WI; and Ferson Creek near St. Charles, IL (table 1). Periphyton samples were homogenized; subsample volumes between 5 and 25 ml were removed for determinations of pigment and AFDM analysis, and the remaining sample was used for algal community analysis as described below. Depending on water clarity, phytoplankton subsample volumes for pigment and AFDM ranged from 25 to 100 ml. The phytoplankton and periphyton subsamples for pigment and AFDM were filtered onto 0.7 µm glass-fiber filters (fig. 10), wrapped in foil to prevent exposure to light, and placed in petri dishes on dry ice. The NWQL analyzed for chlorophyll-*a* and pheophytin-*a* fluorometrically (U.S. Environmental Protection Agency, 1992: Arar and Collins, 1997) and analyzed for AFDM gravimetrically (Britton and Greeson, 1987).

Figure **10.** Filter used for periphyton chlorophyll-*a*, pheophytin-*a*, and ash-free dry mass determinations at Bassett Creek near Twin Lakes, Wisconsin.

Algal community data

All 46 sites were sampled in July 2000 to assess the composition and structure of algal periphyton communities. Periphyton sampling methods followed established NAWQA protocols as described in Porter and others (1993) using either riffle rocks, where available, or woody snags. For comparison, as mentioned earlier, riffle rocks and woody snags were concurrently sampled for periphyton at four sites. The sample for community analysis was preserved in buffered 5 percent formalin, stored away from light, and shipped to the Academy of Natural Sciences in Philadelphia for identification and enumeration. Identification of soft algae was according to Dillard (1990, 1991a and b, 1993); Geitler (1930-1932); Komárek and Anagnostidis (1999); Prescott (1962); Tiffany and Britton, (1952), and Smith (1950). Identification of diatoms was according to Camburn and others (1978, 1984-1986); Hohn and Hellerman (1963); Hustedt (1930a and b, 1959, 1961-1966); Kociolek and Kingston (1999); Kociolek and Stoermer (1988, 1990, 1991); Kociolek and others (1995); Krammer and Lange-Bertalot (1986, 1988, 1991a and b); Lange-Bertalot and Moser (1994); Lowe (1972); Lowe and Kociolek (1984); Patrick and Reimer (1966, 1975); Reichardt (1997); and Simonsen (1987). Raw data on algal abundance and biovolume are reported on the CD-ROM.

Invertebrate community data

Benthic macroinvertebrate community collections followed USGS NAWQA methods (Cuffney and others, 1993). In each reach, a benthic macroinvertebrate sample was collected from either cobbles or submerged branches (woody debris). At four sites, two samples were collected, one from cobble and the other from submerged branches. The USGS National Water Quality Laboratory Biology Unit sorted the invertebrate samples using a 500-organism count method and identified the organisms according to the Standard Taxonomic Assessment as provided by Moulton and others (2000). When possible, mollusks, crustaceans, and insects were identified to either genus or species level, and other benthic macroinvertebrate groups were identified to higher taxonomic levels.

When a cobble riffle was present, a Hess sampler was used to collect macroinvertebrates (fig. 11). The Hess sampler allows sampling in depths up to 400 mm and its enclosed area helps assure that organisms in the sampling area are captured in both fast and slow current. The Hess sampler consists of a stainless-steel cylinder with two windows that allow water to flow through the sampler. The upstream window of the sampler was outfitted with a 425 µm mesh net and the downstream window was trailed by a mesh net and capture bucket. The sampler was pushed and rotated into the stream bottom; the bottom opening of the sampler defined an area of 0.086 m^2. Large cobbles were removed from the stream bottom and scrubbed to remove organisms, and the bottom substrate was disturbed to a depth of about 100 mm so the organisms and debris were carried by the current into the capture bucket. Where possible, five or six subsamples were obtained from two riffles and were combined for a single sample; total area sampled ranged from 0.43 to 0.51 m^2.

Figure **11.** Using Hess sampler to collect benthic macroinvertebrates from rock surfaces at Little Rock Creek at Millhurst Road near Plano, Illinois.

One site, Sugar Run at Mills Road at Joliet, IL (table 1), was sampled with a modified kick net because the Hess Sampler did not properly seal with the stream bottom. The kick net was 0.5 m wide. Benthic macroinvertebrates were collected from an area of approximately 0.25 m^2 immediately upstream of the net in a manner similar to the Hess sampler. This sampler is described in Cuffney and others (1993) as a “Slack sampler”. Six slack samples were composited for a 1.5 m^2 total area sampled.

If no cobble riffle was present at a site, macroinvertebrates were collected from submerged branches. About 10 branches were collected from each study reach. A 425 µm net was held downstream of each branch. A 0.3 to 0.5 m long section of the branch then was cut and the dislodged macroinvertebrates were collected with the net. Branches that appeared to have been submerged in flowing water for an extended period of time were chosen for sampling. Organisms and debris were washed in a 425 µm sieve and all branches were handpicked as they dried. The average length and diameter for each branch were used to calculate the total surface area sampled; total area sampled ranged from 0.15 to 0.56 m^2.

Invertebrate data, as returned from the laboratory, are included as raw data on the CD-ROM. In the summary data file, invertebrate sample information is provided along with some common summary statistics. Statistics include richness measures, composition (relative abundance) measures, and functional feeding group composition. Taxa that are not normally considered part of the benthic fauna were excluded from calculations; these taxa included neustonic taxa (the true bug families Gerridae and Veliidae), and terrestrial taxa (adult midges).

Fish community data

Fish-community data were collected (fig. 12) by three different agencies (fig. 13): the USGS (2 sites sampled in 2000 and 22 sites sampled in 2001), the Illinois Department of Natural Resources (IDNR) (17 sites sampled during the period from 1995 to 1999), and the Wisconsin Department of Natural Resources (WDNR) (5 sites sampled in July 1997). The USGS used a barge or backpack electroshocker to sample one pass of the entire stream reach (fig. 12) and then conducted supplementary riffle kicks and seine hauls (Meador and others, 1993). The IDNR collected fish in a single pass using a backpack electroshocker, barge electroshocker, or electric seine (Bertrand and others, 1996). The WDNR used a barge or backpack electroshocker to sample all major habitats in a stream reach. The reach length for WDNR sampling was determined by stream size, which is based on stream width (Lyons, 1992). Fish data for the Addison Creek at Bellwood, IL (table 1) site were collected near but not at the same reach as the other samples.

Figure **12.** A barge-electroshocking unit being used to collect fish-community data.

Ten summary statistics were calculated for each fish sample. These statistics are part of the Illinois Index of Biotic Integrity (Bertrand and others, 1996). Criteria published in Bertrand and others (1996) were used to make the calculations. Five statistics are based on number of species (total, darter, sunfish, sucker, intolerant). Six statistics are based on relative abundance (percents of green sunfish, omnivores, insectivorous cyprinids, piscivores, hybrids, intolerant fish).

Quality Control

Quality-control procedures were conducted during the sampling and analysis of chemical and biological data. Approximately 15 percent of all chemical samples consisted of replicates. Blank samples also accompanied the water-chemistry samples. Concurrent samples of branches and cobbles were collected at four sites for algal and invertebrate samples.

PHYSICAL, CHEMICAL, AND BIOLOGICAL DATA

The physical, chemical, and biological data collected for the LUG study are presented in tab-delimited American Standard Code for Information Interchange (ASCII) text files (on CD-ROM at the back of this report). The ASCII text files of the data can be imported into a spreadsheet or database for data analysis or, for a quick review of the data, the files can be viewed from an Internet browser. However, the files specifically were created to allow import into a spreadsheet or database of the users choice. Because of the tab delimiters in the text files, the data does not appear as neat columns of text in the browser window.

In order to take complete advantage of the hypertext markup language (HTML) and data files on the CD-ROM, the system requirements are an Internet browser and a spreadsheet or database application. However, if these system requirements are not met, the ASCII text files of data on the CD-ROM are usable in any application that can open them, such as a word-processing application. The data files are located in the tables directory of the CD-ROM.

To begin navigating through the CD-ROM using an Internet browser, *open the index.html file first*. The following describes the files contained on the CD-ROM:

README.txt provides an introduction to the contents of the CD-ROM, including files and directories. There is also an HTML version (README.html).

index.html is the introductory (index) page that is viewable in an Internet browser. It describes the information that is contained on the CD-ROM. This file should be the first one opened in an Internet browser because it contains useful links that organize the data such as links to the report text, data, and data documentation.

datalist.html is a file that is viewable from an Internet browser. Index.html links to it. Datalist.html contains links to data file documentation that is viewable with an Internet browser, and tab-delimited ASCII summary and raw data files that can be imported into a spreadsheet application.

uirb.css is the cascading style sheet used to set the colors for the HTML pages contained on this CD-ROM. It is used by the HTML files and Internet browser, and need not be opened by the user.

documentation is a directory containing data-file documentation. The documentation for each data file is available as HTML files that are viewable with an Internet browser and also as ASCII text files. The HTML files are linked from the datalist.html page.

images is a directory containing the images used by the HTML files on this CD-ROM.

tables is a directory containing all the files of raw and summary data collected during the land-use-gradient study. This directory is divided into sub-directories by data type, which loosely corresponds to the datalist.html categories. Data files are named such that they correspond to the type of data collected. The data files are accessible from datalist.html.

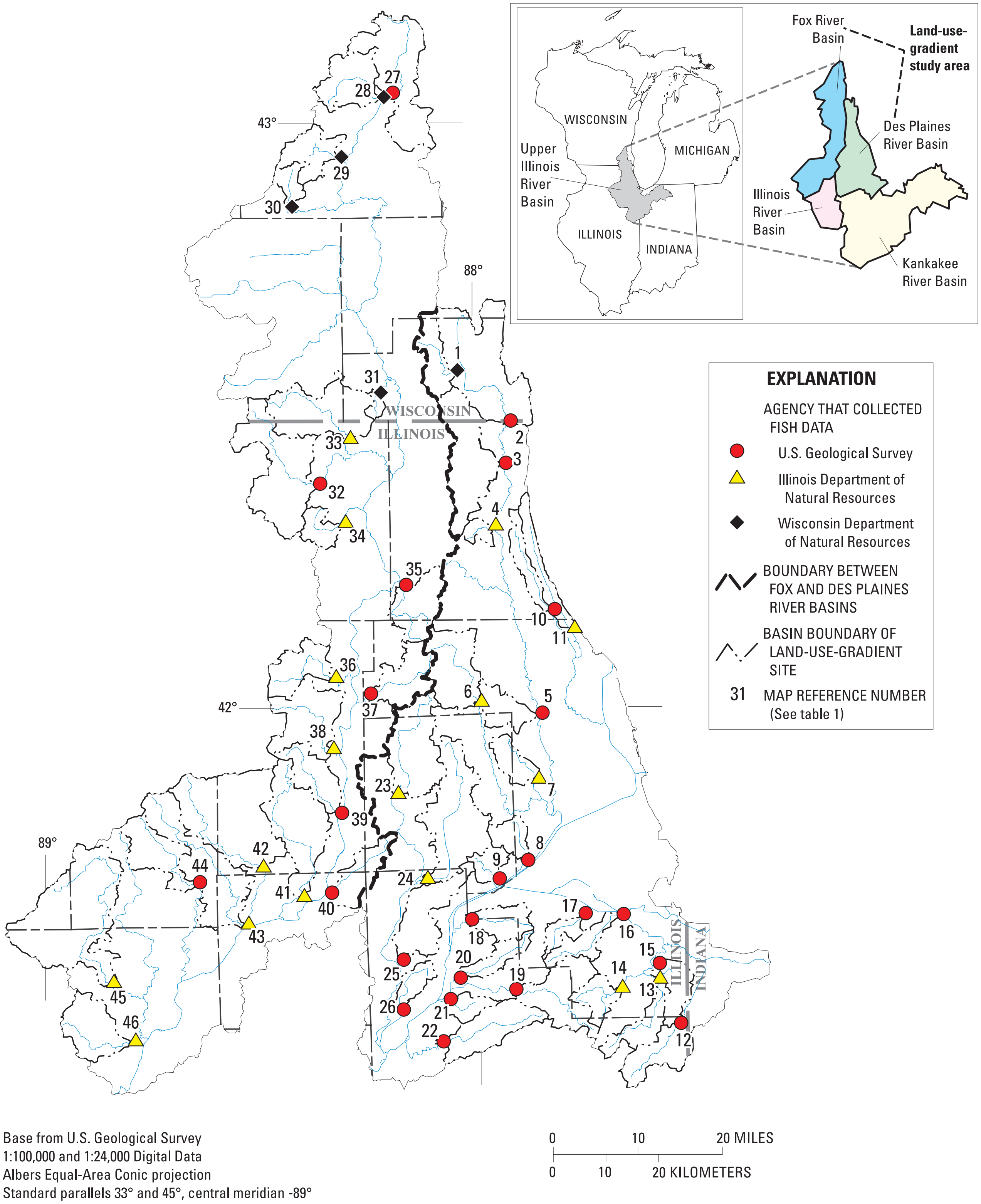

Figure **13.** Site locations and agencies that collected fish data used for the land-use-gradient synoptic study in the Fox and Des Plaines River Basins, Illinois.

SUMMARY

As part of the upper Illinois River Basin National Water-Quality Assessment (NAWQA) Program, a land-use-gradient data-collection synoptic study was conducted to understand how urbanization of the areas surrounding the Chicago metropolitan area affects the physical, chemical, and biological aspects of streams. The methods used and data collected for this study are presented in this report. The land-use-gradient study focused on tributaries to the Des Plaines and Fox Rivers in the Chicago metropolitan area. The 46 LUG sites were sampled once in July 2000 for habitat, geomorphic characteristics, water discharge, water chemistry (nutrients, major ions, wastewater indicators, pH, and specific conductance), and aquatic community characteristics (algae, macroinvertebrates, and fish). The data collected for this study are available on the CD-ROM included with this report.

Basin characteristics that were collected and/or computed include: maximum elevation, relief, azimuth, shape factor, elongation ratio, compactness ratio, main channel length, main channel slope, stream density, and Strahler stream order. Demographics for the individual basins, estimated road density, and percent land use also were calculated for each basin. Segment-scale characteristics that were collected and/or computed include: valley length, curvilinear channel length, upstream and downstream elevations, sinuosity, segment gradient, and upstream and downstream latitudes and longitudes. Reach-scale habitat measures that were collected were grouped into the following categories: channel, substrate, and bank. The actual measurements and computations conducted on each group are too extensive to list individually. In addition to typical NAWQA protocols, the length of bank erosion at the end of each transect and the depth of the silt at each transect point were both measured.

At various sites, water temperatures were collected continuously starting in the spring of 2000, but the data set is incomplete because approximately one-third of the temperature sensors were lost or vandalized. Water samples collected in July 2000 were analyzed for concentrations of nutrients, major ions, and for municipal wastewater-indicator constituents. Water temperature, air temperature, pH, specific conductance, and dissolved oxygen also were measured at the time of sampling. Chlorophyll-*a* from seston in the water sample was collected. Periphyton samples (from rocks or woody debris) were analyzed for chlorophyll-*a*, pheophytin-*a*, and ash-free dry mass. In the sampling reach, streambed sediment samples were collected for trace-element analysis. These samples were collected from the top 2 cm of the sediment depositional zones. Particle size was determined for the sampled materials. Quantitative periphyton (benthic algae) samples were collected in July 2000. Rocks were scraped for algal communities when possible; however, in areas without rock, submerged branches were used for sampling. Benthic macroinvertebrate communities were sampled in July 2000. If riffles were present in the reaches, they were sampled for macroinvertebrates. Submerged branches were sampled where riffles were not present.

Fish-community data were compiled from three sources, the U.S. Geological Survey, the Illinois Department of Natural Resources, and the Wisconsin Department of Natural Resources. For each site, the entire reach was sampled using a variety of electroshocking techniques. Seines were used to supplement the sample. Dates of the fish samples range from 1995 to 2001.

Quality-control procedures were conducted during the sampling on approximately 15 percent of the samples that were collected. Quality-control methods included blank and concurrent samples collected along with the data samples.

The data presented in this report are being analyzed and will be used in the evaluation of water quality in urbanizing areas in the upper Illinois River Basin. The results of these analyses will be presented in future reports. The urban land-use-gradient study in the upper Illinois River Basin is one of several similar studies being conducted by NAWQA study units in the United States.

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