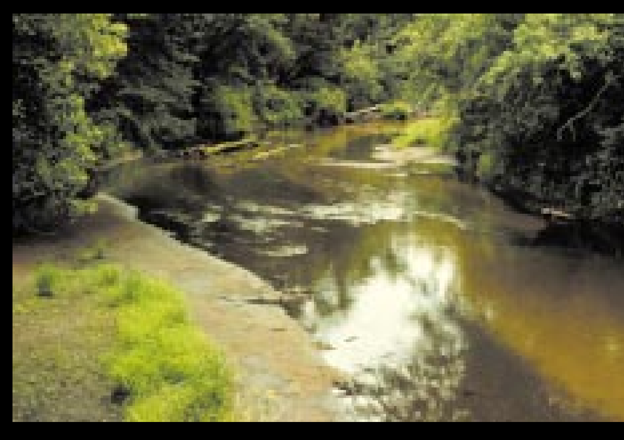
Water Quality and Habitat Conditions in Upper Midwest Streams Relative to Riparian Vegetation and Soil Characteristics, August 1997: Study Design, Methods, and Data



U.S. Geological Survey
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By Stephen K. Sorenson, Stephen D. Porter, Kimberlee K.B. Akers, Mitchell A. Harris, Stephen J. Kalkhoff, Kathy E. Lee, Linda R. Roberts, and Paul J. Terrio

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U.S. GEOLOGICAL SURVEY

Open-File Report 99–202

Denver, Colorado
1999

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, ABBREVIATIONS, AND ACRONYMS

Multiply	By	To obtain
micrometer (µm)	0.00003937	inch
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
square centimeter (cm^2)	0.1550	square inch
square meter (m^2)	10.76	square foot
cubic meter (m^3)	1.308	cubic yards
square kilometer (km^2)	0.3861	square mile
cubic meter per second (m^3/s)	35.31	cubic feet per second
meters per kilometer (m/km)	5.280	feet per mile
centimeters per second (cm/s)	0.3937	inches per second
gram (g)	0.03527	ounce
milligram	0.00003527	ounce
microgram	0.00000003527	ounce
liter (L)	0.2642	gallon
milliliter (mL)	0.0002642	gallon

Temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = 1.8(°C) + 32.$$

Electrical conductivity is measured as specific electrical conductance in units of microsiemens per centimeter (µS/cm) at 25 degrees Celsius.

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Abstract

Water-chemistry, biological, and habitat data were collected from 70 sites on Midwestern streams during August 1997 as part of an integrated, regional water-quality assessment by the U.S. Geological Survey National Water-Quality Assessment (NAWQA) Program. The study area includes the Corn Belt region of southern Minnesota, eastern Iowa, and west-central Illinois, one of the most intensive and productive agricultural regions of the world. The focus of the study was to evaluate the condition of wooded-riparian zones and the influence of basin soil-drainage characteristics on water quality and biological-community responses. This report includes a description of the study design and site-characterization process, sample-collection and processing methods, laboratory methods, quality-assurance procedures, and summaries of data on nutrients, herbicides and metabolites, stream productivity and respiration, biological communities, habitat conditions, and agricultural-chemical and land-use information.

INTRODUCTION

The Midwestern Corn Belt region of the United States is one of the most intensive and productive agricultural regions in the world. Nearly 80 percent of the Nation's corn and soybeans is grown in the region, and more than 6 million metric tons of nitrogen fertilizer and more than 100,000 metric tons of pesticides are applied to cropland in the Midwest annually (Goolsby and others, 1993). Intensive use of agricultural chemicals poses potential problems of nonpoint-source contamination of surface and ground waters throughout the Midwest. Results from studies conducted by the U.S. Geological Survey (USGS) during the past decade indicate that large amounts of nutrients and pesticides are flushed from cropland and transported into tributary streams of major Midwestern rivers during periods of rainfall in late spring and early summer (Goolsby and others, 1991; Thurman and others, 1991, 1992; Coupe and others, 1995; Scribner and others, 1998). Following seasonal flushes of nutrients, sediments, and herbicides, concentrations of contaminants in Midwestern streams and rivers generally decline; however, relatively little is known about the fate of herbicide-degradation products during low-flow conditions. In addition, the overall effects of intense agricultural activity on biological communities and their responses to natural landscape factors, such as differences in surficial geology and soil drainage among watersheds, and the abundance of wooded-riparian vegetation along stream and river corridors are poorly understood.

The USGS National Water-Quality Assessment (NAWQA) Program builds upon the existing base of water-quality studies in the Midwestern Corn Belt region as part of its overall objectives to describe water-quality conditions for a large part of the Nation's streams, rivers, and aquifers; to describe how water quality is changing over time; and to improve understanding of natural and human factors that affect water-quality conditions (Hirsch and others, 1988; Gilliom and others, 1995). Objectives of the NAWQA Program are accomplished through water-quality investigations in 59 large river basins and aquifer systems (study units) throughout the United States, and synthesis of results on a regional or national basis.

As a collaborative effort by the Lower Illinois River Basin (LIRB), Eastern Iowa Basins (EIWA), and Upper Mississippi River Basin (UMIS) NAWQA study units, a regional, low-flow synoptic study was conducted during August 1997. The objectives of the study were to:

1. Characterize chemical, biological, and habitat conditions at 70 sites on Midwestern streams and rivers affected by high agricultural intensity during seasonal low-flow conditions in August 1997.
2. Evaluate water-chemistry conditions and biological responses in relation to surficial geology and characteristics of basin soils, wooded-riparian cover in stream segments, and regional differences in hydrologic conditions.
3. Assess algal-nutrient relations in reference to stream productivity ("eutrophication") and agricultural sources of nutrients and herbicides. Compare and contrast effects of row-crop agriculture with confined livestock practices (for example, high-density hog-feeding operations) on water chemistry and rates of primary productivity. Provide understanding of algal-species and community responses to nutrients, turbidity, herbicides, and metabolites.
4. Describe responses of benthic invertebrate communities to agricultural nonpoint sources. Provide understanding of invertebrate-species responses to stream eutrophication and physical habitat conditions in a region of high agricultural intensity.

Purpose and Scope

This report describes the study design, methods, and quality assurance for a low-flow synoptic water-quality study conducted during August 1997 in streams of the Illinois, Skunk, Cedar, Iowa, Wapsipinicon, and Minnesota River watersheds and summarizes physical, chemical, biological, and habitat data collected during the study (objective 1 listed above). The study area includes parts of west-central Illinois, eastern Iowa, and southern Minnesota, including all or parts of the LIRB, EIWA, and UMIS NAWQA study units.

Effects of Agricultural Intensity on Water Quality and Aquatic Life

The effects of high row-crop intensity in a stream watershed may include accelerated erosional and depositional processes, increased water temperature resulting from the removal of riparian trees that provide canopy shading, reduced dissolved oxygen (DO) associated with nutrient and organic enrichment, and toxicity associated with agricultural pesticides, all of which can reduce or destroy habitat for fish and other aquatic organisms and alter aquatic communities. Confined livestock operations can cause increases in nutrient, carbon, and bacterial contamination, as well as fish kills, in streams if wastes are accidentally discharged or leach into streams through ground-water discharge. However, potential adverse effects from field application of manure slurry on stream quality are poorly understood.

Agricultural contaminants typically enter streams from diffuse (nonpoint) sources, such as runoff from fields during spring and summer precipitation, and from ground-water discharge. Direct (point) discharges from small wastewater-treatment plants or agricultural tile drains in agricultural communities also could contribute to water-quality degradation during low-flow periods (Osborne and Wiley, 1988; Wiley and others, 1990).

Excessive loads of nitrogen and phosphorus in streams and rivers resulting from human activities frequently result in a degraded water-quality condition known as cultural eutrophication that is commonly accompanied by large in-stream growths of algae or other aquatic plants. Dense growths of algae in streams and rivers provide visible evidence that the waters may be polluted, which can reduce the recreational quality of the water resource and impair other beneficial water uses such as domestic water supplies. Natural senescence and decomposition of algae, as well as microbial decomposition of other sources of organic carbon, can result in the depletion of DO to levels that cause fish to die from asphyxia. During active growth, algal processes such as photosynthesis and nutrient uptake can influence water-quality dynamics over relatively short periods of time. For example, diel changes in DO and pH can regulate the partitioning, retention, transport, and bioavailability of contaminants in stream water and bed sediments (Fuller and Davis, 1989). Algal primary productivity also can be viewed as a measure of the ecological health of a stream in relation to the abundance and rate at which food-web resources are being produced for potential consumption by invertebrates and fish.

The effects of cultural eutrophication are best evaluated by integrated evaluation of physical, chemical, and biological conditions and responses. The abundance and productivity of algal communities are positively influenced when nutrient concentrations, light conditions, velocity, and other factors are favorable. These conditions may be negatively affected by some physical factors (hydrologic disturbance, scouring and washout, water turbidity, and canopy shading), chemical factors (contaminant toxicity), and biological factors (grazing consumption by invertebrates and fish, and natural senescence of algal assemblages) (Stevenson and others, 1996). Although previous studies frequently have determined that nutrients are rarely limiting in agricultural streams of the Midwest (Munn and others, 1989; Wiley and others, 1990), the availability of light (mediated by riparian shading and water turbidity) differs among streams and rivers, resulting in high rates of primary productivity where light conditions are favorable.

Soil erosion from agricultural fields to streams could potentially affect algal production negatively by reducing light availability (high suspended-sediment concentrations) or positively by increasing the availability of phosphorus associated with suspended sediments (Stevenson, 1997). However, during stable hydrologic conditions in summer, relatively low dissolved-nutrient concentrations have been measured in Iowa streams and rivers that contained substantial amounts of suspended algae, as indicated by phytoplankton chlorophyll *a* (CHL*a*) concentrations (data on file at U.S. Geological Survey, Iowa City, Iowa). Isenhart and Crumpton (1989) documented significant losses of nitrate in Bear Creek, Iowa, that corresponded with increases in benthic-algal productivity. Thus, the evidence of cultural eutrophication in Midwestern streams and rivers during summer low-flow conditions may be indicated more by algal production than by elevated nutrient concentrations.

Chemical indicators of eutrophication (for example, nutrient concentrations) may be revealed only when in-stream rates of nutrient flux exceed rates of nutrient uptake by algae or other aquatic plants in combination with other biogeochemical processes such as denitrification (Hill, 1983, 1988). Rates of nutrient uptake by algae are expected to correspond closely with rates of primary productivity because nutrient uptake is an active physiological process, requiring energy derived primarily from photosynthesis. During stable low-flow conditions, nutrients are temporarily retained [nutrient cycling or spiraling (Newbold and others, 1982)] in aquatic systems rather than immediately being transported downstream. The retention of nutrients by algae or aquatic plants contributes to the biological health or productivity of streams and rivers. Water turbidity in streams with elevated suspended-sediment loads is likely to limit primary production, adversely affecting the abundance of food resources for higher organisms in those streams and resulting in greater transport of nutrients downstream to larger rivers and, eventually, the Gulf of Mexico.

Differences in soil and riparian-canopy conditions in watersheds of the Midwest are likely to influence eutrophication processes in major tributaries to the Mississippi River, as well as eutrophication and hypoxia issues in the Gulf of Mexico. The Gulf of Mexico hypoxia issues are currently being addressed by the USGS National Stream Quality Accounting Network (NASQAN) and Toxics Hydrology Programs (Battaglin and others, 1997; D.A. Goolsby, U.S. Geological Survey, World Wide Web URL http://wwwrcolka.cr.usgs.gov/midconherb/hypoxia.html), as well as many other investigators (for example, Turner and Rabalais, 1994; Rabalais and others, 1996). The effects of agriculture on stream eutrophication could be moderated by the presence of wooded-riparian areas that serve as buffer strips to control nutrient and sediment inflows and provide shading and habitat for aquatic communities. Soil characteristics of stream basins also may modify the effects of agricultural activities by influencing the timing and processes by which nutrients and sediments enter aquatic systems.

Effects of Wooded-Riparian Areas on Water Quality and Aquatic Life

Wooded-riparian areas provide beneficial effects to water quality and aquatic life. In small to midsize streams, forested riparian zones can moderate water temperature; reduce inputs of nutrients, herbicides, and sediment; provide important sources of particulate organic matter; and stabilize streambanks (Osborne and Kovacic, 1993). Contaminant movement through wooded-riparian areas occurs along stream courses and from land directly adjacent to the stream. Wooded-riparian buffers serve as a depositional area for runoff from the adjacent watershed and as an area of contaminant uptake along streams, rivers, and wetlands (Mitsch and Gosselink, 1993). Many nutrients, sediments, and other contaminants that would otherwise impair aquatic communities are removed by adsorption and aggradation with sediment, microbial processes (for example, denitrification) as contaminants pass through riparian soils, or uptake by terrestrial plants. However, the ultimate fate of nutrients trapped by riparian vegetation is uncertain. Osborne and Kovacic (1993) reported that riparian buffer strips acted as nutrient sinks for much of the growing season but released phosphorus to shallow ground water during the non-growing season. Streams in basins with substantial wooded-riparian areas might be expected to contain higher concentrations of dissolved and suspended organic carbon than streams without riparian zones. Particulate and dissolved forms of organic carbon have been shown to be important sources of energy for benthic invertebrates (Merritt and Cummins, 1984).

Maintenance or enhancement of existing wooded-riparian buffer strips between agricultural fields and streams provides a physical barrier that may improve water quality and aquatic habitat by reducing nutrient and sediment inflows (Lowrance and others, 1984; Osborne and Kovacic, 1989; Puckett and others, 1993). Aquatic biological communities may benefit from wooded-riparian cover because of reduced inputs of sediments and contaminants to streams, increased woody habitat within stream channels, moderation of water-temperature ranges, and a reduction in the diel variability of pH and DO concentrations associated with high rates of primary production. However, rates of herbicide degradation by photolysis and related processes (Larson and others, 1997) and rates of benthic primary production may be lower in densely shaded streams than in streams with sparse riparian vegetation.

The relative influence of riparian buffer zones on water quality at local, stream-segment, and basin scales is known to be variable and is poorly understood. Many studies conducted in small stream watersheds (less than 100 square miles) have concluded that water chemistry and sediment-related habitat variables are related closely to forested and agricultural land cover nearest to the stream (Schlosser and Karr, 1981; Lowrance and others, 1984; Osborne and Wiley, 1988; Richards and others, 1996). Other investigators have suggested that nutrient concentrations, stream habitat, and biological community structure are strongly related to land uses in the basin but not to land cover near stream margins (Omernik and others, 1981; Roth and others, 1996; Richards and others, 1997). The relative importance of local- and basin-scale vegetation factors may vary seasonally (Johnson and others, 1997). Seasonal differences in rainfall, runoff, and metabolic rates of riparian vegetation are likely to influence timing and rates of contaminant delivery to streams and the efficiency with which riparian vegetation serves as a contaminant filter.

In contrast, the effects of wooded-riparian areas on the quality of larger streams and rivers (100- to 1,000-mi^2 drainage basins), as well as the spatial scale of those effects, are relatively unknown. The presence of mature riparian forest and dense tree canopy may exert local (sampling location) control on the distribution and abundance of benthic organisms and aquatic habitats, whereas riparian conditions along some larger stream length (segment to basin scale) are more likely to influence water-quality processes such as nutrient assimilation, herbicide degradation, and primary productivity, particularly during summer low-flow conditions. Longitudinal (upstream to downstream) changes in wooded-riparian conditions in Midwestern prairie river systems differ considerably from those described for other regions of the United States (for example, the River Continuum Concept; Vannote and others, 1980). The upper portions of Midwestern watersheds generally are open and unforested and dominated by cropland. Riparian forests eventually develop along the drainage network but are restricted primarily to the lower half of the basin (Wiley and others, 1990; aerial observations by the authors). Previous studies in the Midwest have demonstrated that small first- to third-order (for instance, Strahler, 1957) streams generally are autotrophic; primary production by algae, rather than inputs of terrestrial leaf detritus, determines energy flow and food-resource relations in the upper portions of stream basins. In general, beneficial effects of wooded-riparian trees, as well as gradients of wooded-riparian density, are more likely to occur in larger fourth- to sixth-order streams and rivers.

Effects of Soil Characteristics on Water Quality and Aquatic Life

Soil permeability influences the delivery of water and contaminants to streams and affects runoff and base-flow conditions. Contaminants in the dissolved phase may reach streams through runoff or through ground-water discharge into the stream, depending on soil texture and slope. Particulate forms of nutrients and contaminants may reach the stream through adsorption to sediment and transport to the stream. Areas with well-drained soils may have a greater potential for inputs of nutrients (Kalkhoff, 1995; Mueller and Helsel, 1996; Jordan and others, 1997) and herbicides (Squillace and others, 1993, 1996; Larson and others, 1997) entering the stream through ground-water discharge. In contrast, areas with poorly drained soils have limited ground-water discharge due to low soil permeability. The poorly drained soils are more easily eroded, however, providing more particulate forms of contaminants and sediments to streams. Agricultural areas with poorly drained soils typically have tile drains to facilitate drainage. Because most of the agriculture in this study area is in areas of moderate to poorly drained soils, tile drains are present throughout the region. Because tile drains facilitate drainage from agricultural fields to the stream, they short-circuit the mitigating effects of subsurface drainage through riparian soils and buffer strips and function as point sources of contaminants.

Differences in soil-drainage characteristics in the upper Mississippi River region are associated with historical patterns of glacial advance and retreat, as well as other natural factors such as regional deposits of loess. For example, soils on the Wisconsin glacial lobe in north-central Iowa and southern Minnesota are characterized by fine-grained materials that are characteristic of prairie-pothole landscapes, whereas soils in eastern Iowa and western Illinois contain relatively larger proportions of sand and coarser grained materials in a more riverine terrain. The proportion of stream water that is derived from ground-water inflow is substantially less in streams on the Wisconsin lobe (Winter and others, 1998, fig. B–2) than in streams located to the southeast of the Wisconsinon glacial advance. This proportion corresponds with differences, or gradients, in soil-drainage properties between hydrologic regions.

The characteristics and composition of flood-plain deposits and bottom materials in Midwestern streams reflect soil-drainage properties and alluvial processes in the drainage basin. Streams draining basins with coarse well-drained soils frequently have a well-developed hyporheic zone, the subsurface zone where stream water flows through short reaches of its adjacent bed and banks (Hynes, 1983; Winter and others, 1998). Because of mixing of ground water with surface water in the hyporheic zone, biogeochemical processes, such as sorption-desorption and oxidation-reduction reactions associated with microbial processing, may have a significant effect on water chemistry and biological communities. The interaction of ground water and surface water in stream basins and segments is influenced by the interchange of local and regional ground-water flow systems. Rates of contaminant transport along ground-water flow paths to streams vary considerably in relation to soil properties, rainfall, and other factors, and range from several months to many years. As a result, the influence of agriculture on ground- and surface-water relations in streams with sandy alluvial aquifers could reflect historical fertilizer and herbicide application practices, in addition to those used during the most recent growing season. The 1997 growing season produced the largest soybean crop and second-largest corn crop on record in the Midwest.

Hypotheses Concerning Relations Between Stream Quality and Selected Factors

The following hypotheses were considered in designing this study:

- Streams in basins with poorly drained soils and significant wooded-riparian cover are expected to contain lower concentrations of suspended sediment, nutrients, and other contaminants than streams with sparse wooded-riparian cover. Algal productivity is expected to be greater in streams with low riparian cover, and dissolved-nutrient concentrations are expected to decrease as stream productivity increases.
- Riparian buffer zones in basins with moderately well-drained soils may be less effective in intercepting and removing nutrients and herbicides washed in from agricultural fields than in basins with poorly drained soils. Riparian vegetation may have little effect in reducing contaminant concentrations discharged from ground-water sources.

- Ratios of herbicide metabolites (degradation products) to parent herbicide concentrations in streams are expected to be greater in watersheds with significant riparian cover and moderately well-drained soils than in basins with little wooded-riparian cover and poorly drained soils.
- Streams in basins with significant wooded-riparian cover are expected to have lower rates of primary production, as indicated by reduced algal biomass, chlorophyll concentrations, and low diel variability in DO and pH. The abundance of benthic algae also is expected to decrease as populations of invertebrate and fish consumers of algae increase.
- Streams in basins with moderately well-drained soils and significant wooded-riparian cover are expected to have more diverse invertebrate communities, with higher numbers of invertebrate taxa and higher EPT (mayflies, caddisflies, and stoneflies) richness than streams in basins with poorly drained soils and little wooded-riparian cover.

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STUDY DESIGN AND METHODS

The study was designed to examine the effects of wooded-riparian cover on water chemistry and biological responses in basins (watersheds) with moderate- and low-permeability soils within a region of high agricultural intensity. Sites were selected in each of three NAWQA study units (LIRB, EIWA, and UMIS) with basin areas in the range of existing NAWQA agricultural-indicator basic fixed sites (BFSs), generally larger than 100 mi^2 and smaller than 1,000 mi^2. Land-use, land-cover, soils, and riparian-tree information were determined using geographic information system (GIS) procedures to be described later in this report. All sites selected represent basins with at least 75 percent of the land area in row-crop production (corn and soybeans); the average area in row-crop production among all basins in the study exceeded 90 percent. All NAWQA agricultural-indicator BFSs in the region were included in the study, and sites with existing streamflow gages and minimal urban influence were selected when possible. Within each study unit, sites were classified into the following groups:

1. *Good Riparian Conditions, Moderately Well-Drained Soils*—Riparian-tree density greater than 35 percent within a 100-m buffer along both banks of the upstream segment, and more than 50 percent of the basin area in Soil Hydrologic Groups A or B (moderately well-drained soils; Soil Conservation Service, 1993).
2. *Poor Riparian Conditions, Moderately Well-Drained Soils*—Riparian-tree density less than 35 percent within a 100-m buffer along both banks of the upstream segment, and more than 50 percent of the basin area in Soil Hydrologic Groups A or B (moderately well-drained soils).
3. *Good Riparian Conditions, Poorly Drained Soils*—Riparian-tree density greater than 35 percent within a 100-m buffer along both banks of the upstream segment, and more than 50 percent of the basin area in Soil Hydrologic Groups C or D (poorly drained soils; Soil Conservation Service, 1993).

4. *Poor Riparian Conditions, Poorly Drained Soils*—Riparian-tree density less than 35 percent within a 100-m buffer along both banks of the upstream segment, and more than 50 percent of the basin area in Soil Hydrologic Groups C or D (poorly drained soils).

Sites were selected in accordance with a nested (study units within region) two-factor analysis of variance design to test whether constituent concentrations or biological conditions differed significantly between factors or their interactions. Review of confined animal feeding operation (CAFO) locations based on State permits revealed that most CAFO facilities were located in stream basins with poorly drained soils (Groups 3 and 4). Therefore, the study design for the effects of confined hog and cattle operations on the quality of Midwestern streams is limited to the effects of riparian conditions and water quality and biological responses to a gradient of livestock populations resident in different stream basins. Locations and descriptions of sites are shown in figure 1 and listed in table 1. Site-classification variables and study-design groups are listed in table 1.

Site Characterization

Site characterization was primarily done using various GIS coverages as outlined in this and following sections. Stream sites and associated basin boundaries were located and marked on 7.5-minute USGS topographic maps. The exact latitude and longitude of the sampling location were obtained by using the three-point orient function on a digitizing table. Point coverages, representing discrete sampling locations, were created using values determined for latitude and longitude. Polygon coverages were created to represent watershed boundaries by digitizing lines marked on the topographic maps. The drainage-basin area for each site was calculated from the watershed boundary polygon coverages. Polygon coverages also were created to quantify agricultural land uses or natural landscape features, such as crop acreage or soil conditions, and were defined by a series of arcs or lines that form many-sided, closed figures. A label point inside each polygon was used to assign attributes to the polygon. Attributes can contain any information that pertains to the area represented by the polygon. For example, each basin polygon was identified by an eight-digit USGS station identification code (table 1).

Characterization of Wooded-Riparian Zones in Stream Segments

Digital Raster Graphics (DRG) images (1:24,000 scale) were used to estimate the percentage of wooded-riparian vegetation within a buffered area of a stream segment. DRG images are raster images of scanned USGS topographic maps and are useful sources or background layers for GIS procedures. Using the 7.5-minute USGS topographic maps discussed previously, a segment of stream with adjacent flood-plain areas was digitized for each site. The length of a “stream segment,” as defined operationally in this study, ranges from 2 to 3 mi upstream from the sampling location, corresponding with drainage-basin areas that range from 100 mi^2 to about 1,000 mi^2 (table 1). Automated GIS procedures were developed for processing the sampling location (point) coverage and the stream-segment (arc) coverage into a polygon coverage that represents the stream segment with length equal to the base-10 logarithm of the basin area, and riparian buffers of 100 m on both sides of the stream. The area of the buffered stream segment was then clipped from the DRG coverage, and the newly created stream-segment coverage was “cleaned” of any roads, contour lines, or text that overlaid the forested area, using an automated GIS procedure. The percentage of trees (riparian-tree density; table 1) in each stream segment was calculated as follows:

$$D_{RT} = \frac{P_f}{P_T - P_W} * 100$$

where

D_{RT} = riparian tree density (percent),
P_f = number of forest pixels in stream-segment area,
P_T = number of total pixels in stream-segment area, and
P_W = number of water pixels in stream-segment area.

GIS procedures generally were coded in Arc-Info AML (Environmental Systems Research Institute, 1992) (procedures on file at U.S. Geological Survey, Iowa City, Iowa). Subsequent aerial verification and photodocumentation of the stream segments (September 1997) indicated that, with several exceptions, wooded-riparian conditions had not changed substantially during the 10 to 20 years that had elapsed since the preparation of the USGS topographic maps and DRG images.

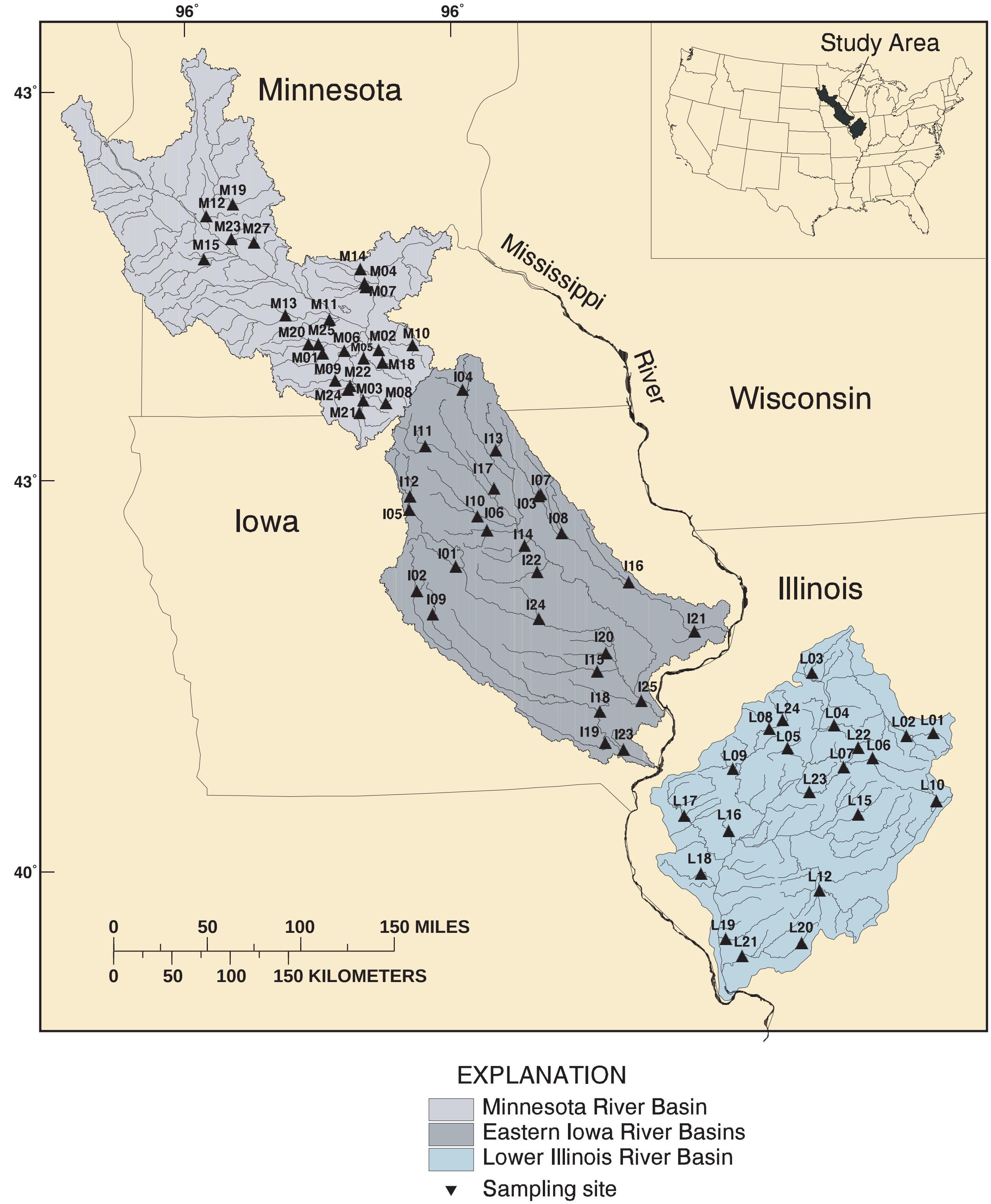

Figure 1. Locations of 70 sites on Midwestern streams where water quality and habitat conditions were characterized in August 1997.

Table 1. Locations and basin characteristics of 70 sites on Midwestern streams and rivers where water quality and habitat conditions were evaluated in August 1997

[°, degrees; ', minutes; ", seconds; STATSGO, Soil Conservation Service Soil Hydrologic Group]

Site number	U.S. Geological Survey station identification	Site name	Latitude	Longitude	Basin area (mi²)	STATSGO score[1]	Riparian[2] tree density (percent)	Study design group[3]
L01	05554000	North Fork Vermilion River near Charlotte, Illinois	40°50'08"	88°17'58"	186	3.20	3.4	4
L02	05554490	Vermilion River at McDowell, Illinois	40°49'50"	88°34'29"	551	3.20	41.7	3
L03	05556500	Big Bureau Creek at Princeton, Illinois	41°21'55"	89°29'55"	196	2.40	24.2	1
L04	05559500	Crow Creek near Washburn, Illinois	40°57'15"	89°18'30"	115	2.80	35.0	4
L05	05563000	Kickapoo Creek near Kickapoo, Illinois	40°48'00"	89°48'00"	119	2.60	23.6	1
L06	05564300	Mackinaw River near Kappa, Illinois	40°40'46"	88°56'26"	309	2.70	55.2	1
L07	05567500	Mackinaw River near Congerville, Illinois	40°37'25"	89°14'30"	767	2.70	45.9	3
L08	05568830	Spoon River at Elmore, Illinois	40°57'25"	89°58'34"	432	2.60	49.4	3
L09	05569875	Cedar Creek near Avon, Illinois	40°41'25"	90°25'15"	271	2.50	38.0	1
L10	05570910	Sangamon River at Fisher, Illinois	40°18'40"	88°19'20"	240	2.90	41.3	3
L12	05575850	Horse Creek at Springfield, Illinois	39°41'46"	89°34'21"	129	2.80	55.0	3
L15	05580000	Kickapoo Creek at Waynesville, Illinois	40°15'20"	89°07'40"	227	2.60	28.3	4
L16	05583900	Sugar Creek near Ray, Illinois	40°11'45"	90°27'16"	118	2.60	61.0	1
L17	05584500	La Moine River at Colmar, Illinois	40°19'45"	90°53'55"	655	2.60	51.6	1
L18	05585800	McKee Creek near Versailles, Illinois	39°52'47"	90°45'32"	306	2.60	43.5	1
L19	05586598	Apple Creek at Highway 900E near Haypress, Illinois	39°22'11"	90°32'46"	385	2.50	22.1	1
L20	05586645	Macoupin Creek near Carlinville, Illinois	39°18'16"	89°47'15"	132	2.90	43.4	3
L21	05587000	Macoupin Creek near Kane, Illinois	39°14'03"	90°23'40"	868	2.70	29.1	1
L22	05567000	Panther Creek near El Paso, Illinois	40°46'05"	89°04'30"	93.9	2.90	35.7	3
L23	05568000	Mackinaw River near Green Valley, Illinois	40°27'15"	89°36'22"	1,070	2.60	65.4	3
L24	05568800	Indian Creek near Wyoming, Illinois	41°01'06"	89°50'07"	62.7	2.60	25.2	2
I01	05451210	South Fork Iowa River near New Providence, Iowa	42°18'54"	93°04'22"	224	2.97	43.0	3
I02	05469980	South Skunk River near Story City, Iowa	42°08'14"	93°34'02"	214	2.83	49.0	3
I03	05420680	Wapsipinicon River near Tripoli, Iowa	42°50'10"	92°15'26"	346	2.51	63.0	3
I04	05456510	Turtle Creek at Austin, Minnesota	43°40'25"	93°01'11"	153	2.93	11.0	4
I05	05449500	Iowa River near Rowan, Iowa	42°45'36"	93°37'23"	418	2.98	26.0	4

Table 1. Locations and basin characteristics of 70 sites on Midwestern streams and rivers where water quality and habitat conditions were evaluated in August 1997—Continued

[°, degrees; ', minutes; ", seconds; STATSGO, Soil Conservation Service Soil Hydrologic Group]

Site number	U.S. Geological Survey station identification	Site name	Latitude	Longitude	Basin area (mi^2)	STATSGO score[1]	Riparian[2] tree density (percent)	Study design group[3]
I06	05462770	Beaver Creek near Parkersburg, Iowa	42°35'15"	92°48'37"	145	2.52	15.0	4
I07	05420720	East Fork Wapsipinicon River near Tripoli, Iowa	42°50'51"	92°13'48"	144	2.63	66.0	3
I08	05420900	Little Wapsipinicon River at Littleton, Iowa	42°32'27"	92°01'30"	210	2.52	62.0	3
I09	05471120	East Branch Indian Creek near Iowa Center, Iowa	41°57'08"	93°24'21"	128	2.84	33.0	4
I10	05458870	Maynes Creek near Kesley, Iowa	42°41'46"	92°54'28"	136	2.71	27.0	4
I11	05459300	Winnebago River near Fertile, Iowa	43°14'49"	93°26'16"	294	2.80	19.0	4
I12	05449200	East Branch Iowa River at Belmond, Iowa	42°51'48"	93°36'47"	195	2.96	13.0	4
I13	05457950	Little Cedar River near Floyd, Iowa	43°11'55"	92°41'14"	250	2.61	57.0	1
I14	05463510	Black Hawk Creek at Waterloo, Iowa	42°27'24"	92°25'21"	327	2.37	50.0	1
I15	05455500	English River near Kalona, Iowa	41°28'11"	91°42'52"	574	2.41	45.0	1
I16	05421700	Buffalo Creek near Stone City, Iowa	42°08'32"	91°20'44"	233	2.45	32.0	2
I17	05461390	Flood Creek near Powersville, Iowa	42°54'26"	92°43'14"	150	2.49	4.0	2
I18	05473060	Crooked Creek at Coppock, Iowa	41°09'31"	91°42'30"	284	2.48	26.0	2
I19	05473400	Cedar Creek near Oakland Mills, Iowa	40°55'20"	91°40'10"	533	2.81	25.0	2
I20	05455100	Old Mans Creek near Iowa City, Iowa	41°36'23"	91°36'56"	201	2.36	46.0	1
I21	05421870	Mud Creek near Donahue, Iowa	41°44'17"	90°41'26"	119	2.31	54.0	1
I22	05464220	Wolf Creek near Dysart, Iowa	42°15'06"	92°17'55"	327	2.30	34.0	2
I23	05473550	Big Creek near Lowell, Iowa	40°51'38"	91°28'49"	167	2.72	16.0	2
I24	05452020	Salt Creek at Belle Plaine, Iowa	41°53'31"	92°17'60"	200	2.28	10.0	2
I25	05465310	Long Creek near Columbus Junction, Iowa	41°13'36"	91°16'32"	154	2.49	26.0	2
M01	05319050	South Fork Watonwan near St. James, Minnesota	43°58'45"	94°30'49"	192	3.07	28.0	4
M02	05320270	Little Cobb River near Beauford, Minnesota	43°59'48"	93°54'30"	130	3.38	31.0	4
M03	05317828	Coon Creek at Highway 169 near Blue Earth, Minnesota	43°36'38"	94°05'14"	99	3.19	44.0	3
M04	05326150	Middle Branch Rush River near New Rome, Minnesota	44°30'54"	94°02'59"	190	3.10	59.0	3
M05	05320450	Maple River near Sterling Center, Minnesota	43°56'06"	94°04'15"	317	3.42	35.0	3
M06	05319360	Perch Creek below Vernon Center, Minnesota	43°59'46"	94°16'38"	133	3.07	40.0	3

Table 1. Locations and basin characteristics of 70 sites on Midwestern streams and rivers where water quality and habitat conditions were evaluated in August 1997—Continued

[°, degrees; ', minutes; ", seconds; STATSGO, Soil Conservation Service Soil Hydrologic Group]

Site number	U.S. Geological Survey station identification	Site name	Latitude	Longitude	Basin area (mi^2)	STATSGO score[1]	Riparian[2] tree density (percent)	Study design group[3]
M07	05326250	South Branch Rush River near Rush River, Minnesota	44°29'08"	94°02'10"	180	2.99	54.0	1
M08	05318050	East Branch Blue Earth River below Bricelyn, Minnesota	43°35'09"	93°50'52"	186	2.87	31.0	2
M09	05318240	Elm Creek near Northrap, Minnesota	43°46'01"	94°22'57"	232	2.88	37.0	1
M10	05320080	Le Sueur River near Wilton, Minnesota	44°01'38"	93°32'47"	173	2.86	40.0	1
M11	05317170	Little Cottonwood River near Searles, Minnesota	44°14'19"	94°26'05"	162	2.88	50.0	1
M12	05304795	Dry Weather Creek near Watson, Minnesota	45°02'33"	95°45'33"	105	2.88	30.0	2
M13	05316985	Sleepy Eye Creek near Springfield, Minnesota	44°16'33"	94°54'22"	250	3.20	0.0	4
M14	05326700	High Island Creek near Arlington, Minnesota	44°37'22"	94°05'29"	163	3.11	2.0	4
M15	05312000	Spring Creek near Spring Creek, Minnesota	44°42'38"	95°47'16"	112	3.20	9.0	4
M18	05320230	Cobb River near Mapleton, Minnesota	43°53'56"	93°52'14"	111	3.30	27.0	4
M19	05303900	Shakopee Creek near Louriston, Minnesota	45°08'16"	95°28'12"	149	2.84	9.0	2
M20	05318630	Wantonwan River near St. James, Minnesota	44°03'03"	94°39'56"	100	3.05	10.0	2
M21	05317800	West Branch Blue Earth River above Elmore, Minnesota	43°30'56"	94°07'41"	150	2.96	6.0	2
M22	05318178	Center Creek at Huntley, Minnesota	43°43'28"	94°13'20"	111	2.80	0.0	2
M23	05314500	Hawk Creek near Maynard, Minnesota	44°52'11"	95°28'59"	315	2.99	3.0	2
M24	05318138	South Creek near Huntley, Minnesota	43°41'39"	94°14'52"	104	2.84	3.0	2
M25	05318800	St. James Creek near LaSalle, Minnesota	44°03'03"	94°33'25"	60	2.95	0.0	2
M27	05314510	Chetomba Creek near Renville, Minnesota	44°50'24"	95°14'20"	120	3.22	0.0	4

[1]STATSGO scores were calculated by weighted averaging of the spatial distribution of Soil Hydrologic Groups in each stream basin, as explained in "Characterization of Soil Drainage in Stream Basins" subsection.

[2]The percentage of trees in a 100-meter buffer zone on both streambanks was calculated for stream segments using digital raster graphic images from 7.5-minute U.S. Geological Survey topographic maps. The length of a stream segment in miles was defined as the base-10 logarithm of the basin area.

[3]Study design groups: 1, good riparian conditions, moderately well-drained soils; 2, poor riparian conditions, moderately well-drained soils; 3, good riparian conditions, poorly drained soils; 4, poor riparian conditions, poorly drained soils.

Characterization of Soil Drainage in Stream Basins

Soil-drainage conditions were classified for each basin using U.S. Department of Agriculture STATSGO Soil Hydrologic Groups, based primarily on drainage characteristics, but including and integrating several other factors including runoff potential, permeability, depth to water table, depth to impervious layer, water capacity, and shrink-swell potential (Soil Conservation Service, 1993). Soil Hydrologic Groups define groups of soils with the same runoff potential under similar storm and vegetative-cover conditions, varying from Group A (well-drained soils through which water moves rapidly) to Group D (very poorly drained soils through which water moves slowly). Streams that drain basins with well-drained soils would be expected to receive greater contributions from ground-water discharge during seasonal low-flow periods than streams that drain basins with poorly drained soils. Tile drains or ditches are used more commonly in poorly drained agricultural fields than in well-drained fields, to remove excess water from the soil.

Basin-boundary GIS polygon coverages were used to clip information from STATSGO coverages developed within the NAWQA Program (data on file at U.S. Geological Survey, Lakewood, Colorado). For the purpose of site classification, moderately well-drained basins were defined as those where the percentage of Soil Hydrologic Groups A or B exceeded 50 percent; poorly drained basins were defined as those where the percentage of Soil Hydrologic Groups C or D exceeded 50 percent. For subsequent analyses, a STATSGO score was calculated for each site by weighted averaging of Soil Hydrologic Groups found in each basin. To process STATSGO data into a continuous theme of hydrologic groups (HYDGRPs) for use in statistical water-quality models, a simple numeric scheme was developed to simplify the generalization (weighted-average transfer) of soil component HYDGRP data to average HYDGRP values for associations. Assignment of values for mixed-group soil classes (for example, A/D and B/D) was based on discussions with soil experts and review of literature. Possible scores range from near 1 (basin dominated by Group A soils) to 4 (basin dominated by Group D soils). STATSGO scores in this study ranged from 2.28 (moderately well drained) in eastern Iowa to 3.42 (poorly drained) in southern Minnesota (table 1).

Livestock Data

The county boundary polygon coverage was used as the base coverage for estimating the numbers of livestock in each stream basin (table 2). Numbers of livestock present in 1995 or 1996 are given because the 1997 data were not available in time for inclusion in this report. For Illinois and Minnesota, livestock numbers for 1996 were obtained from U.S. Department of Agriculture data at URL http://jan.mannlib.cornell.edu/data-sets/livestock/93105/. For Iowa, the Iowa Poultry Association provided estimated numbers of cattle, sheep, and poultry by county for 1995. This was the most recent data available. The number of hogs and pigs estimated for each county, for 1996, was obtained from URL http://www.econ.iastate.edu/faculty/lawrence/COUNTY.htm (John Lawrence, livestock economist, Iowa State University).

The nitrogen and phosphorus content of manure was calculated from the number of cattle, sheep, hogs, and poultry estimated in each stream basin. Computations were based on formulas provided in an AML (R. Alexander, U.S. Geological Survey, written commun., 1992). The computations are based on estimates of the nutrient content of wastes produced per 1,000 pounds of animal weight per day (table 3). The estimates were obtained from the Soil Conservation Service Agricultural Waste Management Field Handbook (Soil Conservation Service, 1992). In some cases, estimates of nitrogen and phosphorus content represent an average of the reported range of values, or are assumed values.

Population Data

Human-population density per square mile in each basin was estimated using GIS polygon coverages of census-block groups processed from the U.S. Department of Commerce, Bureau of Census 1990 TIGER/Line files (Hitt, 1994) (table 2). The census-block group coverage was intersected with the basin coverages, and the percentage of area of each census-block group that was located within each basin was multiplied by the total number of people in that block group. The total population in all census-block groups within each basin was summed, and population density was estimated by dividing the total population by the basin area.

Table 2. Livestock, nitrogen and phosphorus content of manure, human-population density, and precedent rainfall conditions

Site number	U.S. Geological Survey station identification	Hogs and pigs, estimated number in basin[1]	Cattle, estimated number in basin[1]	Sheep, estimated number in basin[1]	Nitrogen content of manure (metric tons)	Phosphorus content of manure (metric tons)	Human-population density per square mile, 1990	Rainfall in basin, May 1997 (centimeters)	Rainfall in basin, June 1997 (centimeters)	Rainfall in basin, July 1997 (centimeters)
L01	05554000	14,100	3,120	0	294	131	18.6	7.6	9.8	9.2
L02	05554490	50,700	8,230	22	931	429	18.6	6.8	8.6	7.4
L03	05556500	16,600	5,960	14	441	186	39.9	8.9	4.8	5.0
L04	05559500	9,800	3,950	0	278	116	39.9	6.0	4.2	8.8
L05	05563000	4,880	4,010	0	224	86	54.2	8.4	9.4	7.4
L06	05564300	17,400	5,770	455	448	189	19.2	7.8	7.2	6.3
L07	05567500	77,600	17,400	683	1,640	726	19.2	7.1	5.8	6.1
L08	05568830	48,900	12,200	168	1,080	473	14.7	8.0	9.0	7.0
L09	05569875	30,373	16,500	1,230	1,060	421	14.7	11	9.2	6.4
L10	05570910	11,200	3,330	119	270	116	41	14	10	8.7
L12	05575850	13,700	3,720	27	314	137	37.7	6.1	3.8	3.2
L15	05580000	10,200	4,060	265	291	120	34.2	11	9.9	6.4
L16	05583900	5,060	6,010	0	309	115	54.2	8.9	5.4	3.5
L17	05584500	48,100	37,400	118	2,120	819	13.8	13	12	4.3
L18	05585800	30,400	18,200	0	1,110	442	13	8.4	2.9	4.9
L19	05586598	43,200	20,800	97	1,370	558	13	7.8	5.9	1.4
L20	05586645	18,000	5,490	191	441	189	13.1	7.1	4.0	2.6
L21	05587000	11,000	40,700	1,430	2,990	1,250	13.1	7.3	4.2	1.0
L22	05567000	14,100	2,480	14	267	122	19.2	6.2	4.2	5.3
L23	05568000	122,000	24,600	751	2,450	1,100	19.2	6.9	5.6	5.5
L24	05568800	12,400	2,560	102	252	113	14.7	8.1	8.7	5.4
I01	05451210	170,000	5,560	904	2,380	1,200	9.56	10	16	6.7
I02	05469980	96,800	2,730	619	1,540	748	28.2	9.6	16	7.7
I03	05420680	89,600	12,900	2,190	1,940	798	13.3	12	15	15
I04	05456510	33,300	4,960	502	662	286	17.8	10	6.6	17
I05	05449500	138,000	6,900	1,350	2,120	1,030	9.56	11	13	8.4

Table 2. Livestock, nitrogen and phosphorus content of manure, human-population density, and precedent rainfall conditions—Continued

Site number	U.S. Geological Survey station identification	Hogs and pigs, estimated number in basin[1]	Cattle, estimated number in basin[1]	Sheep, estimated number in basin[1]	Nitrogen content of manure (metric tons)	Phosphorus content of manure (metric tons)	Human-population density per square mile, 1990	Rainfall in basin, May 1997 (centimeters)	Rainfall in basin, June 1997 (centimeters)	Rainfall in basin, July 1997 (centimeters)
I06	05462770	34,700	3,360	933	605	276	41.3	8.3	16	5.6
I07	05420720	35,800	5,500	1,280	818	327	13.3	12	18	12
I08	05420900	39,600	5,040	968	912	355	13.3	11	15	8.7
I09	05471120	31,500	2,560	763	503	237	28.2	10	15	8.8
I10	05458870	25,400	2,710	776	457	207	8.4	9.0	17	7.7
I11	05459300	52,300	4,480	1,030	877	402	29.4	10	9.6	12
I12	05449200	49,100	3,390	644	784	376	9.56	10	13	9.2
I13	05457950	87,900	9,440	719	1,610	720	17.8	12	11	17
I14	05463510	65,700	12,500	3,070	1,460	627	41.3	9.7	13	4.7
I15	05455500	132,000	29,900	4,740	3,000	1,290	27.9	14	12	5.5
I16	05421700	72,000	9,500	883	1,530	624	13.3	11	14	5.2
I17	05461390	23,900	3,010	438	427	195	15.7	12	10	17
I18	05473060	119,000	9,340	2,710	2,050	961	12.5	15	8.4	8.2
I19	05473400	86,300	22,100	6,100	2,130	891	12.5	12	12	6.0
I20	05455100	36,700	10,700	1,630	958	393	27.9	15	9.7	4.3
I21	05421870	27,800	3,860	510	534	234	13.5	16	9.4	3.0
I22	05464220	44,100	11,600	3,180	1,100	457	41.3	13	14	4.2
I23	05473550	31,700	4,290	884	707	312	12.5	8.4	8.4	4.2
I24	05452020	28,200	9,610	2,170	794	319	17.5	15	13	4.5
I25	05465310	68,300	5,650	1,200	1,140	537	27.9	15	7.2	7.9
M01	05319050	546	3,720	0	121	118	8.64	10	17	12
M02	05320270	8	96	0	3	3	10.3	11	8.0	17
M03	05317828	1,210	6,570	0	216	210	9.92	11	7.6	13
M04	05326150	10,900	10,800	222	536	335	89.3	6.1	14	18
M05	05320450	4,560	20,400	0	681	657	10.3	12	9.2	14
M06	05319360	488	3,480	0	113	110	8.64	12	14	11
M07	05326250	11,000	11,300	95	519	382	89.3	6.1	13	16

Table 2. Livestock, nitrogen and phosphorus content of manure, human-population density, and precedent rainfall conditions—Continued

Site number	U.S. Geological Survey station identification	Hogs and pigs, estimated number in basin[1]	Cattle, estimated number in basin[1]	Sheep, estimated number in basin[1]	Nitrogen content of manure (metric tons)	Phosphorus content of manure (metric tons)	Human-population density per square mile, 1990	Rainfall in basin, May 1997 (centimeters)	Rainfall in basin, June 1997 (centimeters)	Rainfall in basin, July 1997 (centimeters)
M08	05318050	2,920	15,800	0	521	506	9.92	11	6.9	16
M09	05318240	582	5,710	0	183	180	9.92	11	15	9.9
M10	05320080	362	5,050	0	160	158	10.3	11	6.5	18
M11	05317170	15,000	8,270	397	479	305	27.7	6.9	14	13
M12	05304795	30,500	11,300	494	772	472	12.8	3.1	6.8	15
M13	05316985	10,400	33,600	846	1,550	913	7.82	3.9	9.4	12
M14	05326700	7,930	13,800	203	654	394	89.3	5.0	13	18
M15	05312000	2,520	2,990	76	144	91	10.5	2.9	2.8	13
M18	05320230	755	6,200	0	200	196	10.3	11	6.6	18
M19	05303900	21,600	9,150	320	619	365	12.8	5.3	15	17
M20	05318630	82	510	0	17	16	8.64	8.3	18	13
M21	05317800	88	1,640	0	51	51	9.92	9.7	8.8	13
M22	05318178	469	3,760	0	121	119	9.92	12	12	9.8
M23	05314500	56,800	27,600	1,040	1,730	1,050	10.5	3.4	14	15
M24	05318138	479	5,040	0	161	158	9.92	11	10	11
M25	05318800	287	1,780	0	58	57	8.64	10	16	12
M27	05314510	9,350	10,700	219	563	328	12.8	2.9	13	14

[1]Illinois and Minnesota data (sites L01–L24 and M01–M27) are for 1996; Iowa data (sites I01–I25) are for 1995.

Table 3. Nitrogen and phosphorus content of manure

Animal	Average weight of animal (pounds)	Nitrogen content in pounds per day per 1,000 pounds of animal	Phosphorus content in pounds per day per 1,000 pounds of animal
Beef cows	800	0.315	0.105
Milk cows	1,200	0.400	0.060
Steers-calves	800	0.315	0.105
Hogs-pigs	250	0.280	0.150
Sheep	175	0.450	0.070
Pullets	2	0.620	0.240
Broilers	3	1.100	0.340
Turkeys	3	0.740	0.280

Rainfall Data

The locations (latitude and longitude) of precipitation stations in and near the regional study area were obtained from climatological data reports for Minnesota, Iowa, and Illinois published monthly by the National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center (NCDC) (NOAA-NCDC, 1997a–i). A GIS point coverage representing the location of NOAA-NCDC precipitation stations was created. Rainfall amounts for the months of May, June, and July 1997 (table 2) were obtained from NOAA-NCDC (1997a–i). Precipitation values were attributed to the point coverage. A master grid was created by generating a precipitation value for each cell based on the location of points in the point coverage. Maximum and minimum precipitation values were determined for all cells, and mean values for the basin were determined by a kriging process after the basin was clipped from the master grid coverage.

Agricultural-Chemical Use and Crop Data

A polygon coverage representing county boundaries in the States of Illinois, Iowa, and Minnesota was used as the base coverage for determining agricultural-chemical usage and crop acreage for each stream basin. The county coverages were obtained from the U.S. Bureau of Census TIGER/line files using an AML program (D. Nebert and M. Negri, U.S. Geological Survey, written commun., 1997). These coverages were retrieved from URL http://water.usgs.gov/lookup/getspatial?county100. The scale of the county coverages is 1:100,000. Each county polygon is identified by a five-digit Federal Information Processing Standard (FIPS) code. Basin boundaries were attributed to county coverages using an ARC/INFO command that computes the geometric intersection of two polygon coverages.

County-level crop data for Illinois, Iowa, and Minnesota were obtained from the U.S. Department of Agriculture, National Agricultural Statistical Service (USDA-NASS), from URL http://jan.mannlib.cornell.edu/data-sets/crops/9X100/. The number of acres in corn, soybean, and sugar beet production was determined by calculating the percentage of all counties present in each stream watershed, then multiplying each county percentage by the total acreage of crops grown in that county, and summing results for all counties in the watershed (table 4). Computations for agricultural-chemical use in each basin (table 4) were based on estimates of fertilizer and herbicide use for each crop reported in the 1997 Agricultural Chemical Use Estimates for Field Crops (USDA-NASS, 1999). Specific rates of application on individual crops are reviewed within and among States to promote regional consistency in reporting; however, recommended application rates differ for Illinois, Iowa, and Minnesota.

Characterization of Water Quality

Water-Sample Collection

Samples for chemical analyses were collected from 70 sites in west-central Illinois, eastern Iowa, and southern Minnesota (fig. 1; table 1) during August 1997. Generally, water samples were collected on the same day that biological samples were collected, or within 48 hours. To integrate vertical and horizontal variability in water chemistry, samples were collected using a depth-integrated sampler at 5 to 10 verticals, equally spaced across the stream (Edwards and Glysson, 1988; Ward and Harr, 1990; Shelton, 1994). A cone splitter (Capel and Larson, 1996) was used to divide the collected sample into subsamples for determinations of total nutrients, dissolved nutrients, dissolved herbicides, total and dissolved organic carbon, and total suspended sediment. Subsamples also were obtained for seston (phytoplankton) analyses (see "Algae" subsection). Samples requiring filtration were processed using procedures described by Shelton (1994). Following field processing, all samples were immediately chilled (placed in a cooler with wet ice) for shipment to the analytical laboratories. Samples for total and filtered nutrients and organic carbon

Table 4. Row-crop production, fertilizer application, and herbicide use

[kg, kilograms; --, no data]

Site number	U.S. Geological Survey station identification	Corn (acres planted in 1997)	Soy beans (acres planted in 1997)	Corn, percent of total crop in 1997	Soy beans, percent of total crop in 1997	Corn, percent of total basin area	Soy beans, percent of total basin area	Nitrogen applied to corn and soybeans in 1997 (metric tons)	Phosphorus applied to corn and soybeans in 1997 (metric tons)	Acetochlor use in 1997 (kg)	Alachlor use in 1997 (kg)	Atrazine use in 1997 (kg)	Cyanazine use in 1997 (kg)	Metolochlor use in 1997 (kg)	Simazine use in 1997 (kg)
L01	05554000	54,000	51,600	50	48	45	43	3,740	660	14,700	561	22,600	8,260	18,600	681
L02	05554490	158,000	153,000	50	48	45	43	10,900	1,930	43,000	1,640	66,200	24,200	54,500	1,990
L03	05556500	57,700	36,500	59	37	46	29	3,990	660	15,700	600	24,200	8,840	19,000	728
L04	05559500	26,700	23,400	50	44	36	32	1,850	320	7,270	277	11,200	4,090	9,100	337
L05	05563000	19,600	16,400	47	40	26	22	1,360	230	5,350	204	8,240	3,010	6,660	247
L06	05564300	86,400	82,300	50	48	44	42	5,980	1,050	23,500	897	36,200	13,200	29,700	1,090
L07	05567500	206,000	190,000	50	46	42	39	14,200	2,500	56,000	2,130	86,200	31,500	70,500	2,590
L08	05568830	122,000	84,400	57	39	44	31	8,440	1,410	33,300	1,270	51,200	18,700	40,600	1,540
L09	05569875	64,600	53,200	52	43	37	31	4460	768	17,600	670	27,100	9,880	21,800	814
L10	05570910	61,300	58,700	50	48	40	38	4,240	749	16,700	636	25,700	9,380	21,100	773
L12	05575850	28,700	27,000	48	45	35	33	1,990	350	7,820	298	12,000	4,400	9,880	362
L15	05580000	61,200	58,500	50	48	42	40	4,240	748	16,700	636	25,700	9,370	21,100	772
L16	05583900	17,500	18,500	42	44	23	24	1,220	218	4,780	182	7,350	2,680	6,120	221
L17	05584500	140,000	134,000	46	44	33	32	9,680	1,710	38,100	1,450	58,600	21,400	48,200	1,760
L18	05585800	14,000	42,500	19	57	7	22	983	241	3,800	145	5,850	2,140	6,140	176
L19	05586598	78,600	72,400	47	43	32	29	5,440	954	21,400	817	33,000	12,000	26,700	992
L20	05586645	25,500	24,500	45	44	30	29	1,760	312	6,940	265	10,700	3,900	8,790	322
L21	05587000	153,000	147,000	45	43	28	26	10,600	1,870	41,700	1,590	64,300	23,500	52,800	1,930
L22	05567000	24,300	21,800	50	45	40	36	1,680	294	6,630	253	10,200	3,730	8,320	307
L23	05568000	276,000	253,000	50	46	40	37	19,100	3,350	75,200	2,870	116,000	42,300	94,700	3,480
L24	05568800	18,800	12,500	57	38	47	31	1,300	217	5,130	196	7,900	2,880	6,240	238
I01	05451210	62,000	54,300	52	45	43	38	3,440	532	15,000	5,720	19,800	10,900	28,100	--
I02	05469980	61,200	56,800	51	47	45	41	3,400	530	14,800	5,900	19,600	10,700	27,800	--
I03	05420680	86,500	75,200	49	42	39	34	4,800	740	20,900	7,930	27,700	15,200	39,200	--

Table 4. Row-crop production, fertilizer application, and herbicide use—Continued

[kg, kilograms; --, no data]

Site number	U.S. Geological Survey station identification	Corn (acres planted in 1997)	Soy beans (acres planted in 1997)	Corn, percent of total crop in 1997	Soy beans, percent of total crop in 1997	Corn, percent of total basin area	Soy beans, percent of total basin area	Nitrogen applied to corn and soybeans in 1997 (metric tons)	Phosphorus applied to corn and soybeans in 1997 (metric tons)	Acetochlor use in 1997 (kg)	Alachlor use in 1997 (kg)	Atrazine use in 1997 (kg)	Cyanazine use in 1997 (kg)	Metolochlor use in 1997 (kg)	Simazine use in 1997 (kg)
I04	05456510	37,900	35,300	48	45	39	36	2,100	328	9,140	3,670	12,100	6,650	17,200	--
I05	05449500	120,000	101,000	53	45	45	38	6,660	1,020	29,000	10,800	38,500	21,100	54,400	--
I06	05462770	40,200	34,100	52	44	43	37	2,230	343	9,710	3,620	12,900	7,070	18,200	--
I07	05420720	36,600	30,700	49	41	40	33	2,030	311	8,840	3,270	11,700	6,440	16,600	--
I08	05420900	38,800	27,400	51	36	29	20	2,140	320	9,360	3,040	12,400	6,810	17,400	--
I09	05471120	33,700	31,800	50	47	41	39	1,870	293	8,140	3,300	10,800	5,920	15,300	--
I10	05458870	39,400	32,900	53	44	45	38	2,190	335	9,520	3,500	12,600	6,930	17,800	--
I11	05459300	86,500	70,800	53	44	46	38	4,790	732	20,900	7,570	27,700	15,200	39,100	--
I12	05449200	55,600	45,700	54	44	45	37	3,080	471	13,400	4,880	17,800	9,760	25,100	--
I13	05457950	61,600	53,100	50	44	39	33	3,420	527	14,900	5,620	19,700	10,800	27,900	--
I14	05463510	98,100	85,200	53	45	47	41	5,440	839	23,700	8,990	31,400	17,200	44,400	--
I15	05455500	111,000	89,200	46	37	30	24	6,150	936	26,800	9,580	35,500	19,500	50,100	--
I16	05421700	60,900	37,300	54	33	41	25	3,360	493	14,700	4,300	19,500	10,700	27,200	--
I17	05461390	33,200	28,400	51	44	35	30	1,840	283	8,010	301	10,600	5,830	15,000	--
I18	05473060	57,100	50,800	47	41	31	28	3,170	491	13,800	5,330	18,300	10,000	25,900	--
I19	05473400	78,700	78,100	41	40	23	23	4,380	691	19,000	8,010	25,200	13,800	35,900	--
I20	05455100	37,600	26,500	46	33	29	21	2,080	310	9,070	2,940	12,000	6,600	16,900	--
I21	05421870	29,400	18,500	57	36	39	24	1,620	239	7,090	2,120	9,410	5,160	13,100	--
I22	05464220	70,900	60,800	50	43	34	29	3,930	605	17,100	6,440	22,700	12,400	32,100	--
I23	05473550	32,000	27,700	48	41	30	26	1,770	274	7,720	2,930	10,200	5,620	14,500	--
I24	05452020	47,300	40,600	48	41	37	32	2,620	404	11,400	4,300	15,100	8,310	21,400	--
I25	05465310	31,200	28,000	47	42	32	28	1,730	269	7,540	2,930	10,000	5,490	14,200	--
M01	05319050	52,300	54,500	48	50	43	44	2,590	366	9,840	3,170	5,400	1,620	16,800	--
M02	05320270	33,700	31,500	49	45	41	38	1,660	231	6,340	1,860	3,480	1,040	10,700	--
M03	05317828	28,600	24,300	53	45	45	38	1,410	193	5,380	1,460	2,950	887	8,940	--

Table 4. Row-crop production, fertilizer application, and herbicide use—Continued

[kg, kilograms; --, no data]

Site number	U.S. Geological Survey station identification	Corn (acres planted in 1997)	Soy beans (acres planted in 1997)	Corn, percent of total crop in 1997	Soy beans, percent of total crop in 1997	Corn, percent of total basin area	Soy beans, percent of total basin area	Nitrogen applied to corn and soybeans in 1997 (metric tons)	Phosphorus applied to corn and soybeans in 1997 (metric tons)	Acetochlor use in 1997 (kg)	Alachlor use in 1997 (kg)	Atrazine use in 1997 (kg)	Cyanazine use in 1997 (kg)	Metolochlor use in 1997 (kg)	Simazine use in 1997 (kg)
M04	05326150	40,400	42,000	43	45	33	35	2,000	282	7,600	2,450	4,170	1,250	13,000	--
M05	05320450	81,700	76,400	51	48	40	38	4,030	560	15,400	4,520	8,430	2,530	25,900	--
M06	05319360	36,800	37,300	48	49	43	44	1,820	256	6,920	2,180	3,800	1,140	11,800	--
M07	05326250	40,700	41,600	44	45	35	36	2,010	284	7,660	2,430	4,200	1,260	13,060	--
M08	05318050	49,300	44,500	51	46	41	37	2,430	336	9,280	2,650	5,090	1,530	15,500	--
M09	05318240	64,500	65,100	48	49	43	44	3,190	448	12,100	3,810	6,660	2,000	20,600	--
M10	05320080	45,500	40,900	48	43	41	37	2,240	310	8,560	2,440	4,690	1,410	14,300	--
M11	05317170	39,000	40,600	45	47	38	39	1,930	273	7,340	2,360	4,030	1,210	12,600	--
M12	05304795	24,300	25,100	41	43	36	37	1,200	170	4,570	1,460	2,510	754	7,810	--
M13	05316985	62,800	69,000	45	50	39	43	3,110	443	11,800	3,980	6,480	1,950	20,400	--
M14	05326700	34,200	35,300	42	44	33	34	1,690	238	6,420	2,060	3,520	1,060	11,000	--
M15	05312000	25,800	28,500	43	48	36	40	1,280	182	4,850	1,640	2,660	799	8,360	--
M18	05320230	28,500	26,400	49	45	40	37	1,400	195	5,360	1,570	2,940	883	9,010	--
M19	05303900	27,000	24,300	42	38	28	25	1,330	184	5,080	1,450	2,790	838	8,510	--
M20	05318630	26,000	27,800	47	50	41	43	1,290	183	4,900	1,610	2,690	808	8,410	--
M21	05317800	46,200	37,700	54	44	48	39	2,270	310	8,690	2,280	4,770	1,430	14,400	--
M22	05318178	32,900	32,000	49	48	46	45	1,620	227	6,180	1,880	3,390	1,020	10,500	--
M23	05314500	63,900	60,800	42	40	32	30	3,150	440	12,000	3,590	6,590	1,980	20,300	--
M24	05318138	30,800	29,200	50	47	46	44	1,520	212	5,800	1,720	3,180	956	9,770	--
M25	05318800	16,800	17,500	48	50	44	46	829	117	3,150	1,020	1,730	520	5,390	--
M27	05314510	21,500	19,000	42	37	28	25	1,060	146	4,050	1,140	2,220	668	6,770	--

were shipped to the USGS National Water Quality Laboratory (NWQL) in Arvada, Colorado. Samples for herbicide and degradate analyses were shipped to the USGS Organic Geochemistry Research Laboratory (OGRL) in Lawrence, Kansas. Samples for total suspended sediment were shipped to the USGS Iowa District Sediment Laboratory (IDSL) in Iowa City, Iowa. Seston subsamples were filtered onto glass-fiber filters, and the filters were shipped on dry ice to the USGS Stable Isotope Laboratory in Menlo Park, California, for determinations of $\delta^{15}N$ and $\delta^{12}C$ (Battaglin and others, 1997) and the USGS Iowa District laboratory for CHL*a* determinations. Approximately 15 percent of samples collected for seston CHL*a* determinations were split from the original sample volume and submitted to the NWQL for quality-control purposes. Field measurements of water temperature, specific conductance, pH, DO, and alkalinity were made in accordance with protocols established by Shelton (1994). Results of field measurements and chemical determinations are listed in tables 6 through 9 in the Appendix.

Water-Sample Laboratory Analyses

The NWQL performed analyses for nutrients, organic carbon, and chlorophyll (quality-control comparison samples only) concentrations in water samples. Analytical methods for nutrient determinations are presented by Fishman and Friedman (1989), Patton and Truitt (1992), and Fishman (1993). Methods for determining total and dissolved organic carbon in water samples are given by Wershaw and others (1987) and Brenton and Arnett (1993). Chlorophyll was determined by the high-pressure liquid chromatography (HPLC) method described by Britton and Greeson (1989). Quality-control practices employed by the NWQL are presented by Pritt and Raese (1995). The IDSL performed analyses for total suspended-sediment concentrations in water samples. Samples were analyzed in accordance with methods presented by Guy (1969).

The OGRL performed analyses of herbicide and herbicide-metabolite concentrations in water samples (table 5) using gas chromatography/mass spectrometry (GC/MS) following extraction on C_{18} cartridges (Thurman and others, 1990; Meyer and others, 1993). The analytical reporting limit for this method was 0.05 µg/L for all compounds. Additional analyses for six chloroacetanilide herbicide metabolites—acetochlor ethanesulfonic acid (ESA), acetochlor oxanilic acid (OA), alachlor ESA, alachlor OA, metolachlor ESA, and metolachlor OA—and the atrazine metabolite, hydroxy-atrazine (table 5), were analyzed by HPLC following solid-phase extraction on C_{18} cartridges (Meyer and others, 1993). Quantification of the analytes was achieved by dividing the peak height of the analyte by the peak height of the internal standard (2,4–D) and substituting the peak height into the respective linear regression equation. Complete separation of all analytes was achieved with this method. The analytical reporting limit for this method was 0.2 µg/L for all metabolite compounds. Relative standard deviation for the method is ±10 percent. Standards were run with each sample set at concentrations of 0.25, 0.5, 1.0, and 2.0 µg/L. Confirmation by HPLC-MS negative ion electrospray (Ferrer and others, 1997) was achieved for metolachlor ESA and acetochlor, alachlor, and metolachlor OA. Complete separation of alachlor ESA and acetochlor ESA was not possible by HPLC-MS negative ion electrospray. Tables 8 and 9 list results for all herbicide compounds that were detected.

Water Clarity

Water clarity was quantified by determining or estimating the depth of the euphotic zone, which is the depth at which 1 percent of subsurface photosynthetically-active radiation (PAR) remains (Hutchinson, 1967). Light meters with Li-Cor™ underwater quantum sensors were used to determine PAR approximately 1 cm below the water surface; the sensor was then lowered to a depth where 1 percent of subsurface PAR remained or to the bottom of the deepest pool in the stream reach. When greater than 1 percent of subsurface PAR (PCTPAR) was detected at the stream bottom, the depth and PCTPAR were recorded. The depth of the euphotic zone in meters (EUPHOTIC) was estimated by linear regression, with the concentration of total suspended sediment (TSS), in mg/L, and PCTPAR, using the following relation:

$$\text{Log (EUPHOTIC)} = 0.427 - 0.396\,(\text{Log TSS}) - 0.005\,(\text{PCTPAR})$$

(adjusted $R^2 = 0.548$; $F = 27.036$; $p < 0.001$)

Table 5. Herbicides and herbicide-degradation products analyzed by the U.S. Geological Survey Organic Geochemistry Research Laboratory, Lawrence, Kansas

[GC/MS, gas chromatography/mass spectrometry; HPLC, high-performance liquid chromatography; MCL, maximum contaminant level, U.S. Environmental Protection Agency (Nowell and Resek, 1994); HA, health advisory level, U.S. Environmental Protection Agency (Nowell and Resek, 1994); --, not applicable]

Common name	Chemical name	Use or origin	Method of analysis	MCL or HA
Acetochlor	2-chloro-*N*-(ethoxymethyl)-*N*-(2-ethyl-6-methylphenyl)acetamide	herbicide	GC/MS	--
Acetochlor ethanesulfonic acid (acetochlor ESA)	2-[(2-ethyl-6-methylphenyl)(ethoxymethyl)amino]-2-oxoethane sulfonic acid	herbicide degradate (acetochlor)	HPLC	--
Acetochlor oxanilic acid (acetochlor OA)	2-[(2-ethyl-6-methylphenyl)(ethoxymethyl)amino]-2-oxoacetic acid	herbicide degradate (acetochlor)	HPLC	--
Alachlor	2-chloro-2'-6'-diethyl-*N*-(methoxymethyl)-acetanilide	herbicide	GC/MS	2
Alachlor ethanesulfonic acid (alachlor ESA)	2-[(2,6-diethylphenyl)(methoxymethyl)amino]-2-oxoethane sulfonic acid	herbicide degradate (alachlor)	HPLC	--
Alachlor oxanilic acid (alachlor OA)	2-[(2,6-diethylphenyl)(methoxymethyl)amino]-2-oxoacetic acid	herbicide degradate (alachlor)	HPLC	--
Ametryn	2-(ethylamino)-4-isopropylamino-6-methyl-thio-*s*-triazine	herbicide	GC/MS	2,000
Atrazine	2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine	herbicide	GC/MS	3
Cyanazine	2-[[4-chloro-6-(ethylamino)-1,3,5-triazine-2-yl]amino]-2-methyl propionitrile	herbicide	GC/MS	1
Cyanazine amide	2-chloro-4-(1-carbamoyl-1-methyl-ethylamino-6-ethylamino-*s*-triazine	herbicide degradate (cyanazine)	GC/MS	--
Deethylatrazine	2-amino-4-chloro-6-(isopropylamino)-*s*-triazine	herbicide degradate (atrazine, propazine)	GC/MS	--
Deisopropylatrazine	2-amino-4-chloro-6-(ethylamino)-*s*-triazine	herbicide degradate (atrazine, cyanazine, simazine)	GC/MS	--
Hydroxyatrazine	2-hydroxy-4-(ethylamino)-6-(isopropylamino)-*s*-triazine	herbicide degradate (atrazine)	HPLC	--
Metolachlor	2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methyl ethyl)acetamide	herbicide	GC/MS	100
Metolachlor ethane-sulfonic acid (metolachlor ESA)	2-[(2-ethyl-6-methylphenyl)(2-methoxy-1-methylethyl)amino]-2-oxoethanesulfonic acid	herbicide degradate (metolachlor)	HPLC	--
Metolachlor oxanilic acid (metolachlor OA)	2-[(2-ethyl-6-methylphenyl)(2-methoxy-1-methylethyl)amino]-2-oxoacetic acid	herbicide degradate (metolachlor)	HPLC	--
Metribuzin	4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazine-5(4H)-one	herbicide	GC/MS	200
Prometon	2,4-bis(isopropylamino)-6-methyoxy-*s*-triazine	herbicide	GC/MS	100
Prometryn	2,4-bis(isopropylamino)-6-(methylthio)-*s*-triazine	herbicide	GC/MS	--
Propachlor	2-chloro-*N*-isopropylacetanilide	herbicide	GC/MS	90
Propazine	2-chloro-4,6-bis(isopropylamino)-*s*-triazine	herbicide	GC/MS	10
Simazine	2-chloro-4,6-bis(ethylamino)-*s*-triazine	herbicide	GC/MS	4
Terbutryn	2-tert-butylamino-4-ethylamino-6-methylthio-*s*-triazine	herbicide	GC/MS	--

The depth of the euphotic zone in streams with high water clarity was estimated by setting PCTPAR equal to 1 percent and calculating EUPHOTIC using the regression relation. Results for euphotic-zone depth are listed in table 11 in the Appendix.

Stream Productivity and Respiration

Measurements of water temperature, specific conductance, pH, and DO were recorded at 15-minute intervals over a period of 48 hours using submersible data recorders (HydroLab™ DataSonde™ units) suspended with the probes positioned in the euphotic zone. Data recorder probes were calibrated in accordance with manufacturer's instructions before installation at a site and following retrieval. New batteries and DO sensor membranes were installed each time a unit was deployed. Data recorder values were compared with measurements made independently during the collection of chemical and biological samples.

Stream productivity and respiration were estimated using diel DO and pH curves. Examination of diel DO and pH curves revealed minima and maxima about 8 a.m. and 3 p.m., respectively. Rapid rates of change were linear, increasing between 9 a.m. and 3 p.m. due to algal photosynthesis, and decreasing from midnight to 8 a.m. because of biological respiration. Stream productivity (P_{max}) was quantified by subtracting the DO concentration at 8 a.m. from the concentration at 3 p.m. and calculating the net rate of oxygen accrual in milligrams of O_2 per liter per hour (mg O_2/L/hr), which is equivalent to grams of O_2 per cubic meter per hour (g O_2/m^3/hr). Stream respiration (R_{max}) was quantified by subtracting the DO concentration at midnight from the concentration at 8 a.m. and calculating the rate of oxygen loss in the same manner. Similar calculations for productivity (daylight, rate of increase) and respiration (night, rate of decrease) were made using pH as the response variable. When differences in productivity and respiration estimates were determined between 24-hour cycles due to cloudy weather, the larger of the two estimates was retained. Estimates of P_{max} and R_{max} do not account for rates of oxygen diffusion that are a function of water temperature and the difference in oxygen saturation between water and air (Odum, 1956). Selected summary statistics for the 48-hour period are listed in table 10 in the Appendix.

Algae

Sample Collection

Two quantitative algal samples were collected at each site: periphyton (algae attached to submerged surfaces such as wood) and seston (phytoplankton suspended in the water column). Periphyton samples were collected in accordance with the NAWQA algal protocol for richest targeted habitat (RTH) samples (Porter and others, 1993). All samples were collected from snags (submerged woody debris) that were entirely submerged in the euphotic zone of the stream. Snag samples were collected from a minimum of 10 locations in each stream reach. Snags were gently removed from the water to minimize disturbance of the periphyton community; an 8- to 10-cm cylindrical section was cut from each snag with lopping shears; and the snag sections were retained in a plastic bag prior to processing. After periphyton was removed from the snag sections, the length and diameter of each section was measured, and the surface area of each snag segment was calculated using the following formula:

$$\text{Surface area (cm}^2\text{)} = 3.1416 * \text{average diameter} * \text{length}$$

The areas of all snag sections were summed, and the total surface area was recorded on the field data sheets and sample labels. Periphyton was removed from each snag section using a stiff-bristled toothbrush and de-ionized water from a rinse bottle. The algal suspension was washed into a small, plastic processing pan. Snag sections were processed until about 150 to 200 mL of water had accumulated in the processing pan. The process water was then used to rinse periphyton removed from the remaining snag sections. After all snag sections were processed, each section was rinsed with additional water, and the combined periphyton-water suspension was poured into a labeled 500-mL plastic sample container.

Periphyton Subsampling and Processing

Periphyton samples were subsampled to provide aliquots for determinations of CHL*a*, ash-free dry mass (AFDM), taxonomic analysis, and stable isotope ratios. Results of stable isotope values are not in this report. The sample was homogenized for about 30 seconds, or until the sample appeared to be well mixed, using a hand-held, battery-operated mixer. When algal filaments became wound about the slotted tip of the mixer, they were cut into smaller fragments using small dissecting scissors. This process was repeated until most of the algal filaments were dispersed and the sample appeared to be relatively homogeneous. Two subsamples (generally 10 mL) were withdrawn from each periphyton sample and filtered onto Whatman GF/F glass-fiber filters using procedures described by Porter and others (1993). The filters were wrapped with aluminum foil, placed into labeled plastic bags or disposable petri dishes, and shipped to analytical laboratories in a cooler with dry ice. A subsample of sufficient volume to produce about 10 mg of solid material was withdrawn and delivered into a 20-mL scintillation vial. This subsample was shipped to the USGS National Research Program stable isotope laboratory in Menlo Park, California, for determinations of stable-isotope ratios of nitrogen, carbon, and sulfur. The remainder of the original periphyton sample was preserved and shipped to the NWQL Biological Unit for identification and enumeration of algal taxa using the standard NAWQA RTH 600-cell count method (protocol on file at U.S. Geological Survey, Lakewood, Colorado). The volume of this taxonomic-sample component was determined using a graduated cylinder. After the volume of the taxonomic-sample component was recorded on the field data sheet and sample label, the resulting sample was preserved with sufficient concentrated buffered formalin to result in a final concentration of 5 percent (Porter and others, 1993). The total volume of the original periphyton sample was determined by summing the volumes withdrawn for CHL*a*, AFDM, stable isotopes, and algal taxonomy; the total sample volume was recorded on field data sheets and sample labels.

Seston (phytoplankton) samples for CHL*a* analysis were split from the water sample collected for nutrient and herbicide analyses. Sample volumes, ranging from 50 to 100 mL, depending on water clarity, were recorded on field data sheets, and the sample was filtered onto Whatman GF/F glass-fiber filters for seston CHL*a* analysis using procedures described by Porter and others (1993). The filters were wrapped with aluminum foil, placed into labeled plastic bags or disposable petri dishes, and shipped to the analytical laboratory in a cooler with dry ice. Filters used during the processing of water-chemistry samples were retained, placed into labeled plastic bags, and shipped to the USGS stable isotope laboratory for processing, as described previously.

Chlorophyll *a* and Ash-Free Dry Mass Analyses

Chlorophyll *a* was determined in the Iowa District laboratory using the U.S. Environmental Protection Agency fluorometric method (Arar and Collins, 1992; Eaton and others, 1995). Filters were thawed and extracted in 90 percent aqueous acetone solution by grinding, and then steeping for 24 hours at 4°C. Fluorescence of chlorophyll extracts was determined with a Turner 111 fluorometer that had been calibrated previously with chlorophyll standards provided by the NWQL. Results for periphyton CHL*a* (mg/m^2) and seston CHL*a* (µg/L) (table 7) are corrected for the presence of phaeophytin pigments, corresponding with the U.S. Environmental Protection Agency STORET code 32229. Ash-free dry mass was determined in the USGS Illinois District laboratory using the U.S. Environmental Protection Agency standard method (Weber, 1973; Eaton and others, 1995). Filters were dried to a constant mass at 105°C; the dry weight was determined on an analytical balance; the filters were ashed at 500°C for 1 hour, re-hydrated, dried to a constant mass, and the mass of the residue (ash weight) was determined. Ash-free dry mass (g/m^2) was calculated by subtracting the ash weight from the dry weight of the sample and dividing by the periphyton sample area. Results correspond with STORET code 00572.

Quality-Control Samples

Quality-control samples included filter blanks, triplicate split samples, and replicate samples split with the NWQL. No fluorescence attributable to chlorophyll was detected in repeated analyses of blank filters. Triplicate periphyton filters were analyzed from 12 sites. The average coefficient of variation was 6 percent over a large range of CHL*a* concentrations (13.2 to 80.2 mg/m^2). Results from samples split with the NWQL were highly correlated ($r > 0.99$; $p < 0.001$), but concentrations differed significantly between laboratories. These results are attributable to differences in CHL*a* values determined by fluorometric and HPLC methods (for example, Millie and others, 1993). Values determined by the HPLC method were slightly less than half of those determined by the fluorometric method for the same sample.

Benthic Invertebrates

Benthic invertebrate samples were collected in accordance with the NAWQA protocol for RTH samples (sampler code 27) (Cuffney and others, 1993). All samples were collected from snags that appeared to have been submerged for an extended period of time in areas of flowing water. Snag samples were collected from 5 to 10 locations in each stream reach. A sampling net (Slack sampler) was placed downstream from the snag to retain any organisms dislodged during the collection process. The top portion of the branch was cut underwater with lopping shears. A 12- to 20-in section of the snag was then cut underwater and allowed to flow into the Slack sampler. The snag section was scraped gently with a brush inside the net, then removed and placed into a 5-gal plastic bucket. Organisms clinging to the inside of the net, and those retained in the net-sample bottle, were removed and placed into another plastic bucket containing a small amount of stream water. Contents of the bucket containing organisms were poured into a 425-µm mesh sieve, and invertebrates were removed and placed into a 500-mL plastic container. Snag sections were examined and picked repeatedly, as the sections dried, until no additional organisms were found. The total area associated with each invertebrate sample was calculated using the same formula described for the periphyton samples. Samples were labeled and preserved with 10-percent buffered formalin. All samples were submitted to the NWQL Biology Unit for taxonomic analysis using the standard NAWQA RTH 500-organism count method (S. Moulton, U.S. Geological Survey, written commun., 1998).

Characterization of Habitat Conditions

Stream-habitat conditions were assessed using methods adapted from the NAWQA Level 1 habitat-assessment protocol (Meador and others, 1993; Fitzpatrick and others, 1998). The lower boundary of the sampling reach was established and marked temporarily. Three to six transects were established upstream from the lower reach boundary at intervals of two channel widths. If the site was an existing NAWQA basic fixed site, the existing marked transects were used. Information was collected to quantify riparian-tree canopy cover, stream-habitat conditions (substrate, channel width and depth, velocity, and discharge), stream-bank conditions, and riparian-zone vegetation on the stream flood plain or terrace (tables 11 and 12 in the Appendix).

Canopy Cover

Measurements of canopy shading were made (and presented in table 11) using three different procedures: (1) Solar Pathfinder—measurements were taken in accordance with procedures recommended by the manufacturer (Solar Pathways, Glenwood Springs, Colorado). Canopy shading reflected by the plastic dome of the Solar Pathfinder was quantified in relation to stream latitude and the month of sample collection. Results are presented as the average percentage of canopy shading in the stream reach; (2) spherical densiometer—measurements of riparian-canopy closure were made with a concave spherical densiometer, as described by Fitzpatrick and others (1998). Results are presented as the average percentage of canopy shading in the stream reach; and (3) open canopy angle—the left and right canopy angles were measured with a hand-held clinometer. The left and right angles were subtracted from 180 degrees to give the open canopy angle (in degrees). Percent shading (CANSHADE) was calculated by summing left and right canopy angles, dividing by 180, and multiplying by 100.

Stream-Habitat Conditions

Stream width, depth, velocity, and bottom substrate measurements were made along a minimum of three transects; depth, velocity, and substrate were measured at the stream thalweg (or the center of the stream) and two equidistant points between that first point and the right and left streambanks. Velocity, reported in centimeters per second (cm/s), was determined at a depth equivalent to 0.6 times the measured stream depth. Similarly, the percentage of clay, silt, sand, gravel, and cobble was estimated visually (when greater than 25 percent) at three points along a minimum of three transects. Stream bankfull width (Fitzpatrick and others, 1998) was measured, where possible. Results are presented as the mean and maximum velocity (centimeters per second), width and depth (meters) (table 11), and average percentages of substrate materials in the stream reach (table 12). Stream discharge (in cubic feet per second) was measured at the time of water-sample collection (table 6).

Streambank Characteristics

Bank erosion was classified qualitatively at the ends of stream transects, as described by Meador and others (1993). Bank angle, vegetative cover, height, and material composition were measured, and a Bank Stability Index (BSI), modified from Simon and Hupp (1992), was calculated, as given by Fitzpatrick and others (1998). Values of the BSI are presented in table 12.

Riparian-Zone Vegetation

Temporary, semiquantitative vegetation plots were established at both ends of each stream transect, extending onto the flood plain for 10 m. The percentage ground cover of trees, shrubs, grasses, forbs, and bare soil was estimated visually in a 20-m^2 vegetation plot, 1 m on either side of the 10-m flood-plain transect. The diameter at breast height (dbh) was measured from trees for which at least half of the trunk was present in the vegetation plot. Results are presented as the average percent ground cover of vegetation categories in the stream reach (table 12). The width of the wooded-riparian corridor was measured from the ends of each stream transect onto the flood plain. Distances greater than 50 m were not measured but recorded as greater than 50 m. Results are presented in table 11 as the average wooded-riparian-zone width for the stream reach. Quantification of wooded-riparian zones in stream segments was discussed in a previous section.

Quality Assurance

Written field-sampling procedures for the study were provided to all personnel prior to commencement of field activities (protocol on file at U.S. Geological Survey, Lakewood, Colorado). Additional training was provided during practice field sessions prior to the study and during the first week of sampling activities. Preprinted field data forms and sample labels were prepared to ensure consistency of data collection and sample integrity. Sample-identification codes for biological samples were preassigned to facilitate transmittal of information required for the laboratory analytical-service request process and to ensure accuracy of site and sample information. Field meters were maintained and calibrated in accordance with manufacturer recommendations. Submersible data recorders used for productivity and respiration estimates were calibrated in accordance with manufacturer (Hydrolab™ Corporation, Austin, Texas) recommendations prior to deployment and following retrieval. Batteries and DO membranes were replaced in the data recorders at the end of each 48-hour recording period. Quality-control samples included blanks and replicate samples for water chemistry and split samples and filter blanks for CHL*a* and AFDM. Photodocumentation of stream reaches was supplemented by low-altitude aerial photography and video footage of stream segments, as defined in this report.

DATA

The analytical results of this study are presented in tables 6–12 in the Appendix. Table 6 lists field properties and suspended sediment. Table 7 lists results of nutrient analyses and chlorophyll *a* and ash-free dry mass. Tables 8 and 9 list all triazine and chloroacetamide herbicides and degradation products that were detected in water samples. Table 10 lists summaries of continuous data collected over a 48-hour period at each site. Tables 11 and 12 list measurements of instream, bank, and riparian-zone habitat. Results of periphyton identification and quantification can be found at URL http://wwwrcolka.cr.usgs.gov/nawqa. Results for benthic invertebrate identification and quantification can be found at URL http://wwwrcolka.cr.usgs.gov/nawqa.

SUMMARY

Study design, methods, quality assurance, and results are reported from a low-flow water-quality and habitat characterization study conducted in August 1997 in a region of high agricultural intensity. The study represents a collaborative regional synthesis effort among three NAWQA study units (LIRB, EIWA, and UMIS) in the upper Mississippi River Basin. The objectives of the study were to characterize chemical, biological, and habitat conditions for 70 sites on Midwestern streams and rivers; to relate results to regional differences in soil drainage and wooded riparian conditions; to assess algal-nutrient relations in reference to stream eutrophication; and to describe responses of algal and invertebrate communities to agricultural nonpoint sources of contamination. Methods are described for the collection and analysis of water-chemistry data, stream productivity and respiration, biological communities, habitat conditions, agricultural land-use and landscape information, and quality-assurance/quality-control procedures. With the exception of algal and invertebrate community and isotope data, data are summarized in tables 6 through 12 of the report. Biological-community data are reported on the World Wide Web.

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APPENDIX

Table 6. Basin characteristics, discharge, and selected water-quality properties

[mi^2, square miles; STATSGO, Soil Conservation Service Soil Hydrologic Group; ft^3/s, cubic feet per second; s.u., standard units; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, no data]

Site number	U.S. Geological Survey station identification	Basin area (mi^2)	STATSGO score[1]	Riparian tree density (percent)[2]	Study design group[3]	Date in 1997 when water and biological samples were collected	Discharge (ft^3/s)	pH (s.u.)	Specific conductance (µS/cm)	Alkalinity (mg/L)	Suspended sediment, total (mg/L)
L01	05554000	186	3.20	3.4	4	15-Aug	4.8	8.2	619	184	224
L02	05554490	551	3.20	41.7	3	11-Aug	14	8.2	626	198	158
L03	05556500	196	2.40	24.2	1	11-Aug	18	7.8	466	134	95
L04	05559500	115	2.80	35.0	4	12-Aug	6.0	7.9	1,090	218	46
L05	05563000	119	2.60	23.6	1	12-Aug	26	7.9	681	150	157
L06	05564300	309	2.70	55.2	1	14-Aug	14	8.6	613	220	74
L07	05567500	767	2.70	45.9	3	13-Aug	47	8.1	558	212	55
L08	05568830	432	2.60	49.4	3	4-Aug	50	8.2	585	354	169
L09	05569875	271	2.50	38.0	1	5-Aug	60	7.4	467	162	43
L10	05570910	240	2.90	41.3	3	15-Aug	9.2	7.7	774	204	92
L12	05575850	129	2.80	55.0	3	8-Aug	0.0	7.4	654	240	252
L15	05580000	227	2.60	28.3	4	14-Aug	16	7.9	589	236	72
L16	05583900	118	2.60	61.0	1	6-Aug	0.21	7.7	581	272	53
L17	05584500	655	2.60	51.6	1	5-Aug	22	8.0	542	232	59
L18	05585800	306	2.60	43.5	1	6-Aug	2.0	7.9	618	282	104
L19	05586598	385	2.50	22.1	1	7-Aug	3.2	7.7	614	282	136
L20	05586645	132	2.90	43.4	3	7-Aug	0.0	7.9	616	250	63
L21	05587000	868	2.70	29.1	1	7-Aug	9.8	7.8	601	250	86
L22	05567000	93.9	2.90	35.7	3	14-Aug	2.1	7.9	815	210	40
L23	05568000	1,070	2.60	65.4	3	13-Aug	96	7.7	553	180	67
L24	05568800	62.7	2.60	25.2	2	4-Aug	9.3	8.0	663	228	135
I01	05451210	224	2.97	43.0	3	19-Aug	20	7.9	528	142	30.1
I02	05469980	214	2.83	49.0	3	18-Aug	15	8.3	645	261	14.9
I03	05420680	346	2.51	63.0	3	28-Aug	54	7.9	396	104	7.6
I04	05456510	153	2.93	11.0	4	27-Aug	74	7.5	683	255	258

Table 6. Basin characteristics, discharge, and selected water-quality properties—Continued

[mi^2, square miles; STATSGO, Soil Conservation Service Soil Hydrologic Group; ft^3/s, cubic feet per second; s.u., standard units; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, no data]

Site number	U.S. Geological Survey station identification	Basin area (mi^2)	STATSGO score[1]	Riparian tree density (percent)[2]	Study design group[3]	Date in 1997 when water and biological samples were collected	Discharge (ft^3/s)	pH (s.u.)	Specific conductance (µS/cm)	Alkalinity (mg/L)	Suspended sediment, total (mg/L)
I05	05449500	418	2.98	26.0	4	11-Aug	89	8.2	593	190	60.8
I06	05462770	145	2.52	15.0	4	19-Aug	41	8.0	611	233	55.1
I07	05420720	144	2.63	66.0	3	28-Aug	20	7.8	579	148	21.5
I08	05420900	210	2.52	62.0	3	20-Aug	34	8.2	458	140	17.1
I09	05471120	128	2.84	33.0	4	18-Aug	3.9	7.9	533	216	37.2
I10	05458870	136	2.71	27.0	4	25-Aug	28	8.1	582	199	55.6
I11	05459300	294	2.80	19.0	4	26-Aug	75	8.4	593	203	69.1
I12	05449200	195	2.96	13.0	4	26-Aug	20	8.0	627	199	126
I13	05457950	250	2.61	57.0	1	27-Aug	36	8.0	457	161	5.5
I14	05463510	327	2.37	50.0	1	20-Aug	42	8.0	537	149	19
I15	05455500	574	2.41	45.0	1	11-Aug	37	7.8	473	123	78.6
I16	05421700	233	2.45	32.0	2	14-Aug	42	8.3	471	172	10.1
I17	05461390	150	2.49	4.0	2	25-Aug	22	7.9	488	127	22.8
I18	05473060	284	2.48	26.0	2	12-Aug	13	7.7	661	209	137
I19	05473400	533	2.81	25.0	2	13-Aug	7.9	8.3	569	154	48.5
I20	05455100	201	2.36	46.0	1	11-Aug	5.9	7.6	498	179	32.1
I21	05421870	119	2.31	54.0	1	14-Aug	6.2	7.8	579	248	40.9
I22	05464220	327	2.30	34.0	2	21-Aug	33	7.9	587	173	39.7
I23	05473550	167	2.72	16.0	2	13-Aug	7.0	7.8	1,220	197	330
I24	05452020	200	2.28	10.0	2	21-Aug	32	8.1	573	202	32.8
I25	05465310	154	2.49	26.0	2	12-Aug	6.5	8.0	442	134	72.3
M01	05319050	192	3.07	28.0	4	19-Aug	28	8.2	735	232	150
M02	05320270	130	3.38	31.0	4	18-Aug	35	8.3	539	222	103
M03	05317828	99	3.19	44.0	3	20-Aug	21	8.1	645	264	53
M04	05326150	190	3.10	59.0	3	28-Aug	97	8.0	751	244	--

Table 6. Basin characteristics, discharge, and selected water-quality properties—Continued

[mi^2, square miles; STATSGO, Soil Conservation Service Soil Hydrologic Group; ft^3/s, cubic feet per second; s.u., standard units; μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, no data]

Site number	U.S. Geological Survey station identification	Basin area (mi^2)	STATSGO score[1]	Riparian tree density (percent)[2]	Study design group[3]	Date in 1997 when water and biological samples were collected	Discharge (ft^3/s)	pH (s.u.)	Specific conductance (μS/cm)	Alkalinity (mg/L)	Suspended sediment, total (mg/L)
M05	05320450	317	3.42	35.0	3	19-Aug	50	8.1	657	242	138
M06	05319360	133	3.07	40.0	3	19-Aug	22	8.4	758	300	43
M07	05326250	180	2.99	54.0	1	21-Aug	240	7.6	781	296	132
M08	05318050	186	2.87	31.0	2	20-Aug	47	8.1	594	268	81
M09	05318240	232	2.88	37.0	1	14-Aug	24	8.2	591	219	72
M10	05320080	173	2.86	40.0	1	18-Aug	230	8.1	714	302	153
M11	05317170	162	2.88	50.0	1	13-Aug	49	8.2	785	269	111
M12	05304795	105	2.88	30.0	2	12-Aug	6.7	7.6	1,500	263	178
M13	05316985	250	3.20	0.0	4	13-Aug	89	8.0	1,060	354	53
M14	05326700	163	3.11	2.0	4	28-Aug	190	7.7	698	208	128
M15	05312000	112	3.20	9.0	4	12-Aug	14	8.0	1,750	324	117
M18	05320230	111	3.30	27.0	4	20-Aug	48	8.2	675	253	199
M19	05303900	149	2.84	9.0	2	11-Aug	100	8.1	512	208	113
M20	05318630	100	3.05	10.0	2	15-Aug	33	8.1	824	268	114
M21	05317800	150	2.96	6.0	2	20-Aug	26	8.1	746	294	65
M22	05318178	111	2.80	0.0	2	14-Aug	10	8.7	616	199	18
M23	05314500	315	2.99	3.0	2	11-Aug	81	8.3	959	291	75
M24	05318138	104	2.84	3.0	2	14-Aug	12	8.1	433	157	30
M25	05318800	60	2.95	0.0	2	21-Aug	63	7.6	806	255	135
M27	05314510	120	3.22	0.0	4	25-Aug	28	8.1	1,360	350	86

[1]STATSGO scores were calculated by weighted averaging of the spatial distribution of Soil Hydrologic Groups in each stream basin, as explained in “Characterization of Soil Drainage in Stream Basins” subsection.

[2]The percentage of trees in a 100-meter buffer zone on both streambanks was calculated for stream segments using digital raster graphic images from 7.5-minute U.S. Geological Survey topographic maps. The length of a stream segment in miles was defined as the base-10 logarithm of the basin area.

[3]Study design groups: 1, good riparian conditions, moderately well-drained soils; 2, poor riparian conditions, moderately well-drained soils; 3, good riparian conditions, poorly drained soils; 4, poor riparian conditions, poorly drained soils.

Table 7. Concentrations of nutrients, organic carbon, chlorophyll *a* in water samples, and periphyton chlorophyll and ash-free dry mass

[mg/L, milligrams per liter; N, nitrogen; NO_2, nitrite; NO_3, nitrate; P, phosphorus; µg/L, micrograms per liter; mg/m^2, milligrams per square meter; g/m^2, grams per square meter; <, less than; --, no data]

Site number	U.S. Geological Survey station identification	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2 plus NO_3, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Carbon, organic, dissolved (mg/L)	Carbon, organic, suspended (mg/L)	Chlorophyll *a*, seston (µg/L)	Chlorophyll *a*, periphyton (mg/m^2)	Ash-free dry mass, periphyton (g/m^2)
L01	05554000	0.03	0.41	1.1	0.02	0.11	0.18	0.01	0.02	4.4	2.5	27.9	25.5	19.5
L02	05554490	0.02	0.33	0.87	<0.01	0.08	0.10	<0.01	0.02	7.2	2.3	27.0	13.1	20.6
L03	05556500	0.32	0.78	1.3	0.07	0.94	0.62	0.41	0.41	4.5	3.0	11.1	85.0	27.4
L04	05559500	0.03	0.26	0.61	<0.01	0.17	0.06	<0.01	0.02	2.9	1.0	16.3	34.3	18.2
L05	05563000	0.06	0.39	0.85	0.02	0.72	0.17	0.03	0.04	4.1	2.2	9.89	15.5	19.5
L06	05564300	<0.02	0.33	1.3	<0.01	<0.05	0.15	0.01	0.02	4.0	5.0	70.2	27.6	22.8
L07	05567500	0.02	0.37	0.81	0.02	0.55	0.13	0.05	0.06	3.9	1.9	24.3	40.1	21.0
L08	05568830	0.03	0.40	1.5	0.06	0.60	0.22	<0.01	0.01	6.1	5.0	125	12.9	31.5
L09	05569875	0.08	0.67	1.0	0.05	2.5	0.16	0.06	0.07	5.8	1.1	31.5	40.5	29.8
L10	05570910	0.08	0.49	0.86	0.02	0.24	0.15	0.07	0.07	3.8	1.4	14.0	9.96	17.8
L12	05575850	0.11	0.48	1.1	0.02	0.18	0.38	0.12	0.14	--	1.1	6.4	8.35	11.2
L15	05580000	<0.02	0.30	0.23	0.02	0.69	0.03	0.02	0.02	2.6	1.3	7.0	15.3	19.1
L16	05583900	0.06	<0.20	0.53	<0.01	0.08	0.03	<0.01	0.01	3.6	0.70	12.2	51.5	43.5
L17	05584500	<0.02	0.32	0.80	0.02	0.52	0.12	0.02	0.03	4.1	1.2	48.6	33.3	29.0
L18	05585800	0.02	0.22	0.91	0.01	<0.05	0.10	0.02	0.02	4.2	2.1	17.4	16.6	18.6
L19	05586598	0.06	0.21	0.50	0.04	2.2	0.07	0.04	0.06	3.0	1.1	9.8	25.9	24.8
L20	05586645	0.06	0.53	0.95	0.02	0.10	0.10	0.04	0.05	7.1	3.6	38.7	48.5	32.3
L21	05587000	0.03	0.21	0.86	0.01	<0.05	0.13	0.02	0.03	4.3	1.3	27.0	32.3	39.5
L22	05567000	0.15	0.87	1.2	0.08	1.3	0.21	0.14	0.13	5.9	1.3	21.6	12.3	17.2
L23	05568000	0.06	0.32	1.1	0.04	1.0	0.28	0.11	0.11	3.3	2.6	73.4	19.8	14.3
L24	05568800	0.11	0.54	0.89	0.08	2.2	0.16	0.07	0.08	4.1	0.90	15.7	24.7	26.1
I01	05451210	0.02	0.35	0.52	0.02	1.5	0.05	0.04	0.03	3.9	0.40	11.0	51.9	20.1
I02	05469980	0.03	0.44	0.45	0.03	2.7	0.18	0.17	0.16	3.7	0.30	9.8	29.4	22.7
I03	05420680	<0.02	0.52	0.53	0.15	0.17	0.03	0.02	<0.01	3.1	0.9	15.5	37.0	34.1

Table 7. Concentrations of nutrients, organic carbon, chlorophyll *a* in water samples, and periphyton chlorophyll and ash-free dry mass—Continued

[mg/L, milligrams per liter; N, nitrogen; NO_2, nitrite; NO_3, nitrate; P, phosphorus; µg/L, micrograms per liter; mg/m^2, milligrams per square meter; g/m^2, grams per square meter; <, less than; --, no data]

Site number	U.S. Geological Survey station identification	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2 plus NO_3, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Carbon, organic, dissolved (mg/L)	Carbon, organic, suspended (mg/L)	Chlorophyll *a*, seston (µg/L)	Chlorophyll *a*, periphyton (mg/m^2)	Ash-free dry mass, periphyton (g/m^2)
I04	05456510	<0.02	0.74	1.1	0.08	3.7	0.16	<0.01	<0.01	7.2	4.5	33.0	19.9	24.1
I05	05449500	0.05	0.31	1.8	0.02	1.7	0.24	<0.01	<0.01	3.7	5.0	71.7	--	--
I06	05462770	0.03	0.23	0.54	0.04	6.0	0.07	0.04	<0.05	2.1	0.60	14.1	72.5	47.5
I07	05420720	<0.02	0.98	1.0	0.06	1.2	0.19	0.16	0.02	3.5	1.0	9.7	34.4	25.3
I08	05420900	<0.02	0.23	0.37	0.04	2.7	0.03	0.02	0.01	3.0	0.30	10.7	58.6	34.6
I09	05471120	0.04	0.33	1.1	0.02	0.29	0.12	0.04	0.04	5.6	0.60	87.0	21.5	15.7
I10	05458870	<0.02	0.22	0.33	0.04	3.4	0.04	0.03	0.02	2.1	1.9	32.4	73.0	28.3
I11	05459300	<0.02	0.44	2.1	0.02	0.44	0.20	<0.01	<0.01	5.0	2.8	176	21.0	37.3
I12	05449200	<0.02	0.39	1.4	0.04	0.82	0.18	0.01	<0.01	4.1	2.1	125	28.1	25.9
I13	05457950	<0.02	0.29	0.33	0.21	2.0	<0.01	0.01	<0.01	2.4	0.80	1.6	78.8	39.3
I14	05463510	<0.02	<0.20	0.28	0.03	3.5	0.09	0.07	0.06	2.6	0.50	13.1	20.9	25.4
I15	05455500	0.81	1.4	2.1	0.05	0.27	0.46	0.17	0.18	5.2	2.5	60.0	19.6	19.1
I16	05421700	<0.02	<0.20	0.31	0.05	3.5	0.03	0.04	0.03	2.1	0.50	11.2	80.2	45.4
I17	05461390	<0.02	<0.20	0.26	0.07	8.3	0.05	0.04	0.05	1.6	0.40	29.1	60.4	30.0
I18	05473060	1.3	2.0	3.5	0.03	0.17	0.78	0.31	0.31	7.5	4.4	101	7.35	18.1
I19	05473400	<0.02	0.41	1.0	<0.01	<0.05	0.14	0.02	0.02	5.5	2.6	49.5	16.2	36.5
I20	05455100	0.02	0.43	0.39	0.01	0.14	0.04	0.04	0.04	4.2	1.1	21.0	39.0	22.3
I21	05421870	<0.02	0.94	1.2	0.36	0.72	0.17	0.09	<0.01	4.0	0.80	17.5	33.1	25.0
I22	05464220	<0.02	0.20	0.57	0.05	3.8	0.05	0.05	0.04	2.4	0.50	14.5	47.2	30.7
I23	05473550	0.08	0.52	1.4	0.01	0.14	0.53	0.23	0.25	5.9	2.7	82.6	75.6	46.2
I24	05452020	<0.02	<0.20	0.56	0.03	2.6	0.06	0.05	0.06	2.4	0.50	10.5	13.2	19.3
I25	05465310	0.14	0.53	1.0	0.02	0.68	0.18	0.05	0.06	4.6	2.0	30.6	58.1	42.9
M01	05319050	<0.02	0.57	1.7	0.01	1.6	0.12	<0.01	<0.01	4.3	4.0	88.7	1.92	36.7
M02	05320270	<0.02	0.74	1.2	0.03	2.9	0.17	0.05	0.05	8.0	3.1	58.5	5.75	30.3
M03	05317828	<0.02	0.31	0.58	0.04	6.4	0.06	0.03	0.04	3.7	0.50	6.3	--	23.4

Table 7. Concentrations of nutrients, organic carbon, chlorophyll *a* in water samples, and periphyton chlorophyll and ash-free dry mass—Continued

[mg/L, milligrams per liter; N, nitrogen; NO_2, nitrite; NO_3, nitrate; P, phosphorus; µg/L, micrograms per liter; mg/m^2, milligrams per square meter; g/m^2, grams per square meter; <, less than; --, no data]

Site number	U.S. Geological Survey station identification	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2 plus NO_3, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Carbon, organic, dissolved (mg/L)	Carbon, organic, suspended (mg/L)	Chlorophyll *a*, seston (µg/L)	Chlorophyll *a*, periphyton (mg/m^2)	Ash-free dry mass, periphyton (g/m^2)
M04	05326150	<0.02	0.80	1.3	0.08	8.6	0.40	0.27	0.24	6.9	0.80	9.2	3.67	16.3
M05	05320450	<0.02	0.53	1.2	0.02	2.6	0.16	0.06	0.07	5.6	1.4	45.9	34.1	25.6
M06	05319360	<0.02	0.50	0.89	0.02	7.6	0.08	0.04	0.05	4.6	0.50	18.9	102	46.3
M07	05326250	0.02	0.75	1.1	0.04	12	0.24	0.16	0.15	7.1	0.50	4.3	20.8	--
M08	05318050	0.08	0.58	1.1	0.04	3.2	0.13	0.05	0.05	5.3	1.5	23.8	11.3	27.4
M09	05318240	0.03	0.64	1.6	0.04	2.1	0.13	<0.01	0.01	5.8	1.6	17.1	1.47	20.6
M10	05320080	0.02	0.70	1.1	0.02	10	0.14	0.09	0.09	6.6	0.70	5.0	37.6	27.6
M11	05317170	<0.02	0.50	0.59	0.02	4.6	0.11	0.07	0.09	4.2	0.90	5.9	18.7	16.7
M12	05304795	0.03	0.53	1.0	0.01	0.21	0.08	<0.01	<0.01	6.2	1.6	28.2	42.2	57.8
M13	05316985	0.02	0.52	0.7	0.03	10	0.06	0.03	0.04	4.3	0.60	12.0	82.4	30.6
M14	05326700	<0.02	0.25	1.2	<0.01	0.64	0.16	0.01	<0.01	9.5	2.1	27.0	1.75	5.16
M15	05312000	<0.02	0.91	1.5	0.07	0.97	0.18	0.14	0.13	8.9	0.60	15.6	42.9	29.8
M18	05320230	<0.02	0.29	1.4	0.03	9.5	0.17	0.03	0.03	5.3	1.0	36.0	17.6	28.2
M19	05303900	<0.02	0.94	1.9	0.02	0.68	0.36	0.07	0.07	11	2.5	10.1	4.38	8.54
M20	05318630	<0.02	0.38	0.68	0.02	5.7	0.09	0.03	0.04	3.8	1.5	13.8	4.82	8.27
M21	05317800	0.02	0.46	0.9	0.05	3.2	0.06	0.02	0.02	4.9	0.70	21.6	70.9	35.7
M22	05318178	<0.02	0.58	1.5	0.02	2.3	0.23	0.10	0.11	5.6	3.2	52.2	23.3	25.6
M23	05314500	0.02	0.64	1.9	0.04	3.8	0.44	0.21	0.23	8.5	5.0	46.8	1.30	32.9
M24	05318138	0.78	2.3	3.7	0.1	0.62	0.19	0.03	0.03	11	1.7	59.9	3.50	19.4
M25	05318800	0.04	0.50	1.4	0.03	8.1	0.44	0.27	0.28	4.8	2.7	18.0	2.52	6.05
M27	05314510	<0.02	0.73	0.95	0.05	13	0.10	0.08	0.06	5.9	0.60	--	--	21.8

Table 8. Concentrations of triazine herbicides and degradation products

[µg/L, micrograms per liter; <, less than]

Site number	U.S. Geological Survey station identification	Atrazine (µg/L)	Deethylatrazine (µg/L)	Deisopropylatrazine (µg/L)	Cyanazine (µg/L)	Cyanazine amide (µg/L)	Hydroxyatrazine (µg/L)	Prometon (µg/L)	Simazine (µg/L)
L01	05554000	0.95	0.13	0.14	0.64	0.24	0.50	<0.05	<0.05
L02	05554490	0.22	0.05	0.08	0.13	0.12	0.50	0.07	<0.05
L03	05556500	0.73	0.10	0.36	0.57	0.06	0.92	0.55	0.20
L04	05559500	0.08	<0.05	<0.05	<0.05	<0.05	0.48	<0.05	<0.05
L05	05563000	0.40	0.10	0.10	0.14	0.12	1.5	0.12	<0.05
L06	05564300	0.09	<0.05	0.05	<0.05	0.05	0.24	<0.05	<0.05
L07	05567500	0.19	0.07	0.07	0.20	0.07	0.25	<0.05	<0.05
L08	05568830	0.37	0.13	0.11	0.09	0.09	1.8	<0.05	<0.05
L09	05569875	0.30	0.13	0.14	0.10	0.10	0.69	0.05	<0.05
L10	05570910	0.13	0.05	0.05	0.12	0.15	0.42	<0.05	<0.05
L12	05575850	0.34	0.18	0.15	<0.05	0.11	7.3	<0.05	<0.05
L15	05580000	0.56	0.11	0.07	<0.05	0.10	0.46	0.07	<0.05
L16	05583900	0.56	0.11	0.09	0.17	0.31	3.2	<0.05	<0.05
L17	05584500	0.56	0.21	0.20	0.14	0.19	1.2	<0.05	<0.05
L18	05585800	1.5	0.39	0.33	0.62	1.2	7.2	<0.05	<0.05
L19	05586598	0.26	0.18	0.17	<0.05	0.18	2.2	<0.05	<0.05
L20	05586645	0.60	0.23	0.15	0.09	0.20	8.8	<0.05	<0.05
L21	05587000	0.28	0.08	0.09	<0.05	<0.05	2.1	<0.05	<0.05
L22	05567000	0.35	0.09	<0.05	0.54	0.15	0.57	<0.05	<0.05
L23	05568000	0.33	<0.05	0.05	0.05	<0.05	<0.20	1.4	<0.05
L24	05568800	0.19	0.10	0.07	<0.05	0.07	0.84	<0.05	<0.05
I01	05451210	0.17	0.13	0.08	<0.05	<0.05	<0.20	<0.05	0.06
I02	05469980	0.17	0.11	0.07	<0.05	<0.05	<0.20	0.09	<0.05
I03	05420680	0.14	0.12	<0.05	<0.05	<0.05	0.27	0.05	<0.05
I04	05456510	0.09	0.06	<0.05	<0.05	<0.05	0.24	<0.05	<0.05
I05	05449500	0.05	<0.05	<0.05	<0.05	<0.05	<0.20	<0.05	<0.05
I06	05462770	0.16	0.12	0.05	<0.05	<0.05	<0.20	<0.05	<0.05

Table 8. Concentrations of triazine herbicides and degradation products—Continued

[µg/L, micrograms per liter; <, less than]

Site number	U.S. Geological Survey station identification	Atrazine (µg/L)	Deethylatrazine (µg/L)	Deisopropylatrazine (µg/L)	Cyanazine (µg/L)	Cyanazine amide (µg/L)	Hydroxyatrazine (µg/L)	Prometon (µg/L)	Simazine (µg/L)
I07	05420720	0.13	0.12	<0.05	<0.05	<0.05	<0.20	<0.05	<0.05
I08	05420900	0.21	0.17	0.09	<0.05	<0.05	0.61	<0.05	<0.05
I09	05471120	0.23	0.12	0.05	0.14	<0.05	<0.20	<0.05	<0.05
I10	05458870	0.17	0.11	0.07	<0.05	<0.05	<0.20	<0.05	<0.05
I11	05459300	0.05	<0.05	<0.05	<0.05	<0.05	<0.20	<0.05	<0.05
I12	05449200	0.71	<0.05	<0.05	<0.05	<0.05	<0.20	<0.05	<0.05
I13	05457950	0.11	0.11	0.06	<0.05	<0.05	<0.20	<0.05	<0.05
I14	05463510	0.13	0.08	0.06	<0.05	<0.05	0.56	<0.05	<0.05
I15	05455500	0.15	0.12	0.10	<0.05	<0.05	0.75	<0.05	<0.05
I16	05421700	0.13	0.16	0.05	<0.05	<0.05	0.36	<0.05	<0.05
I17	05461390	0.19	0.18	0.06	<0.05	<0.05	<0.20	<0.05	<0.05
I18	05473060	0.77	0.17	0.21	0.16	0.14	1.0	<0.05	<0.05
I19	05473400	1.1	0.15	0.16	0.19	0.34	2.6	<0.05	<0.05
I20	05455100	0.18	0.09	0.07	<0.05	0.07	2.2	<0.05	<0.05
I21	05421870	0.25	0.08	0.05	<0.05	<0.05	1.6	<0.05	<0.05
I22	05464220	0.18	0.12	0.08	<0.05	<0.05	0.51	<0.05	<0.05
I23	05473550	0.24	0.10	0.12	<0.05	0.07	0.68	0.07	<0.05
I24	05452020	0.08	0.10	0.13	<0.05	<0.05	0.51	<0.05	<0.05
I25	05465310	0.45	0.17	0.20	0.09	0.23	0.72	<0.05	0.06
M01	05319050	0.05	<0.05	0.05	<0.05	<0.05	<0.20	<0.05	<0.05
M02	05320270	0.11	0.06	<0.05	<0.05	<0.05	0.36	<0.05	<0.05
M03	05317828	0.05	0.05	<0.05	<0.05	<0.05	<0.20	<0.05	<0.05
M04	05326150	0.23	0.08	0.09	<0.05	<0.05	0.35	<0.05	<0.05
M05	05320450	0.05	<0.05	<0.05	<0.05	<0.05	0.26	0.13	<0.05
M06	05319360	<0.05	<0.05	<0.05	<0.05	<0.05	<0.20	0.06	<0.05
M07	05326250	0.19	0.13	0.08	<0.05	<0.05	0.35	<0.05	<0.05
M08	05318050	0.07	0.06	0.07	<0.05	<0.05	0.21	<0.05	<0.05

Table 8. Concentrations of triazine herbicides and degradation products—Continued

[µg/L, micrograms per liter; <, less than]

Site number	U.S. Geological Survey station identification	Atrazine (µg/L)	Deethylatrazine (µg/L)	Deisopropylatrazine (µg/L)	Cyanazine (µg/L)	Cyanazine amide (µg/L)	Hydroxyatrazine (µg/L)	Prometon (µg/L)	Simazine (µg/L)
M09	05318240	<0.05	0.05	<0.05	<0.05	<0.05	<0.20	<0.05	0.05
M10	05320080	0.24	0.26	0.08	0.05	<0.05	0.33	<0.05	<0.05
M11	05317170	0.17	0.05	0.11	0.05	0.10	<0.20	<0.05	<0.05
M12	05304795	<0.05	<0.05	<0.05	<0.05	<0.05	<0.20	<0.05	<0.05
M13	05316985	0.17	0.06	0.34	0.07	0.22	<0.20	<0.05	<0.05
M14	05326700	0.17	0.06	<0.05	<0.05	<0.05	<0.20	<0.05	<0.05
M15	05312000	0.12	0.06	0.22	0.06	0.08	<0.20	<0.05	<0.05
M18	05320230	0.08	0.08	<0.05	<0.05	<0.05	<0.20	<0.05	<0.05
M19	05303900	0.12	0.05	0.06	0.13	0.05	0.23	<0.05	<0.05
M20	05318630	0.10	0.07	0.15	0.12	<0.05	<0.20	<0.05	<0.05
M21	05317800	0.06	<0.05	0.10	<0.05	<0.05	<0.20	<0.05	<0.05
M22	05318178	0.06	<0.05	<0.05	<0.05	<0.05	0.25	0.12	0.05
M23	05314500	0.13	0.06	0.14	0.06	0.06	<0.20	<0.05	<0.05
M24	05318138	0.05	0.05	0.05	<0.05	<0.05	<0.20	<0.05	<0.05
M25	05318800	0.10	0.09	<0.05	<0.05	<0.05	<0.20	<0.05	<0.05
M27	05314510	0.10	0.12	0.33	0.06	0.18	0.30	<0.05	<0.05

Table 9. Concentrations of chloroacetamide herbicides and degradation products

[µg/L, micrograms per liter; ESA, ethanesulfonic acid; <, less than]

Site number	U.S. Geological Survey station identification	Acetochlor (µg/L)	Acetochlor ESA (µg/L)	Acetochlor oxanilic acid (µg/L)	Alachlor ESA (µg/L)	Alachlor oxanilic acid (µg/L)	Metolachlor (µg/L)	Metolachlor ESA (µg/L)	Metolachlor oxanilic acid (µg/L)
L01	05554000	<0.05	<0.20	<0.20	0.31	0.22	0.41	1.3	0.53
L02	05554490	<0.05	<0.20	<0.20	0.24	<0.20	0.05	1.1	0.26
L03	05556500	0.06	0.47	<0.20	0.47	0.45	0.16	1.2	0.47
L04	05559500	<0.05	<0.20	<0.20	<0.20	<0.20	<0.05	0.76	<0.20
L05	05563000	<0.05	0.35	0.72	<0.20	<0.20	0.19	0.82	0.35
L06	05564300	<0.05	<0.20	<0.20	0.22	<0.20	<0.05	1.0	0.24
L07	05567500	<0.05	<0.20	<0.20	<0.20	<0.20	0.06	0.78	<0.20
L08	05568830	<0.05	0.46	0.60	0.26	<0.20	0.14	1.9	0.34
L09	05569875	<0.05	<0.20	0.35	0.23	<0.20	0.11	1.5	0.29
L10	05570910	<0.05	0.21	<0.20	0.39	0.22	0.06	1.1	0.31
L12	05575850	<0.05	0.26	<0.20	0.21	<0.20	0.08	1.7	0.36
L15	05580000	<0.05	<0.20	<0.20	<0.20	<0.20	0.08	1.4	0.29
L16	05583900	<0.05	<0.20	<0.20	0.26	<0.20	0.10	0.99	0.31
L17	05584500	<0.05	0.25	0.29	<0.20	<0.20	<0.05	0.61	<0.20
L18	05585800	<0.05	0.53	0.95	0.27	<0.20	0.16	0.59	0.64
L19	05586598	<0.05	<0.20	<0.20	0.20	<0.20	<0.05	0.40	0.25
L20	05586645	<0.05	0.30	<0.20	0.44	<0.20	0.08	2.6	0.69
L21	05587000	<0.05	<0.20	<0.20	<0.20	<0.20	<0.05	0.39	0.20
L22	05567000	<0.05	<0.20	<0.20	0.29	0.24	<0.05	0.87	0.23
L23	05568000	<0.05	<0.20	<0.20	<0.20	<0.20	0.42	0.37	<0.20
L24	05568800	<0.05	<0.20	0.45	<0.20	<0.20	0.05	2.3	<0.20
I01	05451210	<0.05	0.49	0.28	0.62	0.21	0.09	4.7	0.92
I02	05469980	<0.05	0.41	<0.20	0.70	0.41	0.19	4.0	0.86
I03	05420680	<0.05	0.27	<0.20	2.1	<0.20	0.11	2.3	0.45
I04	05456510	<0.05	0.38	<0.20	1.4	<0.20	0.06	1.8	0.76
I05	05449500	<0.05	<0.20	0.24	1.8	<0.20	<0.05	4.1	0.71
I06	05462770	<0.05	0.82	0.21	3.5	0.28	0.33	6.2	1.1

Table 9. Concentrations of chloroacetamide herbicides and degradation products—Continued

[µg/L, micrograms per liter; ESA, ethanesulfonic acid; <, less than]

Site number	U.S. Geological Survey station identification	Acetochlor (µg/L)	Acetochlor ESA (µg/L)	Acetochlor oxanilic acid (µg/L)	Alachlor ESA (µg/L)	Alachlor oxanilic acid (µg/L)	Metolachlor (µg/L)	Metolachlor ESA (µg/L)	Metolachlor oxanilic acid (µg/L)
I07	05420720	<0.05	0.31	<0.20	2.3	0.54	0.06	2.3	0.50
I08	05420900	0.14	0.55	<0.20	3.2	<0.20	0.12	2.1	0.70
I09	05471120	<0.05	0.59	<0.20	0.23	<0.20	0.06	3.3	0.56
I10	05458870	<0.05	0.37	<0.20	1.3	<0.20	<0.05	3.1	0.46
I11	05459300	<0.05	0.42	<0.20	1.4	<0.20	<0.05	1.2	0.33
I12	05449200	<0.05	0.21	<0.20	3.0	<0.20	<0.05	4.0	0.75
I13	05457950	<0.05	<0.20	<0.20	1.2	<0.20	<0.05	2.5	0.29
I14	05463510	<0.05	<0.20	<0.20	2.2	0.31	0.11	6.7	0.99
I15	05455500	<0.05	<0.20	0.35	1.1	<0.20	0.06	1.3	0.29
I16	05421700	<0.05	0.21	<0.20	1.88	<0.20	<0.05	2.4	0.37
I17	05461390	<0.05	0.37	<0.20	1.09	<0.20	<0.05	3.4	0.28
I18	05473060	<0.05	0.69	0.87	0.66	0.24	0.18	2.8	0.87
I19	05473400	<0.05	0.45	0.53	0.86	0.30	0.11	1.4	0.66
I20	05455100	<0.05	0.34	0.40	1.3	0.29	<0.05	1.6	0.36
I21	05421870	<0.05	0.2	<0.20	1.42	<0.20	0.07	3.1	0.60
I22	05464220	<0.05	<0.20	<0.20	1.40	<0.20	<0.05	3.7	0.38
I23	05473550	<0.05	0.51	0.55	0.48	<0.20	0.06	1.2	0.49
I24	05452020	<0.05	<0.20	<0.20	1.2	<0.20	<0.05	2.2	0.21
I25	05465310	<0.05	0.8	0.61	0.90	<0.20	0.08	1.0	0.40
M01	05319050	<0.05	0.63	0.33	0.54	0.21	<0.05	1.6	<0.20
M02	05320270	<0.05	1.3	0.60	1.0	0.21	0.09	3.8	0.51
M03	05317828	0.21	0.50	<0.20	0.82	<0.20	0.12	4.9	0.71
M04	05326150	<0.05	0.87	0.38	1.5	<0.20	0.12	2.8	1.0
M05	05320450	0.07	0.65	0.31	0.55	0.24	0.24	2.9	0.48
M06	05319360	<0.05	0.84	<0.20	0.45	<0.20	<0.05	2.5	0.31
M07	05326250	<0.05	1.2	0.42	2.0	<0.20	0.12	4.4	1.3

Table 9. Concentrations of chloroacetamide herbicides and degradation products—Continued

[µg/L, micrograms per liter; ESA, ethanesulfonic acid; <, less than]

Site number	U.S. Geological Survey station identification	Acetochlor (µg/L)	Acetochlor ESA (µg/L)	Acetochlor oxanilic acid (µg/L)	Alachlor ESA (µg/L)	Alachlor oxanilic acid (µg/L)	Metolachlor (µg/L)	Metolachlor ESA (µg/L)	Metolachlor oxanilic acid (µg/L)
M08	05318050	<0.05	0.68	0.26	0.82	<0.20	<0.05	1.6	<0.20
M09	05318240	<0.05	0.39	<0.20	0.27	<0.20	<0.05	2.7	0.28
M10	05320080	<0.05	1.6	0.55	1.2	<0.20	0.10	3.8	0.74
M11	05317170	<0.05	0.33	<0.20	0.75	<0.20	0.07	1.4	0.27
M12	05304795	<0.05	<0.20	1.4	0.39	<0.20	<0.05	0.28	<0.20
M13	05316985	<0.05	0.31	<0.20	0.41	<0.20	<0.05	0.93	0.22
M14	05326700	<0.05	0.48	0.36	1.2	<0.20	0.09	1.7	0.70
M15	05312000	<0.05	0.42	0.59	<0.20	<0.20	<0.05	0.63	<0.20
M18	05320230	<0.05	0.73	0.23	1.0	<0.20	<0.05	3.5	0.28
M19	05303900	<0.05	<0.20	<0.20	<0.20	<0.20	<0.05	<0.20	<0.20
M20	05318630	<0.05	0.43	<0.20	0.21	<0.20	<0.05	1.0	<0.20
M21	05317800	<0.05	0.27	<0.20	0.60	<0.20	0.10	2.6	0.48
M22	05318178	<0.05	0.22	<0.20	0.28	<0.20	0.07	1.4	0.28
M23	05314500	<0.05	<0.20	<0.20	0.64	<0.20	<0.05	<0.20	<0.20
M24	05318138	<0.05	0.33	<0.20	0.38	<0.20	<0.05	1.1	<0.20
M25	05318800	<0.05	1.4	0.32	0.96	<0.20	0.09	3.1	0.75
M27	05314510	<0.05	0.38	0.21	2.4	0.35	0.11	3.4	0.96

Table 10. Summary of continuous-monitoring data and estimates of stream productivity and respiration

[°C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; s.u., standard units; mg/L, milligrams per liter; $gO_2/m^3/hr$, grams of oxygen per cubic meter per hour; s.u./hr, standard units per hour; --, no data]

Site number	U.S. Geological Survey station identification	Date in 1997 when continuous measurements were taken	Water temperature, minimum (°C)	Water temperature, maximum (°C)	Specific conductance, median (µS/cm)	pH, median (s.u.)	Dissolved oxygen, minimum (mg/L)	Dissolved oxygen, maximum (mg/L)	Dissolved oxygen, median (mg/L)	Dissolved oxygen, saturation, maximum (percent)	Productivity, maximum ($gO_2/m^3/hr$)	Respiration, maximum ($gO_2/m^3/hr$)	pH, daylight, rate of increase (s.u./hr)	pH, night, rate of decrease (s.u./hr)
L01	05554000	10-Aug	19.7	28.1	714	8.2	3.8	7.9	6.1	94.9	0.34	0.06	0.077	0.014
L02	05554490	10-Aug	21.2	27.1	665	8.3	6.5	13	8	167	0.72	0.20	0.047	0.016
L03	05556500	13-Aug	20.3	25.2	562	7.8	3.5	7.0	5.2	87.7	0.48	0.20	0.048	0.022
L04	05559500	13-Aug	20.9	25.2	744	8.2	4.1	9.3	6.2	114	0.37	0.21	0.053	0.030
L05	05563000	13-Aug	19.5	25.5	564	8.0	6.0	7.8	6.6	93.9	0.12	0.00	0.037	0.006
L06	05564300	16-Aug	22.2	27.7	608	8.6	5.5	14	10	178	0.98	0.36	0.083	0.038
L07	05567500	14-Aug	20.8	24.5	557	8.2	3.4	6.3	4.8	75.6	0.32	0.19	0.038	0.036
L08	05568830	5-Aug	23.0	28.0	529	8.4	1.7	14	6.7	179	1.0	0.18	0.083	0.025
L09	05569875	4-Aug	22.9	28.7	445	8.8	3.5	15	6.7	198	1.0	0.80	0.075	0.078
L10	05570910	16-Aug	21.1	26.5	836	7.7	2.7	5.5	3.9	66.7	0.23	0.11	0.045	0.006
L12	05575850	8-Aug	18.4	21.1	659	7.6	1.2	3.8	2.3	42.7	0.02	0.13	0.002	0.005
L15	05580000	24-Aug	20.5	25.2	604	8.1	5.6	8.7	6.8	104	0.33	0.09	0.042	0.012
L16	05583900	5-Aug	17.4	24.0	573	7.6	4.9	8.5	6	99.5	0.57	0.04	0.025	0.008
L17	05584500	4-Aug	21.6	27.2	550	7.7	5.3	11	6.7	139	0.46	0.07	0.060	0.002
L18	05585800	5-Aug	21.3	29.8	641	8.0	4.3	7.7	6.3	102	0.44	0.27	0.027	0.021
L19	05586598	7-Aug	20.5	24.0	633	7.8	5.0	6.1	5.3	71.9	0.11	0.01	0.012	0.001
L20	05586645	8-Aug	20.9	22.7	644	8.1	3.8	8.6	6	101	0.14	0.26	0.005	0.019
L21	05587000	6-Aug	19.4	29.0	610	7.9	5.3	12	7.6	161	0.73	0.03	0.080	0.009
L22	05567000	15-Aug	21.2	25.5	751	7.9	4.6	7.3	5.3	87.9	0.32	0.01	0.022	0.001
L23	05568000	14-Aug	21.1	24.3	546	8.4	5.0	13	8	161	0.95	0.19	0.018	0.039
L24	05568800	3-Aug	23.4	30.0	665	8.2	3.4	7.6	4.5	101	0.63	0.15	0.033	0.021
I01	05451210	18-Aug	18.8	21.6	--	8.1	8.8	12	9.2	104	0.53	0.05	0.043	0.015
I02	05469980	18-Aug	19.0	22.0	678	8.2	6.6	12	8.1	140	0.69	0.13	0.082	0.019
I03	05420680	28-Aug	20.3	24.5	389	8.0	5.8	8.3	6.4	103	0.32	0.00	0.057	0.009
I04	05456510	27-Aug	19.2	23.6	685	7.6	6.8	9.1	7.9	111	0.28	0.16	0.017	0.010
I05	05449500	13-Aug	17.1	21.3	--	8.2	9.0	16	11	187	0.89	0.13	0.038	0.022
I06	05462770	20-Aug	16.4	23.7	605	8.1	7.5	9.7	8.2	117	0.24	0.00	0.025	0.004
I07	05420720	28-Aug	19.5	23.5	564	7.9	5.2	8.1	6.2	95.8	0.32	0.00	0.045	0.021

Table 10. Summary of continuous-monitoring data and estimates of stream productivity and respiration—Continued

[°C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; s.u., standard units; mg/L, milligrams per liter; $gO_2/m^3/hr$, grams of oxygen per cubic meter per hour; s.u./hr, standard units per hour; --, no data]

Site number	U.S. Geological Survey station identification	Date in 1997 when continuous measure-ments were taken	Water tempera-ture, minimum (°C)	Water tempera-ture, maximum (°C)	Specific conduct-ance, median (µS/cm)	pH, median (s.u.)	Dissolved oxygen, minimum (mg/L)	Dissolved oxygen, maximum (mg/L)	Dissolved oxygen, median (mg/L)	Dissolved oxygen, saturation, maximum (percent)	Productivity, maximum ($gO_2/m^3/hr$)	Respiration, maximum ($gO_2/m^3/hr$)	pH, daylight, rate of increase (s.u./hr)	pH, night, rate of decrease (s.u./hr)
I08	05420900	20-Aug	17.2	23.3	449	8.2	7.0	10	7.8	124	0.44	0.00	0.060	0.023
I09	05471120	19-Aug	19.5	24.3	505	8.2	6.0	11	7.9	130	0.70	0.10	0.100	0.031
I10	05458870	25-Aug	19.2	26.6	589	8.1	7.1	8.9	7.8	105	0.10	0.00	0.032	0.006
I11	05459300	26-Aug	19.9	25.9	603	8.2	6.2	15	8.4	189	1.2	0.19	0.090	0.022
I12	05449200	26-Aug	20	28.9	616	8.3	6.2	17	9	221	1.5	0.33	0.083	0.021
I13	05457950	26-Aug	19.5	22.8	445	8.2	6.8	9.9	7.6	117	0.40	0.01	0.047	0.019
I14	05463510	20-Aug	17.4	22.2	530	8.1	7.4	10	8	117	0.34	0.05	0.047	0.011
I15	05455500	16-Aug	21.7	29.0	493	8.1	5.2	14	8.1	185	1.3	0.23	0.102	0.039
I16	05421700	15-Aug	17.7	27.5	480	8.0	6.1	10	7.2	128	0.34	0.00	0.053	0.006
I17	05461390	26-Aug	14.7	20.9	490	7.9	8.2	11	8.8	120	0.34	0.00	0.058	0.005
I18	05473060	13-Aug	20.4	25.8	624	8.2	4.8	15	7.8	182	1.2	0.13	0.133	0.019
I19	05473400	16-Aug	25.4	30.7	546	8.3	6.0	20	10	248	0.99	0.20	0.061	0.031
I20	05455100	11-Aug	18.7	21.2	494	7.8	7.2	9.7	7.6	108	0.24	0.00	0.062	0.002
I21	05421870	15-Aug	19.2	25.9	549	8.0	5.8	8.7	6.8	106	0.36	0.04	0.042	0.020
I22	05464220	22-Aug	17.0	25.5	576	8.2	6.5	13	7.9	164	0.78	0.00	0.060	0.009
I23	05473550	21-Aug	19.4	24.0	649	7.7	5.1	8.5	6.4	103	0.42	0.11	0.047	0.010
I24	05452020	22-Aug	17.8	23.6	518	8.1	7.2	11	7.9	128	0.38	0.04	0.032	0.014
I25	05465310	13-Aug	19.2	16.8	475	7.8	5.3	12	7.1	145	0.86	0.08	0.087	0.010
M01	05319050	27-Aug	21.4	23.6	756	8.3	7.2	8.6	7.7	105	0.16	0.00	0.008	0.004
M02	05320270	20-Aug	18.3	22.9	604	8.1	4.9	8.7	7.4	97.7	0.20	0.03	0.018	0.006
M03	05317828	29-Aug	19.4	23.0	677	8.1	6.8	9.2	7.5	107	0.18	0.02	0.010	0.001
M04	05326150	29-Aug	18.1	28.0	648	7.9	5.5	12	7.1	159	0.69	0.00	0.035	0.014
M05	05320450	23-Aug	18.3	22.9	675	8.3	7.5	12	8.5	140	0.56	0.12	0.033	0.005
M06	05319360	23-Aug	17.6	22.0	752	8.2	8.0	9.4	8.3	110	0.18	0.00	0.010	0.001
M07	05326250	3-Sep	16.9	23.0	844	8.2	7.8	10	8.6	117	0.28	0.02	0.017	0.009
M08	05318050	1-Sep	17.2	23.1	610	8.3	6.2	11	7.3	138	0.65	0.04	0.032	0.019
M09	05318240	26-Aug	21.2	24.7	710	7.7	6.6	10	7.6	129	0.53	0.04	0.010	0.001
M10	05320080	28-Aug	16.7	18.1	723	7.2	8.4	9.0	8.6	96.2	0.08	0.00	0.005	0.003

Table 10. Summary of continuous-monitoring data and estimates of stream productivity and respiration—Continued

[°C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; s.u., standard units; mg/L, milligrams per liter; $gO_2/m^3/hr$, grams of oxygen per cubic meter per hour; s.u./hr, standard units per hour; --, no data]

Site number	U.S. Geological Survey station identification	Date in 1997 when continuous measure-ments were taken	Water tempera-ture, minimum (°C)	Water tempera-ture, maximum (°C)	Specific conduct-ance, median (µS/cm)	pH, median (s.u.)	Dissolved oxygen, minimum (mg/L)	Dissolved oxygen, maximum (mg/L)	Dissolved oxygen, median (mg/L)	Dissolved oxygen, saturation, maximum (percent)	Productivity, maximum ($gO_2/m^3/hr$)	Respiration, maximum ($gO_2/m^3/hr$)	pH, daylight, rate of increase (s.u./hr)	pH, night, rate of decrease (s.u./hr)
M11	05317170	20-Aug	17.6	21.9	789	8.2	8.1	9.4	8.6	109	0.11	0.00	0.012	0.000
M12	05304795	25-Aug	17.5	22.6	1,510	7.5	5.4	10	6.9	121	0.70	0.17	0.013	0.004
M13	05316985	22-Aug	17.5	22.4	1,210	7.3	7.5	10	8.5	119	0.27	0.05	0.015	0.008
M14	05326700	No Data	--	--	--	--	--	--	--	--	--	--	--	--
M15	05312000	No Data	--	--	--	--	--	--	--	--	--	--	--	--
M18	05320230	20-Aug	17.6	21.1	706	8.1	7.2	8.8	7.8	102	0.20	0.04	0.012	0.006
M19	05303900	16-Aug	18.5	23.0	518	8.1	6.9	7.7	7.4	93.4	0.07	0.00	0.007	0.001
M20	05318630	27-Aug	19.9	24.3	805	8.1	7.1	9.1	7.8	109	0.11	0.00	0.012	0.001
M21	05317800	29-Aug	19.8	26.5	845	7.4	4.5	8.9	6.9	111	0.48	0.30	0.025	0.010
M22	05318178	27-Aug	19.8	27.0	660	8.2	5.8	16	8.2	197	0.66	0.00	0.048	0.004
M23	05314500	25-Aug	18.3	24.3	917	8.3	6.9	11	8.6	135	0.47	0.11	0.052	0.011
M24	05318138	30-Aug	21.4	27.8	522	8.2	4.8	15	6.3	198	1.3	0.00	0.082	0.025
M25	05318800	26-Aug	20.5	25.3	807	8.0	6.8	10	7.7	129	0.36	0.00	0.040	0.010
M27	05314510	3-Sep	16.8	24.3	1,110	8.1	6.5	16	9.7	190	1.2	0.36	0.062	0.015

Table 11. Average width, depth, velocity, water clarity, and canopy conditions

[m, meters; cm/s, centimeters per second; --, no data; >, greater than]

Site number	U.S. Geological Survey station identification	Stream width, wetted channel (m)	Stream width, bankfull (m)	Stream depth, mean (m)	Stream depth, maximum (m)	Velocity, mean (cm/s)	Velocity, maximum (cm/s)	Euphotic-zone depth (m)	Secchi depth (m)	Open canopy angle (degrees)	Canopy shading, Solar Pathfinder (percent)	Canopy shading, spherical densiometer (percent)	Average riparian zone width (m)
L01	05554000	20	45	0.10	0.24	4.9	12	0.24	0.13	155	0	0	0
L02	05554490	45	61	0.66	0.79	1.2	4.0	0.32	0.21	122	9	2	31
L03	05556500	15	35	0.48	1.04	14	58	0.37	0.26	83	23	19	26
L04	05559500	9	30	0.31	0.91	15	58	0.67	0.50	80	41	21	48
L05	05563000	11	34	0.32	0.61	40	83	0.36	0.22	104	23	4	17
L06	05564300	27	31	0.44	0.76	5.2	13	0.58	0.36	87	16	12	35
L07	05567500	27	47	0.42	0.94	34	86	0.61	0.30	90	25	15	33
L08	05568830	15	27	0.50	0.70	27	45	0.35	0.17	79	30	35	5
L09	05569875	21	28	1.16	1.28	6.4	9.1	0.57	0.38	52	70	58	>50
L10	05570910	17	22	0.41	0.82	7.3	15	0.60	0.38	40	53	40	34
L12	05575850	7	15	0.16	0.24	0.0	0.0	0.37	0.27	0	97	95	32
L15	05580000	11	22	0.28	0.49	24	61	0.54	0.34	58	51	27	30
L16	05583900	11	23	0.36	1.00	0.0	0.0	0.50	0.44	84	38	29	18
L17	05584500	18	33	1.05	1.22	0.0	0.0	0.44	0.31	45	29	38	27
L18	05585800	19	38	0.41	0.85	2.4	11	0.39	0.31	67	34	42	16
L19	05586598	8	25	0.37	1.07	13	36	0.61	0.37	17	86	76	38
L20	05586645	17	22	0.46	0.80	0.0	0.0	0.51	0.27	90	30	37	18
L21	05587000	13	40	0.13	0.27	18	36	0.32	--	74	13	11	>50
L22	05567000	9	17	0.29	0.49	5.2	27	0.61	--	3	80	85	35
L23	05568000	32	57	0.64	1.20	26	47	0.54	0.29	137	4	1	37
L24	05568800	9	17	0.24	0.43	35	150	0.38	0.28	62	51	38	9
I01	05451210	11	21	0.17	0.30	30	51	0.69	--	107	9	9	32
I02	05469980	12	17	0.43	0.66	12	39	0.91	--	54	62	38	49
I03	05420680	18	21	0.51	1.16	19	33	1.20	--	53	71	52	42
I04	05456510	17	21	0.82	0.98	15	18	0.91	0.18	116	14	2	30
I05	05449500	27	--	0.50	0.75	18	37	0.52	--	79	--	--	--

Table 11. Average width, depth, velocity, water clarity, and canopy conditions—Continued

[m, meters; cm/s, centimeters per second; --, no data; >, greater than]

Site number	U.S. Geological Survey station identification	Stream width, wetted channel (m)	Stream width, bankfull (m)	Stream depth, mean (m)	Stream depth, maximum (m)	Velocity, mean (cm/s)	Velocity, maximum (cm/s)	Euphotic-zone depth (m)	Secchi depth (m)	Open canopy angle (degrees)	Canopy shading, Solar Pathfinder (percent)	Canopy shading, spherical densiometer (percent)	Average riparian zone width (m)
I06	05462770	11	24	0.32	0.65	37	51	0.54	--	107	3	9	12
I07	05420720	20	25	0.52	0.85	16	39	0.78	--	29	77	63	23
I08	05420900	18	30	0.21	0.49	26	49	0.86	--	88	39	4	>50
I09	05471120	7	26	0.10	0.27	20	35	0.63	0.61	66	47	31	21
I10	05458870	10	16	0.29	0.73	34	45	0.54	0.43	104	19	24	40
I11	05459300	18	23	0.48	0.66	27	46	0.49	0.27	82	29	4	26
I12	05449200	14	21	0.36	0.61	21	38	0.39	0.18	104	25	1	39
I13	05457950	15	23	0.26	0.43	38	56	1.30	--	77	27	15	>50
I14	05463510	18	24	0.48	0.98	17	38	0.82	0.82	75	31	13	>50
I15	05455500	26	29	0.40	0.70	12	18	0.70	0.32	61	23	22	>50
I16	05421700	17	24	0.26	0.53	36	59	1.00	--	66	70	48	36
I17	05461390	9	12	0.32	0.46	26	38	0.77	--	30	61	52	35
I18	05473060	12	18	0.29	0.44	22	49	0.50	0.23	114	56	62	47
I19	05473400	21	31	0.25	0.41	17	33	0.57	0.34	86	41	7	>50
I20	05455100	15	23	0.11	0.16	17	35	0.67	--	59	80	30	47
I21	05421870	12	18	0.34	0.45	15	27	0.61	0.40	27	78	44	>50
I22	05464220	24	33	0.20	0.43	31	42	0.61	--	152	3	1	26
I23	05473550	10	17	0.16	0.36	20	40	0.27	0.21	53	57	39	24
I24	05452020	12	21	0.39	0.90	28	48	0.66	0.61	18	99	80	21
I25	05465310	13	16	0.28	0.67	9.2	30	0.48	0.30	100	19	9	7
M01	05319050	10	--	0.31	0.58	17	25	0.76	--	10	88	90	45
M02	05320270	16	--	0.31	0.52	43	66	0.84	--	8	86	79	48
M03	05317828	10	--	0.37	0.55	31	51	0.30	--	30	80	66	37
M04	05326150	12	--	0.61	1.04	31	51	0.51	--	33	65	46	>50
M05	05320450	18	--	0.63	0.85	10	20	0.56	--	105	12	67	29
M06	05319360	13	--	0.34	0.49	19	27	0.51	--	78	17	19	>50

Table 11. Average width, depth, velocity, water clarity, and canopy conditions—Continued

[m, meters; cm/s, centimeters per second; --, no data; >, greater than]

Site number	U.S. Geological Survey station identification	Stream width, wetted channel (m)	Stream width, bankfull (m)	Stream depth, mean (m)	Stream depth, maximum (m)	Velocity, mean (cm/s)	Velocity, maximum (cm/s)	Euphotic-zone depth (m)	Secchi depth (m)	Open canopy angle (degrees)	Canopy shading, Solar Pathfinder (percent)	Canopy shading, spherical densiometer (percent)	Average riparian zone width (m)
M07	05326250	13	--	0.53	1.07	17	36	0.74	--	30	34	67	16
M08	05318050	11	--	0.40	0.55	37	51	0.76	--	23	62	33	>50
M09	05318240	12	--	0.34	0.76	27	45	0.72	--	65	60	46	37
M10	05320080	15	--	0.51	0.73	58	82	1.40	--	52	25	35	>50
M11	05317170	11	--	0.44	0.76	27	58	0.41	--	58	47	34	41
M12	05304795	8	--	0.41	0.76	0.0	0.0	0.56	--	52	49	34	35
M13	05316985	13	--	0.54	0.73	50	61	0.61	--	150	0	0	38
M14	05326700	9	--	0.32	0.43	36	50	0.46	--	146	0	0	34
M15	05312000	12	--	0.42	0.79	9.4	15	0.56	--	108	16	8	23
M18	05320230	13	--	0.29	0.43	0.0	0.0	0.63	--	159	1	0	38
M19	05303900	16	--	0.75	0.98	22	37	0.66	--	158	0	0	32
M20	05318630	10	--	0.35	0.46	40	52	0.51	--	142	7	9	43
M21	05317800	10	--	0.34	0.44	22	48	0.25	--	123	16	0	14
M22	05318178	12	--	0.29	0.58	20	42	0.38	--	158	4	5	47
M23	05314500	15	--	0.56	0.91	28	47	0.36	--	142	24	9	25
M24	05318138	9	--	0.17	0.40	26	53	0.28	--	172	0	0	22
M25	05318800	7	--	0.70	0.82	43	59	0.61	--	150	2	0	>50
M27	05314510	10	--	0.32	0.43	41	62	0.76	--	148	0	0	30

Table 12. Average stream-bottom substrate, bank-stability, and riparian-vegetation cover conditions

[--, no data]

Site number	U.S. Geological Survey station identification	Bottom material, percent clay	Bottom material, percent silt	Bottom material, percent sand	Bottom material, percent gravel	Bottom material, percent cobble	Bottom material, percent boulder	Bank stability index	Riparian-zone cover, percent trees	Riparian-zone cover, percent shrubs	Riparian-zone cover, percent grass	Riparian-zone cover, percent forbs	Riparian-zone cover, percent crops	Riparian-zone cover, percent bare soil or other
L01	05554000	50	19	30	1	0	0	13	0	0	39	1	49	11
L02	05554490	14	46	17	13	10	0	13	8	12	39	33	0	9
L03	05556500	1	10	42	20	21	7	14	6	8	47	28	0	11
L04	05559500	0	10	31	29	30	0	14	5	1	2	89	0	3
L05	05563000	2	17	44	34	4	0	15	5	8	5	50	15	17
L06	05564300	0	4	54	23	5	13	14	9	8	20	54	0	10
L07	05567500	0	3	47	22	28	0	14	3	7	30	37	0	24
L08	05568830	0	8	48	28	17	0	12	18	6	18	40	17	3
L09	05569875	8	83	10	0	0	0	16	8	8	23	52	0	9
L10	05570910	15	10	23	31	21	0	12	9	8	29	34	0	21
L12	05575850	13	84	4	0	0	0	15	5	0	40	46	0	9
L15	05580000	0	6	41	46	8	0	15	8	4	12	63	0	13
L16	05583900	8	3	79	12	0	0	14	5	9	25	53	5	3
L17	05584500	3	33	39	10	15	0	17	4	10	21	43	5	18
L18	05585800	0	8	60	5	26	1	16	1	7	18	54	0	20
L19	05586598	0	29	14	28	30	0	15	9	7	19	59	0	6
L20	05586645	0	28	63	8	0	0	14	3	3	47	15	14	18
L21	05587000	3	17	55	26	0	0	15	6	4	43	34	0	13
L22	05567000	0	35	26	39	1	0	12	5	3	35	54	0	5
L23	05568000	0	12	82	5	1	0	16	8	3	52	33	1	4
L24	05568800	7	47	29	16	2	0	14	6	6	37	24	23	5
I01	05451210	1	0	71	24	5	0	14	6	29	23	30	0	12
I02	05469980	1	22	29	19	28	0	12	9	7	23	41	0	18
I03	05420680	1	7	84	9	0	0	14	6	3	32	32	0	28
I04	05456510	7	35	20	28	9	0	10	3	3	51	29	0	16

Table 12. Average stream-bottom substrate, bank-stability, and riparian-vegetation cover conditions—Continued

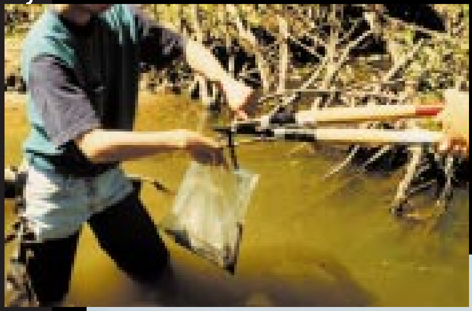
[--, no data]

Site number	U.S. Geological Survey station identification	Bottom material, percent clay	Bottom material, percent silt	Bottom material, percent sand	Bottom material, percent gravel	Bottom material, percent cobble	Bottom material, percent boulder	Bank stability index	Riparian-zone cover, percent trees	Riparian-zone cover, percent shrubs	Riparian-zone cover, percent grass	Riparian-zone cover, percent forbs	Riparian-zone cover, percent crops	Riparian-zone cover, percent bare soil or other
I05	05449500	0	63	25	12	0	0	10	--	--	--	--	--	--
I06	05462770	0	2	93	2	2	0	13	3	7	74	16	0	0
I07	05420720	0	19	80	1	0	0	12	6	8	31	42	0	12
I08	05420900	0	0	98	2	0	0	12	6	10	23	35	0	26
I09	05471120	0	0	75	20	5	0	12	12	5	34	21	0	28
I10	05458870	0	8	85	8	0	0	13	4	1	32	52	0	11
I11	05459300	0	2	32	20	47	0	12	3	8	19	51	0	19
I12	05449200	28	28	44	0	0	0	10	6	8	22	54	0	10
I13	05457950	0	4	76	19	1	0	14	5	6	15	52	0	21
I14	05463510	0	13	65	14	7	0	12	6	3	16	68	0	8
I15	05455500	0	30	59	10	0	0	15	7	0	35	48	0	8
I16	05421700	0	3	38	11	47	0	14	4	22	9	46	0	18
I17	05461390	35	12	46	5	1	0	10	6	5	22	48	0	19
I18	05473060	0	11	48	7	35	0	12	6	10	28	38	0	17
I19	05473400	11	35	44	8	2	0	11	13	18	21	32	0	16
I20	05455100	0	28	72	0	0	0	15	10	3	36	29	22	0
I21	05421870	26	38	37	0	0	0	11	6	2	52	27	0	12
I22	05464220	0	2	91	4	3	0	11	1	1	86	11	0	1
I23	05473550	0	18	52	14	16	0	10	8	10	8	49	1	23
I24	05452020	0	14	73	12	0	0	11	6	2	9	56	0	28
I25	05465310	7	23	66	4	0	0	12	4	4	23	39	8	20
M01	05319050	0	22	72	0	0	6	14	8	1	--	79	0	12
M02	05320270	0	44	12	34	9	0	13	4	0	--	54	17	24
M03	05317828	0	33	16	49	1	1	13	5	10	--	80	0	6
M04	05326150	0	1	46	17	17	19	12	6	5	--	57	0	32
M05	05320450	0	53	25	22	0	0	12	3	7	--	90	0	0

Table 12. Average stream-bottom substrate, bank-stability, and riparian-vegetation cover conditions—Continued

[--, no data]

Site number	U.S. Geological Survey station identification	Bottom material, percent clay	Bottom material, percent silt	Bottom material, percent sand	Bottom material, percent gravel	Bottom material, percent cobble	Bottom material, percent boulder	Bank stability index	Riparian-zone cover, percent trees	Riparian-zone cover, percent shrubs	Riparian-zone cover, percent grass	Riparian-zone cover, percent forbs	Riparian-zone cover, percent crops	Riparian-zone cover, percent bare soil or other
M06	05319360	0	1	38	38	24	0	12	8	27	--	62	0	5
M07	05326250	0	12	10	31	28	19	13	6	39	--	22	17	16
M08	05318050	0	53	44	3	0	0	12	1	0	--	92	0	7
M09	05318240	0	10	88	0	0	2	12	3	10	--	73	0	13
M10	05320080	0	16	31	44	3	6	12	4	2	--	83	0	10
M11	05317170	0	37	9	44	9	0	12	5	15	--	72	0	8
M12	05304795	0	11	29	28	11	21	14	0	27	--	73	0	0
M13	05316985	0	22	59	16	0	3	14	0	0	--	100	0	0
M14	05326700	0	35	58	6	1	0	12	0	17	--	83	0	0
M15	05312000	0	100	0	0	0	0	10	1	1	--	98	0	0
M18	05320230	0	100	0	0	0	0	12	0	0	--	100	0	0
M19	05303900	0	100	0	0	0	0	11	0	0	--	78	5	17
M20	05318630	0	13	78	6	0	3	14	2	2	--	91	0	5
M21	05317800	0	47	22	31	0	0	12	4	21	--	66	5	2
M22	05318178	0	13	20	61	6	0	12	7	0	--	83	0	10
M23	05314500	0	25	31	18	3	25	14	1	0	--	98	0	1
M24	05318138	0	38	44	14	3	0	12	0	0	--	100	0	0
M25	05318800	0	72	28	0	0	0	11	0	1	--	99	0	0
M27	05314510	0	0	56	44	0	0	12	0	0	--	100	0	0



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