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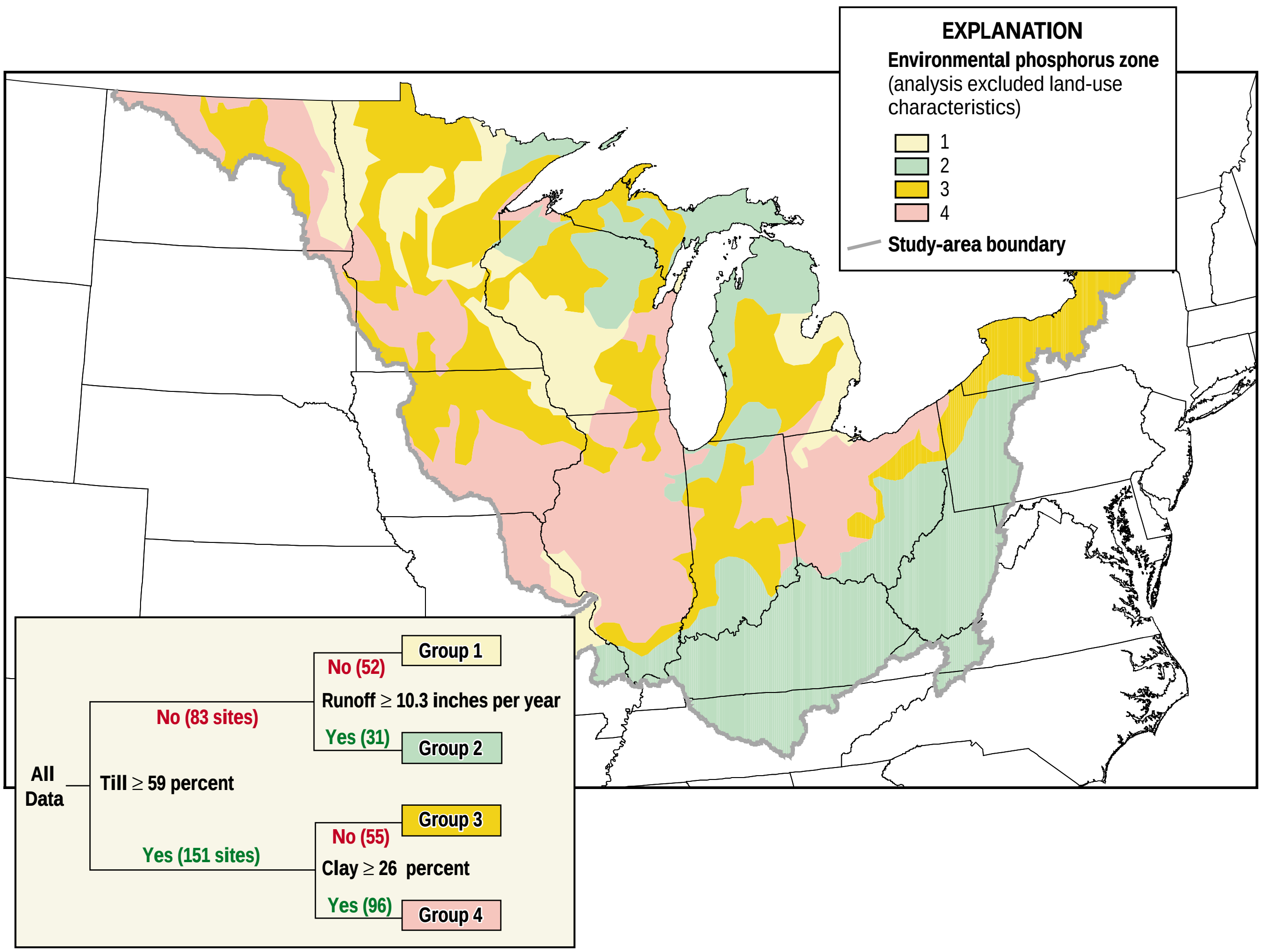
An Alternative Regionalization Scheme for Defining Nutrient Criteria for Rivers and Streams

Water-Resources Investigations Report 01–4073



Prepared in cooperation with the

U.S. Environmental Protection Agency,
Regions V and VII

USGS
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An Alternative Regionalization Scheme for Defining Nutrient Criteria for Rivers and Streams

By Dale M. Robertson, David A. Saad, and Ann M. Wieben

U.S. GEOLOGICAL SURVEY
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Prepared in cooperation with the
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2001

science for a changing world

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To Obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

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

Other Abbreviations

mg/L milligrams per liter

in/hr inches per hour

in/yr inches per year

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An Alternative Regionalization Scheme for Defining Nutrient Criteria for Rivers and Streams

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Abstract

To protect and manage rivers and streams (hereafter, collectively referred to as streams) in the United States, the U.S. Environmental Protection Agency (USEPA) is establishing regionally based nutrient criteria that reflect the natural variability in water quality. As a basic approach to establish these criteria, the USEPA has divided the country into nutrient ecoregions (delineated on the basis of natural and anthropogenic factors) to minimize variability within regions and maximize variability among regions. The USEPA has allowed states and tribes flexibility to modify or improve on this basic approach. As part of activities of a Regional Technical Assistance Group, whose role it is to examine and refine this basic approach, an alternative regionalization scheme was developed for the Upper Midwest. In this refined approach, the relative importance of various environmental characteristics affecting nutrient concentrations are determined by use of regression-tree analysis. The area is then subdivided into relatively homogeneous areas called "environmental nutrient zones" on the basis of distributions of only the most statistically significant environmental characteristics.

On the basis of data from 234 sites, the most statistically significant environmental characteristics affecting nutrient concentrations were the percentage of agriculture (or absence of forest) and factors describing the climate and geology in the watershed. Environmental nutrient zones were then delineated that incorporated distributions in land use (similar to the ecoregion approach) and also delineated with land-use information excluded so the criteria should reflect only the naturally occurring variability in water quality. With the environmental nutrient zone stratification scheme, the variability in total phosphorus concentrations among zones was reduced by approximately 50 percent compared to that among nutrient ecoregions, whereas the variability in total nitrogen concentrations was reduced only slightly. Frequency distributions of data from each zone were then used to define the potential water quality of each zone.

The environmental nutrient zone approach can be applied to specific states or nutrient ecoregions and used to develop criteria as a function of stream type. This approach can also be applied on the basis of environmental characteristics of the watershed alone rather than the general environmental characteristics from the region in which the site is located. The environmental nutrient zone approach will enable states to refine the basic nutrient criteria established by the USEPA by developing attainable criteria given the environmental characteristics where the streams are located.

INTRODUCTION

High concentrations of nutrients in surface waters is not a new problem, but it is among the most persistent water-quality problems in the Nation. According to the U.S. Environmental Protection Agency (USEPA), 50 states, tribes, and other jurisdictions surveyed water-quality conditions in 19 percent of the Nation's 3.6 million miles of rivers and streams (hereafter, collectively referred to as streams) and found nutrient enrichment to be the second most significant cause of water-quality impairment (U.S. Environmental Protection Agency, 1996). Excessive concentrations of nutrients can cause nuisance levels of algae and aquatic vegetation, and they have been linked to eutrophication of downstream impoundments, outbreaks of *Pfiesteria* in several Gulf and Mid-Atlantic states, and hypoxia in the Gulf of Mexico. Under the recommendations of the Clean Water Action Plan released in 1998, USEPA is implementing a national strategy to develop waterbody-specific nutrient criteria (U.S. Environmental Protection

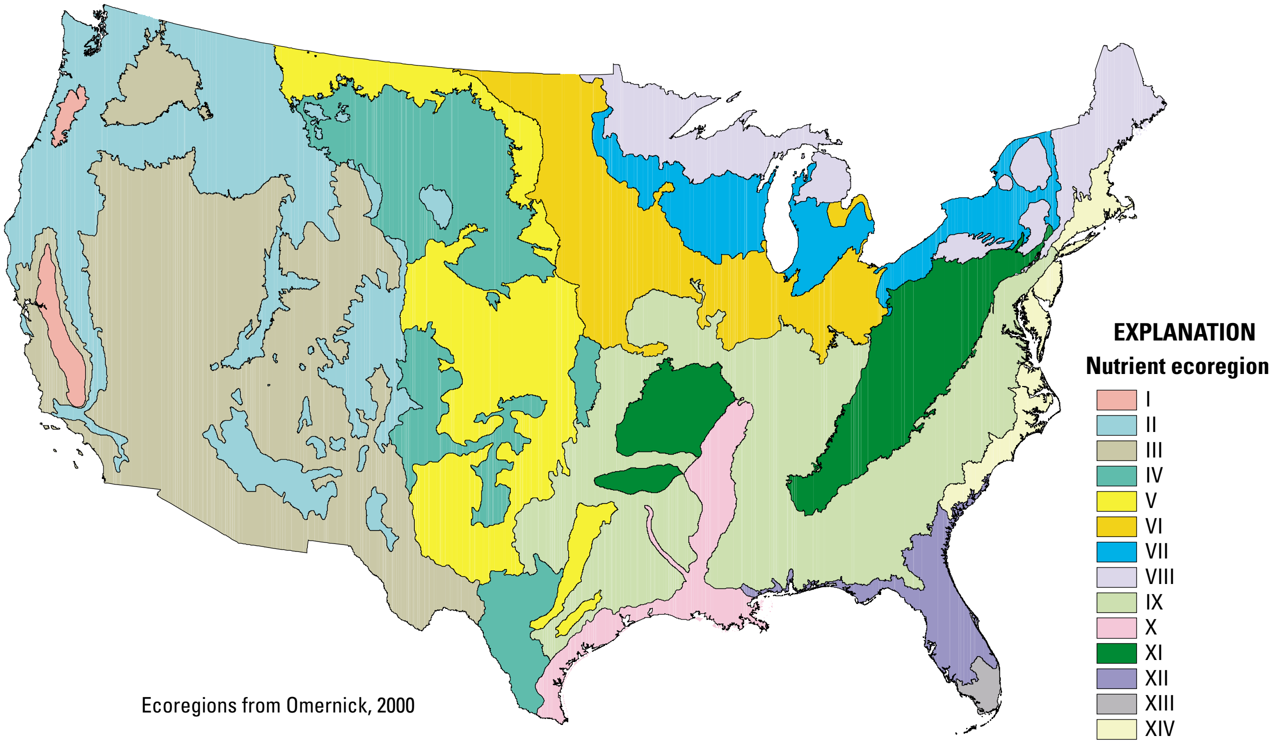


Figure 1. Fourteen nutrient ecoregions delineated for the U.S. Environmental Protection Agency National Nutrient Strategy.

Agency, 1998) for lakes and reservoirs, streams, wetlands, and estuaries; this report is concerned with those criteria for streams. The intent of this strategy was to set out a plan for developing water-quality criteria protective of the uses designated for the surface waters of the Nation. The most effective way to attain the water quality required for the designated uses of surface waters, is to reduce the nutrient contributions due to human activities rather than that from natural loadings. Thus, appropriate nutrient criteria will not be identical for all areas of the Nation, but they will differ regionally and reflect natural nutrient sources.

Factors such as land use, geology, climate, and hydrology play significant roles in water quality. Because these factors vary greatly across the Nation, regional nutrient criteria make sense scientifically. Various frameworks have been used to divide the country into areas of relatively similar environmental characteristics in order to minimize the natural variability in water quality within these areas and maximize the differences among areas. One such framework is the ecoregion scheme developed and refined by Omernik (1987, 1995, and 2000). The ecoregion scheme is a mapped classification system of “ecological regions”; that is, regions with assumed relative homogeneity of ecological characteristics. These regions were defined on the basis of relative differences in land use/land cover, land-surface form, geology, physiography, climate, soils, potential natural vegetation, and other environmental characteristics. The USEPA has taken the initial step in developing regional nutrient criteria based on a national nutrient ecoregion map constructed by combining Omernik’s 84 Level III ecoregions into 14 subdivisions for the conterminous United States (Omernik, 2000; fig. 1).

The use of ecoregions in developing regional nutrient criteria has several inherent problems. First, the relative weighting of each environmental characteristic is

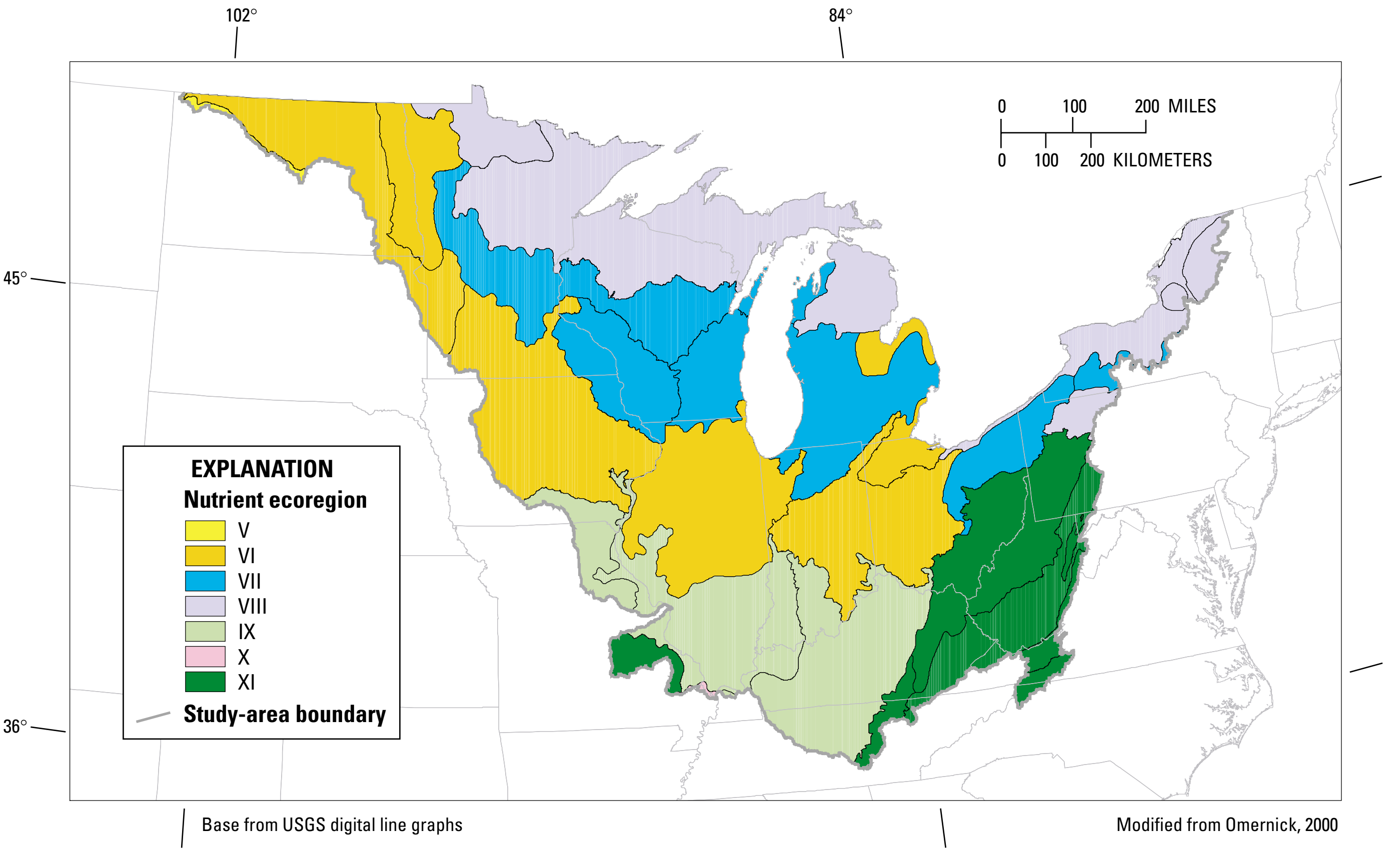


Figure 2. Nutrient ecoregions in the study area. (Black lines within nutrient ecoregions delineate Omernik's Level III ecoregions.)

unknown and varies from boundary to boundary in an unknown way. Therefore, divisions among ecoregions can be rather arbitrary, and differences in water quality among ecoregions can be difficult to attribute to any specific environmental factor. In addition, because the most important environmental characteristic used to delineate the nutrient ecoregions may not be the primary factor affecting water quality, greater variations in water quality may occur within an ecoregion than among ecoregions. Finally, the USEPA has stated that, to the extent possible, classification of environmental characteristics should be restricted to those that are intrinsic, or natural, and are not the result of human activities (U.S. Environmental Protection Agency, 2000a). Nutrient criteria for relatively homogeneous areas should reflect differences in water quality caused by natural factors. Land use, however, was commonly the most important characteristic in subdividing various ecoregions. Differences in land use was the primary factor used to subdivide the Upper Midwest part of the United States in the 14-ecoregion scheme. Because of these inherent problems with ecoregions, subdivision or refinement of the basic delineation may be necessary in some or all of them.

Purpose and Scope

The USEPA has provided its administrative regions flexibility to refine this approach by establishing Regional Technical Assistance Groups (RTAGs), whose roles are to evaluate and possibly refine the boundaries of these relatively homogeneous areas and corresponding nutrient criteria (U.S. Environmental Protection Agency, 2000b). As part of RTAG efforts, the U.S. Geological Survey (USGS), in cooperation with the USEPA, assessed and refined the basic nutrient ecoregion approach for the Upper Midwest area of the United States (fig. 2). This report describes the results of this

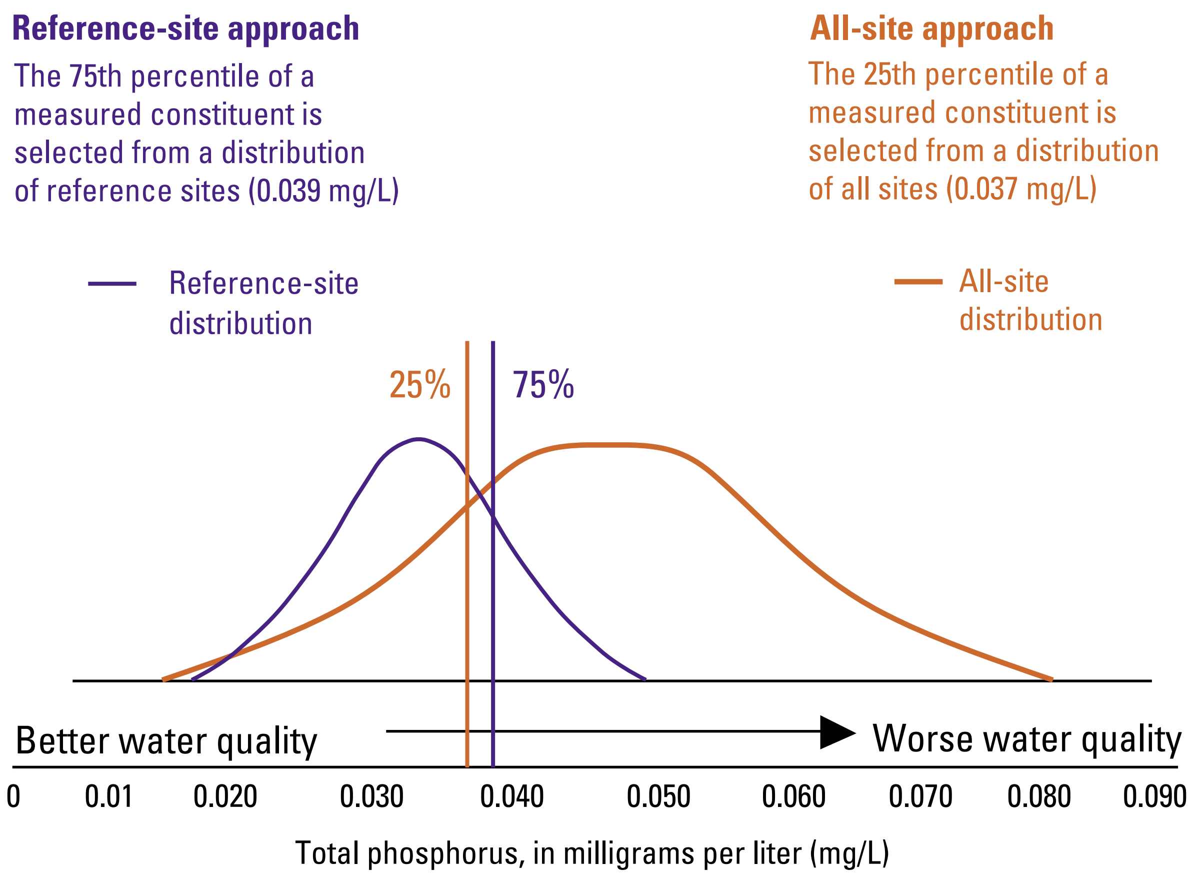


Figure 3. Reference-condition approach for selection of nutrient criteria on the basis of the frequency distribution of water quality for an entire data set (25th percentile of all sites) and that for reference streams (75th percentile of reference sites). (Total phosphorus is shown as an example. The final criteria could be between 0.037 and 0.039 milligrams per liter, if a combination of these two approaches is used.)

effort and describes an alternative regionalization scheme developed by use of regression-tree analyses and a geographic information system (GIS). Various modifications to the method are also presented that would enable states or USEPA administrative regions to apply the method at different geographic scales and locations.

Establishing Specific Nutrient Criteria

The primary factors that determine the productivity of streams are nutrient concentrations (usually phosphorus and nitrogen), light availability, and flow regime (sufficient time to respond to nutrient concentrations). Four variables have been chosen to define specific nutrient criteria: two causal variables, total phosphorus and total nitrogen concentrations; and two response variables, chlorophyll *a* concentrations and a measure of turbidity. In this report, the causal variables, concentrations of total phosphorus and total nitrogen are examined.

Several approaches have been suggested to define quantitative nutrient criteria after relatively homogenous geographic areas are chosen. The basic approach currently used by the USEPA to define criteria involves assigning a concentration value to reference streams from each specific area; in other words, the conditions that are attainable given the geographic location of the site (U.S. Environmental Protection Agency, 2000b). This concentration value can be defined from the frequency distribution of all available data for each area. (On a national basis, these data have been obtained primarily from USEPA Storage and Retrieval, STORET, database plus data from other sources including the USGS, universities, etc.) The lower 25th percentile of all the data has been suggested as representing this reference, or minimally impacted, condition (fig. 3). Another statistical approach to define reference conditions is to choose the upper 75th percentile of a subset of streams thought to be the least impacted streams for a defined area (fig. 3). The final criteria could be between these two concentrations, if a combination of these two approaches is used. States or tribes also may consider analyzing stream data based on designated-use classifications. Using this approach, frequency distributions for specific designated uses could be examined and criteria proposed based on maintenance of high-quality streams that are representative of each designated use (U.S. Environmental Protection Agency, 2000b).

An alternative approach to define the nutrient criteria is to base them on nutrient concentrations associated with specific thresholds of algal productivity found in previous studies (U.S. Environmental Protection Agency, 2000b). In most studies, however, productivity thresholds were at very low nutrient concentrations, lower than those that occur naturally in many areas. Another approach is to base the criteria on the response variables (chlorophyll *a* concentrations or turbidity).

Whatever approach is used, the final criteria must be stringent enough to protect not only the specific site but also downstream waters.

APPROACH, DATA, AND STUDY METHODS

To evaluate the basic nutrient ecoregion classification scheme and understand the relation between water-quality and watershed characteristics, a reliable set of water-quality data was needed with corresponding environmental-characteristic information for each site. Use of the vast body of historically collected water-quality data is appealing; however, the data represent samples collected in many different ways and for many different reasons. The quality of some of these data is suspect, and exactly what these data represent is difficult or impossible to ascertain without a detailed evaluation. Therefore, a database was established with data from 234 sites, all of which were sampled for defined reasons by means of acceptable techniques. For each site, the watershed was delineated and the environmental characteristics were determined by use of a GIS.

Correlations, stepwise linear regressions, and regression-tree analyses (including and excluding land-use variables) were used to determine the most statistically significant environmental characteristics affecting nutrient (phosphorus and nitrogen) concentrations in the Upper Midwest. Results of the regression-tree analyses, which included only the most statistically significant environmental variables affecting total phosphorus or nitrogen concentrations, were then used to subdivide the Upper Midwest into discrete environmental nutrient zones. Water-quality variability within the ecoregions were compared with that within the environmental nutrient zones to determine whether the refined approach better defines the measured distribution in water quality. For each environmental nutrient zone, a range in possible nutrient criteria were developed from the 25th percentile of nutrient concentrations for all of the streams in that zone and the 75th percentile of the minimally impacted streams, on the basis of the percentage of agriculture in the watershed, from the nutrient zone. As an example of how different criteria can be established for specific types of streams within a specific nutrient zone, the streams were subdivided on the basis of how the land around the stream was being used. Four groups were created on the basis of the percentage of agriculture in the watershed.

Water-Quality Data

Water-quality data for this analysis were limited to total phosphorus and total nitrogen concentrations measured in water samples collected from 234 streams in the study area during 1961–99. Concentrations of total nitrogen were either measured directly or computed from the sum of concentrations of individual nitrogen species. Concentrations of total phosphorus were determined for all 234 streams, but total nitrogen could be determined for only 152 streams. A summary of the basic statistics for total phosphorus and total nitrogen are given in table 1.

Of the 234 streams included in this study, 75 streams were sampled by the Illinois Environmental Protection Agency (IEPA) between 1980 and 1995; 48 streams were sampled by the Wisconsin Department of Natural Resources (WDNR) between 1961 and 1998; and 111 streams were sampled by the USGS between 1964 and 1999. Of those sampled by the USGS, 74 streams were sampled from 11 study units in the National Water-Quality Assessment (NAWQA) program (Hirsch and others, 1988) between 1992 and 1999; 15 streams that are part of the Upper Mississippi River System study (U.S. Geological Survey, 1999) were sampled between 1973 and 1998; 7 streams in Wisconsin and Minnesota were sampled from 1997 to 1999 as part of a study of the St. Croix River Watershed

Table 1. Summary statistics for water-quality constituents and environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, 1961–99

[°F, degrees Fahrenheit; ft, feet; K_f, K factor; in/hr, inches per hour; in/yr, inches per year; mg/L, milligrams per liter; mi^2, square miles; %, percent]

Constituent or characteristic	Abbreviation	Units	Number	Mean	Standard deviation	Maximum	Median	Minimum
Water-quality constituents								
Total phosphorus	Total P	mg/L	234	0.17	0.25	2.16	0.11	0.01
Total nitrogen	Total N	mg/L	152	3.61	3.08	13.18	2.26	.34
Basin characteristics								
Area	Area	mi^2	234	429.8	1,032.4	11,628.9	157.5	1.5
Runoff	Roff	in/yr	234	10.28	5.01	40.00	9.00	.30
Climatic characteristics								
Precipitation	Prec	in/yr	234	35.6	5.3	55.0	37.0	17.5
Air temperature	Temp	°F	234	48.1	4.6	56.3	48.8	38.5
Land-use characteristics								
Urban	Urbn	%	234	5.7	14.8	96.1	1.2	.0
Agriculture	Agri	%	234	70.4	28.6	99.7	83.2	.0
Rangeland	Rang	%	234	.1	.7	10.1	.0	.0
Forest	Fors	%	234	20.2	25.0	99.3	8.0	.0
Water	Watr	%	234	.6	1.5	13.1	.2	.0
Forested wetland	Fwet	%	234	1.7	4.3	33.6	.0	.0
Nonforested wetland	Nwet	%	234	.6	1.7	15.6	.0	.0
Barren land	Barr	%	234	.7	2.5	28.5	.1	.0
Surficial-deposit characteristics								
Coarse-grained stratified sediments	Coar	%	234	11.8	17.9	100.0	4.2	.0
Fine-grained stratified sediments	Fine	%	234	3.2	9.6	90.0	.0	.0
Till	Till	%	234	64.2	36.7	100.0	81.5	.0
Patchy Quaternary sediments	Patc	%	234	2.3	10.9	100.0	.0	.0
Exposed bedrock or nonglacial sediments	Xbed	%	234	18.2	36.1	100.0	.0	.0
Organic-rich sediments	Orga	%	234	.2	1.3	14.9	.0	.0
Thickness (depth to bedrock)	Dbed	ft	234	92.0	79.2	427.7	63.8	25.0
Soil characteristics								
Clay content	Clay	%	234	24.1	7.5	41.9	25.7	3.2
Erodibility factor	K_f		234	.31	.06	.42	.32	.13
Organic-matter content	Omat	%	234	2.74	3.51	27.03	1.27	.23
Permeability	Perm	in/hr	234	2.22	1.83	11.39	1.58	.41
Soil slope	Slop	%	234	6.90	6.42	45.52	4.88	.64
Principal aquifer types								
Sandstone	Sdst	%	234	49.2	44.6	100.0	43.9	.0
Carbonate	Carb	%	234	18.0	35.3	100.0	.0	.0
Sandstone and carbonate	Sscb	%	234	5.8	17.6	100.0	.0	.0
No principal aquifer	Noaq	%	234	27.0	37.4	100.0	.0	.0

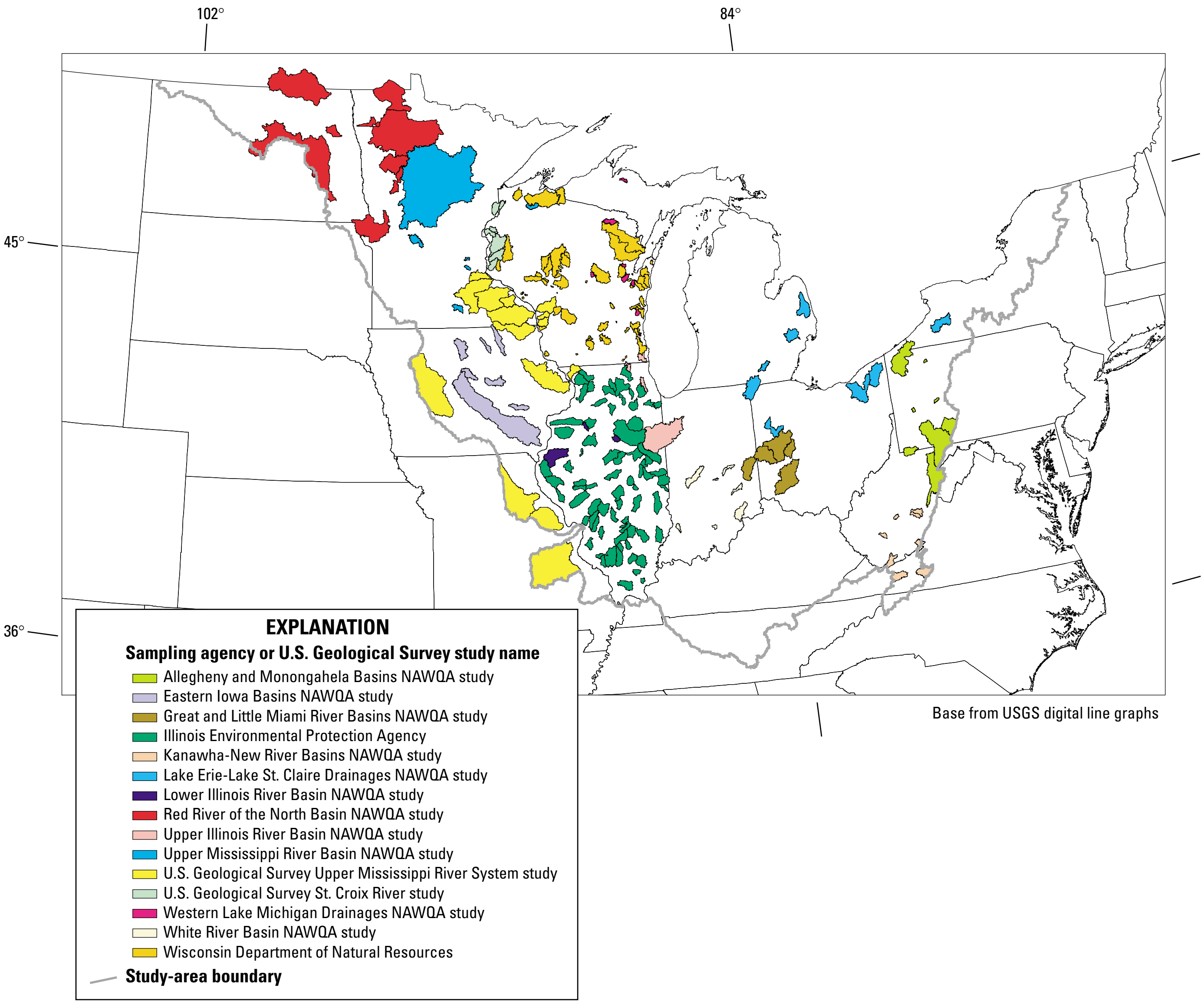


Figure 4. Watersheds of streams included in study, by sampling agency. (Sites from the U.S. Geological Survey National Water-Quality Assessment (NAWQA) program are shown by the study unit that did the sampling.)

(Bernard Lenz, U.S. Geological Survey, written commun., 2000); and 15 streams were sampled as part of USGS Wisconsin District cooperative projects with the WDNR. The watersheds of the 234 streams are shown in figure 4.

Historical IEPA water-quality data were retrieved from the USGS National Water Information System (NWIS) database maintained by the USGS, Illinois District. WDNR data were retrieved from the USEPA STORET database. USGS water-quality data collected as part of the NAWQA program were retrieved from the NAWQA Water-Quality Data Warehouse (U.S. Geological Survey, 2000a). Data from the Upper Mississippi River System study were retrieved from the Upper Mississippi Basin Loading database (U.S. Geological Survey, 2000b). Data from the St. Croix River study were obtained from Bernard Lenz (U.S. Geological Survey, written commun., 2000).

Environmental-Characteristic Data

Environmental characteristics that were thought to affect or be related to nutrient concentrations in streams of the Upper Midwest were compiled for this study. The environmental characteristics include watershed area, runoff, climate (annual air temperature and precipitation), land-use types, surficial-deposit types and thickness, soil characteristics, and principal aquifer types. All characteristics were compiled in digital form by use of a GIS. A summary of the environmental characteristics for all of the watersheds used in this study is given in table 1. (Environmental characteristics for each watershed are provided in appendix 1.) The source of the data and method of compilation for each characteristic are described below.

Watershed Boundaries and Areas. Watershed boundaries for the 234 streams (fig. 4) were obtained from several sources and delineated by means of various methods. Watersheds of the IEPA and USGS St. Croix River studies were manually digitized on the basis of known or published sampling-location information (Illinois Environmental Protection Agency, 1996; Bernard Lenz, U.S. Geological Survey, written commun., 2000). Watershed boundaries for these two studies were initially based on a 1:100,000-scale digital coverage of the USGS Hydrologic Unit maps (Seaber and others, 1984) and refined with digital RF3 stream coverages (U.S. Environmental Protection Agency, 2000c). Watershed boundaries of the USGS Upper Mississippi River System study were obtained from the USGS Upper Midwest Environmental Sciences Center (Hank DeHaan, U.S. Geological Survey, written commun., 2000) and refined to sampling locations with 1:100,000-scale digital stream coverages from the National Hydrography Dataset (U.S. Geological Survey, 2000c). Watershed boundaries of the NAWQA studies were delineated from 1:24,000-scale USGS topographic quadrangle maps. The WDNR watersheds of the Montreal, Oconto, and Peshtigo Rivers were compiled from a 1:100,000-scale digital coverage of the USGS Hydrologic Unit maps. The watersheds of the remaining WDNR and USGS sites were digitized as part of an earlier study and were obtained directly from the WDNR (Gregory Searle, Wisconsin Department of Natural Resources, written commun., 1999).

Runoff. Runoff data (fig. 5) were obtained from a digital linear coverage of average annual runoff (inches per year) for the conterminous United States for the years 1951–80 (Gebert and others, 1987). Originally, this coverage was prepared to represent the runoff of tributary streams rather than major streams, to link small-scale variations in runoff with precipitation, and to show other geographical characteristics. A runoff value for each watershed was estimated by the line of equal runoff closest to the center of the watershed. If the center of a watershed fell between two lines, the average of those two values was used for that watershed.

Climate. Climatic characteristics included in this study were air temperature and precipitation. Average annual air temperature data (fig. 6) were obtained as a digital coverage from data compiled by the National Climatic Data Center (U.S. Geological Survey, 2000d). The digital coverage is generalized and was intended to display air temperatures in the USGS National Water Summary reports. The digital coverage was intersected with watershed boundaries, and an area-weighted average mean annual temperature for each watershed was computed.

Precipitation data (fig. 7) were obtained as a digital coverage from the PRISM (Parameter-elevation Regressions on Independent Slopes Model) of the Climate Mapping Program (Oregon Climate Service, 2000). Area-weighted average total annual precipitation (inches per year) for each watershed was computed.

Land Use. Land-use/land-cover information for the study area was summarized from high-altitude aerial photographs compiled by the USGS (Feagus and others, 1983). This information was manually interpreted on the basis of the land-use classification of Anderson and others (1976). Land-use/land-cover maps at 1:250,000-scale were produced from the interpreted data and digitized into a GIS (U.S. Geological Survey, 2000e). An example of land-use/land-cover data for part of the study area (Illinois) is shown in figure 8. Land use/land cover for watersheds of the NAWQA, St. Croix River, and Upper Mississippi River System studies were updated with urban population information obtained from the 1990 census (Hitt, 1994). Percentages of the land-use types in each watershed were computed and represent the following Anderson's Level I categories

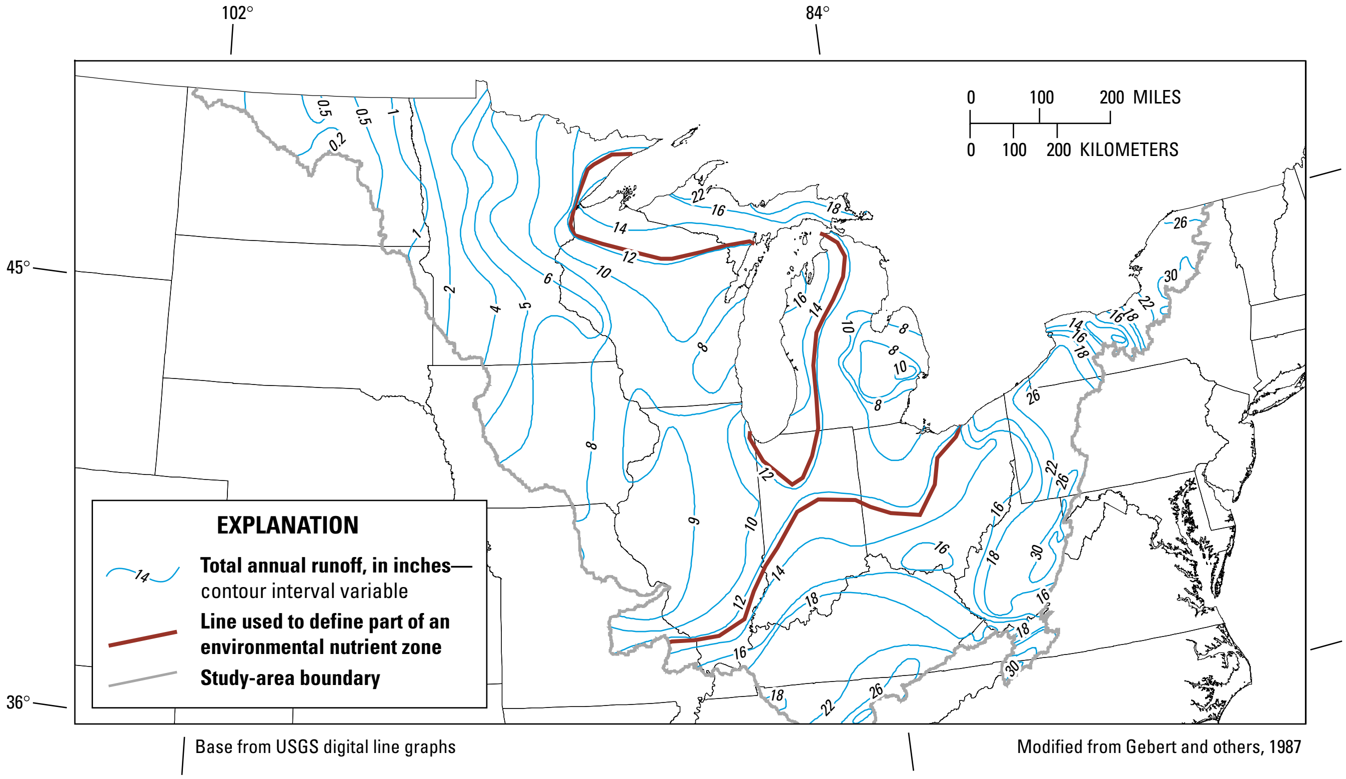


Figure 5. Total annual runoff in the study area.

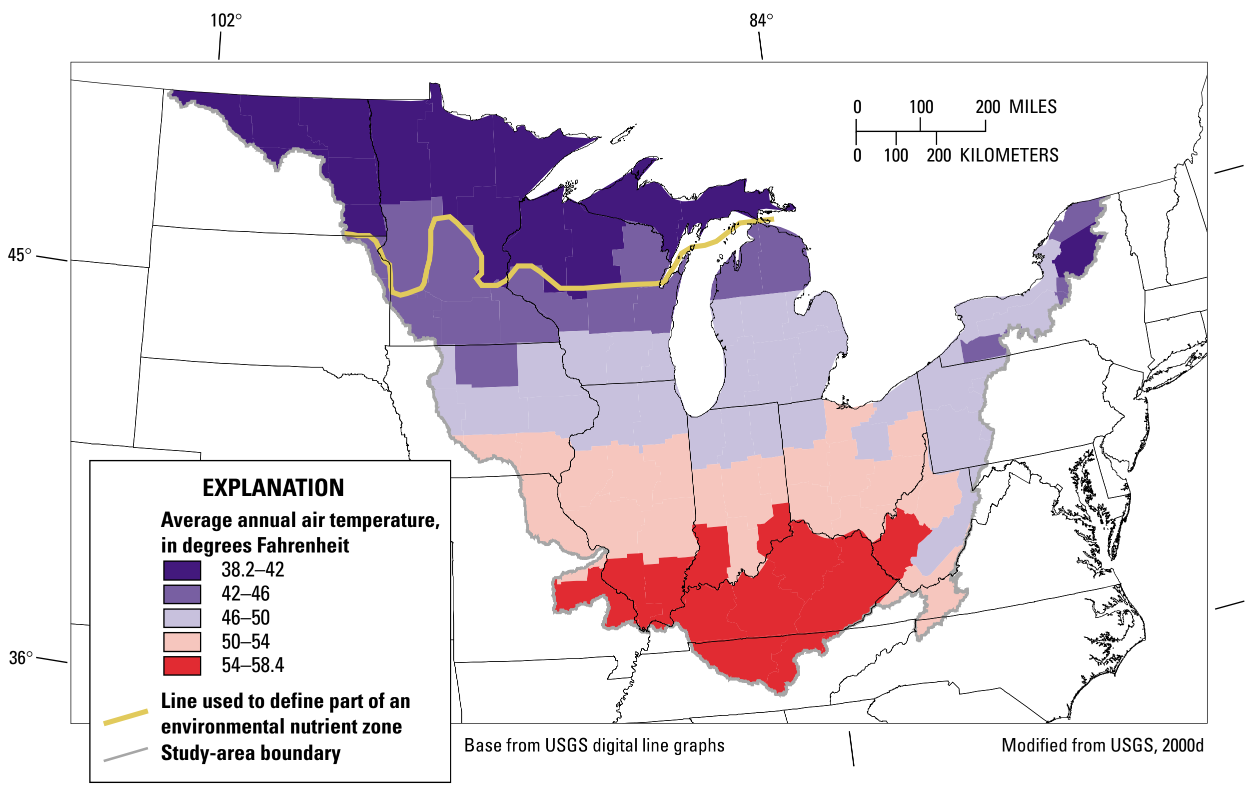


Figure 6. Average annual air temperatures in the study area.

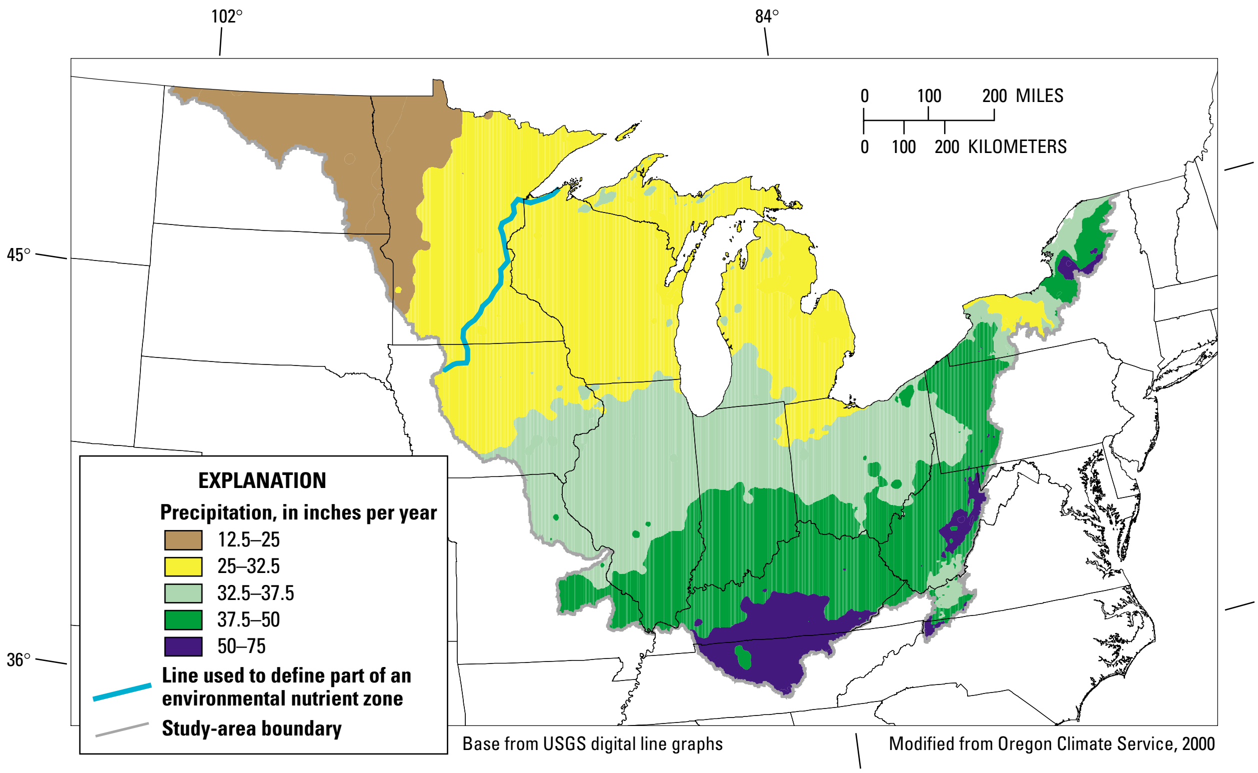


Figure 7. Average total annual precipitation in the study area.

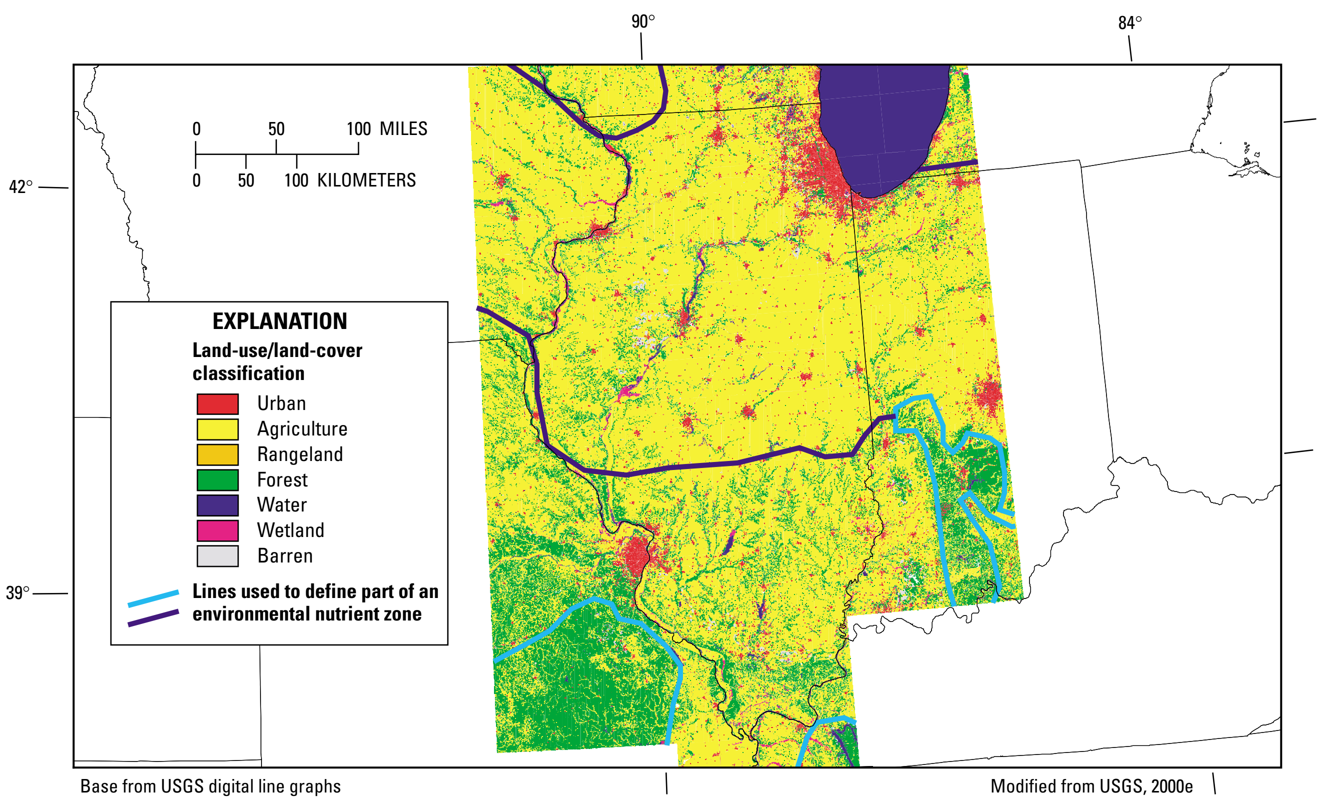


Figure 8. Land use/land cover for Illinois and vicinity.

(Anderson and others, 1976): urban, agriculture, rangeland, forest, water, wetland (further subdivided into forested and nonforested categories), and barren land.

Surficial Deposits. Surficial-deposit type and thickness were compiled from a digital coverage of Quaternary sediments for the glaciated United States east of the Rocky Mountains (Soller and Packard, 1998). The percentage of the following Quaternary sediment types was computed for each watershed: coarse-grained sediments, fine-grained sediments, till, patchy Quaternary sediments, organic-rich sediments, and exposed bedrock or nonglacial sediments (fig. 9). Quaternary sediment thickness (depth to bedrock) is described in this digital coverage by ranges. Those ranges were generalized (fig. 10) by assigning a single thickness equal to the average of the range of values. An area-weighted average depth to bedrock was computed for each watershed by use of these averaged values.

Soil Characteristics. Soil-characteristic data were compiled from the USSOILS digital coverage of the State Soil Geographic (STATSGO) database (Schwarz and Alexander, 1995; U.S. Geological Survey, 2000f). Soil characteristics summarized were clay content (percentage of soil less than 2 micrometers in size; fig. 11), organic-matter content (percentage by weight, fig. 12), soil erodibility factor (K_f; fig. 13), permeability rates (inches per hour; fig. 14), and slope (percent; fig. 15). Soil characteristics were computed as area-weighted averages for each watershed.

Principal Aquifer Type. Principal aquifer types underlying the study area were identified from a digital coverage of the principal aquifers of the 48 contiguous states (Miller, 1998; U.S. Geological Survey, 2000g) (fig. 16). The most common principal aquifer types in the study area are sandstone, carbonate, and sandstone and carbonate aquifers. Parts of the study area are not underlain by a principal aquifer. The percentage of each principal aquifer type or area not underlain by a principal aquifer was computed for each watershed.

Data Summaries and Statistical Methods

Water-Quality Data. One of the selection requirements for each of the 234 sites used in this study was at least 15 total phosphorus samples collected over a period of more than 1 year. The number of water-quality samples collected from each site was highly variable, and the period of record ranged from 2 years to decades. The number of samples collected in any given period was also variable. Therefore, to obtain representative statistical summaries that were not biased by intensively sampled periods, the data were subsampled to monthly intervals. For each site, only one sample per constituent per month per year was used. The sample included in statistical summaries was the one collected closest to the middle of the month. All data reported at less than the detection limit were set to the detection limit. Median values of all midmonthly concentrations of total phosphorus and total nitrogen for each site are given in appendix 2. The median concentrations were log transformed and used in all subsequent statistical analyses (correlations, stepwise regressions, and regression-tree analyses). Log transformation improved the normality of the dependent variables (concentration data) although not always below the 5-percent critical level.

Correlations and Regressions. To determine linear relations between each water-quality characteristic and the environmental factors, Pearson correlation analyses were done, followed by forward stepwise-regression analyses. Correlation analyses were used to describe how much of the linear variability in each water-quality characteristic was explained by each environmental factor. Forward stepwise-regression analyses (with a 5-percent critical level for entry) were then used to determine the direction and magnitude of the interaction between several environmental factors and individual water-quality characteristics, as well as to determine the best multivariate relation to predict total phosphorus and total nitrogen concentrations at a specific site as a function of the environmental characteristics in its watershed. Forward stepwise regressions were also done with land-use characteristics excluded from the environmental factors to determine which natural environmental variables could best describe the distribution of total phosphorus and total nitrogen.

In addition, correlation analyses were used to describe the relation among environmental factors. Sometimes one environmental variable was strongly correlated with one or more other environmental factors, making the actual factor causing variations in water quality difficult to ascertain. For example, the percentage of forest was highly (and negatively) correlated to the percentage of agriculture. Understanding the relations among environmental factors is important

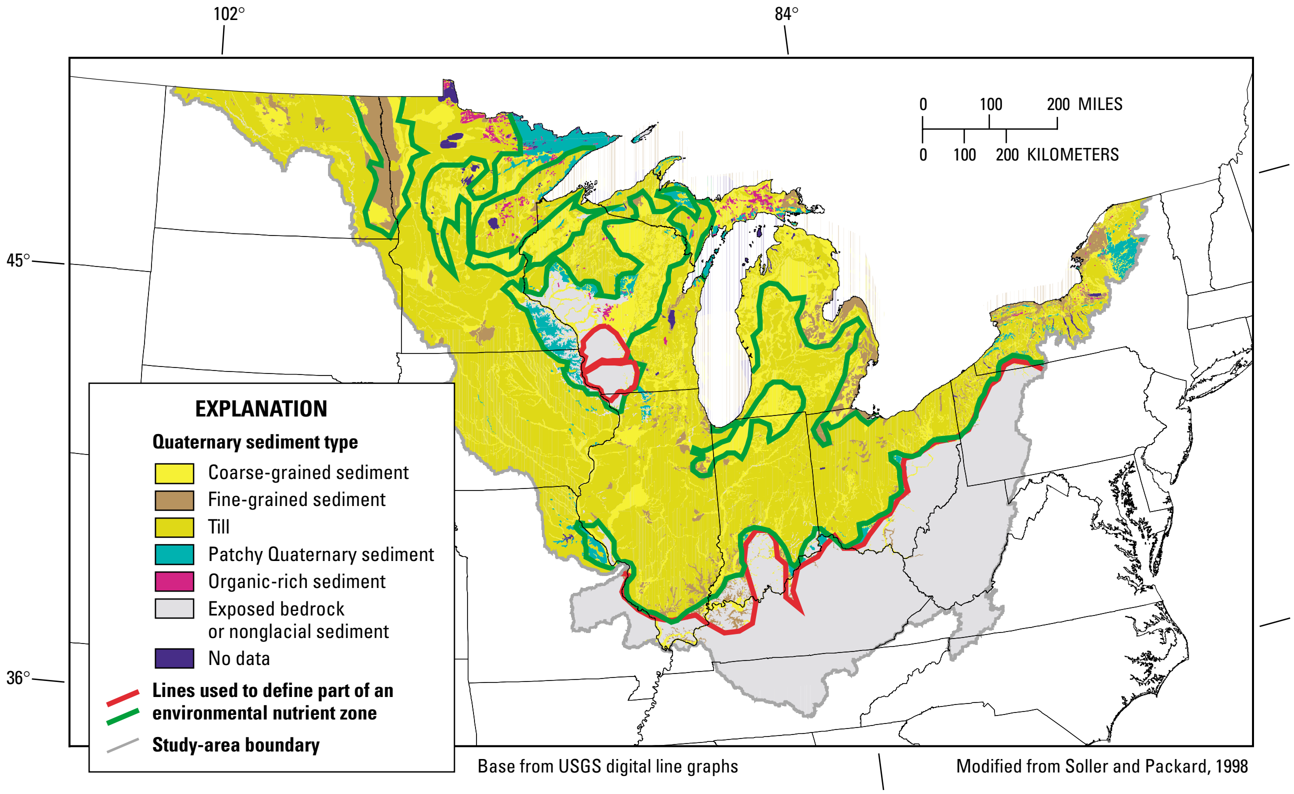


Figure 9. Quaternary sediment types in the study area.

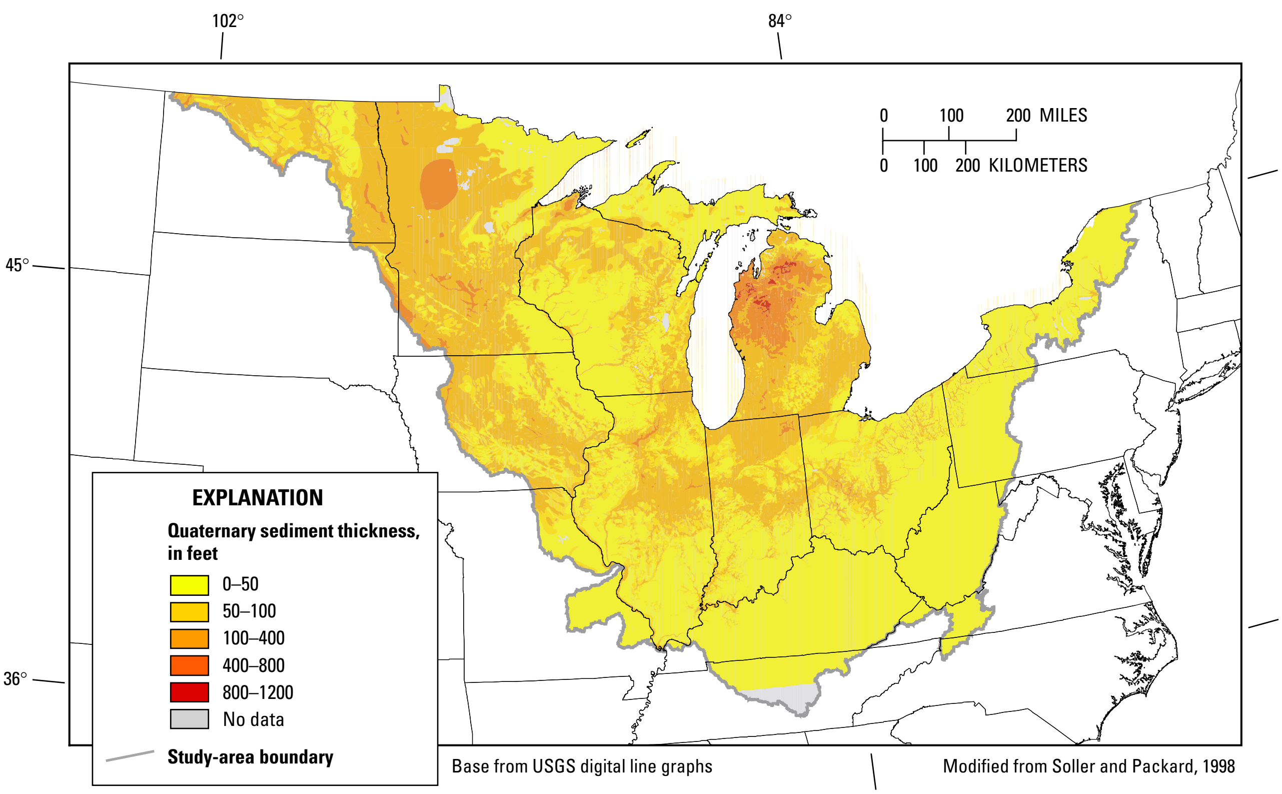


Figure 10. Quaternary sediment thickness in the study area.

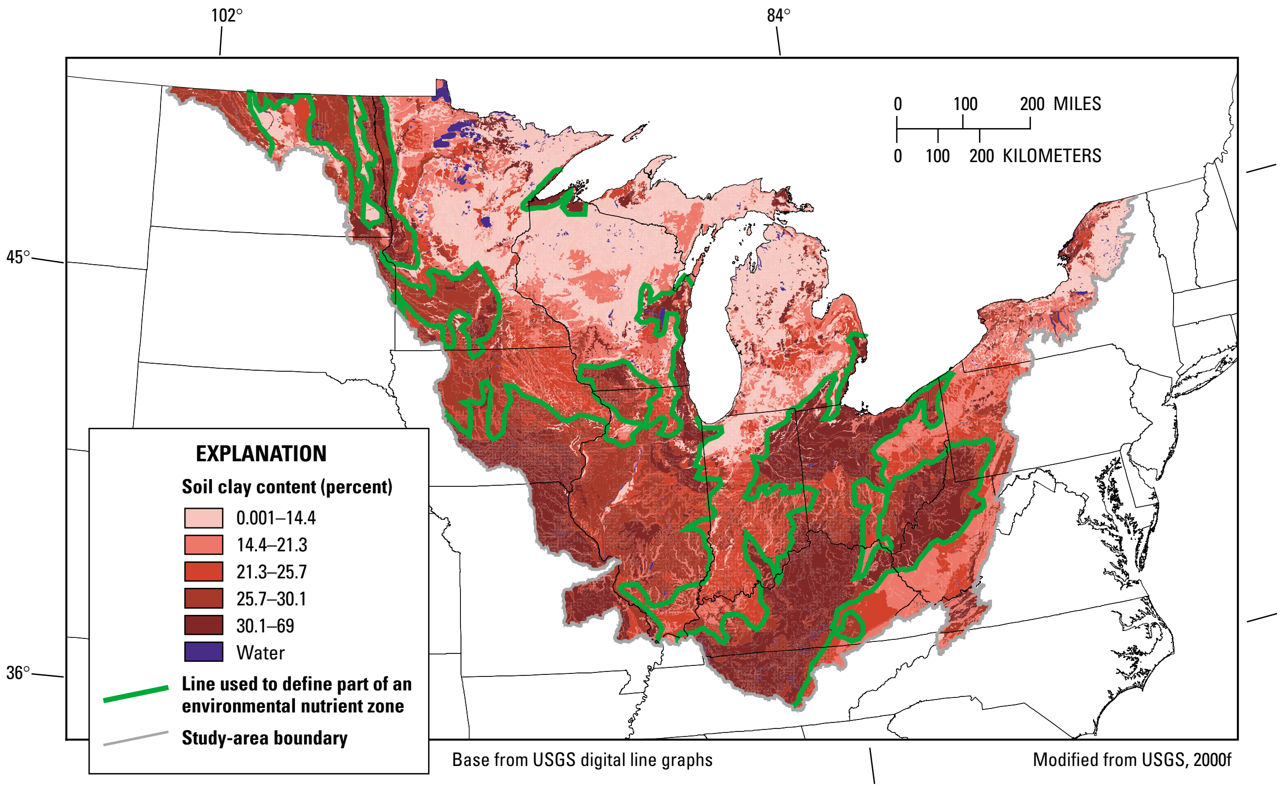


Figure 11. Soil clay content in the study area (gradations represent quantile distributions).

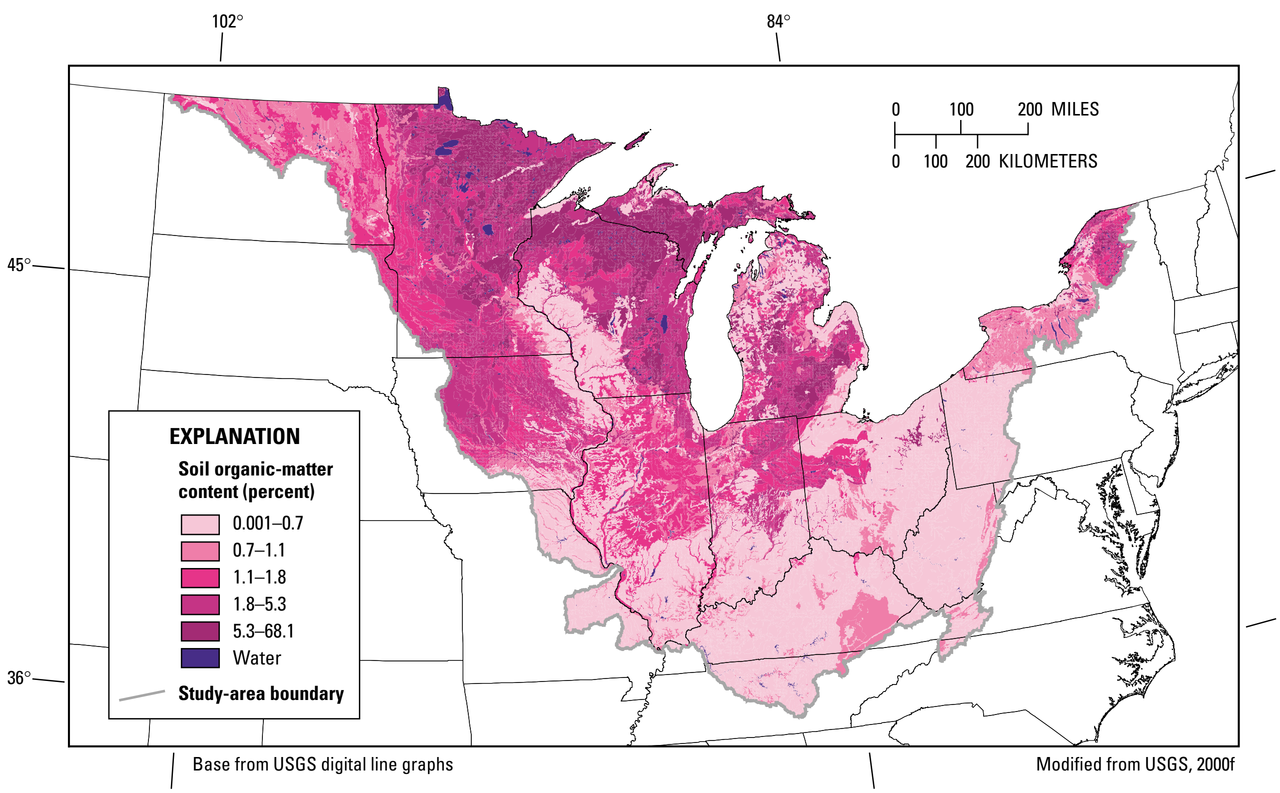


Figure 12. Soil organic-matter content in the study area (gradations represent quantile distributions).

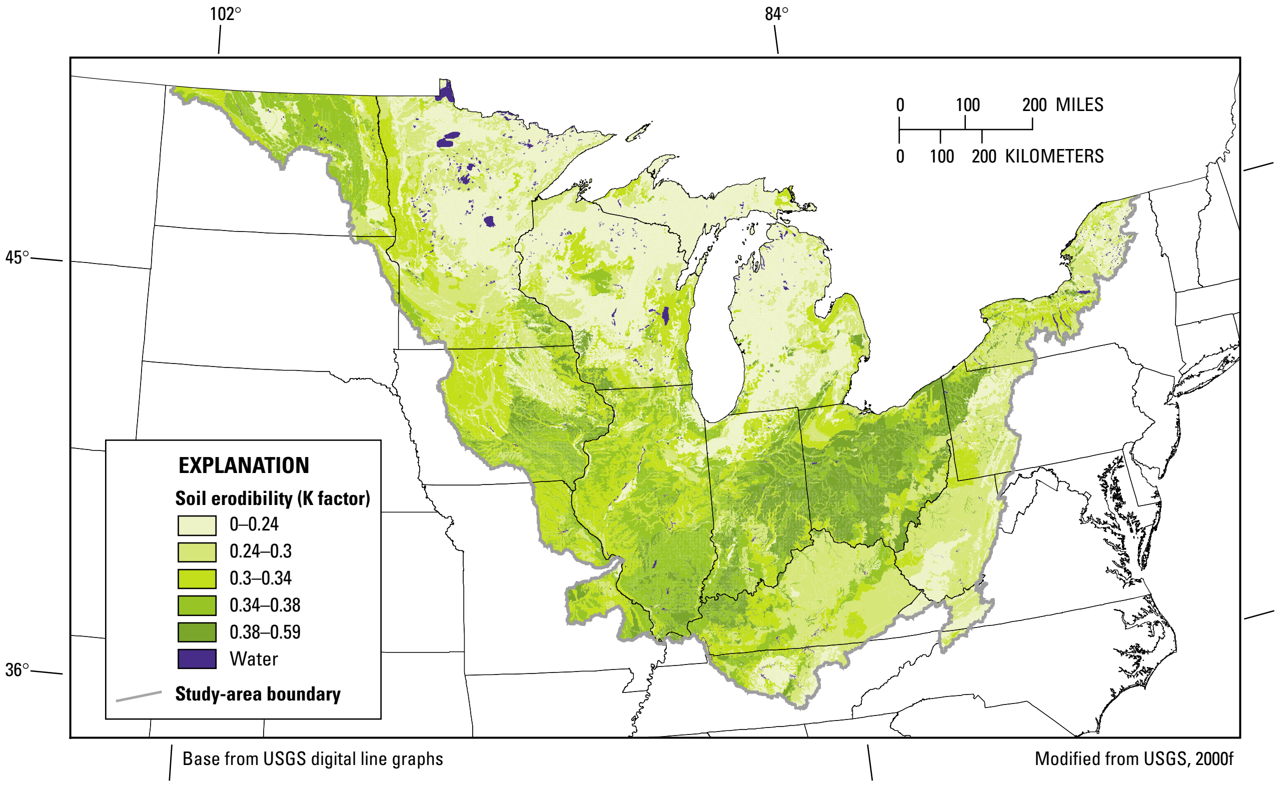


Figure 13. Soil erodibility in the study area (gradations represent quantile distributions).

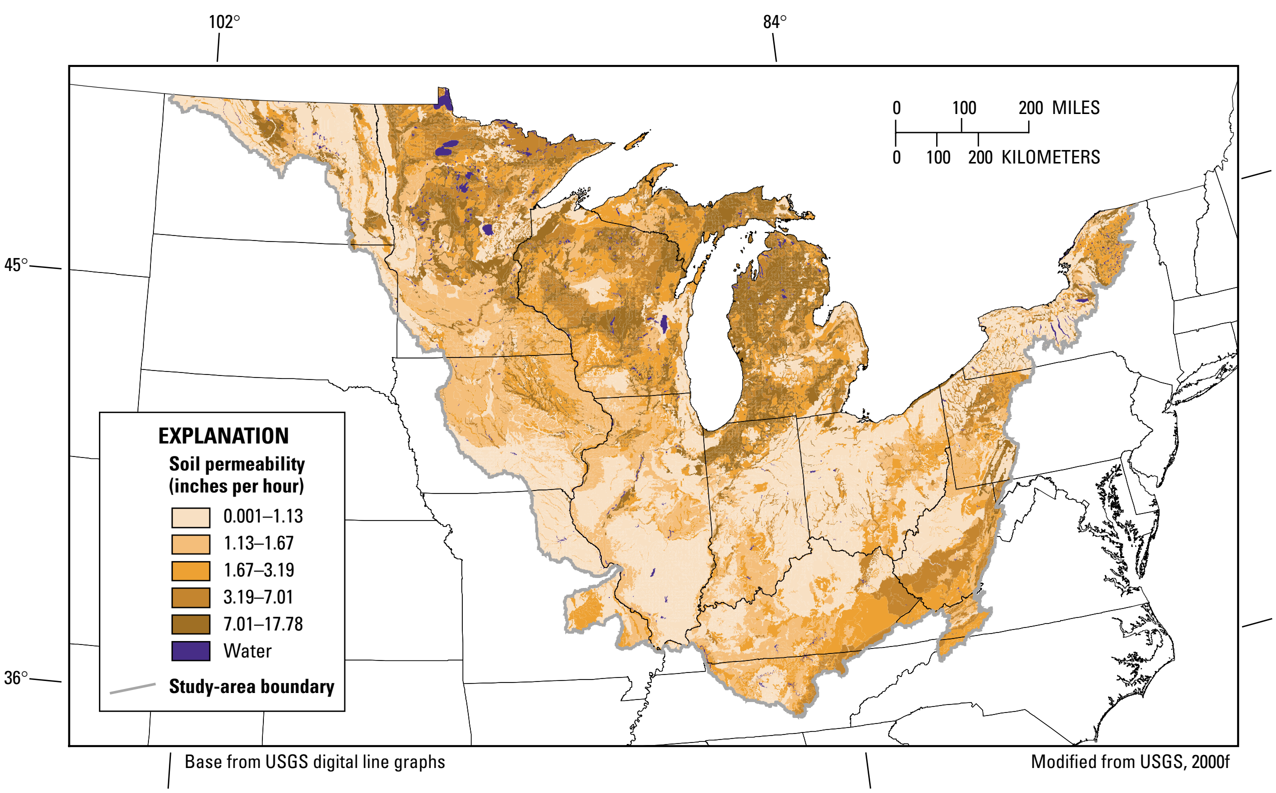


Figure 14. Soil permeability in the study area (gradations represent quantile distributions).

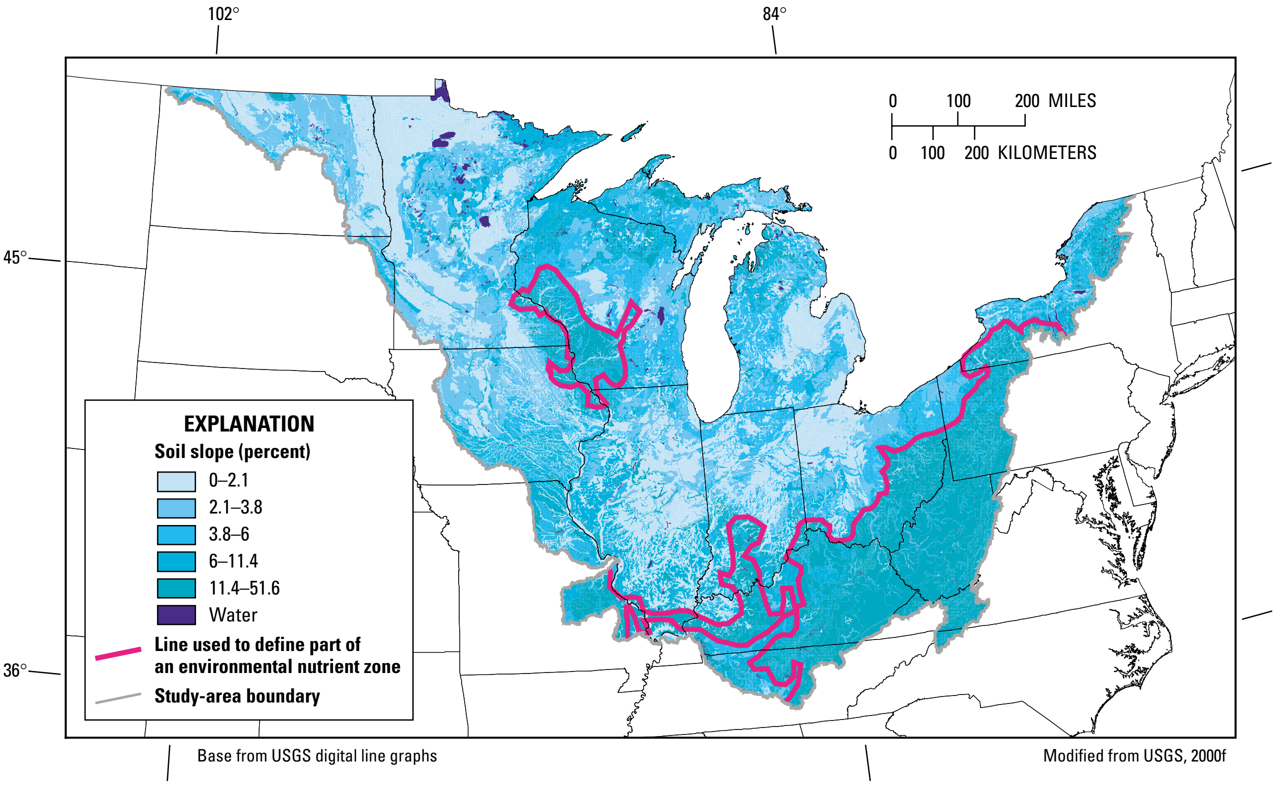


Figure 15. Soil slope in the study area (gradations represent quantile distributions).

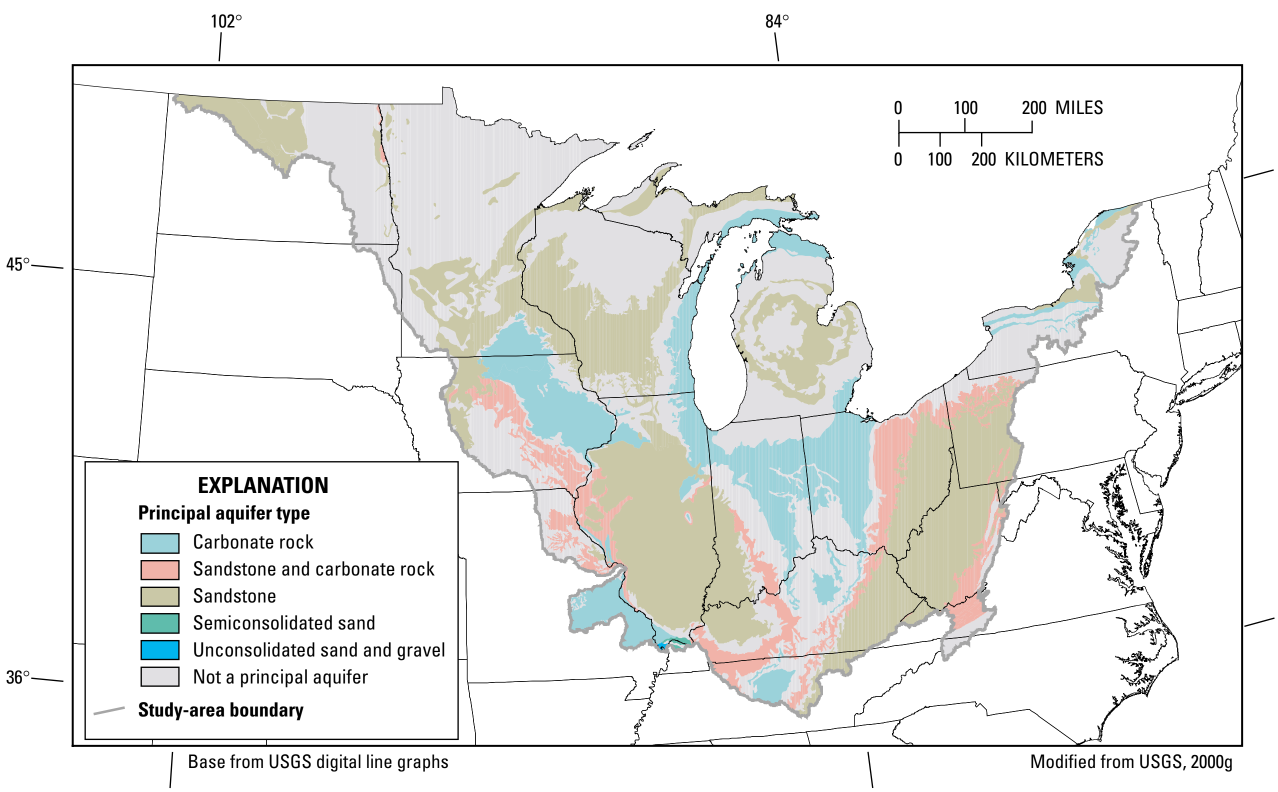


Figure 16. Principal aquifer types in the study area.

to understanding the relations between nutrient concentrations and environmental factors.

The SAS statistical software package (SAS Institute, 1989) was used for all statistical summaries, correlations, and linear regressions.

Regression-Tree Analysis. Regression-tree analysis (Breiman and others, 1984), like forward stepwise regression, is a statistical technique used to explore the relations between a single dependent variable and several independent variables. However, instead of trying to fit a single regression to a large multivariate data set, one can use this method to divide the dependent data into groups with similar statistical relations. The method involves repeated partitioning of a data set into subgroups based on regressions between the dependent variable (for example, total phosphorus concentrations) and one independent variable (for example, percentage agriculture) at a time. A causal relation between the dependent variable and the independent variables is assumed. The partitioning of the data results in smaller and smaller subgroups and graphically resembles the branches of a tree. The choice of independent variable in the regression that results in a "branching" of the data is guided by a least-squares-error criterion. The value of the independent variable at which the data are partitioned is the one that minimizes the total sum of squared residuals of each resulting subgroup. Branching continues until the number of observations in each subgroup is small or the total sum of squared residuals is small.

In this study, regression-tree analyses were used to separate the sites into groups based on relations between median total phosphorus or median total nitrogen concentrations and environmental characteristics of the watershed, except watershed area. Watershed area was not chosen as an environmental characteristic because it would not enable large areas of relatively similar environmental characteristics to be defined. Regression-tree analyses were done with all environmental information and with the land-use characteristics excluded to determine which natural environmental characteristics were most statistically significant in describing the distribution of total phosphorus or total nitrogen. Regression-tree analyses were performed by use of the computer program S-PLUS (MathSoft, 1999).

Comparison of Variability Among Classification Schemes. To determine whether the environmental nutrient zones with relatively similar environmental characteristics defined by the regression-tree analyses had less variance in water quality than that found by use of the nutrient ecoregions, the weighted mean coefficient of variation (MCV) was computed with equation 1 for each scheme, and the percentage of reduction in the MCV was computed. MCVs were computed from water-quality data for all of the sites in the defined areas (nutrient ecoregions and environmental nutrient zones) and also for each group as defined directly from regression-tree results (based on individual watershed characteristics).

$$MCV = \sqrt{\frac{\Sigma(CV^2 \times n)}{N}}, \tag{1}$$

$$CV = \frac{StDev}{\overline{X}},$$

where

CV is the coefficient of variation of each group (or area),

n is the number of observations in each group,

N is the total number of observations in all of the groups,

$StDev$ is the standard deviation of each group, and

$\overline{X}$ is the mean concentration of each group.

DEVELOPMENT OF NUTRIENT ZONES—AN ALTERNATIVE REGIONALIZATION SCHEME

Distribution of Nutrient Concentrations

Median, midmonthly total phosphorus concentrations ranged from 0.01 to 2.16 mg/L. The overall mean and median of these concentrations were 0.17 and 0.11 mg/L, respectively (table 1). High concentrations were found throughout the study area, especially in Illinois, Iowa, and southeastern Wisconsin (fig. 17). The lowest concentrations were found in northern areas of Wisconsin and Minnesota, and along the eastern edge of the study area.

Median, midmonthly total nitrogen concentrations ranged from 0.34 to 13.18 mg/L. The overall mean and median of these concentrations were 3.61 and 2.26 mg/L, respectively (table 1). The highest total nitrogen concentrations were generally found throughout the central part of the study area (fig. 18). The lowest concentrations were found in northern areas of

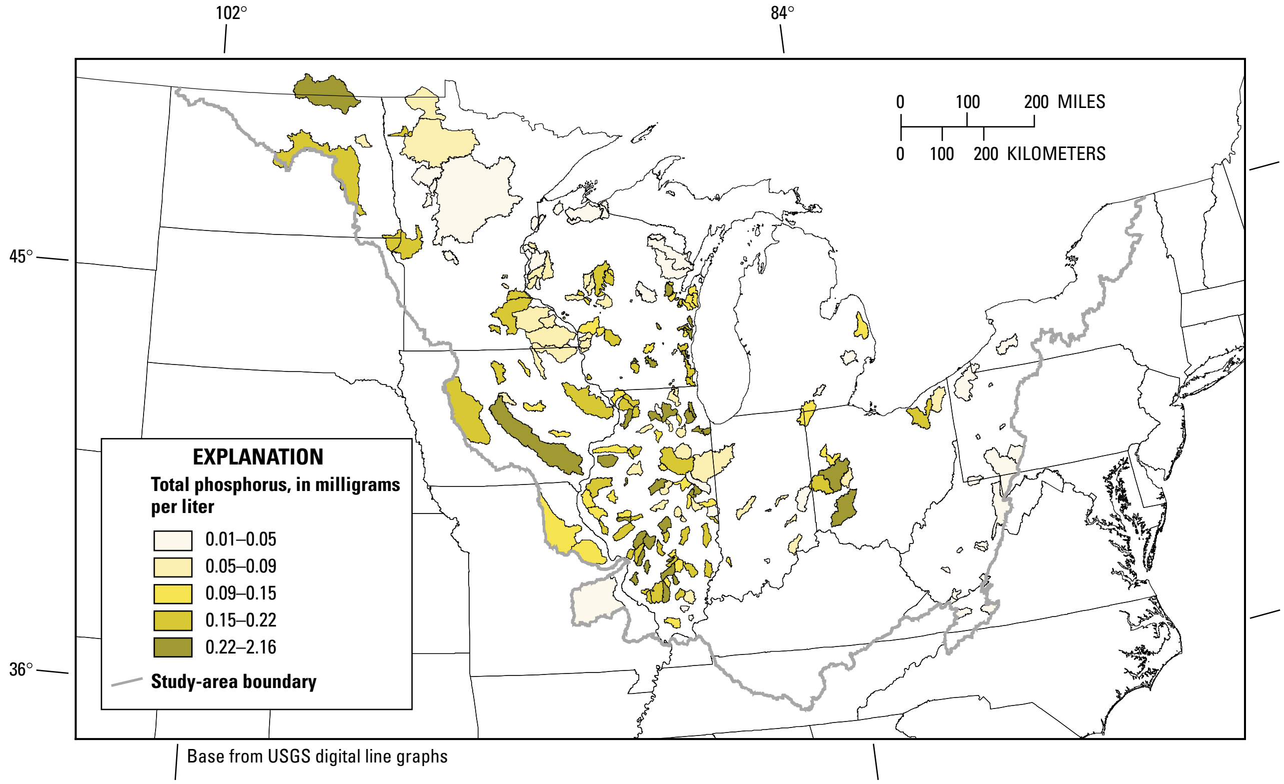


Figure 17. Median, midmonthly total phosphorus concentrations for study sites (gradations represent quantile distributions).

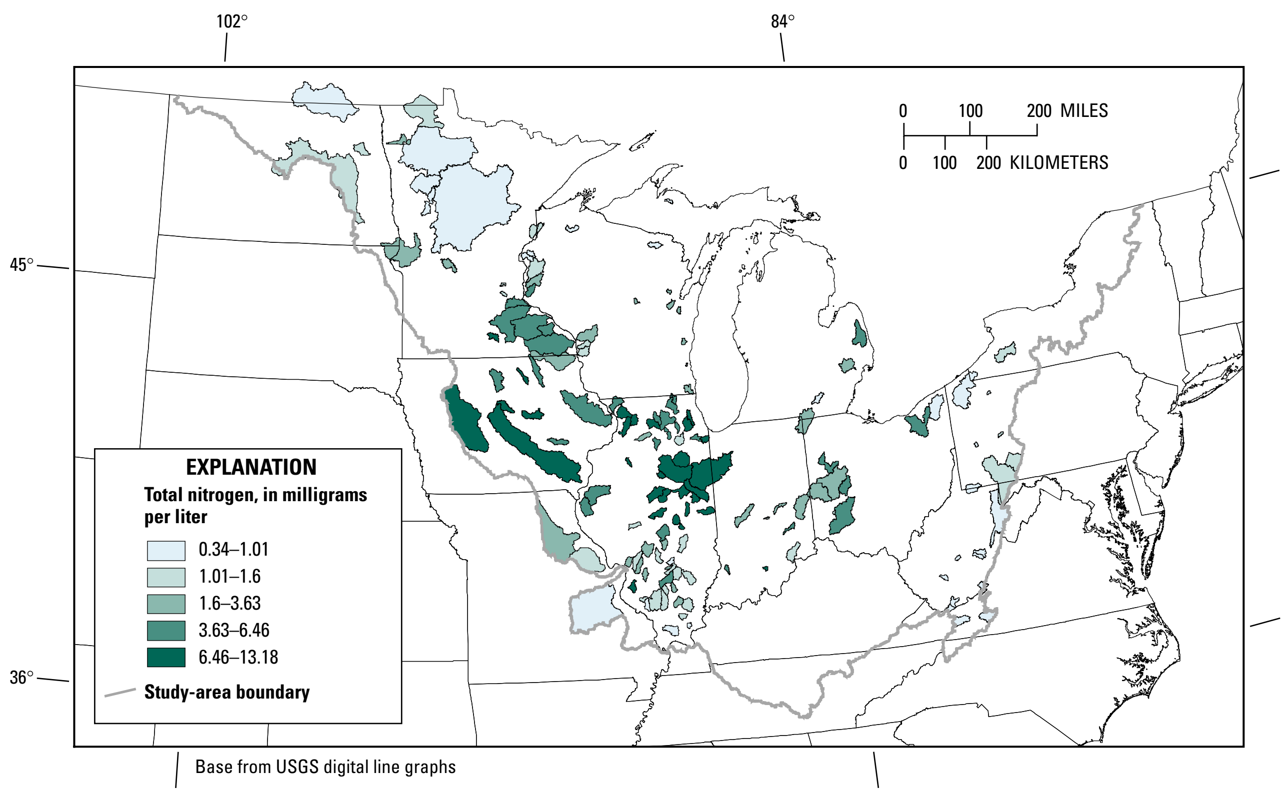


Figure 18. Median, midmonthly total nitrogen concentrations for study sites (gradations represent quantile distributions).

Minnesota and Wisconsin, and along the eastern edge of the study area. Total nitrogen could not be estimated for many sites in Wisconsin because water samples from most of these sites were analyzed only for dissolved nitrate.

Most Statistically Significant Environmental Factors

Correlation Results. Pearson correlation coefficients (r values) between nutrient concentrations (total phosphorus and total nitrogen) and each environmental factor are shown in table 2. Nutrient concentrations were significantly correlated with most environmental variables; however, they were most strongly correlated with factors describing the land use (percentages of forest and agriculture) and surficial deposits or soil in the watershed (percentage of till, percentage of clay, erodibility, permeability, and soil slope), and runoff from the watershed.

Total phosphorus concentrations were most strongly correlated with the absence of forest or amount of agriculture (percentage of forested area had a strong inverse relation with percentage of agriculture; table 3), percentage of till, and percentage of clay in the watershed. Total nitrogen concentrations were most strongly correlated with the absence of forest or presence of agriculture, percentage of till, and average soil slope of the watershed. Total nitrogen concentrations were more highly correlated with land-use characteristics than were total phosphorus concentrations, whereas total phosphorus concentrations were more correlated with soil characteristics than were total nitrogen concentrations.

Stepwise-Regression Results. Forest cover, soil permeability, and runoff were the three most significant variables contributing to the forward stepwise-regression model for total phosphorus concentrations (table 4). Collectively, these three variables, each highly correlated with total phosphorus concentrations, explained 40 percent of the variability in concentration.

Forest cover, agriculture, and rangeland were the three most significant variables contributing to the forward stepwise-regression model for total nitrogen concentrations (table 4). Collectively, these three land-use variables explained 57 percent of the variability in total nitrogen concentrations. The percentage of rangeland was not significantly correlated with total nitrogen concentrations and only minimally improved the regression model.

Forward stepwise-regression analyses were also done with land-use characteristics excluded from the environmental factors to determine the most statistically significant natural environmental factors contributing to variability in water quality. Percentage of till, percentage of clay in the soil, and runoff were the three most statistically significant variables in the total phosphorus model (table 4). Collectively, these three variables explained 39 percent of the variability in total phosphorus concentrations. Each of these variables was highly correlated with total phosphorus concentrations. The final model explained about the same amount of variability in total phosphorus concentrations as the three-parameter model including land-use characteristics.

For total nitrogen concentrations, the percentage of till, percentage of clay in the soil, and soil slope were the three most significant variables contributing to the forward stepwise-regression model (table 4). Collectively, these three variables explained 38 percent of the variability. Each of these variables was highly correlated with total nitrogen concentrations. The final model explained much less of the variability in total nitrogen concentrations than did the three-parameter model that included land-use characteristics, which demonstrates the importance of land use in explaining the distribution of total nitrogen.

Regression-Tree Analysis Results. Regression-tree analysis was used to subdivide the 234 sites into two initial groups, then into four derivative groups on the basis of relations between total phosphorus and all of the environmental characteristics (fig. 19A). The percentage of forested area in the watershed was the independent variable chosen for the first subdivision. Forested land use is strongly correlated (negatively) with agricultural land use (table 3); therefore, the percentage of agricultural land would probably have provided similar results if the percentage of forested land had been removed from the analysis. The two groups in the first subdivision had watersheds that were either less than 30 percent forested (177 sites with a mean concentration of 0.21 mg/L) or greater than or equal to 30 percent forested (57 sites with a mean concentration of 0.06 mg/L). Sites having less than 30 percent of their watersheds forested were further subdivided into group 1, those with soil clay content less than 26 percent (70 sites with a mean concentration of 0.12 mg/L),

Table 2. Pearson correlation coefficients between water-quality constituents (total phosphorus and total nitrogen) and the environmental characteristics of their respective watersheds. The r values are color coded to help demonstrate the strength of the relations (red values indicate | r | > 0.5, green indicate 0.5 > | r | > 0.4, and orange indicate 0.4 > | r | > 0.3)

[All values greater than 0.15 or less than -0.15 were statistically significant at P < 0.05]

Environmental characteristic	Total phosphorus	Total nitrogen
	Basin characteristics	
Area	-0.06	-0.07
Runoff	-.38	-.40
	Climatic characteristics	
Precipitation	-.05	-.08
Air temperature	.25	.16
	Land-use characteristics	
Urban	.13	.01
Agriculture	.48	.71
Rangeland	.05	-.09
Forest	-.55	-.72
Forested wetland	-.29	-.30
Nonforested wetland	-.18	-.23
Barren land	.06	-.07
	Surficial-deposit characteristics	
Coarse-grained stratified sediments	-.28	-.14
Fine-grained stratified sediments	.12	.11
Till	.47	.52
Patchy Quaternary sediments	-.14	-.06
Exposed bedrock or nonglacial sediments	-.32	-.45
Organic-rich sediments	-.11	-.10
	Soil characteristics	
Percent clay	.46	.37
Erodibility	.41	.32
Organic-matter content	-.24	-.21
Permeability	-.43	-.32
Soil slope	-.34	-.52
	Principal aquifer types	
Sandstone	.08	.01
Carbonate	.16	.28
Sandstone and carbonate	-.11	-.08
Depth to bedrock	.03	.24

Table 3. Pearson correlation coefficients between environmental characteristics for sites in the study

[All values in bold are statistically significant at P < 0.05. All abbreviations are defined in table 1]

	Area	Roff	Urbn	Agri	Rang	Fors	Fwet	Nwet	Barr	Coar	Fine	Till	Patc	Xbed	Orga	Sdst	Carb	Sscb	Dbed	Clay	K_f	Omat	Perm	Slop	Prec	Temp
Area																										
Roff	-0.10																									
Urbn	-.10	-0.04																								
Agri	-.05	-.44	-0.34																							
Rang	**.25**	-.15	-.04	0.05																						
Fors	.04	.55	-.20	**-.83**	-0.06																					
Fwet	**.16**	.02	-.12	**-.41**	-.04	0.33																				
Nwet	**.31**	-.23	-.03	**-.20**	.03	.07	**0.43**																			
Barr	-.05	.07	.13	**-.14**	.04	-.01	-.08	-0.03																		
Coar	.09	-.14	.02	**-.20**	-.01	.09	**.42**	**.36**	-0.04																	
Fine	-.05	.00	.06	**.15**	-.02	**-.18**	-.09	-.06	.02	-0.03																
Till	.01	-.34	.14	**.53**	.05	**-.66**	-.09	-.06	.02	**-.23**	-0.08															
Patc	.02	-.01	-.07	-.11	-.02	**.16**	.11	-.03	-.06	-.08	-.07	**-0.19**														
Xbed	-.06	.42	-.14	**-.43**	-.04	**.62**	**-.14**	-.11	.02	**-.23**	**-.14**	**-.82**	-0.05													
Orga	.03	.00	-.05	**-.25**	-.01	**.25**	**.34**	**.27**	-.04	-.02	-.04	-.09	.10	0.04												
Sdst	**-.19**	-.02	-.19	.08	-.01	.07	**-.22**	**-.14**	.09	-.14	-.03	-.09	-.05	**.18**	-0.03											
Carb	-.04	-.09	.32	.10	-.06	**-.28**	-.05	-.11	.00	-.11	-.06	**.29**	-.04	**-.20**	-.07	**-0.53**										
Sscb	.04	.39	-.06	-.10	-.03	**.19**	-.11	-.11	-.04	**-.13**	-.05	**-.18**	-.03	**.28**	-.04	-.20	-0.14									
Dbed	**.21**	-.32	.14	**.17**	.02	**-.33**	.04	**.34**	-.07	**.30**	.01	**.30**	**-.15**	**-.41**	-.09	**-.29**	.13	-0.11								
Clay	-.04	-.03	.20	**.38**	-.02	**-.42**	**-.51**	**-.37**	.06	**-.56**	**.20**	**.36**	**-.16**	-.08	**-.20**	-.10	**.29**	**.19**	-0.01							
K_f	-.06	-.02	.07	**.53**	.07	**-.52**	**-.49**	**-.42**	.02	**-.53**	.12	**.52**	-.09	**-.26**	**-.26**	.01	**.22**	.01	-.07	**0.70**						
Omat	.09	-.11	.08	**-.36**	-.05	**.18**	**.74**	**.55**	-.05	**.45**	-.06	.02	.09	**-.27**	**.41**	**-.31**	.05	**-.17**	**.23**	**-.47**	**-0.59**					
Perm	.09	-.03	-.07	**-.35**	-.02	**.33**	**.35**	**.41**	-.05	**.71**	-.12	**-.47**	-.03	**.16**	.07	-.03	**-.15**	-.05	**.16**	**-.77**	**-.82**	**0.43**				
Slop	-.06	.58	-.08	**-.55**	**-.04**	**.69**	-.09	**-.16**	**.14**	**-.15**	**-.14**	**-.67**	.04	**.79**	-.08	**.14**	**-.19**	**.34**	**-.39**	-.08	**-.24**	**-.21**	**0.13**			
Prec	**-.23**	.73	-.07	-.05	**-.22**	**.19**	**-.27**	**-.46**	.12	**-.36**	.02	.00	-.08	**.20**	-.08	**.24**	-.04	**.29**	**-.36**	**.28**	**.37**	**-.40**	**-.37**	**0.34**		
Temp	**-.16**	.27	.00	**.29**	-.08	**-.22**	**-.45**	**-.45**	**.16**	**-.42**	.09	**.27**	**-.23**	-.01	**-.17**	**.32**	-.04	**.21**	**-.22**	**.57**	**.62**	**-.53**	**-.55**	.06	**0.76**	

Table 4. Forward stepwise-regression models to explain variability in total phosphorus and total nitrogen concentrations including and excluding land-use characteristics in the analyses

[All regressions were on log-transformed nutrient data; r, correlation coefficient with independent variable; Step R^2, coefficient of determination for one, two, and three variable models]

Dependent variables	Independent variables		
	First variable	**Second variable**	**Third variable**
	Land-use characteristics included		
Total phosphorus	Percent forest r = -0.55 Step R^2 = 0.31	Permeability r = -0.43 Step R^2 = 0.37	Runoff r = -0.38 Step R^2 = 0.40
Total nitrogen	Percent forest r = -0.72 Step R^2 = 0.52	Percent agriculture r = 0.71 Step R^2 = 0.55	Percent rangeland r = -0.09 Step R^2 = 0.57
	Land-use characteristics excluded		
Total phosphorus	Percent till r = 0.47 Step R^2 = 0.22	Percent clay r = 0.46 Step R^2 = 0.32	Runoff r = -0.38 Step R^2 = 0.39
Total nitrogen	Percent till r = 0.52 Step R^2 = 0.27	Percent clay r = 0.37 Step R^2 = 0.32	Soil slope r = -0.52 Step R^2 = 0.38

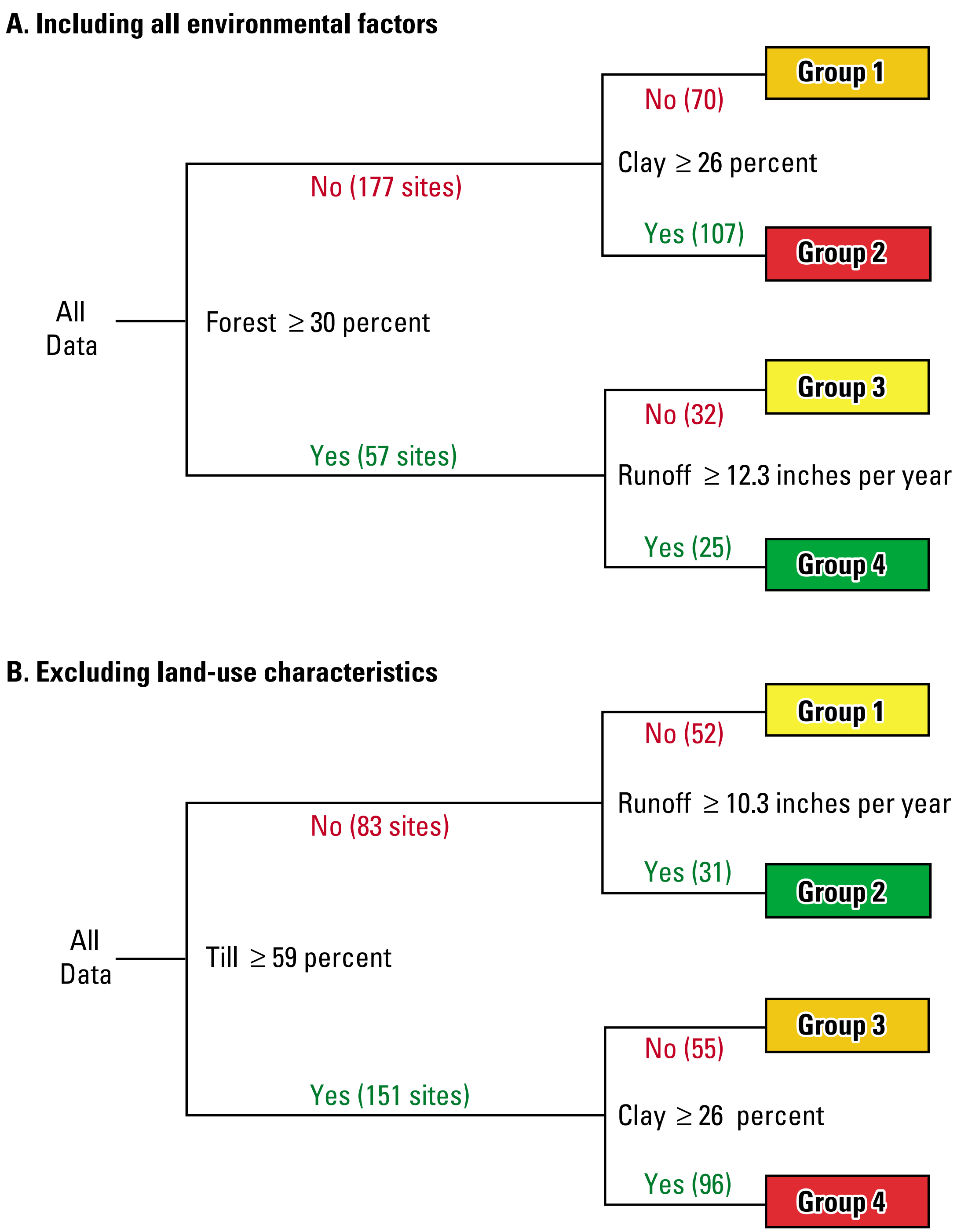


Figure 19. Environmental phosphorus groups from regression-tree analysis (A) including all environmental characteristics and (B) excluding land-use characteristics. (The numbers in brackets are the number of sites in each group. Color code for qualitative concentration range is green (lowest) followed by yellow, orange, and red (highest).)

or group 2, greater than or equal to 26 percent (107 sites with a mean concentration of 0.27 mg/L). Most group 1 sites were scattered throughout the central part of the study area (shown later in fig. 21). Group 2 sites had the highest phosphorus concentrations and were generally in the central and southern parts of the study area and in eastern Wisconsin. Sites with watersheds more than or equal to 30 percent forested were further subdivided into group 3, those with less than 12.3 in/yr of runoff (32 sites with a mean concentration of 0.08 mg/L), or group 4, more than or equal to 12.3 in/yr (25 sites with a mean concentration of 0.03 mg/L). Groups 3 and 4 had the lowest average phosphorus concentrations in the study area. Group 3 sites were mostly in central and northern Wisconsin, and central Minnesota. Group 4 sites were primarily in northern Wisconsin, Upper Michigan, and the extreme eastern part of the study area.

A similar analysis excluding land-use characteristics was done on the 234 sites to determine which natural environmental factors best explained the variability in phosphorus concentrations (fig. 19B). The surficial-deposit type, till, was then the independent variable chosen for the first subdivision. The two groups in the first subdivision had sites where the percentage of till in the watershed was less than 59 percent (83 sites with a mean concentration of 0.08 mg/L) or greater than or equal to 59 percent (151 sites with a mean concentration of 0.23 mg/L). The subgroup with less than 59 percent till was further partitioned in group 1, those with runoff less than 10.3 in/yr (52 sites with a mean concentration of 0.10 mg/L), or group 2, greater than or equal to 10.3 in/yr (31 sites with a mean concentration 0.04 mg/L). Group 1 sites were mainly in the Upper Mississippi Watershed in Minnesota and Wisconsin. Group 2 sites had the lowest phosphorus concentrations and were mainly in the southern part of the study area and northern Wisconsin. The subgroup with till greater than or equal to 59.2 percent was further partitioned into group 3, those with the percentage of clay less than 26 percent (55 sites with a mean concentration of 0.13 mg/L), or group 4, greater than or equal to 26 percent (96 sites with a mean concentration of 0.29 mg/L). Group 3 sites had the second highest phosphorus concentrations and were scattered throughout the study area. Group 4 sites had the highest phosphorus concentrations and were primarily in Illinois, Iowa, northeastern Missouri, eastern North Dakota, Ohio, and eastern Wisconsin.

Regression-tree analyses with respect to nitrogen were done similar to that for phosphorus, except that total nitrogen data were available for only 152 of the 234 sites. The first independent variable chosen when all the factors were used in the analysis was percentage of forest in the watershed, as in the analysis for phosphorus concentration (fig. 20A). The sites were divided in subgroups corresponding to those where the forested land area was less than 9 percent (81 sites with a mean concentration of 5.47 mg/L) or greater than or equal to 9 percent (71 sites with a mean concentration of 1.48 mg/L). Sites with less than 9 percent of the watershed forested were further divided into group 1, those with less than 30.1 in/yr of precipitation (9 sites with a mean concentration of 1.44 mg/L), or group 2, greater than or equal to 30.1 in/yr of precipitation (72 sites with a mean concentration of 5.98 mg/L). Precipitation is highly correlated with runoff; therefore, the differences in these subareas also represent differences in runoff. Group 1 sites were primarily in the northwest part of the study area, in Minnesota and North Dakota (shown later in fig. 21). Group 2 sites had the highest nitrogen concentrations and were throughout the central part of the study area, from southeastern Minnesota through Iowa and northern Illinois and into western Ohio. Sites having watersheds with more than or equal to 9 percent forest were further partitioned into group 3, those sites with forested land use less than 33 percent of the total area (39 sites with a mean concentration of 2.02 mg/L), or group 4, greater than or equal to 33 percent of the total area (32 sites with a mean concentration of 0.83 mg/L). Group 3 sites had the second highest total nitrogen concentrations and were scattered throughout the study area, most notably in southern Illinois and Indiana, eastern Ohio, and southeastern Minnesota. Group 4 sites had the lowest concentrations and were primarily in extreme southern, eastern, and north-central parts of the study area.

A similar analysis was done on the 152 sites excluding land-use characteristics (fig. 20B). The first independent variable chosen was soil slope. The sites were separated into subgroups corresponding to those where the average soil slope was less than 11 percent (130 sites with a mean total nitrogen concentration of 4.08 mg/L) or greater than or equal to 11 percent (22 sites with a mean concentration of 0.82 mg/L). The subgroup with soil slopes less than 11 percent was further partitioned into group 1, those with mean annual air temperature less than 43°F (20 sites with a mean concentration of 1.11 mg/L), or group 2, greater

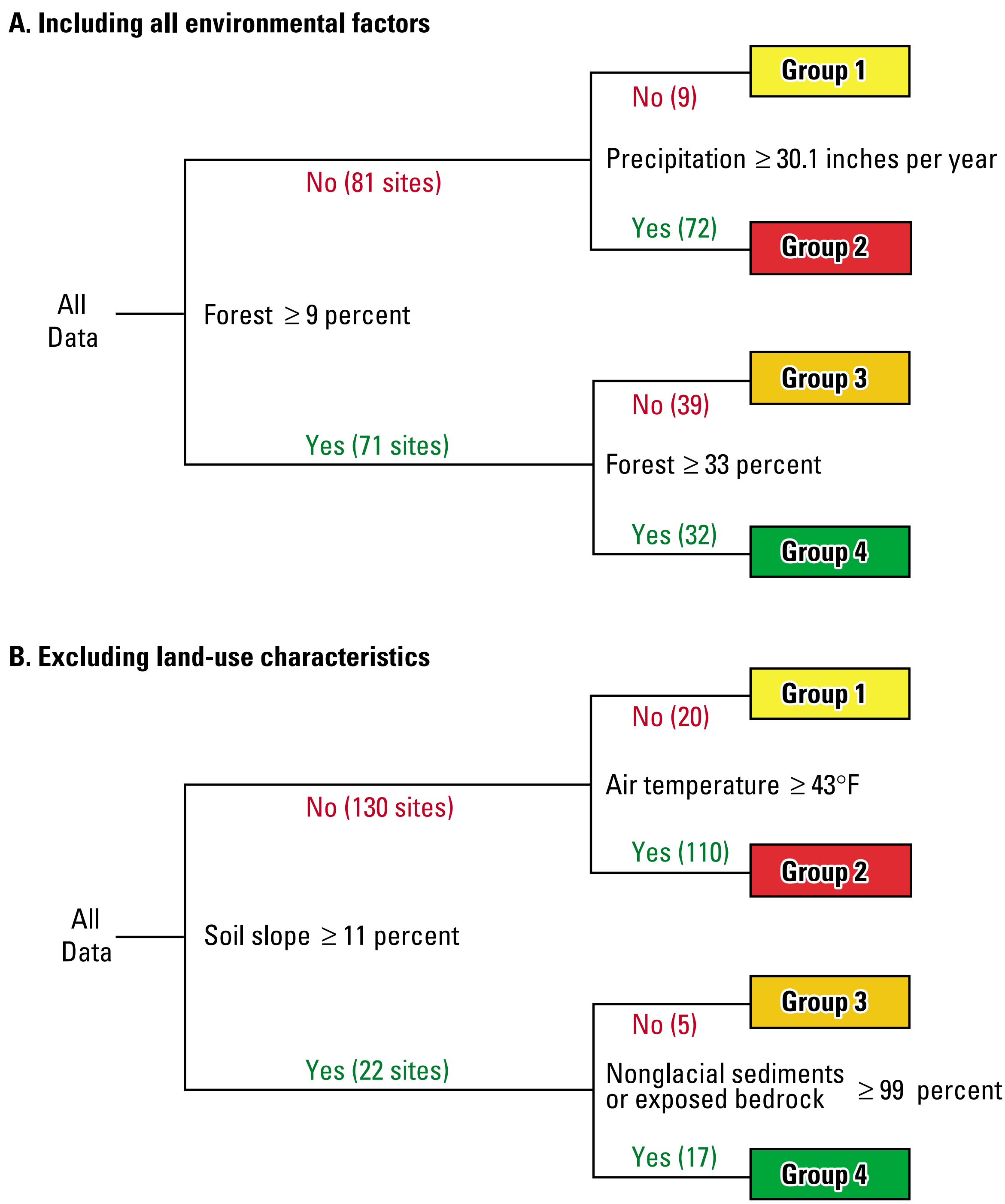


Figure 20. Environmental nitrogen groups from regression-tree analysis (A) including all environmental characteristics and (B) excluding land-use characteristics. (The numbers in brackets are the number of sites in each group. Color code for qualitative concentration range is green (lowest) followed by yellow, orange, and red (highest).)

than or equal to 43°F (110 sites with a mean concentration of 4.62 mg/L). Group 2 sites, which had the highest nitrogen concentrations, were in the central part of the study area. The subgroup with soil slopes greater than or equal to 11 percent was further partitioned into group 3, those where the amount of exposed bedrock or nonglacial sediments covered less than 99 percent of the watershed (5 sites with a mean concentration of 1.28 mg/L), or group 4, more than or equal to 99 percent of the watershed (17 sites with a mean concentration of 0.68 mg/L). The lowest average total nitrogen concentrations were at sites in group 4, which were mainly in the extreme southeastern and southwestern parts of the study area.

Summary of the Most Statistically Significant Environmental Factors. All three types of statistics indicated that land use (primarily the absence of forest or presence of agriculture) was the primary factor related to high concentrations of total phosphorus and total nitrogen. Land-use factors were more important in describing the variability in nitrogen concentrations (top three factors in the stepwise regression) than in describing the variability in phosphorus concentrations. The second most important type of factor was one describing the soil or surficial deposits. In general, total phosphorus concentrations were more strongly correlated with factors describing the permeability and erodibility of the soil, whereas total nitrogen concentrations were more strongly correlated with the soil slope. The third most important type of factor was one describing the climate (precipitation or runoff). Overall, the highest total phosphorus concentrations were found in agricultural areas with till deposits, especially those with high clay content; the highest total nitrogen concentrations were found in agricultural areas with gently sloping soils overlying till deposits, especially those sites in the southern part of the study area.

Delineation of Nutrient Zones

By understanding which environmental factors most strongly affect water quality, and using the distribution of only these factors to define areas of relatively homogeneous environmental characteristics, one should be able to minimize the variability in water quality within a defined area and maximize the variations in water quality among areas. As demonstrated in the preceding discussion, results of the regression-tree analysis can be used to identify the environmental factors most strongly related to water quality. Of additional importance is that the values used to define the branches can also be used as a guide in the delineation of the relatively homogeneous areas.

Environmental Phosphorus Zones (Derived with Land-use Characteristics Included). Regression-tree results (including land-use characteristics) for total phosphorus were used to divide the entire study area into zones having environmental characteristics similar to the four main groups described previously. By use of the available GIS coverages, the entire study area was manually partitioned by the spatial extent of the three independent variables—percentage of forest, percentage of clay, and runoff (figs. 8, 11, and 5). For the continuous variables—percentage of clay and runoff—the study area was partitioned on the basis of “branching” values from the regression-tree results. For discrete characteristics—percentage of forest—the study area was partitioned on the basis of generalized presence or absence of that characteristic. (A generalized coverage of the major land uses in the United States (Anderson, 1967) was used to delineate the extent of the forested areas.) For total phosphorus, the resulting coverages of forest, runoff, and clay were overlain and combined into a single map representing “Environmental Phosphorus Zones” (EPZs) (fig. 21A). The spatial extent of EPZs corresponded closely to the location of the groups of watersheds described in the regression-tree analysis (environmental phosphorus groups). A few sites (typically with larger watersheds) were on the border between EPZs and assigned to the less-alike EPZ because the environmental characteristics used in regression-tree analysis were based on watershed averages for the environmental characteristics. Additionally, a few watersheds (typically smaller watersheds) were “islands” in an EPZ other than that for which they were grouped because they were in small areas with environmental conditions different from most of the surrounding EPZ.

Environmental Phosphorus Zones (Derived with Land-use Characteristics Excluded). The USEPA has stated that, to the extent possible, classification should be based on those characteristics that are intrinsic, or natural, and not the result of human activities (U.S. Environmental Protection Agency, 2000a). Differences in nutrient criteria among areas should reflect differences in water quality caused by natural factors and therefore reflect differences in potential water quality.

Although land use was the most important characteristic in subdividing the area into the nutrient zones in figure 21 and also the primary characteristic in defining the ecoregions of the Midwest, developing zones based on the results of the tree-regression analyses excluding land use is appropriate and in-line with the USEPA classification philosophy.

By use of the method just described, the study area was partitioned by independent variables chosen from the results of regression-tree analysis, excluding land-use characteristics. For total phosphorus, the resulting coverages of percentage of till, runoff, and percentage of clay (figs. 9, 5, and 11) were overlain and combined into a single map representing EPZs (fig. 22A). As with the previous EPZs (incorporating land use), the extent of these areas also corresponded closely to the location of the environmental phosphorus groups described in the regression-tree analysis. The sites are not shown on figure 22 to enable the EPZs to be better illustrated.

In general, EPZs developed including and excluding land-use characteristics were similar because both sets of areas were based on the distribution of clay and runoff; and in general, agriculture is found in areas dominated by till. The differences in the delineation reflect areas that have till but are not farmed (such as north-central Wisconsin) and areas without till that are farmed (such as western Kentucky).

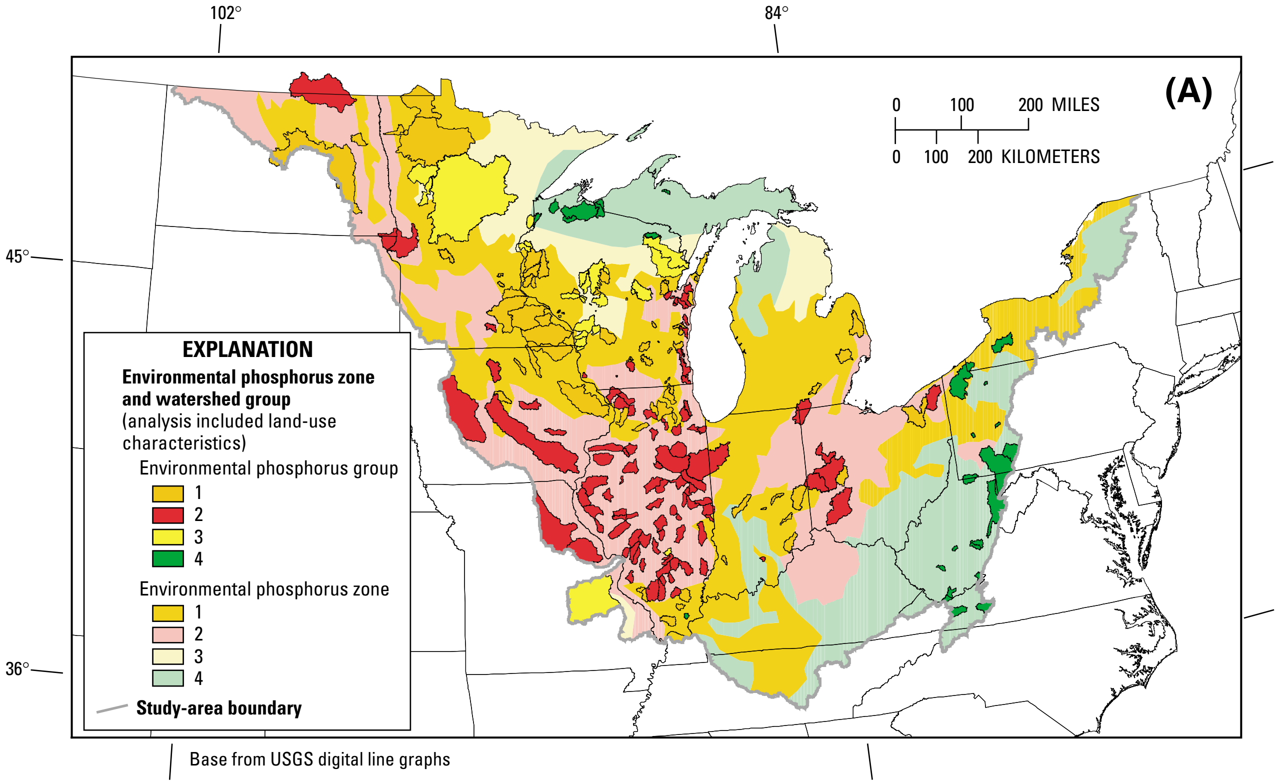
Environmental Nitrogen Zones. The study area was partitioned into "Environmental Nitrogen Zones" (ENZs, fig. 21B) on the basis of independent variables chosen in the regression-tree analysis: percentage of forest and precipitation (figs. 8 and 7). The strong relation between nitrogen concentrations and land use was especially evident here, the percentage of forested land being used as first and secondary breaks in the regression-tree analysis. Therefore, the ENZs primarily represent low, moderate, and high amounts of agriculture.

In an attempt to remove the effects of land use, the study area was partitioned on the basis of independent variables chosen in the regression-tree analysis excluding land-use characteristics. The resulting coverages of soil slope, mean annual air temperature, and percentage of exposed bedrock or nonglacial sediment (figs. 15, 6, and 9) were overlain and combined into a single map representing ENZs excluding land-use characteristics (fig. 22B).

In general, ENZs developed including and excluding land-use characteristics were substantially different. The ENZs, derived excluding land-use characteristics, divide the area primarily into three zones from northwest to southeast. A fourth zone—ENZ 3 in southwestern Wisconsin and western New York—is made up of areas with steeply sloping soils and at least some glacial sediments. The completely nonglaciated area in southwestern Wisconsin that is surrounded by ENZ 3 was classified as ENZ 4, the same as southeastern part of the study area.

COMPARISON OF ENVIRONMENTAL NUTRIENT ZONES TO NUTRIENT ECOREGIONS

The goal of subdividing the study area into various nutrient ecoregions or environmental nutrient zones was to develop areas of relatively homogeneous water quality based on various environmental factors. The ecoregion subdivision was based on relative differences in a suite of factors, whereas the environmental nutrient zone subdivision was based only on the most important two or three factors. This leads to the question, "Which approach is best in subdividing the entire area into four or five subareas?" In general, nutrient ecoregions (at this 14-subdivision level) provide larger, more contiguous subareas than do nutrient zones. But which approach minimizes the variability in water quality within the subareas? To compare the two approaches, the weighted mean coefficient of variation (MCV, eq. 1) was computed for each scheme. Land use was the primary factor influencing the distribution of phosphorus and nitrogen; therefore, to fairly compare the two approaches, the MCVs for the nutrient ecoregions are compared with those for environmental nutrient zones derived including land-use characteristics. For total phosphorus, the MCV for the nutrient ecoregions was 1.96 compared to 0.98 for the EPZs (table 5). (The values in table 5 are based on the environmental nutrient zones in which the watersheds were located, not necessarily the environmental nutrient group in which the site was classified.) Therefore, the environmental nutrient zone approach was better than the nutrient ecoregion approach for total phosphorus and reduced the variability within the subareas by about 50 percent. For total nitrogen, the MCV for the nutrient ecoregions was 0.59 compared to 0.58 for the ENZs. Therefore, the environmental nutrient zone approach was not much better than the ecoregion approach for total nitrogen and only reduced the MCV by about 1 percent. This similarly was expected because the ENZs (including land-use characteristics) were similar to the nutrient ecoregions.



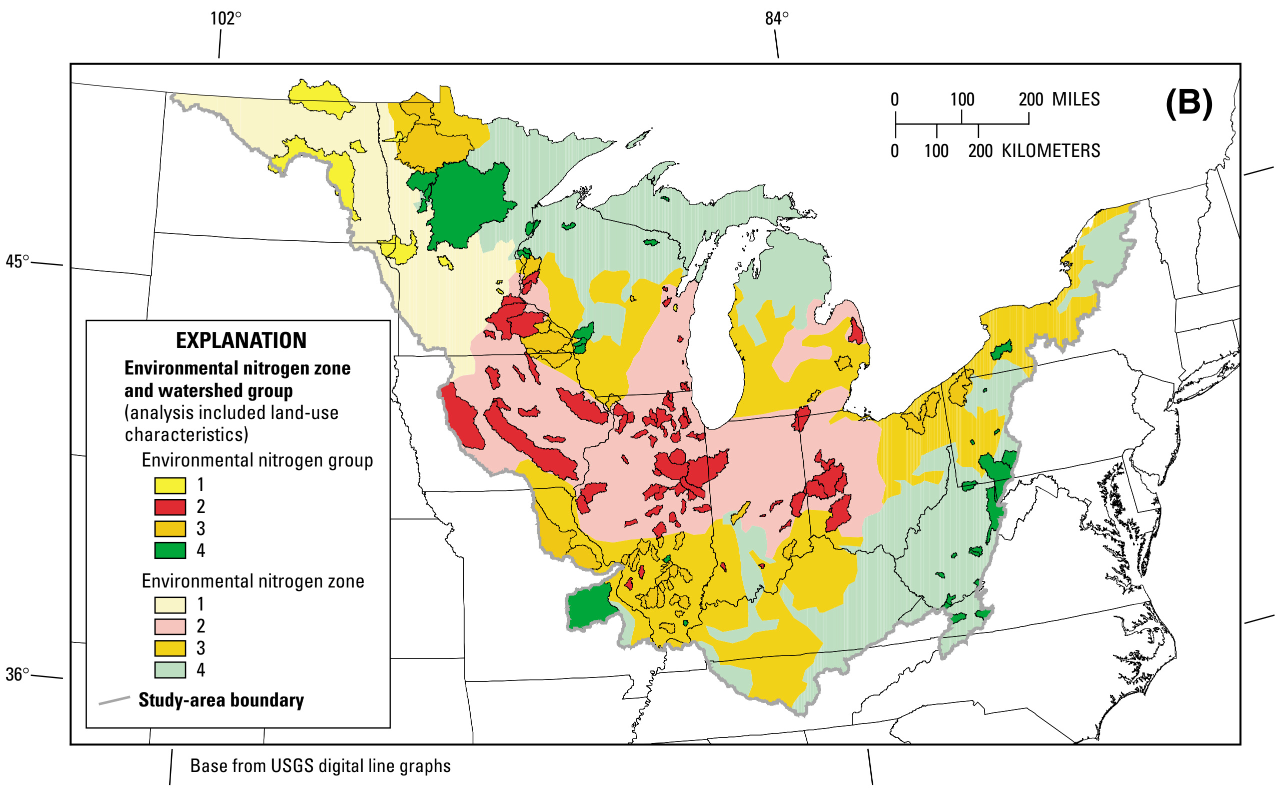


Figure 21. (A) Environmental phosphorus zones and (B) environmental nitrogen zones for study area when land-use characteristics were included in the regression-tree analyses. (Watersheds are color coded by the regression-tree group to which they were assigned. Color code for qualitative concentration range is green (lowest) followed by yellow, orange, and red (highest).)

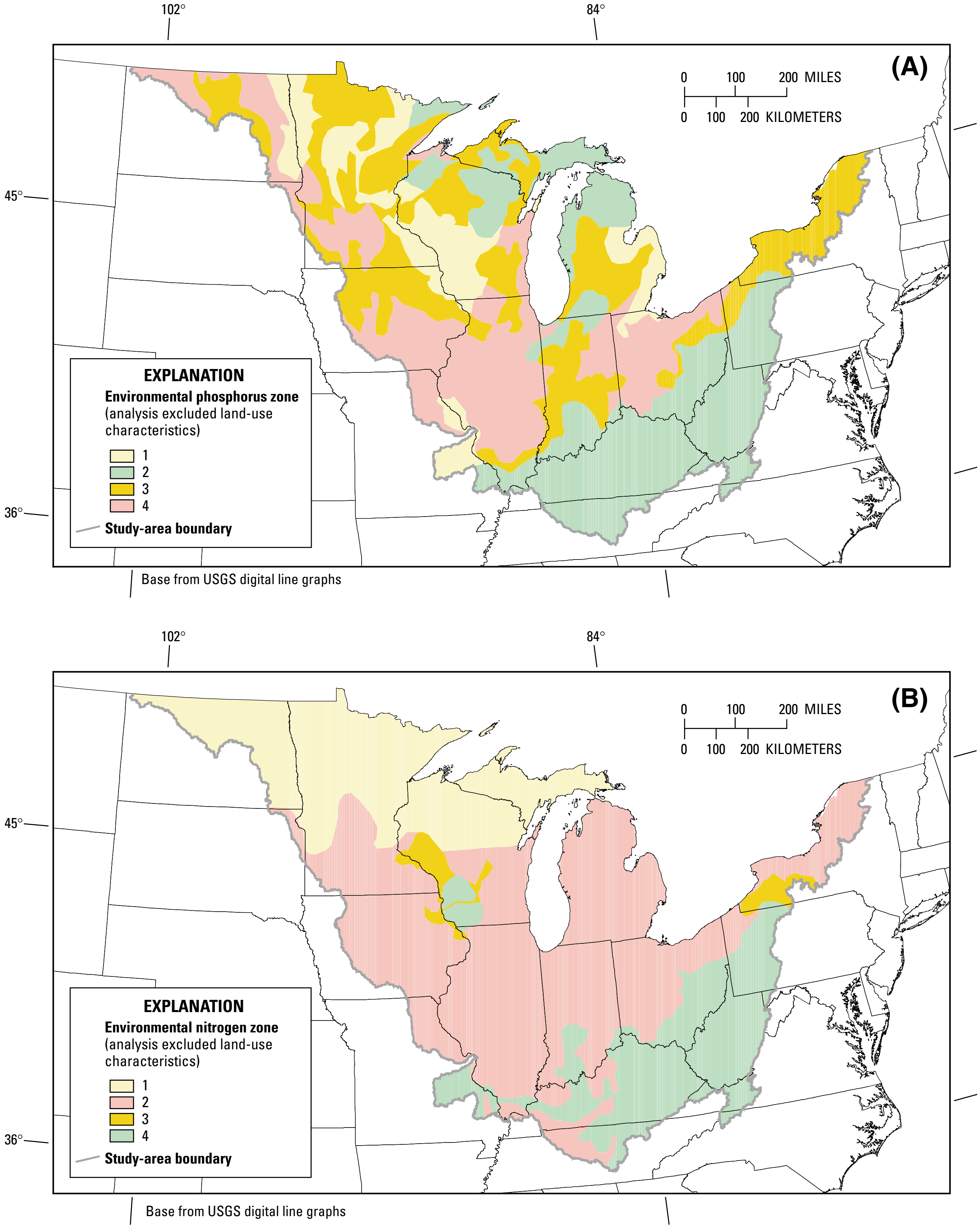


Figure 22. (A) Environmental phosphorus zones and (B) environmental nitrogen zones for study area when land-use characteristics were excluded from the regression-tree analyses. (Watersheds are color coded by the regression-tree group to which they were assigned. Color code for qualitative concentration range is green (lowest) followed by yellow, orange, and red (highest).)

Table 5. Comparison of water quality and variability in water quality within nutrient ecoregions and within environmental nutrient zones (delineated with results from regression-tree analyses)

	Total phosphorus					Total nitrogen				
					Ecoregions					
Ecoregion	Count	Mean	Median	Standard deviation	Coefficient of variation	Count	Mean	Median	Standard deviation	Coefficient of variation
VI	83	0.24	0.15	0.37	1.51	68	5.81	5.83	3.10	0.53
VII	86	.13	.10	.12	.90	29	2.32	1.88	1.37	.59
VIII	14	.00	.03	.02	.58	10	.77	.73	.32	.42
IX	36	.23	.17	.21	.93	30	2.26	1.55	1.82	.81
XI	15	.04	.05	.02	.49	15	.73	.68	.22	.31
Total	234		Weighted mean coefficient of variation (MCV)		1.96	152		Weighted mean coefficient of variation (MCV)		.59
					Nutrient Zones - Regression tree (including land-use characteristics)					
Zone	Count	Mean	Median	Standard deviation	Coefficient of variation	Count	Mean	Median	Standard deviation	Coefficient of variation
1	82	0.11	0.09	0.08	0.68	8	1.42	1.33	0.37	0.26
2	109	.27	.17	.34	1.26	70	5.88	5.76	2.94	.50
3	23	.06	.05	.04	.65	49	2.17	1.52	1.66	.76
4	20	.03	.04	.02	.55	25	.77	.68	.33	.43
Total	234		Weighted mean coefficient of variation (MCV)		.98	152		Weighted mean coefficient of variation (MCV)		.58
					Nutrient Zones - Regression tree (excluding land-use characteristics)					
Zone	Count	Mean	Median	Standard deviation	Coefficient of variation	Count	Mean	Median	Standard deviation	Coefficient of variation
1	44	0.10	0.08	0.06	0.60	21	1.08	1.10	0.38	0.36
2	30	.04	.03	.03	.75	110	4.62	4.01	3.05	.66
3	58	.12	.09	.08	.66	4	1.48	1.42	.29	.19
4	102	.28	.17	.35	1.26	17	.68	.66	.24	.36
Total	234		Weighted mean coefficient of variation (MCV)		.97	152		Weighted mean coefficient of variation (MCV)		.59

Similar results were found when comparing the variability within nutrient ecoregions to that within environmental nutrient zones derived excluding land-use characteristics. The MCV for the EPZs (excluding land-use characteristics) also was 50 percent less than that for the nutrient ecoregions, and the MCV for ENZs (excluding land-use characteristics) also was about the same as that for nutrient ecoregions (table 5). Therefore, for total phosphorus, environmental nutrient zones developed by use of the methods described in this report, including only natural occurring environmental factors, reduce the variance within each subarea and yet should reflect areas with similar potential water quality. For total nitrogen, the variance within the environmental nutrient zones was similar to that for the nutrient ecoregions, but should reflect areas with similar potential water quality.

DEFINING NUTRIENT CRITERIA FOR ENVIRONMENTAL NUTRIENT ZONES

Criteria for each nutrient zone can be defined with a reference-condition approach similar to that described earlier for nutrient ecoregions. This concentration can be defined from the frequency distribution of all available data for a specified area (for example, the lower 25th percentile) or the frequency distribution of a subset of streams thought to be the least impacted (for example, the upper 75th percentile) (fig. 3). The final criteria could be between these two concentrations.

On the basis of concentrations of the lower 25th percentiles of all of the data from the EPZs (derived by excluding land-use characteristics, fig. 22a), phosphorus criteria could range from 0.02 mg/L for EPZ 2 to 0.11 mg/L for EPZ 4 (table 6). If it is assumed that the least impacted streams in each zone have less than 25 percent agriculture in their watersheds, then alternative criteria could be established. Based on the 75th percentile of this subset of streams, phosphorus criteria could range from 0.05 mg/L for EPZ 2 to 0.16 mg/L for EPZ 4 (table 6).

On the basis of concentrations of the lower 25th percentiles of all data from the ENZs (derived by excluding land-use characteristics), nitrogen criteria could range from 0.51 mg/L for ENZ 4 to 1.75 mg/L for ENZ 2 (table 6). Based on the 75th percentiles of the subsets of streams with less than 25 percent agriculture in their watersheds, nitrogen criteria could range from 0.67 mg/L for ENZ 4 to 9.00 mg/L for ENZ 2 (table 6). Only two sites had data available for ENZ 2 with less than 25 percent agriculture.

For many environmental nutrient zones, few sites had less than 25 percent agriculture in their watersheds. Some of these "reference" sites did not actually represent natural conditions because they were dominated by urban land use. Therefore, reference sites must be closely examined to keep atypical conditions from corrupting this approach.

Within each environmental nutrient zone, streams may be classified by size, stream order, or use for example. In this report, as an example of how different criteria could be established for specific types of streams within a specific environmental nutrient zone, the sites were subdivided into four types on the basis of how the land around the stream was being used (based on the percentage of agriculture in the watershed). Nutrient criteria for each stream type can be developed with an approach that is similar to that for all streams in an environmental nutrient zone; that is, by examining the frequency distribution of all available data for a specific type of stream. For example, in streams with more than 75 percent of their watershed being used for agriculture in EPZ 4 (fig. 22a), if the 25th percentile of all of the data of this type of stream is used to define the criterion, then the criterion would be 0.12 mg/L (table 6). In EPZ 4, most of the streams had more than 75 percent of their watershed area in agriculture; therefore, the concentration of the 25th percentile of this subset of streams was similar to that for all of the streams in EPZ 4 (0.11 mg/L). If the 75th percentile of the reference streams (defined as streams with less than 25 percent agricultural land) from the area are used, the criterion would again be 0.16 mg/L. Therefore the criterio for streams with 75 to 100 percent agriculture would be between 0.12 and 0.16 mg/L. With this approach, a specific type of stream may have more or less stringent criteria than other types of streams within the defined area.

REFINING ENVIRONMENTAL NUTRIENT ZONES

The USEPA has taken the initial step in developing regional nutrient criteria based on national nutrient ecoregions (fig. 1); however, the criteria may be refined on the basis of Omernik's original 84 Level III ecoregions (fig. 2). The environmental nutrient zones in figure 22 were developed for the entire study area; however, individual states or tribes may wish to refine the results at a smaller spatial scale or refine the basic USEPA approach but maintain its basic classification scheme. With slight modifications to the approach, the four environmental nutrient groups can be refined by further subdivision, or new zones can be defined within smaller geographical areas (such as specific states or specific nutrient ecoregions).

Further Subdivision of the Environmental Nutrient Zones

To refine the classification scheme found for the entire Midwest (fig. 22), the regression trees shown in figures 19 and 20 can be further branched. Further branching results in a larger number of groups with a smaller number of sites in each group (fig. 23). The location of the sites in each of the resulting groups for total phosphorus (developed from analyses excluding land-use characteristics) are shown in figure 24. Group 1 sites from figure 19b were further partitioned on the basis of whether the soil erodibility factor was less than 0.22 (17 sites) or greater than or equal to 0.22 (35 sites). Group 2 sites were further partitioned on the basis of whether average annual air temperature was less than 50°F (21 sites) or greater than or equal to 50°F (10 sites). Group 3 sites were further partitioned on the basis of whether runoff was less than 11.5 in/yr (41 sites) or greater than or equal to 11.5 in/yr (14 sites). Group 4 sites were further partitioned on the basis of whether the surficial-deposit type "coarse-grained sediment" was not present (20 sites) or present (76 sites). Overall, the lowest total phosphorus concentrations occurred at sites with less than 59 percent till, more than

Table 6. Percentiles of nutrient concentrations, by the percentage of agriculture in the watershed, for each environmental nutrient zone (created on the basis of results of regression-tree analyses when land-use characteristics were excluded from the analyses)
[--, no data]

Percent agriculture	Number	Mean	Standard deviation	Percentiles				
				10th	25th	50th	75th	90th
Phosphorus Zone 1								
0–100	44	0.10	0.06	0.04	0.06	0.08	0.14	0.18
0–25	2	.04	.03	.02	.02	.04	.06	.06
25–50	12	.08	.08	.03	.03	.06	.11	.15
50–75	14	.09	.04	.05	.06	.08	.12	.14
75–100	16	.13	.06	.08	.08	.12	.18	.21
Phosphorus Zone 2								
0–100	30	.04	.03	.01	.02	.03	.05	.05
0–25	14	.03	.02	.01	.01	.03	.05	.05
25–50	8	.03	.02	.01	.02	.03	.05	.05
50–75	5	.05	.05	.02	.02	.02	.05	.14
75–100	3	.05	.03	.02	.02	.05	.08	.08
Phosphorus Zone 3								
0–100	58	.12	.08	.03	.06	.24	.17	.09
0–25	4	.05	.01	.03	.04	.05	.06	.06
25–50	3	.12	.09	.06	.06	.07	.22	.22
50–75	11	.09	.07	.01	.03	.07	.16	.19
75–100	40	.14	.08	.06	.08	.11	.21	.25
Phosphorus Zone 4								
0–100	102	.28	.35	.07	.11	.17	.27	.54
0–25	5	.04	.63	.04	.08	.13	.16	1.51
25–50	3	1.11	1.06	.05	.05	1.13	2.16	2.16
50–75	15	.23	.17	.07	.10	.19	.38	.54
75–100	79	.25	.28	.08	.12	.17	.25	.50

Percent agriculture	Number	Mean	Standard deviation	Percentiles				
				10th	25th	50th	75th	90th
Nitrogen Zone 1								
0–100	21	1.08	0.38	0.58	0.91	1.10	1.26	1.61
0–25	6	.80	.35	.41	.47	.84	1.10	1.15
25–50	5	.91	.19	.66	.79	.91	1.00	1.16
50–75	4	1.09	.16	.95	.95	1.08	1.22	1.26
75–100	6	1.48	.33	.99	1.30	1.48	1.72	1.90
Nitrogen Zone 2								
0–100	110	4.62	3.05	1.24	1.75	4.01	6.80	9.35
0–25	2	4.97	5.71	.93	.93	4.97	9.00	9.00
25–50	4	5.04	2.56	1.35	3.32	6.02	6.77	6.80
50–75	18	1.81	1.27	.86	.95	1.24	2.40	4.30
75–100	86	5.18	3.00	1.56	2.60	4.73	7.75	9.40
Nitrogen Zone 3								
0–100	4	1.48	.29	1.21	1.29	1.42	1.67	1.88
0–25	0	--	--	--	--	--	--	--
25–50	1	1.88	--	1.88	1.88	1.88	1.88	1.88
50–75	3	1.35	.13	1.21	1.21	1.37	1.47	1.47
75–100	0	--	--	--	--	--	--	--
Nitrogen Zone 4								
0–100	17	.68	.24	.37	.51	.66	.76	1.06
0–25	8	.56	.14	.37	.45	.58	.67	.74
25–50	7	.79	.27	.34	.59	.76	1.05	1.06
50–75	2	.79	.40	.51	.51	.79	1.08	1.08
75–100	0	--	--	--	--	--	--	--

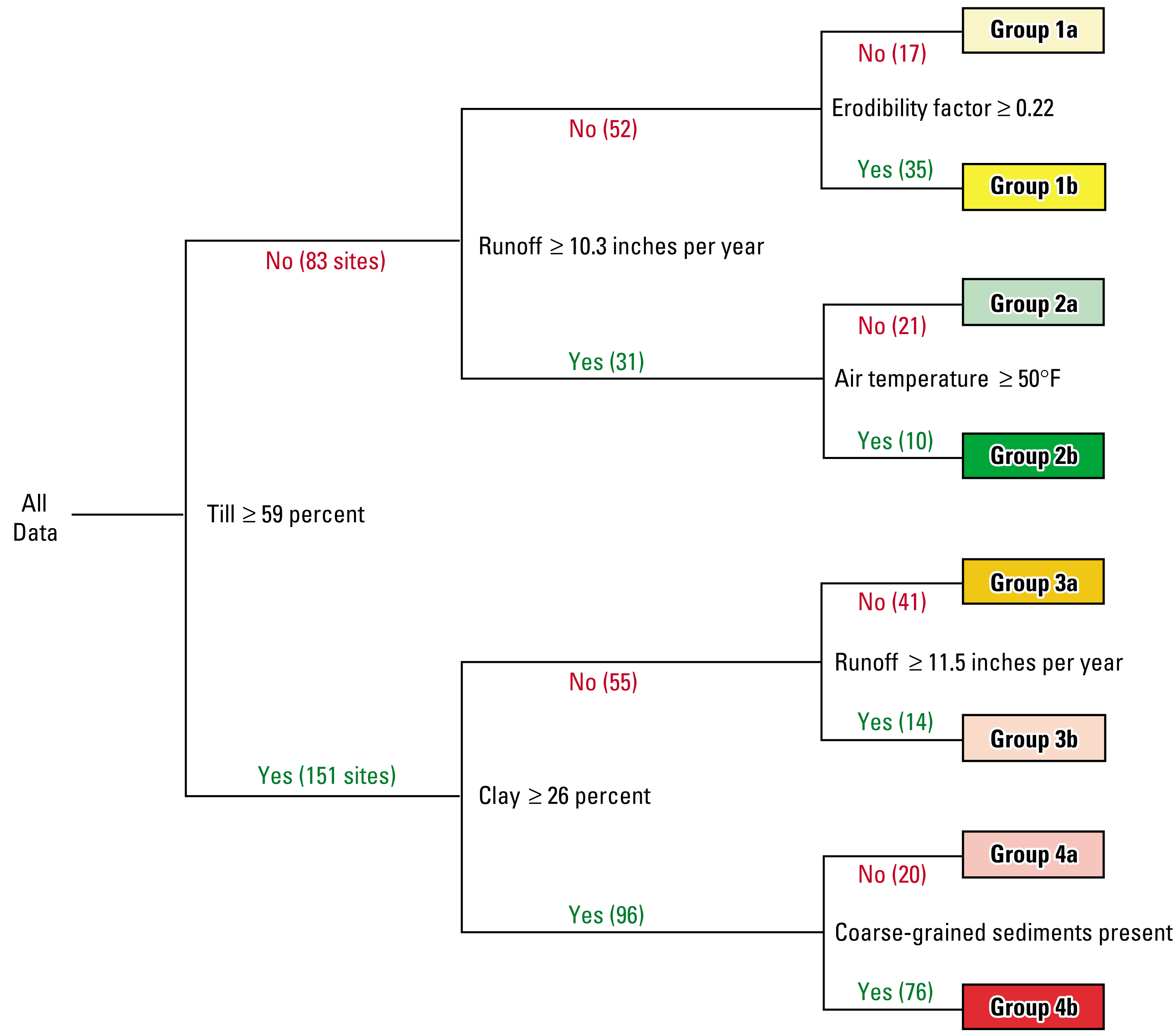


Figure 23. Detailed environmental phosphorus groups from regression-tree analysis results excluding land-use characteristics, subdividing the data into eight groups. (The numbers in brackets are the number of sites in each group. Color code for qualitative concentration range is green (lowest) followed by yellow, orange, and red (highest). The lighter shade of color corresponds to the lower qualitative concentration for each of the four original groups.))

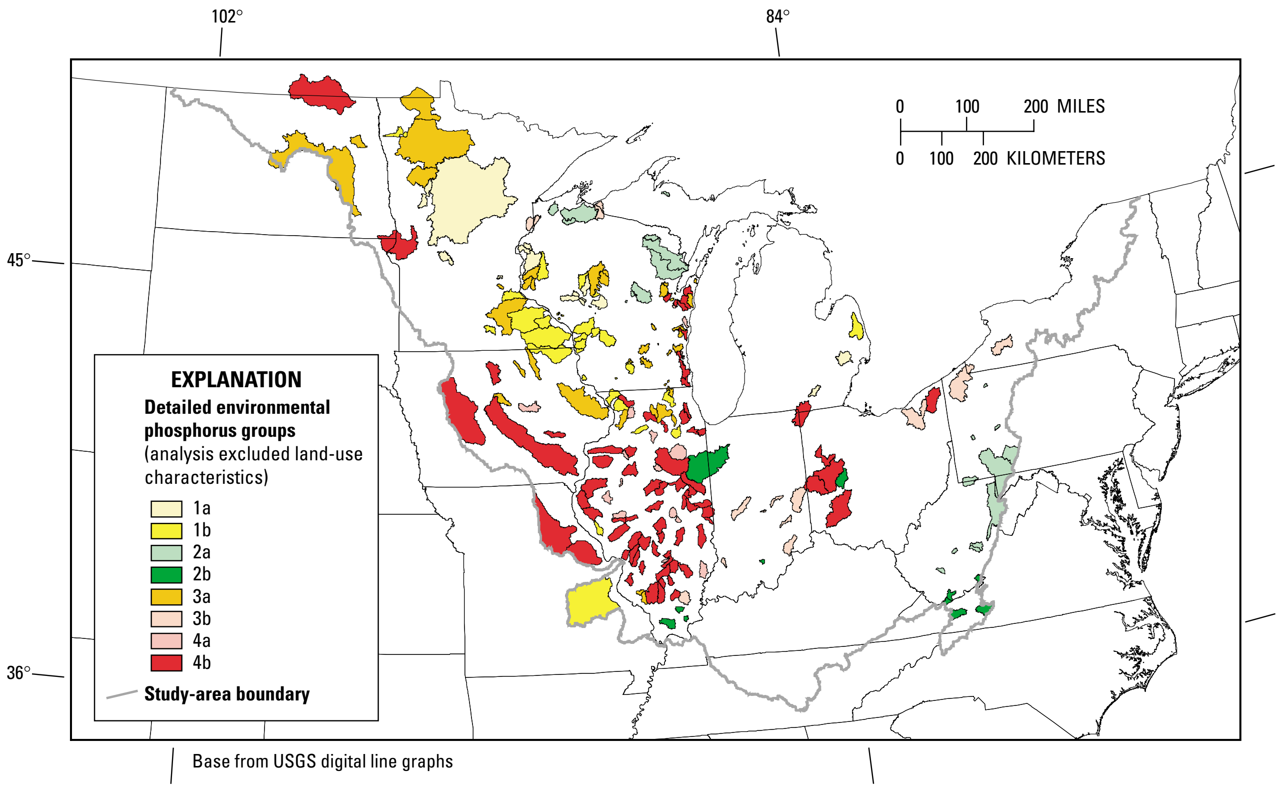


Figure 24. Location of the watersheds for the eight environmental phosphorus groups when land-use characteristics were excluded from the regression-tree analysis. (Color code for qualitative concentration range is green (lowest) followed by yellow, orange, and red (highest). The lighter shade of color corresponds to the lower qualitative concentration for each of the four original groups.)

10.3 in/yr of runoff, and have a mean annual air temperature of less than 50°F (group 2a, with a mean concentration of 0.03 mg/L). The highest concentrations occurred at sites with more than 59 percent till, more than 26 percent soil clay content, and coarse-grained surficial deposits present (group 4b, with a mean concentration of 0.32 mg/L). By use of the GIS coverages for these additional variables, the four environmental nutrient zones (fig. 22) could be further subdivided into eight zones corresponding to each of these groups.

Refinement for Smaller Geographical Areas

To demonstrate refinement of the approach for smaller geographical areas, regression-tree analyses (excluding land-use characteristics) were performed on two subregions of the study area.

As an example of a subdivision for an individual state, total phosphorus for the sites in Illinois were used in a regression-tree analysis, excluding land-use characteristics. This subset of 75 sites was chosen because it provides a good spatial coverage of an entire state. An asymmetrical branching of the regression tree (not shown) resulted in three subgroups (fig. 25). The first independent variable chosen was surficial-deposit type, till (fig. 9). The sites were partitioned into subgroups corresponding to those with less than 66 percent till (group 1, 9 sites) or greater than or equal to 66 percent till (66 sites). Those sites with less than 66 percent till were not further subdivided. The sites with more than or equal to 66 percent till were further partitioned on the basis of whether the soil slope was less than 3.2 percent (group 2, 19 sites) or greater than or equal to 3.2 percent (group 3, 47 sites). Group 1, with less than 66 percent till, had the lowest total phosphorus concentrations (mean concentration of 0.10 mg/L). These sites are mostly found in the extreme northern and southern part of Illinois (fig. 25). Group 3, with more than or equal to 66 percent till and average soil slopes greater than 3.2 percent, had the highest concentrations (mean concentration of 0.33 mg/L) and were scattered throughout the state.

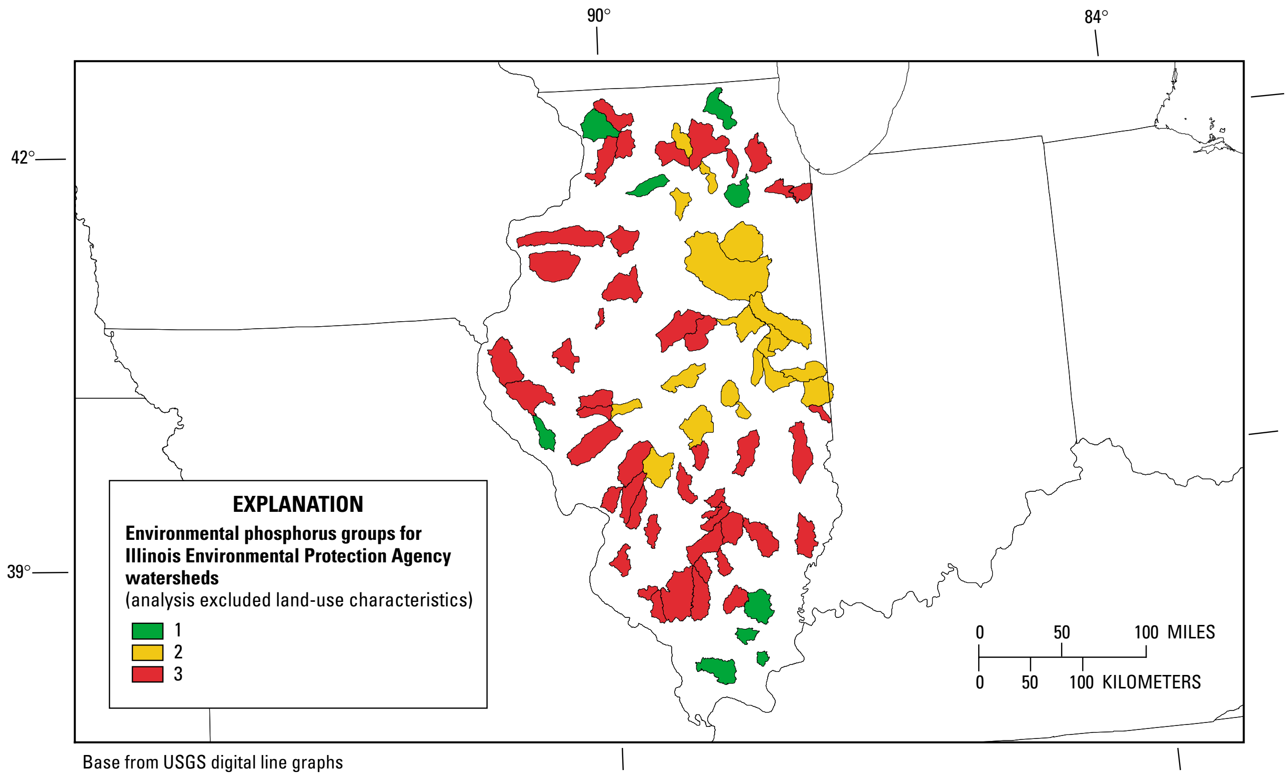


Figure 25. Environmental phosphorus groups for Illinois Environmental Protection Agency watersheds when land-use characteristics were excluded from the regression-tree analysis. (Color code for qualitative concentration range is green (lowest) followed by orange and red (highest).)

As an example of a subdivision for a specific nutrient ecoregion, sites in the study area with watersheds mostly or entirely in nutrient ecoregion VI were used in a regression-tree analysis, excluding land-use characteristics. This subset of 83 sites was chosen because it had the best spatial coverage of a nutrient ecoregion in the study area. Two branchings of the regression tree (not shown) based on three independent variables resulted in four subgroups. The first independent variable chosen was the soil characteristic percentage of clay. The sites were partitioned into subgroups corresponding to those with average soil clay less than 26 percent (25 sites) or greater than or equal to 26 percent (58 sites). Those sites with soil clay less than 26 percent were further subdivided on the basis of whether the proportion of the watershed underlain by till was less than 88 percent (group 1, 17 sites) or greater than or equal to 88 percent (group 2, 8 sites). Sites with average soil clay content greater than or equal to 26 percent were further partitioned on the basis of whether the proportion of the watershed underlain by carbonate aquifer was less than 80 percent (group 3, 50 sites) or greater than or equal to 80 percent (group 4, 8 sites). Sites in group 2 had the lowest total phosphorus concentrations (mean concentration of 0.06 mg/L) and were scattered throughout nutrient ecoregion VI (fig. 26). Sites in group 4 had the highest concentrations (mean concentration of 0.75 mg/L) and were primarily in the eastern part of the nutrient ecoregion in northeastern Illinois, western Ohio, and southeastern Wisconsin.

WATERSHED-SPECIFIC APPROACH

Although environmental nutrient zones were defined to be relatively homogeneous areas, small watersheds within each zone may still have considerably different environmental characteristics than those of the generalized zone. Therefore, another refinement of this method may be to use a watershed approach with classification based only on the environmental characteristics of the watershed of a specific stream. With this approach, available data would be used to establish environmental nutrient groups (such as depicted in figures 19, 20, or 23), then only the watershed characteris-

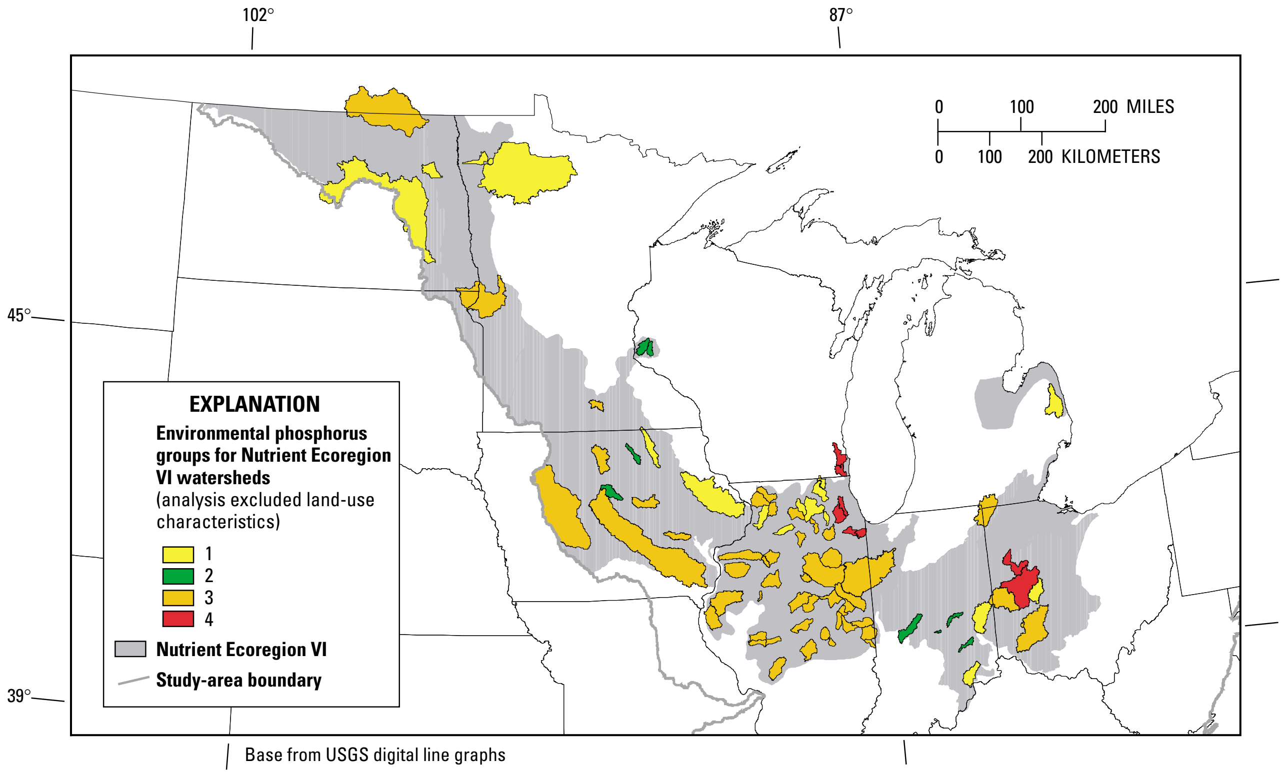


Figure 26. Environmental phosphorus groups for Nutrient Ecoregion VI watersheds when land-use characteristics were excluded from the regression-tree analysis. (Color code for qualitative concentration range is green (lowest) followed by yellow, orange, and red (highest).)

tics of the site would be used to place the site into an environmental nutrient group. The criteria for the site would thus be based on the distribution of existing data in that group. This approach would work best for highly heterogeneous areas where the specific environmental nutrient zone is difficult to define, for streams with large watersheds that span more than one environmental nutrient zone, and for small areas of atypical environmental characteristics.

By applying a watershed-specific approach to the sites used in this study, rather than the generalized nutrient-zone approach, the overall variability in water quality within the groups was found to be highly similar to that within the nutrient zones. For total phosphorus concentrations, the MCV (0.94) for the environmental phosphorus groups was similar to that for the EPZs (MCV of 0.98; table 5); both subdivisions had about 50 percent less variability than within the nutrient ecoregions (MCV of 1.96). For total nitrogen concentrations, the MCV for the environmental nitrogen groups was about the same as that for the ENZs (MCV of 0.59; table 5); the variability within both subdivisions was about the same as within the nutrient ecoregions (MCV of 0.59).

In general, the watershed-specific approach should provide more relevant nutrient criteria than any generalized approach. The difficulty in applying the watershed approach, however, is that site-specific information is needed to classify a watershed into the appropriate nutrient group and thus determine its corresponding criterion. Therefore, the watershed-specific approach may be most appropriate where detailed environmental information is available at the statewide scale—or even more local scales—and can be used to evaluate sites before final criteria are set and management actions are implemented.

SUMMARY AND CONCLUSIONS

In order to establish regional nutrient criteria that reflect the influence of various environmental factors, the USEPA has divided the country into nutrient ecoregions (areas of relatively similar environmental characteristics) and proposed different criteria for each region. These regions were supposed to incorporate the effects of relative differences in natural and anthropogenic factors; however, the distribution in land-use practices was commonly the primary factor used in to delineate the nutrient ecoregions, such as in the Upper Midwest part of the United States. Therefore, because land use is commonly the primary factor affecting water quality, the differences among ecoregions strongly reflect anthropogenic effects.

As part of a Regional Technical Assistance Group (RTAG) for the USEPA, whose role it is to examine and refine this basic approach, an alternative regionalization scheme was developed for the Upper Midwest. Through the use of a regression-tree analyses and a geographic information system (GIS), the importance of various environmental characteristics were determined and then the distributions of only the most statistically significant environmental characteristics were used to subdivide the Midwest into relatively homogeneous environmental nutrient zones. The most statistically significant characteristics affecting nutrient concentrations were percentage of agriculture (lack of forest), and surficial-deposit and climatic characteristics of the watershed. Environmental nutrient zones were delineated that incorporated land-use distributions (similar to the basic approach) and also delineated excluding land-use information so that the criteria should reflect the differences in water quality caused by natural factors.

The environmental nutrient zones reduced the variability in water quality within the defined areas better than the basic nutrient ecoregions by approximately 50 percent for total phosphorus, but only slightly reduced the variability for total nitrogen. Various modifications were demonstrated to this refined approach, including development of nutrient zones for specific states or nutrient ecoregions and development of criteria as a function of stream type (described here as a function of land use in the watershed). An additional modification would be to develop nutrient criteria based only on the environmental characteristics of the watershed of a stream rather than the general environmental characteristics from the region in which the watershed is located.

This alternative regionalization scheme and various modifications presented in this report provide states methods to refine the basic nutrient criteria proposed by the USEPA. This alternative scheme should enable streams to be better managed and protected because criteria based on this regionalization should better reflect concentrations that are attainable given the environmental conditions where the streams are located.

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APPENDIXES 1–2

Appendix 1a. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site

[almn, Allegheny and Monongahela River Basins NAWQA study unit; eiwa, Eastern Iowa Basins NAWQA study unit; iepa, Illinois Environmental Protection Agency; kana, Kanawha-New River Basins NAWQA study unit; leri, Lake Erie-Lake Saint Clair Drainages NAWQA study unit; lirb, Lower Illinois River Basin NAWQA study unit; miam, Great and Little Miami River Basins NAWQA study unit; redn, Red River of the North Basin NAWQA study unit; stx, U.S. Geological Survey, St. Croix River Watershed study; uirb; Upper Illinois River Basin NAWQA study unit; umbl, U.S. Geological Survey, Upper Mississippi River System study; umis, Upper Mississippi River Basin NAWQA study unit; wdnr, Wisconsin Department of Natural Resources; whit, White River Basin NAWQA study unit; wmic, Western Lake Michigan Drainages NAWQA study unit; mi^2, square miles; in/yr, inches per year; °F, degrees Fahrenheit]

				Climate		Land-use characteristics (percent)							
Station number	Sampling agency or USGS study name	Area (mi^2)	Runoff (in/yr)	Precipitation (in/yr)	Temperature (°F)	Urban	Agriculture	Rangeland	Forest	Water	Forested wetland	Nonforested wetland	Barren land
03015795	almn	20	25.5	42.5	47.1	0.0	0.7	0.0	99.3	0.0	0.0	0.0	0.0
03024000	almn	1,067	24.0	42.5	47.1	2.8	63.3	.0	31.5	.5	1.5	.3	.2
03037350	almn	33	24.0	42.5	49.8	.0	50.2	.0	49.6	.0	.0	.0	.2
03040000	almn	452	24.0	42.5	49.8	2.9	33.3	.0	58.4	.6	.0	.0	4.8
03049646	almn	27	18.0	37.5	49.8	15.3	47.5	.0	36.1	.0	.0	.0	1.2
03070350	almn	1,128	30.0	53.6	49.1	.5	10.4	.0	86.6	.4	.0	.9	1.1
03072000	almn	227	18.0	42.5	50.2	.7	24.9	.0	73.8	.1	.0	.0	.5
03083500	almn	1,710	26.0	43.0	49.1	3.5	34.6	.0	59.4	.8	.1	.0	1.6
40001	umbl	337	5.5	31.0	44.1	8.4	82.3	.0	4.6	.9	2.9	.3	.6
40007	umbl	1,481	6.0	31.9	44.7	2.4	88.6	.0	4.3	2.4	.5	1.6	.2
50001	umbl	1,420	6.0	32.5	44.2	2.9	90.0	.0	6.7	.2	.0	.0	.1
50003	umbl	323	6.0	32.5	44.2	.8	79.6	.0	19.2	.0	.0	.3	.0
80001	umbl	477	8.5	32.5	44.5	8.6	39.9	.0	49.2	.2	1.3	.5	.2
80003	umbl	1,665	7.0	32.5	44.2	.8	77.4	.0	21.5	.0	.1	.1	.1
80007	umbl	141	8.5	32.5	45.7	.5	51.0	.0	48.2	.0	.0	.3	.0
90001	umbl	188	8.5	32.5	46.2	1.4	56.6	.0	38.9	.1	.1	2.8	.0
90003	umbl	992	8.0	32.5	45.9	.6	83.4	.0	16.0	.0	.0	.0	.0
130001	umbl	1,860	9.0	33.7	47.7	.8	94.1	.0	4.9	.1	.0	.0	.1
130003	umbl	256	9.0	32.6	48.8	.8	87.2	.0	10.5	.2	.0	.0	1.4
200003	umbl	3,444	5.5	32.3	48.0	1.0	96.0	.1	2.3	.3	.0	.1	.2
240001	umbl	2,484	8.5	37.6	53.9	1.0	87.4	.0	11.4	.1	.0	.0	.1
260001	umbl	1,227	8.0	37.5	53.9	1.1	79.9	.1	18.7	.1	.0	.0	.1
280001	umbl	3,781	9.5	41.7	55.3	1.5	30.0	.0	67.4	.3	.0	.0	.9
05420680	eiwa	346	7.5	32.5	46.1	1.2	92.5	.0	1.9	.1	3.5	.7	.1
05449500	eiwa	418	6.0	32.5	46.0	1.1	97.1	.0	.7	.2	.0	.7	.2

Appendix 1a. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Sampling agency or USGS study name	Area (mi^2)	Runoff (in/yr)	Climate: Precipitation (in/yr)	Climate: Temperature (°F)	Land-use characteristics (percent): Urban	Agriculture	Rangeland	Forest	Water	Forested wetland	Nonforested wetland	Barren land
05451210	eiwa	224	6.5	32.5	47.9	0.4	97.8	0.0	1.7	0.0	0.1	0.1	0.0
05455100	eiwa	201	8.0	37.5	49.1	1.4	95.8	.0	2.8	.0	.0	.0	.0
05461390	eiwa	124	7.0	32.5	46.0	.2	97.7	.0	1.6	.0	.0	.4	.0
05464220	eiwa	299	7.5	32.5	47.9	.8	98.0	.0	1.3	.0	.0	.0	.0
05474000	eiwa	4,311	7.5	35.1	49.6	1.5	93.1	.0	5.2	.1	.0	.0	.1
BPK07	iepa	442	10.0	37.5	51.3	.8	96.7	.0	2.2	.1	.0	.0	.2
BPJ07	iepa	135	10.0	37.5	51.3	4.8	95.1	.0	.0	.0	.0	.0	.0
BPJC06	iepa	73	10.0	37.5	51.3	12.6	86.7	.0	.5	.0	.0	.0	.1
BO07	iepa	196	10.0	37.5	51.3	1.3	96.4	.0	2.2	.0	.0	.0	.0
BN01	iepa	255	11.0	41.2	53.5	.7	97.5	.0	1.9	.0	.0	.0	.0
BM02	iepa	59	11.0	42.5	53.4	6.9	79.2	.0	13.3	.5	.0	.0	.0
BE14	iepa	181	10.0	37.5	51.9	3.4	96.3	.0	.3	.0	.0	.0	.0
BEF05	iepa	304	11.0	42.3	53.8	1.5	83.7	.0	14.5	.0	.0	.0	.2
BC02	iepa	226	13.0	42.5	55.3	1.3	91.0	.0	7.6	.1	.0	.0	.0
C21	iepa	237	9.5	37.6	53.8	1.3	88.3	.0	9.2	1.1	.0	.0	.0
CD01	iepa	254	11.0	42.5	55.2	1.6	87.2	.0	11.1	.0	.0	.0	.0
CA06	iepa	208	10.0	42.5	53.8	.2	71.0	.0	27.8	.4	.0	.0	.1
ATGC01	iepa	82	13.0	42.5	56.3	1.0	64.0	.4	15.2	.4	.2	.9	17.9
ATF04	iepa	249	13.0	42.5	56.3	1.2	85.6	.2	12.2	.1	.5	.0	.0
AK02	iepa	45	15.0	42.5	56.3	.2	29.5	.3	66.9	3.1	.0	.0	.0
AD02	iepa	242	15.0	42.5	56.3	1.4	70.2	.4	24.4	.1	2.6	.3	.8
MJ01	iepa	272	9.0	36.7	49.0	.6	90.9	.0	7.3	.3	.0	.0	.9
PWN01	iepa	194	9.0	32.5	49.0	1.6	96.2	.0	1.9	.0	.0	.0	.3
PQ10	iepa	225	9.0	37.5	49.4	3.6	89.3	.0	5.7	.2	.2	.3	.7
PQC06	iepa	396	9.5	37.5	49.4	3.9	94.3	.0	1.3	.1	.0	.0	.3
PQB02	iepa	134	9.5	37.5	49.1	1.2	97.7	.0	.9	.0	.0	.1	.1
PL03	iepa	196	9.5	37.5	49.0	2.2	95.7	.0	1.7	.2	.0	.0	.2
PH16	iepa	146	9.0	37.0	49.0	1.1	97.1	.0	1.7	.0	.0	.0	.1
PE05	iepa	241	9.0	37.5	49.0	1.2	96.6	.0	2.0	.1	.0	.0	.0
PB02	iepa	147	9.0	37.5	49.0	2.4	89.7	.0	7.2	.3	.0	.1	.2
LF01	iepa	434	9.0	37.2	49.0	1.3	91.6	.0	6.7	.1	.0	.0	.2
LD02	iepa	432	9.0	37.5	51.1	3.6	92.3	.0	3.9	.1	.0	.0	.1

Appendix 1a. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site—Continued

				Climate		Land-use characteristics (percent)							
Station number	Sampling agency or USGS study name	Area (mi^2)	Runoff (in/yr)	Precipitation (in/yr)	Temperature (°F)	Urban	Agriculture	Rangeland	Forest	Water	Forested wetland	Nonforested wetland	Barren land
KI02	iepa	354	8.5	37.5	51.8	.6	90.9	0.0	8.5	0.0	0.0	0.0	0.0
KCA01	iepa	140	8.5	37.5	53.5	1.4	90.9	.0	7.7	.1	.0	.0	.0
HBD04	iepa	102	12.0	37.5	49.5	39.2	48.1	.0	7.6	.7	1.4	.7	2.3
GG02	iepa	105	11.0	37.5	49.4	16.8	72.3	.0	7.8	.3	.9	.0	1.8
GB10	iepa	214	10.5	37.5	49.4	48.4	36.9	.0	5.4	.6	.0	.2	8.5
DW01	iepa	177	10.0	37.5	49.4	.7	98.3	.0	.8	.0	.0	.0	.1
DV04	iepa	451	9.5	37.5	50.6	1.3	95.8	.0	.4	.2	.0	.0	2.3
DTD02	iepa	73	10.0	37.5	49.4	8.0	86.2	.0	2.6	.3	.0	.5	1.8
DTB01	iepa	90	9.5	37.5	49.4	4.0	91.8	.0	3.4	.6	.0	.0	.3
DS07	iepa	1,230	9.5	37.3	51.0	1.5	97.4	.0	.7	.1	.0	.0	.2
DR01	iepa	119	9.5	37.5	49.4	2.9	92.1	.0	3.6	.2	.0	.0	.9
DL01	iepa	302	9.0	37.5	51.7	9.8	73.9	.0	10.9	.1	.0	.0	5.1
DJ06	iepa	196	9.0	37.5	50.6	1.9	94.0	.0	1.3	.0	.0	.0	2.8
DJB18	iepa	32	8.5	37.5	51.8	9.0	51.1	.0	11.3	.1	.0	.0	28.5
E29	iepa	238	9.5	37.5	51.4	1.2	98.4	.0	.3	.0	.0	.0	.1
EOH01	iepa	289	9.5	37.8	53.3	1.0	97.5	.0	1.5	.0	.0	.0	.0
EL01	iepa	106	9.0	37.5	53.5	6.6	91.2	.0	1.7	.0	.0	.0	.4
EIG01	iepa	213	9.0	37.5	51.9	.9	98.6	.0	.1	.0	.0	.0	.3
EIE04	iepa	224	9.5	37.5	51.7	2.6	96.0	.0	.9	.2	.0	.0	.3
EID04	iepa	331	9.0	37.5	51.7	5.6	92.0	.0	1.6	.2	.0	.0	.3
DH01	iepa	160	8.5	37.5	51.8	.3	68.6	.0	29.7	.1	.0	.0	1.3
DF04	iepa	167	9.0	37.5	53.5	.8	94.1	.0	5.1	.0	.0	.0	.0
DE01	iepa	339	8.5	37.5	51.9	.5	75.4	.0	24.0	.1	.0	.0	.0
DD04	iepa	109	9.0	37.5	53.5	5.9	91.7	.0	2.1	.0	.0	.0	.1
DB01	iepa	405	9.0	37.5	53.5	.9	86.0	.0	12.3	.1	.7	.0	.0
DA04	iepa	299	9.0	37.5	53.5	1.2	87.5	.0	10.5	.4	.0	.0	.3
JR02	iepa	121	9.0	37.5	53.5	10.3	68.0	.0	21.0	.3	.0	.0	.4
JQ05	iepa	211	9.0	37.5	53.5	4.3	71.0	.0	23.6	.5	.0	.0	.5
O31	iepa	113	9.5	37.5	51.3	11.8	87.7	.0	.0	.1	.0	.0	.3
OU01	iepa	54	9.5	37.5	53.8	.0	99.7	.0	.2	.0	.0	.0	.0
OT02	iepa	132	9.5	37.5	52.2	.8	98.8	.0	.4	.0	.0	.0	.0

Appendix 1a. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Sampling agency or USGS study name	Area (mi^2)	Runoff (in/yr)	Climate: Precipitation (in/yr)	Climate: Temperature (°F)	Land-use characteristics (percent): Urban	Agriculture	Rangeland	Forest	Water	Forested wetland	Nonforested wetland	Barren land
OQ01	iepa	113	9.5	38.8	53.7	2.3	81.0	0.0	16.3	0.4	0.0	0.0	0.0
ON01	iepa	78	9.5	42.5	53.8	.2	66.2	.0	33.6	.0	.0	.0	.0
OL02	iepa	152	9.5	37.5	53.7	.6	87.3	.0	11.9	.0	.0	.0	.2
OK01	iepa	111	9.5	42.5	53.8	1.4	7.5	.0	27.6	.2	.0	.0	.0
OKA01	iepa	37	9.5	42.5	53.8	3.2	85.3	.0	11.3	.1	.0	.0	.0
OJ08	iepa	254	10.0	42.4	54.5	5.7	73.7	.0	19.4	.7	.1	.0	.0
OI09	iepa	285	9.0	38.9	53.5	2.5	85.7	.0	10.8	.9	.0	.0	.1
OH01	iepa	115	9.0	37.5	54.5	3.1	89.9	.0	6.8	.1	.0	.0	.0
OD06	iepa	155	9.0	37.5	53.5	2.8	83.2	.0	13.3	.1	.0	.0	.0
OC04	iepa	125	9.0	37.7	56.3	10.9	78.0	.0	6.2	.4	.0	.0	4.3
OZC01	iepa	61	10.0	42.5	56.3	2.3	77.6	4.0	10.2	.1	.0	.0	5.8
II03	iepa	109	10.5	42.5	56.3	4.5	73.3	.0	20.8	.3	.0	.0	1.1
NK01	iepa	94	10.0	42.5	56.3	.5	76.7	.0	22.5	.2	.0	.0	.1
NJ07	iepa	88	10.5	42.5	56.2	9.0	64.4	.0	25.7	.8	.0	.0	.1
NH06	iepa	152	11.5	42.5	56.3	1.4	85.2	.1	11.7	.1	1.1	.0	.0
NE05	iepa	253	11.0	42.5	56.3	2.7	83.1	.0	11.0	.6	1.4	.0	1.1
NC07	iepa	476	10.5	42.2	56.3	.8	76.8	.0	18.5	.4	.0	.0	3.3
03167000	kana	258	17.0	38.6	52.8	4.2	46.8	.0	48.8	.1	.0	.0	.2
03170000	kana	307	18.5	43.1	53.0	.5	52.4	.0	46.8	.0	.0	.0	.1
03178000	kana	200	17.0	38.5	52.6	6.7	14.1	.0	75.8	.2	.0	.0	3.2
03183000	kana	85	18.0	38.7	52.5	.3	28.0	.0	71.4	.2	.0	.0	.0
03186500	kana	127	40.0	55.0	49.1	.0	3.1	.0	95.9	.0	.0	.0	.9
03187500	kana	80	40.0	55.0	49.1	.0	.2	.0	99.3	.0	.0	.0	.5
03191500	kana	40	25.0	42.5	49.1	1.1	8.9	.0	88.8	.0	.0	.0	1.2
03198350	kana	64	20.0	42.5	49.3	1.1	1.6	.0	89.7	.1	.0	.0	7.5
04159492	leri	462	8.5	30.1	46.9	1.5	89.7	.0	6.8	.1	.7	.9	.3
04161820	leri	310	10.0	32.5	48.6	23.2	51.3	.0	14.9	4.9	1.9	.5	3.4
04175600	leri	128	9.0	32.5	48.0	5.3	70.0	.1	12.3	4.5	3.5	3.7	.7
04178000	leri	618	10.5	34.9	48.9	1.4	90.1	.0	6.8	1.0	.0	.3	.3
04186500	leri	331	11.0	37.0	50.1	2.8	95.4	.0	1.5	.0	.0	.0	.2

Appendix 1a. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Sampling agency or USGS study name	Area (mi²)	Runoff (in/yr)	Climate: Precipitation (in/yr)	Climate: Temperature (°F)	Land-use characteristics (percent): Urban	Agriculture	Rangeland	Forest	Water	Forested wetland	Nonforested wetland	Barren land
04208504	leri	789	17.0	38.6	49.2	29.8	47.2	.0	18.0	1.5	2.3	.0	1.2
04211820	leri	553	20.0	39.4	49.2	2.0	72.8	.0	16.3	.3	8.5	.0	.1
04213500	leri	436	23.0	42.4	46.1	1.5	50.3	.0	47.0	.3	.6	.0	.2
05567000	lirb	94	9.5	37.5	51.6	1.0	98.8	.0	.2	.0	.0	.0	.0
05568800	lirb	63	8.5	37.5	50.6	2.2	96.5	.0	1.1	.0	.0	.0	.1
05584500	lirb	655	8.5	37.5	51.8	1.2	90.0	.0	8.5	.1	.0	.0	.2
03245500	miam	1,203	14.0	40.4	53.0	10.5	83.3	.0	5.1	.6	.0	.0	.4
03267900	miam	310	11.5	37.5	50.3	4.3	87.6	.0	7.8	.2	.0	.0	.2
03275000	miam	529	13.0	40.2	50.4	3.1	93.1	.0	3.6	.0	.0	.0	.1
393944084120700	miam	20	13.5	37.5	53.2	52.4	44.9	.0	2.7	.0	.0	.0	.0
395355084173600	miam	646	12.5	37.5	50.5	2.9	96.1	.0	.7	.1	.0	.0	.2
395457084095100	miam	1,142	12.0	37.5	50.3	4.4	92.3	.0	2.1	.9	.0	.0	.2
05030150	redn	336	3.5	23.2	39.8	.2	25.2	.0	52.7	13.1	4.3	4.3	.1
05051300	redn	1,553	1.5	22.5	42.7	.4	93.9	.2	.1	2.4	.0	3.0	.0
05058700	redn	4,493	.3	17.6	40.0	.4	85.5	10.1	.8	1.5	.0	1.6	.0
05062500	redn	929	3.0	22.9	38.9	.2	50.1	.0	36.8	4.8	3.2	4.7	.2
05079000	redn	5,268	5.0	22.9	38.8	.3	42.6	.0	23.3	10.0	12.2	11.5	.1
05082625	redn	254	.8	17.5	38.5	.5	96.2	.9	1.0	.5	.0	.7	.1
05085900	redn	218	2.0	19.3	38.9	.6	91.5	.0	4.4	.0	1.6	1.6	.3
05099600	redn	3,202	.5	17.5	38.5	.3	88.8	1.6	6.0	1.3	.0	2.0	.0
05112000	redn	1,556	3.0	21.5	38.9	.1	54.2	.0	15.3	.3	14.4	15.6	.1
05333579	stx	95	12.5	32.5	41.5	.0	2.4	.0	74.8	.3	19.6	2.9	.0
05335151	stx	181	12.0	32.5	41.7	.0	3.7	.0	74.7	.1	16.4	5.1	.0
05338955	stx	84	10.0	32.5	41.4	.4	55.2	.0	37.7	4.5	1.3	.9	.0
05340390	stx	133	9.0	32.5	41.4	.5	47.2	.0	37.5	2.6	4.3	8.0	.0
05341500	stx	549	8.0	32.5	41.6	.5	62.7	.0	24.4	5.2	5.2	1.9	.1
05341752	stx	278	7.0	32.5	44.1	.8	89.3	.0	8.0	.9	.3	.7	.0
05342000	stx	173	5.5	32.5	44.5	2.3	92.9	.0	4.6	.2	.0	.0	.0
05526000	uirb	2,087	11.0	37.5	50.7	1.2	95.4	.0	3.0	.1	.0	.1	.1
05527800	uirb	123	8.5	32.8	46.8	6.1	85.7	.0	4.4	.8	.3	1.6	1.1
05531500	uirb	115	11.0	37.5	49.4	70.5	18.1	.0	5.8	.9	.0	.0	4.6

Appendix 1a. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Sampling agency or USGS study name	Area (mi²)	Runoff (in/yr)	Climate: Precipitation (in/yr)	Climate: Temperature (°F)	Land-use characteristics (percent): Urban	Agriculture	Rangeland	Forest	Water	Forested wetland	Nonforested wetland	Barren land
05548105	uirb	85	9.0	37.5	49.3	5.6	88.2	.0	3.4	.3	.1	1.4	1.0
05267000	umis	11,629	6.0	27.3	40.4	.5	25.1	.0	48.7	8.6	11.0	5.2	.9
05276005	umis	232	4.5	27.5	43.1	.3	90.2	.0	2.1	1.7	.8	4.8	.1
05288705	umis	28	5.5	27.5	41.7	38.7	45.7	.0	1.5	4.0	.0	4.0	6.2
05320270	umis	130	5.5	32.4	44.9	.2	94.4	.0	.5	.6	1.5	2.4	.0
05330902	umis	45	5.5	27.5	41.7	70.0	16.2	.0	5.1	3.7	.0	4.1	.8
05331833	umis	128	14.0	32.5	41.4	.7	1.8	.0	77.9	6.3	12.3	.1	1.0
04027595	wdnr	979	14.5	33.2	41.0	.1	9.3	.0	80.4	1.2	8.6	.4	.0
040734644	wdnr	37	9.0	32.5	44.8	7.3	85.6	.0	1.1	.2	1.6	3.8	.4
04085463	wdnr	77	8.0	32.5	44.8	2.8	87.9	.0	7.9	.5	.5	.1	.3
04086500	wdnr	122	8.0	32.5	46.7	3.6	82.6	.0	8.0	1.9	3.1	.3	.5
053230	wdnr	4	9.0	30.0	44.8	87.0	5.4	.0	7.7	.0	.0	.0	.0
053232	wdnr	18	9.0	30.1	44.8	.6	98.4	.0	1.1	.0	.0	.0	.0
053511	wdnr	20	8.0	30.2	44.8	1.1	89.8	.0	8.8	.0	.0	.0	.4
05368000	wdnr	420	8.0	32.5	43.1	.5	77.0	.0	19.6	1.0	1.2	.6	.0
05378185	wdnr	8	6.0	32.5	44.5	.0	33.0	.0	67.0	.0	.0	.0	.0
05379430	wdnr	8	6.0	32.5	44.5	.0	47.2	.0	52.8	.0	.0	.0	.0
05379472	wdnr	10	6.0	32.5	44.4	.0	34.5	.0	65.5	.0	.0	.0	.0
05406460	wdnr	13	8.5	32.5	46.6	2.6	67.5	.0	28.4	.2	.0	.0	1.3
05407500	wdnr	130	9.0	32.5	44.6	.4	62.6	.0	36.9	.0	.0	.0	.0
05427950	wdnr	11	8.5	32.5	46.6	6.0	93.8	.0	.2	.0	.0	.0	.0
05429580	wdnr	15	8.0	32.5	46.6	4.2	93.3	.0	1.0	.2	.0	.0	1.3
05431014	wdnr	9	8.5	37.5	46.7	2.8	97.0	.0	.0	.2	.0	.0	.0
05431018	wdnr	9	8.5	37.0	46.7	1.4	93.1	.0	30.4	.4	.0	1.7	.0
05433510	wdnr	6	9.0	32.5	46.2	.0	72.2	.0	27.8	.0	.0	.0	.0
063035	wdnr	192	8.5	32.5	44.1	1.0	68.2	.0	3.8	.0	.0	.0	.0
063037	wdnr	6	6.0	32.5	44.5	.0	36.1	.0	63.9	.0	.0	.0	.0
103094	wdnr	682	10.0	32.5	40.7	.9	62.7	.0	31.8	.4	3.8	.1	.2
103105	wdnr	61	9.5	32.5	40.7	1.5	80.1	.0	18.3	.1	.0	.0	.1
113086	wdnr	154	8.0	32.5	46.6	.8	90.1	.0	3.2	.4	2.2	3.1	.1
123023	wdnr	52	8.5	32.5	46.2	.1	54.4	.0	44.0	.0	1.5	.0	.0

Appendix 1a. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Sampling agency or USGS study name	Area (mi^2)	Runoff (in/yr)	Climate: Precipitation (in/yr)	Climate: Temperature (°F)	Land-use characteristics (percent): Urban	Agriculture	Rangeland	Forest	Water	Forested wetland	Nonforested wetland	Barren land
133024	wdnr	146	8.0	32.5	46.6	4.4	89.2	.0	2.1	.8	2.1	1.0	.3
133119	wdnr	137	8.5	32.5	46.6	2.4	90.2	.0	6.5	.2	.0	.2	.5
133336	wdnr	10	8.5	32.5	46.6	1.3	81.5	.0	16.7	.5	.0	.0	.0
133337	wdnr	6	8.5	32.5	46.6	.0	55.4	.0	44.5	.0	.0	.0	.0
143012	wdnr	3	8.0	32.5	46.6	3.1	95.1	.0	.0	.0	.0	.0	1.8
163002	wdnr	180	14.0	32.5	41.4	.1	2.6	.0	85.0	1.7	1.5	.0	.0
183042	wdnr	57	9.0	32.5	41.5	1.2	75.1	.0	23.6	.2	.0	.0	.0
183064	wdnr	204	9.5	32.5	40.9	.9	61.0	.0	36.1	.2	1.1	.4	.3
183077	wdnr	215	9.5	32.5	40.7	.1	38.7	.0	51.5	.4	7.9	1.5	.0
223248	wdnr	42	9.0	32.5	46.2	.0	99.2	.0	.8	.0	.0	.0	.0
263001	wdnr	269	14.5	33.6	40.5	1.8	5.2	.0	76.8	2.2	14.0	.0	.0
273015	wdnr	48	9.0	32.5	44.5	.8	64.5	.0	34.7	.0	.0	.0	.0
273016	wdnr	26	9.0	32.5	42.8	.8	38.1	.0	60.4	.2	.5	.0	.0
273031	wdnr	5	9.0	32.5	44.5	.0	1.2	.0	96.1	.8	.0	1.9	.0
273032	wdnr	298	9.0	32.5	43.1	.0	14.7	.0	68.1	.7	11.1	5.4	.0
273034	wdnr	2	9.0	32.5	44.5	.0	33.2	.0	66.8	.0	.0	.0	.0
313023	wdnr	25	9.0	32.5	44.8	.3	78.3	.0	4.2	.0	15.3	1.8	.0
313038	wdnr	133	8.0	32.5	44.8	1.0	89.6	.0	6.3	.0	2.6	.0	.4
363070	wdnr	130	8.0	30.6	44.8	1.4	82.8	.0	8.7	.2	6.8	.0	.1
363071	wdnr	167	8.0	31.4	44.8	2.0	86.8	.0	9.4	.1	1.1	.0	.6
363218	wdnr	108	8.0	30.8	44.8	.9	87.1	.0	6.0	.0	5.8	.0	.2
373047	wdnr	55	11.0	32.5	40.7	.7	59.2	.0	36.9	.1	2.5	.0	.5
373325	wdnr	220	10.5	32.5	40.7	1.1	82.1	.0	16.1	.1	.6	.0	.0
383001	wdnr	1,165	11.0	32.5	42.2	1.0	20.7	.0	54.7	1.8	2.9	.8	.2
413006	wdnr	11	8.5	32.5	46.7	94.3	5.3	.0	.0	.0	.0	.0	.5
413008	wdnr	18	8.0	32.5	46.7	20.7	74.5	.0	3.5	.0	.0	.0	1.3
413011	wdnr	2	8.0	32.5	46.7	81.3	17.5	.0	.0	.0	.0	.0	1.2
433002	wdnr	1,036	11.0	32.5	42.2	.7	28.6	.0	49.4	1.8	17.8	1.2	.5
453030	wdnr	185	10.0	32.4	43.5	.9	77.4	.0	7.8	.2	11.6	1.8	.3
483043	wdnr	94	6.0	32.5	44.5	1.2	92.7	.0	6.1	.0	.0	.0	.0
503069	wdnr	8	10.5	32.5	44.0	.0	90.0	.0	3.4	.0	1.9	3.0	1.7

Appendix 1a. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Sampling agency or USGS study name	Area (mi^2)	Runoff (in/yr)	Climate: Precipitation (in/yr)	Climate: Temperature (°F)	Land-use characteristics (percent): Urban	Agriculture	Rangeland	Forest	Water	Forested wetland	Nonforested wetland	Barren land
523061	wdnr	204	8.5	32.5	46.7	24.8	70.7	.0	3.2	.2	.2	.1	.9
573076	wdnr	386	9.0	32.5	45.3	1.0	72.3	.0	22.8	.5	2.1	.6	.7
603049	wdnr	80	8.0	34.9	44.8	4.8	74.6	.0	14.6	.8	2.6	1.8	.8
603304	wdnr	94	8.0	33.7	45.0	1.1	92.7	.0	4.2	.3	1.5	.0	.2
603326	wdnr	9	8.0	36.2	44.8	6.4	84.5	.0	6.6	1.6	.7	.0	.3
683001	wdnr	60	8.0	32.5	46.7	30.4	64.8	.0	3.1	.0	.8	.0	.9
683271	wdnr	27	8.0	32.5	46.7	2.6	86.9	.0	2.6	.6	4.5	2.8	.0
693021	wdnr	516	11.0	32.5	43.5	.5	48.4	.0	35.8	1.1	12.5	1.6	.1
03353637	whit	17	13.5	37.5	51.3	44.5	55.1	.0	.5	.0	.0	.0	.0
03360895	whit	56	14.5	42.5	55.0	1.8	93.7	.0	4.2	.0	.0	.0	.3
03366500	whit	292	15.5	42.5	54.3	3.9	71.3	.0	24.4	.1	.0	.0	.2
03373530	whit	35	16.0	42.5	53.9	.6	94.2	.0	5.2	.0	.0	.0	.0
391732085414401	whit	88	14.0	42.5	51.3	.7	98.4	.0	.8	.0	.0	.0	.0
393306086585201	whit	318	13.0	42.5	51.5	1.2	83.2	.0	14.4	.2	.0	.0	.9
394340085524601	whit	95	13.0	41.1	51.2	3.4	95.5	.0	.9	.2	.0	.0	.1
04062085	wmic	44	17.0	35.5	40.4	.0	.0	.0	87.7	2.3	9.9	.0	.0
04063700	wmic	140	13.0	32.5	42.2	.1	3.0	.0	61.1	.7	33.6	1.5	.0
04071795	wmic	34	10.0	32.5	42.2	.2	86.0	.0	4.4	.0	9.3	.0	.1
04072050	wmic	95	9.0	31.5	44.8	.6	89.3	.0	4.6	.0	4.9	.0	.6
04080798	wmic	44	11.0	32.5	44.0	.2	58.3	.0	31.5	1.3	6.5	2.3	.0
04085109	wmic	47	8.0	30.0	44.8	.8	91.5	.0	5.1	.0	2.3	.2	.1
040863075	wmic	51	8.0	33.5	44.8	1.1	88.1	.0	6.4	.3	3.8	.2	.1
040869415	wmic	10	8.0	32.5	46.7	96.1	3.9	.0	.0	.0	.0	.0	.0

Appendix 1b. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site

[%, percent; ft, feet, K_f, K factor; in/hr, inches per hour]

Station number	Surficial-deposit characteristics							Soil characteristics					Principal aquifer type			
	Coarse-grained stratified sediment (%)	Fine-grained stratified sediment (%)	Till (%)	Patchy Quaternary sediment (%)	Exposed bedrock or non-glacial sediments (%)	Organic-rich sediments (%)	Thickness (ft)	Clay content (%)	Erodibility (K_f)	Organic-matter content (%)	Permeability (in/hr)	Soil slope (%)	Sandstone (%)	Carbonate (%)	Sandstone and carbonate (%)	No principal aquifer (%)
03015795	0.0	0.0	0.0	0.0	100.0	0.0	25.0	19.0	0.24	0.5	4.53	14.7	31.2	0.0	68.8	0.0
03024000	17.9	13.0	69.1	.0	.0	.0	62.5	18.3	.40	.8	2.04	4.3	3.0	.0	22.0	75.0
03037350	.0	.0	.0	.0	100.0	.0	25.0	23.9	.30	.7	2.53	20.9	100.0	.0	.0	.0
03040000	.0	.0	.0	.0	100.0	.0	25.0	23.5	.26	.5	2.76	17.1	89.9	.0	10.1	.0
03049646	.0	.0	.0	.0	100.0	.0	25.0	25.2	.28	.5	1.65	19.1	100.0	.0	.0	.0
03070350	.0	.0	.0	.0	100.0	.0	25.0	20.0	.25	.6	3.88	29.2	28.1	.0	4.7	31.1
03072000	.0	.0	.0	.0	100.0	.0	25.0	31.9	.33	.5	1.67	21.3	100.0	.0	.0	.0
03083500	.0	.0	.0	.0	100.0	.0	25.0	22.3	.26	.6	3.49	17.3	74.6	.0	19.4	6.0
40001	6.5	.0	36.8	.0	2.7	.0	128.3	14.9	.24	2.0	6.40	5.1	100.0	.0	.0	.0
40007	11.5	.0	78.0	1.9	8.4	.2	120.3	23.6	.29	3.2	2.45	4.9	58.4	25.7	.0	15.9
50001	6.6	.0	49.3	34.3	9.8	.0	59.8	22.2	.32	1.3	2.19	6.4	42.0	40.5	.0	17.5
50003	2.1	.0	.0	76.3	21.6	.0	25.6	22.7	.34	.8	2.09	11.0	65.6	15.8	.0	18.7
80001	21.3	.0	.0	.0	78.7	.0	37.5	15.5	.22	.4	4.62	14.3	100.0	.0	.0	.0
80003	4.1	.0	21.4	42.9	31.6	.0	38.0	21.7	.33	1.1	2.32	10.3	45.5	40.0	.0	14.5
80007	1.5	.0	.0	.0	98.5	.0	25.9	22.8	.31	.4	1.95	15.5	100.0	.0	.0	.0
90001	2.4	.0	.0	.0	97.6	.0	25.4	24.6	.33	.5	1.71	13.6	100.0	.0	.0	.0
90003	3.7	.0	38.2	3.7	27.4	.0	38.5	24.2	.33	1.1	1.91	10.2	31.9	32.6	.0	35.5
130001	2.8	.0	87.1	4.5	5.6	.0	47.6	23.8	.33	1.2	2.16	8.1	.0	99.4	.0	.6
130003	1.5	1.2	4.9	.0	92.4	.0	25.8	29.2	.33	.8	1.21	10.0	.0	1.1	.0	98.9
200003	9.8	.0	90.2	.0	.0	.0	181.0	26.8	.31	2.6	1.49	4.0	51.9	.0	2.5	45.6
240001	4.9	.0	88.7	3.4	.0	.0	48.2	37.1	.34	.6	.47	7.8	.0	.0	24.4	75.6
260001	4.6	.0	62.7	32.7	.0	.0	37.3	39.5	.33	.6	.46	9.1	4.9	.0	51.2	43.9
280001	.0	.0	.0	.0	100.0	.0	25.0	35.9	.35	.4	1.68	12.1	.0	90.6	.0	9.4
05420680	21.1	.0	78.9	.0	.0	.0	121.8	21.4	.28	2.1	3.21	2.2	.0	100.0	.0	.0
05449500	29.6	.0	70.4	.0	.0	.0	120.2	26.3	.30	2.8	1.75	2.5	5.6	60.4	33.8	.2
05451210	7.9	.0	92.1	.0	.0	.0	153.8	25.6	.30	2.9	1.69	2.6	.0	.0	83.0	17.0
05455100	3.3	.0	96.7	.0	.0	.0	253.2	32.2	.37	1.3	1.07	6.5	.0	32.7	.0	67.3
05461390	.0	.0	100.0	.0	.0	.0	41.7	23.6	.31	2.0	2.30	2.1	.0	100.0	.0	.0
05464220	.0	.0	100.0	.0	.0	.0	208.3	28.9	.38	1.7	1.31	4.9	.0	65.0	20.6	14.4
05474000	11.3	.0	88.7	.0	.0	.0	133.2	30.4	.35	1.6	1.17	5.6	.0	.0	53.6	46.4
BPK07	11.6	.0	88.4	.0	.0	.0	278.8	35.7	.32	1.7	.66	2.5	46.8	31.5	6.4	15.4
BPJ07	12.7	.0	87.3	.0	.0	.0	227.3	28.4	.34	1.3	1.24	2.1	38.0	.0	33.4	28.6
BPJC06	.1	.0	99.9	.0	.0	.0	275.5	26.4	.33	1.3	1.35	1.9	64.0	.0	14.8	21.3
BO07	.1	.0	99.9	.0	.0	.0	95.6	26.8	.33	1.3	1.19	2.2	100.0	.0	.0	.0
BN01	2.7	.0	79.3	.0	.0	.0	70.9	26.9	.34	1.2	1.18	2.0	100.0	.0	.0	.0

Appendix 1b. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Surficial-deposit characteristics							Soil characteristics					Principal aquifer type			
	Coarse-grained stratified sediment (%)	Fine-grained stratified sediment (%)	Till (%)	Patchy Quaternary sediment (%)	Exposed bedrock or non-glacial sediments (%)	Organic-rich sediments (%)	Thickness (ft)	Clay content (%)	Erodibility (K_f)	Organic-matte content (%)	Permeability (in/hr)	Soil slope (%)	Sandstone (%)	Carbonate (%)	Sandstone and carbonate (%)	No principal aquifer (%)
BM02	0.5	0.0	99.5	0.0	0.0	0.0	80.1	26.1	0.36	0.8	1.10	7.5	100.0	0.0	0.0	0.0
BE14	.9	2.8	78.3	.0	.0	.0	210.1	26.6	.32	1.3	1.36	1.8	91.6	.0	6.8	1.6
BEF05	7.5	.0	92.5	.0	.0	.0	41.3	27.3	.37	.6	.60	5.0	100.0	.0	.0	.0
BC02	.0	26.0	74.0	.0	.0	.0	29.7	27.2	.37	.6	.62	4.9	100.0	.0	.0	.0
C21	7.0	.0	93.0	.0	.0	.0	61.5	28.1	.37	.7	.68	3.7	100.0	.0	.0	.0
CD01	3.7	3.8	92.5	.0	.0	.0	26.8	28.0	.37	.5	.50	5.2	100.0	.0	.0	.0
CA06	4.9	.0	95.1	.0	.0	.0	25.0	28.5	.37	.5	.46	4.9	100.0	.0	.0	.0
ATGC01	.0	18.5	41.6	.0	39.9	.0	27.6	24.7	.39	.6	.74	8.8	100.0	.0	.0	.0
ATF04	.0	35.6	64.4	.0	.0	.0	30.5	25.8	.38	.6	.70	5.8	100.0	.0	.0	.0
AK02	.0	.0	0.0	.0	100.0	.0	25.0	25.4	.39	.4	.85	11.8	89.8	.0	.0	10.2
AD02	.1	8.0	0.0	.0	91.9	.0	25.0	22.5	.38	.4	.94	10.8	42.2	.5	.0	57.3
MJ01	3.0	.7	50.6	.0	45.6	.0	25.0	28.7	.33	.9	1.21	8.6	.0	39.5	.0	60.5
PWN01	3.5	4.5	91.6	.0	.3	.0	25.5	28.2	.36	1.2	1.32	4.3	1.0	4.7	.0	94.3
PQ10	32.4	8.8	58.8	.0	.0	.0	200.9	22.1	.31	3.1	3.41	5.7	.0	18.9	.0	81.1
PQC06	9.1	13.8	77.0	.0	.0	.0	184.9	25.1	.34	1.1	1.41	3.5	1.8	1.1	.0	88.0
PQB02	15.6	6.5	77.0	.9	.0	.0	106.1	25.3	.35	1.2	1.47	3.2	4.6	.0	.0	59.4
PL03	6.2	23.8	67.4	1.9	.7	.0	124.9	25.9	.35	1.2	1.62	3.4	73.9	.0	.0	26.1
PH16	.0	.0	93.1	.0	6.9	.0	32.4	28.0	.37	1.2	1.30	4.5	14.5	.0	.0	85.5
PE05	18.3	.6	81.0	.0	.1	.0	37.1	25.3	.35	1.7	1.72	4.5	.0	59.1	.0	40.9
PB02	42.8	.0	57.2	.0	.0	.0	222.0	19.8	.30	1.2	3.93	3.4	37.8	2.9	.0	41.2
LF01	17.3	.0	82.7	.0	.0	.0	73.2	27.5	.35	1.0	1.28	4.8	98.4	.0	.0	1.6
LD02	5.6	.0	94.4	.0	.0	.0	65.5	27.9	.36	1.1	1.20	4.0	79.1	.4	9.4	11.1
KI02	4.1	.7	95.2	.0	.0	.0	80.4	30.7	.34	.8	.87	5.7	26.2	.0	73.8	.0
KCA01	5.0	.0	35.5	.0	59.5	.0	25.9	26.4	.34	.6	1.23	7.5	17.7	.3	82.1	.0
HBD04	1.9	29.8	68.3	.0	.0	.0	64.2	34.3	.30	3.0	1.27	3.5	.0	100.0	.0	.0
GG02	5.4	6.2	88.3	.0	.1	.0	94.9	37.8	.35	3.1	.54	4.7	.0	100.0	.0	.0
GB10	9.7	4.8	85.6	.0	.0	.0	100.6	29.4	.29	3.7	2.19	4.5	.0	100.0	.0	.0
DW01	.3	52.8	44.3	.0	2.7	.0	79.9	30.4	.34	1.3	1.12	2.3	47.5	5.8	.0	46.7
DV04	.0	17.4	82.6	.0	.0	.0	111.2	33.2	.28	1.4	1.26	2.1	94.1	2.0	.0	3.9
DTD02	28.9	3.4	67.7	.0	.0	.0	107.0	25.2	.34	1.5	1.62	3.5	.0	14.3	.0	85.7
DTB01	.6	1.1	98.3	.0	.0	.0	127.3	26.5	.32	1.3	1.41	1.9	44.5	.0	.0	55.5
DS07	7.9	9.9	82.2	.0	.0	.0	129.1	33.6	.31	1.4	1.04	1.9	99.0	1.0	.0	.0
DR01	.0	.5	98.9	.0	.7	.0	113.6	28.4	.34	1.6	1.27	2.3	100.0	.0	.0	.0
DL01	8.9	.3	90.7	.0	.0	.0	72.1	28.9	.34	.7	1.02	6.9	100.0	.0	.0	.0
DJ06	10.7	1.2	88.2	.0	.0	.0	67.3	28.1	.35	1.2	1.26	3.4	100.0	.0	.0	.0
DJB18	.0	.0	100.0	.0	.0	.0	48.3	29.1	.34	.5	.86	10.4	100.0	.0	.0	.0

Appendix 1b. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Surficial-deposit characteristics							Soil characteristics					Principal aquifer type			
	Coarse-grained stratified sediment (%)	Fine-grained stratified sediment (%)	Till (%)	Patchy Quaternary sediment (%)	Exposed bedrock or non-glacial sediments (%)	Organic-rich sediments (%)	Thickness (ft)	Clay content (%)	Erodibility (K_f)	Organic-matte content (%)	Permeability (in/hr)	Soil slope (%)	Sandstone (%)	Carbonate (%)	Sandstone and carbonate (%)	No principal aquifer (%)
E29	15.7	0.0	84.3	0.0	0.0	0.0	282.0	29.7	0.34	1.5	1.14	2.5	38.8	61.2	0.0	0.0
EOH01	9.3	1.0	89.7	.0	.0	.0	96.6	29.9	.35	1.2	.97	2.0	100.0	.0	.0	.0
EL01	.5	.0	99.5	.0	.0	.0	68.0	29.8	.35	1.1	.99	2.7	100.0	.0	.0	.0
EIG01	2.1	.0	79.9	.0	.0	.0	164.8	28.3	.36	1.2	1.18	2.4	100.0	.0	.0	.0
EIE04	3.0	.0	97.0	.0	.0	.0	255.8	27.8	.35	1.2	1.09	4.2	100.0	.0	.0	.0
EID04	5.9	.0	94.1	.0	.0	.0	282.6	28.9	.35	1.2	1.05	3.3	100.0	.0	.0	.0
DH01	.0	.0	100.0	.0	.0	.0	29.9	29.9	.33	.6	.97	7.1	96.9	.0	3.1	.0
DF04	.0	.0	100.0	.0	.0	.0	89.2	29.5	.34	.8	1.02	5.2	100.0	.0	.0	.0
DE01	1.3	13.7	76.1	.0	8.9	.0	34.0	29.3	.33	.6	.97	7.1	67.0	.0	33.0	.0
DD04	.1	.0	99.9	.0	.0	.0	82.0	29.7	.35	.9	.99	4.1	100.0	.0	.0	.0
DB01	4.9	.1	94.0	1.0	.0	.0	29.6	29.7	.34	.8	1.03	5.7	84.3	.0	15.7	.0
DA04	1.8	.0	98.0	.0	.1	.0	63.3	31.2	.34	.9	.80	4.2	100.0	.0	.0	.0
JR02	3.2	.0	96.8	.0	.0	.0	43.4	28.7	.33	.6	1.02	7.1	99.7	.0	.3	.0
JQ05	4.2	.0	95.8	.0	.0	.0	46.1	29.4	.34	.7	.90	5.5	100.0	.0	.0	.0
O31	2.3	.0	97.7	.0	.0	.0	244.6	26.9	.32	1.3	1.34	1.7	81.0	.0	15.9	3.1
OU01	.0	.0	100.0	.0	.0	.0	83.7	27.6	.31	1.3	1.23	1.5	100.0	.0	.0	.0
OT02	.0	.0	100.0	.0	.0	.0	182.2	27.8	.33	1.3	1.15	2.0	100.0	.0	.0	.0
OQ01	5.6	.0	94.4	.0	.0	.0	53.4	29.4	.37	.6	.46	4.0	100.0	.0	.0	.0
ON01	1.3	.0	98.7	.0	.0	.0	25.0	28.7	.37	.5	.41	4.4	100.0	.0	.0	.0
OL02	8.6	.3	91.1	.0	.0	.0	74.2	27.8	.37	.5	.45	3.9	100.0	.0	.0	.0
OK01	1.5	.0	98.5	.0	.0	.0	25.0	28.7	.37	.5	.41	4.4	100.0	.0	.0	.0
OKA01	.0	.0	100.0	.0	.0	.0	25.0	28.7	.37	.5	.42	4.5	100.0	.0	.0	.0
OJ08	4.2	.0	95.8	.0	.0	.0	25.3	27.9	.37	.6	.46	4.2	100.0	.0	.0	.0
OI09	3.5	.0	96.5	.0	.0	.0	68.4	30.1	.36	.9	.56	2.9	100.0	.0	.0	.0
OH01	4.2	.0	95.8	.0	.0	.0	41.2	28.4	.36	.7	.72	4.2	100.0	.0	.0	.0
OD06	2.3	.0	96.1	.0	1.6	.0	57.5	29.1	.35	.8	.88	4.8	100.0	.0	.0	.0
OC04	12.8	.0	87.2	.0	.0	.0	27.2	26.0	.35	.6	1.11	5.9	100.0	.0	.0	.0
OZC01	6.6	.0	93.4	.0	.0	.0	34.3	25.6	.36	.5	.59	5.8	100.0	.0	.0	.0
II03	4.7	6.6	88.8	.0	.0	.0	26.5	25.0	.36	.5	.68	7.3	100.0	.0	.0	.0
NK01	1.7	6.2	92.1	.0	.0	.0	25.0	28.6	.37	.5	.47	4.9	100.0	.0	.0	.0
NJ07	3.3	8.0	88.7	.0	.0	.0	25.0	26.9	.37	.5	.74	8.5	100.0	.0	.0	.0
NH06	3.4	12.6	84.0	.0	.0	.0	25.0	27.2	.37	.5	.65	7.2	100.0	.0	.0	.0
NE05	7.1	9.4	83.5	.0	.0	.0	28.8	27.1	.37	.6	.55	4.8	100.0	.0	.0	.0
NC07	6.5	2.9	90.6	.0	.0	.0	29.1	26.7	.37	.5	.54	6.4	100.0	.0	.0	.0
03167000	.0	.0	.0	.0	100.0	.0	25.0	36.9	.25	.5	2.56	24.4	.0	.0	100.0	.0
03170000	.0	.0	.0	.0	100.0	.0	25.0	26.5	.22	.6	3.42	21.1	.0	.0	23.8	76.2

Appendix 1b. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Surficial-deposit characteristics							Soil characteristics					Principal aquifer type			
	Coarse-grained stratified sediment (%)	Fine-grained stratified sediment (%)	Till (%)	Patchy Quaternary sediment (%)	Exposed bedrock or non-glacial sediments (%)	Organic-rich sediments (%)	Thickness (ft)	Clay content (%)	Erodibility (K_f)	Organic-matte content (%)	Permeability (in/hr)	Soil slope (%)	Sandstone (%)	Carbonate (%)	Sandstone and carbonate (%)	No principal aquifer (%)
03178000	0.0	0.0	0.0	0.0	100.0	0.0	25.0	29.6	0.28	0.5	2.16	34.7	26.0	0.0	74.0	0.0
03183000	.0	.0	.0	.0	100.0	.0	25.0	24.7	.25	.6	5.00	31.8	.0	.0	52.1	47.9
03186500	.0	.0	.0	.0	100.0	.0	25.0	22.5	.26	.4	2.40	31.1	29.4	.0	70.6	.0
03187500	.0	.0	.0	.0	100.0	.0	25.0	20.6	.25	.4	2.84	26.7	48.6	.0	51.4	.0
03191500	.0	.0	.0	.0	100.0	.0	25.0	23.4	.27	.5	1.73	30.3	100.0	.0	.0	.0
03198350	.0	.0	.0	.0	100.0	.0	25.0	19.8	.20	.4	3.32	45.5	100.0	.0	.0	.0
04159492	24.8	25.8	49.4	.0	.0	.0	121.9	20.6	.27	5.7	2.34	1.1	11.4	.0	.0	88.6
04161820	47.0	.0	53.0	.0	.0	.0	286.7	15.1	.15	7.9	4.59	6.2	1.5	.0	.0	98.5
04175600	5.4	.0	49.6	.0	.0	.0	122.8	11.9	.18	12.3	6.91	7.9	99.9	.0	.0	.1
04178000	9.0	.0	91.0	.0	.0	.0	276.2	28.3	.34	3.6	1.65	3.3	.0	.0	.0	100.0
04186500	3.0	.7	96.4	.0	.0	.0	79.6	35.5	.38	1.8	0.61	2.8	.0	100.0	.0	.0
04208504	26.9	4.6	68.6	.0	.0	.0	90.1	25.6	.38	1.4	1.43	6.7	43.2	.0	47.4	9.4
04211820	3.0	12.3	84.7	.0	.0	.0	53.5	30.4	.41	.5	.55	3.5	3.5	.0	35.6	60.9
04213500	21.8	2.8	73.1	2.3	.0	.0	54.6	19.7	.31	1.0	1.90	11.3	.0	.0	.0	100.0
05567000	.0	.0	100.0	.0	.0	.0	179.6	31.3	.31	1.4	.94	1.6	100.0	.0	.0	.0
05568800	.0	.0	100.0	.0	.0	.0	43.1	29.7	.34	0.9	1.00	4.8	100.0	.0	.0	.0
05584500	1.8	6.7	90.4	.0	1.2	.0	57.6	30.0	.35	0.9	.98	4.5	48.8	.0	46.8	4.4
03245500	10.2	0.7	89.1	.0	.0	.0	84.3	26.6	.40	0.6	1.26	5.1	.0	43.3	.0	56.7
03267900	45.7	0.4	53.9	.0	.0	.0	201.9	24.2	.42	0.8	2.52	4.1	.0	10.0	.0	.0
03275000	23.6	0.0	76.4	.0	.0	.0	173.8	24.9	.41	0.7	1.67	5.3	.0	29.8	.0	70.2
393944084120700	.0	.0	100.0	.0	.0	.0	49.5	26.4	.41	0.5	.93	5.3	.0	.0	.0	100.0
395355084173600	3.1	.0	96.9	.0	.0	.0	86.7	27.5	.41	1.0	.99	3.8	.0	79.5	.0	20.5
395457084095100	6.1	3.0	90.9	.0	.0	.0	130.5	30.5	.40	1.3	1.02	3.3	.0	81.4	.0	18.6
05030150	42.3	.0	57.7	.0	.0	.0	427.7	12.2	.22	4.5	6.28	4.3	.0	.0	.0	100.0
05051300	5.6	.2	94.1	.0	.0	.0	245.8	28.4	.32	1.5	1.30	2.1	3.3	.0	.0	96.7
05058700	13.8	.2	83.5	.0	2.5	.0	147.7	20.9	.34	1.2	2.60	3.5	25.7	.0	.0	74.3
05062500	18.0	.0	82.0	.0	.0	.0	405.1	21.2	.27	4.3	2.65	3.5	.0	.0	.0	100.0
05079000	20.7	0.2	70.9	.0	.0	.0	265.0	18.7	.23	9.8	4.02	1.7	.2	.0	.0	99.8
05082625	27.8	7.5	62.8	.0	1.9	.0	96.4	25.4	.33	1.2	2.12	2.7	.0	.0	.0	100.0
05085900	42.8	16.2	41.0	.0	.0	.0	321.5	20.6	.27	2.0	4.75	.9	2.0	.0	.0	98.0
05099600	2.4	1.0	92.5	.0	4.1	.0	104.5	26.4	.35	1.1	1.67	3.3	5.3	.0	.0	94.7
05112000	28.7	0.0	71.3	.0	.0	.0	205.9	16.8	.21	14.5	4.64	.6	.0	.0	.0	100.0
05333579	.0	0.0	70.4	25.8	.0	3.8	27.1	11.8	.21	16.8	1.55	2.2	.0	.0	.0	100.0
05335151	.6	0.0	85.9	1.2	.0	12.2	28.8	11.8	.16	27.0	2.46	2.0	.0	.0	.0	100.0
05338955	77.5	0.0	22.5	.0	.0	.0	123.6	13.6	.22	5.7	5.40	6.2	56.8	.0	.0	43.2
05340390	63.4	0.0	36.6	.0	.0	.0	116.1	10.0	.20	7.8	6.41	5.2	59.2	.0	.0	40.8

Appendix 1b. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Surficial-deposit characteristics							Soil characteristics					Principal aquifer type			
	Coarse-grained stratified sediment (%)	Fine-grained stratified sediment (%)	Till (%)	Patchy Quaternary sediment (%)	Exposed bedrock or non-glacial sediments (%)	Organic-rich sediments (%)	Thickness (ft)	Clay content (%)	Erodibility (K_f)	Organic-matte content (%)	Permeability (in/hr)	Soil slope (%)	Sandstone (%)	Carbonate (%)	Sandstone and carbonate (%)	No principal aquifer (%)
05341500	63.6	0.0	36.4	0.0	0.0	0.0	128.1	8.4	0.22	3.3	5.65	7.9	83.7	0.0	0.0	16.3
05341752	9.9	.0	90.1	.0	.0	.0	75.2	10.1	.26	1.7	4.21	5.3	100.0	.0	.0	.0
05342000	.0	.0	97.7	2.3	.0	.0	37.2	13.1	.26	1.7	3.89	5.4	100.0	.0	.0	.0
05526000	24.1	18.9	57.0	.0	.0	.0	147.7	26.3	.29	1.9	3.15	2.2	16.4	42.5	5.5	35.6
05527800	11.2	.0	88.8	.0	.0	.0	197.0	34.4	.34	5.2	.72	3.8	.0	100.0	.0	.0
05531500	1.6	1.2	97.2	.0	.0	.0	113.1	34.7	.26	3.9	.78	3.9	.0	97.2	.0	2.8
05548105	2.7	13.6	83.7	.0	.0	.0	224.6	21.8	.31	3.2	2.31	3.7	.0	53.9	.0	46.1
05267000	41.2	.0	53.6	.5	.0	1.5	265.7	12.1	.19	9.2	5.74	4.9	3.7	.0	.0	96.3
05276005	59.5	.0	40.5	.0	.0	.0	282.5	15.4	.21	2.8	6.46	2.2	69.7	.0	.0	30.3
05288705	45.8	.0	54.2	.0	.0	.0	181.3	14.0	.20	8.2	6.83	3.7	23.0	.0	.0	77.0
05320270	.0	48.7	51.3	.0	.0	.0	185.9	32.0	.31	3.0	.89	2.0	58.8	7.9	.0	33.3
05330902	33.1	.0	66.9	.0	.0	.0	256.8	17.2	.21	12.7	4.66	5.4	100.0	.0	.0	.0
05331833	74.5	.0	23.7	.0	1.0	.8	53.6	6.9	.20	11.2	5.00	10.1	.0	.0	.0	100.0
04027595	24.8	1.5	54.5	.3	18.8	.1	92.7	17.5	.21	8.6	2.35	8.9	.0	.0	.0	100.0
040734644	4.7	.0	95.3	.0	.0	.0	51.2	21.5	.35	4.3	1.67	3.2	29.7	.0	.0	70.3
04085463	.0	.4	99.6	.0	.0	.0	114.7	37.5	.32	4.1	1.00	3.2	.0	100.0	.0	.0
04086500	2.7	.0	79.3	.0	.0	.0	99.7	19.5	.29	9.2	2.97	4.5	.0	85.8	.0	14.2
053230	61.8	38.2	.0	.0	.0	.0	75.0	26.6	.29	.6	3.47	6.6	.0	.0	.0	100.0
053232	8.5	90.0	1.4	.0	.0	.0	75.3	41.9	.32	4.6	.82	3.1	.0	.0	.0	100.0
053511	.0	.0	100.0	.0	.0	.0	155.5	41.9	.32	4.6	.82	3.1	.0	4.8	.0	95.2
05368000	11.7	.0	55.4	3.5	29.5	.0	68.1	12.2	.23	1.3	3.28	8.6	100.0	.0	.0	.0
05378185	.0	.0	.0	.0	100.0	.0	25.0	20.4	.28	.5	2.38	18.8	100.0	.0	.0	.0
05379430	9.7	.0	.0	.0	90.3	.0	29.5	18.8	.26	.4	2.67	23.1	100.0	.0	.0	.0
05379472	.0	.0	.0	.0	100.0	.0	25.0	19.9	.27	.4	2.47	20.2	100.0	.0	.0	.0
05406460	27.3	.5	46.1	.0	26.1	.0	58.9	18.3	.25	3.8	4.78	9.3	100.0	.0	.0	.0
05407500	.0	.0	.0	.0	100.0	.0	25.0	28.6	.27	.3	1.53	16.5	100.0	.0	.0	.0
05427950	14.1	26.3	59.6	.0	.0	.0	89.2	15.7	.24	5.6	5.27	5.8	100.0	.0	.0	.0
05429580	7.1	4.9	88.0	.0	.0	.0	50.5	17.7	.27	5.2	4.00	5.3	100.0	.0	.0	.0
05431014	.0	.0	100.0	.0	.0	.0	159.4	20.5	.28	6.8	2.23	3.8	.0	100.0	.0	.0
05431018	.9	.0	99.1	.0	.0	.0	356.4	19.0	.27	6.3	2.41	4.6	.0	.0	.0	100.0
05433510	.0	.0	.0	.0	100.0	.0	25.0	32.6	.29	1.2	1.05	11.2	9.0	.0	.0	91.0
063035	22.6	.0	.0	.0	77.4	.0	31.3	12.1	.19	.5	5.17	11.3	100.0	.0	.0	.0
063037	.0	.0	.0	.0	100.0	.0	25.0	19.6	.27	.4	2.52	21.0	100.0	.0	.0	.0
103094	12.1	.0	63.4	24.5	.0	.0	57.8	15.3	.31	3.6	1.71	4.0	18.2	.0	.0	81.8
103105	.0	.0	53.4	46.6	.0	.0	29.9	18.5	.34	1.4	1.05	2.8	60.6	.0	.0	39.4
113086	13.5	.0	86.5	.0	.0	.0	34.3	19.4	.29	4.3	2.69	5.0	95.2	.0	.0	4.8

Appendix 1b. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Surficial-deposit characteristics							Soil characteristics					Principal aquifer type			
	Coarse-grained stratified sediment (%)	Fine-grained stratified sediment (%)	Till (%)	Patchy Quaternary sediment (%)	Exposed bedrock or non-glacial sediments (%)	Organic-rich sediments (%)	Thickness (ft)	Clay content (%)	Erodibility (K_f)	Organic-matte content (%)	Permeability (in/hr)	Soil slope (%)	Sandstone (%)	Carbonate (%)	Sandstone and carbonate (%)	No principal aquifer (%)
123023	0.4	0.0	0.0	0.0	99.6	0.0	25.0	25.2	0.34	0.5	1.56	14.6	100.0	0.0	0.0	0.0
133024	34.4	.0	65.6	.0	.0	.0	76.6	16.5	.25	6.1	5.24	5.7	96.1	.0	.0	3.9
133119	16.0	.0	18.2	5.3	60.4	.0	33.2	26.0	.26	2.1	2.28	9.4	88.5	.0	.0	11.5
133336	.0	.0	100.0	.0	.0	.0	27.6	19.0	.27	6.2	2.41	4.9	100.0	.0	.0	.0
133337	11.9	.0	.0	.0	88.1	.0	27.0	23.9	.27	.6	1.99	16.5	100.0	.0	.0	.0
143012	.0	.0	100.0	.0	.0	.0	25.0	21.0	.35	2.5	1.82	3.5	.0	.0	.0	100.0
163002	51.6	.0	47.9	.5	.0	.0	181.0	14.0	.18	12.2	5.97	7.5	4.1	.0	.0	95.9
183042	.0	.0	.0	.0	100.0	.0	25.0	12.0	.19	1.7	5.16	7.2	100.0	.0	.0	.0
183064	8.7	.0	47.4	43.9	.0	.0	49.9	13.8	.28	2.6	2.50	4.2	50.5	.0	.0	49.5
183077	15.6	.0	13.7	52.9	11.8	6.0	26.8	13.8	.22	3.4	3.24	2.9	94.1	.0	.0	5.9
223248	.0	.0	.0	.0	100.0	.0	25.0	28.6	.39	1.0	1.30	7.5	0.0	.0	.0	100.0
263001	13.7	.0	65.1	.2	20.2	.8	41.3	11.6	.23	11.2	1.74	7.2	7.8	.0	.0	92.2
273015	24.3	.0	.0	.0	75.7	.0	25.0	12.7	.19	.7	4.94	8.7	100.0	.0	.0	.0
273016	3.0	.0	.0	.0	97.0	.0	25.0	12.6	.16	1.5	4.72	5.3	100.0	.0	.0	.0
273031	67.4	.0	.0	.0	32.6	.0	25.0	9.4	.14	1.3	6.63	6.0	62.3	.0	.0	37.7
273032	9.5	.0	.5	.0	75.1	14.9	25.2	13.4	.15	7.6	4.09	2.7	63.6	.0	.0	36.4
273034	.0	.0	.0	.0	100.0	.0	25.0	3.2	.13	.3	10.90	10.5	100.0	.0	.0	.0
313023	.2	.0	97.1	2.8	.0	.0	40.1	15.2	.30	4.4	1.95	3.0	.0	100.0	.0	.0
313038	14.5	.0	84.9	.6	.0	.0	83.4	32.1	.30	4.0	2.11	3.9	.0	100.0	.0	.0
363070	27.5	3.6	68.9	.0	.0	.0	73.9	24.0	.28	2.3	4.04	5.7	.0	100.0	.0	.0
363071	9.5	3.4	87.1	.0	.0	.0	80.2	33.0	.32	3.2	1.26	4.0	.0	100.0	.0	.0
363218	8.2	3.6	88.2	.0	.0	.0	62.0	27.0	.31	5.3	1.49	4.0	.0	99.6	.0	.4
373047	14.8	.0	85.2	.0	.0	.0	60.8	14.5	.33	1.6	1.29	3.3	.0	.0	.0	100.0
373325	1.3	.0	98.7	.0	.0	.0	36.7	17.9	.35	2.0	1.21	2.0	.0	.0	.0	100.0
383001	55.1	.0	44.8	.0	.0	.0	101.1	7.7	.17	11.3	7.04	6.9	28.1	.0	.0	71.9
413006	.3	.0	99.7	.0	.0	.0	144.1	35.1	.35	4.3	.63	5.3	.0	100.0	.0	.0
413008	.0	.0	100.0	.0	.0	.0	57.6	35.1	.35	4.3	.63	5.3	.0	100.0	.0	.0
413011	.0	.0	100.0	.0	.0	.0	150.0	35.1	.35	4.3	.63	5.3	.0	100.0	.0	.0
433002	49.0	.0	50.9	.0	.0	.0	135.6	9.3	.20	8.1	6.34	6.2	41.5	.0	.0	58.5
453030	27.9	.0	72.1	.0	.0	.0	110.2	14.0	.27	6.5	3.25	2.6	93.3	.0	.0	6.7
483043	.0	.0	88.3	.4	11.3	.0	46.7	18.6	.32	.8	1.92	6.6	100.0	.0	.0	.0

Appendix 1b. Environmental characteristics of the watersheds of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Surficial-deposit characteristics							Soil characteristics					Principal aquifer type			
	Coarse-grained stratified sediment (%)	Fine-grained stratified sediment (%)	Till (%)	Patchy Quaternary sediment (%)	Exposed bedrock or non-glacial sediments (%)	Organic-rich sediments (%)	Thickness (ft)	Clay content (%)	Erodibility (K_f)	Organic-matte content (%)	Permeability (in/hr)	Soil slope (%)	Sandstone (%)	Carbonate (%)	Sandstone and carbonate (%)	No principal aquifer (%)
503069	100.0	0.0	0.0	0.0	0.0	0.0	99.3	4.0	0.14	9.1	11.39	1.6	14.6	0.0	0.0	85.4
523061	7.5	.0	92.5	.0	.0	.0	162.9	34.0	.34	4.7	.89	4.4	.0	100.0	.0	.0
573076	5.1	.0	.0	.0	94.9	.0	25.9	24.4	.26	.3	2.03	16.4	100.0	.0	.0	.0
603049	14.4	.0	85.6	.0	.0	.0	107.0	23.3	.27	6.3	4.47	4.9	.0	100.0	.0	.0
603304	5.6	.0	94.4	.0	.0	.0	127.2	35.0	.31	4.2	1.78	3.7	.0	100.0	.0	.0
603326	.0	.0	100.0	.0	.0	.0	116.0	28.6	.31	3.6	2.08	3.9	.0	100.0	.0	.0
683001	4.0	.0	96.0	.0	.0	.0	61.6	30.3	.34	3.7	.98	4.9	.0	100.0	.0	.0
683271	36.3	.0	63.7	.0	.0	.0	119.3	14.0	.23	7.6	6.82	6.1	.0	22.3	.0	77.7
693021	62.4	.0	37.6	.0	.0	.0	96.1	12.4	.18	10.3	4.91	4.6	32.5	.0	.0	67.5
03353637	4.3	.0	95.7	.0	.0	.0	228.0	23.7	.40	1.3	1.61	3.3	.0	62.9	.0	37.1
03360895	.2	27.4	72.4	.0	.0	.0	63.5	23.5	.37	.5	1.39	6.0	100.0	.0	.0	.0
03366500	.0	.3	86.6	.0	13.2	.0	25.9	25.8	.40	.2	.59	5.6	.0	98.4	.0	1.6
03373530	.0	.0	.0	.0	100.0	.0	25.0	37.6	.31	.4	1.22	10.7	.0	.0	100.0	.0
391732085414401	.0	.0	100.0	.0	.0	.0	42.3	25.7	.39	.8	1.08	3.9	.0	100.0	.0	.0
393306086585201	4.0	5.5	90.5	.0	.0	.0	85.0	25.2	.38	.9	1.14	7.1	3.1	.0	32.4	64.5
394340085524601	2.1	.0	97.9	.0	.0	.0	161.8	24.9	.42	1.5	1.23	2.2	.0	100.0	.0	.0
04062085	.0	.0	.0	100.0	.0	.0	25.0	9.5	.17	10.8	1.70	13.7	.0	.0	.0	100.0
04063700	80.3	.0	19.7	.0	.0	.0	70.6	7.4	.15	15.5	5.22	9.9	.0	.0	.0	100.0
04071795	.0	.0	100.0	.0	.0	.0	45.8	14.7	.31	4.6	1.91	2.7	100.0	.0	.0	.0
04072050	3.0	.0	97.0	.0	.0	.0	48.9	26.9	.31	5.0	1.09	3.2	37.1	.0	.0	62.9
04080798	50.1	.0	49.9	.0	.0	.0	143.1	8.3	.15	11.3	5.36	5.1	96.8	.0	.0	3.2
04085109	.3	.0	99.7	.0	.0	.0	94.0	37.3	.32	4.6	1.04	3.7	.0	28.3	.0	71.7
040863075	8.2	.0	91.8	.0	.0	.0	171.1	17.3	.31	3.1	2.87	4.4	.0	100.0	.0	.0
040869415	.0	.0	100.0	.0	.0	.0	126.7	35.1	.35	4.3	.63	5.3	.0	100.0	.0	.0

Appendix 2. Median, midmonthly nutrient concentrations of 234 sites sampled in the Upper Midwest, by site

[mg/L, milligrams per liter; --, no data; almn, Allegheny and Monongahela River Basins NAWQA study unit; eiwa, Eastern Iowa Basins NAWQA study unit; iepa, Illinois Environmental Protection Agency; kana, Kanawha-New River Basins NAWQA study unit; leri, Lake Erie-Lake Saint Clair Drainages NAWQA study unit; lirb, Lower Illinois River Basin NAWQA study unit; miam, Great and Little Miami River Basins NAWQA study unit; redn, Red River of the North Basin NAWQA study unit; stx, U.S. Geological Survey, St. Croix River Watershed study; uirb, Upper Illinois River Basin NAWQA study unit; umbl, U.S. Geological Survey, Upper Mississippi River System study; umis, Upper Mississippi River Basin NAWQA study unit; wdnr, Wisconsin Department of Natural Resources; whit, White River Basin NAWQA study unit; wmic, Western Lake Michigan Drainages NAWQA study unit]

Station number	Sampling agency or USGS study name	Total nitrogen (mg/L)	Total phosphorus (mg/L)
03015795	almn	0.37	0.01
03024000	almn	.93	.03
03037350	almn	1.08	.02
03040000	almn	1.05	.02
03049646	almn	.71	.02
03070350	almn	.68	.01
03072000	almn	.51	.01
03083500	almn	1.06	.01
40001	umbl	3.81	.19
40007	umbl	4.70	.16
50001	umbl	4.76	.08
50003	umbl	3.80	.09
80001	umbl	1.88	.15
80003	umbl	3.99	.08
80007	umbl	1.37	.08
90001	umbl	1.47	.06
90003	umbl	3.63	.07
130001	umbl	6.46	.21
130003	umbl	4.16	.14
200003	umbl	7.20	.18
240001	umbl	1.85	.14
260001	umbl	1.60	.10
280001	umbl	.76	.04
05420680	eiwa	4.89	.09
05449500	eiwa	6.33	.17
05451210	eiwa	10.00	.09
05455100	eiwa	5.10	.13
05461390	eiwa	8.55	.10
05464220	eiwa	10.09	.13
05474000	eiwa	7.06	.32
BPK07	iepa	7.73	.05
BPJ07	iepa	8.20	.28
BPJC06	iepa	--	1.85
BO07	iepa	10.40	.11
BN01	iepa	--	.05
BM02	iepa	--	.20
BE14	iepa	--	.09
BEF05	iepa	--	.16
BC02	iepa	--	.19
C21	iepa	1.35	.17

Appendix 2. Median, midmonthly nutrient concentrations of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Sampling agency or USGS study name	Total nitrogen (mg/L)	Total phosphorus (mg/L)
CD01	iepa	1.56	.20
CA06	iepa	1.20	.14
ATGC01	iepa	1.27	.02
ATF04	iepa	1.50	.09
AK02	iepa	0.34	.01
AD02	iepa	.86	.14
MJ01	iepa	8.45	.18
PWN01	iepa	--	.21
PQ10	iepa	4.25	.08
PQC06	iepa	5.50	.25
PQB02	iepa	5.86	.05
PL03	iepa	7.75	.39
PH16	iepa	8.20	.16
PE05	iepa	7.80	.23
PB02	iepa	3.20	.06
LF01	iepa	--	.15
LD02	iepa	--	.50
KI02	iepa	6.10	.15
KCA01	iepa	--	.22
HBD04	iepa	6.73	2.16
GG02	iepa	4.30	.38
GB10	iepa	6.80	1.13
DW01	iepa	1.10	.09
DV04	iepa	9.30	.07
DTD02	iepa	3.95	.10
DTB01	iepa	5.40	.08
DS07	iepa	9.40	.22
DR01	iepa	5.80	.15
DL01	iepa	--	.08
DJ06	iepa	--	.17
DJB18	iepa	--	.43
E29	iepa	10.10	.11
EOH01	iepa	6.40	.23
EL01	iepa	1.60	.20
EIG01	iepa	8.70	.09
EIE04	iepa	10.00	.07
EID04	iepa	9.40	.51
DH01	iepa	--	.10
DF04	iepa	--	.15
DE01	iepa	--	.10
DD04	iepa	--	1.17
DB01	iepa	--	.21
DA04	iepa	--	.28
JR02	iepa	3.05	.17
JQ05	iepa	1.30	.20
O31	iepa	9.40	.15
OU01	iepa	10.17	.09
OT02	iepa	10.60	.07
OQ01	iepa	2.66	.20
ON01	iepa	.96	.12

Appendix 2. Median, midmonthly nutrient concentrations of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Sampling agency or USGS study name	Total nitrogen (mg/L)	Total phosphorus (mg/L)
OL02	iepa	1.38	.16
OK01	iepa	1.20	.19
OKA01	iepa	1.62	.29
OJ08	iepa	4.86	.54
OI09	iepa	2.00	.41
OH01	iepa	2.70	.85
OD06	iepa	2.50	.66
OC04	iepa	8.40	1.00
OZC01	iepa	1.54	.16
II03	iepa	.57	.21
NK01	iepa	1.52	.14
NJ07	iepa	3.40	.25
NH06	iepa	1.75	.17
NE05	iepa	1.52	.25
NC07	iepa	1.35	.17
03167000	kana	1.02	.05
03170000	kana	.51	.05
03178000	kana	.66	.05
03183000	kana	.59	.05
03186500	kana	.42	.05
03187500	kana	.48	.05
03191500	kana	.65	.05
03198350	kana	.74	.05
04159492	leri	4.10	.10
04161820	leri	1.84	.05
04175600	leri	.92	.01
04178000	leri	2.32	.12
04186500	leri	5.71	.14
04208504	leri	5.30	.22
04211820	leri	.95	.06
04213500	leri	1.21	.01
05567000	lirb	13.18	.13
05568800	lirb	8.62	.13
05584500	lirb	5.40	.17
03245500	miam	3.70	.37
03267900	miam	4.29	.08
03275000	miam	2.88	.05
393944084120700	miam	1.35	.05
395355084173600	miam	3.18	.17
395457084095100	miam	3.17	.32
05030150	redn	.66	.03
05051300	redn	1.72	.20
05058700	redn	1.35	.22
05062500	redn	.95	.04
05079000	redn	1.00	.07
05082625	redn	1.30	.09
05085900	redn	1.61	.18
05099600	redn	.99	.23
05112000	redn	1.26	.09
05333579	stx	1.15	.03

Appendix 2. Median, midmonthly nutrient concentrations of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Sampling agency or USGS study name	Total nitrogen (mg/L)	Total phosphorus (mg/L)
05335151	stx	1.10	.04
05338955	stx	.96	.06
05340390	stx	.91	.04
05341500	stx	1.19	.05
05341752	stx	2.95	.07
05342000	stx	5.28	.08
05526000	uirb	7.40	.08
05527800	uirb	2.64	.19
05531500	uirb	9.00	1.51
05548105	uirb	4.03	.08
05267000	umis	.79	.03
05276005	umis	2.09	.04
05288705	umis	1.16	.06
05320270	umis	8.95	.16
05330902	umis	1.10	.06
05331833	umis	.41	.01
04027595	wdnr	--	.04
040734644	wdnr	--	.24
04085463	wdnr	--	.33
04086500	wdnr	--	.22
053230	wdnr	--	.16
053232	wdnr	--	.27
053511	wdnr	--	.83
05368000	wdnr	--	.09
05378185	wdnr	--	.09
05379430	wdnr	--	.30
05379472	wdnr	--	.13
05406460	wdnr	--	.14
05407500	wdnr	--	.12
05427950	wdnr	--	.26
05429580	wdnr	--	.14
05431014	wdnr	--	.08
05431018	wdnr	--	.27
05433510	wdnr	--	.11
063035	wdnr	--	.07
063037	wdnr	--	.07
103094	wdnr	--	.16
103105	wdnr	--	.10
113086	wdnr	--	.14
123023	wdnr	--	.06
133024	wdnr	--	.38
133119	wdnr	--	.16
133336	wdnr	--	.17
133337	wdnr	--	.12
143012	wdnr	--	.11
163002	wdnr	--	.03
183042	wdnr	--	.18
183064	wdnr	--	.08
183077	wdnr	--	.06
223248	wdnr	--	.21

Appendix 2. Median, midmonthly nutrient concentrations of 234 sites sampled in the Upper Midwest, by site—Continued

Station number	Sampling agency or USGS study name	Total nitrogen (mg/L)	Total phosphorus (mg/L)
263001	wdnr	--	.05
273015	wdnr	--	.10
273016	wdnr	--	.06
273031	wdnr	--	.02
273032	wdnr	--	.06
273034	wdnr	--	.02
313023	wdnr	--	.05
313038	wdnr	--	.11
363070	wdnr	--	.12
363071	wdnr	--	.10
363218	wdnr	--	.14
373047	wdnr	--	.11
373325	wdnr	--	.22
383001	wdnr	--	.03
413006	wdnr	--	.13
413008	wdnr	--	.07
413011	wdnr	--	.08
433002	wdnr	--	.04
453030	wdnr	--	.28
483043	wdnr	--	.02
503069	wdnr	--	.02
523061	wdnr	--	.20
573076	wdnr	--	.17
603049	wdnr	--	.19
603304	wdnr	--	.38
603326	wdnr	--	.06
683001	wdnr	--	.56
683271	wdnr	--	.09
693021	wdnr	--	.05
03353637	whit	1.16	.03
03360895	whit	5.10	.10
03366500	whit	1.45	.07
03373530	whit	6.80	.05
391732085414401	whit	6.30	.07
393306086585201	whit	2.40	.07
394340085524601	whit	2.10	.06
04062085	wmic	.47	.01
04063700	wmic	.58	.02
04071795	wmic	1.90	.15
04072050	wmic	2.70	.15
04080798	wmic	2.40	.02
04085109	wmic	1.65	.20
040863075	wmic	2.60	.12
040869415	wmic	.93	.04