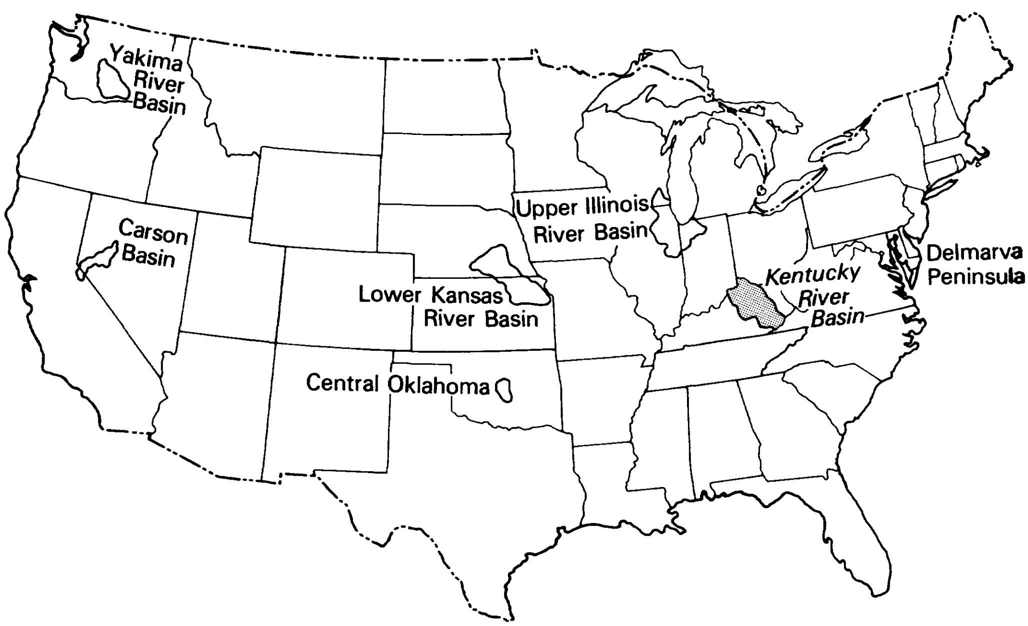
SURFACE WATER-QUALITY ASSESSMENT OF THE KENTUCKY RIVER BASIN, KENTUCKY: PROJECT DESCRIPTION

by K.D. White, J.L. Smoot, J.K. Jackson, and A.F. Choquette



U.S. GEOLOGICAL SURVEY
Open-File Report 87—234

1987

DEPARTMENT OF THE INTERIOR
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ABBREVIATIONS, CONVERSION FACTORS, AND GEODETIC DATUM

Abbreviations used in the tables

Abbreviation	Definition
mi^2	square mile
ft^3/s	cubic feet per second
$ft^3/s/mi^2$	cubic feet per second per square mile
mL	milliliters
mg/L	milligrams per liter
ug/L	micrograms per liter
deg. C	degrees Celsius
deg. F	degrees Fahrenheit
P-C units	platinum cobalt units

For use of those readers who prefer to use metric (International System) units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound units	By	To obtain metric units
inch	25.40	millimeter (mm)
foot	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
pound (lb)	0.4535	kilogram (kg)
acre	0.4047	hectare (ha)
gallon (gal)	3.785	liter (L)
cubic foot per second (ft^3/s)	28.32	cubic decimeter per second (dm^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
micromho (umho)	1.000	microsiemens (uS)

Temperature in degrees Fahrenheit can be converted to degrees Celsius as follows:

$$\text{deg. C} = (\text{deg. F} - 32)/1.8$$

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

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ABSTRACT

In April 1986, the U.S. Geological Survey began the National Water Quality Assessment Program to (1) provide a nationally-consistent description of the current status of water quality, (2) define water-quality trends that have occurred over recent decades, and (3) relate past and present water-quality conditions to relevant natural features, the history of land and water use, and land- and waste-management practices.

At present (1987), the National Water Quality Assessment Program is in a pilot phase, in which assessment concepts and approaches are being tested and modified to prepare for full implementation of the program in the future. Seven pilot projects (four surface-water projects and three ground-water projects) have been started. The preliminary plans for the surface-water-quality assessment of the Kentucky River basin pilot project are described in this report.

The Kentucky River basin drains an area of approximately 7,000 square miles in east-central Kentucky and is underlain by rocks that range in composition from limestone to sandstone and shale. Because greater than 95 percent of the basin population relies on surface water, surface-water quality is of great concern. Land-use practices that affect the surface-water quality in the basin include agriculture, forestry, oil and gas production, coal mining, and urbanization. Water-quality concerns resulting from the various land uses include the effects of: oil and gas field brine discharges; agricultural chemicals; sedimentation caused by coal mining; and trace-element impacts from industrial and urban environments.

Assessment activity is designed to occur over a 9-year period of time. During the first 3-year period of the cycle, concentrated data acquisition and interpretation will occur. For the next 6 years, sample collection will occur at a much lower level of intensity to document the occurrence of any gross changes in water quality. This 9-year cycle will then be repeated.

Historical data will be evaluated to provide, to the extent possible, a description of existing and past trends in water-quality conditions and to develop conceptual models that relate the observed conditions to the sources and causes, both natural and human-controlled. New data will be collected to verify the water-quality conditions documented by historic data, to track long-term trends in water quality, to intensify temporal and spatial sampling densities, and to improve the understanding of the relations between water-quality conditions and causative factors. Sampling activities that will be used for data acquisition include: fixed-location station sampling, synoptic sampling, and intensive-reach investigations. These activities will define both spatial and temporal trends in water quality, provide a baseline for future trend analysis, and relate water quality to relevant natural and human factors.

INTRODUCTION

Background

The continued growth and vitality of the Nation is linked to the maintenance of or improvement in the quality of its water resources. Public awareness of the importance of water quality has increased greatly in the past two decades. The Congress has passed such major pieces of legislation as the Clean Water Act, the Safe Drinking Water Act, the Resource Conservation and Recovery Act, the Toxic Substances Control Act, and the Comprehensive Environmental Response, Compensation, and Liability Act. State and local governments and industry have also made significant commitments to water-pollution abatement, particularly in regard to point-source discharges. Because of these combined efforts, it is perceived that the quality of the Nation's rivers and streams has improved significantly. This is true even though industrial activity and population have increased during the period with corresponding increases in water use and in the volume of wastes discharged. For example, 15 years ago, low dissolved-oxygen levels were common in rivers and streams because of the discharge of large volumes of oxygen-demanding wastes. Today, as a result of the construction of new waste-treatment facilities and the upgrading of existing facilities, the quality of effluents is much improved.

Despite progress, several water-quality issues still remain. Among them are the contamination of surface and ground water from nonpoint-source pollution, acid precipitation, and the disposal of hazardous waste. Cost-effective solutions to many of these problems will be more difficult because end-of-pipe treatment solutions are not always feasible and may involve changes in industrial processes or land-use practices. As a result, additional progress in water-quality improvement will require increased knowledge of the nature and extent of these problems as well as the physical, chemical, and biological processes affecting the water quality of surface and ground waters.

The National Water Quality Assessment Program

In April 1986 the U.S. Geological Survey began a National Water Quality Assessment (NAWQA) Program to: (1) provide nationally-consistent descriptions of the current status of water quality for a large, diverse, and geographically distributed part of the Nation's water resources; (2) where possible, define trends in water quality that have occurred over recent decades and provide a baseline for evaluating future trends in water quality; and (3) identify and describe the relations of both the status and the trends in water quality to the relevant natural factors and the history of land use and waste-management practices. This information will be useful for examining the likely consequences of future management actions.

For surface water, these study units would typically be the hydrologic subregions (watershed units defined by the Water Resources Council, of which there are 222 in the Nation). The program would focus on about 90 of these units, selected to account in aggregate for more than 80 percent of the surface-water withdrawals in the Nation but only about 40 percent of the land area.

At the proposed full-implementation level, the surface-water program would be conducted on a rotational basis with about one-third of the designated study units undergoing intense data acquisition and study at any one time. For any given study unit, there would be a 3-year period of concentrated data acquisition and interpretation. At the conclusion of the 3-year period, reports would be written and published which assess the quality of the water resource. These reports would describe frequency distributions of concentrations over space and time, provide estimates of mass balances of fluxes of constituents, give locations and descriptions of the problem areas and areas of high-quality water, and quantify cause-and-effect relations where possible. After this, the activity in the study unit would be maintained at a lower level for 6 years, to document any gross changes in water quality which may occur. While 60 study units operate at lower levels of activity, the major efforts would be centered in the other 30 study units, and the national level of effort would remain constant. In any given year the array of active study units would be widely dispersed around the Nation. After each 3-year active phase, the new data would be compared to those from previous active phases to identify and explain changes in water quality occurring in the study unit.

At present (1987) the NAWQA program is in a pilot phase. Assessment concepts and approaches will be tested and modified as necessary in preparation for possible full implementation of the program. The pilot program also provides an opportunity to evaluate the potential benefits and costs of a fully-implemented program. Seven pilot projects (four surface-water projects and three ground-water projects) have been started.

The Kentucky River Basin Project

The Kentucky River basin in Kentucky is one of the four surface-water pilot-study areas. Others include the Yakima River basin in Washington, the lower Kansas River basin in Kansas and Nebraska, and the Upper Illinois River basin in Illinois, Indiana, and Wisconsin. The Kentucky River basin was selected as a pilot-study area because of its variety of land uses, including agriculture, oil and gas production, coal mining, forestry, and urbanization. In addition, most of the basin population derives its drinking water supply from the Kentucky River or its tributaries. To achieve the National goals and objectives, the national plan of study has been adapted to the hydrologic and land-use conditions of the Kentucky River basin.

Specific objectives of the pilot study in the Kentucky River basin are to: (1) define the existing water-quality conditions, (2) determine trends (spatial and temporal) in water quality, (3) define the average annual constituent transport, and (4) identify stream segments where water quality may be impacted adversely by natural processes or human activities.

Purpose and Scope

This is the first report from the Kentucky River basin pilot study. The purpose and scope of this report are to: (1) describe the study area, (2) summarize the water-quality conditions, data collection activities, and the water-quality issues, and (3) describe the general approach of the Kentucky River basin water-quality assessment.

DESCRIPTION OF THE BASIN

The Kentucky River flows through east-central Kentucky and drains an area of about 7,000 square miles (fig. 1). The river originates in the uplands of southeast Kentucky and flows northwestward through the central part of the State to its junction with the Ohio River at Carrollton in north-central Kentucky. The main stem of the Kentucky River, including the North Fork, is about 405 miles long. Other major tributaries of the Kentucky River include the Middle and South Forks, Red River, Dix River, Elkhorn Creek, and Eagle Creek. Principal municipalities, in downstream order, are: Hazard, Richmond, Danville, Lexington, Georgetown, Frankfort, and Carrollton. The Kentucky River drains all or parts of 39 of the State's 120 counties (fig. 1).

Physiography, Geology, and Soils

The Kentucky River basin is in several physiographic regions: the Bluegrass (Inner and Outer), the Knobs, and the Eastern Coal Field (fig. 2). Each of these regions is distinct and represents the variation in underlying geology. The variation in soil type, land use, population distribution, surface water features, and the prevailing water-quality characteristics and issues are largely attributable to the physiographic and geologic features.

The Kentucky River basin is underlain by indurated sedimentary rocks of the Paleozoic age. As seen in figure 3, exposed rocks range in stratigraphic sequence from the Middle Ordovician to the Pennsylvanian Systems (McFarlan, 1943). Numerous faults cross the Kentucky River and its tributaries. The principal fault, known as the Kentucky River Fault is responsible for the directional character of the river in the middle part of the basin. Except for the Bluegrass Region, the overburden in the basin is relatively shallow.

Inner Bluegrass region

The north-central part of the basin lies within the Inner Bluegrass region. This region is a gently rolling upland underlain by thick-bedded limestone in which the Kentucky River and some of its tributaries are entrenched more than 350 feet. The limestone of the Inner Bluegrass has been subjected to considerable weathering by solution, both on and beneath the surface to produce an extensive area of karst topography. As a result, a significant part of the drainage occurs through the subsurface. The karst topography is dotted with sinkholes, some as large as 60 feet deep and one square mile in area. Elkhorn Creek is the only major tributary located entirely within the Inner Bluegrass region.

The Inner Bluegrass soils developed from high-phosphate limestones of Ordovician age. These soils have good drainage characteristics and are especially well suited to burley tobacco and grassland production. The principal soil series are Maury soils, found on gentler slopes, and McAfee soils, located on steeper slopes and around areas of karst topography. These soils are moderately deep and consist of a silt loam surface layer and a clayey subsoil (U.S. Department of Agriculture, 1983).

Surface altitude in the Inner Bluegrass region ranges from about 800 to 1,000 feet above sea level. Average slope of the Kentucky River in this region is

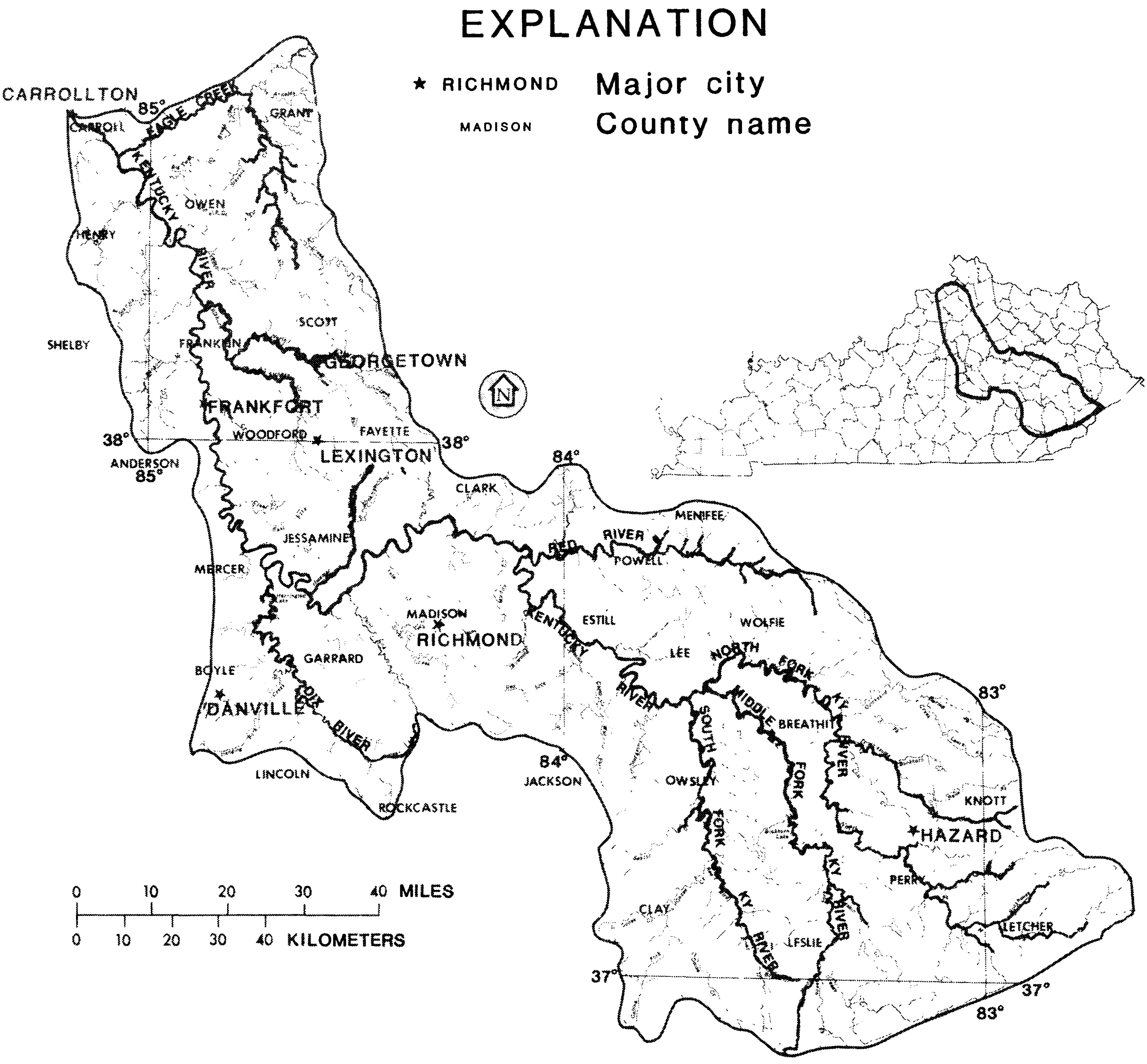

Figure 1.--Kentucky River basin.

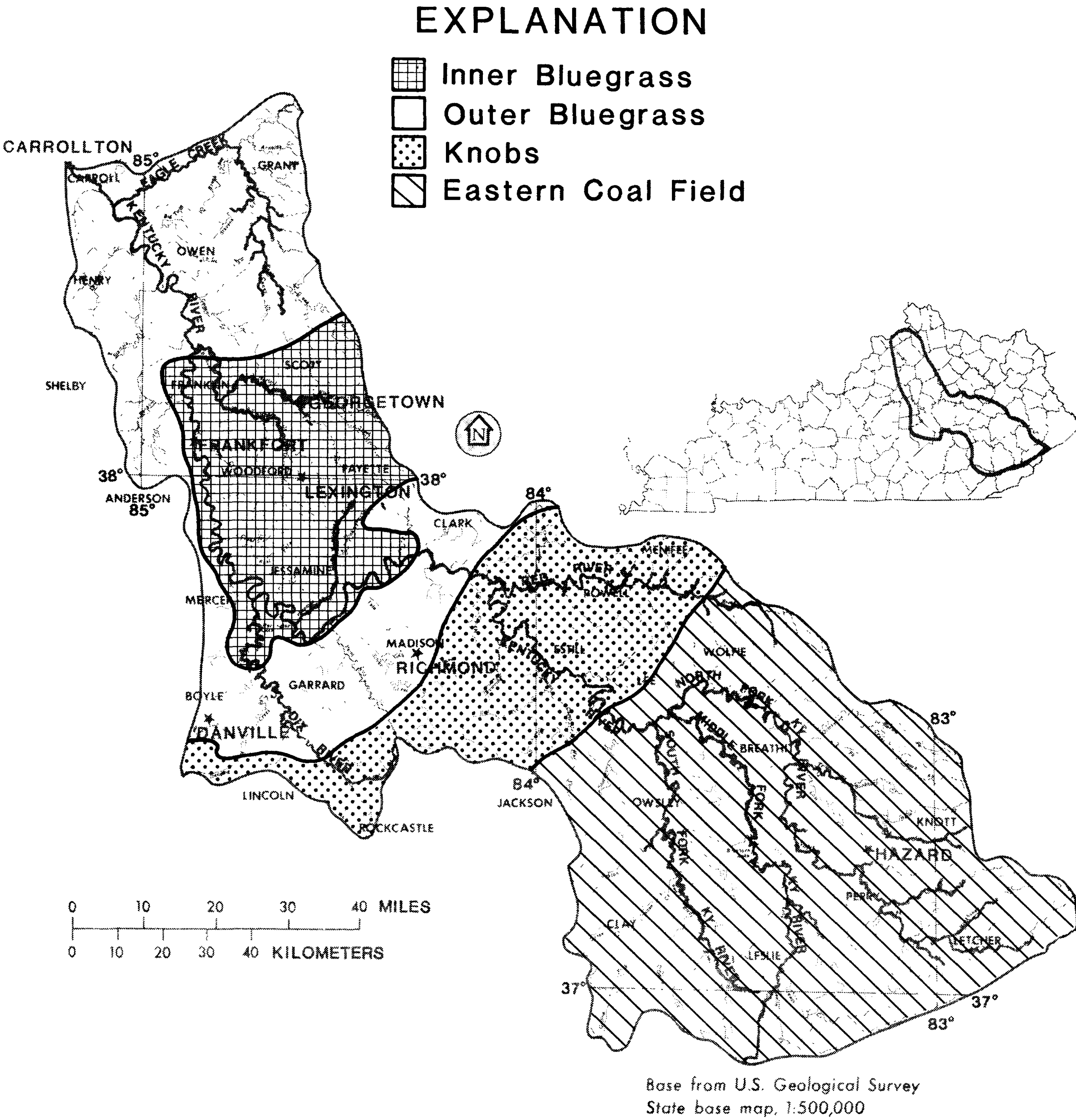

Figure 2.--Physiographic regions of the Kentucky River basin (U.S. Department of Agriculture, 1981).

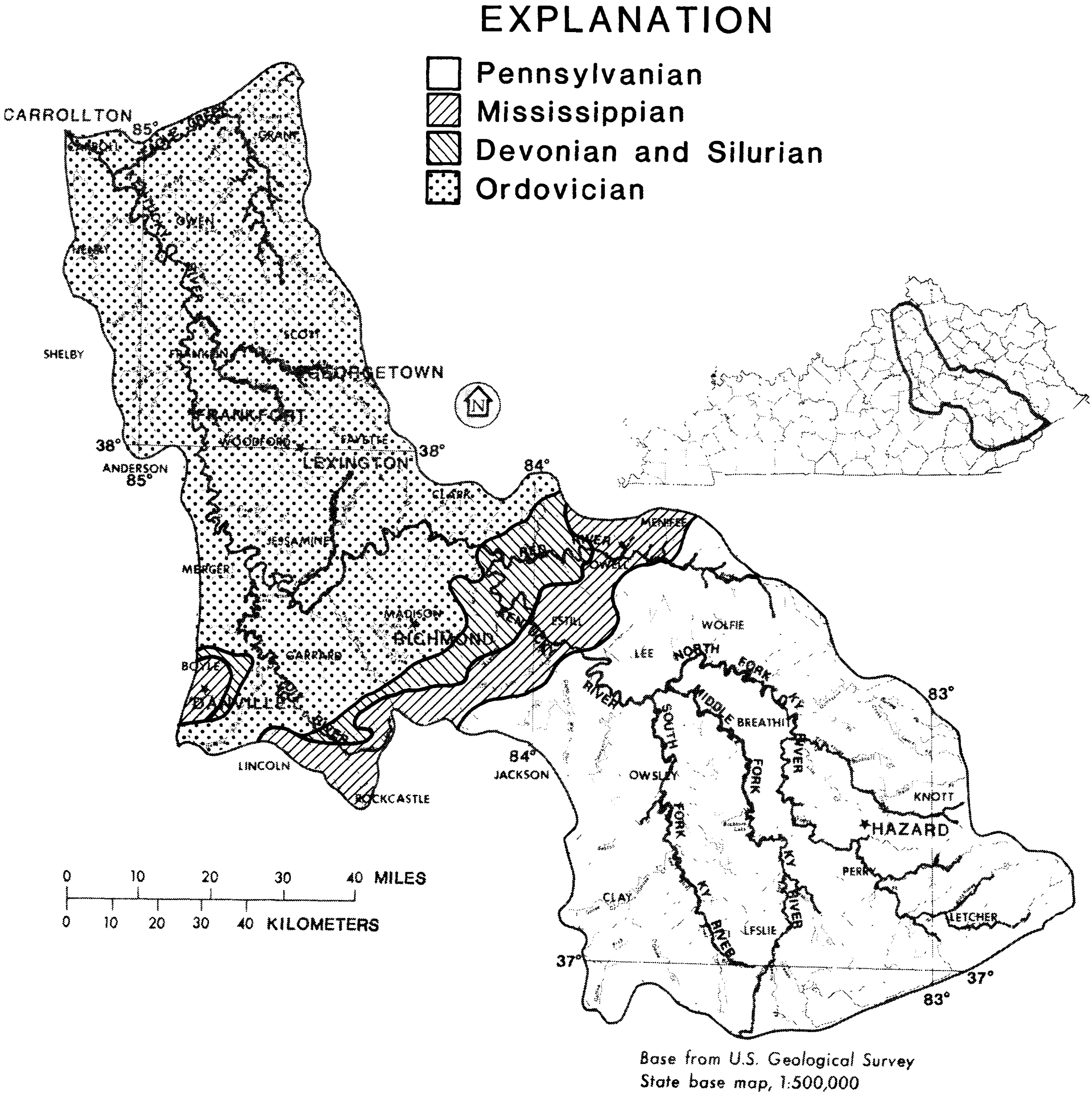

Figure 3.--Generalized geology of the Kentucky River basin (Modified from Kentucky Geological Survey, 1979).

approximately 0.7 feet per mile (Kentucky Department of Natural Resources and Environmental Protection, 1975).

Outer Bluegrass region

The northern half of the basin not included in the Inner Bluegrass region lies within the Outer Bluegrass region (fig. 2). The Outer Bluegrass region is underlain by thin-bedded limestones that include considerable interbedded shale (McFarlan, 1943, p. 172). Topography in this region resembles that of the Inner Bluegrass except near streams, where it is dissected and rugged. Some surface and subsurface solution has occurred and small sinkholes are fairly common, but most of the drainage is on the surface. Eagle Creek and the Dix River are major tributaries draining the Outer Bluegrass region.

Soils in the Outer Bluegrass region developed from weathered Ordovician limestone and, in places, from an overlying loess mantle. These soils range in depth from shallow to deep and are moderately drained. The principal soil series are Lowell, Shelbyville, and Fairmont. All the soils in the region are generally suited to farming (U.S. Department of Agriculture, 1975).

Surface altitudes in the Outer Bluegrass typically range from 800 to 1,000 feet above sea level. The Kentucky River is deeply entrenched through this region; normal river altitudes range from about 420 feet at Carrollton to about 580 feet above sea level near Richmond. The steepest slopes of most tributaries in the Outer Bluegrass region are where the streams drop down to the Kentucky River from the upland areas. The average slope on the main stem in the Outer Bluegrass region is 0.7 feet per mile (Kentucky Department for Natural Resources and Environmental Protection, 1975).

Knobs region

The Knobs region forms a crescent separating the Bluegrass regions from the Eastern Coal Field region. This region is named for its characteristic conical and flat-topped hills. These characteristic hills, which are erosional remnants, are comprised of sandy limestone and sandstone caprock over shales. The Red River drains a major part of the Knobs region. No major urban areas are located within this region.

Soils on hillsides in the Knobs region developed from shales and sandstones of Mississippian and Devonian ages. The Rockcastle and Coyler series, which are shallow, clayey soils that have developed in acid shale residuum on steep slopes, predominate. Soils in the valleys of the Knobs region are poorly drained because of the presence of a dense, subsurface layer of compacted silt (U.S. Department of Agriculture, 1975).

Eastern Coal Field region

The Eastern Coal Field region, in the southeastern part of the basin, is a very rugged, dissected area consisting of narrow valleys and narrow, steep-sided ridges. Rocks of the region are mainly sandstone, siltstone, and shale with numerous interbedded coal beds. Major tributaries draining this region include the North, South, and Middle Fork Kentucky River. Hazard is the only major urban area in this region. Mountain-top altitudes in the Eastern Coal

Field region range from about 1,000 feet to 3,273 feet above sea level. Average slope of tributaries in this region ranges from about 3 to 7.2 feet per mile, and the slope of the main stem averages about 0.9 feet per mile (Kentucky Department for Natural Resources and Environmental Protection, 1975).

Soils in the Eastern Coal Field are formed from siltstones, sandstones, and shales. The most prevalent soil series are Shelocta, Jefferson, and Brookside, which are deep, well-drained soils located toward the base of the mountain sides and on benches (U.S. Department of Agriculture, 1975).

Land Use

The Kentucky River basin has five major land uses: forestry, agriculture, coal mining, oil and gas production, and urbanization. Within each land use area are scattered or concentrated areas of commercial and industrial activity. The distribution of these land uses and their relative locations is shown in figure 4.

Forests comprise just over 50 percent of the basin land area, and the largest are in the more rugged parts of the Eastern Coal Field region. The Kentucky River basin is in or near the prime range of many of the most prominent hardwood timber species. Hardwoods constitute over 90 percent of the timber volume. An assortment of pines and eastern red cedar comprise the non-hardwood species. Hickory and poplar are the most prevalent forest tree species, each comprising about 13 percent of the growing stock (U.S. Department of Agriculture, 1981).

Nearly 40 percent of the basin is used for agricultural purposes (U.S. Department of Agriculture, 1981). Farming is concentrated in the Inner and Outer Bluegrass regions, but some farming takes place in the limited level areas and hollows of the Eastern Coal Field region of the basin. Tobacco, livestock, and corn are the dominant enterprises. Of the three, tobacco occupies the least land area, but it is generally the highest valued crop. Soy beans and wheat also are grown in parts of the basin, but usually in small quantities.

Mining of bituminous coal, both at the surface and underground, is a significant land-use activity in the Eastern Coal Field region of the Kentucky River basin. Kentucky is the Nation's largest coal producing State and out-distances its nearest state rival by 29 million tons. In 1985, 23 percent of the 170 million tons of coal mined in the State was produced in counties within the Kentucky River basin. Of the total produced, 55 percent was from underground mines (Stanley, 1985). Perry, Breathitt, Knott, Leslie, and Letcher Counties account for 93 percent of the basin's coal production. It is estimated that when market demand is high, there are more than 1,200 active mines in these counties, employing some 13,500 people. In addition to the active mines, there are an estimated 41,000 acres of former surface mines in the basin. Geological studies indicate that the coal reserves in the area approach 3.4 billion tons (U.S. Department of Agriculture, 1981).

Production of oil and gas is a major activity in parts of the Knobs and Eastern Coal Field regions, particularly in Lee, Letcher, Estill, and Powell Counties (fig. 1). About one million barrels of oil were extracted from the basin in 1980 (Stanley, 1980). Annual oil production in the State of Kentucky

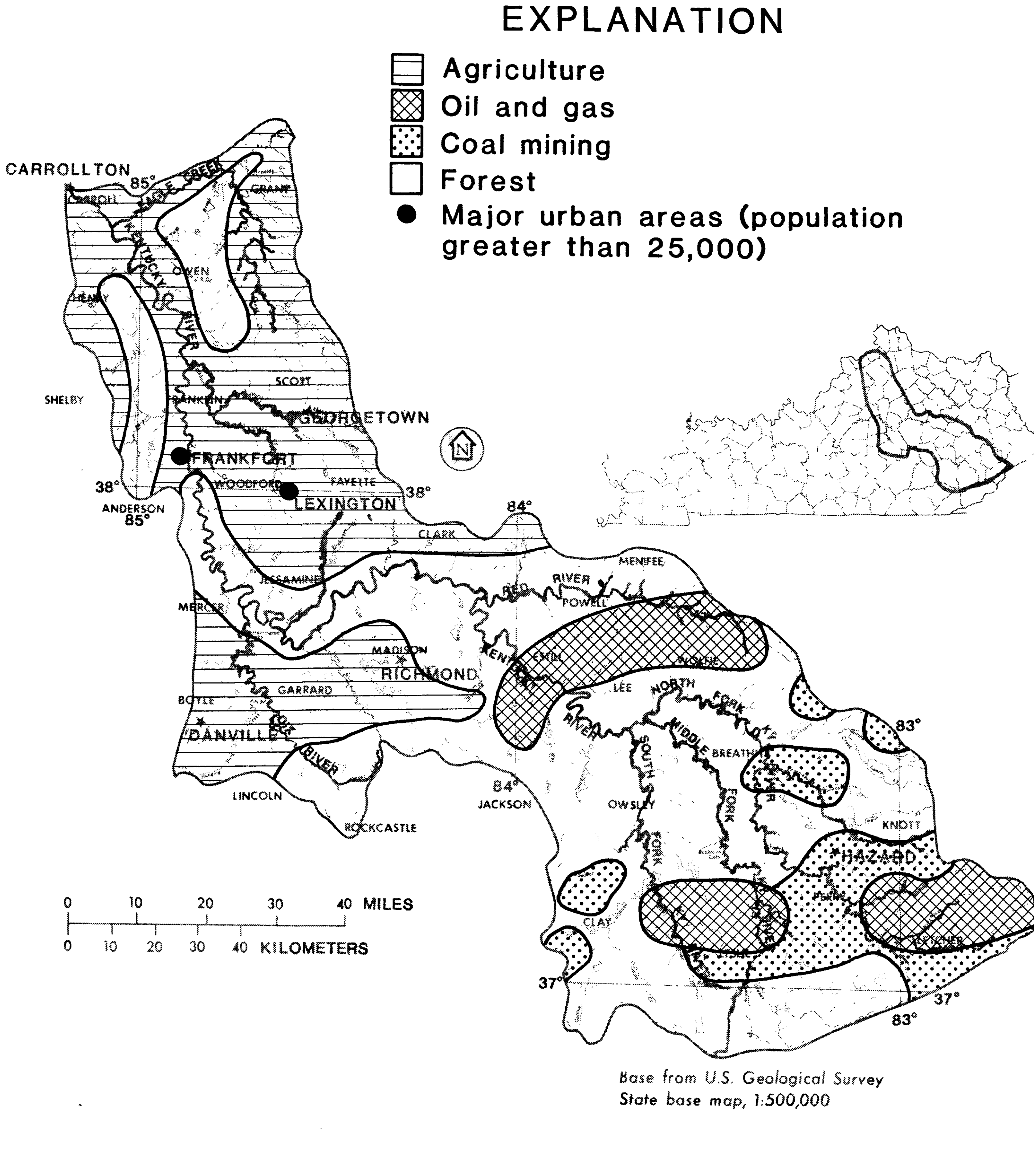

Figure 4.--Land use in the Kentucky River basin (U.S. Department of Agriculture, 1981).

approached 6.5 million barrels in 1981 representing 0.2 percent of the nation's total production (Kentucky Natural Resources and Environmental Protection Cabinet, 1984). Production of natural gas in Kentucky was about 63 billion cubic feet in 1981, or 0.33 percent of that produced nationally (Kentucky Natural Resources and Environmental Protection Cabinet, 1984).

As of 1980, approximately 632,000 people resided in the Kentucky River basin (U.S. Department of Commerce, 1982). Approximately 54 percent of the basin population resides in urban centers defined as having a population of at least 2,500 people (U.S. Department of Commerce, 1982). Urban centers are more numerous in the Inner and Outer Bluegrass regions, and they include Lexington, Frankfort, Carrollton, Georgetown, Danville, and Richmond (fig. 1). The city of Hazard is an urban center located in the sparsely populated Eastern Coal Field region.

Surface-Water Features

The Kentucky River hydrologic system drains about 7,000 square miles and consists of about 3,500 stream miles (U.S. Geological Survey hydrologic unit map, Kentucky, 1:500,000, 1974). Because many streams in the Inner and Outer Bluegrass regions flow through karst terrane, surface-water/ground-water interaction is significant. The underlying limestone of these regions is highly susceptible to solution, thus making sinking and rising streams a common occurrence. As of 1985, the Survey maintained 20 active surface-water stations on streams within the Kentucky River basin (fig. 5). Stream discharge and stage information are routinely monitored at these stations. Typical stream-flow characteristics at selected stations in the Kentucky River basin are given in table 1.

The navigation system on the Kentucky River involves 14 locks and dams which provide for a minimum water depth of 6.0 feet from a point just downstream of the confluence of the North, Middle, and South Forks of the Kentucky River to the mouth at Carrollton. Currently, these locks and dams are maintained by the State of Kentucky and operated on a seasonal basis for commercial and recreational traffic.

There are no significant natural lakes in the Kentucky River basin. Many man-made reservoirs have been constructed in the basin to help meet varied water-supply needs and to protect against floods. There are 15 reservoirs in the basin with a volume greater than 1,000 acre-feet or surface area greater than 100 acres (Kentucky Department for Natural Resources and Environmental Protection Cabinet, 1975). These 15 reservoirs have a total combined volume of 286,000 acre-feet and a total combined surface area of 10.2 square miles (Kentucky Department for Natural Resources and Environmental Protection, 1975).

Three reservoirs, shown in figure 6, comprise approximately 75 percent of the total reservoir surface area: Herrington, Buckhorn, and Carr Fork (Kentucky Department for Natural Resources and Environmental Protection, 1975). Buckhorn reservoir (21,800 acre-feet) and Carr Fork reservoir (6,480 acre-feet) are regulated by the U.S. Army Corps of Engineers to meet flood, recreation, fish and wildlife, and low-flow augmentation objectives (U.S.

EXPLANATION

▲ Gaging station

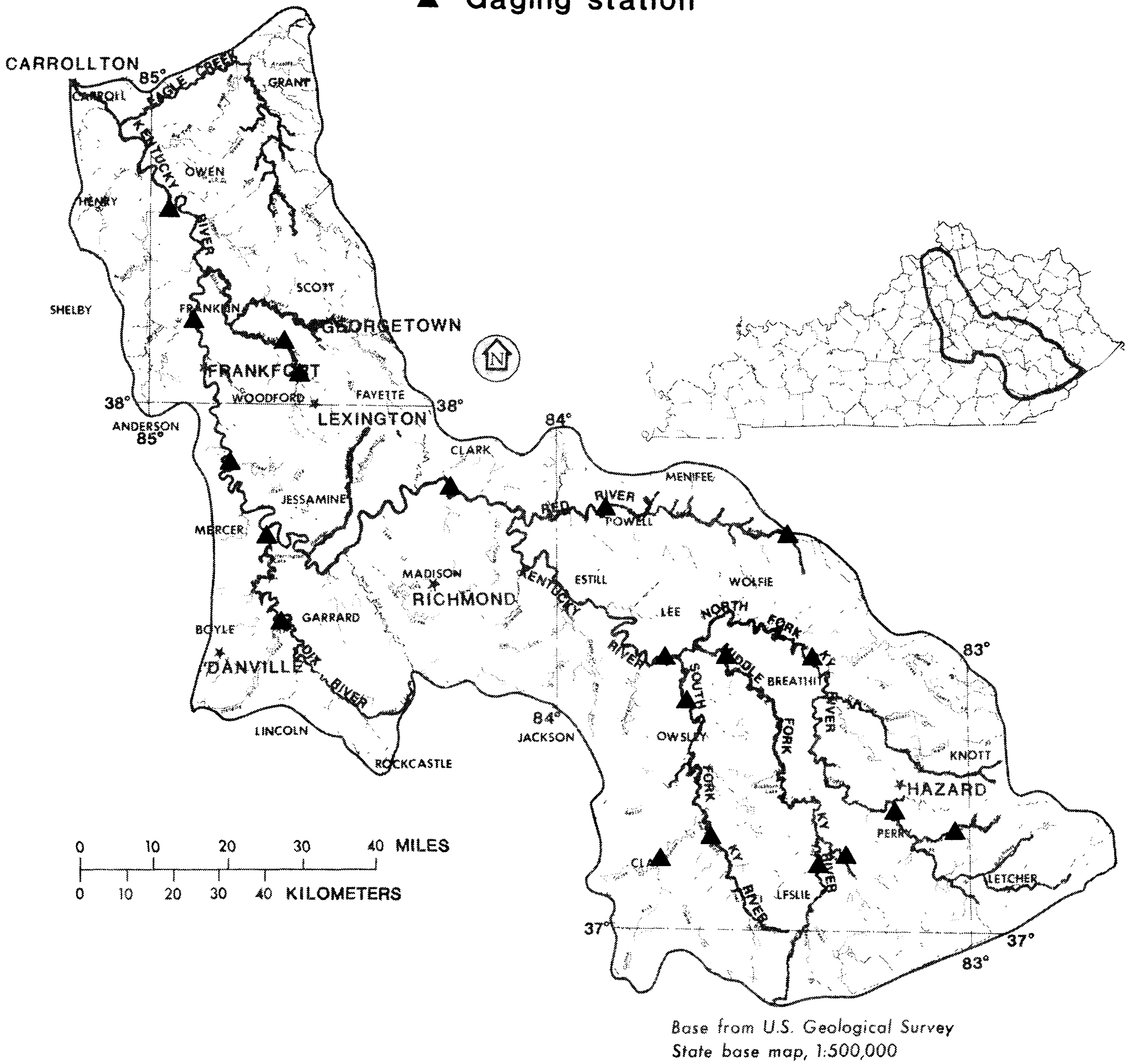

Figure 5.--Surface water gaging stations in the Kentucky River basin, 1984.

Table 1.--Streamflow characteristics at selected stations in the Kentucky River basin

[Units: mi², square miles; ft³/s, cubic feet per second; [(ft³/s)/mi²], cubic feet per second per square mile]

Station	Period of record	Drainage area (mi²)	Average discharge (ft³/s)	7-day 10-year low flow (ft³/s)	Average specific discharge [(ft³/s)/mi²)]
North Fork Kentucky River at Jackson (03280000)	1928-31 1938-82	1,101	1,360	3.1	1.24
Middle Fork Kentucky River at Tallega (03281000)	1931-32 1940-82	537	730	0.6	1.36
South Fork Kentucky River at Booneville (03281500)	1925-31 1940-82	722	1,060	1.1	1.47
Kentucky River at Lock 14, Heidelberg (03282000)	1926-31 1938-82	2,660	3,640	22.0	1.37
Red River at Clay City (03283500)	1931-32 1938-82	362	483	3.7	1.33
Dix River at Danville (03285000)	1943-82	318	468	0.0	1.47
Kentucky River at Lock 4, Frankfort (03287500)	1926-82	5,410	7,110	175.0	1.31
Elkhorn Creek near Frankfort (03289500)	1915-18 1940-82	473	609	6.5	1.29
Kentucky River at Lock 2, Lockport (03290500)	1926-82	6,180	8,320	206.0	1.35

source: Melcher and Ruhl, 1984.

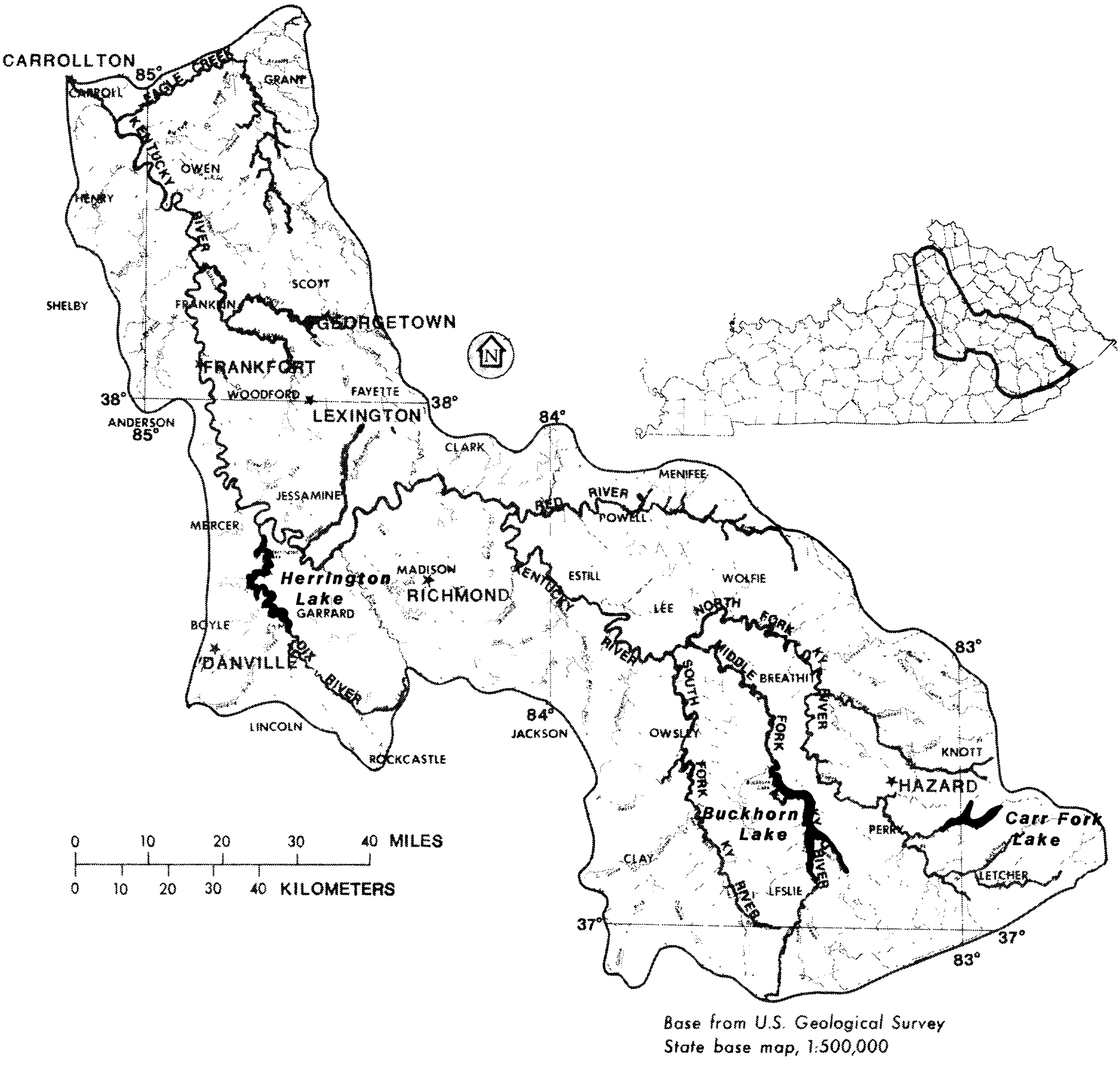

Figure 6.--Major lakes in the Kentucky River basin.

Army Corps of Engineers, 1981). Herrington reservoir (230,500 acre-feet) is maintained and operated by a private utility for use in the generation of electric power for public consumption. Herrington reservoir is also used as a public water supply by the City of Danville and the Kentucky State Hospital. The reservoir contains a usable storage volume of 123,200 acre-feet, covers 3.62 square miles, and impounds 439 square miles of the Dix River Basin (U.S. Department of Agriculture, 1981).

Water Use

The Kentucky River and its tributaries are used extensively for municipal and industrial water supply, recreation, propagation of fish and wildlife, and municipal and industrial waste discharge and assimilation. Surface water from the Kentucky River, its tributaries, and Herrington reservoir provide more than 95 percent of the public water supply in the basin. The basin itself is the most densely populated river basin in Kentucky and is projected to be the area of most growth in the future.

In 1985, an estimated 98 billion gallons of water were withdrawn from the Kentucky River and its tributaries for domestic, agricultural, industrial, and thermo-electric power production uses (Sholar, U.S. Geological Survey, written commun., 1987). Annual surface-water use in the basin (1985) exceeded the flow of the Kentucky River about 4 percent of the time, based on flow duration near the river mouth (Quinones and others, 1980). Currently (1986), 20 municipalities use the Kentucky River for public water supply. The largest of these municipalities are Lexington (population 204,000), Frankfort (population 26,000), Richmond (population 21,700), and Winchester (population 15,200). Figure 7 shows the surface-water withdrawal points within the basin, and figure 8 shows the relative amounts of surface water used for various purposes in the Kentucky River basin.

Climate

Mean-annual air temperature in the Kentucky River Basin is 56 degrees Fahrenheit. The coldest months are January and February, during which daily minimum temperatures average 25 degrees Fahrenheit; the warmest months are July and August, during which daily-maximum temperatures average 87 degrees Fahrenheit (U.S. Department of Agriculture, 1981).

The growing season, which is defined as the last damaging frost in the spring to the first one in the fall, averages 184 days. The last frost is usually in April and the first is in October.

Annual precipitation in the basin averages about 46 inches and ranges from 40 inches in the northern part of the basin to 48 inches in the southern part (Elam and others, 1972). The monthly distribution of precipitation is fairly uniform with October usually having the least amount and March the largest amount (Conner, 1982). Snowfall varies widely, with an average season usually having about 14 days with one or more inches of snowcover on the ground. Thunderstorms occur about 48 days a year on average, but are more frequent in the spring and summer.

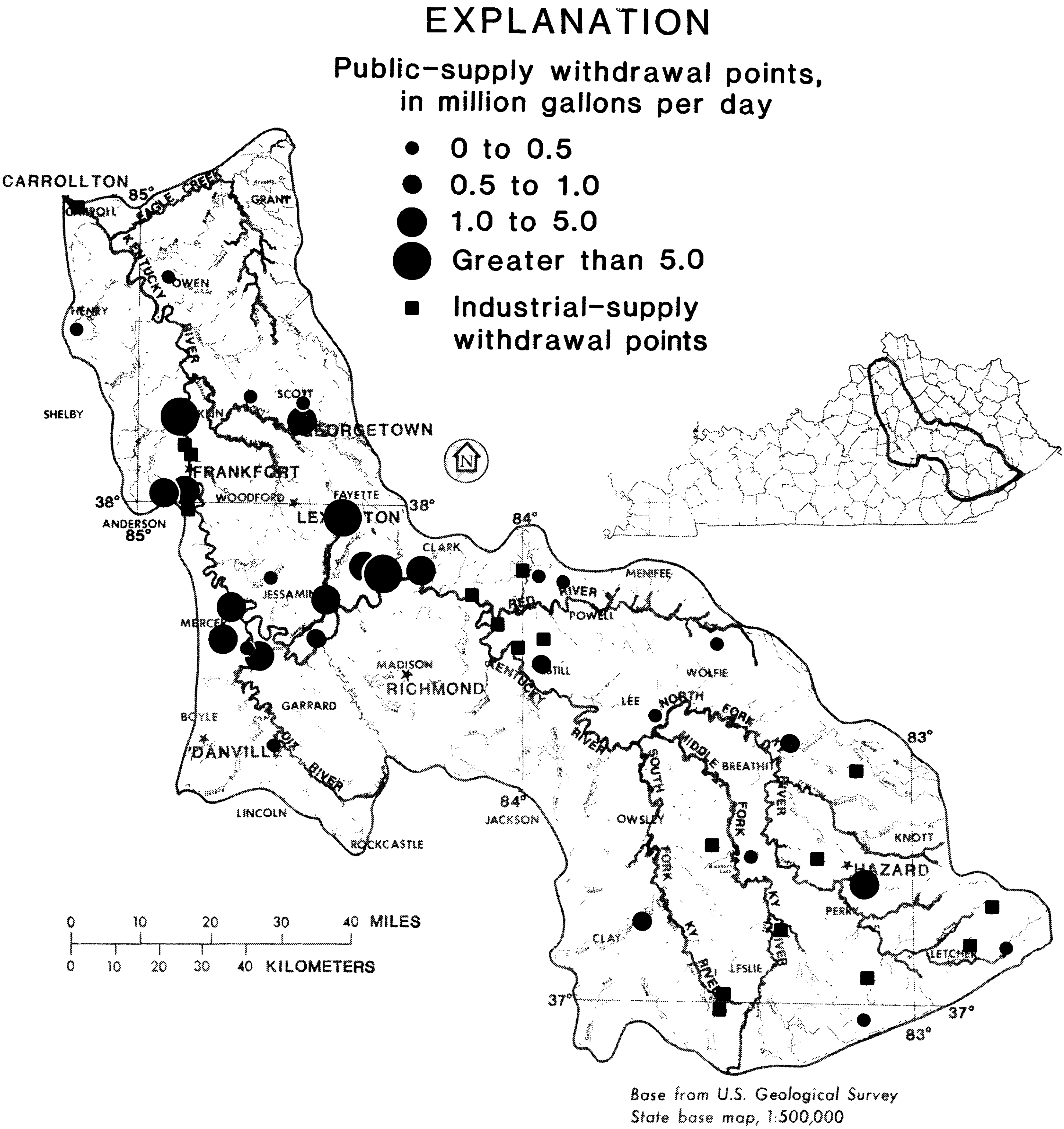

Figure 7.--Public and industrial surface water supply withdrawals in the Kentucky River basin, 1985 (Kentucky Department for Natural Resources and Environmental Protection, 1985).

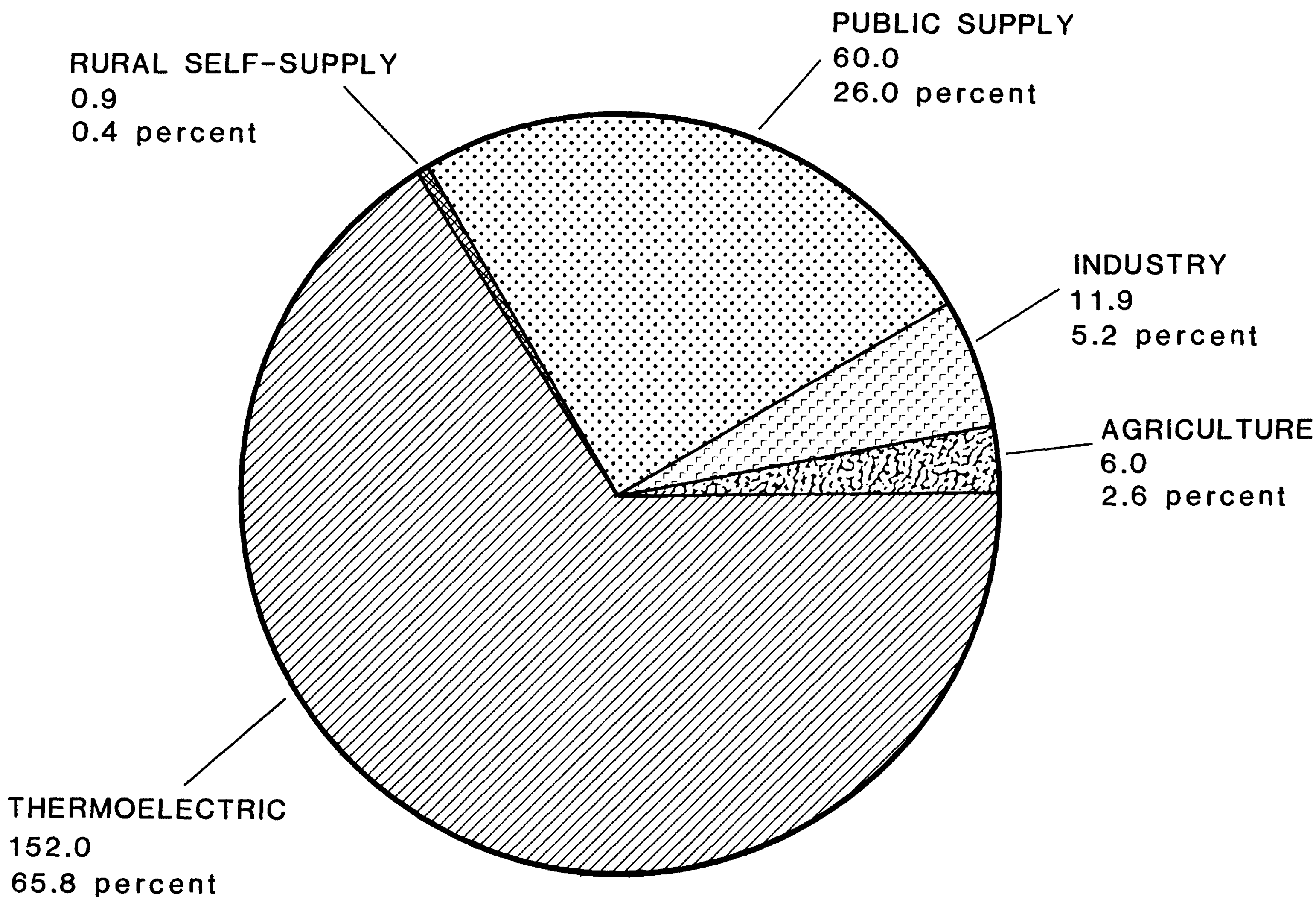

Figure 8.--Surface-water use (in million gallons per day) in the Kentucky River basin (Kentucky Department for Natural Resources and Environmental Protection, 1985).

Variations in the water budget occur seasonally and throughout the basin. Approximately 63 percent of the 46 inches of annual precipitation returns to the atmosphere through evaporation and transpiration, about 28 percent runs off the surface directly into streams, and about 9 percent enters the ground (Kentucky Department for Natural Resources and Environmental Protection, 1975). During the summer months, evapotranspiration tends to be higher in the forested headwater region of the basin than in the agricultural areas of the Bluegrass. Within the basin, there is also a considerable difference in the amount of rainfall runoff and the amount of recharge to the ground-water system. Runoff is higher in the mountains of the Eastern Coal Field than it is in the more rolling Inner and Outer Bluegrass regions. In the karst areas of the Bluegrass regions, a significant amount of rainfall enters the ground water through numerous sinkholes (Kentucky Department for Natural Resources and Environmental Protection, 1975).

Surface-Water Classifications and Standards

All surface waters in the State of Kentucky have been assigned an aquatic life use (either warmwater or coldwater aquatic habitat) and a recreational use (primary and secondary contact recreation) by the Kentucky Natural Resources and Environmental Protection Cabinet, Division of Water. In addition, part of the Red River, a tributary of the Kentucky River, is classified as an outstanding resource water (Kentucky Natural Resources and Environmental Protection Cabinet, 1986). Table 2 lists the use classifications for specific streams or stream reaches in the Kentucky River basin. Streams or stream reaches not specifically listed in table 2 are designated for the use of warmwater aquatic habitat, primary contact recreation, secondary contact recreation, and domestic water supply.

Surface-water-quality criteria adopted by the State of Kentucky are defined as the minimum criteria which apply to all surface waters to protect public health and welfare, protect and enhance the quality of water, and fulfill Federal and State requirements for the establishment of water-quality standards. Table 3 lists the surface-water-quality criteria by category, as adopted by Kentucky and approved by the U.S. Environmental Protection Agency.

WATER QUALITY IN THE BASIN

Data-Collection Activities

Current knowledge of the water-quality characteristics (physical, chemical, and biological) of the Kentucky River basin has been developed over a period of many years from data collected by a variety of organizations for numerous purposes. The Survey has operated 33 continuous streamflow gaging stations within the basin for many years, some since 1901. Generally, stage and(or) discharge are determined for each station. In addition, many miscellaneous stage and discharge measurements, as well as temperature and specific conductance measurements, have been made at numerous locations throughout the basin. The Survey also has performed several site-specific investigations within the Kentucky River basin, including those associated with its Coal Hydrology Program. Several cooperative studies at specific locations within the basin have included water-quality components.

Table 2. Stream-use classifications in the Kentucky River basin

WAH - Warmwater Aquatic Habitat
CAH - Coldwater Aquatic Habitat
PCR - Primary Contact Recreation
SCR - Secondary Contact Recreation
ORW - Outstanding Resource Water

(Waters not specifically listed in this table are designated for the use of warmwater aquatic habitat, primary contact recreation, secondary contact recreation, and domestic water supply.)

Stream name	Stream segment	Use classification
Chimney Top Creek	Basin	CAH, PCR, SCR
East Fork Indian Creek	Source to Indian Creek	CAH, PCR, SCR
Gladie Creek	Basin	CAH, PCR, SCR
Middle Fork Red River	Source to river mile 10.6	CAH, PCR, SCR
Red River	River mile 68.6 to 59.5	WAH, PCR, SCR, ORW
Silver Creek	Source to Kentucky River	WAH, PCR, SCR
South Fork Elkhorn Creek	Source to North Fork Elkhorn Creek	WAH, PCR, SCR
Swift Camp Creek	Source to Red River	CAH, PCR, SCR
Town Branch	Source to South Fork Elkhorn Creek	WAH, PCR, SCR

source: Kentucky Natural Resources and Environmental Protection Cabinet, 1985a

Table 3. Kentucky surface water quality criteria

* Primary contact recreation.
** Secondary contact recreation.
*** not to exceed natural seasonal variations
Soft - Soft water has an equivalent concentration of calcium carbonate of 0 to 75 mg/L.
Hard - Hard water has an equivalent concentration of calcium carbonate of over 75 mg/L.

Parameter	Domestic water supply	Warmwater aquatic habitat	Coldwater aquatic habitat	Recreational waters
Ammonia (un-ionized)	-	0.05 mg/L	-	-
Arsenic	-	50 ug/L	-	-
Barium	1 mg/L	-	-	-
Beryllium	-	11 ug/L (soft) 1100 ug/L (hard)	- -	- -
Cadmium	-	4 ug/L (soft) 12 ug/L (hard)	- -	- -
Chlordane	-	0.0043 ug/L	-	-
Chloride	250 mg/L	600 mg/L	-	-
Chlorine, total residual	-	10 ug/L	2 ug/L	-
Chromium	0.05 mg/L	0.10 mg/L	-	-
Color	75 P-C Units	-	-	-
Copper	1 mg/L	-	-	-
Cyanide	-	5 ug/L	-	-
Dissolved Oxygen	-	>4.0 mg/L	5.0 mg/L	-
Fecal Coliform	2000/100 mL	-	-	* 200/100 mL ** 1000/100 mL
Fluoride	1 mg/L	-	-	-
Hydrogen Sulfide (undissociated)	-	2 ug/L	-	-
Iron	-	1.0 mg/L	-	-
Lead	0.05 mg/L	-	-	-
Manganese	0.05 mg/L	-	-	-
Mercury	-	0.2 ug/L	-	-
Methylene Blue Active Substances	0.5 mg/L	-	-	-
Nitrate (as N)	10 mg/L	-	-	-
PCB's	-	0.0014 ug/L	-	-
pH	-	6<pH<9	-	* 6<pH<9 ** 6<pH<9
Phenolics	-	5 ug/L	-	-
Phthalate Esters	-	3 ug/L	-	-
Selenium	0.01 mg/L	-	-	-
Silver	0.05 mg/L	-	-	-
Sulfate	250 mg/L	-	-	-
Temperature	-	<31.7 deg.C	***	-
Total Dissolved Solids	750 mg/L	-	-	-
Zinc	-	47 ug/L	-	-

source: Kentucky Natural Resources and Environmental Protection Cabinet, 1985b.

The Survey has collected water-quality data on the Kentucky River at Lockport since 1974 as part of the National Stream Quality Accounting Network (NASQAN) program (fig. 9). Water samples are collected from this station every other month and analyzed for a wide variety of constituents including physical characteristics, major ions, selected heavy metals, nutrients, bacteria, and suspended sediment. Discharge at this station averages 8,279 cubic feet per second. Maximum recorded discharge at this station reached 123,000 cubic feet per second during January, 1937. A minimum discharge of 80 cubic feet per second was recorded at this station in October, 1941 (Bettandorff and others, 1985).

Daily records for specific conductance and temperature are available from this station since 1973. Extremes in specific conductance for the period of daily record range from 100 to 581 microsiemens per centimeter. Table 4 summarizes the available information on several key water-quality constituents at the NASQAN station at Lockport. The period of water-quality record summarized covers 10 years (1974 to 1984) in most cases. Table 4 shows the name of the constituent or property, the units of measurement, the number of measurements, the 5th-percentile, median (50th-percentile), and 95th-percentile values. The median represents the central tendency of the data because it is insensitive to extreme values. Similarly, the 5th and 90th percentiles provide an estimate of the common variation in the data and are insensitive to extreme values.

The Kentucky Natural Resources and Environmental Protection Cabinet, Division of Water, is now operating 12 fixed-station ambient water-quality monitoring sites within the Kentucky River basin as part of the Basic State Water Monitoring Program mandated by the Clean Water Act (fig. 9). Samples are collected monthly and analyzed for a wide variety of constituents, including selected metals, bacteria, and nutrients. The Division of Water also conducts periodic intensive surveys to provide additional information about specific water-quality problems. Since 1982, five intensive surveys have been performed in the basin, two of which addressed site-specific impacts of oil brines on water quality. The other three intensive surveys addressed the appropriateness of stream use classifications associated with treated municipal wastewater discharges. Every 2 years the Division of Water prepares a report assessing the quality of water in Kentucky to fulfill a National mandate established by section 305b of the Clean Water Act.

The Kentucky Geological Survey has also been involved in several projects related to defining specific water-quality problems within the Kentucky River basin. The cooperative program between the Kentucky Geological Survey and the Survey, which began as early as 1920, has resulted in the collection of a significant amount of water data. These data have been published in more than 200 maps and reports. Current cooperative projects within the Kentucky River basin are intended to determine the occurrence of barium in surface and ground waters and to study the hydrogeology and geochemistry of oil and gas producing fields. A new cooperative investigation in the basin will assess the occurrence, movement, and quality of brines associated with oil and gas exploration and production.

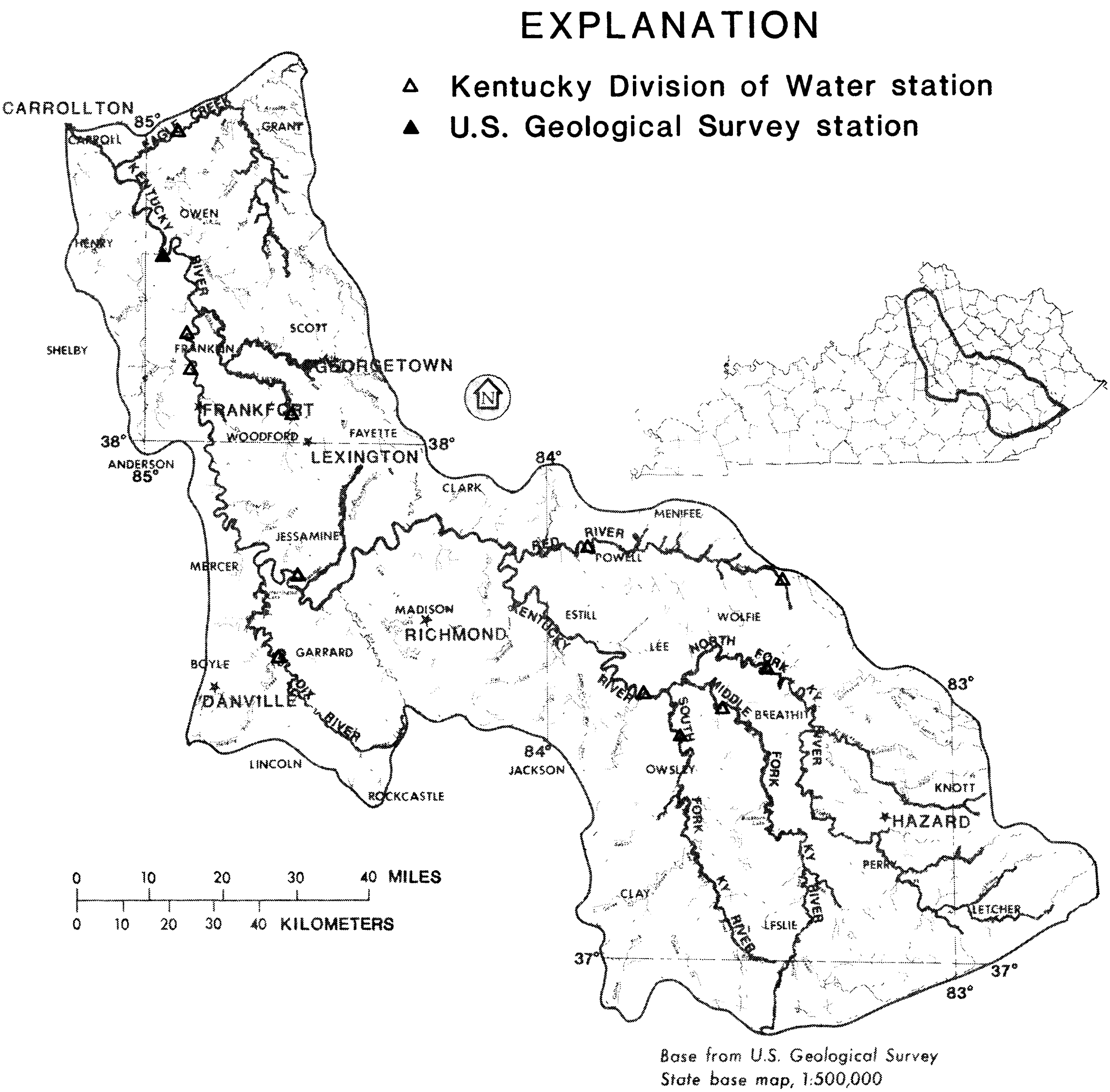

Figure 9.--Surface-water quality-sampling stations in the Kentucky River basin, 1986.

Table 4. Summary of selected chemical, physical, and biological data from the U.S. Geological Survey computer files; Kentucky River at Lockport NASQAN station, 1974 to 1984

Constituent or property	Number of meas-ure-ments	5th percen-tile	Median	95th percen-tile
pH (standard units)	120	6.50	7.50	8.20
Alkalinity (mg/L as CaCO3)	92	56.6	76.0	113.5
Nitrogen, total (mg/L as N)	92	.62	1.20	2.10
Phosphorus, total (mg/L as P)	125	.07	.15	.43
Carbon, organic, total (mg/L as C)	49	2.3	4.9	12.5
Chloride, dissolved (mg/L)	126	4.74	9.70	24.95
Barium, dissolved (ug/L)	30	0	41.0	96.15
Cadmium, dissolved (ug/L)	46	0	0	4.0
Chromium, dissolved (ug/L)	48	0	0	10.0
Lead, dissolved (ug/L)	47	0	3.0	6.6
Mercury, dissolved (ug/L)	43	0	0	.5
Coliform, fecal (colonies/100 mL)	75	7.0	290.0	3,780
Streptococci, fecal (colonies/100 mL)	72	7.95	172.0	7,320
Sediment, suspended (mg/L)	105	9.3	49.0	343.7
Specific conductance (uS/cm)	124	197.5	270.0	386.0

Other Federal agencies contributing to the current knowledge of water quality in the basin include the Environmental Protection Agency, the Forest Service, the Office of Surface Mining, and the Fish and Wildlife Service. State and local organizations contributing to this knowledge include the Kentucky Department for Natural Resources; Department of Surface Mining, Reclamation, and Enforcement; and various research and educational institutions. Reports published by these agencies and institutions have indicated several water-quality concerns, including erosion and sedimentation, agricultural runoff contamination, oil-field brine contamination, and municipal and industrial point-source contamination.

Water-Quality Issues

The quality of surface water in the Kentucky River basin is affected by a wide variety of activities including: coal mining, oil and gas production, agricultural practices, industrial discharges, and municipal wastewater treatment plant discharges (Kentucky Natural Resources and Environmental Protection Cabinet, 1986). The factors influencing water quality in the upper basin generally are distinctive from those in the lower basin due to differences in land use, geology, and topography. In the upper Kentucky River basin, coal mining and oil and gas production are the major sources of surface-water degradation. Agriculture is the major land use impacting water quality in the lower Kentucky River basin. The water quality of the lower basin is also impacted by activities in the larger urban areas. Generally, non-point sources account for more of the contaminant amounts discharged annually into the Kentucky River than point sources (Gianessi, 1986). However, some significant point-source impacts on water quality in the Kentucky River basin have been identified (Kentucky Natural Resources and Environmental Protection Cabinet, 1984 and 1986).

In the Kentucky River basin, there are 11 municipal wastewater treatment facilities discharging more than one million gallons per day (Mgal/d) of effluent. The locations of these significant municipal discharges in the basin are shown in figure 10 (R. Ware, Kentucky Natural Resources and Environmental Protection Cabinet, written commun., 1986). Another 30 municipal wastewater treatment facilities discharge wastewater quantities of less than one million gallons per day. In addition, there are 293 small domestic wastewater treatment plants permitted to operate within the Kentucky River basin. Two of these plants discharge greater than 1 Mgal/d of effluent.

Municipal wastewater is generally a combination of wastewaters collected in sanitary sewers for treatment in a municipally-owned treatment facility. Municipal wastewaters are composed primarily of human wastes, but frequently contain wastewaters from commercial and industrial facilities. Pre-treatment of wastewater by commercial and industrial facilities is frequently required before the wastewater can be discharged to the sanitary sewer. Municipal and domestic wastewater contains many undesirable components, some of which deplete stream oxygen when discharged into a receiving stream, while others may stimulate the growth of certain microorganisms such as algae. Bacteria, some of which may cause disease, metals, and other non-biodegradable compounds also are contained in many municipal and domestic wastewaters. These undesirable components include both organic and inorganic matter, most of which is removed during wastewater treatment.

There are 29 industrial facilities discharging greater than 1 Mgal/d of wastewater to the Kentucky River. Another 47 industries and 1 landfill discharge more than 50,000 gallons of wastewater per day but less than 1 Mgal/d. Additionally, 48 industrial facilities, 12 agricultural operations, and 2 landfills have wastewater facilities, but are excluded from State permitting procedures (R. Ware, Kentucky Natural Resources and Environmental Protection Cabinet, written commun., 1986). Figure 11 shows the location of each of the industrial facilities discharging greater than 1 Mgal/d of wastewater to the river.

Industrial wastewater effluents contain a wide variety of undesirable components, depending on the industrial process involved. Representative compounds consist of both simple and complex organics, and trace metals, many of which are toxic. Heated wastewater from cooling operations also can be detrimental to aquatic life in receiving streams.

During 1984-85, two point-source discharges (one municipal and one industrial), and several oil-field discharges were identified as having significant impacts on aquatic ecosystems. Municipal wastewater effluent from Lexington significantly impacted the benthic invertebrate communities in Town Branch and South Elkhorn Creek (Kentucky Natural Resources and Environmental

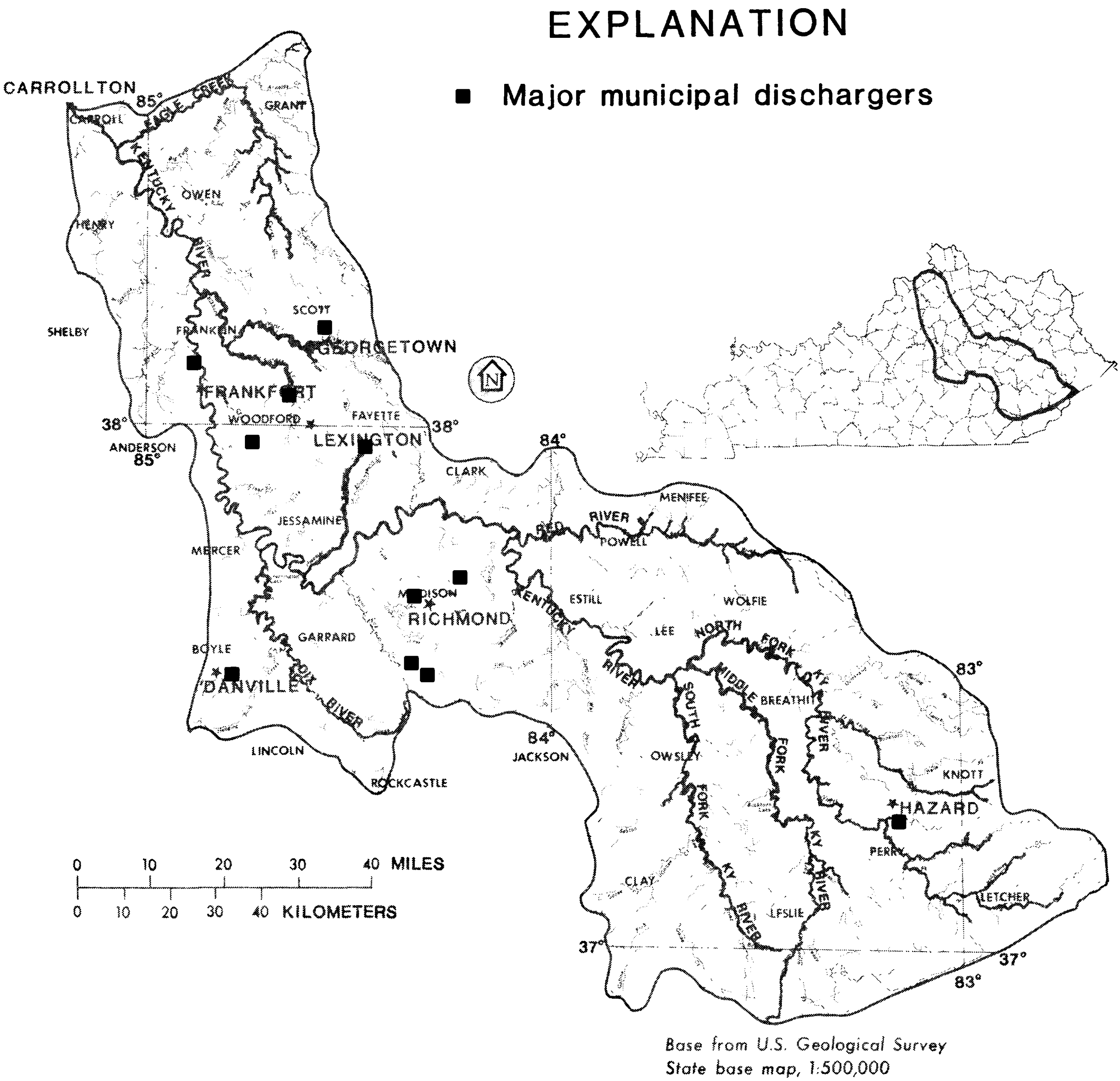

Figure 10.--Municipal wastewater dischargers in the Kentucky River basin (R. Ware, Kentucky Natural Resources and Environmental Protection Cabinet, written commun., 1986).

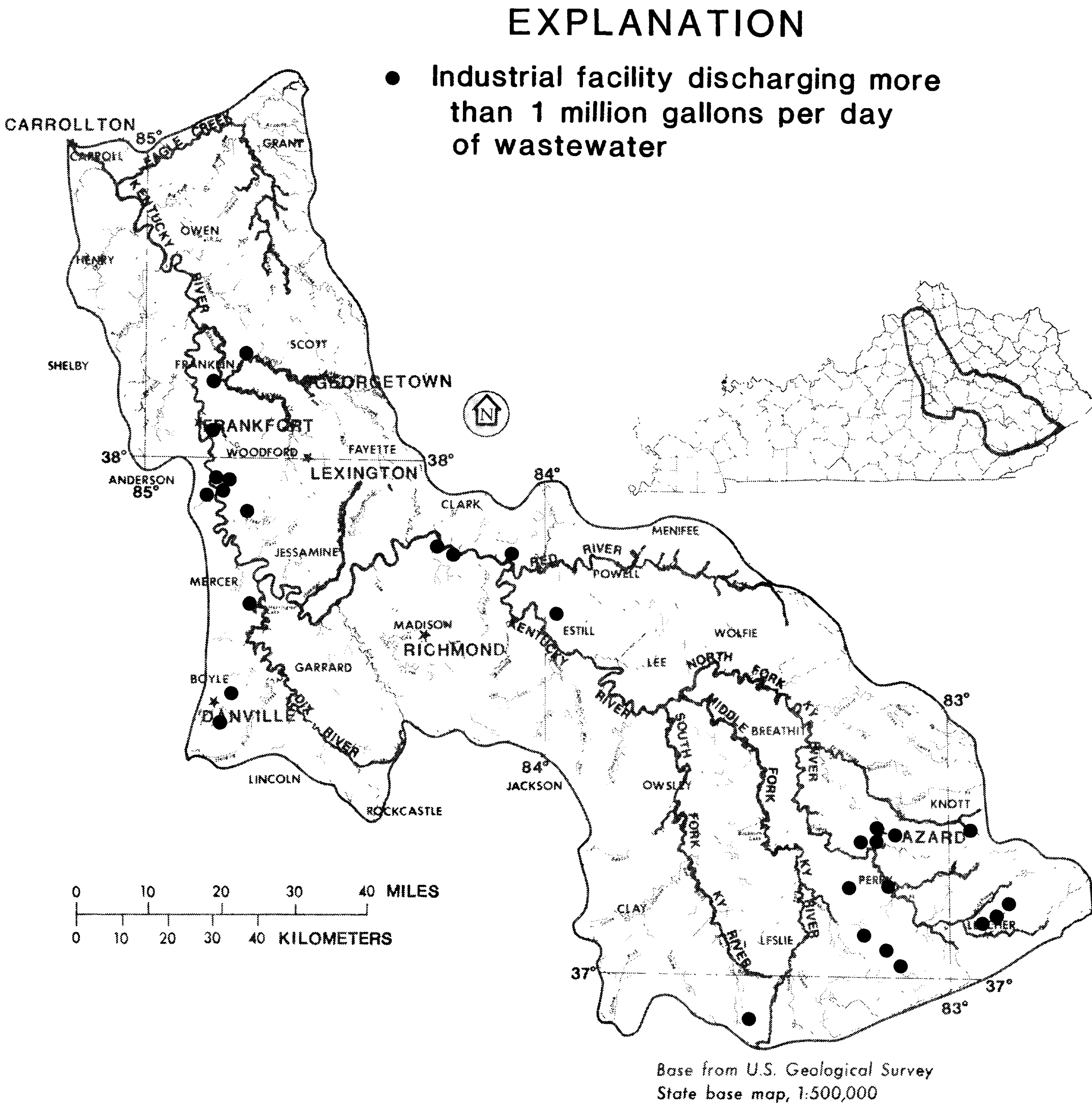

Figure 11.--Industrial wastewater dischargers in the Kentucky River basin, 1986 (R. Ware, Kentucky Natural Resources and Environmental Protection Cabinet, written commun., 1986).

Protection Cabinet, 1986). At a sampling site in South Elkhorn Creek, the benthic invertebrate community consisted of only one species of organism despite an abundance of available habitats. Continuous monitoring of dissolved oxygen (DO) concentrations indicated extended periods of DO depletion resulting from oxygen demanding municipal effluents (Kentucky Natural Resources and Environmental Protection Cabinet, 1986).

Similarly, metals and cyanide in wastewater effluent from a metal fabricating plant impacted several stream miles near Lexington (Kentucky Natural Resources and Environmental Protection Cabinet, 1986).

Sampling in oil fields showed that at least 31 stream miles were impacted by chloride from oil brines (Kentucky Natural Resources and Environmental Protection Cabinet, 1986). Aquatic life impairments, such as reduced benthic and fish communities, were related to increasing chloride concentrations. A cooperative project between the Kentucky Geological Survey and the Survey (KY85-069) is currently investigating the extent and severity of oil brine impacts on the Kentucky River basin.

The 1986 report to Congress for Kentucky assessed water-quality conditions for about 900 of the 3,450 stream miles in the Kentucky River basin. Only 6 percent of the stream miles assessed were determined to be significantly impacted by water pollution (Kentucky Natural Resources and Environmental Protection Cabinet, 1986).

Agriculture, silviculture, oil and gas exploration and production, coal mining, and urban runoff all contribute to nonpoint-source contamination of the Kentucky River basin. Evaluating the significance of nonpoint sources is more complex than for point sources because they normally are spread over a larger area and involve numerous variables and interactions. Only limited data are available describing nonpoint-source contamination in the basin.

Suspended sediment is the most noticeable nonpoint-source stream contaminant. The U.S. Department of Agriculture (1981) has estimated that one million tons of sediment enter the Kentucky River system each year. Other reports indicate that the amount of sediment may be as high as 20 million tons per year (Gianessi, 1986). The major sources of sediment are surface mining in the upper basin, cultivation of narrow floodplains in the Eastern Coal Field region, intensive farming throughout the Knobs and Blue Grass regions, and construction and development activities around the larger urban areas (especially Lexington and Frankfort). Although the effects of sedimentation and erosion are visible throughout the basin, the upper basin shows the heaviest impacts. The most frequently reported biological impacts due to sedimentation in the Kentucky River basin are loss of microhabitats, reduction in the number of fish species, elimination of entire mussel communities, and domination of the benthic invertebrate community by species tolerant of siltation (Kentucky Natural Resources and Environmental Protection Cabinet, 1986). Other sediment related impacts include flood plain scour, channel filling, and swamping or ponding.

Sediment also serves as a vehicle for the transport of nutrients (nitrogen and phosphorus), organic carbon, trace elements, and slightly soluble organics such as pesticides. Once these compounds enter the stream, they either can remain on the sediments or enter the solution phase depending on such factors as water temperature, pH, and dissolved-oxygen content. The interaction between these constituents and sediment, and the fate of these constituents once they are deposited in the surface-water system are not well understood. More knowledge regarding the adsorption and desorption phenomena is needed. In addition, knowledge of sediment transport mechanisms and the particle sizes dominant in the movement of chemical constituents is needed.

In addition to impacts due to sedimentation, other water-quality problems were indicated by biological assessments conducted by the Kentucky Natural Resources and Environmental Protection Cabinet at its ambient water-quality monitoring stations in the Kentucky River basin. The lower basin was impacted by elevated concentrations of the pesticide chlordane, heavy metals, and coliform bacteria resulting from urban land uses, and by nutrients from agricultural practices.

KENTUCKY RIVER BASIN WATER-QUALITY ASSESSMENT

This pilot study is designed to be a perennial program of data acquisition, interpretation, and assessment of the quality of the water resources in the Kentucky River basin. As part of the National Water Quality Assessment Program, the proposed study approach includes both national and local objectives.

In most general terms, the study approach in the Kentucky River basin, as well as in the other pilot-study areas, will be to make maximum use of existing data to: (1) provide, to the extent possible, a description of existing and past trends in water-quality conditions and (2) develop conceptual models that relate the observed conditions (concentrations and transport of substances and biological conditions) to the sources and causes, both natural and human-controlled. New data will be collected to: (1) verify the description of water-quality conditions obtained from the historical data, (2) track long-term trends in water quality, (3) reduce the uncertainty of the description of conditions by intensifying temporal or spatial sampling densities, and (4) improve the understanding of the linkages between the causative factors and water quality, using statistical methods and analyses of physical, chemical, and biological processes.

The first work element of the Kentucky River basin pilot study will be a retrospective analysis of existing water-quality conditions and trends in the basin. In this work element, historical water-quality and support data collected prior to September 1985 from all available sources will be compiled. The data will be screened to identify those data with adequate quality assurance and analyzed using a variety of techniques to determine spatial and temporal variability, relations, and trends in water-quality conditions that may be significant. In addition, observations in the screened data set will be compared with applicable State and Federal water-quality standards and criteria, respectively. The results of the retrospective analysis will be published as a separate report.

Sampling Design

Determination of proper spatial density and distribution of sampling points gives rise to a difficult decision affecting the design of the pilot study. The main reason for this difficulty is the very large discrepancy between the much smaller scale of the Kentucky River basin assessment and the much larger scale of the National program. On the one hand, the degree of resolution must be sufficient to adequately characterize the water-quality condition of the basin and to ensure a high probability of detecting and delineating significant water-quality problem areas. On the other hand, the degree of resolution must not be so fine, that the assessment will require unrealistic levels of support. As a result, many relatively small, contaminated areas will not be detected and characterized as part of the assessment. Even if not essential from the point of view of assessing the current National water-quality situation, these areas may be important. However, they cannot be treated within a broad, nationwide resource-assessment program. Instead, many such areas are within the purview of, and can be best treated by, regulatory agencies (Federal, State, or local) and by nonregulatory local entities. Continual exchange of information between the agencies involved in water-quality data collection activities will make it possible for many of the small contaminated areas to be taken into account by the assessment. Thus, the Kentucky River basin water-quality assessment must focus on nonpoint-source contamination and those point sources that may significantly impact relatively long reaches of principal streams.

For consistency with the other basin studies, both target water-quality constituents and support variables will be measured in the Kentucky River basin. Target variables are those constituents that are of direct relevance to broad National water-quality issues, such as: (1) chemical contamination, (2) nutrient enrichment, (3) acidification, (4) sedimentation, and (5) acceptability of water for use. A list of target constituents is being developed by a committee of scientists from the Survey and other State and Federal agencies and universities. The committee is considering a variety of factors in this selection process: (1) importance to the major water-quality issues, (2) extent of distribution, (3) persistence, (4) effects on humans and biota, and (5) laboratory capability to make reliable determinations at ranges of concentration. Concentrations of target constituents will be measured during the early phase in each study area for various flow regimes and in various media, such as water, suspended sediment, and streambed material. After sufficient data are available, the list of target constituents will be narrowed for each study area to those constituents and compounds important from a public health or ecological perspective.

Support variables aid in the interpretation of the target constituent data. Streamflow rate, velocity, and other hydraulic characteristics that affect the transport of water-quality constituents are examples of support variables. Support variables also will include descriptive information concerning the characteristics of the watershed, such as climate, geology, soils, land cover and use, population, and known sources of contaminants.

Acquisition of 3 years' data is considered necessary for the Kentucky River basin assessment because water quality can be substantially affected by hydrologic conditions, such as dry or wet periods, which may persist for 1 or more years. A cyclic system in which the intensive sampling lasts for only 1 to 2 years in each cycle may make it difficult to identify trends in water quality because of differences in year-to-year hydrologic conditions. Through a series of 3-year intensive phase studies and 6-year periods of data collection, knowledge of a study area will increase in detail and in interpretational quality, such that after several complete cycles a thorough picture of water quality, from a National perspective, can be attained for the study area and from the combined results of the area studies.

Three major types of activities will be undertaken in the Kentucky River basin to achieve the objectives of the National Water-Quality Assessment Program: fixed-location station sampling, synoptic sampling, and intensive-reach studies.

Fixed-Station Studies

Fixed-location river-sampling stations operated in each study area may include existing (NASQAN) stations, Hydrologic Benchmark Network stations, stations operated under the Survey Federal/State Cooperative Program or operated by the Survey on behalf of other Federal agencies, and stations maintained under the Basic State Water Monitoring Program operated by State agencies. Reactivation of stations from the U.S. Environmental Protection Agency's National Water Quality Surveillance System (NWQSS) network may also be desirable. Special consideration will be given to sampling at or near major drinking-water intakes; above and below reservoirs, urban areas, and industrial complexes; and in various small, relatively homogeneous, sub-basins. Information on point- and nonpoint-source discharges and on atmospheric deposition, mostly collected by existing sampling programs, will be used to interpret the surface-water quality.

Fixed-stations will be sampled for many of the target constituents at least once a month during the 3-year high-activity period. In addition to regularly scheduled sampling, additional high- and low-flow samples will be collected as necessary. The need for repetitive sampling arises from the considerable temporal variability of surface-water quality. This variability mainly is a result of variations in river discharge, waste inputs, and temperature. Data from these stations will be interpreted and summarized in terms of frequency distributions of concentrations and mass balances of constituents between stations. Hypotheses aimed at relating these conditions to causative factors will be developed and tested to draw inferences about water quality on a regional scale and to point out some of the policy implications of the observations. The results will also be considered in national analyses to examine the relations between the water quality and various causative factors. In each 3-year intensive study phase, the newly collected data will be compared with any appropriate past data (from before the program began or from earlier cycles of the program) to detect and describe trends in water quality.

Up to eight fixed-location sampling stations will be located throughout the Kentucky River basin to collect data for use in determining mass loadings and seasonal variations of constituent concentrations. The fixed-location stations may be located at existing streamflow gaging or water-quality sampling stations (both Survey and State) that meet sufficient criteria to allow representative sampling.

Synoptic Studies

The purpose of synoptic sampling is to provide a "snapshot" of the occurrence of certain kinds of water-quality conditions over a broad geographical area by making single measurements at many sites during a brief period of time. The synoptic studies will be tailored to a specific type of known or suspected problem. Water, suspended sediment, bed material, and biota will be sampled to provide information on conditions and certain problems which cannot be assessed through the fixed-location station approach. The synoptic studies will also test the sensitivity of the fixed-location station network for detecting potential problems, thereby leading to possible adjustments in station location. Such adjustments would occur in cases where the synoptic surveys reveal important water-quality problems that are not apparent from the fixed-location station data. One of the goals of the synoptic sampling is to identify reaches of 50 miles or more with chronic water-quality problems.

Synoptic sampling will be used to assess the spatial variability and conditions of water quality during some selected time frame or hydrologic condition over all or a part of the basin. This sampling mode can be used to collect data during a worst-case condition and identify reaches with water-quality problems which may require further investigation. Constituents sampled for in this mode may include trace elements, organic compounds (including pesticides), nutrients, bacteria, dissolved oxygen (DO), and biota. The condition to be evaluated will vary depending on the nature of the constituent. Some will depend on seasonal or diel factors and others on flow conditions. The locations for synoptic sampling stations will be based on geographic coverage, geology, land use, location of known point and nonpoint sources, and other pertinent factors to the constituents or measures being sampled.

Dissolved oxygen will be one of several parameters measured synoptically in the Kentucky River hydrologic system. The concentration of dissolved oxygen in a stream is an important indicator of existing water quality and the ability of the stream to assimilate wastes and support a well balanced biological community. The objective of this synoptic survey is to describe existing dissolved-oxygen conditions and to relate these conditions to their associated causes (land-use, water-use, and waste-management practices). Particular emphasis will be given to the identification of stream reaches where dissolved-oxygen depletion is significant. Ideally, the stream survey should be conducted during critical conditions for dissolved oxygen. This critical condition is usually met during some combination of low-flow (less dilution of wastes) and high-temperature (low dissolved-oxygen saturation and high biochemical oxygen demand rate constant). The 24-hour variation in the concentration of dissolved oxygen due to biologic activity must also be considered when defining the critical sampling period. Stream sampling locations will be determined in consideration of basin geography, geology, land use, waste effluent outfalls, channel configuration, river developments (locks and dams), and the self-purification characteristics of the stream. Where possible, dissolved oxygen will be measured in-situ by standard Survey techniques (Skougstad, 1979). It is anticipated that dissolved oxygen will be measured at a minimum of 40 locations throughout the basin during the synoptic survey.

Trace metals in bottom and suspended sediments, nutrients in the dissolved phase and associated with sediment, and pesticides in the water column and associated with sediment will also be assessed via synoptic sampling techniques.

Intensive-Reach Studies

During the course of active study in a basin, certain reach-specific water-quality problems will probably be identified that require intensive, process-oriented investigations to better define water-quality conditions and gain an understanding of their causes. Such studies would be primarily concerned with the origin, movement, and fate of particular contaminants. If the results show that cause-and-effect relations are well understood, then mathematical models could be used to project the outcome of alternative management strategies for dealing with the water-quality issues of interest. Intensive-reach studies could be revisited in later study cycles (9 years) to determine changes and establish whether changes correspond to prior understanding of the processes at work. Some intensive-reach studies would be likely candidates for other programs of the Survey, such as the Federal-State Cooperative Program.

Intensive-reach studies will be planned and carried out to address specific water-quality issues or problems identified as a result of the retrospective analysis or resulting from synoptic or fixed-location station sampling. Process-oriented studies within the Kentucky River basin may address water-quality impacts associated with brine discharges, nonpoint agricultural-chemical runoff, or lock and dam navigational structures.

The study of trihalomethane (THM) formation and its relation to brine discharge containing bromides is a significant water-quality issue within the Kentucky River basin. Trihalomethanes are detrimental to human health and are now regulated by the U.S. Environmental Protection Agency. This issue will likely be intensively studied during the 3-year active-study phase. Because THM's can be formed by the reaction of bromide with natural organic compounds present in surface waters, an understanding of the factors controlling THM formation is needed. A chemical characterization of brine and its significance in forming THM's are potential study elements to be considered.

Data Management

All support and water-quality data collected in the Kentucky River basin assessment will be permanently maintained as a computerized data base. Historic data used in the retrospective data report also will be compiled and maintained in a computerized data base. New data will be available to other agencies and to the public through WATSTORE and STORET. In addition, the data collected each year will be published in the annual data report prepared by the Survey for Kentucky. The entire data base for the basin, both historical and new data, will be permanently stored so that during future active study periods the data will be available for further analysis.

Both historical and new data will be analyzed and evaluated using various techniques including geographic information system (GIS). GIS is a computerized geographic information management system which is composed of two elements: a data-base manager that stores, updates, and manipulates geographic information; and an analysis tool that combines related information by geographic location to create new information. This system will be used to relate geology, geography, land use, climate, physiography, and many other parameters to water-quality information. This data management system is a powerful tool for use in project planning, interpretive analysis, and data presentation.

Photographic Documentation

A photographic library will be maintained to document water-quality conditions, factors influencing water quality, sampling techniques and laboratory methods. The photographs will provide benchmarks for evaluating existing conditions and changes over time, and can be used as a documentary record not only for persons interested in the study but also for future participants in the study. Subjects of the photographs will include physical and biological conditions at sampling sites, specific impacts on water quality in the basin, and any non-standard field or analytical techniques used in the study.

Stream conditions at fixed-location stations and selected synoptic sampling sites will be photographed in detail. Photos at sampling stations will include upstream, cross-section, and downstream views of the channel, ideally under a range of flow conditions. These photos will be used to compare stream-channel characteristics between sites in the basin, to reference site locations for personnel involved with water-quality sampling, and to evaluate long-term changes at the sites. Detailed notes and permanent photo-point markers will be established for all repeat-photo locations.

Both black and white prints and color slides will be on record for the study. Audio-visual tapes may be used to document water-quality sampling and laboratory techniques. Aerial photographs may be included for overviews of the basin and photo composites of the main stem channel, selected tributary reaches, and problem areas.

All photographs will be numbered and referenced, at a minimum, with information on the photo-site location, date, time, subject caption, and name of photographer. Potential photo sites warranting repeat photographs should have more detailed descriptive information on record. Written documentation of photo sites, including site location and subject descriptions, will be maintained as part of the photographic library.

Quality Assurance

Variability in analytical results, caused by errors in the sample-collection and analysis process, always occurs even under rigorously controlled field and laboratory conditions. For example, errors can be introduced into sample results through: (1) selection of a sampling location or method that produces a sample that fails to represent the conditions of interest; (2) improper use of instruments; (3) contamination of the sample; and (4) inappropriate methods of analysis. These errors can be so small that they cannot be measured, or so large that their presence is obvious. Quality-assurance programs are used to detect and control these errors and to maintain and document the reliability of results.

A technical quality assurance plan is being prepared for the National Water-Quality Assessment program. This plan will address all aspects of sample collection, analysis, and reporting needed to produce reliable and verifiable data in a nationally consistent manner. The plan will draw heavily upon existing Survey quality-assurance policies and procedures described in manuals by the Office of Water Data Coordination (1977) and Friedman and Erdmann (1982).

Agency Coordination

Coordination between Survey personnel and other interested scientists and water-management personnel is an important component of the NAWQA program.

Each NAWQA study unit will have a liaison committee to ensure that the scientific information produced by the program is relevant to local and regional interests. Specific activities could include: exchanging information about local and regional water-quality and water data management issues; identifying water-quality constituents and study locations of local and regional interest; discussing adjustments in NAWQA, other Survey, and other agencies' sampling program objectives; and reviewing and commenting on draft planning documents and reports from the study. Organizations currently represented in the Kentucky River basin liaison committee include: the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the U.S. Office of Surface Mining, the U.S. Army Corps of Engineers, the Kentucky Department for Environmental Protection, the Kentucky Geological Survey, the Kentucky Department of Agriculture, the Kentucky Department of Fish and Wildlife Resources, the Kentucky Water Resources Research Institute, the City of Lexington, and the Kentucky-American Water Company.

In addition to the local liaison committees, a National Coordinating Work Group has been established by the Director of the Survey to advise the Survey on the coordination of the NAWQA program. The work group functions under the general auspices of the Interagency Advisory Committee on Water Data and the Advisory Committee on Water Data for Public Use. The general purposes of the work group are to advise the Survey on (a) water-quality information needs of non-Federal and Federal communities of water users and (b) coordination procedures for making the data and information stemming from the NAWQA program timely and appropriately available. The work group currently consists of the Chief Hydrologist of the Survey, eight Federal members, seven non-Federal members, and some members from the pilot project local liaison committees. Organizations represented include: American Water Resources Association, Association of American State Geologists, Association of State and Interstate Water Pollution Control Administrators, Chemical Manufacturers Association, Interstate Conference on Water Programs, National Association of Conservation Districts, U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, Council on Environmental Quality, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, U.S. Forest Service, and U.S. Soil Conservation Service.

Report Products

Initially, the results of the retrospective analysis will be published as a report. During the 3 years of active investigation, several reports discussing individual water-quality topics will be prepared which will be followed by preparation of a summary report. The summary report will address the spatial and temporal nature of water-quality conditions in the basin. It will also further verify conditions and trends identified in the retrospective report with the additional data collected. Information in the summary report will include both descriptive (including statistical) information, as well as explanations of the observed water-quality conditions. The descriptive information will include summaries of probability distributions of concentrations and estimates of transport of important substances for many individual sites or regions within the basin. Estimates of the relative impact of point versus nonpoint sources will be evaluated. In addition, statistical analyses will be carried out relating water-quality characteristics to the characteristics of the river basin, such as geology, climate, land-use practices, waste disposal, and other factors thought to influence water quality. Such results will be used to extend results to areas not sampled and to formulate hypotheses about the causes of water-quality conditions.

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GLOSSARY OF TERMS

Acre-foot - A unit quantity of water; the amount that will cover an area of one acre to a depth of one foot; consists of 326,000 gallons.

Ambient - Surrounding, completely encompassing; especially of or pertaining to the environment.

Benthic - Referring to bottom zones or bottom-dwelling forms.

Biochemical oxygen demand (BOD) - The amount of dissolved oxygen, in milligrams per liter, consumed by microorganisms (mainly bacteria) while utilizing decomposable organic matter present in water.

Brine - Water, usually of deep subsurface strata, containing an unusually high concentration of salts, including chlorides and bromides.

Diel - Of or pertaining to a 24-hour day.

Discharge - Outflow; the flow rate of a fluid system (stream, canal, or aquifer) at a given instant expressed as volume per unit of time. Also known as effluent.

Effluent - Flowing out; The liquid waste of sewage and industrial processing; liquid which flows away from a containing space or a main waterway.

Evapotranspiration - The overall loss of water by evaporation from land and water surfaces and by transpiration from plants growing thereon.

Formation - A geologic unit consisting of a group of rocks composed of similar materials and displaying common group characteristics.

Gage height - The elevation of the water surface as measured by a staff marked off in feet and parts of feet.

Invertebrate - Animals having no backbone.

Karst - A type of terrain, marked by sinkholes, caves, solution valleys, and other features resulting from the dissolution of rock, usually limestone, by surface and ground water.

Loess. Unconsolidated, wind-deposited silt and dust.

Non-point-source pollution - Pollution from sources that cannot be defined as discrete points, such as areas of crop production, timber production, urban development, mining, construction, and various other activities.

Perennial - Lasting or active for many years; continually recurring.

Physiographic region - A region of which all parts are similar in geologic structure and topography. Similar land features.

Point-source pollution - Pollution resulting from any confined, discrete source, such as a pipe, ditch, tunnel, well, concentrated animal feeding operation, or floating craft.

Reach (or segment) - A finite length of river, ranging in length from a few hundred feet to several miles.

Residuum - Residue remaining from the process of erosion due to weathering.

Runoff - The part of precipitation that appears in surface streams having reached the stream channel by surface routes.

Silviculture - The care and cultivation of trees; forestry.

Sinkhole - A depression, often steep-sided, in limestone of a cavernous region. Sinkholes may represent a collapse of bedrock (limestone) structure due to underground dissolution.

Slope - The rate at which stream surface elevation changes with respect to the change in downstream distance.

Specific conductance - Pertains to the capacity of water to conduct an electrical current. It varies with temperature, ion concentration, and chemical composition of the water. Specific conductance is reported in units of microsiemens (micromhos per centimeter at 25 degrees Celsius).

STORET - The acronym used to identify the computerized data base system maintained by the U.S. Environmental Protection Agency for the STOrage and RETrieval of data relating to the quality of the waterways within and contiguous to the United States.

Transpiration - The process by which water vapor escapes from the living plant and enters the atmosphere.

WATSTORE - The acronym used to identify the National WATer data STOrage and REtrieval system, a computerized data base containing water data collected by the U.S. Geological Survey.