In cooperation with the Kentucky Energy and Environment Cabinet–Kentucky Division of Water

Concentrations, and Estimated Loads and Yields of Total Nitrogen and Total Phosphorus at Selected Water-Quality Monitoring Network Stations in Kentucky, 1979–2004

Scientific Investigations Report 2009–5240

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

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KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

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Conversion Factors, Abbreviations, and Acronyms

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
yard (yd)	.9144	meter (m)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Mass	
ton, short (2,000 lb)	.9072	megagram (Mg)
ton, long (2,240 lb)	1.016	megagram (Mg)
ton per year (ton/yr)	.9072	megagram per year (Mg/yr)
ton per year (ton/yr)	.9072	metric ton per year
	Flow rate	
cubic foot per second (ft^3/s)	.02832	cubic meter per second (m^3/s)

Horizontal coordinate information is referenced to North American Datum of 1983 (NAD 83).

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Abbreviations and Acronyms

AIC	Akaike Information Criterion
AMLE	Adjusted Maximum Likelihood Estimation
BMU	Basin Management Unit
KDOW	Kentucky Division of Water
LAD	Least Absolute Deviation
LOC	line of organic correlation
MDL	method detection limit
MLE	Maximum Likelihood Estimation
NLCD	National Land Cover Data
$NO_2 + NO_3$-N	nitrite plus nitrate-nitrogen
OLS	ordinary-least-squares multiple-linear regression
STORET	Storage and Retrieval water-quality database
TKN	total Kjeldahl nitrogen
TKN-N	total Kjeldahl nitrogen as nitrogen
TN	total nitrogen
TP	total phosphorus
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
>	greater than
<	less than

Concentrations, and Estimated Loads and Yields of Total Nitrogen and Total Phosphorus at Selected Water-Quality Monitoring Network Stations in Kentucky, 1979–2004

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Abstract

To evaluate the State's water quality, the Kentucky Division of Water collects data from a statewide network of primary ambient stream water-quality monitoring stations and flexible, rotating watershed-monitoring stations. This ambient stream water-quality monitoring network program is directed to assess the conditions of surface waters throughout Kentucky. Water samples were collected monthly for the majority of the stations from 1979 to 1998, which represented agricultural, undeveloped (mainly forested), and areas of mixed land use/land cover. In 1998, the number of water samples collected was reduced to a collection frequency of six times per year (every 2 months) every 4 of 5 years, because a new monitoring network was implemented involving a 5-year rotating Basin Management Unit scheme of monitoring. This report presents the results of a study conducted by the U.S. Geological Survey, in cooperation with the Kentucky Energy and Environment Cabinet–Kentucky Division of Water, to summarize concentrations of total nitrogen and total phosphorus and provide estimates of total nitrogen and total phosphorus loads and yields in 55 selected streams in Kentucky's ambient stream water-quality monitoring network, which was operated from 1979 through 2004.

Streams in predominately agricultural basins had higher concentrations of total nitrogen (TN) and concentrations of total phosphorus (TP) than streams in predominately undeveloped (forested) basins. Streams in basins in intensely developed karst areas characterized by caves, springs, sinkholes, and sinking streams had a higher median concentration of TN (1.5 milligrams per liter [mg/L]) than streams in basins with limited or no karst areas (0.63 mg/L). As with TN, median concentrations of TP also were higher in areas of intense karst (0.05 mg/L) than in areas with limited or no karst (0.02 mg/L).

The U.S. Environmental Protection Agency (USEPA) has recommended ecoregional nutrient water-quality criteria as a starting point for States to establish more precise numeric water-quality criteria for nutrients to protect aquatic life and recreational and other uses of rivers and streams. On the basis of the 25th percentile of concentration data from reference stations aggregated by ecoregion, the USEPA established recommended water-quality criteria for TN and TP in the two Aggregated Ecoregions (IX and XI) in Kentucky waters. The 25th percentile median values for TN and TP from this study exceeded the USEPA's recommendations in both aggregated ecoregions in the agricultural and mixed land-use/land-cover basins, and for TN in the undeveloped land-use/land-cover basins in Aggregated Ecoregion XI. However, the 25th percentile median values for TN (Aggregated Ecoregion IX) and TP in both aggregated ecoregions did not exceed the USEPA's recommendations in the undeveloped land-use/land-cover basins.

Estimated loads and yields of TN and TP varied substantially among the individual stations. Estimated mean annual yields of TN ranged from 0.10 [tons per year per square mile (ton/yr)/mi^2] to 7.2 (ton/yr)/mi^2, and estimated mean annual yields of TP ranged from 0.02 (ton/yr)/mi^2 to 1.4 (ton/yr)/mi^2. Estimated mean annual yields of TN and TP were generally highest at stations in predominately agricultural basins, and lowest at stations in undeveloped land-use/land-cover basins.

Introduction

In 1972, Congress enacted the Federal Water Pollution Control Act of 1972 (Public Law 92–500) and passed subsequent amendments in 1977, 1981, and 1987 (commonly referred to as the Clean Water Act). The Act and its amendments established a National policy to sharply reduce discharge of contaminants into waterways, to finance municipal wastewater-treatment facilities, direct States to establish water-quality criteria for waters within their boundaries, and fund development of programs to manage and control nonpoint sources of contamination. The act also required States to submit biannual reports to the U.S. Environmental Protection Agency (USEPA) that presented a comprehensive water-quality assessment (305) [b] report) and listed the water-quality-impaired streams or stream segments (303[d] report) within the States. In 2006, the USEPA released guidance for combining the 305(b) and 303(d) reports into an Integrated Water

Monitoring and Assessment Report (IR). Data contained in the IR is obtained through each state's ambient stream water-quality monitoring network. This information is necessary to identify trends in water-quality conditions, set priorities for protecting and restoring the health of aquatic resources, and assess stream water quality relative to criteria established by each State.

In 1998, a new initiative to the Clean Water Act called the Clean Water Action Plan was launched to direct States, in conjunction with USEPA, to develop numeric criteria for total nitrogen and total phosphorus along with chlorophyll *a* and turbidity (U.S. Environmental Protection Agency, 1998). Although individual States are responsible for establishing their own water-quality criteria, the USEPA has recommended ecoregional nutrient water-quality criteria as a baseline and has provided guidance to States to establish more precise numeric water-quality criteria for nutrients to protect aquatic life and recreational and other uses of rivers and streams on a station-specific or subregion-specific basis (U.S. Environmental Protection Agency, 2000a,b). The USEPA-recommended water-quality criteria serves as a basis for States to evaluate their relative success in reducing the level of pollutant to protect the designated uses of ambient waters.

The demands on the water resources of Kentucky have increased over time. Both the quantity and quality of water can be affected by increased use of land and water. As issues concerning water quality emerge, the Commonwealth of Kentucky will need a comprehensive base of information from which to evaluate conditions and make resource-management decisions for using and protecting water resources, thus allowing for the development and implementation of effective management plans in the future.

Although nutrients such as nitrogen and phosphorus are necessary for plant and animal life, in excessive quantities they can be detrimental to the health of an aquatic system by promoting excessive plant growth. Nutrient enrichment in streams can lead to eutrophication, which is a condition characterized by increased biological productivity and associated decomposition of organic material. Eutrophication can lead to nuisance levels of algae, accumulation of organic material on the streambed, or the depletion of dissolved oxygen in the water.

Nutrients (primarily nitrogen and phosphorus) are commonly cited as principal reasons why water bodies in Kentucky do not fully support their designated uses (Kentucky Energy and Environment Cabinet, 2008). Nitrogen and phosphorus are essential nutrients for the growth of plants and animals. Nitrogen and phosphorus compounds occur naturally, but also are applied to land in the form of commercial fertilizers and livestock waste to enhance plant growth. High phosphorus content occurs naturally in parts of Kentucky where the soils are derived from phosphatic rocks. Nutrients that are not utilized by crops or stored in the soil can travel in runoff to streams or through soil to ground water. Although these nutrients are necessary for the growth of plants and animals, excessive amounts can be detrimental to aquatic ecosystems and to the health of organisms living in and using water, and can limit human uses of a water body.

In 2005, the U.S. Geological Survey (USGS), in cooperation with the Kentucky Energy and Environment Cabinet–Kentucky Division of Water, conducted an investigation to summarize concentrations of total nitrogen and total phosphorus, and provide estimates of total nitrogen and total phosphorus loads and yields for 55 ambient stream water-quality network monitoring stations in Kentucky from 1979 through 2004 (fig. 1 and table 1).

Purpose and Scope

This report summarizes concentrations of total nitrogen and total phosphorus and provides estimates of total nitrogen and total phosphorus loads and yields from water-quality samples collected by the Kentucky Division of Water at 55 ambient stream water-quality stations in Kentucky. Water-quality records for these stations were retrieved from USEPA's Legacy Data Center and Modernized Storage and Retrieval (STORET) database. The records were screened and analyzed for selected periods of record during the water years 1979 through 2004 (U.S. Environmental Protection Agency, 2004). A water year is defined as the 12-month period from October 1, for any given year, through September 30 of the following year. This report updates previous work by Crain (2001) that estimated loads at 20 ambient stream water-quality monitoring network stations from 1979 through 1994, and that estimated the loads and yields at 22 ambient stream water-quality monitoring network stations from 1979 through 1997. Some supporting information is presented to provide assistance in the interpretation of the estimated loads and yields.

Description of Study Area

Kentucky is located in the south-central United States and ranks 37th in land size, with 39,732 mi^2. Kentucky is bordered by seven states: Indiana, Ohio, West Virginia, Virginia, Tennessee, Missouri, and Illinois (fig.1). The northern border is formed by the Ohio River and the western border is formed by the Mississippi River.

Natural and human factors affect the physical, chemical, and biological quality of surface water and groundwater in Kentucky. These factors and their combinations also can influence the potential for the contamination of surface water and groundwater and may explain regional water-quality differences or similarities in estimated loads and yields.

Population

The population of Kentucky increased from 3.66 million in 1980 to 4.04 million in 2000, which is an increase of 9.4 percent (U.S. Census Bureau, 2003). Kentucky ranked 25th out of all 50 States in population density in 2000 with about 102 people per square mile (U.S. Census Bureau, 2003). More

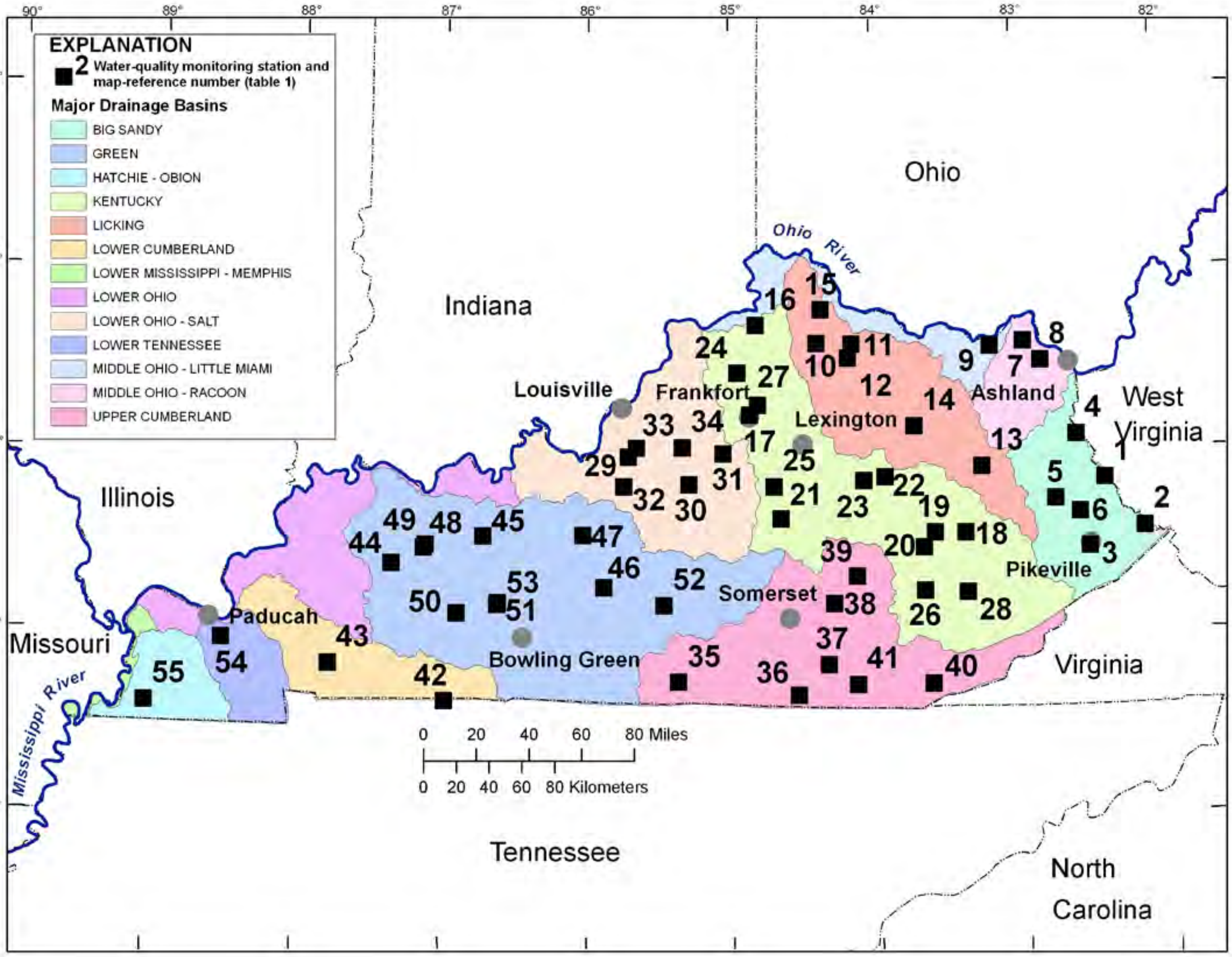


Figure 1. Location of water-quality stations in the statewide ambient water-quality monitoring network selected for load analysis, 1979–2004.

than one-half of the population of Kentucky is concentrated in what is referred to as the Golden Triangle—the land area between Louisville, Lexington, and the Northern Kentucky region (near Covington, Ky.) (fig. 2). Some of the highest growth rates experienced by counties occurred in this area from 1980 to 2000—Anderson County (34 percent), Boone County (47 percent), Gallatin County (38 percent), Grant County (40 percent), Oldham County (40 percent), Shelby County (30 percent), and Spencer County (50 percent). Only five other counties outside this area experienced similar growth rates—Bullitt County (29 percent) located just south of Louisville; Garrard County (27 percent) located southwest of Lexington; Jessamine County (33 percent) located southwest of Lexington; Laurel County (26 percent) located three counties west of Hazard; and Trigg County (25 percent) located just west of Hopkinsville.

Physiography and Geology

The physiography of Kentucky can be generalized as a series of dissected plateaus and gently rolling terrain separated by faults (McDowell, 1986). The western and central parts of Kentucky have rolling terrain, whereas the eastern part of Kentucky has rugged terrain with high relief. The maximum land-surface altitude in Kentucky is the peak of Black Mountain (4,145 ft above NAVD 88) in Harlan County near the Kentucky–Virginia border; the lowest land-surface altitude is the Mississippi River at 260 ft above NAVD 88 (McGrain and Currens, 1978).

Kentucky lies within eight distinct physiographic regions that reflect the underlying geology: (1) Eastern Coal Field (also known as the Cumberland Plateau); (2) Inner Bluegrass; (3) Outer Bluegrass; (4) the Knobs; (5) Eastern Pennyroyal (also known as the Mississippian Plateau); (6) Western Pennyroyal (also known as the Mississippian Plateau); (7) Western

Table 1. Station information for selected Kentucky ambient water-quality monitoring stations in major rivers basins for load and yield analysis.

[KDOW, Kentucky Division of Water; USGS, U.S. Geological Survey; mi², square miles]

Map reference number (figure 1)	KDOW station name	USGS stream-gaging station number used for discharge[1]	KDOW station number	Drainage area (mi²)	Latitude (decimal degrees)	Longitude (decimal degrees)
		Big Sandy				
1	Tug Fork at Kermit, W. Va.	03214500	PRI002	1,280	37.838	−82.410
2	Tug Fork at Freeburn, W. Va.	Multiple stations	PRI003	271	37.566	−82.144
3	Levisa Fork near Pikeville	03209500	PRI006	1,238	37.464	−82.526
4	Levisa Fork near Louisa	03215000	PRI064	2,326	38.081	-82.600
5	Levisa Fork at Auxier	03212500	PRI094	1,726	37.729	−82.754
6	Johns Creek at McCombs	03210000	PRI096	168	37.655	−82.587
		Middle Ohio-Racoon				
7	Tygarts Creek at Load	03217000	PRI048	242	38.599	−82.526
8	Little Sandy at Argillite	03216500	PRI049	522	38.491	−82.834
		Middle Ohio-Little Miami				
9	Kinniconick Creek near Tannery	03237250	PRI063	175	38.574	-83.188
		Licking				
10	South Fork Licking River at Morgan	Multiple stations	PRI059	839	38.603	−84.401
11	North Fork Licking River near Milford	03251200	PRI060	290	38.597	−84.156
12	Licking River at Claysville	03249500	PRI061	1,993	38.521	−84.183
13	Licking River at West Liberty	Multiple stations	PRI062	327	37.915	−83.262
14	Slate Creek near Owingsville	03250190	PRI093	230	38.142	−83.727
15	Licking River at Butler	03253500	PRI111	3,385	37.790	−84.368
		Kentucky				
16	Eagle Creek at Glencoe	03291500	PRI022	437	38.706	−84.826
17	Kentucky River at Frankfort (Lock 4)	03287500	PRI024	5,412	38.213	−84.873
18	North Fork Kentucky River at Jackson	03280000	PRI031	1,101	37.551	−83.384
19	Middle Fork Kentucky River at Tallega	03281000	PRI032	537	37.555	−83.594
20	South Fork Kentucky River at Booneville	03281500	PRI033	722	37.475	−83.671
21	Dix River near Danville	03285000	PRI045	318	37.642	−84.661
22	Red River at Clay City	03283500	PRI046	362	37.865	−83.933
23	Kentucky River near Trapp	Multiple stations	PRI058	3,246	37.847	−84.081
24	Kentucky River at Lockport (Lock 2)	03290500	PRI066	6,180	38.445	−84.957
25	Kentucky River at High Bridge (Lock 7)	03286500	PRI067	5,036	37.819	−84.706
26	Goose Creek near Oneida	03281100	PRI092	250	37.237	−83.671
27	Elkhorn Creek at Peaks Mill	03289500	PRI098	473	38.269	−84.814
28	Middle Fork Kentucky River at Dryhill	Multiple stations	PRI104	324	37.223	−83.377

Table 1. Station information for selected Kentucky ambient water-quality monitoring stations in major rivers basins for load and yield analysis—Continued.

[KDOW, Kentucky Division of Water; USGS, U.S. Geological Survey; mi^2, square miles]

Map reference number (figure 1)	KDOW station name	USGS stream-gaging station number used for discharge[1]	KDOW station number	Drainage area (mi^2)	Latitude (decimal degrees)	Longitude (decimal degrees)
		Lower Ohio-Salt				
29	Salt River at Shepherdsville	03298500	PRI029	1,197	37.985	−85.718
30	Beech Fork near Maud	03300400	PRI041	436	37.833	−85.296
31	Salt River at Glensboro	03295400	PRI052	172	38.002	−85.060
32	Rolling Fork near Lebanon Junction	03310500	PRI057	1,375	37.823	−85.748
33	Floyds Fork near Shepherdsville	03298200	PRI100	259	38.035	−85.659
34	Brashears Creek at Taylorsville	03295890	PRI105	262	38.037	−85.341
		Upper Cumberland				
35	Cumberland River near Burkesville	Multiple stations	PRI007	6,053	36.746	−85.372
36	South Fork Cumberland River at Blue Heron	03410500	PRI008	954	36.670	−84.549
37	Cumberland River at Cumberland Falls	03404000	PRI009	562	36.836	−84.340
38	Rockcastle River at Billows	03406500	PRI010	604	37.171	−4.297
39	Horse Lick Creek near Lamero	03404900	PRI051	62	37.320	−84.139
40	Cumberland River at Calvin	03402900	PRI086	770	36.722	−83.626
41	Clear Fork near Williamburg	03403910	PRI087	370	36.726	−84.142
		Lower Cumberland				
42	Red River near Keysburg	03435305	PRI069	509	36.641	−86.979
43	Little River near Cadiz	03438000	PRI043	244	36.841	−87.778
		Green				
44	Pond River near Sacramento	Multiple stations	PRI012	523	37.395	−87.353
45	Rough River near Dundee	Multiple stations	PRI014	757	37.547	−86.721
46	Green River at Munfordville	03308500	PRI018	1,673	37.269	−85.885
47	Nolin River at White Mills	03310300	PRI021	357	37.555	−86.031
48	Rough River near Livermore	03319000	PRI054	1,068	37.499	−87.119
49	Green River at Livermore	03316500	PRI055	6,431	37.484	−87.134
50	Mud River near Gus	Multiple stations	PRI056	268	37.123	−86.901
51	Barren River at Woodbury	Multiple stations	PRI072	1,968	37.173	−86.623
52	Russell Creek near Bramlett	03307000	PRI077	289	37.168	−85.470
53	Green River near Woodbury	03316500	PRI103	5,404	37.183	−86.616
		Lower Tennessee				
54	Clarks River near Sharpe	03610200	PRI106	313	36.972	−88.515
		Hatchie-Obion				
55	Bayou de Chien near Moscow	07024000	PRI109	178	36.616	−89.030

[1]Refer to table 5 for estimates of daily mean discharge for stations with no available discharge or incomplete discharge records.

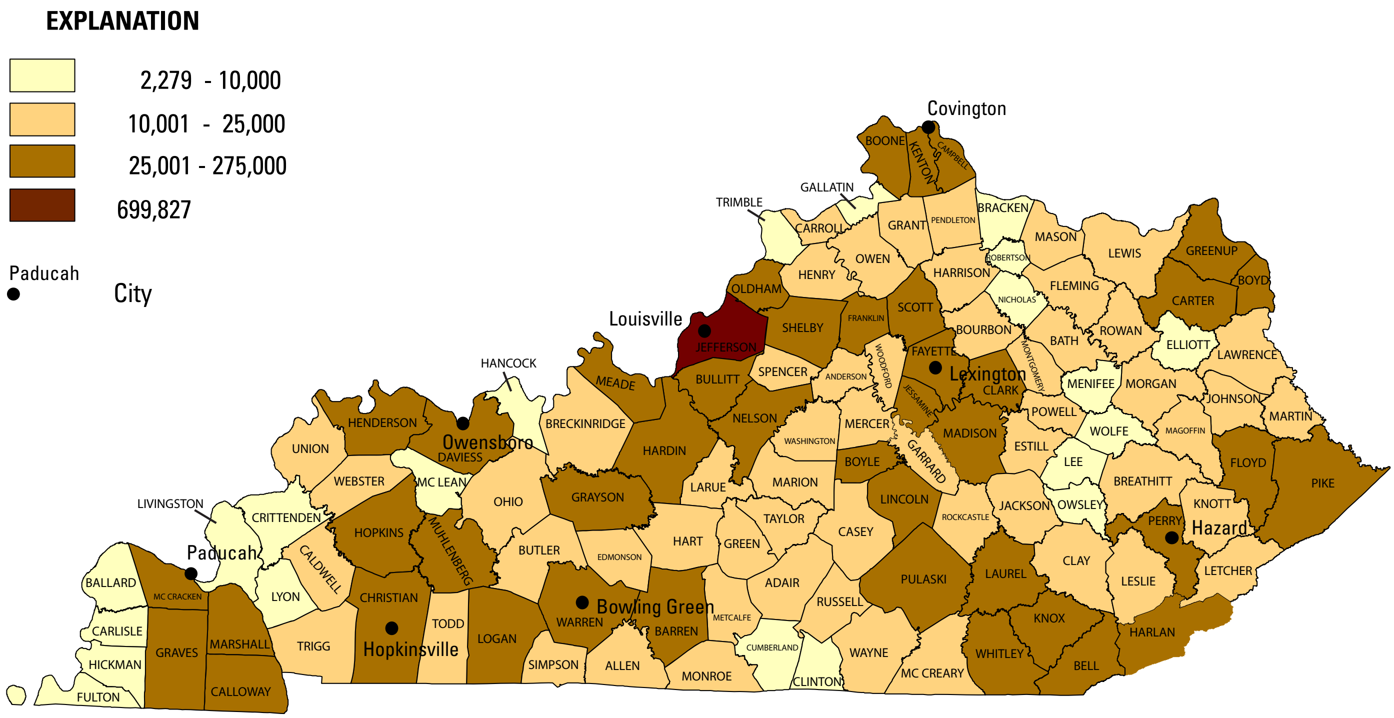


Figure 2. Total population by county in Kentucky, 2005. (County population data from the Population Division, U.S. Census Bureau, 2006).

Coal Field; and (8) Purchase region (also known as the Mississippian Embayment) (McDowell, 1986) (fig. 3).

The Eastern Coal Field is part of a larger physiographic region known as the Cumberland Plateau (southern part of Appalachian Plateau), which extends from Kentucky to Alabama. It is characterized by very rugged terrain consisting of narrow valleys and narrow, steep-sided ridges. Rocks of the region are of Pennsylvanian age and are mainly sandstone, siltstone, and shale with numerous interbedded coal beds.

The Bluegrass physiographic region is restricted to the north-central part of the Commonwealth, where Ordovician- and Silurian-age limestones and shales are exposed at the surface. The Bluegrass region is subdivided into the Inner-Bluegrass and Outer-Bluegrass regions. The Inner-Bluegrass region is characterized by gently rolling upland and abundant sinkholes underlain by thick-bedded phosphatic limestone of Ordovician age (Smoot and others, 1995). The Outer-Bluegrass region is underlain by thin-bedded limestones of late Ordovician age and includes considerable interbedded shale of Silurian age (McFarlan, 1943, p. 172). The topography in this region resembles the Inner Bluegrass except near streams, where it is dissected and rugged (Smoot and others, 1995).

The Knobs physiographic region is shaped like a crescent. It separates the Bluegrass region from the Eastern Coal Field region and consists of isolated, steeply sloping, cone-shaped hills. These hills are erosional remnants and are capped by erosionally resistant limestones and sandstones of Mississippian age and overlain shales of Devonian age.

Much of the Eastern and Western Pennyroyal regions are characterized by karst topography. Karst topography is defined as a landscape that contains caves, springs, sinkholes, and sinking streams. Numerous karst features are present in these regions. The regions are predominantly underlain by Mississippian-age limestone.

The Western Coal Field region is similar to the Eastern Coal Field region in that it consists of bedrock of mostly Pennsylvanian age. The region is characterized by hilly upland with low to moderately-high relief dissected by streams in poorly drained and often swampy bottomlands (McDowell, 1986).

The Purchase region is located in western Kentucky and is characterized by flat, low plains dissected by low-gradient streams. This region is underlain by unconsolidated Cretaceous-age sand, gravel, silt, and clay deposits, which are easily eroded. Stream bottoms are underlain by Quaternary alluvium (McDowell, 1986).

The geographic location of a stream can greatly affect its water quality, because of the characteristic geomorphology of each drainage basin. Of the 55 selected ambient-monitoring network stations, 28 stations are located within the Eastern and Western Coal Field regions (fig. 3), where water quality is primarily affected by coal extraction (Leist and others 1981; Quinones and others, 1981). Nineteen stations are located within the Inner- and Outer-Bluegrass regions and the Knobs

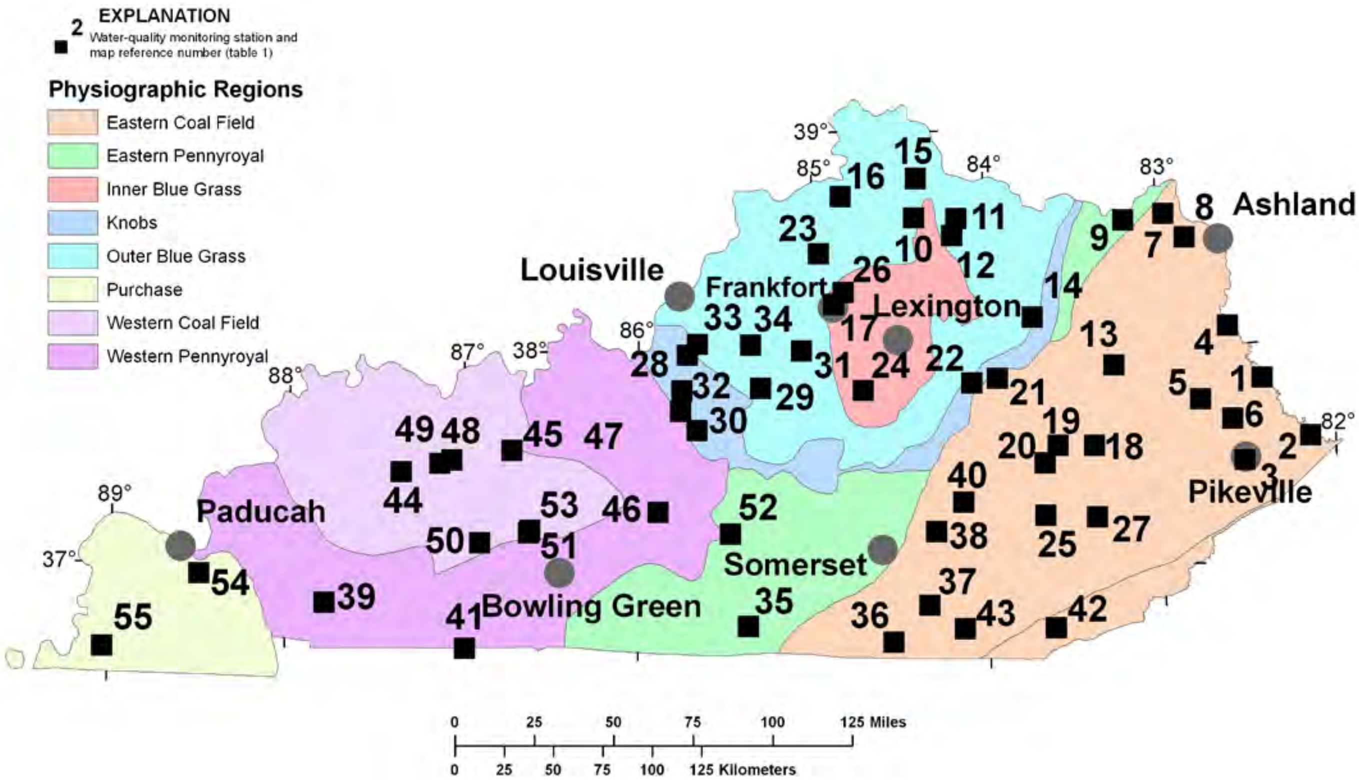


Figure 3. Physiographic regions of Kentucky and location of selected ambient water-quality monitoring stations for load analysis, 1979–2004.

region, where water quality is primarily affected by activities associated with urbanization. Six ambient-network stations are located in the Eastern- and Western-Pennyroyal region. This region is characterized by karst topography, and the water quality is primarily affected by agricultural activities. Two of the 55 selected ambient-network stations are located in the Purchase region, where water quality is primarily affected by agricultural activities (Kleiss and others, 2000).

Land Use and Land Cover

The term "land use" implies human activity, and human activity implies a potential affect on the hydrology and quality of water in a watershed. The type and severity of water contamination often is directly associated with human activity; therefore, it can be qualified in terms of the intensity and type of land use in the source areas of water to streams. For example, the land use defined as agriculture indicates that the application of fertilizers is partially associated with human activity. Land use in Kentucky largely reflects the geology and physiography of the Commonwealth and the population distribution.

Land cover relates to land use because land cover refers not only to the vegetation on the land surface, but also to the artificial structures and surfaces on the land. Land cover during 2001 for Kentucky is shown in figure 4, and classifications for the drainage area defined by each station are presented in appendix 1. The drainage basins at seven stations were categorized as agricultural, with agriculture covering greater than 50 percent of the basin land area. Drainage basins categorized as undeveloped represented 23 of the 55 drainage basins, with undeveloped land covering from 66 to 82 percent of the basin land area. Stations within undeveloped drainage basins had less than 5 percent urban land use/land cover and less than 25 percent agricultural land use/land cover. Twenty-five drainage basins were categorized as having mixed land use/land cover (combinations of urban, agricultural, and undeveloped [forested] land).

The National Land Cover Data 2001 (NLCD 2001) datasets were used to identify differences in land cover throughout Kentucky. The NLCD 2001 land-cover data were based on the National Land Cover Data 2001 (NLCD 2001) dataset classification scheme and protocols (U.S. Geological Survey, 2007). The NLCD 2001 is a 16-class, 30-m resolution dataset primarily based on Landsat-7 Enhanced Thematic Mapper Plus data for 1999–2002 (U.S. Geological Survey, 2007). The NLCD 2001 was aggregated to eight Anderson Level I classes (table 2) (Anderson and others, 1976). For example, the land-cover classes "Deciduous Forest," "Evergreen Forest," and "Mixed Forest" were aggregated to "Forest" (table 2). Table 3 quantifies the percentage of land cover for Kentucky using the NLCD 2001 dataset.

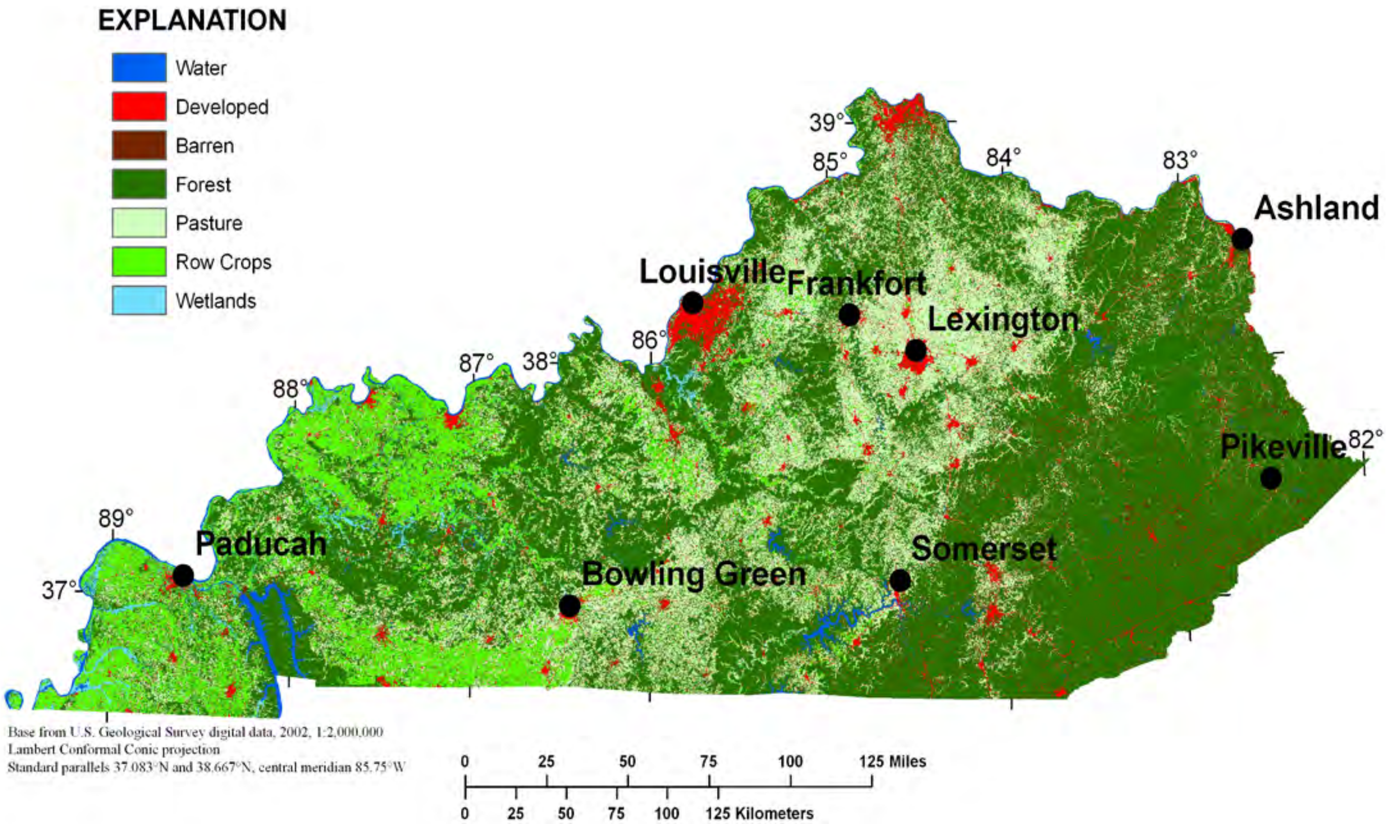


Figure 4. Land cover within Kentucky, 2001([The National Land Cover Data 2001 [U.S. Geological Survey, 2007]), was aggregated to eight Anderson Level I classes (Anderson and others, 1976).

Climate

Kentucky has a temperate-continental climate characterized by well-defined winter and summer seasons that are accompanied by large annual temperature variations. Mean monthly temperatures in Kentucky range from about 23°F in the winter months to 87°F in the summer months (NState, 2008). Variations in seasonal temperatures reflect the polar continental air masses in the late fall and winter and the tropical maritime air masses in the early spring, summer, and early fall. The tropical maritime air masses originate from the Gulf of Mexico and Atlantic Ocean and often result in thunderstorms, tornados, and intense rainfall. Mean annual precipitation from 1979 to 2004 for Kentucky was 48.8 in. Yearly precipitation totals throughout Kentucky from 1979 to 2004 ranged from 37.2 in. in 1980 to 62.9 in. in 1979 (Kentucky Climate Center, 2007). The amount of precipitation generally decreases from south to north.

Hydrology

Variations in climate, physiography, land use/land cover, and geology cause localized variations in streamflow characteristics in Kentucky. High-flow conditions in streams generally occur in the spring, and low-flow conditions generally occur in late summer or early fall. However, flooding can occur at any time of the year. During dry periods, groundwater discharge to springs and streams constitutes the majority of streamflow in areas with karst topography. Numerous impoundments cause variations in streamflow. Impoundments tend to increase base flow in streams when stored water is released during dry periods, and tend to reduce flood peaks by storing floodwaters.

About 55 percent of Kentucky is underlain by karst. Karst topography is characterized by internal or sinkhole drainage and rapid flow through solutional conduits, providing reduced attenuation of contaminants and enhanced potential for surface-water and groundwater contamination relative to non-karst environments (Field, 1990). As stated earlier, Kentucky includes eight physiographic region (fig. 3), with each region differing in its hydrologic characteristics. The Eastern Coal Field is part of a larger physiographic region known as the Cumberland Plateau. This region contains numerous mountain streams that drain into five major waterways: the Licking River, the Big and Little Sandy Rivers, the Cumberland River, and the Kentucky River. Groundwater flow in this region is predominately through fissures in the rocks.

The hydrology in the Bluegrass Region is influenced by the amount of shale in the subsurface, which generally prevents infiltration of precipitation (Ray and others, 1994). Many streams in the Bluegrass Region flow through highly permeable karst terrane, creating substantial surface-water/

groundwater interaction, especially in the Inner-Bluegrass Region. As a result, these streams commonly have dry and flowing reaches as water moves from one system to the other (Smoot and others, 1995). The hydrology in the Knobs Region, which is bordered by the Eastern Coal Field and Outer Bluegrass Regions, contains hydrologic features of both the Eastern Coal Field and Outer-Bluegrass Regions.

Karst topography and hydrology are well developed in much of the Eastern and Western Pennyroyal Regions. Streams in these regions are moderate to low gradient. The upper portion of the Green River and its tributaries drain much of the Pennyroyal regions with substantial surface-water/groundwater interaction. The lower portion of the Green River and its tributaries traverses the Western Coal Field, where groundwater flow within bedrock is predominately through fractures (Ray and others, 1994).

Shallow, low-gradient streams flow through the Purchase Region and into the Mississippi River. This region generally is underlain by semi-consolidated Crestaceous-age and younger sand, silt, gravel, and clay deposits (Ray and others, 1994). The coarser sediments are prolific aquifers that can supply large volumes of water to industrial, municipal, and domestic water-supply wells. Groundwater can migrate quickly through coarser sediments, especially at shallow depths (Ray and others, 1994).

Data Collection

The Kentucky ambient stream water-quality monitoring network (fig. 1 and table 1) was designed to characterize background conditions of water-quality properties and constituents in streams, determine compliance with applicable surface-water-quality standards, provide data to support development of new or revised water-quality standards, and determine long-term trends in the surface-water quality of streams across Kentucky (Kentucky Energy and Environment Cabinet, 2005). The statewide ambient water-quality monitoring stations are generally in midstream or downstream reaches on major rivers or on their major tributaries as well as stream-inflow points and outflows from U.S. Army Corp of Engineers reservoirs. The ambient water-quality monitoring network stations also are in streams where particular water-quality issues may be associated with local land uses (non-point sources or point sources); however, most stations are located away from point sources. Many of the 55 stations selected were at or near active, or formerly active, USGS streamflow-gaging stations. The use of streamflow information enhances the understanding of water quality in relation to changing flow conditions.

Nutrient samples were collected monthly for the majority of the stations from 1979 to 1998. In 1998, nutrient samples were reduced to a frequency of six times per year (every 2 months) every 4 of 5 years because a new monitoring network was implemented involving a 5-year rotating Basin Management Unit (BMU) scheme of monitoring. The BMU scheme facilitates the efficient use of water- management

Table 2. Classification scheme of Anderson level I and II systems used with the National Land Cover Data dataset, 2001 (U.S. Geological Survey, 2007), in this study.

[—, not used]

National Land Cover Data 2001	
Level I[1]	**Level II[1]**
1 Developed	21 Developed open space
	22 Developed, low intensity
	23 Developed, medium intensity
	24 Developed, high intensity
2 Pasture	81 Pasture/hay
3 Row crops	82 Cultivated crops
4 Openland	—
5 Forest	41 Deciduous forest
	42 Evergreen forest
	43 Mixed forest
	52 Shrub/shrub
	71 Grassland/herbaceous
6 Water	11 Open water
7 Wetlands	90 Woodland wetlands
	95 Emergent wetland
8 Barren	31 Bare rock/sand/clay

[1]Anderson and others, 1976

Table 3. Percentage of land use/land cover for Kentucky from the National Land Cover Data dataset, 2001(U.S. Geological Survey, 2007), using Anderson level I classifications.

[NA, not available]

Anderson level I[1]	National Land Cover Data 2001 (in percent)
1 Developed	7.06
2 Pasture/hay	22.0
3 Row crops	11.0
4 Open land	NA
5 Forest	56.7
6 Water	1.83
7 Wetlands	1.07
8 Barren	.292

[1]Anderson and others, 1976

resources by focusing major watershed management efforts (such as stream monitoring) in different regions of the state each year. The Kentucky Division of Water also established about 30 rotating water-quality stations in each of the selected BMUs. These selected water-quality stations are monitored once every 5 years to provide more in-depth water-quality information in each BMU. These data were not included in the load analyses for this report.

Station Selection, Period of Record and Data Screening

Station selection for loads and yields was based primarily on the availability of long-term water-quality data at a station. Stations were selected in consultation with Kentucky Division of Water staff. Stations selected were all part of the Commonwealth's ambient stream water-quality monitoring network. This network contains 70 stations; however, only 55 stations were included in this study. Loads were not estimated at the remaining 15 ambient water-quality monitoring network stations because of an insufficient amount of water-quality data and (or) the network stations were not at or near active, or formerly active, USGS streamflow-gaging stations.

Analysis of water-quality data focused on a comprehensive review of the data collected by the Kentucky Division of Water. Data from 1979–2004 were retrieved from the USEPA's STORET repository for water-quality data. Streamflow data measured by the USGS were retrieved from the World Wide Web at *http://waterdata.usgs.gov/ky/nwis*. Other streamflow data were obtained from the U.S. Army Corps of Engineers Louisville District Water Management website at URL *www.lrl.usace.army.mil/brl/.*

Table 4 lists the nutrients selected for load analysis in this report. Concentrations of total nitrogen (TN) were computed from measured concentrations of dissolved nitrite plus nitrate-nitrogen (NO_2+NO_3-N) and total Kjeldahl nitrogen (TKN) (ammonia plus organic nitrogen). If the concentrations of NO_2+NO_3-N and TKN were greater than or equal to their respective method detection limit (MDL), their concentrations were summed to obtain TN. However, if the concentration of NO_2+NO_3-N or the concentration of TKN was less than an MDL, then the following rules were applied. If the NO_2+NO_3-N concentration was censored (MDL <0.01 mg/L), but the concentration of TKN was not censored, then the concentration of TN was computed as the sum of the TKN value and the censored value of NO_2+NO_3-N. If the concentration of NO_2+NO_3-N was not censored and the concentration of TKN was censored (<0.05 mg/L), the concentration of TN was computed as the sum of the NO_2+NO_3-N concentration and the censored value of TKN. If either the concentration of TKN or the concentration of NO_2+NO_3-N was missing, then the concentration of TN was not computed. Ten percent of all concentrations of TN were computed using censored data. The substitution of censored values does result in a high bias for the mean TN concentrations.

Several quality-assurance measures were taken prior to data analysis. Boxplots and scatterplots were initially used to identify erroneous data. Water-quality-data values also were checked to ensure that they fit into the context of other concentrations identified in a given sample. A water-quality value identified as suspect by any data-quality-assurance measure was evaluated individually, taking into account the collection location, time of year, and other samples collected at or near the station. Median concentrations of TN and TP were evaluated for comparisons, because median concentrations are a more appropriate measure of the central tendency of a highly censored data set.

Estimates of Daily Mean Discharge

Daily mean discharges were estimated at 19 water-quality-sampling stations where no discharge data were available or where the available discharge record was incomplete (missing) for a part of the water-quality-sampling period, 1979–2004. No discharge data were available for 6 of the 19 stations; the available discharge record was incomplete for the remaining 13 stations. The discharges were estimated by use of a drainage-area-ratio adjustment and (or) regression methods. For stations lacking discharge records that were located on the same stream reach or in close proximity to a streamflow-gaging station, the drainage-area-ratio adjustment was made to estimate the discharges at the nearby ungaged

Table 4. Nutrients selected for load analysis in Kentucky.

[USEPA, U.S. Environmental Protection Agency; STORET, Storage and Retrieval; mg/L, milligrams per liter; N, nitrogen; P, phosphorus]

Nutrient	Reporting units	Laboratory Reporting Limit (mg/L)	USEPA STORET parameter code
Nitrogen, ammonia-plus-organic, total (Kjeldahl nitrogen)	mg/L as N	0.05	00625
Nitrite plus nitrate, total	mg/L as N	.01	00630
Phosphorus, total as P	mg/L as P	.01	00665

location. Extension in time (augmentation) of an existing short-term gage record (a short-term station) was accomplished by developing a regression relation among concurrent daily mean discharges at the short-term stations and at one or more nearby stations that are hydrologically similar and with discharge records through the sampling period (long-term stations). The final regression discharge estimates were made by use of the Maintenance of Variance Extension Type 1 (MOVE.1), as described by Hirsch (1982), in which a line of organic correlation (LOC) regression model was fit to the concurrent daily mean discharges (Insightful Corporation, 2005). The MOVE.1 method provides the estimated discharges with some of the variance characteristics of the observed discharge record. The MOVE.1 method is unlike ordinary-least-squares regression, which tends to “smooth” the estimated discharge and provides lower variance than in the original observed discharges. The MOVE.1 regression estimates were computed by use of log-transformed values of the concurrent nonzero daily mean discharges as

$$Q_s = M_s + (S_s / S_l) \times (Q_l - M_l), \quad (1)$$

where

Q_s is the estimated daily mean discharge at the short-term stations;

Q_l is the observed daily mean discharge at the long-term stations;

M_s and M_l are the mean of the daily mean discharges for the concurrent period at the short- and long-term stations, respectively; and

S_s and S_l are the standard deviations of the daily mean discharges for the concurrent period at the short- and long-term stations, respectively.

Some of the short-term stations had more than one long-term index station available to provide additional information for an improved discharge estimate. In these cases, an ordinary-least-squares multiple-linear regression (OLS) initially was developed to estimate the missing daily mean discharge from the concurrent daily mean discharges at two or three nearby, hydrologically similar, long-term index stations. The nonzero, log-transformed discharge values were used for the multiple-linear regression. These OLS regression estimates were then “post-processed” by use of a MOVE.1 LOC regression that related the OLS-regression-estimated discharges to the observed daily mean discharges at the short-term stations. The OLS-regression-estimated discharge record was used as the discharge record for the long-term index stations to fit the final LOC-regression model and for estimating discharge at the short-term stations.

Load-Estimation Methods

A load, also referred to as mass flux, is the transport (mass discharge) of a constituent past a given point in a specific time period. A load is determined by multiplying the concentration of the constituent by the stream discharge. Daily mean streamflow data and discrete water-quality samples collected over a minimum of 2 years (24 samples) are required when using regression methods for estimating loads.

Linear regression was used to evaluate relations between the selected water-quality constituents (dependent variables) and streamflow and time variables (independent variables). Loads were estimated using S-LOADEST, a software program based on the FORTRAN version developed by Runkel and others (2004). This program uses time-series streamflow data and constituent concentrations to calibrate a regression model that describes constituent loads in terms of various functions of streamflow and time (Runkel and others, 2004). Load estimations within S-LOADEST are based on three statistical estimation methods to measure uncertainty in the estimated loads. The first two methods, Adjusted Maximum Likelihood Estimation (AMLE) and Maximum Likelihood Estimation (MLE), are used when the residuals are normally distributed. The AMLE method is the method of choice when the data set contains censored data (David Lorenz, USGS, written commun., 2006). The AMLE and MLE methods give the same results when no censored data are present. The third method, Least Absolute Deviation (LAD), is used when the residuals are not normally distributed but cannot be used for censored datasets. A complete discussion of the theory and principles behind the calibration and estimation methods can be found in Runkel and others (2004).

The S-LOADEST program allows the user to choose between selecting the general form of the regression from several predefined models and letting the software automatically select the best-defined model on the basis of the Akaike Information Criterion (AIC) (Akaike, 1981). The predefined model with the lowest value for the AIC was then selected for use in load estimation. The AMLE method was used to estimate coefficients of the dependent variables in the best-fit regression model in LOADEST, because censored data were present in nearly all datasets. The AMLE method also corrects for transformation bias in the regression-model coefficients of the estimated logarithms of load (Cohn and others, 1992). There was evidence of nonnormality in the distribution of the residuals at many stations; however, those stations contained censored data, so the LAD method could not be used (appendixes 2 and 3). The Turnbull-Weiss likelihood ratio normality statistic (Turnbull and Weiss, 1978) was used to examine the validity of the normality assumption for the residuals. If the p-value from the Turnbull-Weiss statistic was less than 0.05, the residual plots were examined for homoscedasticity (having equal statistical variances) and normality (having an even distribution). For this study, the software was allowed to choose the best model. Table 6 provides a list of the regression models included in the S-LOADEST computations. In addition, the ratio of the standard error of prediction to the mean load standardized the model error, and provided a comparison among stations having large differences in load estimates.

Table 5. Estimates of daily mean discharge for ambient water-quality-sampling stations with no available discharge or incomplete discharge records.

[KDOW, Kentucky Division of Water; USGS, U.S. Geological Survey; —, no assigned USGS station number]

Map reference number (figure 1)	KDOW station number	KDOW station name	USGS stream-gaging station number	Area adjustment factor	USGS stream-gaging station number(s) used for estimating discharge	USGS stream-gaging station name(s) used for estimating discharge	Pearson correlation coefficient (s)
2	PRI003	Tug Fork at Freeburn	—		03213620	Tug Fork at Vulcan	0.99
					03213700	Tug Fork at Williamson, W. Va.	
4	PRI064	Levisa Fork near Louisa	03212545	1.08	03212500	Levisa Fork at Paintsville	0.99
7	PRI048	Tygarts Creek at Load	—		03217000	Tygarts Creek at Greenup	0.99
9	PRI063	Kinniconick Creek near Tannery	03237260	1.18	03237250	Kinniconick Creek near Tannery	0.99
					03237255	Kinniconick Creek below Trace Creek at Tannery	
10	PRI059	South Fork Licking River at Morgan	—	1.35	03252500	South Fork Licking River at Cynthiana	0.94
					03252300	Hinkston Creek near Carlisle	
					03253500	Licking River at Catawba	
11	PRI060	North Fork Licking near Milford	03251400	1.26	03251200	North Fork Licking near Mt. Olivet	0.99
13	PRI062	Licking River at West Liberty	03248620		03248500	Licking River near Salyersville	.79–.81
					03283500	Red River at Clay City	
15	PRI111	Licking River at Butler	03254000		03253500	Licking River at Catawba	0.99
23	PRI058	Kentucky River near Trapp	03282300		03284000	Kentucky River at Lock 10 near Winchester	.78–.99
					03283500	Red River at Clay City	
28	PRI104	Middle Fork Kentucky River at Dry Hill	—	1.23	03280600	Middle Fork Kentucky River near Hyden	0.94
					03280700	Cutshin Creek at Wooton	

Table 5. Estimates of daily mean discharge for ambient water-quality-sampling stations with no available discharge or incomplete discharge records—Continued.

[KDOW, Kentucky Division of Water; USGS, U.S. Geological Survey; —, no assigned USGS station number]

Map reference number (figure 1)	KDOW station number	KDOW station name	USGS stream-gaging station number	Area adjustment factor	USGS stream-gaging station number(s) used for estimating discharge	USGS stream-gaging station name(s) used for estimating discharge	Pearson correlation coefficient (s)
32	PRI057	Rolling Fork near Lebanon Junction	03301630	1.06	03310500	Rolling Fork near Boston	0.99
35	PRI007	Cumberland River near Burkeville	03414110	1.04	03414000	Cumberland River near Rowena	0.99
					03413500	Lake Cumberland/Wolf Creek Dam outflow	
37	PRI009	Cumberland River at Cumberland Falls	03404500		03404000	Cumberland River at Williamsburg	0.99
39	PRI051	Horse Lick Creek near Lamero	03405842		03404900	Lynn Camp Creek at Corbin	0.99
44	PRI012	Pond River near Sacramento	03321060		03320500	Pond River at Apex (discharge and stage)	.93–.95
					03383000	Tradewater River at Olney	
45	PRI014	Rough River near Dundee	03319000		03318005	Rough River Dam outflows	.91–.95
					03319600	Rough River at Hartford	
					03320500	Pond River at Apex	
					03310300	Nolin River at White Mills	
					03383000	Tradewater River at Olney	
50	PRI056	Mud River near Gus	—		03320500	Pond River at Apex (discharge and stage)	.91–.92
					03316275	Mud River near Huntsville	
					03383000	Tradewater River at Olney	
51	PRI072	Barren River at Woodbury	—	1.22	03314500	Barren River at Bowling Green	.73–.93
						Barren River Lake outflows	
					03313700	West Fork Drakes Creek near Franklin	
53	PRI103	Green River near Woodbury	03315500		03316500	Green River at Paradise	0.98

Table 6. S-LOADEST predefined regression models.

[ln, natural logarithm; Q, centered streamflow, in cubic feet per second; sin, sine; cos, cosine; π, pi; dtime, centered decimal time]

Model number	Regression model
1	$av_0 + a_1 \ln Q$
2	$a_0 + a_1 \ln Q + a_2 \ln Q^2$
3	$a_0 + a_1 \ln Q + a_2 dtime$
4	$a_0 + a_1 \ln Q + a_2 \sin(2\pi dtime) + a_3 \cos(2\pi dtime)$
5	$a_0 + a_1 \ln Q + a_2 \ln Q^2 + a_3 dtime$
6	$a_0 + a_1 \ln Q + a_2 \ln Q^2 + a_3 \sin(2\pi dtime) + a_4 \cos(2\pi dtime)$
7	$a_0 + a_1 \ln Q + a_2 \sin(2\pi dtime) + a_3 \cos(2\pi dtime) + a_4 dtime$
8	$a_0 + a_1 \ln Q + a_2 \ln Q^2 + a_3 \sin(2\pi dtime) + a_4 \cos(2\pi dtime) + a_5 dtime$
9	$a_0 + a_1 \ln Q + a_2 \ln Q^2 + a_3 \sin(2\pi dtime) + a_4 \cos(2\pi dtime) + a_5 dtime + a_6 dtime^2$

Concentrations, and Estimated Loads and Yields of Nutrients

Concentrations of TN and TP in Kentucky from 1979 through 2004 are described in terms of mean concentrations and mean annual loads and yields for the period of record. Loads of TN and TP were estimated for all stations using the S-LOADEST program. This program computes mean constituent loads in rivers using regression models (Runkel and others, 2004).

Discussions on the USEPA numeric nutrient criteria relevant to this study are limited to TN and TP. The USEPA established recommended water-quality criteria for TN and TP on the basis of the upper 25th percentile of concentration data from reference sites aggregated by ecoregion. Reference sites represent conditions of pristine or minimally impaired waters in each ecoregion. The standards for TN and TP are based on data sets from Legacy STORET, National Stream Quality Accounting Network (NASQAN), National Water-Quality Assessment (NAWQA), Auburn University, and USEPA Regions 3 and 5 from 1990 through 1999 (U.S. Environmental Protection Agency, 1998). Two Aggregated Level III ecoregions are located in Kentucky as defined by the USEPA for the National Nutrient Strategy. These include the Aggregated Ecoregion IX (Southeastern Temperate Forested Plains and Hills) and the Aggregated Ecoregion XI (Central and Eastern Forested Uplands) (U.S. Environmental Protection Agency, 2000a,b) (fig 5). For Aggregated Ecoregion XI (eastern Kentucky), the USEPA numeric nutrient criteria are 0.31 mg/L for concentrations of TN and 0.01 mg/L for concentrations of TP in rivers and streams (table 7). The corresponding numeric nutrient criteria for Aggregated Ecoregion IX (central and western Kentucky) for the concentration of TN is 0.69 mg/L and for the concentration of TP is 0.037 mg/L for rivers and streams (table 7).

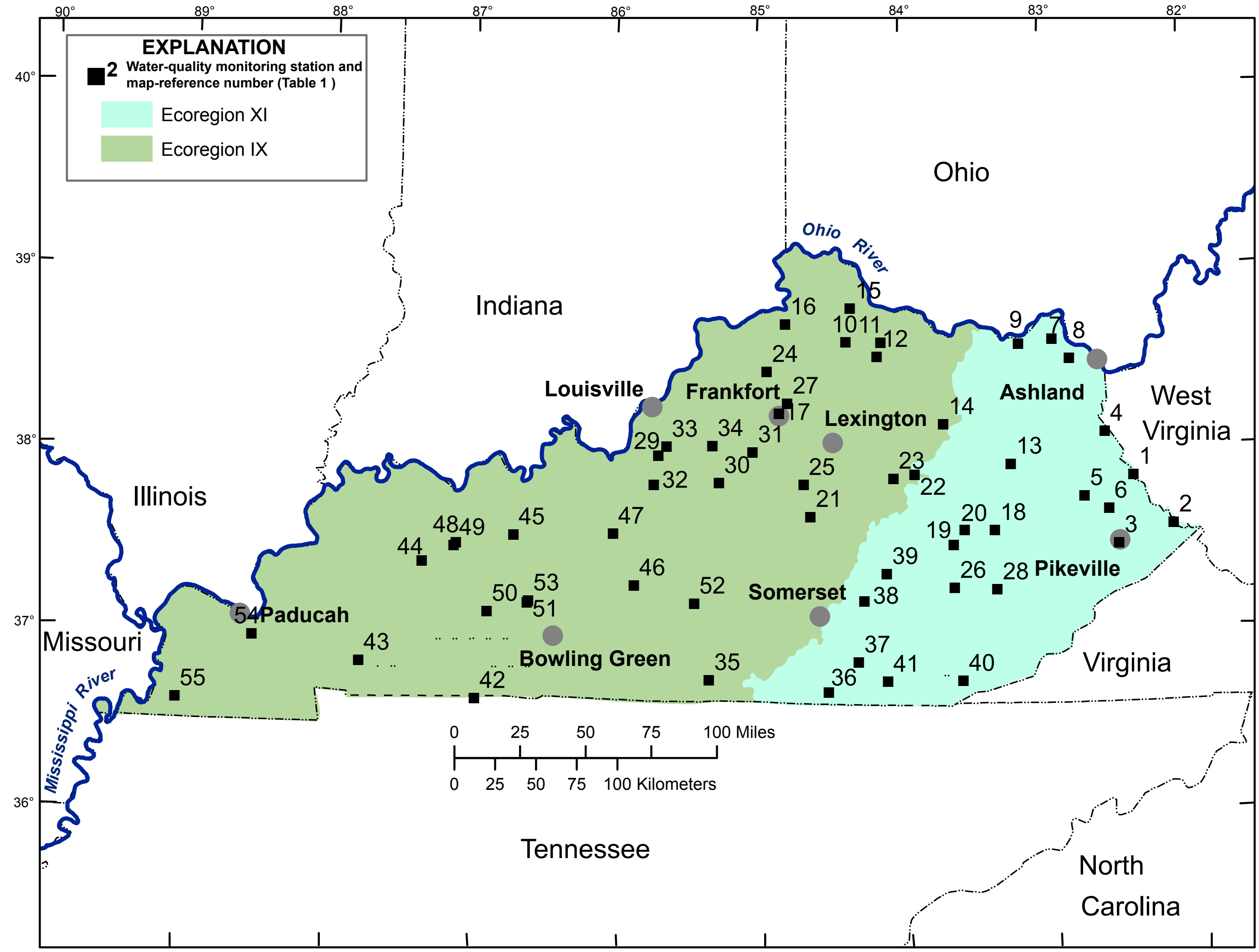
Concentrations

Summary statistics for the concentrations of TN and TP for 55 selected ambient water-quality network stations in Kentucky are shown in table 8 and table 9, respectively. These data provide the basis for analysis of concentrations and estimation of mean annual loads and yields at the selected stations. To provide an approximate measure of TN concentrations, the concentrations of NO_2+NO_3-N and total Kjeldahl nitrogen as nitrogen (TKN-N) (ammonia plus organic nitrogen) were summed.

Total Nitrogen

Concentrations of TN ranged from 0.05 mg/L to 15 mg/L and were highest in basins with the most intensive agricultural land use (fig. 6, table 8). The highest median concentration of TN (4.6 mg/L) was measured at the Red River near Keysburg station (map number 42); the lowest median concentration of total nitrogen (0.31 mg/L) was measured at the Clear Fork near Williamsburg station (map number 41).

Seven stations were categorized as having agriculture drainage basins, in which agriculture covers greater than 50 percent of the basin land area and less than 5 percent developed (urban). Stations with drainage basins categorized as undeveloped represented 23 of the 55 drainage basins, with undeveloped land covering from 66 to 82 percent of the basin



Base from U.S. Geological Survey digital data, 2002, 1:2,000,000
Lambert Conformal Conic projection
Standard parallels 37.083°N and 38.667°N, central meridian 85.75°W

Figure 5. U.S. Environmental Protection Agency Ecoregions IX (Temperate Forested Plains and Hills) and XI (Central and Eastern Forested Uplands), and locations of water-quality stations in the statewide ambient water-quality monitoring network selected for load analysis, Kentucky, 1979–2004.

land area. Stations within undeveloped drainage basins had less than 5 percent urban land use/land cover and less than 25 percent agricultural land use/land cover. Twenty-five stations had drainage basins that were categorized as having mixed land use/land cover (combinations of urban, agricultural, and undeveloped [forested]) land. Comparisons using the Wilcoxon rank-sum test showed the agricultural land-use/land-cover stations had a higher average median concentration of TN (2.3 mg/L) than the mixed (1.4 mg/L) (p-value < 0.001) or the undeveloped land-use/land-cover (0.57 mg/L) (p-value < 0.001) stations. Median concentrations of TN ranged from 0.93 mg/L to 4.6 mg/L at stations in the agricultural land-use/land-cover basins; 1.1 mg/L to 3.8 mg/L at stations in the mixed land-use/land-cover basins; and 0.31 mg/L to 1.3 mg/L at stations in the undeveloped land-use/land-cover basins.

The intrabasin comparisons for concentrations of TN show the Lower Cumberland basin had a higher median concentration of TN (4.0 mg/L) when compared to the other basins (fig. 7 and fig. 8). A possible explanation is that agriculture has been a predominant land use in a basin that is characterized by karst topography, making the Lower Cumberland basin potentially vulnerable to applications of fertilizers. Significant differences (Wilcoxon rank-sum, p-value = < 0.001) in median concentrations of TN occurred among basins in intensely developed karst topography (Lower Cumberland, Lower Ohio-Salt, and the Green), but not in basins with limited or no karst topography. Pair-wise comparisons showed median concentrations of TN in karst topography basins (median concentration: 1.5 mg/L as N) were higher than in basins with limited or no karst topography (median concentration: 0.63 mg/L as N). The lowest median concentration of

TN (0.52 mg/L) was in the Upper Cumberland basin. Unlike the Lower Cumberland basin, the Upper Cumberland basin is mainly forested. This type of land cover can potentially act as a buffer to nutrient runoff.

The USEPA-established recommended water-quality criteria for TN were compared to the 25th-percentile median values from this study for Aggregated Ecoregions IX and XI (figs. 9–10, table 7). The 25th-percentile median values for Aggregated Ecoregion IX and XI for TN were 0.89 mg/L and 0.51 mg/L, respectively. These concentrations of TN exceeded the USEPA concentrations for both aggregated ecoregions. The 25th-percentile median values for TN in the agricultural and mixed land-use/land-cover basins exceeded the USEPA's recommendations for TN in both aggregated ecoregions (table 7). The 25th-percentile median values of TN in Aggregated Ecoregion XI also exceeded the USEPA concentration for TN in the undeveloped land-use/land-cover basins, but not in the undeveloped land-use/land-cover basins in Aggregated Ecoregion IX (table 7).

Table 7. The 25th percentile values for the median concentrations of total nitrogen and total phosphorus measured in U.S. Environmental Protection Agency Ecoregions IX (Southeastern Temperate Forested Plains and Hills) and XI (Central and Eastern Forested Uplands) compared to the 25th median percentile values measured at the select ambient water-quality network stations located in the land-use/land-cover classifications of agriculture, mixed, and undeveloped (forested).

[USEPA, U.S. Environmental Protection Agency; mg/L, milligrams per liter; N, nitrogen; —, not available; P, phosphorus]

Land-use/land-cover classification	Number of stations	Total nitrogen, in mg/L as N		Total phosphorus, in mg/L as P	
		Ecoregion IX	Ecoregion XI	Ecoregion IX	Ecoregion XI
Agriculture	7	1.6	—	0.12	—
Mixed	25	1.1	0.73	.04	0.01
Undeveloped (forested)	23	.45	.45	.02	.01
All land-use/land-cover classifications listed above	55	.89	.51	.04	.01
USEPA criteria[1]	—	.69	.31	.037	.01

[1]U.S. Environmental Protection Agency, 2000a,b.

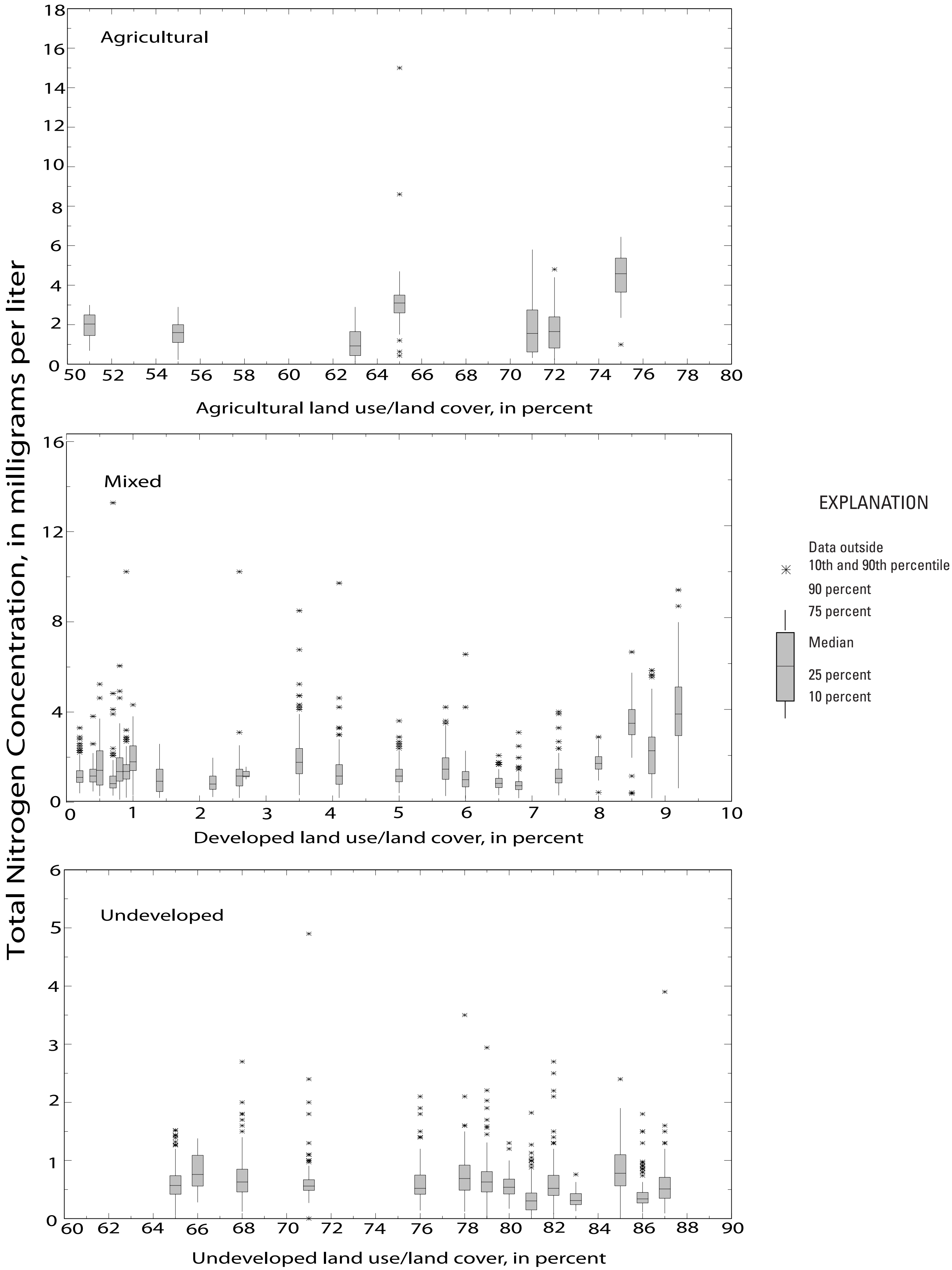


Figure 6. Distribution of concentrations of total nitrogen in the land-use/land-cover classifications of agriculture, mixed, and undeveloped at selected ambient water-quality monitoring stations in Kentucky, 1979–2004.

Table 8. Summary statistics of streamflow and concentrations of total nitrogen for selected ambient water-quality monitoring stations in Kentucky and station information, 1979–2004.

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; USGS, U.S. Geological Survey; KDOW, Kentucky Division of Water; Min, minimum; Max, maximum; A, agriculture; M, mixed; U, undeveloped; MOR, Middle Ohio-Raccoon; MOLM, Middle Ohio-Little Miami; LOS, Lower Ohio-Salt; UC, Upper Cumberland; LC, Lower Cumberland; LT, Lower Tennessee; Aggregated ecoregion XI, Central and Eastern Forested Uplands; Aggregated ecoregion IX, Southeastern Temperate Forested Plains and Hills]

Map reference number (figure 1)	USGS station number	KDOW station number	Period of record	Mean	Min.	Percentile values 25th	Median	75th	Max.	Number of water-quality observations	Mean	Min.	Percentile values 25th	Median	75th	Max.	Land-use/ land-cover classification[1]	Major drainage basin	Aggregated ecoregion
				Streamflow, in ft^3/s							Total nitrogen, in mg/L								
1	03214500	PRI002	1985-2004	1,270	89	332	794	1,620	8,210	168	0.86	0.19	0.60	0.79	1.1	2.4	U	Big Sandy	XI
2	03213700	PRI003	1998-2004	744	48	206	491	945	4,180	41	.53	.14	.29	.45	0.69	1.4	U	Big Sandy	XI
3	03209500	PRI006	1979-2004	7,310	193	1,680	4,230	9,330	59,000	251	.65	.13	.46	.62	.79	2.9	U	Big Sandy	XI
4	03215000	PRI064	1991-2004	2,720	303	676	1,240	3,020	19,500	96	.71	.27	.54	.68	.83	1.9	U	Big Sandy	XI
5	03212500	PRI094	1998-2004	1,540	225	544	882	2,240	7,960	37	.61	.26	.41	.59	.78	.98	U	Big Sandy	XI
6	03210000	PRI096	1998-2004	156	10	36	75	185	1,400	42	.89	.12	.52	.85	1.0	3.5	U	Big Sandy	XI
7	03217000	PRI048	1985-2004	1,260	0.49	85	447	1,310	22,100	181	.71	.12	.46	.63	.85	2.7	U	MOR	XI
8	03216500	PRI049	1985-2004	762	39	72	212	815	6,930	161	.84	.27	.60	.78	1.0	2.0	M	MOR	XI
9	03237250	PRI063	1991-2004	305	.06	21	95	278	3,020	101	.63	.10	.35	.53	.84	2.2	U	MOLM	XI
10	03252500	PRI059	1991-2004	997	2	35	301	1,320	10,800	128	1.7	.22	.82	1.7	2.4	4.8	A	Licking	IX
11	03251400	PRI060	1991-2004	312	.01	5	82	280	4,430	115	1.5	.23	.71	1.4	2.2	5.1	M	Licking	IX
12	03249500	PRI061	1991-2004	1,100	41	168	337	1,860	4,840	122	.83	.19	.53	.75	1.1	1.9	M	Licking	IX
13	03248640	PRI062	1992-2004	365	9.3	48	189	469	2,000	113	.60	.09	.35	.51	.71	3.9	U	Licking	XI
14	03250190	PRI093	1998-2004	276	2.2	29	101	340	2,010	47	1.3	.15	.74	1.1	1.4	10	M	Licking	IX
15	03253500	PRI111	1999-2004	2,740	55	241	1,040	4,130	17,500	44	.97	.15	.43	.88	1.4	2.5	M	Licking	IX
16	03291500	PRI022	1983-2004	532	.01	22	149	433	6,390	143	1.0	.12	.63	.94	1.3	6.4	M	Kentucky	IX
17	03287500	PRI024	1983-2004	6,960	137	1,200	3,260	9,020	79,900	207	1.1	.26	.80	1.0	1.4	3.9	M	Kentucky	IX
18	03280000	PRI031	1984-2004	1,260	35	257	650	1,510	16,000	183	.73	.14	.52	.68	.86	3.0	M	Kentucky	XI
19	03281000	PRI032	1995-2004	766	9.5	110	316	847	4,690	176	.45	.11	.32	.41	.50	1.8	U	Kentucky	XI
20	03281500	PRI033	1984-2004	910	5.1	127	396	961	11,300	193	.47	.05	.31	.42	.62	1.8	U	Kentucky	XI
21	03285000	PRI045	1985-2004	487	.01	30	124	456	14,700	169	1.5	.23	.96	1.4	1.9	4.1	M	Kentucky	IX
22	03283500	PRI046	1995-2004	477	12	49	181	517	15,400	153	.62	.14	.42	.52	.75	2.1	U	Kentucky	IX
23	03282300	PRI058	1991-2004	4,520	99	910	2,520	5,750	32,500	112	.53	.17	.43	.54	.68	1.3	U	Kentucky	IX
24	03290500	PRI066	1996-2004	7,900	165	1,490	4,000	10,600	64,300	73	1.2	.36	1.0	1.2	1.4	2.5	M	Kentucky	IX
25	03286500	PRI067	1997-2004	6,400	220	900	2,580	8,000	57,500	47	.80	.28	.57	.76	1.1	1.4	U	Kentucky	IX

Table 8. Summary statistics of streamflow and concentrations of total nitrogen for selected ambient water-quality monitoring stations in Kentucky and station information, 1979–2004—Continued.

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; USGS, U.S. Geological Survey; KDOW, Kentucky Division of Water; Min, minimum; Max, maximum; A, agriculture; M, mixed; U, undeveloped; MOR, Middle Ohio-Raccoon; MOLM, Middle Ohio-Little Miami; LOS, Lower Ohio-Salt; UC, Upper Cumberland; LC, Lower Cumberland; LT, Lower Tennessee; Aggregated ecoregion XI, Central and Eastern Forested Uplands; Aggregated ecoregion IX, Southeastern Temperate Forested Plains and Hills]

Map reference number (figure 1)	USGS station number	KDOW station number	Period of record	Mean	Min.	Percentile values 25th	Percentile values Median	Percentile values 75th	Max.	Number of water-quality observations	Mean	Min.	Percentile values 25th	Percentile values Median	Percentile values 75th	Max.	Land-use/ land-cover classification[1]	Major drainage basin	Aggregated ecoregion
				Streamflow, in ft^3/s							Total nitrogen, in mg/L								
26	03281100	PRI092	1998-2004	187	62	67	120	260	892	34	.56	.08	.36	.51	.71	1.1	U	Kentucky	XI
27	03289500	PRI098	1998-2004	520	31	108	297	644	2,500	49	4.0	.57	2.9	3.8	5.0	9.2	M	Kentucky	IX
28	03280600	PRI104	1999-2004	423	6	46	124	465	3,130	30	.40	.08	.32	.38	.45	.69	U	Kentucky	XI
29	03298500	PRI029	1980-2004	1,640	15	124	497	2,250	27,400	251	1.9	.27	1.2	1.7	2.3	8.3	M	LOS	IX
30	03300400	PRI041	1984-2004	611	.01	27	155	441	27,200	199	1.3	.15	.74	1.1	1.6	9.5	M	LOS	IX
31	03295400	PRI052	1989-2004	302	.32	21	100	325	4,540	159	2.2	.14	1.2	2.2	2.8	5.7	M	LOS	IX
32	03301500	PRI057	1991-2004	1,800	8	144	650	2,140	16,700	123	1.5	.38	.91	1.3	1.8	5.9	M	LOS	IX
33	03298470	PRI100	2001-2004	590	10	53	145	382	7,980	28	1.7	.39	1.4	1.7	1.9	2.8	M	LOS	IX
34	03295890	PRI105	1998-2004	711	21	107	271	766	6,190	40	1.8	.32	.62	1.6	2.7	5.8	A	LOS	IX
35	03414110	PRI007	1980-2004	10,000	888	4,930	7,760	13,300	36,700	211	.63	.27	.49	.56	.67	4.9	U	UC	IX
36	03410500	PRI008	1979-2004	1,600	33	192	741	1,870	41,200	123	1.4	.38	.91	1.3	1.8	5.9	U	UC	XI
37	03404500	PRI009	1979-2004	3,170	105	534	1,560	3,400	40,400	246	.61	.14	.41	.52	.75	2.7	U	UC	XI
38	03406500	PRI010	1979-2004	1,060	4.5	80	370	1,150	14,900	253	.60	.05	.42	.57	.74	1.5	U	UC	XI
39	03405842	PRI051	1985-2004	61	.60	13	33	74	795	183	.41	.06	.22	.31	.42	1.8	U	UC	XI
40	03402900	PRI086	1999-2004	972	84	190	502	1,270	4,960	35	.54	.17	.32	.43	.69	1.5	U	UC	IX
41	03403910	PRI087	1998-2004	267	5.4	59	172	377	1,400	33	.35	.13	.24	.31	.43	.76	U	UC	IX
42	03435100	PRI069	1999-2004	658	47	143	402	760	4,050	38	4.4	1.0	3.7	4.6	5.4	6.5	A	LC	XI
43	03438000	PRI043	1985-2004	359	12	55	142	386	4,590	159	3.4	.33	2.9	3.4	4.0	6.5	M	LC	XI
44	03321060	PRI012	1991-2004	485	.15	29	145	553	5,120	98	1.1	.25	.58	.77	1.1	13	M	Green	IX
45	03319000	PRI014	1980-2004	1,180	34	150	500	1,620	19,100	231	1.2	.40	.89	1.1	1.4	3.3	M	Green	IX
46	03308500	PRI018	1983-2004	2,710	172	508	1,270	4,180	18,700	212	1.2	.36	.85	1.1	1.4	3.5	M	Green	IX
47	03310300	PRI021	1980-2004	477	38	97	250	578	4,550	221	3.1	.43	2.6	3.1	3.5	15	A	Green	IX
48	03319880	PRI054	1998-2004	1,580	48	180	469	2,200	8,590	49	1.2	.43	.84	1.1	1.4	3.7	M	Green	IX
49	03316500	PRI055	1991-2004	8,590	279	2,140	5,170	12,600	45,000	118	1.5	.49	1.2	1.4	1.8	10	M	Green	IX
50	03316275	PRI056	1991-2004	444	3.9	38	153	420	5,320	126	1.2	.16	.84	1.1	1.4	2.7	M	Green	IX

Table 8. Summary statistics of streamflow and concentrations of total nitrogen for selected ambient water-quality monitoring stations in Kentucky and station information, 1979–2004—Continued.

[ft³/s, cubic feet per second; mg/L, milligrams per liter; USGS, U.S. Geological Survey; KDOW, Kentucky Division of Water; Min, minimum; Max, maximum; A, agriculture; M, mixed; U, undeveloped; MOR, Middle Ohio-Raccoon; MOLM, Middle Ohio-Little Miami; LOS, Lower Ohio-Salt; UC, Upper Cumberland; LC, Lower Cumberland; LT, Lower Tennessee; Aggregated ecoregion XI, Central and Eastern Forested Uplands; Aggregated ecoregion IX, Southeastern Temperate Forested Plains and Hills]

Map reference number (figure 1)	USGS station number	KDOW station number	Period of record	Mean	Min.	Percentile values			Max.	Number of water-quality observations	Mean	Min.	Percentile values			Max.	Land-use/ land-cover classification[1]	Major drainage basin	Aggregated ecoregion
						25th	Median	75th					25th	Median	75th				
				Streamflow,in ft³/s							Total nitrogen, in mg/L								
51	03314500	PRI072	1998-2004	2,790	147	564	1,390	4,130	11,500	44	1.9	.68	1.5	2.0	2.5	3.0	A	Green	IX
52	03307000	PRI077	1998-2004	306	6	52	138	385	1,950	45	1.4	.07	.78	1.3	2.0	4.5	M	Green	IX
53	03315500	PRI103	1998-2004	1,530	632	778	1,280	1,940	4,550	43	1.9	.27	1.4	1.7	2.4	4.2	M	Green	IX
54	03610200	PRI106	2000-2004	316	15	33	105	238	3,250	32	1.5	.22	1.1	1.6	2.0	2.9	A	LT	IX
55	07024000	PRI109	2000-2004	344	42	62	71	117	5,520	32		.11	.45	.93	1.6	2.9	A	Hatchie-Obion	IX

[1]Land-use/land-cover classifications

Agricultural	Greater than 50 percent agricultural land and less than or equal to 5 percent urban.
Urban	Greater than 25 percent urban and less than or equal to 25 percent agricultural land
Undeveloped	Less than or equal to 5 percent urban land and less than or equal to 25 percent agricultural land.
Mixed	All other combinations of urban, agricultural, and forested land.

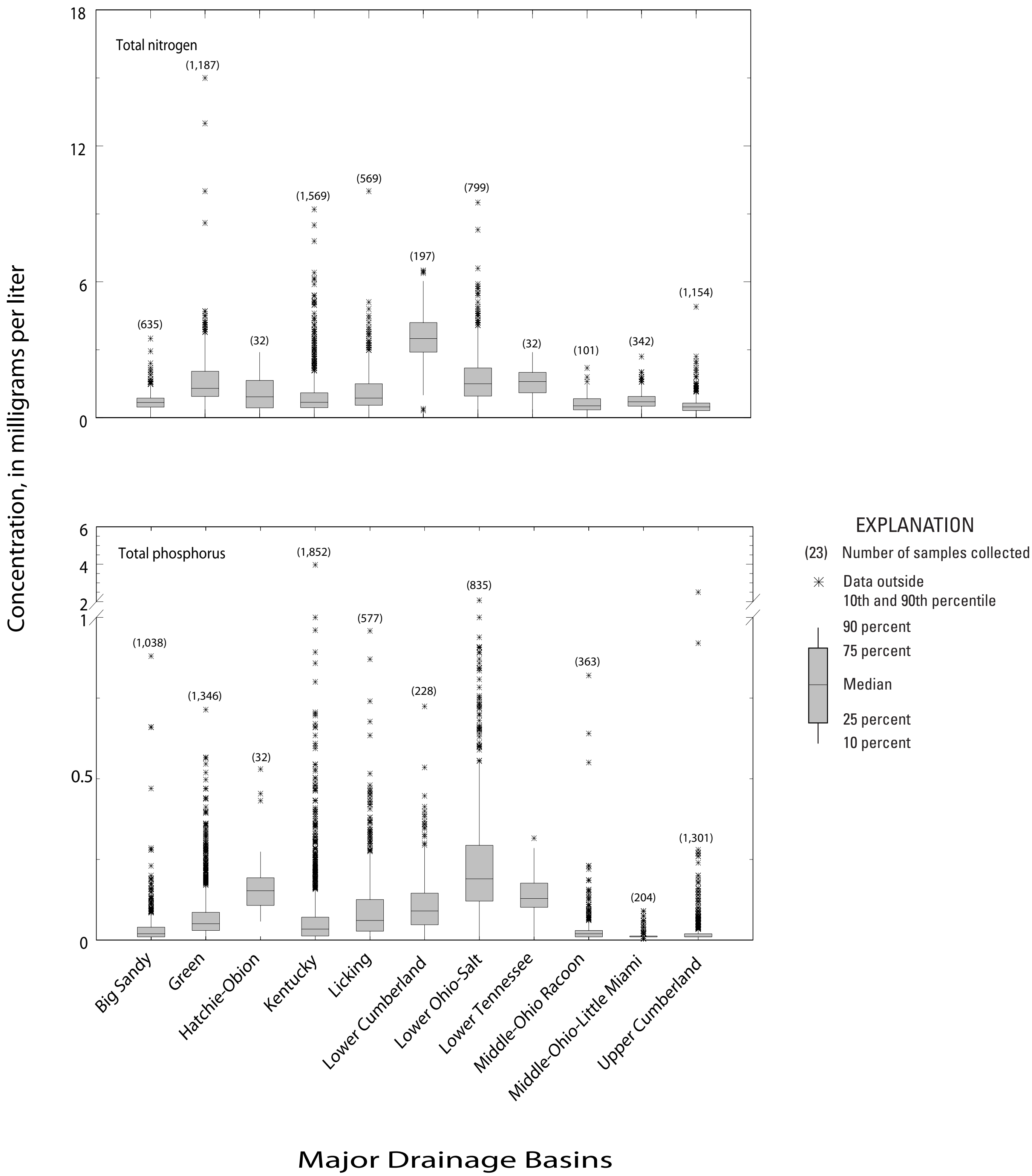


Figure 7. Distribution of concentrations of total nitrogen and total phosphorus at selected ambient water-quality monitoring stations in the major drainage basins in Kentucky, 1979–2004.

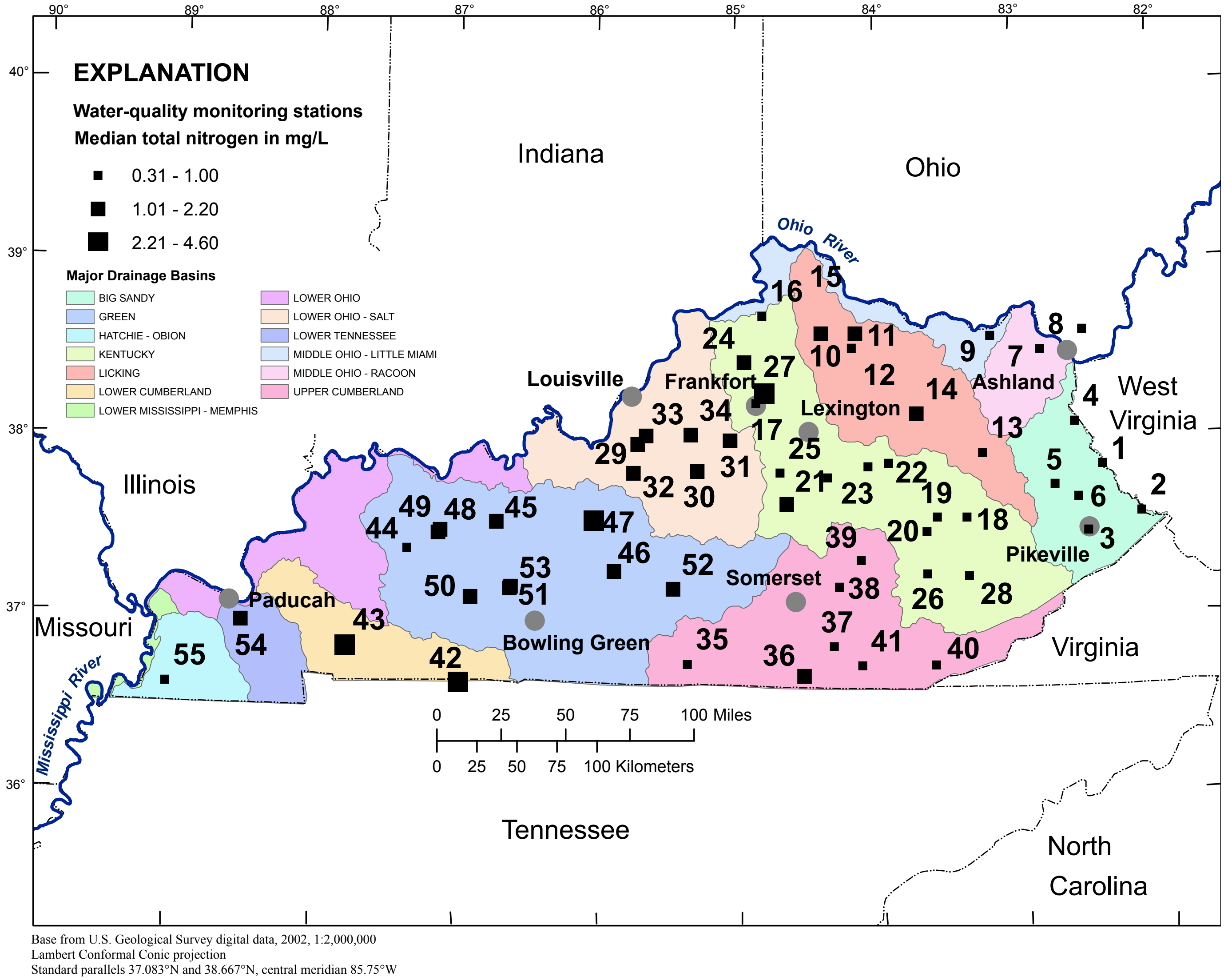


Figure 8. Spatial patterns of the 25th percentile median concentrations of total nitrogen at selected ambient water-quality monitoring stations in the major drainage basins in Kentucky, 1979–2004.

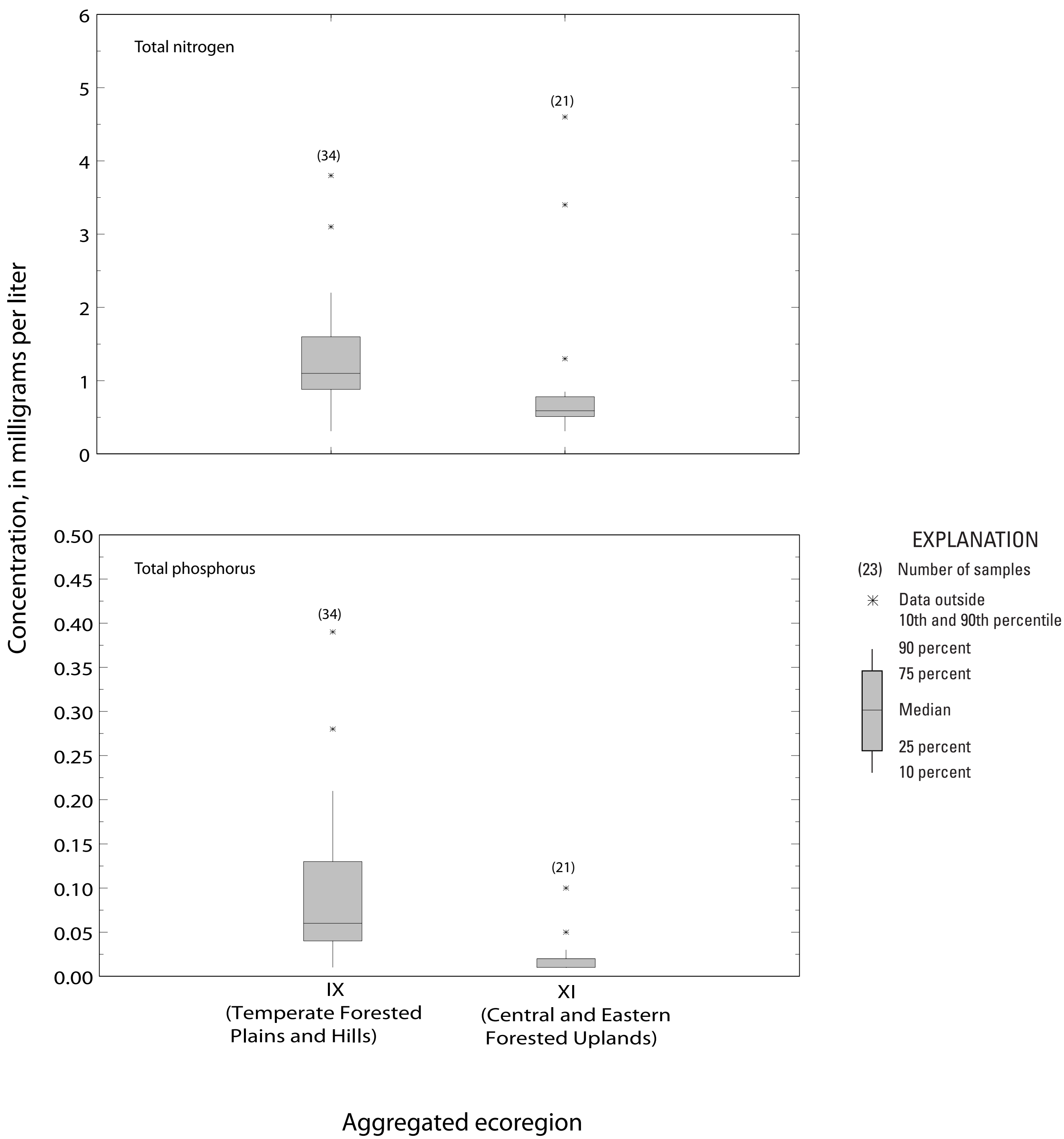
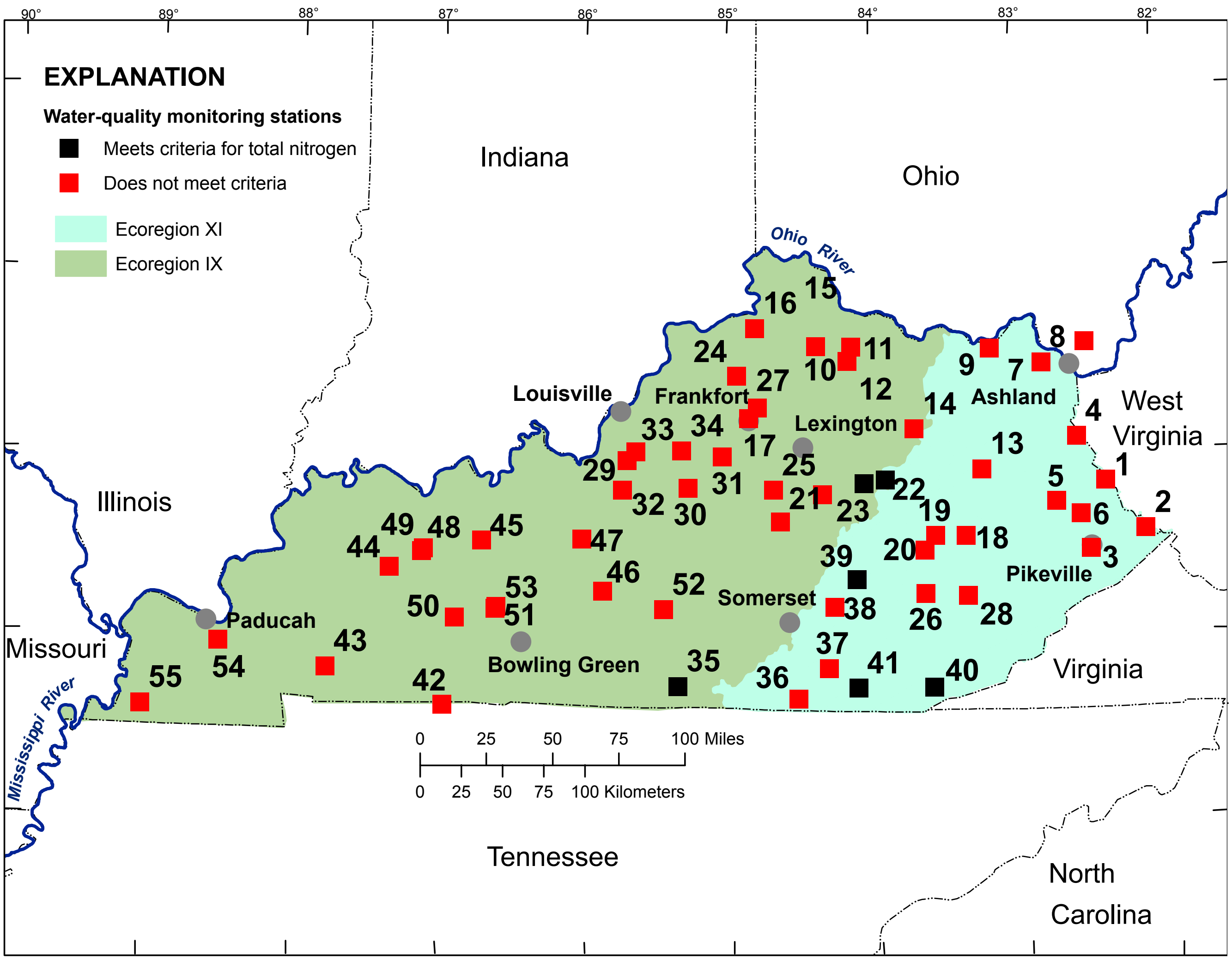


Figure 9. Distribution of median concentrations of total nitrogen and total phosphorus at selected ambient water-quality monitoring stations in U.S. Environmental Protection Agency Ecoregions IX (Temperate Forested Plains and Hills) and XI (Central and Eastern Forested Uplands) in Kentucky.



Base from U.S. Geological Survey digital data, 2002, 1:2,000,000
Lambert Conformal Conic projection
Standard parallels 37.083°N and 38.667°N, central meridian 85.75°W

Figure 10. Median concentrations of total nitrogen that exceed the total nitrogen criteria in U.S. Environmental Protection Agency Ecoregions IX (Temperate Forested Plains and Hills) and XI (Central and Eastern Forested Uplands) at selected ambient water-quality monitoring stations in Kentucky.

Total Phosphorus

Concentrations of TP ranged from less than 0.01 mg/L to 4.0 mg/L and were highest at stations in basins with the most agriculture (fig. 11 and table 9). The Elkhorn Creek at Peaks Mill station (map number 27) had the highest measured concentration of TP (4.0 mg/L), and the highest median concentration of TP (0.39 mg/L) (table 9). The lowest median concentration of TP (0.01 mg/L) was observed at 13 of the 55 stations (table 9).

The 7 stations with drainage basins categorized as agriculture had a higher average median concentration of TP (0.13 mg/L) than the 25 mixed land-use/land-cover basin stations (0.06 mg/L) (fig. 11). Comparisons using the Wilcoxon rank-sum test showed the agricultural land-use/land-cover stations had a higher average median concentration of TP (0.12 mg/L) than the mixed (0.09 mg/L) (p-value < 0.001) or the undeveloped land-use/land-cover (0.02 mg/L) (p-value < 0.001) stations. The average median concentration of TP for the agricultural land-use/land-cover stations was more than 7.5 times higher than the undeveloped land-use/land-cover stations (0.01 mg/L). Median concentrations of TP ranged from 0.05 mg/L to 0.21 mg/L at stations in the agricultural land-use/land-cover basins; 0.02 mg/L to 0.39 mg/L at stations in the mixed land-use/land-cover basins; and 0.01 mg/L to 0.05 mg/L at stations in the undeveloped land-use/land-cover basins (table 9).

The Lower Ohio-Salt basin had the highest average median concentration of TP (0.17 mg/L) followed by the Hatchie-Obion (0.15 mg/L), the Lower Tennessee (0.13 mg/L), the Lower Cumberland (0.07 mg/L), the Licking (0.06 mg/L), and the Green (0.04 mg/L) basins (fig. 7

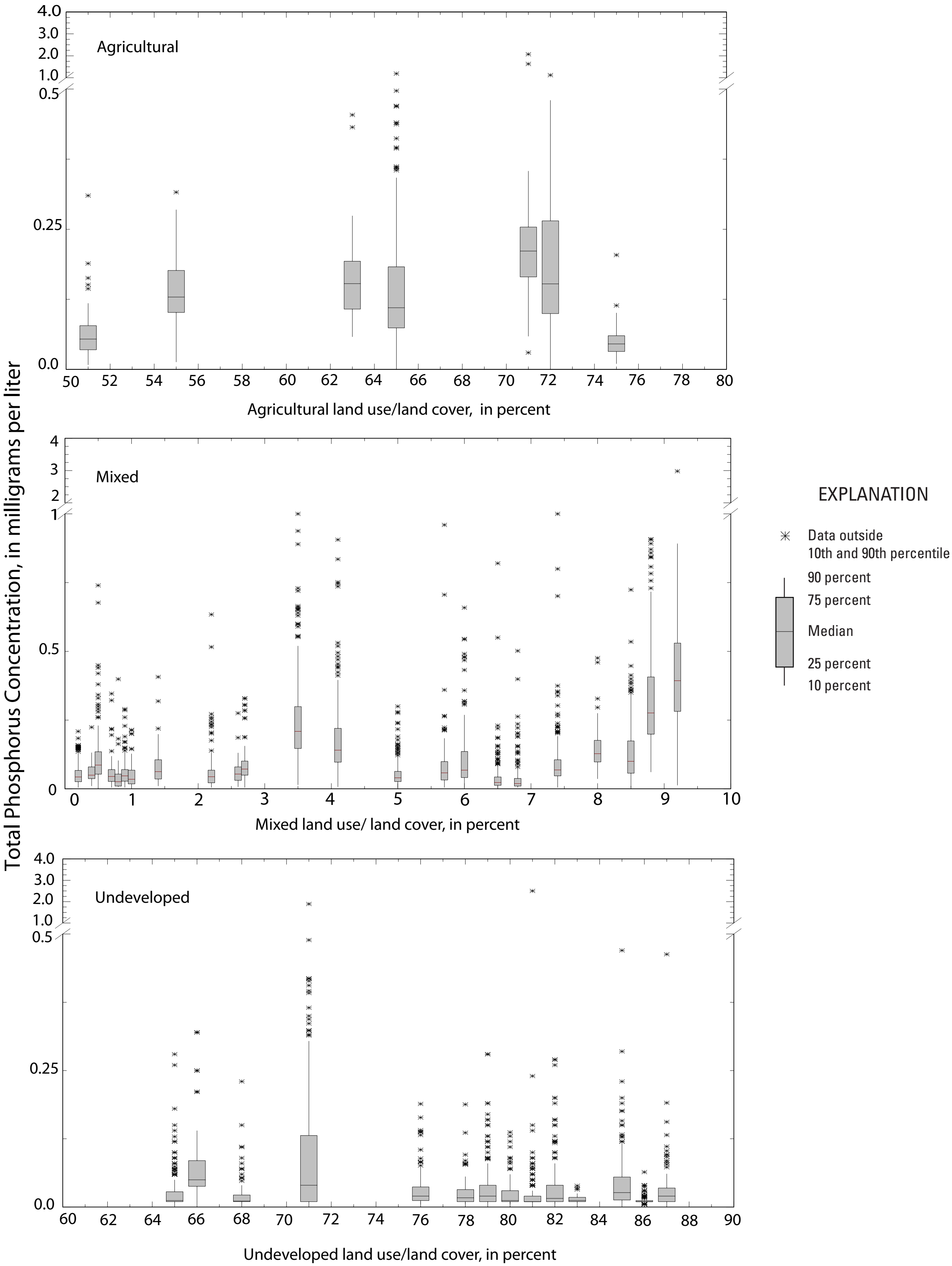


Figure 11. Distribution of concentrations of total phosphorus in the land-use/land-cover classifications of agriculture, mixed, and undeveloped at selected ambient water-quality monitoring stations in Kentucky, 1979–2004

Table 9. Summary statistics of streamflow and concentrations of total phosphorus for selected ambient water-quality monitoring stations in Kentucky and station information, 1979–2004.

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; KDOW, Kentucky Division of Water; Min, minimum; Max, maximum; A, agriculture; M, mixed; U, undeveloped; MOR, Middle Ohio-Racoon; MOLM, Middle Ohio-Little Miami; LOS, Lower Ohio-Salt; UC, Upper Cumberland; LC, Lower Cumberland; LT, Lower Tennessee; HO, Hatchie-Obion; Aggregated ecoregion XI, Central and Eastern Forested Uplands; Aggregated ecoregion IX, Southeastern Temperate Forested Plains and Hills]

Map reference number (figure 1)	USGS station number	KDOW station number	Period of record	Mean	Min.	Percentile values			Max.	Number of water-quality observations (censored values)	Mean	Min.	Percentile values			Max.	Land-use/ land-cover classification[1]	Major drainage basin	Aggregated ecoregion
						25th	Median	75th					25th	Median	75th				
				Streamflow, in ft^3/s							Total phosphorus, in mg/L								
1	03214500	PRI002	1985-2004	1,270	89	332	794	1,620	8,210	246(29)	0.05	<0.01	0.01	0.03	0.05	0.09	U	Big Sandy	XI
2	03213700	PRI003	1998-2004	744	48	206	491	945	4,180	44(11)	.02	<.01	<.01	.01	.03	.09	U	Big Sandy	XI
3	03209500	PRI006	1979-2004	7,310	193	1,680	4,230	9,330	59,000	246(52)	.10	<.01	.01	.02	.04	.66	U	Big Sandy	XI
4	03215000	PRI064	1991-2004	2,720	303	676	1,240	3,020	19,500	111(20)	.03	<.01	.01	.02	.04	.17	U	Big Sandy	XI
5	03212500	PRI094	1998-2004	1,540	225	544	882	2,240	7,960	42(2)	.03	<.01	.01	.02	.04	.08	U	Big Sandy	XI
6	03210000	PRI096	1998-2004	156	10	36	75	185	1,400	43(5)	.03	<.01	.01	.02	.02	.19	U	Big Sandy	XI
7	03217000	PRI048	1985-2004	1,260	0.49	85	447	1,310	22,100	179(47)	.03	<.01	.01	.01	.02	.64	U	MOR	XI
8	03216500	PRI049	1985-2004	762	39	72	212	815	6,930	184(6)	.04	<.01	.01	.02	.04	.82	M	MOR	XI
9	03237250	PRI063	1991-2004	305	.06	21	95	278	3,020	117(51)	.02	<.01	.01	.01	.01	.09	U	MOLM	XI
10	03252500	PRI059	1991-2004	997	2	35	301	1,320	10,800	128(1)	.20	<.01	.10	.15	.26	1.1	A	Licking	IX
11	03251400	PRI060	1991-2004	312	.01	5	82	280	4,430	126(4)	.13	<.01	.05	.09	.13	1.0	M	Licking	IX
12	03249500	PRI061	1991-2004	1,100	41	168	337	1,860	4,840	129(6)	.07	<.01	.02	.04	.07	.63	M	Licking	IX
13	03248640	PRI062	1992-2004	365	9.3	48	189	469	2,000	105(16)	.03	<.01	.01	.02	.04	.46	U	Licking	XI
14	03250190	PRI093	1998-2004	276	2.2	29	101	340	2,010	47(2)	.06	<.01	.03	.05	.08	.28	M	Licking	IX
15	03253500	PRI111	1999-2004	2,740	55	241	1,040	4,130	17,500	44(2)	.09	<0.01	.04	.06	.10	.41	M	Licking	IX
16	03291500	PRI022	1983-2004	532	.01	22	149	433	6,390	215(4)	.12	<.01	.04	.07	.14	1.0	M	Kentucky	IX
17	03287500	PRI024	1983-2004	6,960	137	1,200	3,260	9,020	79,900	229(4)	.10	<.01	.05	.07	.11	1.0	M	Kentucky	IX
18	03280000	PRI031	1984-2004	1,260	35	257	650	1,510	16,000	205(31)	.04	<.01	.01	.02	.04	.50	M	Kentucky	XI
19	03281000	PRI032	1995-2004	766	9.5	110	316	847	4,690	208(43)	.02	<.01	.01	.01	.02	.43	U	Kentucky	XI
20	03281500	PRI033	1984-2004	910	5.1	127	396	961	11,300	206(49)	.02	<.01	.01	.01	.02	.22	U	Kentucky	XI
21	03285000	PRI045	1985-2004	487	.01	30	124	456	14,700	185(4)	.08	<.01	.03	.06	.10	.96	M	Kentucky	IX
22	03283500	PRI046	1995-2004	477	12	49	181	517	15,400	64(11)	.03	<.01	.01	.02	.04	.19	U	Kentucky	IX
23	03282300	PRI058	1991-2004	4,520	99	910	2,520	5,750	32,500	129(27)	.02	<.01	.01	.01	.03	.14	U	Kentucky	IX
24	03290500	PRI066	1996-2004	7,900	165	1,490	4,000	10,600	64,300	73(3)	.10	<.01	.05	.07	.10	1.1	M	Kentucky	IX

Table 9. Summary statistics of streamflow and concentrations of total phosphorus for selected ambient water-quality monitoring stations in Kentucky and station information, 1979–2004—Continued.

[ft³/s, cubic feet per second; mg/L, milligrams per liter; KDOW, Kentucky Division of Water; Min, minimum; Max, maximum; A, agriculture; M, mixed; U, undeveloped; MOR, Middle Ohio-Racoon; MOLM, Middle Ohio-Little Miami; LOS, Lower Ohio-Salt; UC, Upper Cumberland; LC, Lower Cumberland; LT, Lower Tennessee; HO, Hatchie-Obion; Aggregated ecoregion XI, Central and Eastern Forested Uplands; Aggregated ecoregion IX, Southeastern Temperate Forested Plains and Hills]

Map reference number (figure 1)	USGS station number	KDOW station number	Period of record	Mean	Min.	Percentile values 25th	Median	75th	Max.	Number of water-quality observations (censored values)	Mean	Min.	Percentile values 25th	Median	75th	Max.	Land-use/ land-cover classification[1]	Major drainage basin	Aggregated ecoregion
				Streamflow, in ft³/s							Total phosphorus, in mg/L								
25	03286500	PRI067	1997-2004	6,400	220	900	2,580	8,000	57,500	50(3)	.07	<.01	.04	.05	.08	.32	U	Kentucky	IX
26	03281100	PRI092	1998-2004	187	62	67	120	260	892	36(10)	.03	<.01	.01	.02	.03	.12	U	Kentucky	XI
27	03289500	PRI098	1998-2004	520	31	108	297	644	2,500	42(0)	.49	.01	.28	.39	.53	4.0	M	Kentucky	IX
28	03280600	PRI104	1999-2004	423	6	46	124	465	3,130	32(4)	.02	<.01	<.01	.01	.02	.05	U	Kentucky	XI
29	03298500	PRI029	1980-2004	1,640	15	124	497	2,250	27,400	257(0)	.27	.01	.15	.21	.30	1.8	M	LOS	IX
30	03300400	PRI041	1984-2004	611	.01	27	155	441	27,200	211(0)	.20	.01	.10	.14	.22	1.6	M	LOS	IX
31	03295400	PRI052	1989-2004	302	.32	21	100	325	4,540	173(0)	.37	.01	.20	.28	.41	1.8	M	LOS	IX
32	03301500	PRI057	1991-2004	1,800	8	144	650	2,140	16,700	129(1)	.18	<.01	.08	.13	.23	1.9	M	LOS	IX
33	03298470	PRI100	2001-2004	590	10	53	145	382	7,980	28(0)	.19	.04	.10	.13	.17	1.1	M	LOS	IX
34	03295890	PRI105	1998-2004	711	21	107	271	766	6,190	41(0)	.31	.03	.17	.21	.25	2.1	A	LOS	IX
35	03414110	PRI007	1980-2004	10,000	888	4,930	7,760	13,300	36,700	259(68)	.03	<.01	<.01	.01	.01	2.5	U	UC	IX
36	03410500	PRI008	1979-2004	1,600	33	192	741	1,870	41,200	257(73)	.02	<.01	.01	.01	.02	.23	U	UC	XI
37	03404500	PRI009	1979-2004	3,170	105	534	1,560	3,400	40,400	262(39)	.04	<.01	.01	.02	.04	.28	U	UC	XI
38	03406500	PRI010	1979-2004	1,060	4.5	80	370	1,150	14,900	261(54)	.02	<.01	.01	.01	.03	.26	U	UC	XI
39	03405842	PRI051	1985-2004	359	12	55	142	386	4,590	190(6)	.14	<.01	.06	.10	.17	1.3	M	LC	XI
40	03402900	PRI086	1985-2004	61	.60	13	33	74	795	183(72)	.01	<.01	.01	.01	.01	.06	U	UC	XI
41	03403910	PRI087	1999-2004	658	47	143	402	760	4,050	38(3)	.05	<.01	.03	.05	.06	.20	A	LC	XI
42	03435100	PRI069	1999-2004	972	84	190	502	1,270	4,960	40(8)	.05	<.01	<.01	.01	.02	1.2	U	UC	IX
43	03438000	PRI043	1998-2004	267	5.4	59	172	377	1,400	44(7)	.01	<.01	<.01	.01	.02	.04	U	UC	IX
44	03321060	PRI012	1991-2004	485	.15	29	145	553	5,120	128(10)	.06	<.01	.03	.05	.07	.35	M	Green	IX
45	03319000	PRI014	1980-2004	1,180	34	150	500	1,620	19,100	252(8)	.05	<.01	.03	.04	.07	.53	M	Green	IX
46	03308500	PRI018	1983-2004	2,710	172	508	1,270	4,180	18,700	226(8)	.06	<.01	.03	.04	.06	1.3	M	Green	IX
47	03310300	PRI021	1980-2004	477	38	97	250	578	4,550	256(5)	.15	<.01	.07	.11	.18	1.2	A	Green	IX
48	03319880	PRI054	1998-2004	1,580	48	180	469	2,200	8,590	49(5)	.06	<.01	.04	.05	.08	.22	M	Green	IX

Table 9. Summary statistics of streamflow and concentrations of total phosphorus for selected ambient water-quality monitoring stations in Kentucky and station information, 1979–2004—Continued.

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; KDOW, Kentucky Division of Water; Min, minimum; Max, maximum; A, agriculture; M, mixed; U, undeveloped; MOR, Middle Ohio-Racoon; MOLM, Middle Ohio-Little Miami; LOS, Lower Ohio-Salt; UC, Upper Cumberland; LC, Lower Cumberland; LT, Lower Tennessee; HO, Hatchie-Obion; Aggregated ecoregion XI, Central and Eastern Forested Uplands; Aggregated ecoregion IX, Southeastern Temperate Forested Plains and Hills]

Map reference number (figure 1)	USGS station number	KDOW station number	Period of record	Mean	Min.	Percentile values			Max.	Number of water-quality observations (censored values)	Mean	Min.	Percentile values			Max.	Land-use/ land-cover classification[1]	Major drainage basin	Aggregated ecoregion
						25th	Median	75th					25th	Median	75th				
				Streamflow, in ft^3/s							Total phosphorus, in mg/L								
49	03316500	PRI055	1991-2004	8,590	279	2,140	5,170	12,600	45,000	123(4)	.06	<.01	.03	.04	.06	1.4	M	Green	IX
50	03316275	PRI056	1991-2004	444	3.9	38	153	420	5,320	132(7)	.06	<.01	.03	.06	.07	.23	M	Green	IX
51	03314500	PRI072	1998-2004	2,790	147	564	1,390	4,130	11,500	44(4)	.07	<.01	.04	.05	.08	.31	A	Green	IX
52	03307000	PRI077	1998-2004	306	6	52	138	385	1,950	47(8)	.05	<.01	.01	.03	.05	.40	M	Green	IX
53	03315500	PRI103	1998-2004	1,530	632	778	1,280	1,940	4,550	43(5)	.05	<.01	.02	.04	.06	.21	M	Green	IX
54	03610200	PRI106	2000-2004	316	15	33	105	238	3,250	32(0)	.15	.01	.10	.13	.17	.32	A	LT	IX
55	07024000	PRI109	2000-2004	344	42	62	71	117	5,520	32(0)	.18	.06	.11	.15	.19	.53	A	HO	IX

[1]Land-use/land-cover classifications

Agricultural	Greater than 50 percent agricultural land and less than or equal to 5 percent urban.
Urban	Greater than 25 percent urban and less than or equal to 25 percent agricultural land
Undeveloped	Less than or equal to 5 percent urban land and less than or equal to 25 percent agricultural land.
Mixed	All other combinations of urban, agricultural, and forested land.

and fig. 12). The remaining basins (Kentucky, Big Sandy, Middle Ohio-Raccoon, Middle Ohio-Little Miami, and the Upper Cumberland) had median concentrations of TP less than 0.03 mg/L and have limited karst areas, if any. The basins with high median concentrations of TP are located in physiographic regions where water quality is affected primarily by agricultural activities. The Lower Ohio-Salt and Licking basins are located physiographic regions where water quality is possibly affected more by urbanization than by agriculture. These basins are also affected by the naturally high phosphorus content in the soils. Like TN, pair-wise comparisons (Wilcoxon rank-sum, p-value = < 0.001) for concentrations of TP in basins with karst topography (Lower Cumberland, Lower Ohio-Salt, and the Green) and basins with limited or no karst topography showed median concentrations of TP also were significantly higher in intensely developed areas of karst (median concentration: 0.05 mg/L) than in areas with limited or no karst (median concentration: 0.02 mg/L).

The USEPA established recommended water-quality criteria for TP was compared to the 25th-percentile median values from this study for Aggregated Ecoregions IX and XI (fig. 9, fig. 13 and table 7). The USEPA 25th-percentile median values for Aggregated Ecoregion IX and XI for TP were 0.037 mg/L and 0.01 mg/L, respectively. The 25th-percentile median value in Aggregated Ecoregion IX for median TP for this study (0.04 mg/L) was slightly greater than the USEPA value, and the 25th-percentile value in Aggregated Ecoregion XI was the same as the USEPA value for TP (0.01 mg/L), which is also the method detection limit for TP. The 25th-percentile median concentrations of TP at the stations in undeveloped land-use/land-cover basins in both aggregated ecoregions did not exceed the USEPA's recommended concentration of TP (table 7). However, the 25th-percentile median concentrations of TP in agricultural land-use/land-cover basins and in mixed land-use/land-cover basins in the aggregated ecoregions exceeded their recommended concentrations of TP (table 7).

Estimated Mean Annual Loads and Mean Yields

Load represents the mass (usually expressed in pounds or tons) of a given water-borne constituent moving past a given point per unit of time. Mean annual loads (in tons per year [ton/yr]) for total nitrogen and total phosphorus were estimated using Kentucky Division of Water water-quality data from 1979 through 2004 for 55 ambient stream water-quality stations in Kentucky (table 10). All mean annual loads are estimated values calculated by S-LOADEST. The ratio of the standard error of prediction to the mean load standardizes the model error and provides a comparison among sites with large differences in load estimates. The prediction error ranged from 4.5 to 36 percent of the mean loads for TN estimates and from 10 to 220 percent of the mean loads for TP estimates (table 10). This indicates that the regression models had low error in the estimates of TN and more error in the estimates of TP. The best-fit regression equations, coefficients of determination (R^2), and the estimate residual variance for load models used to estimate loads of total nitrogen and total phosphorus for each station are in appendixes 2 and 3.

Yields were calculated by dividing the estimated mean annual TN and TP loads by the drainage area, in square miles, of each basin. Normalizing the mean annual yield by the respective basin area allows for comparison between the basins. Mean annual yields of TN and TP calculated from the respective multiyear Kentucky Division of Water water-quality data are presented in table 10.

Total Nitrogen

Estimated mean annual TN loads ranged from 28 ton/yr at Horse Lick Creek near Lamero, which is the smallest basin in the study (map number 39), to 22,700 ton/yr at Green River near Woodbury, which is one of the largest basins in the study area (map number 53) (table 10). Of the 13 major drainage basins, the largest estimated mean annual TN load (15,200 ton/yr) was in the Green River basin at that station Green River at Livermore (map number 49, farthest monitored downstream site); the smallest estimated mean annual TN load (258 ton/yr) was in the Middle Ohio-Little Miami basin (table 10). Load variability is predominantly controlled by basin size; larger basins generate larger nutrient loads.

The drainage basins at seven stations were categorized as agriculture, with agriculture covering greater than 50 percent of the basin land area. Estimated mean annual yields for TN were generally greater than 3 (ton/yr)/mi^2 among the agricultural basin stations (table 10). The two largest estimated mean annual yields for TN among the agricultural basins were for the Brashears Creek at Taylorsville station (map number 34) [11 (ton/yr)/mi^2], in the Lower Ohio-Salt basin, and for the Red River near Keysburg station (map number 42) [7.5 (ton/yr)/mi^2], in the Lower Cumberland basin (table 10). Agricultural land constitutes 72 percent of the drainage area at the Brashears Creek at Taylorsville station (map number 34) and about 76 percent of the drainage basin at the Red River near Keysburg station (map number 42). Potential sources of TN discharging into the streams are agricultural fertilizers, livestock waste, and residential fertilizers.

Drainage basins categorized as undeveloped included 23 of the 55 drainage basins, with undeveloped land covering from 66 to 82 percent of the basin land area. Stations within undeveloped drainage basins had less than 5 percent urban land use/land cover and less than 25 percent agricultural land use/land cover. Estimated mean annual yields for TN were generally about 1 (ton/yr)/mi^2 in the undeveloped basins. The smallest mean annual yield for TN [0.45 (ton/yr)/mi^2] was estimated at the Horse Lick Creek near Lamero station (map number 39) (table 10). Typically, nutrient yields from undeveloped/undisturbed forested land are lower than those of agriculture and urban land. According to the U.S. Department of Agriculture (1992), riparian forest buffers can be effective in reducing excess amounts of nutrients in surface-water runoff.

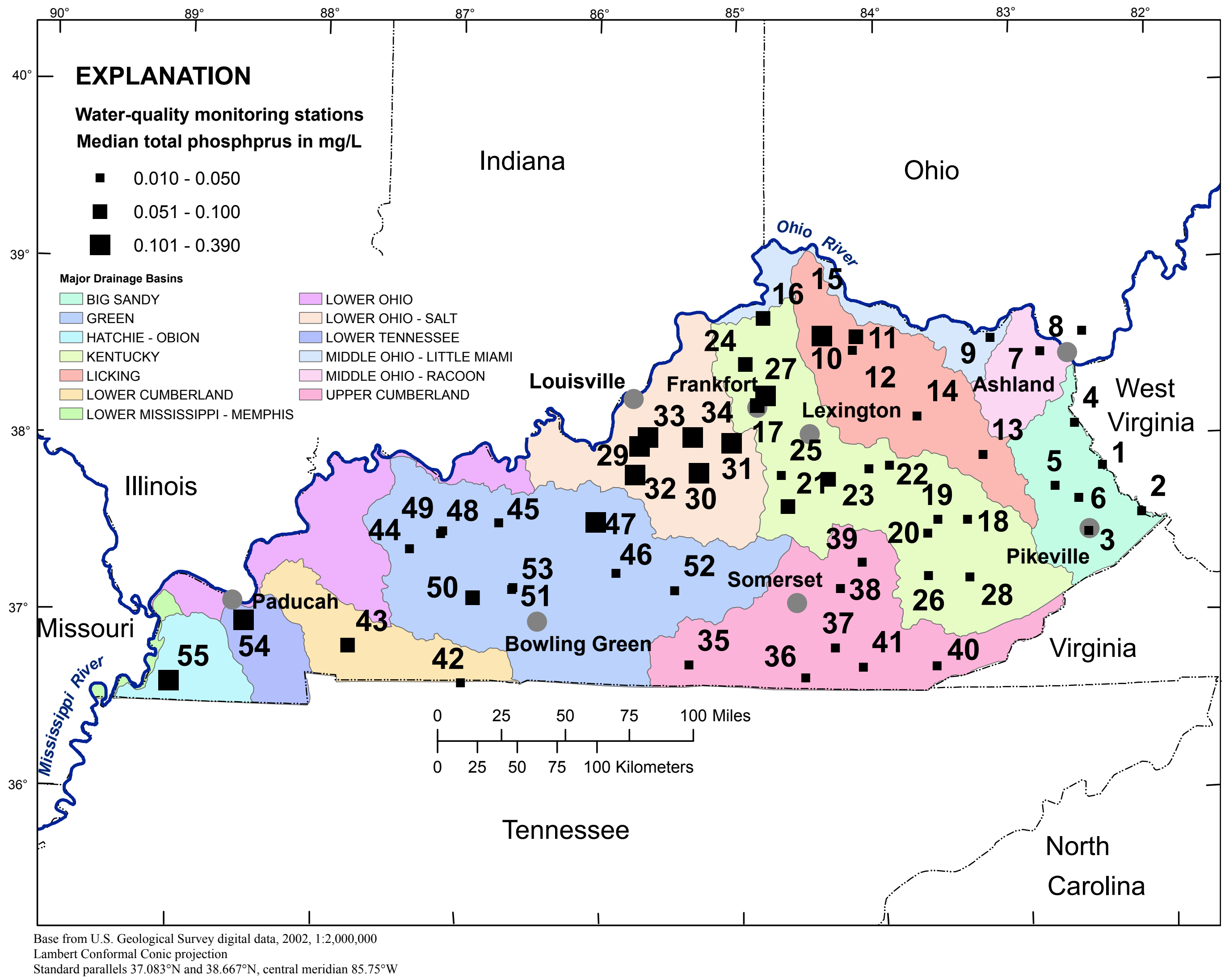
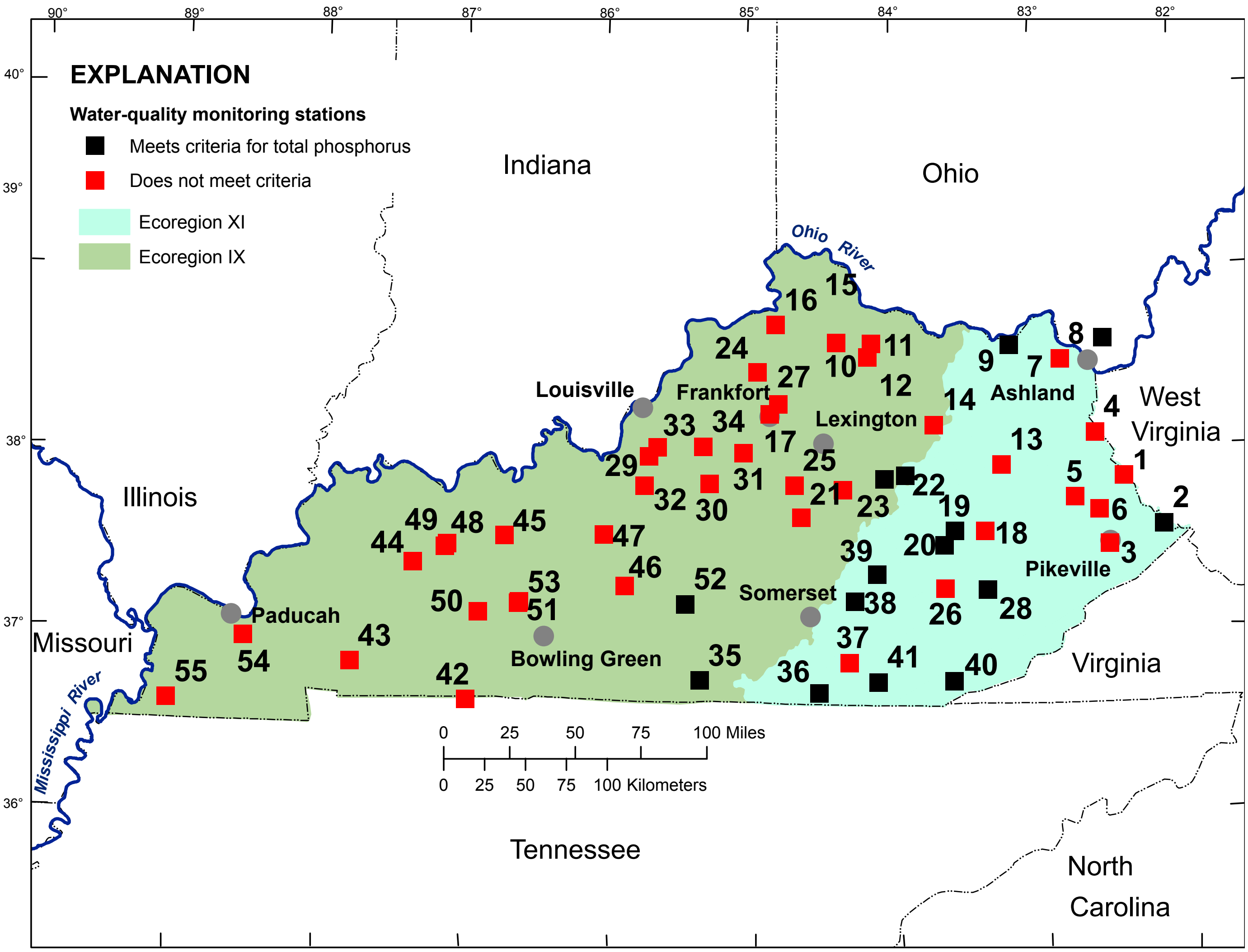


Figure 12. Spatial patterns of the 25th percentile median concentrations of total phosphorus at selected ambient water-quality monitoring stations in the major drainage basins in Kentucky, 1979–2004.

Twenty-five drainage basins were categorized as having mixed land-use/land-cover (combinations of urban, agricultural, and undeveloped [forested] land). Estimated mean annual yields for TN ranged from 1.1 (ton/yr)/mi^2 to 7.2 (ton/yr)/mi^2 for the mixed land-use/land-cover drainage basins (table 10). The largest estimated mean annual yield for TN in the mixed land-use/land-cover drainage basins was 7.2 (ton/yr)/mi^2 at the Elkhorn Creek at Peaks Mill station (map number 27) (table 10). This station also had the highest percentages of developed land-use/land-cover basins and one of the highest percentages of agricultural land-use/land-cover basins with 9.2 percent and 72 percent, respectively. The Pond River at Sacramento station (map number 44) had the smallest mean annual yield for TN estimate of 1.1 (ton/yr)/mi^2 (table 10). This station had one of the lowest percentages of developed land- use/land-cover basins (less than 1 percent), and had 26 percent agricultural land use/land cover.

Comparison of the different land uses/land covers showed estimated mean annual yields of TN at stations in agricultural basins were 107 percent larger than stations in the undeveloped land-use/land-cover basins and 63 percent larger than stations in the mixed land-use/land-cover drainage basins. Stations in the mixed land-use/land-cover basins had 53 percent larger estimated mean annual yields of TN than stations in the undeveloped land-use/land-cover basins.



Base from U.S. Geological Survey digital data, 2002, 1:2,000,000
Lambert Conformal Conic projection
Standard parallels 37.083°N and 38.667°N, central meridian 85.75°W

Figure 13. Median concentrations of total phosphorus that exceed the total phosphorus criteria in U.S. Environmental Protection Agency Ecoregions IX (Temperate Forested Plains and Hills) and XI (Central and Eastern Forested Uplands) at selected ambient water-quality monitoring stations in Kentucky

Total Phosphorus

Estimated mean annual TP loads ranged from 1 ton/yr at the Horse Lick Creek near Lamero station (map number 39; the smallest basin in this to study) to 1,290 ton/yr at the Kentucky River Lock 4 at Frankfort station (map number 17; one of the largest basins in this study) (table 10). The Lower Ohio-Salt drainage basin had the largest mean annual TP load (550 ton/yr). The Middle Ohio-Little Miami drainage basin had the smallest mean annual TP load (4 ton/yr). Load variability is predominantly controlled by basin size; larger basins generate larger nutrient loads.

The estimated mean annual yield of TP among the seven agricultural drainage basin stations was 0.48 (ton/yr)/mi^2 with a range of 0.08 (ton/yr)/mi^2 to 1.32 (ton/yr)/mi^2 (table 10). The largest estimated mean annual yield 1.3 (ton/yr)/mi^2 was for Brashears Creek at Taylorsville (map number 34), a stream in the Lower Ohio-Salt basin. This station also had the highest estimated mean annual yield of TN among the agricultural basin stations. Agricultural land constitutes about 72 percent of the station's drainage basin with the majority being pasture. The high estimated mean annual yields of TP and TN at the Brashears Creek at Taylorsville station (map number 34) indicate the presence of livestock and possibly the associated application of manure as fertilizer in the basin.

The 23 stations in undeveloped drainage basins were defined as having less than 5 percent urban land use/land cover and less than 25 percent agricultural land use/land cover. Estimated mean annual yields for TP were generally about 0.10 (ton/yr)/mi^2 at the stations in the undeveloped basins (table 10). The largest mean annual yield for TP of 0.55 (ton/yr)/mi^2 was estimated at the Cumberland River at

Table 10. Estimated mean annual total nitrogen and total phosphorus loads and yields using S-LOADEST from concentrations in water-quality samples collected by the Kentucky Division of Water for their ambient water-quality monitoring network in major river basins, 1979–2004.

[USGS, U.S. Geological Survey; KDOW, Kentucky Division of Water; mi^2, square miles; ton/yr, ton per year; SEP, standard error of prediction; —, not available; $(ton/yr)mi^2$, ton per year per square mile; A, agriculture, M, mixed, U, undeveloped]

Map reference number (figure 1)	KDOW station name	USGS stream-gaging station number used for discharge[1]	Period of record	Drainage area (mi^2)	Estimated mean annual total nitrogen load (ton/yr) (+/– SEP)	Estimated mean annual total phosphorus load (ton/yr) (+/– SEP)	Estimated mean annual total nitrogen yield $(ton/yr)mi^2$	Estimated mean annual total phosphorus yield $(ton/yr)mi^2$	Land-use/land-cover classification[2]	Prediction error of total nitrogen load (percent)	Prediction error of total phosphorus load (percent)
				Big Sandy							
1	Tug Fork at Kermit, W. Va.	03214500	1986-2004	1,280	1,510 (157)	73 (22)	1.2	0.06	U	10	30
2	Tug Fork at Freeburn, W. Va.	Multiple stations	1998-2004	271	760 (117)	70 (153)	2.8	.26	U	15	219
3	Levisa Fork near Pikeville	03209500	1980-2004	1,238	6,520 (529)	278 (51)	5.3	.22	U	8.1	18
4	Levisa Fork near Louisa	03215000	1979-2004	2,326	2,100 (121)	—	0.90	—	U	5.8	—
5	Levisa Fork at Auxier	03212500	1999-2004	1,726	1,600 (343)	85 (20)	.93	.05	U	21	24
6	Johns Creek at McCombs	03210000	1998-2004	168	247 (55)	15 (27)	1.5	.09	U	22	180
				Middle Ohio-Racoon							
7	Tygarts Creek at Load	03217000	1986-2004	242	1,150 (106)	58 (13)	4.8	.24	U	9.2	22
8	Little Sandy at Argillite	03216500	1979-2004	522	523 (26)	47 (9)	1.0	.09	M	5.0	19
				Middle Ohio-Little Miami							
9	Kinniconick Creek near Tannery	03237250	1992-2004	175	258 (35)	4 (1)	1.5	.02	U	14	25
				Licking							
10	South Fork Licking River at Morgan	Multiple stations	1994-2004	839	4,640 (770)	641 (153)	5.5	.76	A	17	24
11	North Fork Licking River near Milford	03251200	1992-2004	290	1,240 (198)	139 (34)	4.3	.48	M	16	24
12	Licking River at Claysville	03249500	1983-2004	1,993	1,120 (117)	91 (13)	.56	.05	M	10	14
13	Licking River at West Liberty	Multiple stations	1991-2004	327	295 (33)	100 (80)	.90	.31	U	11	80
14	Slate Creek near Owingsville	03250190	1998-2004	230	497 (103)	37 (24)	.10	.16	M	21	65
15	Licking River at Butler	03253500	1999-2004	3,385	7,820 (1,391)	770 (162)	2.3	.23	M	18	21
				Kentucky							
16	Eagle Creek at Glencoe	03291500	1989-2004	437	1,140 (174)	264 (79)	2.6	.60	M	15	30
17	Kentucky River at Frankfort (Lock 4)	03287500	1980-2004	5,412	9,930 (766)	1,290 (226)	1.8	.24	M	7.7	18
18	North Fork Kentucky River at Jackson	03280000	1984-2004	1,101	1,300 (133)	238 (179)	1.2	.22	M	10	75
19	Middle Fork Kentucky River at Tallega	03281000	1980-2004	537	411 (25)	56 (14)	.77	.32	U	6.1	25

Table 10. Estimated mean annual total nitrogen and total phosphorus loads and yields using S-LOADEST from concentrations in water-quality samples collected by the Kentucky Division of Water for their ambient water-quality monitoring network in major river basins, 1979–2004—Continued.

[USGS, U.S. Geological Survey; KDOW, Kentucky Division of Water; mi^2, square miles; ton/yr, ton per year; SEP, standard error of prediction; —, not available; $(ton/yr)mi^2$, ton per year per square mile; A, agriculture, M, mixed, U, undeveloped]

Map reference number (figure 1)	KDOW station name	USGS stream-gaging station number used for discharge[1]	Period of record	Drainage area (mi^2)	Estimated mean annual total nitrogen load (ton/yr) (+/– SEP)	Estimated mean annual total phosphorus load (ton/yr) (+/– SEP)	Estimated mean annual total nitrogen yield $(ton/yr)mi^2$	Estimated mean annual total phosphorus yield $(ton/yr)mi^2$	Land-use/ land-cover classification[2]	Prediction error of total nitrogen load (percent)	Prediction error of total phosphorus load (percent)
20	South Fork Kentucky River at Booneville	03281500	1979-2004	722	691 (146)	157 (102)	.96	.21	U	21	65
21	Dix River near Danville	03285000	1980-2004	318	1,160 (106)	84 (28)	3.6	.08	M	9.1	33
22	Red River at Clay City	03283500	1979-2004	362	393 (42)	77 (39)	1.1	.21	U	11	51
23	Kentucky River near Trapp	Multiple stations	1979-2004	3,246	2,810 (562)	—	.87	—	U	20	—
24	Kentucky River at Lockport (Lock 2)	03290500	1980-2004	6,180	12,500 (1,007)	1,200(303)	2.0	.19	M	8.1	25
25	Kentucky River at High Bridge (Lock 7)	03286500	1993-2004	5,036	4,770 (416)	639 (146)	.95	.13	U	8.7	23
26	Goose Creek near Oneida	03281100	1998-2004	250	178 (53)	6 (2)	.71	.02	U	30	33
27	Elkhorn Creek at Peaks Mill	03289500	1998-2004	473	3,380 (1,051)	680 (1,270)	7.2	1.4	M	31	187
28	Middle Fork Kentucky River at Dryhill	Multiple stations	1999-2004	324	149 (22)	7 (1)	.46	.02	U	15	14
				Lower-Ohio Salt							
29	Salt River at Shepherdsville	03298500	1979-2004	1,197	4,000 (280)	953 (179)	3.3	.24	M	7.0	19
30	Beech Fork near Maud	03300400	1980-2004	436	1,630 (289)	352 (69)	3.7	.22	M	18	20
31	Salt River at Glensboro	03295400	1990-2004	172	981 (125)	160 (29)	5.7	.93	M	13	18
32	Rolling Fork near Lebanon Junction	03301500	1980-2004	1,375	3,710 (335)	1,130 (1,024)	2.7	.82	M	9.0	91
33	Floyds Fork near Shepherdsville	03298200	2001-2004	259	909 (140)	347 (108)	3.5	1.3	M	15	31
34	Brashears Creek at Taylorsville	03295890	1998-2004	262	3,000 (796)	347 (120)	11	1.3	A	27	35
				Upper Cumberland							
35	Cumberland River near Burkesville	Multiple stations	1979-2004	6,053	5,770 (261)	145 (22)	.95	.02	U	4.5	15
36	South Fork Cumberland River at Blue Heron	03410500	1979-2004	954	1,100 (338)	110 (40)	1.1	.12	U	31	36
37	Cumberland River at Cumberland Falls	03404000	1979-2004	562	2,620 (225)	310 (69)	4.4	.55	U	8.6	22
38	Rockcastle River at Billows	03406500	1979-2004	604	807 (79)	52 (16)	1.3	.09	U	10	31
39	Horse Lick Creek near Lamero	03404900	1985-2004	62	28 (2)	1 (0.1)	.45	.02	M	7.1	10
40	Cumberland River at Calvin	03402900	1999-2004	770	968 (150)	—	3.3	—	U	15	—
41	Clear Fork near Williamburg	03403910	1998-2004	370	225 (40)	8 (1)	.61	.02	A	18	13

Table 10. Estimated mean annual total nitrogen and total phosphorus loads and yields using S-LOADEST from concentrations in water-quality samples collected by the Kentucky Division of Water for their ambient water-quality monitoring network in major river basins, 1979–2004—Continued.

[USGS, U.S. Geological Survey; KDOW, Kentucky Division of Water; mi^2, square miles; ton/yr, ton per year; SEP, standard error of prediction; —, not available; $(ton/yr)mi^2$, ton per year per square mile; A, agriculture, M, mixed, U, undeveloped]

Map reference number (figure 1)	KDOW station name	USGS stream-gaging station number used for discharge[1]	Period of record	Drainage area (mi^2)	Estimated mean annual total nitrogen load (ton/yr) (+/– SEP)	Estimated mean annual total phosphorus load (ton/yr) (+/– SEP)	Estimated mean annual total nitrogen yield $(ton/yr)mi^2$	Estimated mean annual total phosphorus yield $(ton/yr)mi^2$	Land-use/land-cover classification[2]	Prediction error of total nitrogen load (percent)	Prediction error of total phosphorus load (percent)
				Lower Cumberland							
42	Red River near Keysburg	03435305	2000-2004	509	3,830 (584)	42 (8)	7.5	.08	U	15	19
43	Little River near Cadiz	03438000	1980-2004	244	1,340 (94)	132 (50)	5.5	.54	U	7.0	38
				Green							
44	Pond River near Sacramento	Multiple stations	1992-2004	523	565 (68)	37 (7)	1.1	.07	M	12	19
45	Rough River near Dundee	Multiple stations	1980-2004	757	1,380 (75)	84 (9)	1.8	.11	M	5.4	11
46	Green River at Munfordville	03308500	1980-2004	1,673	4,190 (278)	217 (46)	2.5	.05	M	6.6	21
47	Nolin River at White Mills	03310300	1980-2004	357	1,520 (69)	109 (38)	4.3	.31	A	4.5	35
48	Rough River near Livermore	03319000	1998-2004	1,068	1,800 (179)	127 (28)	1.7	.12	M	10	22
49	Green River at Livermore	03316500	1992-2004	6,431	15,200 (795)	765 (151)	2.4	.12	M	5.2	20
50	Mud River near Gus	Multiple stations	1991-2004	268	502 (34)	31 (4)	1.9	.12	M	6.8	13
51	Barren River at Woodbury	Multiple stations	1998-2004	1,968	6,970 (726)	256 (60)	3.5	.13	A	10	23
52	Russell Creek near Bramlett	03307000	1998-2004	289	919 (234)	42 (17)	3.2	.15	M	25	40
53	Green River near Woodbury	03316500	1979-2004	5,404	22,700 (3,175)	126 (119)	4.2	.02	M	14	94
				Lower Tennessee							
54	Clarks River near Sharpe	03610200	2000-2004	313	606 (161)	77 (40)	1.9	.25	A	27	52
				Hatchie-Obion							
55	Bayou de Chien near Moscow	07024000	2000-2004	178	599 (213)	89 (21)	3.4	.50	A	36	24

[1]Refer to table 5 for estimates of daily mean discharge for stations with no available discharge or incomplete discharge records.

[2]Land-use/land-cover classifications

Agricultural	Greater than 50 percent agricultural land and less than or equal to 5 percent urban.
Urban	Greater than 25 percent urban and less than or equal to 25 percent agricultural land
Undeveloped	Less than or equal to 5 percent urban land and less than or equal to 25 percent agricultural land.
Mixed	All other combinations of urban, agricultural, and forested land.

Cumberland Falls (map number 37) (table 10). This station is located in the Cumberland River State Resort Park, a high-use recreational area.

Estimated mean annual yields for TP ranged from 0.02 (ton/yr)/mi^2 to 1.4 (ton/yr)/mi^2 for the mixed land-use/land-cover drainage basins (table 10). The largest estimated mean annual yield for TP in the mixed land-use/land-cover drainage basins was 1.4 (ton/yr)/mi^2 at the Elkhorn Creek at Peaks Mill station (map number 27). This station also had the highest percentages of developed land use/land cover and some of the highest percentages of agricultural land use/land cover with 9.2 percent and 72 percent, respectively. Seven stations had the smallest mean annual yield for TP estimate of 0.02 (ton/yr)/mi^2 (table 10). These stations are Kinniconick Creek near Garrison station (map number 9); the Goose Creek near Oneida station (map number 26); the Middle Fork Kentucky River at Dryhill station (map number 28); the Cumberland River near Burkesville station (map number 35); the Horse Lick Creek near Lamero station (map number 39); the Clear Fork near Williamsburg station (map number 41); and the Green River near Woodbury station (map number 53). All seven stations had drainage basins with 2 percent or less developed land use/land cover. Six of the seven stations had basins with less than 14 percent agricultural land use/land cover; the Green River near Woodbury station (map number 53) had 45 percent agricultural land use/land cover with 36 percent of that in pasture land.

Comparison of the different land uses/land covers showed estimated mean annual yields of TP at stations in agricultural basins were 100 percent larger than stations in the undeveloped land-use/land-cover basins and 34 percent larger than stations in the mixed land-use/land-cover drainage basins. Stations in the mixed land- use/land-cover basins had 72 percent larger estimated mean annual yields of TP than stations in the undeveloped land-use/land-cover basins.

Summary and Conclusions

Nutrients (primarily nitrogen and phosphorus) are commonly cited as principal reasons why water bodies in Kentucky do not fully support their designated uses. In 2005, the U.S. Geological Survey, in cooperation with the Kentucky Energy and Environment Cabinet–Kentucky Division of Water, conducted an investigation to evaluate the State's water quality by summarizing the concentrations of total nitrogen (TN) and total phosphorus (TP), and providing estimates of total nitrogen and total phosphorus loads and yields for 55 primary ambient stream water-quality network monitoring stations in Kentucky from 1979 through 2004. Water samples were collected by the Kentucky Division of Water at a monthly frequency for the majority of the stations from 1979 to 1998 representing agricultural, undeveloped (mainly forested), and areas of mixed land use/land cover. In 1998, the number of water samples collected was reduced to a frequency of six times per year (every 2 months) every 4 of 5 years because a new monitoring network was implemented involving a 5-year rotating Basin Management Unit scheme of monitoring. Water-quality records for the selected stations were retrieved from U.S. Environmental Protection Agency's (USEPA) Legacy Data Center and Modernized Storage and Retrieval (STORET) database.

Concentrations of TN and TP varied throughout Kentucky, and were principally associated with land-use/land-cover characteristics. Streams in predominately agricultural basins had higher concentrations of TN and TP; whereas, streams in predominately undeveloped (forested) basin generally had lower concentrations of TN and TP. Streams in basins in intensely developed karst areas (caves, springs, sinkholes, and sinking streams) had a higher median concentration of TN [1.5 milligrams per liter (mg/L)] than streams in basins with limited or no karst areas (0.63 mg/L). As with TN, median concentrations of TP also were higher in areas of intense karst (0.05 mg/L) than in areas with limited or no karst (0.02 mg/L).

Concentrations of total nitrogen (TN) ranged from 0.05 mg/L to 15 mg/L and were highest in basins with the most intensive agriculture. Median concentrations of TN ranged from 0.93 mg/L to 4.6 mg/L at stations in the agricultural land-use/land-cover basins; from 1.1 mg/L to 3.8 mg/L at stations in the mixed land-use/land-cover basins; and from 0.31 mg/L to 1.3 mg/L at stations in the undeveloped (forested) land-use/land-cover basins. The highest median concentration of TN (4.6 mg/L) was measured at the Red River near Keysburg station; the lowest median concentration of total nitrogen (0.31 mg/L) was measured at the Clear Fork near Williamsburg station.

The Lower Cumberland basin had a higher median concentration of TN (4.0 mg/L) than the other basins. A possible explanation is agriculture has been a predominant land use in this basin that is characterized by karst topography making the Lower Cumberland basin potentially vulnerable to enrichment of nitrogen from application of fertilizers. The lowest median concentration of TN (0.52 mg/L) was in the Upper Cumberland basin. Unlike the Lower Cumberland basin, the Upper Cumberland basin is mainly forested. This type of land cover can potentially act as a buffer to nutrient runoff (U.S. Department of Agriculture, 1992).

The 25th percentile values of TN for Aggregated Ecoregions IX (0.89 mg/L) and XI (0.51 mg/L) in this study exceeded the USEPA-established recommended water-quality criteria for both aggregated ecoregions. The USEPA-established recommended water-quality criteria for TN for the Aggregated Ecoregions IX and XI are 0.69 mg/L and 0.31 mg/L, respectively.

Concentrations of TP ranged from less than 0.01 mg/L to 4.0 mg/L. The highest concentrations of TP were observed in basins with the most agricultural land use. The Elkhorn Creek at Peaks Mill station had the highest measured concentration of TP (4.0 mg/L), and the highest median concentration of TP (0.39 mg/L). The lowest median concentration of TP (0.01 mg/L) was observed at many of the stations.

Stations in the basins categorized as agriculture had higher median concentrations of TP (0.13 mg/L) than the 25 mixed land-use/land-cover basin stations (0.06 mg/L). The median concentration of TP for the agricultural land-use/land-cover stations was over 7.5 times higher than undeveloped land use/land-cover stations (0.01 mg/L).

The Lower Ohio-Salt basin had the highest median concentration of TP (0.17 mg/L), followed by the Hatchie-Obion (0.15 mg/L), the Lower Tennessee (0.13 mg/L), the Lower Cumberland (0.07 mg/L), the Licking (0.06 mg/L), and the Green (0.04 mg/L) basins. The remaining basins (Kentucky, Big Sandy, Middle Ohio-Raccoon, Middle Ohio-Little Miami, and the Upper Cumberland) had median concentrations of TP less than 0.03 mg/L and have limited karst areas, if any.

The USEPA-recommended 25th-percentile values for TP in Aggregated Ecoregion IX and XI were 0.037 mg/L and 0.01 mg/L, respectively. The 25th-percentile value in Aggregated Ecoregion IX for median TP for this study (0.04 mg/L) was slightly greater than the USEPA value, and the 25th-percentile value in Aggregated Ecoregion XI was the same as the USEPA value for TP (0.01 mg/L).

Estimated loads and yields of TN and TP varied substantially among the individual stations. Load variability is predominantly controlled by basin size; larger basins generate larger nutrient loads. Yields of TN and TP were higher in basins with higher percentages of agricultural land, whereas, lower yields of TN and TP were indicated in areas with higher percentages of undeveloped (mainly forested) land and less agriculture.

Estimated mean annual TN loads ranged from 28 ton/yr at Horse Lick Creek near Lamero to 22,700 tons per year (ton/yr) at Green River near Woodbury. The estimated mean annual TN load was largest in the Green River basin (5,580 ton/yr); the smallest estimated mean annual TN load was in the Middle Ohio-Little Miami basin (258 ton/yr).

Drainage basins categorized as undeveloped represented 23 of the 55 drainage basins, with undeveloped land covering from 66 to 82 percent of the basin land area. Estimated mean annual yields for TN were generally about 1 ton per year per square mile [(ton/yr)/mi^{2}] in the undeveloped basins. The smallest mean annual yield for TN was estimated at the Horse Lick Creek near Lamero station [0.45 (ton/yr)/mi^{2}]. Typically, nutrient yields from undeveloped/undisturbed forested land are lower than those of agricultural and developed (urban) land. The U.S. Department of Agriculture has shown that riparian forest buffers can reduce excess amounts of nutrients in surface-water runoff (U.S. Department of Agriculture, 1992).

Estimated mean annual yields for TN ranged from 1.1 (ton/yr)/mi^{2} to 7.2 (ton/yr)/mi^{2} for the 25 mixed land-use/land-cover drainage basins. The largest estimated mean annual yield for TN in the mixed land-use/land-cover drainage basins was 7.2 (ton/yr)/mi^{2} at the Elkhorn Creek at Peaks Mill station. This station also had the highest percentages of developed land use/land cover, and one of the highest percentages of agricultural land use/land cover with 9.2 percent and 64 percent, respectively. The Pond River at Sacramento station had the smallest mean annual yield for TN estimate of 1.1 (ton/yr)/mi^{2}.

Estimated mean annual TP loads ranged from 1 ton/yr at the Horse Lick Creek near Lamero station to 1,290 ton/yr at the Kentucky River Lock 4 at Frankfort station. The Lower Ohio-Salt drainage basin had the largest mean annual TP load (550 ton/yr). The Middle Ohio-Little Miami drainage basin had the smallest mean annual TP load (4 ton/yr).

The estimated mean annual yield of TP among the agricultural drainage basin stations was 0.48 (ton/yr)/mi^{2} with a range of 0.08 (ton/yr)/mi^{2} to 1.32 (ton/yr)/mi^{2}. The largest estimated mean annual yield [1.3 (ton/yr)/mi^{2}] was for a stream in the Lower Ohio-Salt basin (Brashears Creek at Taylorsville). Estimated mean annual yields for TP were generally about 0.10 (ton/yr)/mi^{2} at the stations in the undeveloped basins. Estimated mean annual yields for TP ranged from 0.02 (ton/yr)/mi^{2} to 1.4 (ton/yr)/mi^{2} for the mixed land-use/land-cover drainage basins. The largest estimated mean annual yield for TP in the mixed land-use/land-cover drainage basins was 1.4 (ton/yr)/mi^{2} at the Elkhorn Creek at Peaks Mill station. Seven stations had the smallest mean annual yield for TP estimate of 0.02 (ton/yr)/mi^{2}. These stations are Kinniconick Creek near Garrison station (map number 9); the Goose Creek near Oneida station (map number 26); the Middle Fork Kentucky River at Dryhill station (map number 28); the Cumberland River near Burkesville station (map number 35); the Horse Lick Creek near Lamero station (map number 39); the Clear Fork near Williamsburg station (map number 41); and the Green River near Woodbury station (map number 53).

References Cited

Akaike, H., 1981, Likelihood of a model and information criterion: Journal of Econometrics, v. 16, p. 3–14.

Anderson, J.R., Hardy, E.E., Roach, J.T., and Witmer, R.E., 1976, A land use and land cover classification system for use with remote sensor data: U.S. Geological Survey Circular 671, 41 p.

Cohn, T.A., Caulder, D.L., Gilroy, E.J., Zynjuk, L.D., and Sommers, R.M., 1992, The validity of a simple statistical model for estimating fluvial constituent loads: An empirical study involving nutrient loads entering Chesapeake Bay: Water Resources Research, v. 28, no. 9, p. 2,352–2,363.

Crain, A.S., 2001, Estimated loads and yields of suspended solids and water-quality constituents in Kentucky streams: U.S. Geological Survey Water-Resources Investigations Report 2001–4075, 125 p.

Field, M.S., 1990, Transport of chemical contaminants in karst terranes—Outline and summary, *in* Simpson, E.S., and Sharp, J.M., Jr., eds., Selected papers on hydrogeology from the 28th International Geological Congress, July 9–19, 1989: Washington, D.C., International Association of Hydrologists, v. 1, p. 17–27.

Hirsch, R.M., 1982, A comparison of four streamflow record extension techniques: Water Resources Research, v. 18, no. 4, p. 1,081–1,088.

Insightful Corp., 2005, S-Plus 7.0 for Windows Professional Developer: Seattle, Wash., Insightful Corporation.

Kentucky Climate Center, 2007, Kentucky precipitation monthly observations: accessed January 2007 at *http://kyclim.wku.edu/tableData/observations/KY_PRECIP.htm*

Kentucky Energy and Environment Cabinet, Kentucky Division of Water, 2005, Kentucky ambient/watershed water quality monitoring standard operating procedure manual: Accessed May 2008 at *http://www.water.ky.gov/NR/rdonlyres/6449D7B7-054D-40D0-844E-8E1F537A7FC0/0/ambient_SOP.pdf*

Kentucky Energy and Environment Cabinet, Kentucky Division of Water, 2008, Overview of Kentucky's Waters, accessed in May 2008 at *http://www.water.ky.gov/homepage_repository/overview.htm*

Kleiss, B.A., Coupe, R.H., Gontheir, G.J., Justus, B.G, 2000, Water quality in the Mississippi Embayment: Mississippi, Louisiana, Arkansas, Missouri, Tennessee, and Kentucky: U.S. Geological Survey Circular 1208, 36 p.

Leist, D.W., Quinones, F., Mull, D.S., and Young, M., 1981, Hydrology of area 15, Eastern coal province, Kentucky and Tennessee: U.S. Geological Survey Open-File Report 81–809, 81 p.

McDowell, R.C., 1986, The geology of Kentucky; a text to accompany the Geologic Map of Kentucky: U.S. Geological Survey Professional Paper 1151–H, 76 p.

McFarlan, A.C., 1943, Geology of Kentucky: Lexington, Ky., University of Kentucky, 531 p.

McGrain, P, and Currens, J.C., 1978, Topography of Kentucky: Lexington, Ky., University of Kentucky, Kentucky Geological Survey, ver. X, Special Publication 25, 76 p.

NSTATE, 2008, The geography of Kentucky: Accessed May 2008 at *http://www.netstate.com/states/geography/ky_geography.htm*.

Quinones, F., Mull, D.S., York, K., and Kendall, V., 1981, Hydrology of area 14 Eastern coal province, Kentucky and Tennessee: U.S. Geological Survey Open-File Report 81–137, 82 p.

Ray, J.A., Webb, J.S., and O'Dell, P.W., 1994, Groundwater sensitivity regions of Kentucky: Frankfort, Ky., Kentucky Department of Environmental Protection, Division of Water, Groundwater Branch, accessed April 7, 2006, at *http://kgsweb.uky.edu/download/wrs/sensitivity.pdf*

Runkel, R.L., Crawford, C.G., and Cohn, T.A., 2004, Load Estimator (LOADEST): A FORTRAN program for estimating constituent loads in streams and rivers: U.S. Geological Survey Techniques and Methods book 4, chap. A–5, 69 p.

Smoot, J.L., Liebermann, T.D., Evaldi, R.D., and White, K.D., 1995, Water-quality assessment of Kentucky River Basin, Kentucky—Analysis of available surface-water-quality data through 1986: U.S. Geological Survey Water-Supply Paper 2351, 194 p.

Turnbull, B.W., and Weiss, L., 1978, A likelihood ratio statistic for testing goodness of fit with randomly censored data: Biometrics, v. 34, p. 367–375.

U.S. Census Bureau, 2003: accessed in May 2008 at *http://www.census.gov/census2000/states/ky.html*

U.S. Census Bureau, 2006, Annual estimates of population for counties in Kentucky: April 1, 2000 to July 1, 2005: KY–EST2005–01, accessed February 2009 at *http://water.usgs.gov/usgs/watuse/2005compilation/countypop/index.html*

U.S. Department of Agriculture, Forest Service, 1992, Riparian forest buffers: function and design for protection and enhancement of water resources, *prepared by* David J. Welsch: Radnor, Penn., State & Private Forestry–Northeastern Area, Forest Resources Management Publication NA–PR–07–91, accessed in November 2008 at *http://www.na.fs.fed.us/spfo/pubs/n_resource/buffer/cover.htm*

U.S. Environmental Protection Agency, 1998, National strategy for the development of regional nutrient criteria: Washington D.C., EPA 822–R–98–002, 53 p., accessed in November 2008 at *http://www.epa.gov/waterscience/criteria/nutrient/strategy/nutstra3.pdf*

U.S. Environmental Protection Agency, 2000a, Ambient water quality criteria recommendations: information supporting the development of state and tribal nutrient criteria: rivers and streams in nutrient ecoregion XI: U.S. Environmental Protection Agency, EPA 822–B–00–020, 99 p.

U.S. Environmental Protection Agency, 2000b, Ambient water quality criteria recommendations: information supporting the development of state and tribal nutrient criteria: rivers and streams in nutrient ecoregion IX: U.S. Environmental Protection Agency, EPA 822–B–00–019, 108 p.

U.S. Environmental Protection Agency, 2004, STORET: accessed in August 2005 at *http://www.epa.gov/STORET/index.html*

U.S. Geological Survey, 2007, National Land Cover Database 2001 (NLCD 2001): accessed in January 2007 at *http://www.mrlc.gov/mrlc2k_nlcd.asp*.

Appendixes 1–3

Appendix 1. Percent land use/land cover of watersheds represented by selected Kentucky Energy and Environment Cabinet–Kentucky Division of Water ambient water-quality network stations, 2001.

[KDOW, Kentucky Division of Water; mi², square miles;WV, West Virginia; S.F., South Fork; U, undeveloped; M, mixed; A, agriculture; <, less than; >, greater than]

Map reference number (table 1, figure 1)	KDOW station name	KDOW station number	Drainage area (mi²)	Mean annual precipitation (inches)	Land-cover classification[1]	Percent land cover in 2001					
						Developed	Agriculture		Forested (Undeveloped)	Water	Wetland
							Row crop	Pasture			
1	Tug Fork at Kermit, W. Va.	PRI002	1,280	45.96	U	2.5	0.3	1.6	82.6	0.3	0.0
2	Tug Fork at Freeburn, W. Va.	PRI003	271	43.10	U	2.1	0.0	1.8	86.6	.20	0.0
3	Levisa Fork near Pikeville	PRI006	1,238	45.58	U	2.4	.1	4.2	79.0	.4	0.0
4	Levisa Fork near Louisa	PRI064	2,326	45.10	U	2.6	.2	4.	79.1	.4	0.0
5	Levisa Fork at Auxier	PRI094	1,726	45.28	U	2.7	.1	4.	78.8	.34	0.0
6	Johns Creek at McCombs	PRI096	168	45.24	U	2.1	.5	2.3	78.8	.13	0.0
7	Tygarts Creek at Load	PRI048	242	42.51	U	2.4	.2	14.6	68.6	.1	0.0
8	Little Sandy River at Argillite	PRI049	400	42.86	M	6.5	.5	11.9	74.5	.5	0.0
9	Kinniconick Creek near Tannery	PRI063	175	43.56	U	.8	0.0	6.1	85.6	0.0	0.0
10	South Fork Licking River at Morgan	PRI059	839	44.47	A	1.8	3.8	68.5	18.7	.3	.3
11	North Fork Licking River near Milford	PRI060	290	44.17	M	.5	4.3	45.5	42.1	.1	0.0
12	Licking River at Claysville	PRI061	278	45.69	U	2.2	1.7	24.8	62.7	.8	0.0
13	Licking River at West Liberty	PRI062	327	45.41	U	1.	.9	4.1	83.8	0.0	0.0
14	Slate Creek near Owingsville	PRI093	230	47.60	M	2.6	2.4	46.8	41.5	.21	.01
15	Licking River at Butler	PRI111	3,385	45.09	M	1.4	2.5	37.7	50.2	.60	.05
16	Eagle Creek at Glencoe	PRI022	437	43.86	U	6.	.4	35.4	52.4	.3	0.0
17	Kentucky River at Frankfort (Lock 4)	PRI024	5,412	47.38	M	7.4	1.2	19.8	64.3	.5	0.0
18	North Fork Kentucky River at Jackson	PRI031	1,101	45.87	M	6.8	0.0	.8	76.7	.2	0.0
19	Middle Fork Kentucky River at Tallega	PRI032	537	48.47	U	.8	.1	1.2	87.0	.4	0.0
20	South Fork Kentucky River at Booneville	PRI033	722	48.84	U	1.4	.1	4.6	83.9	.3	0.0
21	Dix River near Danville	PRI045	318	49.67	M	5.7	4.8	45.1	42.1	.1	0.0
22	Red River at Clay City	PRI046	362	48.17	U	2.5	.4	11.	76.9	.1	0.0
23	Kentucky River near Trapp	PRI058	3,246	47.38	U	1.6	.1	4.9	79.2	.3	0.0
24	Kentucky River at Lockport (Lock 2)	PRI066	6,180	46.92	U	2.7	1.4	23.9	60.2	.5	0.0
25	Kentucky River at High Bridge (Lock 7)	PRI067	5,036	47.48	U	2.2	1.	17.8	66.6	.4	0.0

Appendix 1. Percent land use/land cover of watersheds represented by selected Kentucky Energy and Environment Cabinet–Kentucky Division of Water ambient water-quality network stations, 2001—Continued.

[KDOW, Kentucky Division of Water; mi², square miles;WV, West Virginia; S.F., South Fork; U, undeveloped; M, mixed; A, agriculture; <, less than; >, greater than]

Map reference number (table 1, figure 1)	KDOW station name	KDOW station number	Drainage area (mi^2)	Mean annual precipitation (inches)	Land-cover classification[1]	Percent land cover in 2001					
						Developed	Agriculture		Forested (Undeveloped)	Water	Wetland
							Row crop	Pasture			
26	Goose Creek near Oneida	PRI092	250	49.49	U	2.1	.1	5.7	80.7	.21	0.0
27	Elkhorn Creek at Peaks Mill	PRI098	473	44.20	A	9.2	4.	68.1	8.9	.25	.04
28	Middle Fork Kentucky River at Dryhill	PRI104	324	49.05	U	.9	0.0	.3	86.0	.09	0.0
29	Salt River at Shepherdsville	PRI029	1,197	46.27	A	3.5	8.1	41.2	37.5	.8	.3
30	Beech Fork near Maud	PRI041	436	47.83	U	4.1	3.6	35.4	50.3	.2	0.0
31	Salt River at Glensboro	PRI052	172	46.41	M	8.8	6.3	58.	24.6	.2	1.0
32	Rolling Fork near Lebanon Junction	PRI057	1,375	49.30	U	.8	7.4	28.4	55.2	.3	.4
33	Floyds Fork near Shepherdsville	PRI100	259	45.62	M	8.	5.1	29.5	43.5	.67	.40
34	Brashears Creek at Taylorsville	PRI105	262	45.78	A	2.7	15.2	56.7	19.4	.51	.09
35	Cumberland River near Burkesville	PRI007	6,053	51.01	U	2.2	1.1	12.6	71.0	1.6	0.0
36	South Fork Cumberland River at Blue Heron	PRI008	954	55.53	U	1.3	0.0	5.	80.2	.3	.2
37	Cumberland River at Cumberland Falls	PRI009	562	51.41	U	2.	.1	4.2	80.7	.3	0.0
38	Rockcastle at Billows	PRI010	604	49.60	U	2.6	.1	17.1	65.6	.3	0.0
39	Horse Lick Creek near Lamero	PRI051	62	49.84	U	.9	0.0	6.8	83.1	0.0	0.0
40	Cumberland River at Calvin	PRI086	770	52.21	U	1.9	0.0	.4	85.8	.30	0.0
41	Clear Fork near Williamburg	PRI087	370	51.90	U	1.7	.1	4.3	81.3	.15	.13
42	Red River near Keysburg	PRI069	509	50.77	A	.6	51.8	23.9	16.6	.09	.01
43	Little River near Cadiz	PRI043	244	50.45	M	8.5	35.5	21.6	32.5	.4	.1
44	Pond River near Sacramento	PRI012	523	49.51	M	.7	13.6	12.5	60.2	.9	3.9
45	Rough River near Dundee	PRI014	757	50.33	U	.2	7.8	26.7	55.9	1.2	.2
46	Green River at Munfordville	PRI018	1,673	52.13	U	5.	5.4	32.3	52.7	1.1	0.0
47	Nolin River at White Mills	PRI021	357	50.23	A	2.5	25.3	40.	24.7	.4	0.0
48	Rough River near Livermore	PRI054	1,068	49.52	M	.4	11.2	22.8	55.9	.94	.75
49	Green River at Livermore	PRI055	6,431	51.43	U	.9	9.4	33.2	46.5	1.1	.5
50	Mud River near Gus	PRI056	268	50.93	U	.9	9.3	30.7	49.7	.4	.7

Appendix 1. Percent land use/land cover of watersheds represented by selected Kentucky Energy and Environment Cabinet–Kentucky Division of Water ambient water-quality network stations, 2001—Continued.

[KDOW, Kentucky Division of Water; mi^2, square miles;WV, West Virginia; S.F., South Fork; U, undeveloped; M, mixed; A, agriculture; <, less than; >, greater than]

Map reference number (table 1, figure 1)	KDOW station name	KDOW station number	Drainage area (mi^2)	Mean annual precipitation (inches)	Land-cover classification[1]	Percent land cover in 2001					
						Developed	Agriculture		Forested (Undeveloped)	Water	Wetland
							Row crop	Pasture			
51	Barren River at Woodbury	PRI072	1,968	52.12	A	1.3	11.1	40.4	37.4	.82	.07
52	Russell Creek near Bramlett	PRI077	289	52.26	M	.8	6.4	43.3	41.6	.48	0.0
53	Green River near Woodbury	PRI103	5,404	51.78	U	1.	8.9	35.7	45.2	.9	.1
54	Clarks River near Sharpe	PRI106	313	52.23	A	1.9	43.6	12.2	31.7	.15	3.0
55	Bayou de Chien near Moscow	PRI109	178	52.33	A	.3	48.5	14.9	23.2	.21	7.1

[1]Land-use/land-cover classifications

Agricultural	Greater than 50 percent agricultural land and less than or equal to 5 percent urban.
Urban	Greater than 25 percent urban and less than or equal to 25 percent agricultural land
Undeveloped	Less than or equal to 5 percent urban land and less than or equal to 25 percent agricultural land.
Mixed	All other combinations of urban, agricultural, and forested land.

Appendix 2. Regression equations and coefficients of determination (R^2) for load models used to estimate loads of total nitrogen for selected ambient water-quality monitoring stations in Kentucky, 1979–2004.

[USGS, U.S. Geological Survey; KDOW, Kentucky Division of Water; ln, natural logarithm; Q, centered streamflow, in cubic feet per second; sin, sine; cos, cosine; π, pi; dtime, centered decimal time; R^2 represents the amount of variance explained by the model. The Adjusted Maximum Likelihood Estimation method (requires normally distributed residuals) was used in developing all regression equations. Regression equations in bold-face type do not have normally distributed residuals, but contain censored data.]

Map reference number (table 1, figure 1)	USGS station number	KDOW station number	Number of water-quality observations	Total nitrogen regression equations	R^2 (percent)	Estimated residual variance[1]
1	03214500	PRI002	168	$0.66 + 1.30 \ln(Q) - 0.02 \ln(Q)^2 - 0.39 \sin(2\pi dtime) - 0.04 \cos(2\pi dtime) - 0.003 (dtime) - 0.01 (dtime)^2$	91	0.148
2	03213700	PRI003	41	$0.60 + 1.41 \ln(Q) - 0.23 \sin(2\pi dtime) + 0.12 \cos(2\pi dtime) + 0.10 (dtime)$	94	.139
3	03209500	PRI006	251	$1.57 + 1.12 \ln(Q) + 0.01 \ln(Q)^2 + 0.01 \sin(2\pi dtime) + 0.02 \cos(2\pi dtime) - 0.004 (dtime) + 0.002 (dtime)2$	93	.179
4	03215000	PRI064	96	$1.38 + 1.21 \ln(Q) - 0.06 \ln(Q)^2 - 0.15 \sin(2\pi dtime) - 0.07 \cos(2\pi dtime)$	94	.099
5	03212500	PRI094	37	$0.71 + 1.25 \ln(Q) + 0.02 \ln(Q)^2 - 0.13 \sin(2\pi dtime) - 0.05 \cos(2\pi dtime) + 0.02 (dtime) - 0.06 (dtime)^2$	94	.094
6	03210000	PRI096	42	$-1.55 + 1.22 \ln(Q) + 0.13 (dtime)$	88	.276
7	03217000	PRI048	181	$-1.51 + 1.12 \ln(Q) - 0.18 \sin(2\pi dtime) + 0.04 \cos(2\pi\pi dtime)$	96	.193
8	03216500	PRI049	161	$0.53 + 0.96 \ln(Q) + 0.07 \ln(Q)^2 - 0.11 \sin(2\pi dtime) + 0.07 \cos(2\pi dtime) + 0.03 (dtime)$	95	.104
9	03237250	PRI063	101	$3.63 + 1.14 \ln(Q) - 0.246 \sin(2\pi dtime) + 0.13 \cos(2\pi dtime)$	96	.286
10	03252500	PRI059	128	$0.33 + 1.25 \ln(Q) + 0.01 \ln(Q)^2 - 0.03 \sin(2\pi dtime) + 0.14 \cos(2\pi dtime)$	96	.249
11	03251400	PRI060	115	$3.74 + 1.13 \ln(Q) + 0.02 \ln(Q)^2 - 0.12 \sin(2\pi dtime) + 0.14 \cos(2\pi dtime)$	98	.290
12	03249500	PRI061	122	$0.164 + 1.14 \ln(Q)$	93	.197
13	03248640	PRI062	113	$1.57 + 1.24 \ln(Q) - 0.24 \sin(2\pi dtime) - 0.13 \cos(2\pi dtime)$	91	.259
14	03250190	PRI093	47	$-1.54 + 1.18 \ln(Q)$	91	.391
15	03253500	PRI112	44	$0.60 + 1.27 \ln(Q)$	93	.319
16	03291500	PRI022	143	$2.73 + 1.13 \ln(Q) + 0.02 \ln(Q)^2 - 0.15 \sin(2\pi dtime) + 0.09 \cos(2\pi dtime) - 0.02 (dtime)$	97	.231
17	03287500	PRI024	207	$1.97 + 1.16 \ln(Q) + 0.01 \ln(Q)^2 - 0.17 \sin(2\pi dtime) + 0.16 \cos(2\pi dtime) - 0.01 (dtime) + 0.002 (dtime)^2$	95	.120
18	03280000	PRI031	183	$0.13 + 1.28 \ln(Q) - 0.02 \ln(Q)^2 - 0.23 \sin(2\pi dtime) - 0.18 \cos(2\pi dtime) - 0.02 (dtime) + 0.002 (dtime)^2$	94	.138
19	03281000	PRI032	176	$-0.98 + 1.11 \ln(Q)$	93	.172
20	03281500	PRI033	193	$1.41 + 1.13 \ln(Q) - 0.01 \ln(Q)^2 - 0.20 \sin(2\pi dtime) - 0.01 \cos(2\pi dtime) - 0.001 (dtime) + 0.004 (dtime)^2$	92	.272
21	03285000	PRI045	169	$1.32 + 1.21 \ln(Q) - 0.01 \ln(Q)^2 - 0.18 \sin(2\pi dtime) + 0.06 \cos(2\pi dtime)$	97	.151
22	03283500	PRI046	153	$1.26 + 1.17 \ln(Q) - 0.32 \sin(2\pi dtime) - \cos(2\pi dtime)$	91	.231
23	03282300	PRI058	112	$1.04 + 1.11 \ln(Q)$	94	.126
24	03290500	PRI066	73	$2.22 + 1.13 \ln(Q) + 0.03 \ln(Q)^2 - 0.15 \sin(2\pi dtime) + 0.16 \cos(2\pi dtime)$	96	.077

Appendix 2. Regression equations and coefficients of determination (R^2) for load models used to estimate loads of total nitrogen for selected ambient water-quality monitoring stations in Kentucky, 1979–2004—Continued.

[USGS, U.S. Geological Survey; KDOW, Kentucky Division of Water; ln, natural logarithm; Q, centered streamflow, in cubic feet per second; sin, sine; cos, cosine; π, pi; dtime, centered decimal time; R^2 represents the amount of variance explained by the model. The Adjusted Maximum Likelihood Estimation method (requires normally distributed residuals) was used in developing all regression equations. Regression equations in bold-face type do not have normally distributed residuals, but contain censored data.]

Map reference number (table 1, figure 1)	USGS station number	KDOW station number	Number of water-quality observations	Total nitrogen regression equations	R^2 (percent)	Estimated residual variance[1]
25	03286500	PRI067	47	$1.68 + 0.90 \ln(Q)$	93	.128
26	03281100	PRI092	34	$-1.46 + 0.94 \ln(Q)$	63	.308
27	03289500	PRI098	49	$0.86 + 0.94 \ln(Q) + 0.09 \ln(Q)^2$	85	.245
28	03280600	PRI104	30	$1.86 + 1.14 \ln(Q) - 0.10 \ln(Q)^2 - 0.09 (dtime)$	97	.097
29	03298500	PRI029	251	$0.76 + 1.12 \ln(Q) + 0.01 \sin(2\pi dtime) + 0.22 \cos(2\pi dtime) - 0.02 (dtime)$	96	.138
30	03300400	PRI041	199	$3.02 + 1.15 \ln(Q) + 0.02 \ln(Q)^2 - 0.25 \sin(2\pi dtime) + 0.05 \cos(2\pi dtime) - 0.02 (dtime) + 0.003 (dtime)^2$	97	.272
31	03295400	PRI052	159	$1.03 + 1.26 \ln(Q) - 0.02 \ln(Q)^2$	96	.227
32	03301500	PRI057	123	$0.34 + 1.18 \ln(Q) - 0.16 \sin(2\pi dtime) + 0.09 \cos(2\pi dtime)$	97	.162
33	03298470	PRI100	28	$0.05 + 1.08 \ln(Q) - 0.28 \sin(2\pi dtime) + 0.02 \cos(2\pi dtime)$	96	0.129
34	03295890	PRI105	40	$0.18 + 1.49 \ln(Q) - 0.09 (dtime)$	94	.278
35	03414110	PRI007	211	$2.38 + 1.01 \ln(Q) + 0.04 \sin(2\pi dtime) - 0.12 \cos(2\pi dtime) - 0.01 (dtime)$	84	.108
36	03410500	PRI008	123	$1.18 + 1.17 \ln(Q) + 0.04 \ln(Q)^2 - 0.06 (dtime)$	77	.906
37	03404500	PRI009	246	$0.81 + 1.16 \ln(Q) - 0.03 (dtime)$	91	.186
38	03406500	PRI010	253	$0.93 + 1.10 \ln(Q) - 0.10 \sin(2\pi dtime) + 0.03 \cos(2\pi dtime) - 0.02 (dtime)$	93	.244
39	03405842	PRI051	183	$-3.84 + 1.08 \ln(Q)$	90	.238
40	03402900	PRI086	35	$-0.22 + 1.27 \ln(Q)$	93	.181
41	03403910	PRI087	33	$2.67 + 1.20 \ln(Q) - 0.06 \sin(2\pi dtime) - 0.25 \cos(2\pi dtime)$	95	.143
42	03435100	PRI069	38	$2.60 + 1.19 \ln(Q) + 0.21 \sin(2\pi dtime) - 0.15 \cos(2\pi dtime)$	95	.137
43	03438000	PRI043	159	$0.59 + 1.02 \ln(Q) + 0.13 \sin(2\pi dtime) - 0.03 \cos(2\pi dtime) + 0.01$	95	.109
44	03321060	PRI012	98	$-1.79 + 1.08 \ln(Q)$	92	.370
45	03319000	PRI014	231	$0.42 + 1.01 \ln(Q) + 0.12 \sin(2\pi dtime) -0.01 \cos(2\pi dtime) - 0.01 (dtime)$	94	.129
46	03308500	PRI018	212	$1.33 + 1.15 \ln(Q) + 0.01 \ln(Q)^2 + 0.14 \sin(2\pi dtime) - 0.06 \cos(2\pi dtime) + 0.003 (dtime) + 0.002 (dtime)^2$	96	.091
47	03310300	PRI021	221	$0.96 + 1.06 \ln(Q) - 0.04 \ln(Q)^2 + 0.05 \sin(2\pi dtime) - 0.04 (2\pi dtime)$	95	.129
48	03319880	PRI054	49	$0.69 + 1.05 \ln(Q) - 0.07 (dtime)$	95	.135

Appendix 2. Regression equations and coefficients of determination (R^2) for load models used to estimate loads of total nitrogen for selected ambient water-quality monitoring stations in Kentucky, 1979–2004—Continued.

[USGS, U.S. Geological Survey; KDOW, Kentucky Division of Water; ln, natural logarithm; Q, centered streamflow, in cubic feet per second; sin, sine; cos, cosine; π, pi; dtime, centered decimal time; R^2 represents the amount of variance explained by the model. The Adjusted Maximum Likelihood Estimation method (requires normally distributed residuals) was used in developing all regression equations. Regression equations in bold-face type do not have normally distributed residuals, but contain censored data.]

Map reference number (table 1, figure 1)	USGS station number	KDOW station number	Number of water-quality observations	Total nitrogen regression equations	R^2 (percent)	Estimated residual variance[1]
49	03316500	PRI055	118	$2.87 + 1.11\ln(Q) + 0.18\sin(2\pi dtime) - 0.01\cos(2\pi dtime)$	94	.109
50	03316275	PRI056	126	$0.68 + 1.15\ln(Q) - 0.06\ \ln(Q)^2 - 0.02\,(dtime)$	97	.114
51	03314500	PRI072	44	$1.74 + 1.07\ln(Q) + 0.08\ \ln(Q)^2 + 0.24\sin(2\pi dtime) + 0.02\cos(2\pi dtime) + 0.04\,(dtime)$	96	.100
52	03307000	PRI077	45	$0.96 + 1.46\ln(Q) - 0.07\ \ln(Q)^2$	94	.253
53	03315500	PRI103	43	$2.76 + 1.21\ln(Q) + 0.06\ \ln(Q)^2 + 0.11\sin(2\pi dtime) - 0.18\cos(2\pi dtime)$	93	.185
54	03610200	PRI106	32	$0.31 + 1.18\ln(Q) - 0.09\ \ln(Q)^2 + 0.29\sin(2\pi dtime) - 0.14\cos(2\pi dtime) + 0.07\,(dtime)$	97	.136
55	07024000	PRI109	32	$0.90 + 1.40\ln(Q) - 0.19\ \ln(Q)^2$	86	.430

[1]Estimated residual variance is the maximum likelihood estimation variance corrected for the number of observations, number of censored observations, and number of parameters in the regression model.

Appendix 3. Regression equations and coefficients of determination (R^2) for load models used to estimate loads of total phosphorus for selected ambient water-quality monitoring stations in Kentucky, 1979–2004.

[USGS, U.S. Geological Survey; KDOW, Kentucky Division of Water; ln, natural logarithm; Q, centered streamflow, in cubic feet per second; sin, sine; cos, cosine; π, pi; dtime, centered decimal time; R^2 represents the amount of variance explained by the model; The Adjusted Maximum Likelihood Estimation method (requires normally distributed residuals) was used in developing all regression equations. Regression equations in bold−face type do not have normally distributed residuals, but contain censored data.

Map reference number (table 1, figure 1)	USGS station number	KDOW station number	Total phosphorus regression equations	R^2 (percent)	Estimated residual variance[1]
1	03214500	PRI002	$-3.13 + 1.60 \ln(Q) + 0.004 \ln(Q)^2 - 0.63 \sin(2\pi dtime) - 0.31 \cos(2\pi dtime) - 0.08 (dtime) + 0.004 (dtime)^2$	75	0.750
2	03213700	PRI003	$-4.26 + 1.46 \ln(Q) + 0.22 \ln(Q)^2 - 0.54 \sin(2\pi dtime) - 0.42 \cos(2\pi dtime) + 0.12 (dtime) - 0.05 (dtime)^2$	85	.404
3	03209500	PRI006	$-4.06 + 1.20 \ln(Q) + 0.16 \ln(Q)^2 - 0.48 \sin(2\pi dtime) - 0.36 \cos(2\pi dtime) + 0.13 (dtime) + 0.06 (dtime)^2$	65	.786
4	03215000	PRI064	$-2.34 + 1.54 \ln(Q) + 0.03 \ln(Q)^2 - 0.44 \sin(2\pi dtime) - 0.21 (2\pi dtime) - 0.02 (dtime) + 0.01 (dtime)^2$	77	.608
5	03212500	PRI094	$-2.83 + 1.50 \ln(Q) - 0.49 \sin(2\pi dtime) - 0.48 \cos(2\pi dtime) + 0.14 (dtime)$	85	.301
6	03210000	PRI096	$-5.62 + 1.29 \ln(Q) + 0.16 \ln(Q)^2 - 0.15 \sin(2\pi dtime) - 0.50 \cos(2\pi dtime) + 0.24 (dtime)$	82	.580
7	03217000	PRI048	$-5.57 + 1.23 \ln(Q) + 0.04 \ln(Q)^2 - 0.52 \sin(2\pi dtime) - 0.49 \cos(2\pi dtime) - 0.02 (dtime)$	90	.602
8	03216500	PRI049	$-3.83 + 1.38 \ln(Q) + 0.07 \ln(Q)^2 - 0.29 \sin(2\pi dtime) - 0.21 \cos(2\pi dtime) - 0.02 (dtime)$	79	.900
9	03237250	PRI063	$-7.36 + 1.08 \ln(Q) - 0.29 \sin(2\pi dtime) - 0.27 \cos(2\pi dtime)$	90	.584
10	03252500	PRI059	$-2.77 + 1.29 \ln(Q) + 0.04 \ln(Q)^2 - 0.26 \sin(2\pi dtime) - 0.22 \cos(2\pi dtime) - 0.05 (dtime) + 0.01 (dtime)^2$	95	.337
11	03251400	PRI060	$-6.81 + 1.19 \ln(Q) + 0.04 \ln(Q)^2 - 0.53 \sin(2\pi dtime) - 0.29 \cos(2\pi dtime) - 0.04 (dtime) + 0.01 (dtime)^2$	96	.429
12	03249500	PRI061	$-2.96 + 1.27 \ln(Q) - 0.15 \sin(2\pi dtime) - 0.34 \cos(2\pi dtime)$	76	.899
13	03248640	PRI062	$-5.32 + 1.60 \ln(Q) + 0.19 \ln(Q)^2 - 0.47 \sin(2\pi dtime) - 0.61 \cos(2\pi dtime) + 0.04 (dtime)$	86	.688
14	03250190	PRI093	$-4.66 + 1.25 \ln(Q) + 0.06 \ln(Q)^2 - 0.41 \sin(2\pi dtime) - 0.24 \cos(2\pi dtime) + 0.10 (dtime) - 0.05 (dtime)^2$	91	.461
15	03253500	PRI111	$-1.97 + 1.43 \ln(Q) - 0.53 \sin(2pdtime) - 0.45 \cos(2\pi dtime)$	93	.379
16	03291500	PRI022	$-5.43 + 1.31 \ln(Q) + 0.04 \ln(Q)^2 - 0.70 \sin(2\pi dtime) - 0.12 \cos(2\pi dtime)$	94	.537
17	03287500	PRI024	$-0.80 + 1.40 \ln(Q) + 0.08 \ln(Q)^2 - 0.50 \sin(2\pi dtime) - 0.09 \cos(2\pi dtime) - 0.03 (dtime)$	87	.413
18	03280000	PRI031	$-3.87 + 1.55 \ln(Q) + 0.11 \ln(Q)^2 - 0.44 \sin(2\pi dtime) - 0.51 \cos(2\pi dtime) - 0.03 (dtime) + 0.01 (dtime)^2$	75	.896
19	03281000	PRI032	$-4.93 + 1.44 \ln(Q) + 0.13 \ln(Q)^2 - 0.12 \sin(2\pi dtime) - 0.22 \cos(2\pi dtime) - 0.02 (dtime) + 0.01 (dtime)^2$	85	.652
20	03281500	PRI033	$-5.57 + 1.33 \ln(Q) + 0.08 \ln(Q)^2 - 0.47 \sin(2\pi dtime) - 0.40 \cos(2\pi dtime) - 0.001 (dtime) + 0.01 (dtime)^2$	83	.729
21	03285000	PRI045	$-5.32 + 1.23 \ln(Q) + 0.01 \ln(Q)^2 - 0.64 \sin(2\pi dtime) - 0.50 \cos(2\pi dtime) - 0.04 (dtime) + 0.01 (dtime)^2$	90	.543
22	03283500	PRI046	$-5.00 + 1.32 \ln(Q) + 0.09 \ln(Q)^2 - 0.51 \sin(2\pi dtime) - 0.45 \cos(2\pi dtime) - 0.05 (dtime) + 0.01 (dtime)^2$	82	.600

Appendix 3. Regression equations and coefficients of determination (R^2) for load models used to estimate loads of total phosphorus for selected ambient water-quality monitoring stations in Kentucky, 1979–2004—Continued.

[USGS, U.S. Geological Survey; KDOW, Kentucky Division of Water; ln, natural logarithm; Q, centered streamflow, in cubic feet per second; sin, sine; cos, cosine; π, pi; dtime, centered decimal time; R^2 represents the amount of variance explained by the model; The Adjusted Maximum Likelihood Estimation method (requires normally distributed residuals) was used in developing all regression equations. Regression equations in bold−face type do not have normally distributed residuals, but contain censored data.

Map reference number (table 1, figure 1)	USGS station number	KDOW station number	Total phosphorus regression equations	R^2 (percent)	Estimated residual variance[1]
23	03282300	PRI058	$-2.92 + 1.53\ln(Q) + 0.13\ln(Q)^2 - 0.50\sin(2\pi dtime) - 0.40\cos(2\pi dtime) + 0.03(dtime) + 0.02(dtime)^2$	88	.445
24	03290500	PRI066	$-0.69 + 1.46\ln(Q) + 0.10\ln(Q)^2 - 0.50\sin(2\pi dtime) - 0.18\cos(2\pi dtime) + 0.06(dtime)$	88	.392
25	03286500	PRI067	$-0.89 + 1.34\ln(Q) - 0.74\sin(2\pi dtime) - 0.38\cos(2\pi dtime)$	85	.454
26	03281100	PRI092	$-4.81 + 0.79\ln(Q) + 0.18\sin(2\pi dtime) - 0.57\cos(2\pi dtime) + 0.18(dtime)$	64	.533
27	03289500	PRI098	$-1.65 + 0.82\ln(Q) + 0.27\ln(Q)^2$	65	.585
28	03280600	PRI104	$-5.28 + 1.04\ln(Q) - 0.07\sin(2\pi dtime) - 0.30\cos(2\pi dtime) + 0.10(dtime)$	94	.217
29	03298500	PRI029	$-1.59 + 1.20\ln(Q) + 0.08\ln(Q)^2 - 0.26\sin(2\pi dtime) - 0.11\cos(2\pi dtime) - 0.03(dtime) + 0.001(dtime)^2$	92	.305
30	03300400	PRI041	$-5.10 + 1.21\ln(Q) + 0.04\ln(Q)^2 - 0.59\sin(2\pi dtime) - 0.33\cos(2\pi dtime) - 0.01(dtime)$	97	.247
31	03295400	PRI052	$-3.25 + 1.19\ln(Q) + 0.04\ln(Q)^2 - 0.40\sin(2\pi dtime) - 0.18\cos(2\pi dtime) - 0.04(dtime) + 0.01(dtime)^2$	95	0.236
32	03301500	PRI057	$-2.28 + 1.31\ln(Q) + 0.04\ln(Q)^2 - 0.39\sin(2\pi dtime) - 0.34\cos(2\pi dtime) - 0.03(dtime) + 0.01(dtime)^2$	92	.463
33	03298470	PRI100	$-2.67 + 1.34\ln(Q) + 0.13\ln(Q)^2 - 0.42\sin(2\pi dtime) - 0.36\cos(2\pi dtime)$	97	.138
34	03295890	PRI105	$-1.88 + 1.10\ln(Q) + 0.12\ln(Q)^2 + 0.17(dtime)$	91	.325
35	03414110	PRI007	$-1.99 + 1.04\ln(Q) + 0.10\ln(Q)^2 - + 0.11\sin(2\pi dtime) + 0.05\cos(2\pi dtime) - 0.02(dtime) + 0.003(dtime)^2$	43	.892
36	03410500	PRI008	$-4.43 + 1.32\ln(Q) + 0.07\ln(Q)^2 - 0.29\sin(2\pi dtime) - 0.33\cos(2\pi dtime) - 0.07(dtime) + 0.01(dtime)^2$	85	.585
37	03404500	PRI009	$-2.67 + 1.56\ln(Q) + 0.05\ln(Q)^2 - 0.40\sin(2\pi dtime) - 0.24\cos(2\pi dtime) - 0.07(dtime) + 0.004(dtime)^2$	86	.584
38	03406500	PRI010	$-4.88 + 1.27\ln(Q) + 0.06\ln(Q)^2 - 0.30\sin(2\pi dtime) - 0.24\cos(2\pi dtime) - 0.04(dtime) + 0.003(dtime)^2$	88	.567
39	03405842	PRI051	$-7.54 + 1.10\ln(Q) + 0.06\ln(Q)^2 - 0.09\sin(2\pi dtime) - 0.26\cos(2\pi dtime) - 0.02(dtime)$	83	.377
40	03402900	PRI086	$-4.61 + 1.37\ln(Q) - 0.16\ln(Q)^2 - 0.18\sin(2\pi dtime) - 0.50\cos(2\pi dtime) - 0.17(dtime) + 0.19(dtime)^2$	75	.852
41	03403910	PRI087	$-5.73 + 1.11\ln(Q)$	91	.248
42	03435100	PRI069	$-3.31 + 1.11\ln(Q)$	80	.461
43	03438000	PRI043	$-3.29 + 1.18\ln(Q) + 0.10\ln(Q)^2 - 0.48\sin(2\pi dtime) - 0.28\cos(2\pi dtime) - 0.10(dtime) + 0.004(dtime)^2$	79	.491
44	03321060	PRI012	$-5.26 + 1.12\ln(Q) + 0.02\ln(Q)^2 - 0.23\sin(2\pi dtime) - 0.48\cos(2\pi dtime)$	87	.722

Appendix 3. Regression equations and coefficients of determination (R^2) for load models used to estimate loads of total phosphorus for selected ambient water-quality monitoring stations in Kentucky, 1979–2004—Continued.

[USGS, U.S. Geological Survey; KDOW, Kentucky Division of Water; ln, natural logarithm; Q, centered streamflow, in cubic feet per second; sin, sine; cos, cosine; π, pi; dtime, centered decimal time; R^2 represents the amount of variance explained by the model; The Adjusted Maximum Likelihood Estimation method (requires normally distributed residuals) was used in developing all regression equations. Regression equations in bold−face type do not have normally distributed residuals, but contain censored data.

Map reference number (table 1, figure 1)	USGS station number	KDOW station number	Total phosphorus regression equations	R^2 (percent)	Estimated residual variance[1]
45	03319000	PRI014	$-3.21 + 1.22 \ln(Q) + 0.08 \ln(Q)^2 - 0.06 \sin(2\pi dtime) - 0.37 \cos(2\pi dtime) - 0.01 (dtime) + 0.004 (dtime)^2$	85	.481
46	03308500	PRI018	$-2.05 + 1.22 \ln(Q) + 0.14 \ln(Q)^2 - 0.31 \sin(2\pi dtime) - 0.30 \cos(2\pi dtime) - 0.03 (dtime)$	75	.588
47	03310300	PRI021	$-2.71 + 0.98 \ln(Q) + 0.23 \ln(Q)^2 - 0.32 \sin(2\pi dtime) - 0.21 \cos(2\pi dtime)$	67	.500
48	03319880	PRI054	$-2.71 + 1.15 \ln(Q) + 0.11 \ln(Q)^2$	84	.590
49	03316500	PRI055	$-1.16 + 1.39 \ln(Q) + 0.18 \ln(Q)^2 - 0.12 \sin(2\pi dtime) - 0.23 \cos(2\pi dtime) - 0.03 (dtime) + 0.01 (dtime)^2$	82	.495
50	03316275	PRI056	$-4.25 + 1.32 \ln(Q) + 0.01 \ln(Q)^2 - 0.47 \sin(2\pi dtime) - 0.46 \cos(2\pi dtime) - 0.04 (dtime) + 0.02 (dtime)^2$	91	.355
51	03314500	PRI072	$-1.85 + 1.34 \ln(Q) - 0.18 \sin(2\pi dtime) - 0.57 \cos(2\pi dtime)$	79	.654
52	03307000	PRI077	$-4.90 + 1.61 \ln(Q) - 0.87 \sin(2\pi dtime) - 0.72 \cos(2\pi dtime)$	84	.697
53	03315500	PRI103	$-2.05 + 1.01 \ln(Q) + 0.18 (dtime)$	31	.807
54	03610200	PRI106	$-2.71 + 1.23 \ln(Q) - 0.06 \ln(Q)^2$	92	.263
55	07024000	PRI109	$-1.49 + 1.29 \ln(Q)$	92	.176

[1]Estimated residual variance is the maximum likelihood estimation variance corrected for the number of observations, number of censored observations, and number of parameters in the regression model.

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