AN EVALUATION OF WATER-QUALITY DATA FROM HYDROLOGIC ACCOUNTING UNIT 051100, GREEN RIVER BASIN, KENTUCKY

By D. W. Leist

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DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
Water Resources Division
Stoddard Johnston Building
2301 Bradley Avenue
Louisville, Kentucky 40217

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Conversion of inch-pound units to International System of Units (SI)

Data in this report are given in inch-pound units. To convert inch-pound units, to SI units, the following conversion factors are used:

Multiply inch-pound units	By	To obtain SI units
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	4,047	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
ton, short	0.9072	megagram (Mg)
ton per day (short ton/d)	0.9072	metric ton per day (t/d) megagram per day (Mg/d)

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°C = (°F-32)/1.8$$

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ABSTRACT

Streamflow and water-quality data collected by the U.S. Geological Survey and the Kentucky Natural Resources and Environmental Protection Cabinet from 37 sites in the Green River basin were compared to data from the U.S. Geological Survey National Stream Quality Accounting Network Station, Green River near Beech Grove, Kentucky. This comparison was used to determine variability of water-quality data throughout the basin, and to determine if water-quality data from the NASQAN station were representative of water-quality data upstream. Water-quality concentrations, yields, and trends were studied.

Water-quality data from the NASQAN station were fairly representative of conditions throughout the basin for specific conductance, pH, phosphorus and nitrogen, but were not representative for chloride, sulfate, iron, and water temperature. Water-quality characteristics which were not representative can generally be attributed to impacts of specific land uses such as coal mining or oil production. Mean concentrations of suspended sediment were similar, but extreme concentrations varied throughout the basin.

Suspended-sediment yields decreased downstream and dissolved solids, sulfate, and iron yields increased downstream on the Green River. Phosphorus yields were similar throughout the basin.

There were no temporal trends detected in instantaneous streamflow, sulfate, or total iron concentrations. Specific conductance was increasing at three stations and decreasing at one, chloride was increasing at two stations and decreasing at one, phosphorus was increasing at two stations, dissolved iron was increasing at one station and decreasing at one, pH was increasing at three stations and decreasing at two, suspended sediment was increasing at one station and decreasing at one, and water temperature was decreasing at two stations. The NASQAN station had increasing trends in chloride, phosphorus, pH, and suspended sediment, and a decreasing trend in water temperature with time.

INTRODUCTION

The U.S. Geological Survey operates a national network of surface water quality stations throughout the nation, termed the National Stream Quality Accounting Network (NASQAN) (Ficke and Hawkinson, 1975). Nearly all NASQAN stations are located near the terminus of large drainage areas (Accounting Units) (Seaber and others, 1984). The water flowing past these stations is a composite of drainage from basins of various land uses within the Accounting Unit, ranging from forest and agricultural land to large metropolitan areas and industrial centers. The quality of this composite drainage is a mixture of the natural drainage and the point and non-point discharges associated with various land uses. The variability in water quality from point to point within an Accounting Unit could be extremely large, and may be much greater than the variability between Accounting Units as measured at or near the mouths of the rivers.

Purpose and Scope

The purpose of this report is to provide information on the variability of water quality in the Green River basin (Accounting Unit 051100), to relate this variability to selected basin characteristics including land and water use, and to assess how well water quality at the NASQAN station on the Green River near Beech Grove, Kentucky, represents water quality in the basin upstream of the station. Data at 38 stations throughout the Green River basin were studied, compared, and related to basin characteristics including land and water use. Locations and report station numbers for stations are shown in figure 1.

Description of Study Area

The Green River basin, the largest drainage basin in Kentucky, contains an area of 8,821 mi^2 in west-central Kentucky and 408 mi^2 in north-central Tennessee (fig. 1). The Green River flows 330 miles from its head waters in Casey and Lincoln Counties to its confluence with the Ohio River at mile point 636.4 near Evansville, Indiana. The river flows through the Mammoth Cave National Park where it has been designated as a Wild and Scenic River. The main tributaries to the Green River are the Nolin River (727 mi^2), Barren River (226 mi^2), Mud River (375 mi^2), Rough River (1,081 mi^2), and Pond River (799 mi^2). Rough River Lake, Nolin River Lake, Barren River Lake, and Green River Lake are U.S. Army Corps of Engineers reservoirs and were impounded in 1959, 1963, 1964, and 1969, respectively. Five Corps of Engineers navigation locks have been built along the Green River, but three are no longer in operation.

The headwaters of the Green River are in the southern part of the Bluegrass region, but most of the drainage basin lies in the Mississippian Plateau and Western Coal Field regions (fig. 2). Most of the Mississippian Plateau is characterized by gently rolling karst topography, subsurface drainage, and a low density of streams. The outer edge of the plateau has a more rugged topography with a well developed stream system. Karst areas in Kentucky are shown in figure 3. The Western Coal Field region is characterized by hills and ridges on an upland terrain with wide, nearly flat flood plains occurring along the lower Green River and its main tributaries.

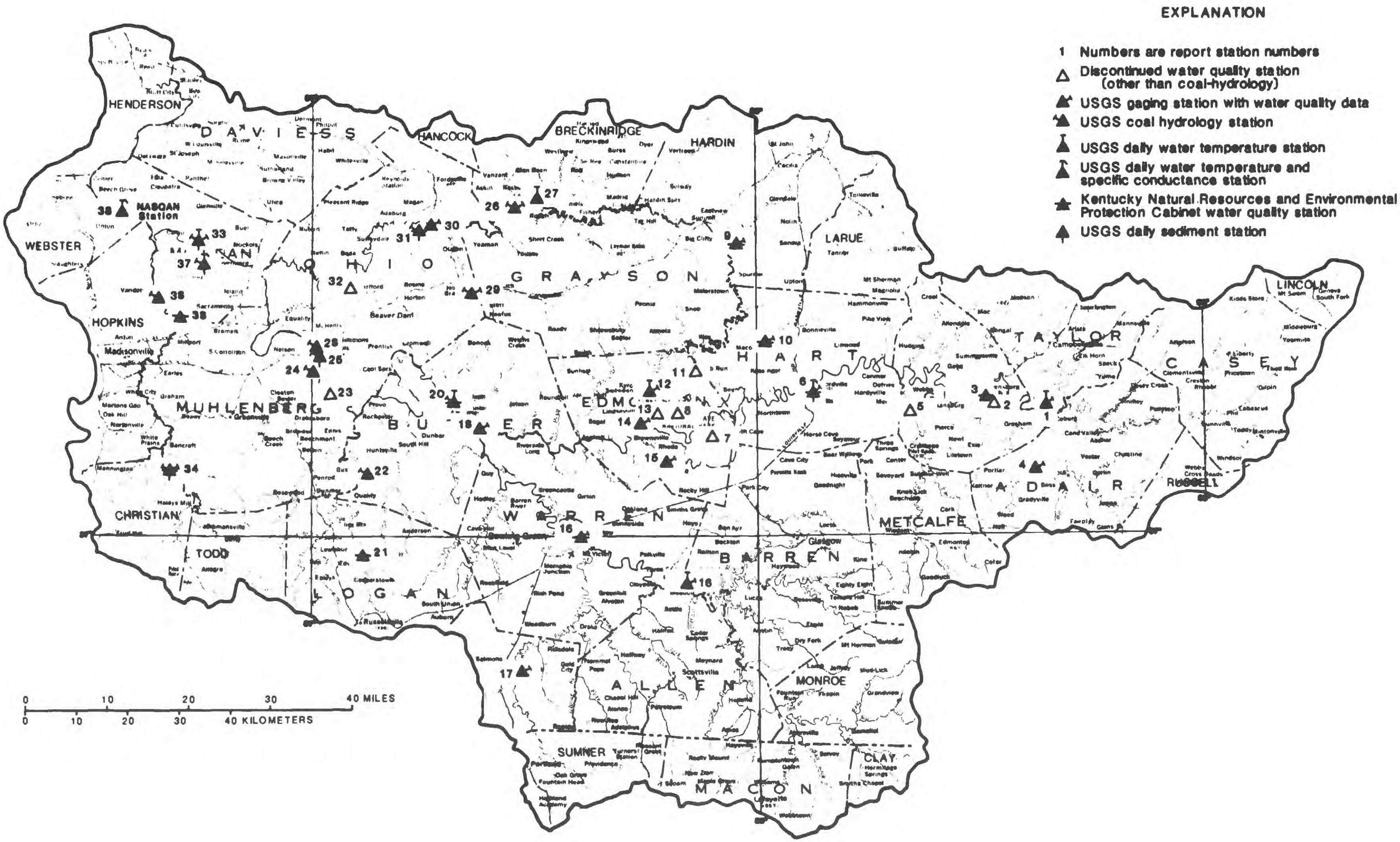

Figure 1.--Study area and location of sampling sites.

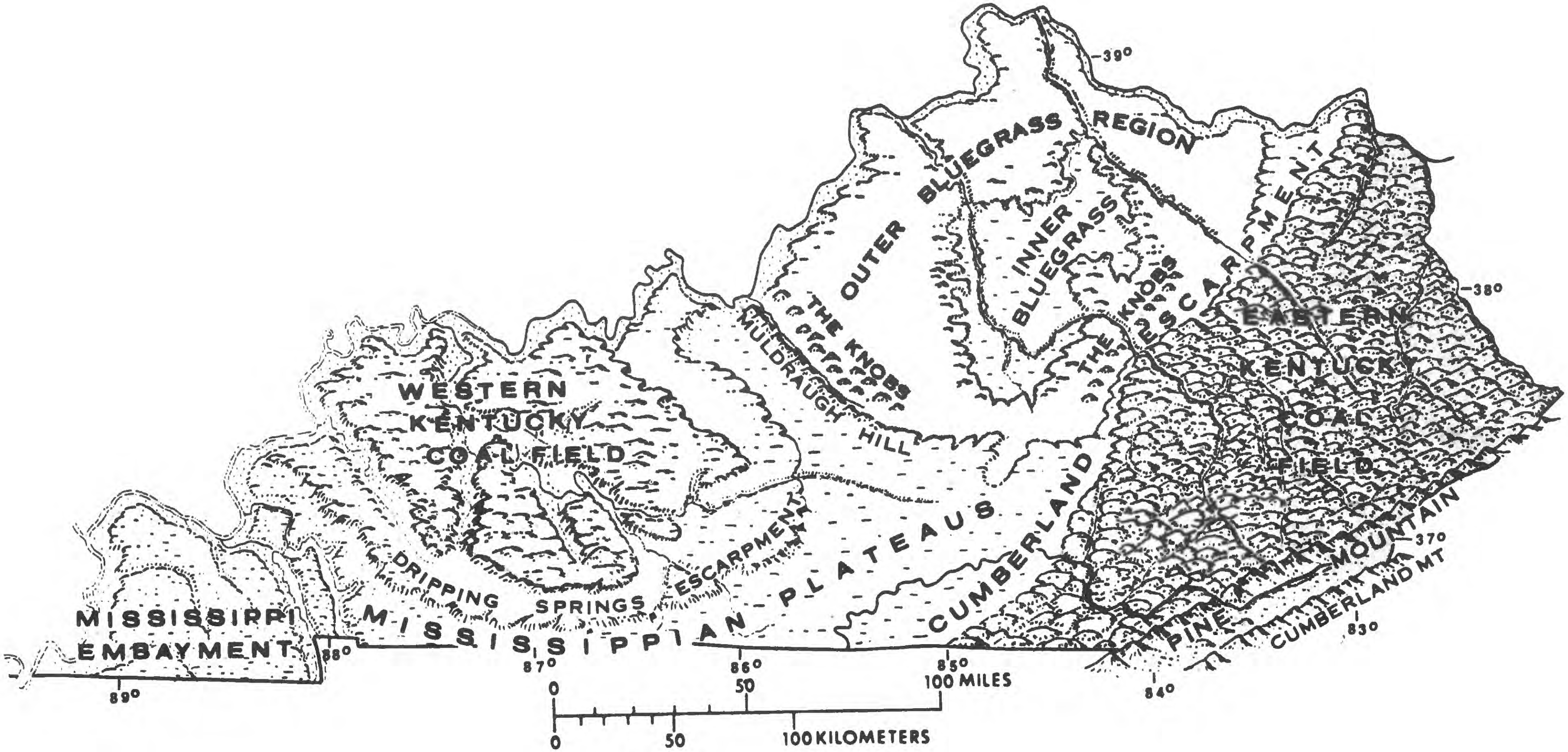

Figure 2.--Physiographic regions of Kentucky.

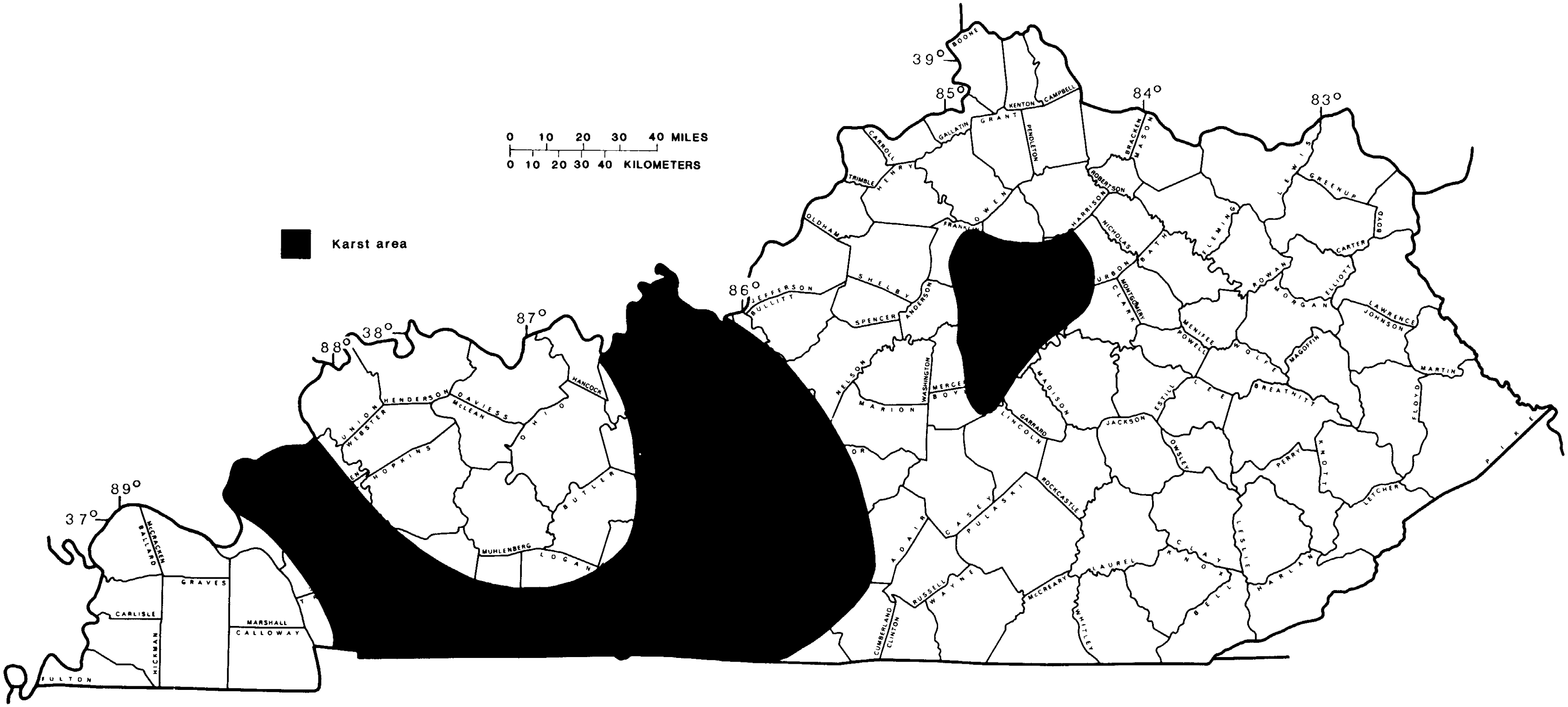

Figure 3.--Approximate areas of karst topography in Kentucky.

Method of Investigation

Water-quality data used in this study have been collected by the Survey and the Kentucky Natural Resources and Environmental Protection Cabinet (KNREPC). These data are filed in the National Water Data Storage and Retrieval System (WATSTORE) of the Survey's computer system and in STORET, the U.S. Environmental Protection Agency's computer system.

The statistics presented in this report were computed using Statistical Analysis System (SAS) programs (Blair and others, 1979). The trend analysis techniques were initially developed by Hirsch, Slack, and Smith of the Survey and later developed for use with SAS (Crawford and others, 1983).

HYDROLOGY

Flow data (table 1) are available throughout the basin, and indicate that many streams go dry during periods of low rainfall, but flooding can be severe during wet periods. The 7-day 10-year low flow for streams draining less than approximately 100 mi^2 is zero in the Western Kentucky Coal Field, but varies from 0.0 to 7.7 ft^3/s in karst areas (Quinones, 1983, p. 30 and Sullavan, 1980). During the floods of 1978, the peak discharge exceeded a recurrence interval of 50 years at Bacon Creek near Priceville (Station 10) and at Russell Creek near Columbia (Station 4). The Green River at Lock 2 near Calhoun (Station 33) recorded a peak discharge of 73,800 ft^3/s during this flood, which is almost seven times its average flow.

The karst topography has a major influence on the hydrology of the basin. Drainage is mostly subsurface with short ephemeral streams that flow into sinkholes or solution openings. Resurgence of water discharged into these sinkholes or solution openings is generally to major streams some distance away.

Between 1959 and 1969 four major flood control reservoirs were completed. These were the Rough River Lake, Nolin River Lake, Barren River Lake, and Green River Lake reservoirs. The streamflow regulation provided by these reservoirs significantly affects downstream flow characteristics. Hale (1979) developed a streamflow model to provide estimates of reservoir-altered low-flow characteristics (7-day 10-year) of several stream sites downstream from the four reservoirs to the Green River at Lock 2, (Station 33). These estimates are included in table 1.

HYDROGEOLOGY

The Mississippian Plateau region includes two major plateau areas which are separated by the southward facing U-shaped Dripping Springs escarpment (fig. 2). The inner plateau, called the Mammoth Cave Plateau, lies between the escarpment and the Western Coal Field (McFarlan, 1950). The outer plateau, the Pennyroyal Plain, lies generally to the south and is concentric to the escarpment.

Table 1.--Streamflow data for stations

Report station number	Station name	USGS station number	Period of record	Drainage area (mi2)	Flow, in cubic feet per second: Average flow	Maximum flow	Minimum flow	7-day 10-year low flow	Remarks
1	Green River near Campbellsville.	03306000	1963-82	682	1,106	29,000	1/0.0	50	Flow regulated by Green River Lake since 1969.
4	Russell Creek near Columbia.	03307000	1939-82	188	294	40,600	.4	1.8	
6	Green River at Munfordville.	03308500	1937-82	1,673	2,713	76,800	39	2/220	Flow regulated by Green River Lake.
9	Nolin River at White Mills.	03310300	1959-82	357	492	19,400	31	36	
10	Bacon Creek near Priceville.	03310400	1959-82	85.4	58.7	6,600	4.4	5.7	
12	Nolin River at Kyrock.	03311000	1939-50 1960-82	703	929	22,700	3/.0	4/50	Flow regulated by Nolin River Lake since 1963.
14	Green River at lock 6.	03311500	1938-82	2,762	4,357	120,000	120	2/310	Flow regulated by Nolin River Lake and Green River Lake.
15	Beaver Dam Creek at Rhoda.	03311600	1972-82	10.9	18.6	4,890	.25	Not determined.	
16	Barren River near Finney.	03313000	1960-82	942	1,511	78,000	3/.0	4/50	Flow regulated by Barren River Lake since 1964.
17	West Fork Drakes Creek near Franklin.	03313700	1968-82	110	208	27,300	1.0	7.7	
18	Barren River at Bowling Green.	03314500	1938-82	1,849	2,588	85,000	44	2/100	Flow regulated by Barren River Lake.
19	Green River at Lock 4.	03315500	1937-82	5,404	8,374	205,000	200	2/500	Flow regulated by Green River Lake, Nolin River Lake, and Barren River Lake.
23	Green River at Paradise.	03316500	1939-50 1960-81	6,183	9,437	107,000	250	2/520	Flow regulated by Green River Lake, Nolin River Lake, and Barren River Lake.
28	Rough River at Falls of Rough.	03318500	1939-82	504	769	12,400	6.0	4/50	Flow regulated by Rough River Lake since 1959.
29	Caney Creek near Horse Branch.	03318800	1956-82	124	187	10,000	.0	.0	
30	Rough River near Dundee.	03319000	1939-82	757	1,057	22,200	8.1	2/50	Flow regulated by Rough River Lake.
33	Green River at Lock 2.	03320000	1930-82	7,566	11,160	208,000	280	2/600	Flow regulated by Green Barren, Nolin and Rough River Lakes.
34	Pond River near Apex.	03320500	1940-82	194	265	22,800	.0	.0	

1/ Green River Dam was closed for repair in May, 1982. Minimum designed flow is 50 ft^3/s.
2/ Estimated from Hale, 1979.
3/ Dam closed for repairs.
4/ Minimum designed flow is 50 ft^3/s.

The Dripping Springs escarpment and the Mammoth Cave Plateau are underlain by rocks of the Chesterian Series of the Late Mississippian age. These rocks consist of alternating beds of limestone, sandstone, and shale. Most of the streams in this area are small and short with steep gradients. The Pennyroyal Plain is underlain by rocks of the Osagean and Meramecian Series and the lowermost limestones of the Chesterian Series. In this area, drainage is mostly subsurface. Short ephemeral streams flow to sinkholes. Ground water in the Mississippian Plateau can be difficult to develop in places because most of the water moves through solution openings which may not be penetrated during drilling, and because of the poor water bearing characteristics of some of the units.

The Western Coal Field region is mostly an area of Pennsylvanian rocks. These rocks consist of carbonaceous siltstone and clay shale, medium to fine-grained sandstone, coal beds, and marine and non-marine limestones in beds less than 6 to more than 18 feet in thickness (Quinones and others, 1983). Sandstone and siltstone constitute about 55 to 80 percent of the Pennsylvanian rocks, and silty shale and clay shale most of the remainder. Limestone constitutes only about 5 percent of the section. Sandstones are the best aquifers in the Pennsylvanian rocks. They vary in thickness and composition and may thin and disappear in very short distances. The aquifers may be highly permeable, or may contain large amounts of shale or cementing material. The thickness and character of geologic units in the Pennsylvanian may change greatly over short distances, thus the availability of ground water in any unit may range widely.

SOILS

Most of the soils in Kentucky, with the exception of stream deposits, have developed under forest cover and essentially the same climate. Differences between soils are mainly due to differences in parent material, topography, and the length of time these materials have been exposed to weathering. The principal soil associations in the Green River basin are the Zanesville-Frondorf, Caneyville-Zanesville-Frondorf, Crider-Cumberland, and the Trimble-Baxter (fig. 4, table 2). Slopes of these soil associations range from 0 to 80 percent. Suitability for agriculture is good to fair, with corn, hay, soybeans, and tobacco being the predominant crops. Most of the coal deposits in the Green River basin underlie the soils of the Zanesville-Frondorf association.

POPULATION

The population of the Green River basin is approximately 467,000, and 35 percent is urban and 65 percent is rural. This represents approximately 13 percent of the population of Kentucky (U.S. Bureau of the Census, 1981). Considering that the land area of the basin is about 23 percent of the area of Kentucky, the population figures indicate that the basin is fairly sparsely populated. Population of some of the larger cities are listed on the next page.

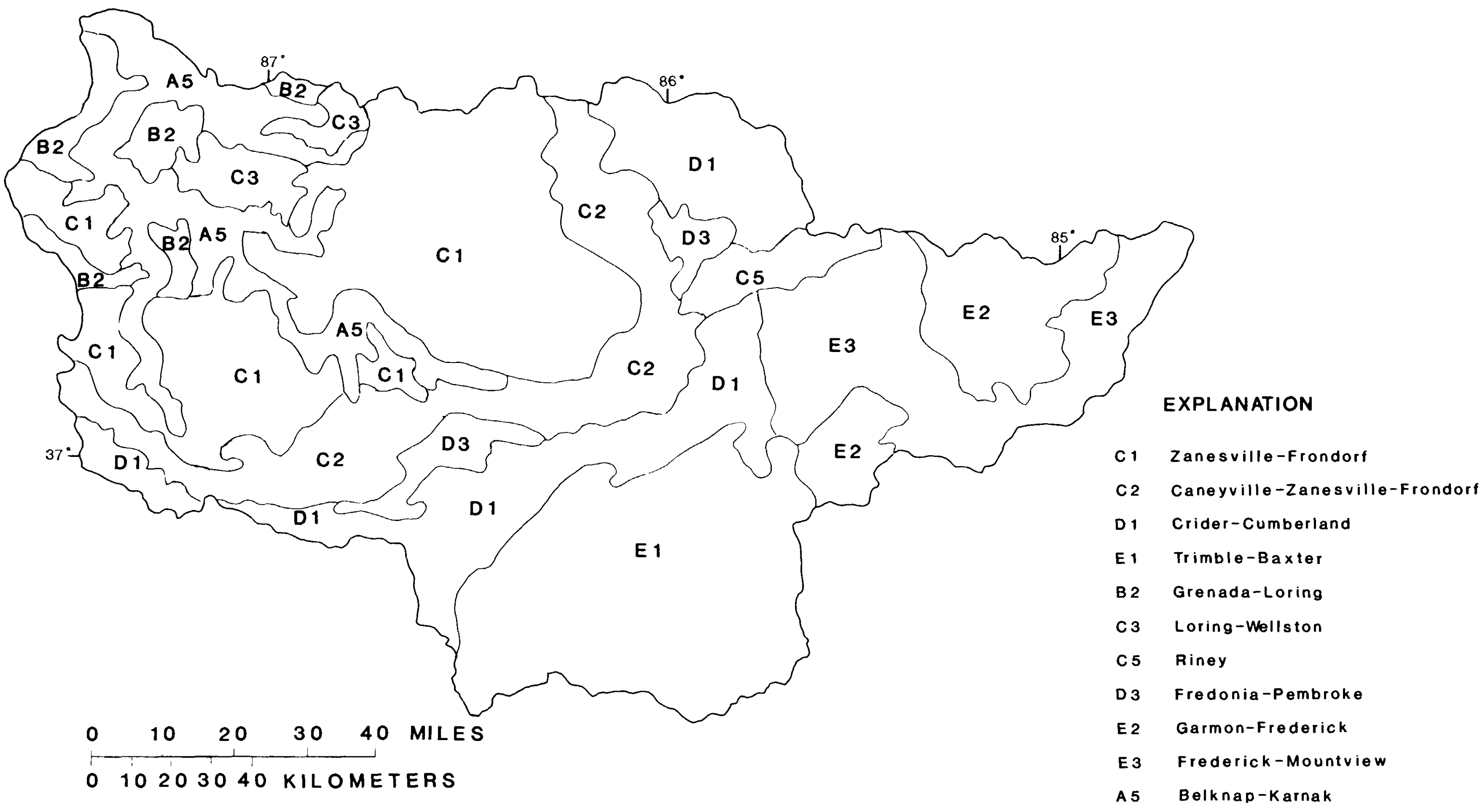

Figure 4.--Soil associations in the Green River basin.

Table 2.--Soil associations in the Green River basin
[Source: Modified from U.S. Department of Agriculture, 1975]

Name	Occurrence	Normal slope range (percent)	Hydrologic properties	Limiting properties
Zanesville-Frondorf	Undulating broad ridge tops and steep side slopes, in the Western Coal Fields.	Zanesville 2 to 12	Deep, well drained soils formed in loess over sandstone, siltstone and shale.	Slopes above 6 percent
		Frondorf 6 to 50	Moderately deep, well drained soils formed in loamy material over sandstone, siltstone, and shale.	Slope
Caneyville-Zanesville-Frondorf	Steep side slopes and undulating broad ridge tops in Western Coal Field.	Caneyville 6 to 30	Moderately deep, well drained soils formed in clayey limestone residuum.	Slope
		Zanesville 2 to 12		Slopes above 6 percent
		Frondorf 6 to 50		Slope
Crider-Cumberland	Undulating karst upland plains in Western Pennyroyal.	Crider 2 to 12	Deep, well drained soils formed in loess over limestone residuum.	Slopes above 6 percent
		Cumberland 6 to 20	Deep, well drained soils in limestone residuum.	Slope
Trimble-Baxter	Hilly uplands with moderately steep side slopes and narrow rolling ridge tops in the Eastern Pennyroyal.	Trimble 6 to 30	Deep, well drained soils formed in loamy residuum from cherty limestone.	Slope
		Baxter 6 to 30	Deep, well drained soils formed in clayey residuum from cherty limestone.	Slope
Grenada-Loring	Undulating upland plain in Western Coal Field.	Grenada 0 to 6	Deep, moderately drained soils formed in loess.	Slopes above 6 percent, wetness.
		Loring 2 to 12	Deep, moderately drained soils formed in loess.	Slopes above 6 percent
Loring-Wellston	Rolling, upland plain dissected by many small streams in Western Coal Field.	Loring 2 to 12	Deep, well drained soils formed in loess.	Slopes above 6 percent
		Wellston 6 to 30	Deep, well drained soils formed in loess over residuum from sandstone, siltstone, and shale.	Slopes
Riney	Hilly uplands dissected by many small streams between Pennyroyal areas.	Riney 6 to 30	Deep, well drained soils formed in loamy residuum from sandstone and shale.	Slope
Fredonia-Pembroke	Rolling karst upland plains in Western Pennyroyal.	Fredonia 6 to 30	Moderately deep, well drained soils formed in clayey residuum.	Slope
		Pembroke 2 to 12	Deep, well drained soils formed in mixed loess and limestone residuum.	Slopes above 6 percent
Garmon-Frederick	Hilly uplands with steep side slopes and narrow ridge crests, in Eastern Pennyroyal.	Garmon 20 to 80	Moderately deep, well drained soils formed in loamy residuum.	Slope
		Frederick 6 to 30	Deep, well drained soils formed in clayey residuum from limestone.	Slope
Frederick-Mountview	Rolling broad ridge tops dissected by small stream.	Frederick 6 to 30		Slope
		Mountview 2 to 12	Deep, well drained soils formed in loess over clayey residuum.	Slopes above 6 percent
Belknap-Karnak	Flood Plains and terraces in thick loess area of Western Coal Field.	Belknap 0 to 2	Deep, poorly drained soils formed in loamy alluvium.	Wetness, floods
		Karnak 0 to 1	Deep, poorly drained soils formed in clayey alluvium.	Wetness, floods

(U.S. Bureau of Census, 1981)

City	County	Population (1980)
Bowling Green	Warren	40,450
Elizabethtown	Hardin	15,380
Glasgow	Barren	12,958
Madisonville	Hopkins	16,979
Greenville-Central City	Muhlenburg	9,845

WATER USE

Water use in the Green River basin in 1980 was about 64 Mgal/d (Mull and Lee, 1984). Of this, 42.5 Mgal/d was for public supply, 15.5 Mgal/d for industrial uses, and 6 Mgal/d for rural and agricultural uses. Surface water accounted for about 77 percent of the water withdrawn in 1980.

Reservoirs covering approximately 35,000 acres are used for recreation in the basin. The four reservoirs of the Corps of Engineers account for about 29,000 acres, and had about 2.9 million visitor days in 1969 (Kentucky Natural Resources and Environmental Protection Cabinet, 1977, p. 164).

LAND USE

About 90 percent of the land in the Green River basin is classified as rural. Rural land is further classified as pasture, cropland, forest, and other (farmsteads, farm roads, feed lots, strip mining, ditch banks, fences, industrial tracts, gravel pits, and so forth). Pasture land accounts for about 19 percent of the basin. This is agricultural land which is unsuitable for cultivation because of hilly terrain, poorly drained land, or poor soil conditions. Cropland makes up about 34 percent of the basin. About 40 percent of the basin is forest, most of which has commercial value. About 1.4 percent is used for strip mining, and about 0.5 percent is covered by streams and lakes.

Kentucky produces about 20 percent of the coal mined in the United States. In 1981, total coal production in Kentucky was about 158 million tons, and about 40 million tons came from the Western Kentucky Coal Field (Stanley, 1982, p. 3). Hopkins, Ohio, Muhlenburg, and Webster counties were the largest producing counties in the area, and they accounted for approxi-imately 29 million tons. Approximately 170 mines were active in Western Kentucky-140 strip and 30 underground mines. The underground mines accounted for 46 percent of the coal produced in 1981.

In 1980 there were approximately 15,000 oil wells in Kentucky which produced 5.9 million barrels of oil (Stanley, 1982, p. 186 and Van Den Berg and others, 1982, p. 1899). Of this, approximately 3.9 million barrels were produced from the Green River basin, and most of this was from the Western Kentucky Coal Field region.

SOURCES OF POLLUTION

Point Sources

There are 31 municipal sewage treatment plants, 22 significant domestic discharges (trailer parks, schools, truck stops, and others with a discharge of 50,000 gallons per day or greater), and 22 significant industrial discharges in the Green River basin (Kentucky Natural Resources and Environmental Protection Cabinet, 1972, p. 4-7 to 4-15). Approximately 214 of 1,670 stream miles studied would have dissolved oxygen concentrations less than 5 mg/L during 7-day, 10-year low flow conditions based on a model used by the Natural Resources and Environmental Protection Cabinet (1977). Of this, 172 miles are affected by municipal discharges, 7 miles by industrial discharges, and 35 miles by discharges from schools, trailer parks, and so forth. There were four fish kills in 1982 and five in 1983 which were attributed to pollution from sewage, mining, or oil drilling operations (Kentucky Natural Resources and Environmental Protection Cabinet, 1984, p. 59).

Brines from oil production have been a serious problem in the basin since 1958. Oil production from the Greensburg Oil Field in Green County increased from 5,400 barrels in January 1958 to about 1.4 million in May 1959, then decreased to 381,000 by December 1959 (Krieger, 1960, p. 10). This oil was produced with large quantities of brine water which was allowed to drain into ditches, streams, and ultimately the Green River. Chloride concentrations in the Green River at Munfordville increased from 10 to 1,000 mg/L during this period. Although oil production (47,000 barrels in 1980, Kentucky Geological Survey, written commun., 1982) and thus brine production is greatly reduced from these levels today, brine production still occurs in places throughout the basin.

Heated wastes are also a problem in the basin. For example, cooling towers are used by coal fired generating stations along the Green River, but monitoring data show temperature violations downstream of these facilities (Kentucky Natural Resources and Environmental Protection Cabinet, 1972 p. 3-49).

The extensive cave system in and around Mammoth Cave has been affected by sewage treatment and septic tank effluent. Damage done by these sources has destroyed fragile cave ecosystems and forced the closure of cave systems that were once used for public tours. Quinlan and Rowe (1977) report that irreversible damage may occur in Mammoth Cave unless extensive sewage treatment upgrading occurs.

Non-Point Sources

Acid mine drainage, siltation, agricultural runoff, and storm drainage from large cities located near streams are the major non-point sources of pollution in the basin. Acid mine drainage and siltation caused by coal production occurs primarily in Muhlenburg, Ohio, and Hopkins Counties. The Green River basin has the greatest number of stream miles affected by acid-mine drainage in Kentucky. There are about 540 stream miles affected by mine runoff in the basin, and about 270 stream miles are directly affected by acid-mine drainage (Kentucky Natural Resources and Environmental Protection Cabinet, 1981, p. 141.) The Pond River basin is the most severely impacted area in the Green River basin as indicated by low pH values and high iron, sulfate, and suspended sediment concentrations (figs. 7, 8, 13, and 16). An estimated 18 million tons of sediment enters the Green River system annually; 53 percent is produced from cropland erosion, 25 percent from gully erosion, 12 percent from disturbed forest land, and 10 percent from surface mines, road banks, and stream banks (Kentucky Natural Resources and Environmental Protection Cabinet, 1977, p. 163).

SURFACE-WATER QUALITY

Description of Sampling Stations

Several different data-collection programs have been implemented in the Green River basin, resulting in stations with different data-collection schemes and frequencies. Stations used in this report include Survey surface-water gaging stations, suspended-sediment stations, miscellaneous water-quality stations, coal-hydrology stations, and KNREPC monthly water-quality stations in addition to the NASQAN station on the Green River. The coal-hydrology stations used in this report were sampled approximately every six weeks during 1979-81 as part of the nationwide Geological Survey Coal Hydrology Program. A description of stations is presented in table 3 and station locations are shown in figure 1.

Comparison of Statistical Measures--Means, Medians and Variances

Water-quality data collected since 1969 were used to determine the maximum, minimum, median, mean, and confidence limits about the mean at the 95 percent probability level for several parameters from stations in the Green River basin. Only data after 1969 were used because the last Corps of Engineers reservoir in the basin was completed that year, thus providing stable basin conditions for station comparisons. The parameters selected were checked for statistical assumptions; mean and variance values were plotted to check for independence, and tests were performed to determine if data approximated a normal distribution. Log transformation was performed on data that did not approximate a normal distribution. In most cases, the transformed data were normally distributed. Confidence limits about the mean were not reported if the raw data did not approximate a normal distribution or if the antilog of the transformed mean was not similar to the arithmetic mean. Also, confidence limits were not reported for stations having less than ten data points.

Table 3.--Sampling stations in the Green River basin

Report station number	Station name	USGS station number	Period of record	Type of station
1	Green River near Campbellsville	03306000	1963-82	USGS gaging station, daily water temperature
2	Green River near Greensburg	03306490	1959-77	USGS water quality
3	Green River at Greensburg	03306500	1979-82	KNREPC monthly water quality
4	Russell Creek near Columbia	03307000	1939-82	USGS gaging station
5	Little Barren River near Monroe	03307800	1960-72	USGS water quality
6	Green River at Munfordville	03308500	1937-82	USGS gaging station, water quality, daily water temperature, daily suspended sediment, daily conductance, KNREPC monthly water quality
7	Green River at Mammoth Cave	03309000	1960-74	USGS water quality
8	Wet Prong Buffalo Creek near Mammoth Cave.	03309100	1962-74	USGS water quality
9	Nolin River at White Mills	03310300	1959-82	USGS gaging station, KNREPC monthly water quality
10	Bacon Creek near Priceville	03310400	1959-82	USGS gaging station, KNREPC monthly water quality
11	Dog Creek near Mammoth Cave	03310600	1961-74	USGS water quality
12	Nolin River at Kyrock	03311000	1939-50 1960-82	USGS gaging station, water quality, daily temperature
13	Bylew Creek near Mammoth Cave	03311100	1965-74	USGS water quality
14	Green River at Lock 6	03311500	1938-82	USGS gaging station
15	Beaver Dam Creek at Rhoda	03311600	1965-82	USGS gaging station, water quality
16	Barren River near Finney	03313000	1960-82	USGS gaging station, daily temperature
17	West Fork Drakes Creek near Franklin.	03313700	1968-82	USGS gaging station
18	Barren River at Bowling Green	03314500	1938-82	USGS gaging station, water quality station, KNREPC monthly water quality
19	Green River at Lock 4	03315500	1937-82	USGS gaging station
20	Green River at Aberdeen	03315520	1979-82	USGS daily temperature, coal hydrology station, KNREPC monthly water quality
21	Mud River near Homer	03315915	1979-82	KNREPC monthly water quality
22	Mud River at Huntsville	03316257	1979-82	USGS coal hydrology
23	Green River at Paradise	03316500	1939-50 1960-81	USGS gaging station, water quality
24	Pond Creek near Martwick	03316640	1979-82	USGS coal hydrology
25	Green River at Rockport	03316645	1979-81	USGS coal hydrology, daily suspended sediment
26	Lewis Creek at Rockport	03316660	1979-81	USGS coal hydrology
27	Rough River at Rough River Dam	03318010	1962-82	USGS daily temperature
28	Rough River at Falls of Rough	03318500	1939-82	USGS gaging station, coal hydrology
29	Caney Creek near Horse Branch	03318800	1956-82	USGS gaging station, coal hydrology
30	Rough River near Dundee	03319000	1939-82	USGS gaging station
31	Rough River at Dundee	03319500	1979-82	USGS coal hydrology, daily suspended sediment, KNREPC monthly water quality
32	Rough River at Hartford	03319600	1966-72	USGS water quality
33	Green River at Lock 2	03320000	1930-82	USGS gaging station, coal hydrology, daily temperature, daily suspended sediment
34	Pond River near Apex	03320500	1940-82	USGS gaging station, coal hydrology, daily suspended sediment, KNREPC monthly water quality
35	Pond River near Sacremento	03321100	1957-73 1979-82	USGS water quality station, KNREPC monthly water quality
36	Pond River near Vandetta	03321120	1979-82	USGS coal hydrology station
37	Cypress Creek near Calhoun	03321210	1979-81	USGS coal hydrology station, daily temperature, daily conductance, daily suspended sediment
38	Green River near Beech Grove	03321230	1974-82	USGS NASQAN station, daily temperature, daily conductance

Each parameter is discussed separately in the following sections and presented separately in figures 5-17. The figures begin with stations in the headwaters and end with the NASQAN station (38) at Beech Grove.

No specific criterion was adopted to judge the representativeness of the water-quality data at the NASQAN station to that of the rest of the data in the basin. Rather each constituent was reviewed separately and a partially subjective conclusion was reached. The distribution of data for each site for each constituent is presented in figures 5-17 such that the reader using various criteria can draw his own conclusions about representativeness of the NASQAN station.

Specific Conductance

Specific-conductance data have been collected periodically at 37 stations in the basin (fig. 5). Values range from 66 to 4,500 microsiemens per centimeter at 25 °C (μS/cm) throughout the basin. Mean values range from 75 to 2,300 μS/cm throughout the basin and from 145 to 308 μS/cm on the main stem of the Green River. Values at the Green River near Beech Grove NASQAN station (38) range from 130 to 580 μS/cm and have a mean of 308 μS/cm. With the exception of streams that are heavily impacted by coal mining or oil drilling, the NASQAN station (38) provides a good estimate of specific conductance throughout the basin. Stations not represented by the data from the NASQAN station (38) are; 5, Little Barren River near Monroe (oil drilling); 24, Pond Creek near Martwick (coal mining); 26, Lewis Creek at Rockport (coal mining); 35, Pond River near Sacremento (coal mining and oil drilling); 36, Pond River near Vandetta (coal mining and oil drilling); and 37, Cypress Creek near Calhoun (coal mining).

Specific-conductance data have also been collected on a daily basis at Stations 6, Green River at Munfordville; 37, Cypress Creek near Calhoun; and 38, Green River near Beech Grove. Statistics for these data are presented below for comparison to those for the periodic data above. However, these daily measurements are not part of the data base that was used to prepare figure 5 and table 10. Green River at Munfordville data range from 50 to 780 μS/cm and have a mean of 233 μS/cm (1,935 measurements). Cypress Creek near Calhoun data range from 118 to 3,790 μS/cm and have a mean of 1,760 μS/cm (307 measurements). Green River near Beech Grove data range from 80 to 542 μS/cm and have a mean of 297 μS/cm (2,545 measurements). Values from daily measurements coincide very closely with those of periodic measurements made at these stations (the 95 percent confidence intervals overlap), and indicate that daily measurements do not appreciably add to information gained from long term periodic measurements.

Chloride (dissolved, as Cl)

Chloride data have been collected at 33 stations in the basin (fig. 6). Concentrations range from 0.5 to 155 milligrams per liter (mg/L) throughout the basin. Mean concentrations range from 1.2 to 42 mg/L throughout the basin and from 3 to 21 mg/L on the main stem. Chloride concentrations on the Green

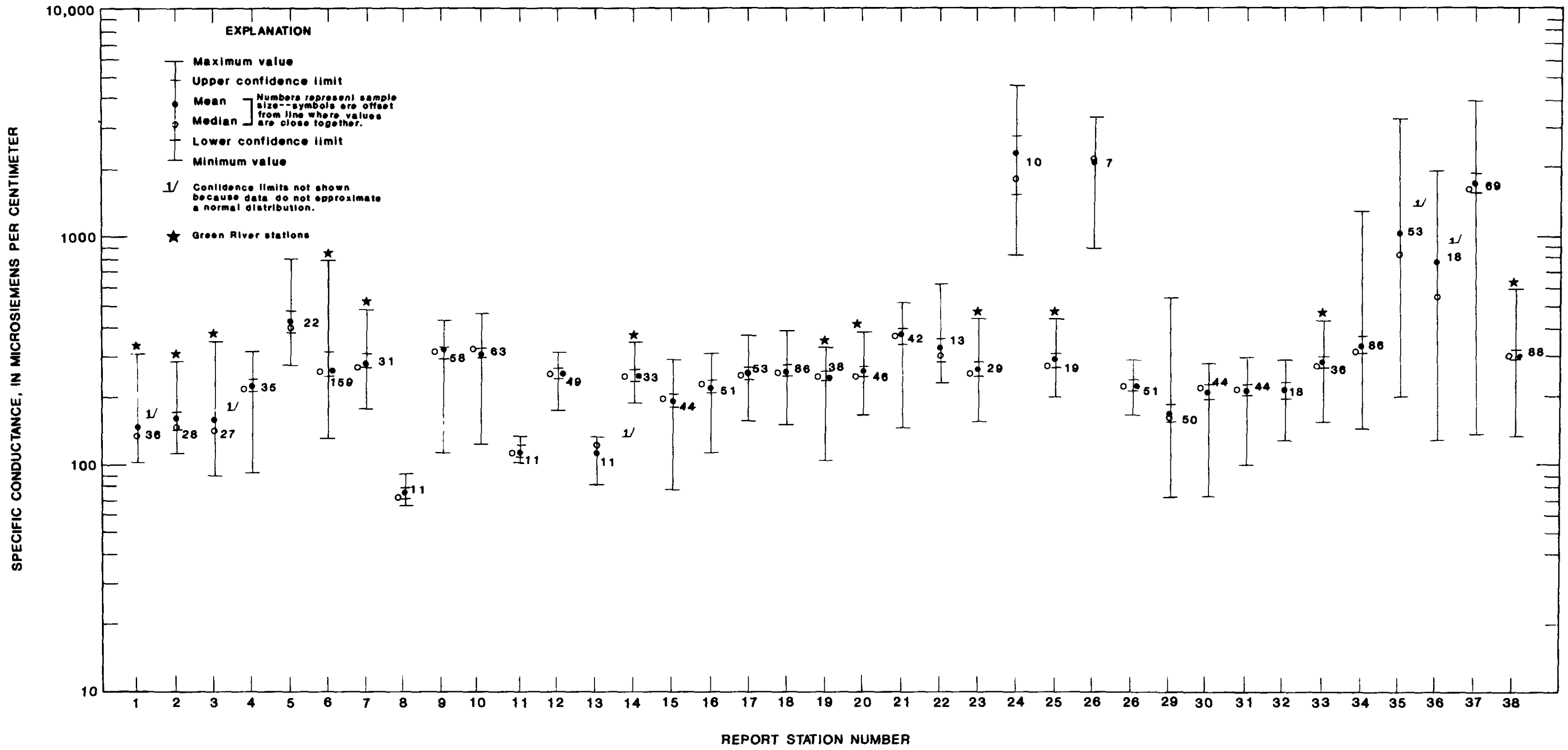

Figure 5.--Range, mean, and median of periodic specific-conductance data at stations.

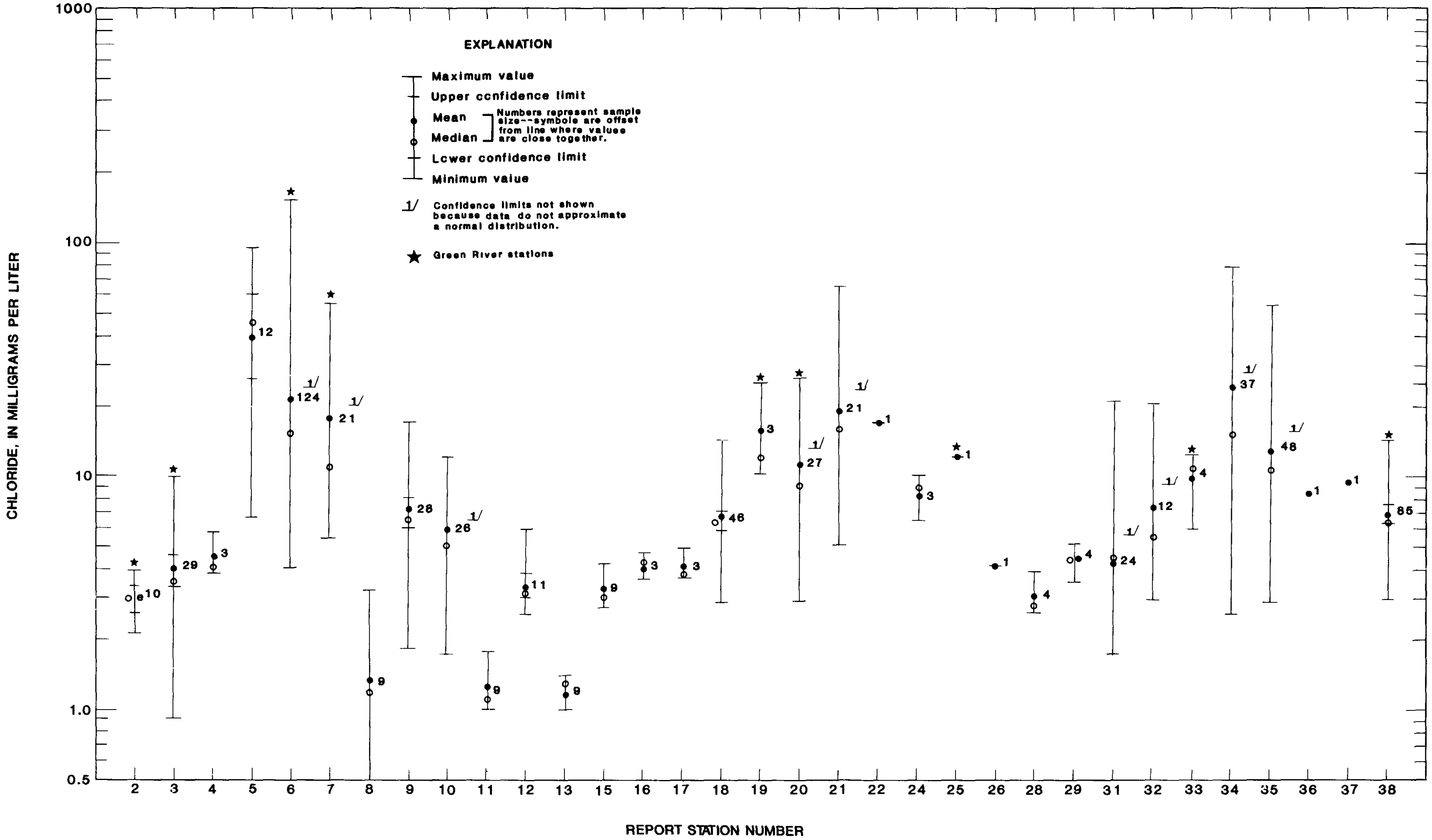

Figure 6.--Range, mean, and median of periodic chloride data at stations.

River increase dramatically below the Greensburg oil field in Green County. Concentrations at Station 3, Green River at Greensburg, upstream of the oil field, range from 0.9 to 10 mg/L and have a mean of 4 mg/L and a median of 3.5 mg/L. Concentrations at Station 6, Green River at Munfordville, downstream of the oil field, range from 4 to 155 mg/L, and have a mean of 21 mg/L and a median of 15 mg/L. Concentrations then decrease downstream on the Green River, and at the NASQAN station the mean and median values were 6.9 and 6.3 mg/L, respectively. The data collected on the main stem and throughout the basin are highly variable, indicating that the Beech Grove NASQAN station (38) is not representative of chloride concentrations in streams in the Green River basin.

Sulfate (dissolved, as SO_4)

Sulfate data have been collected at 33 stations in the basin (fig. 7). Concentrations range from 2.0 to approximately 2,100 mg/L throughout the basin. Mean values range from 5 to 1,180 mg/L throughout the basin and from 15 to 55 mg/L on the main stem. The mean value at the Beech Grove NASQAN station (38) was 55 mg/L, which was the highest mean value in the basin excluding stations directly affected by coal mining (Pond Creek, Lewis Creek, Pond River, and Cypress Creek). Because of these streams, the NASQAN station is not representative of sulfate concentrations in the Green River basin.

pH

Thirty-three stations have pH data in the basin and the minimum, maximum, and median values for these stations are given in figure 8. Values range from 2.6 to 9.1 units throughout the basin. Median values range from 4.95 to 8.1 units throughout the basin and from 7.2 to 7.8 units on the main stem. Quinones (1983) reported miscellaneous pH measurements at 66 sites in the Western Coal Field region. Two of those miscellaneous measurements, not used in this report, had low pH values. Flat Creek, Hopkins County, had pH values less than 3.6 units (three measurements), and Drakes Creek, Hopkins County, had values that ranged from 2.9 to 4.9 units (five measurements). Overall, the Beech Grove NASQAN station (38) is representative of pH values in the basin, but localized problems such as Flat Creek and Drakes Creek are not reflected in Beech Groves' data.

Phosphorus (total, as P)

Phosphorus data have been collected at 29 stations in the basin, but only 11 stations had more than 10 samples analyzed (fig. 9). Phosphorus concentrations range from 0.01 mg/L (the analytical detection limit) to 1.13 mg/L. Mean values at stations with ten or more points range from 0.03 to 0.21 mg/L throughout the basin and from 0.03 to 0.09 mg/L on the main stem. Based on this limited data, the Beech Grove NASQAN station (38) is representative of phosphorus concentrations throughout the basin. Only Station 9, Nolin River at White Mills, and Station 21, Mud River near Homer, seem appreciably different.

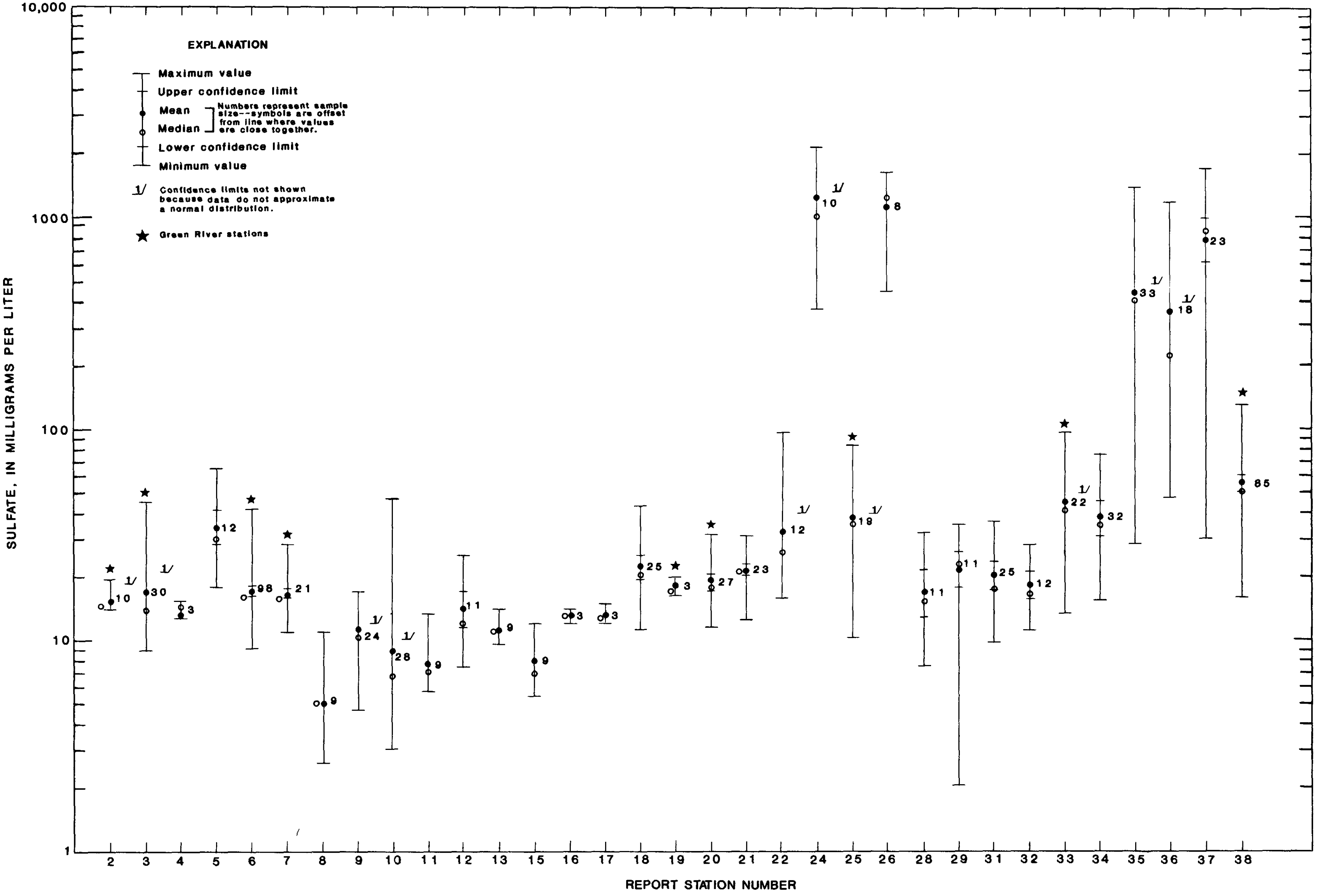

Figure 7.--Range, mean, and median of periodic sulfate data at stations.

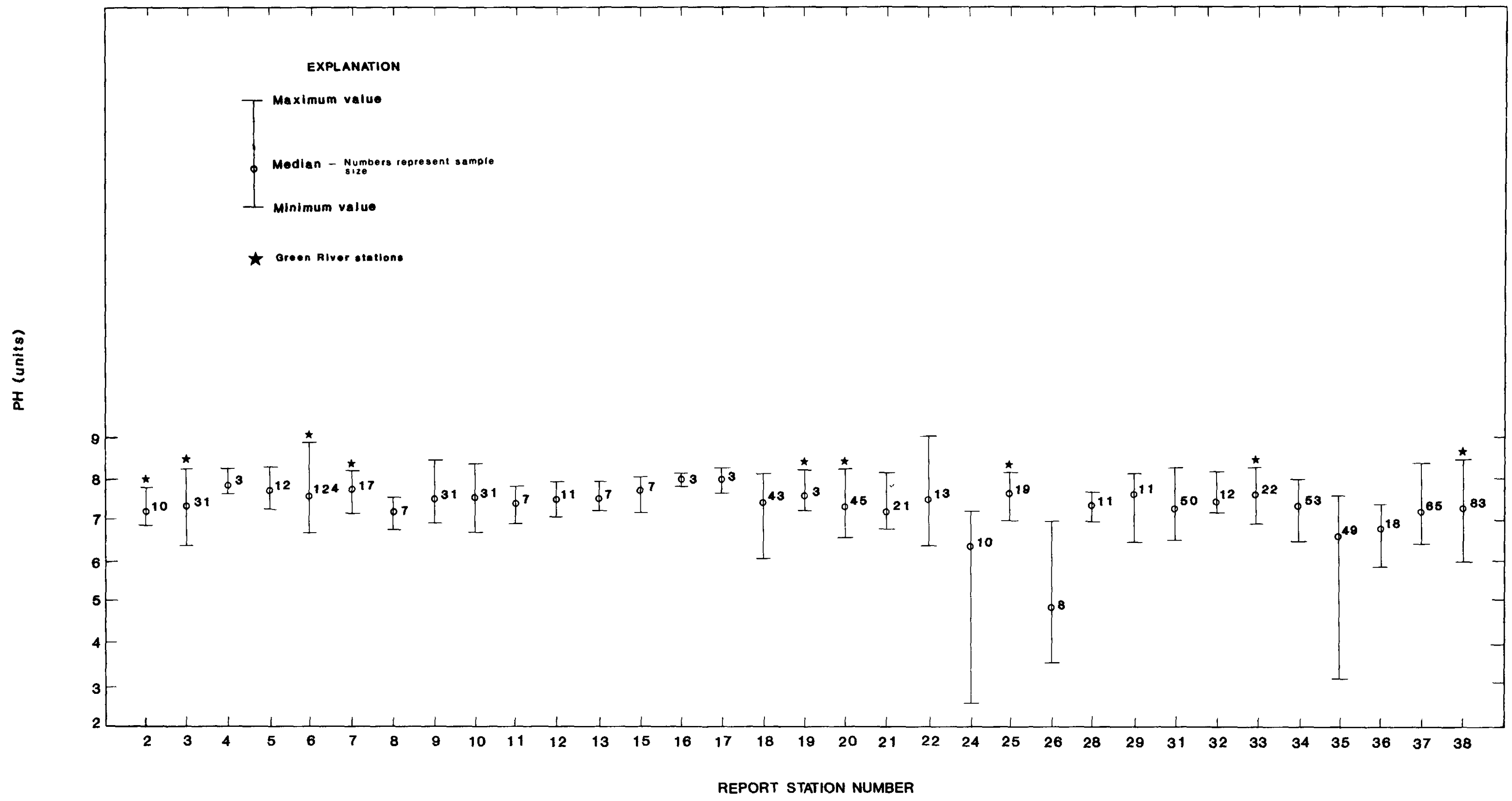

Figure 8.--Range and median of periodic pH data at stations.

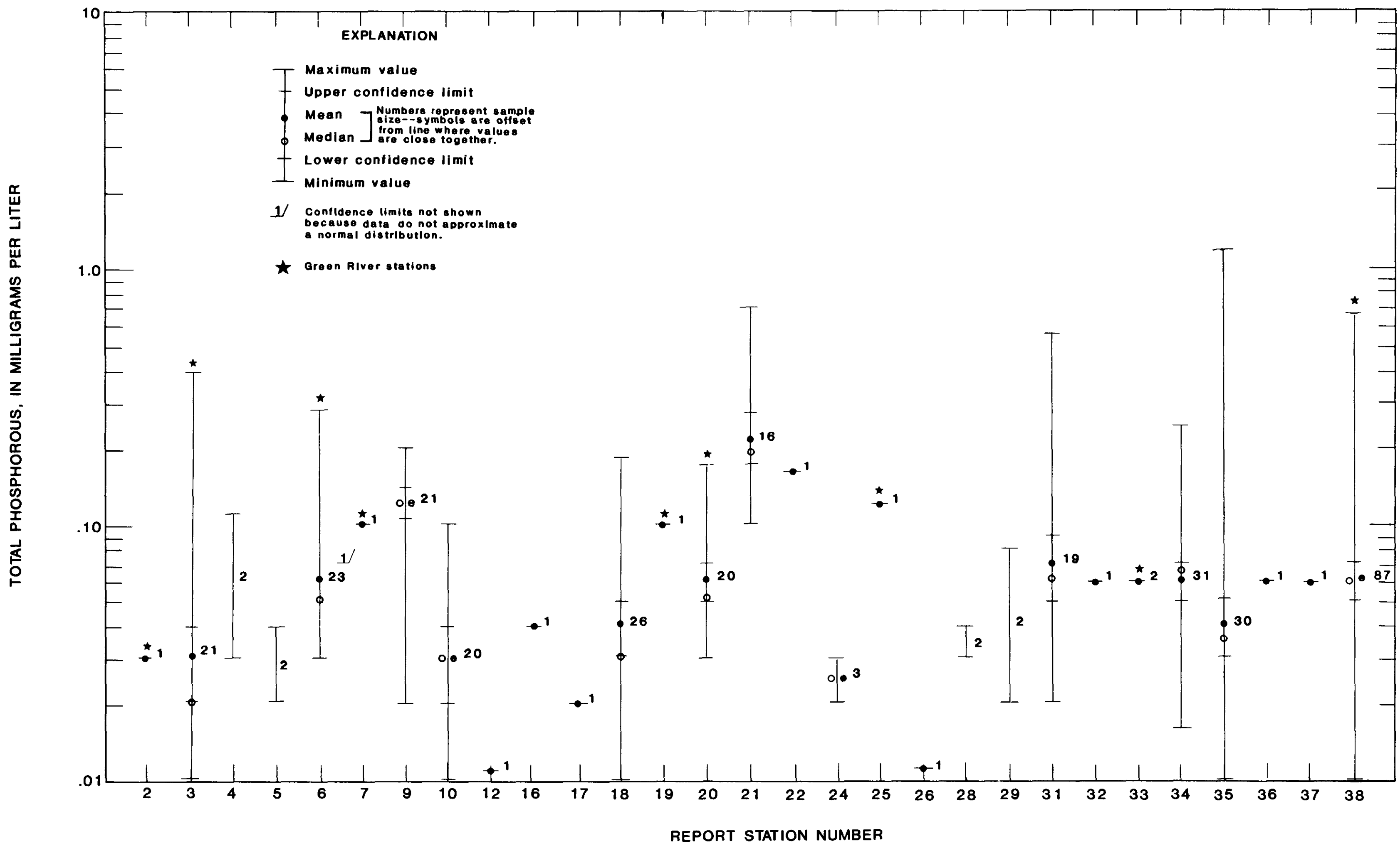

Figure 9.--Range, mean, and median of periodic total-phosphorus data at stations.

Nitrogen (total, as N, and total organic, as N)

Nitrogen data have been collected at 11 stations in the basin (figs. 10 and 11). Total nitrogen ranges from 0.32 to 5.6 mg/L, and mean concentrations range from 1.0 to 2.6 mg/L. Total organic nitrogen ranges from 0.04 to 2.1 mg/L, and mean concentrations range from 0.29 to 0.71 mg/L. Similar to the total phosphorus data, the Beech Grove NASQAN station (38) is representative of total nitrogen concentrations in the basin with the exception of Station 9, the Nolin River at White Mills, and Station 21, Mud River near Homer.

Iron (dissolved, as Fe)

Dissolved iron data have been collected at 29 stations in the basin (fig. 12). Concentrations throughout the basin range from less than 10 (analytical detection limit) to 5,800 micrograms per liter (µg/L). Mean concentrations range from 40 to 2,800 µg/L throughout the basin and from 40 to 134 µg/L on the main stem. Dissolved iron concentrations at the Beech Grove NASQAN station (38) are affected by the iron inputs from the heavily mined Pond River and Cypress Creek basins, and are not representative of iron concentrations throughout the basin.

Iron (total recoverable, as Fe)

Total iron data have been collected at 20 stations in the basin (fig. 13). Concentrations range from 40 to 28,000 µg/L throughout the basin. Mean concentrations range from 400 to 5,200 µg/L throughout the basin, and from 850 to 2,900 µg/L on the main stem. Stations in basins with little or no mining occasionally had total iron concentrations greater than the maximum permissible concentrations of 7,000 µg/L established by the Surface Mining Control and Reclamation Act of 1977 (PL 95-87). The Pond River and Cypress Creek basins, however, are both heavily mined and have higher total iron concentrations than most stations sampled in the study area. Water from these two basins enters the Green River just upstream from the Beech Grove NASQAN station (38). This results in high iron concentrations at the NASQAN station and makes it non-representative of total iron data collected throughout the basin.

Water Temperature

Water-temperature data have been collected periodically at 29 stations in the basin (fig. 14). Values range from 0.0 to 34.0 °C throughout the basin. Mean values range from 13.0 to 18.5 °C throughout the basin, and from 13.2 to 18.5°C on the main stem. Station 25, Green River at Rockport, had the highest mean value in the basin, 18.5 °C, but with only 20 measurements made over a 3-year period, this value is probably not representative.

Water-temperature data have also been collected on a daily basis at eight stations in the basin (fig. 15). Values range from 0.0 to 33.5 °C at these stations, and mean values range from 12.0 to 16.8 °C.

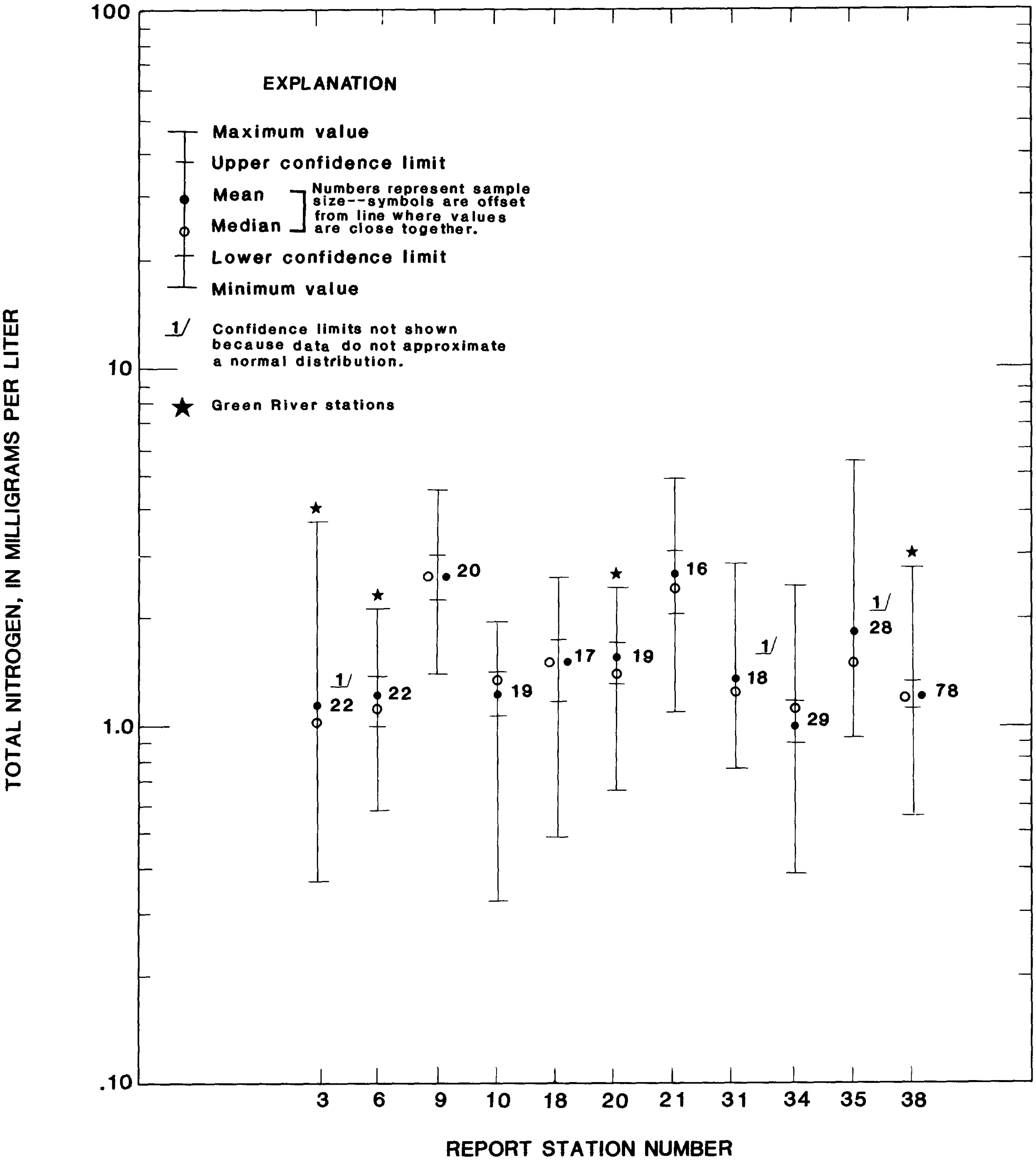

Figure 10.--Range, mean, and median of periodic total-nitrogen data at stations.

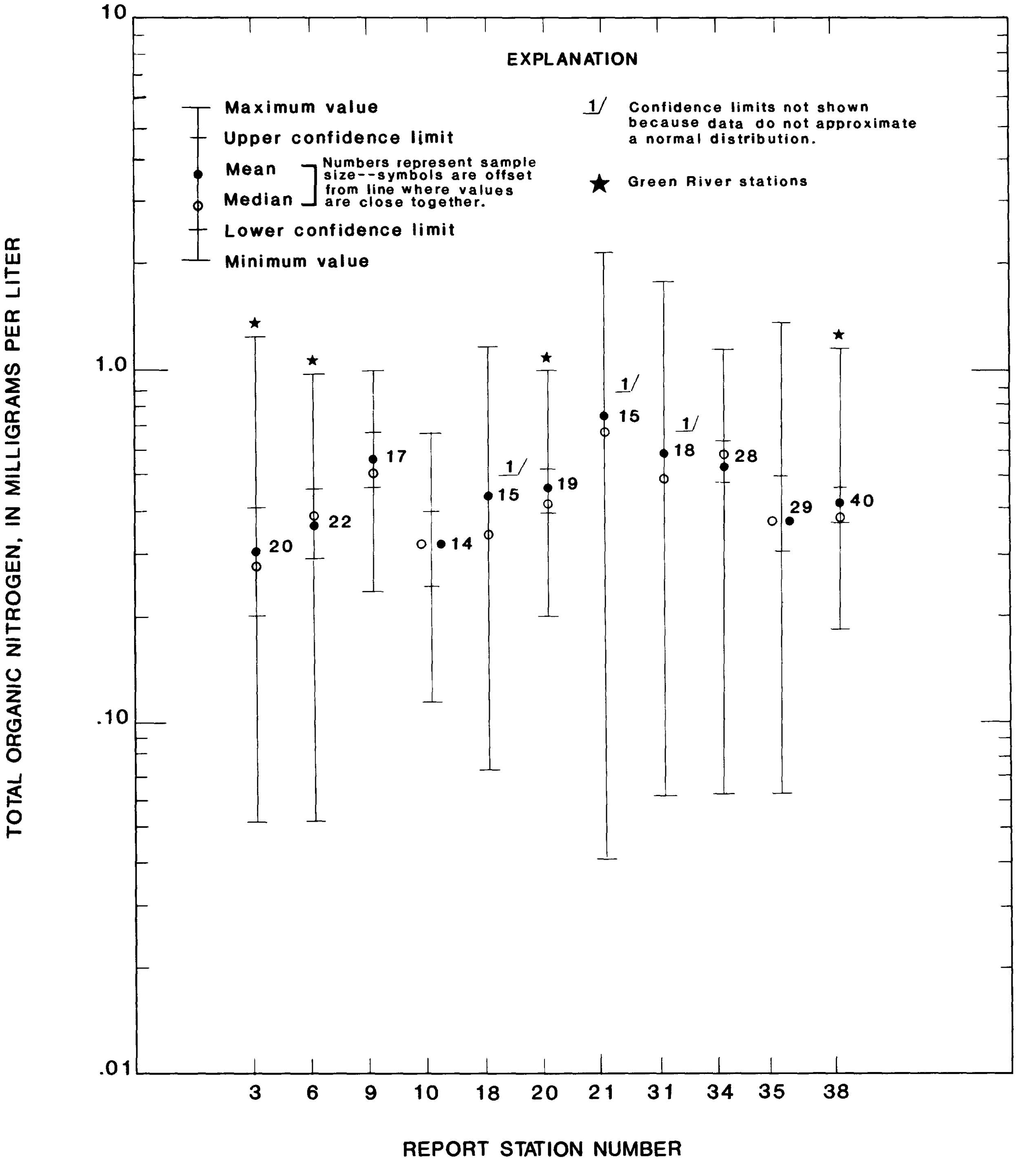

Figure 11.--Range, mean, and median of periodic total organic nitrogen data at stations.

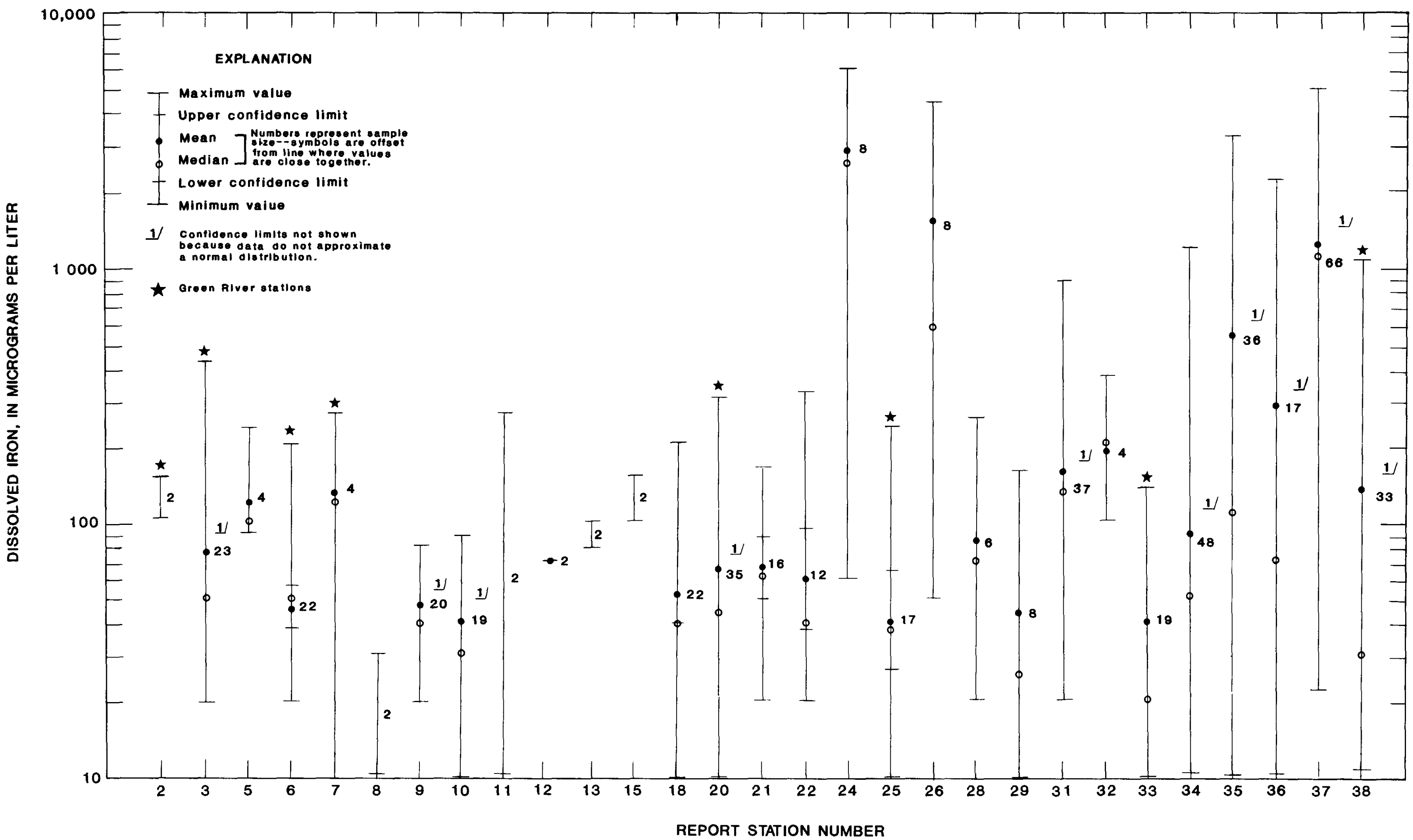

Figure 12.--Range, mean, and median of periodic dissolved-iron data at stations.

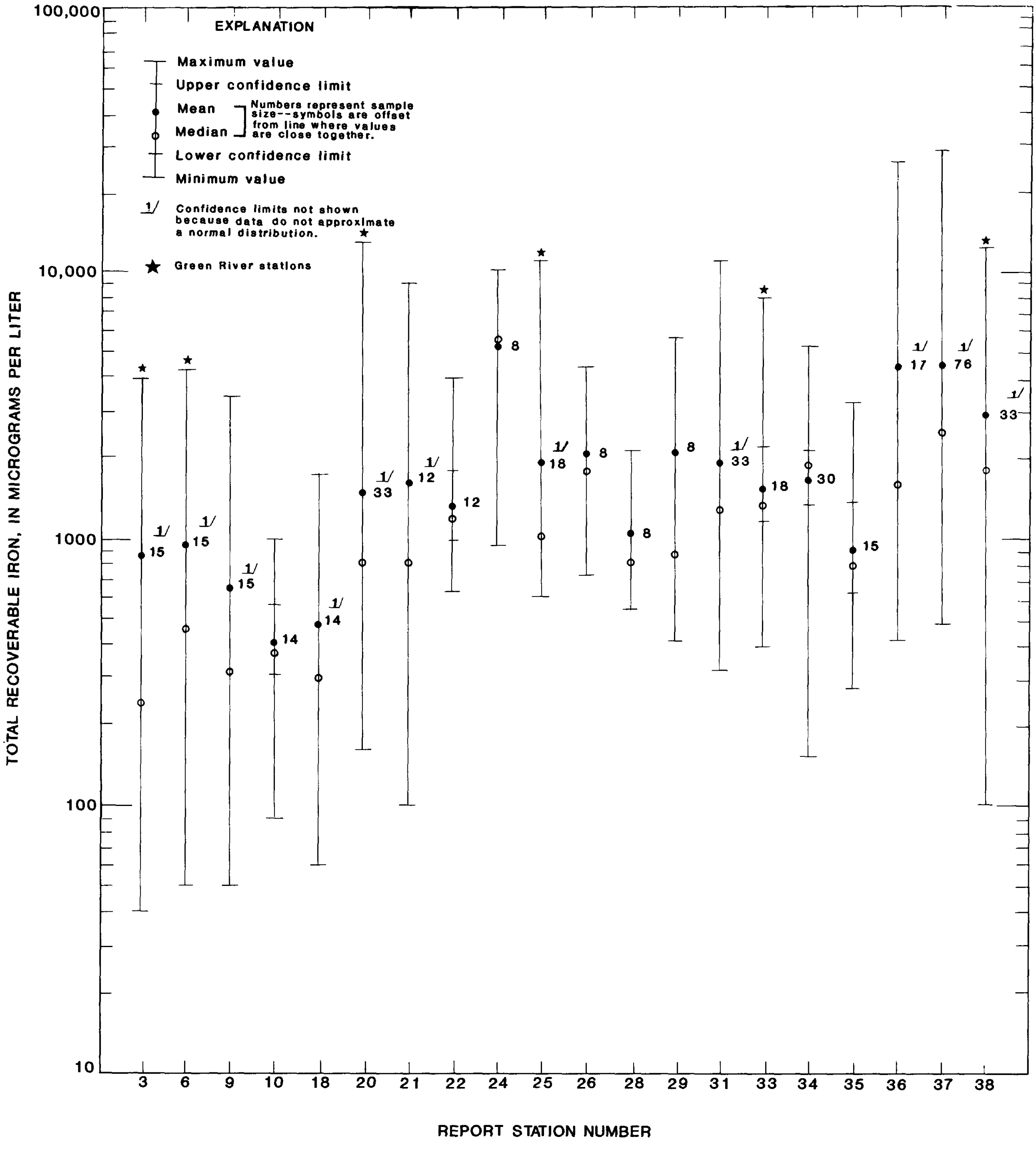

Figure 13.--Range, mean, and median of periodic total recoverable iron data at stations.

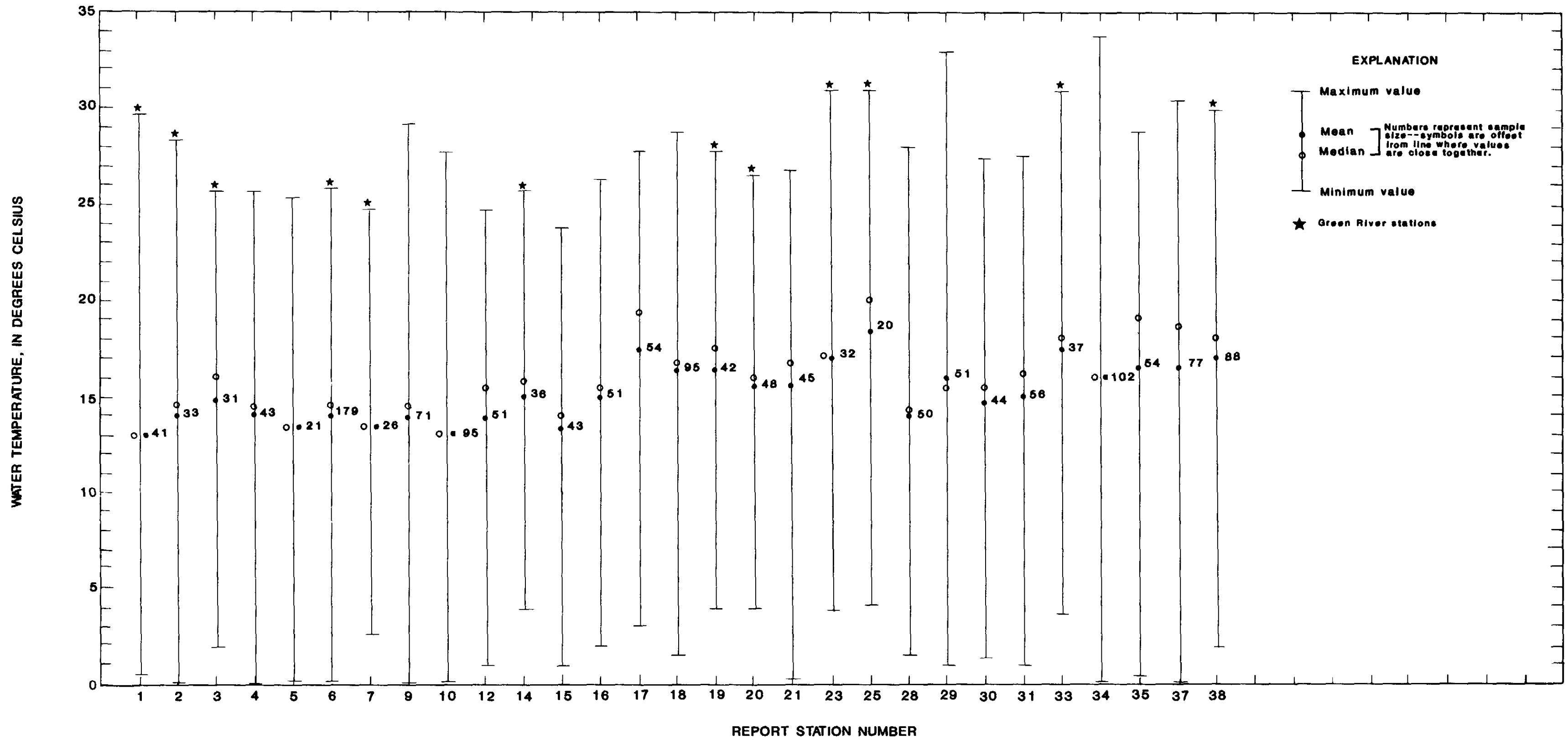

Figure 14.--Range, mean, and median of periodic water temperature data at stations.

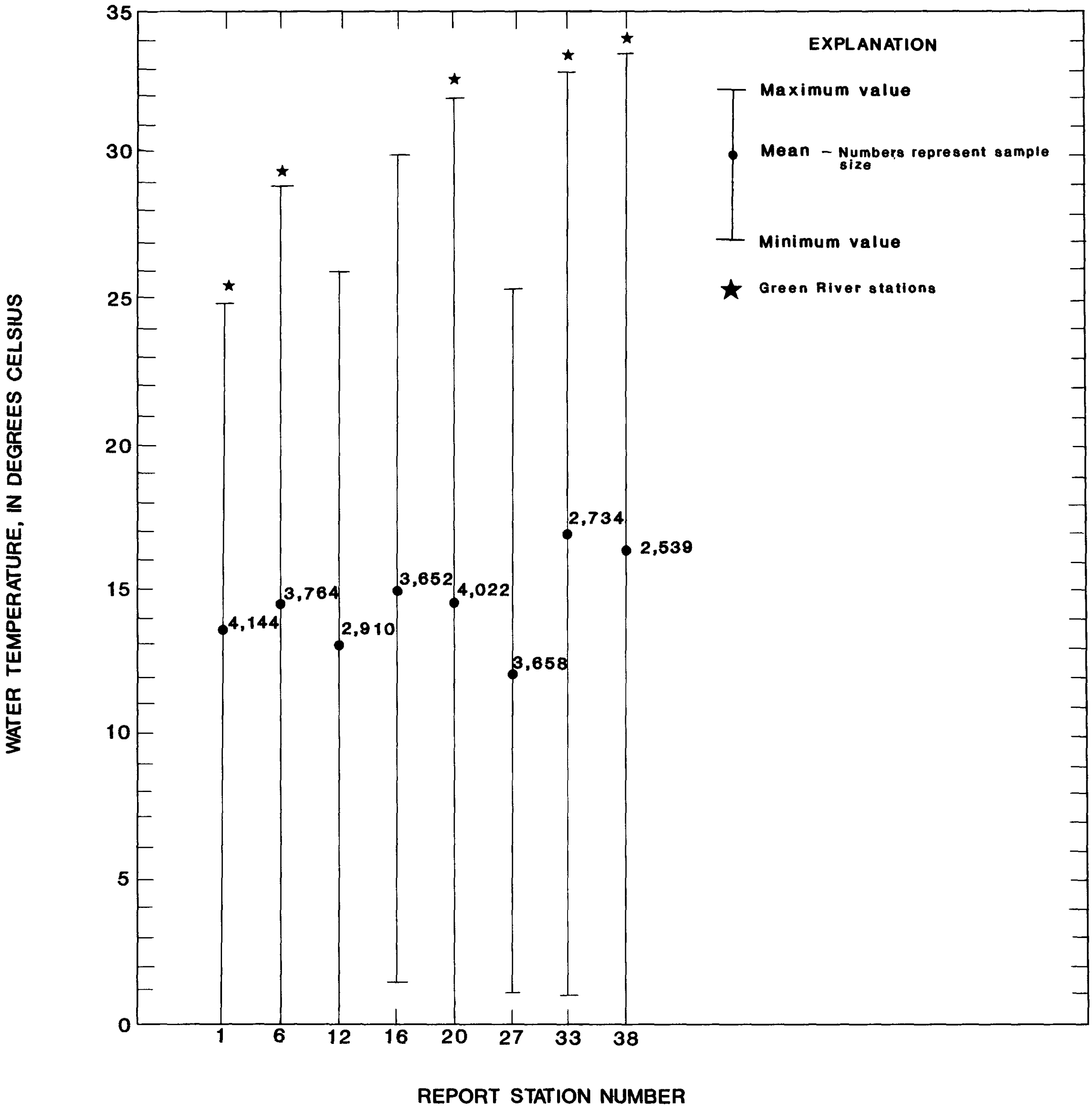

Figure 15.--Range and mean of daily water temperature data at stations.

Both the periodic and daily data show that the Green River main stem increases in temperature downstream. Zogorski and Kiesler (1976) also note this increase in a study of temperature data collected throughout Kentucky. They report that the lower Green River is two degrees higher, on the average, than other major river basins in the State. These higher temperatures may be caused by inefficient cooling of heated water at coal fired power plants, or by significant ground-water inflow from the karst area.

These data indicate that the Beech Grove NASQAN station (38) is not representative of temperature data collected throughout the basin. Daily data and periodic data collected at the same stations have nearly the same mean values but the range of daily data is larger than that of the periodic data.

Suspended Sediment

Suspended-sediment data have been collected periodically at 17 stations in the basin (fig. 16). Concentrations range from 3 to 2,600 mg/L throughout the basin. Mean concentrations range from 28 to 510 mg/L throughout the basin and from 71 to 510 mg/L on the main stem. The Green River at Beech Grove NASQAN station (38) had the lowest mean value on the main stem. A review of the data reveals that most stations in the basin had periodic sediment data collected primarily during high flow resulting from storms. This type of collection creates a bias towards the higher concentrations, and makes comparison to monthly collected data, such as NASQAN data, unreliable. Daily suspended-sediment concentration data at six stations support this observation (fig. 17). For example, the mean and median of periodic data collected at Station 6, Green River at Munfordville, were 510 and 580 mg/L, respectively; but the mean and median of daily collected data were 88 and 52 mg/L, respectively. A comparison of daily data to the NASQAN monthly data (figs. 16 and 17) indicates that the NASQAN station appears to be fairly representative of average sediment concentrations, but not of the range of concentrations. Most stations in the basin did not have enough data for comparison.

Comparison of Constituent Discharges and Yields

Long-term suspended-sediment, dissolved solids, sulfate, phosphorus, and total iron discharge values, in tons per day, and yield values, in tons per day per square mile, were estimated at stations throughout the basin (tables 4 to 8). Discharge-estimation techniques, developed by Miller (1951), were used to derive a mean daily constituent discharge from the period 1969 to 1982. This technique uses a streamflow-duration curve coupled with a constituent-rating curve to develop a mean daily discharge for the period that the flow-duration curve represents. Flow-duration curves are based on daily streamflow records. Constituent-rating curves were developed based on regression analysis of load (in tons) versus instantaneous streamflow. Miller's method was used only at stations where daily flow records exist for the period 1969 to 1982, and where the correlation coefficient for the regression analysis was 0.80 or higher. Data were plotted and checked for seasonality and were determined not to be significantly different between winter and summer periods. Discharge values at the NASQAN station were not determined using

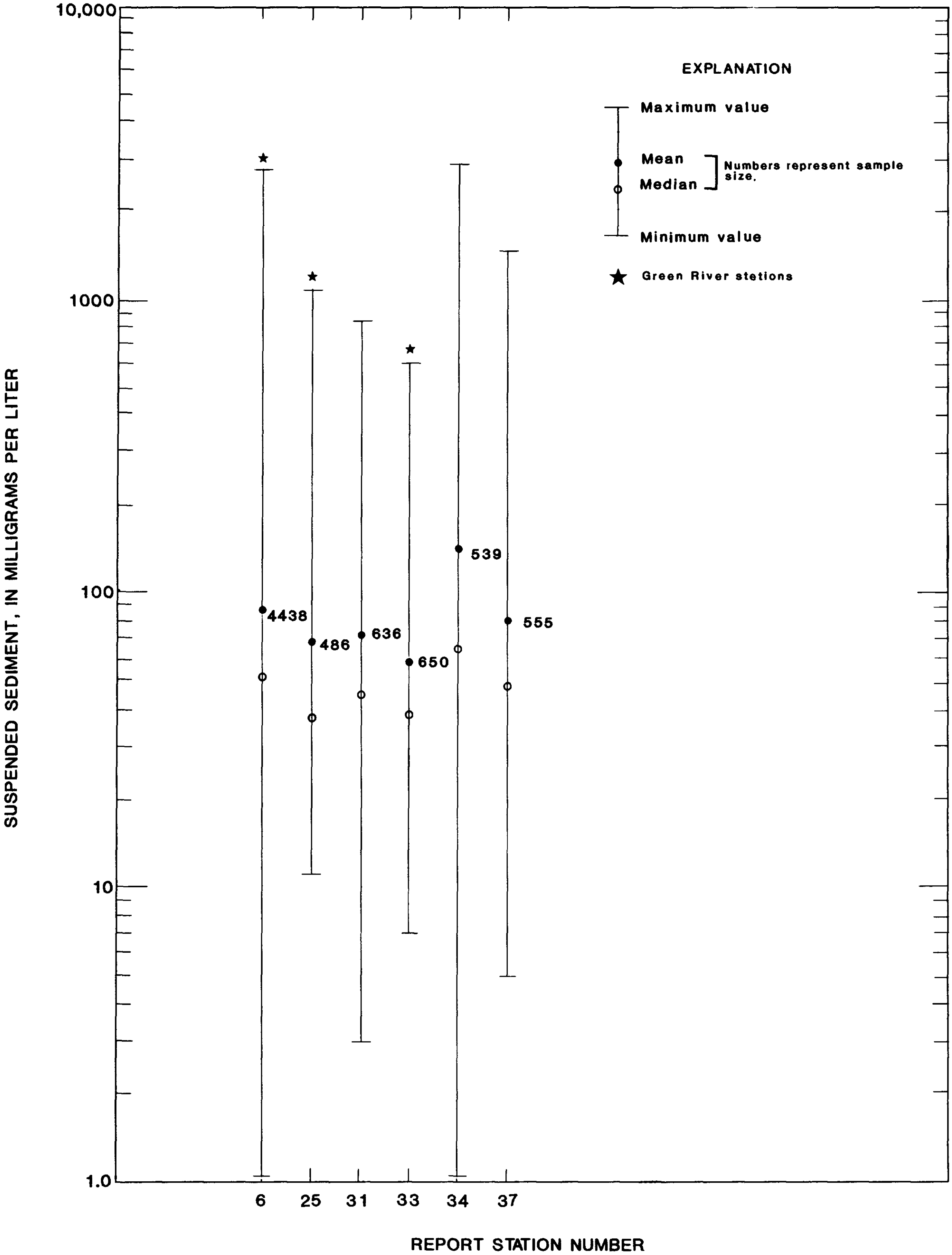

Figure 16.--Range, mean, and median of instantaneous suspended sediment data at stations.

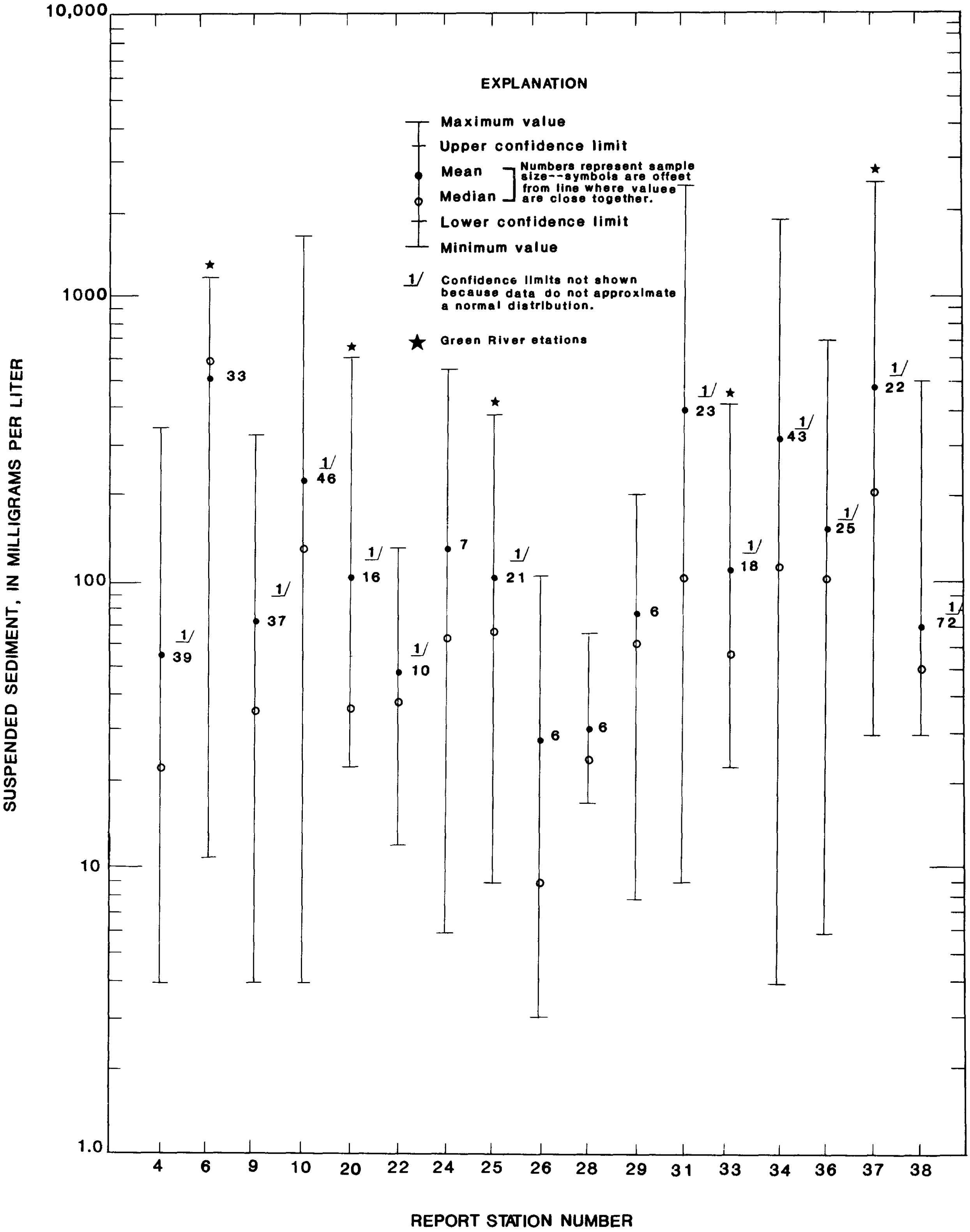

Figure 17.--Range, mean, and median of daily suspended sediment data at stations.

Miller's method because of a lack of daily streamflow data. The nearest daily flow station on the Green River is at Calhoun, 14 mile upstream and 900 mi^2 smaller in drainage area. Flow data at Calhoun were not considered to be representative of flow data at Beech Grove. Discharges at the NASQAN station were computed, however, by multiplying the mean of the constituent concentration by the mean instantaneous streamflow and a conversion factor to convert to tons per day. These values are not considered as accurate as those obtained by Miller's method, but are considered a close approximation because of the number of samples collected over the entire flow regime.

Suspended Sediment

Only seven stations in the basin had enough suspended-sediment and daily-flow data to be used in determining sediment discharges. Sediment yields are variable throughout the basin (table 4). These data indicate that there is generally less suspended-sediment generated per square mile in the Green River basin as the river progresses downstream. Station 25, Green River at Rockport, mile 94.6, had an average yield of 0.66 (tons/d)/mi^2; Station 33, Green River at Lock 2, 31 miles further downstream, had an average yield of 0.48 (tons/d)/mi^2, and Green River at Beech Grove (the lower-most station) had an average yield of 0.37 (tons/d)/mi^2. This observation is supported by basic data records; the maximum reported sediment yield at Rockport was 13.34 (tons/d)/mi^2 on May 20, 1981, while the maximum at Lock 2 was 7.30 (tons/d)/mi^2 on May 21, 1981. Other selected time periods also indicate higher sediment discharges and yields upstream than downstream. During the three-year period of record, suspended-sediment was apparently deposited as water progressed downstream. Scouring and transport of this deposited sediment may occur during flow events more severe than those observed during the period of record. Station 34, Pond River near Apex, had the highest yield of 1.76 (tons/d)/mi^2 of the stations studied. Land use above Apex is primarily agricultural.

Dissolved Solids

Long-term estimated dissolved solids yields were determined at ten sites in the basin. Values range from 0.37 to 0.93 (tons/d)/mi^2 (table 5). These data indicate that dissolved solids yields on the main stem of the Green River slowly increase from Munfordville to Rockport, remain constant to Lock 2, and increase considerably at the Beech Grove NASQAN station (38). Yield values increased from 0.74 to 0.93 (tons/d)/mi^2 from Lock 2 to Beech Grove. These values, however, are based on two different discharge estimation methods and this may be partly the reason for the large increase.

Dissolved-solids concentrations, and thus yields, can also be estimated from specific-conductance measurements. A review of specific-conductance data (fig. 5) shows that specific-conductance increased from Lock 2 to Beech Grove, but only by approximately 10 percent. Dissolved-solids yields, therefore, do increase somewhat from Lock 2 to Beech Grove but probably not by the amounts indicated from the discharge-estimation techniques. The major source of the increase is probably from the heavily mined Pond River and Cypress Creek basins.

Table 4.--Long-term estimated suspended-sediment yields at selected stations in the Green River basin

Report station number	Station name	Discharge (tons per day)	Yield (tons per day per square mile)	Type of station
6	Green River at Munfordville	1,094	0.65	Daily station, data collected from 1969 to 1981.
9	Nolin River at White Mills	150	.42	Miscellaneous station, 37 samples collected from 1977 to 1981.
25	Green River at Rockport	4,062	.66	Daily station, data collected from 1979 to 1981.
31	Rough River at Dundee	297	.39	Daily station, data collected from 1979 to 1981.
33	Green River at Lock 2	3,642	.48	Daily station, data collected from 1979 to 1981.
34	Pond River near Apex	341	1.76	Daily station, data collected from 1979 to 1981.
38	Green River near Beech Grove.	3,101	.37	NASQAN station, 72 samples collected from 1974 to 1982.

Table 5.--Long-term estimated dissolved-solids yields at selected stations in the Green River basin

Report station number	Station name	Discharge (tons per day)	Yield (tons per day per square mile)	Type of station
6	Green River at Munfordville	1,046	0.63	Miscellaneous station, 96 measurements made from 1969 to 1973.
10	Bacon Creek near Priceville	31	.37	Miscellaneous station, 19 measurements made from 1980 to 1982.
12	Nolin River at Kyrock[1]	387	.55	Miscellaneous station, 45 measurements made from 1964 to 1972.
18	Barren River at Bowling Green	1,118	.60	Miscellaneous station, 22 measurements made from 1979 to 1982.
20	Green River at Aberdeen	3,700	.67	Miscellaneous station, 19 measurements made from 1979 to 1981.
25	Green River at Rockport	4,608	.75	Miscellaneous station, 19 measurements made from 1979 to 1981.
31	Rough River at Dundee	413	.55	Miscellaneous station, 19 measurements made from 1979 to 1981.
33	Green River at Lock 2	5,629	.74	Miscellaneous station, 22 measurements made from 1970 to 1981.
34	Pond River near Apex	98	.51	Miscellaneous station, 32 measurements made from 1979 to 1982.
38	Green River near Beech Grove	7,849	.93	NASQAN station, 85 measurements made from 1974 to 1982.

[1]Data prior to 1969 were used at this site for the regression analysis. Nolin Lake was completed in 1963, providing stable basin conditions

Sulfate

Long-term estimated sulfate yield values were determined at 10 stations in the basin. Values range from 0.01 to 0.26 (tons/d)/mi^2 (table 6). Sulfate yields in the Green River remain constant from Munfordville to Aberdeen, and then steadily increase downstream. The Beech Grove NASQAN station (38) had the highest value on the main stem of 0.26 (tons/d)/mi^2. Once again, this value was calculated using a different method, and may not be as accurate as the calculated values from the other stations. A review of sulfate concentration data (fig. 7) shows an increase of about 10 mg/L from Lock 2 to Beech Grove and indicates higher discharges at Beech Grove. The steadily increasing sulfate yields downstream in the Green River are probably the result of inputs from heavily mined areas such as Pond Creek, Lewis Creek, Pond River, and Cypress Creek.

Phosphorus

Six stations had enough data to determine long-term estimated phosphorus yields in the basin. Values range from 0.0002 to 0.0009 (tons/d)/mi^2 (table 7). Phosphorus yield at the Beech Grove NASQAN station (38) was 0.0004 (tons/d)/mi^2. This value, when compared with the yields from Station 6, Green River at Munfordville, of 0.0004 (tons/d)/mi^2 and Station 20, Green River at Aberdeen of 0.0005 (tons/d)/mi^2, indicate that phosphorus yields are stable throughout the Green River main stem, and seem to vary only slightly throughout the basin.

Total Iron

Long-term estimated total iron yields were determined at six sites in the basin. Values range from 0.007 to 0.013 (tons/d)/mi^2 (table 8). Four of the stations are located on the Green River, and the data indicate that iron yields steadily increase downstream. Iron inputs from the Pond Creek, Pond River, and Cypress Creek basins affect iron yields in the Green River main stem, as noted from iron concentration data (fig. 13).

Comparison of Temporal Trends

Trend-analysis techniques, developed by the U.S. Geological Survey, were used for the analysis of time trend in seasonally varying water quality data from fixed, regularly sampled monitoring sites (Smith, Hirsch, and Slack 1982, and Crawford, Slack, and Hirsch, 1983). The procedure, the Seasonal Kendall test, includes an estimate of the median rate of change in the constituent over the sampling period (trend slope), and a method for adjusting the concentration values to remove variation in water quality caused by streamflow. The trend p level is the level of statistical significance of the test. Values of p less than 0.05 are considered here to be significant and indicating a trend. The magnitude of this trend is the slope, which is then

Table 6.--Long-term estimated sulfate yields at selected stations in the Green River basin

Report station number	Station name	Discharge (tons per day)	Yield (tons per day per square mile)	Type of station
6	Green River at Munfordville	128	0.08	Miscellaneous station, 124 measurements made from 1969 to 1982.
9	Nolin River at White Mills	14	.04	Miscellaneous station, 28 measurements made from 1979 to 1982.
10	Bacon Creek near Priceville	1.07	.01	Miscellaneous station, 26 measurements made from 1979 to 1982.
18	Barren River at Bowling Green	152	.08	Miscellaneous station, 48 measurements made from 1969 to 1982.
20	Green River at Aberdeen	413	.08	Miscellaneous station, 45 measurements made from 1979 to 1982.
25	Green River at Rockport	812	.13	Miscellaneous station, 19 measurements made from 1979 to 1981.
31	Rough River at Dundee	68	.09	Miscellaneous station, 44 measurements made from 1979 to 1982.
33	Green River at Lock 2	1,189	.16	Miscellaneous station, 22 measurements made from 1970 to 1981.
34	Pond River near Apex	16	.08	Miscellaneous station, 50 measurements made from 1970 to 1982.
38	Green River at Beech Grove.	2,216	.26	NASQAN station, 85 measurements made from 1974 to 1982.

Table 7.--Long-term estimated phosphorus yields at selected stations in the Green River basin

Report station number	Station name	Discharge (tons per day)	Yield (tons per day per square mile)	Type of station
6	Green River at Munfordville	0.66	0.0004	Miscellaneous station, 22 measurements made from 1980 to 1982.
10	Bacon Creek near Priceville	.013	.0002	Miscellaneous station, 19 measurements made from 1980 to 1982.
20	Green River at Aberdeen	2.63	.0005	Miscellaneous station, 20 measurements made from 1979 to 1982.
31	Rough River at Dundee	.67	.0009	Miscellaneous station, 19 measurements made from 1979 to 1982.
34	Pond River near Apex	.041	.0002	Miscellaneous station, 30 measurements made from 1979 to 1982.
38	Green River near Beech Grove.	3.24	.0004	NASQAN station, 87 measurements made from 1974 to 1982.

Table 8.--Long-term estimated total iron yields at selected stations in the Green River basin

Report station number	Station name	Discharge (tons per day)	Yield (tons per day per square mile)	Type of station
20	Green River at Aberdeen	44	0.008	Miscellaneous station, 33 measurements made from 1979 to 1982.
25	Green River at Rockport	60	.010	Miscellaneous station, 18 measurements made from 1979 to 1981.
31	Rough River at Dundee	7.9	.010	Miscellaneous station, 33 measurements made from 1979 to 1982.
33	Green River at Lock 2	86	.011	Miscellaneous station, 18 measurements made from 1979 to 1981.
34	Pond River near Apex	1.4	.007	Miscellaneous station, 29 measurements made from 1979 to 1982.
38	Green River near Beech Grove.	114	.013	NASQAN station, 33 measurements made from 1974 to 1982.

divided by the mean concentration and reported as the percent change per year. A positive slope indicates an upward trend, a negative slope indicates a downward trend. Trend-slope estimates are reported for all stations regardless of the significance level of the test.

Trends on Unadjusted Water-Quality Data

The Seasonal Kendall test was used to determine trends on water-quality data not adjusted for changes due to streamflow for selected constituents at stations throughout the basin (tables 9 to 18). Many stations were sampled on a regular monthly basis. Thus the seasonal value used in the test was 12. In this manner, for monthly data with seasonality, January data are compared only with January data, and so on. The Seasonal Kendall test was performed twice, once for data collected between 1969 to 1982 (the period of record for this study), and once for data collected between 1979 to 1982, when KNREPC began their sampling program. Only the test results for data from 1969 to 1982 are reported unless the test indicated significant trends for one period and not for the other. In these cases, the test results from both periods are reported.

Trends on Flow-Adjusted Water-Quality Data

Concentrations of water-quality constituents are often related to streamflow. When this occurs, significant trends reported in water quality may be due in part to fluctations in streamflow and not wholly to long-term temporal changes in stream chemistry. In order to remove the effect of streamflow, flow-adjustment procedures can be used. A time series of flow-adjusted concentrations (FAC) is developed, and that series is tested for trends. The FAC is defined as the actual concentration minus the expected concentration predicted from a discharge constituent regression equation. Models tested for flow adjustment are listed below. "C" is the predicted constituent concentration, "Q" is surface-water discharge, and "a" and "b" are regression constants.

1)	$C = a+bQ$	linear
2)	$C = a+b(\log Q)$	log-linear
3)	$C = a+b\left(\frac{1}{1+BQ}\right)$	hyperbolic, B is a constant typically in the range $10^{-3} Q_m^{-1} \leq B \leq 10^{2} Q_m^{-1}$ where Qm is the mean discharge
4)	$C = a+b\left(\frac{1}{Q}\right)$	inverse
5)	$C = a+bQ+b_2Q^2$	quadratic
6)	$\log C = a+b(\log Q)$	log-log
7)	$\log C = a+b(\log Q)+b_2(\log Q)^2$	log-quadratic

Trends on flow-adjusted concentrations were determined at stations where the coefficient of determination (R^2) was greater than 0.5 and the regression was significant at the 95 percent probability level for any of the models listed. When this occurred, the R^2, trend p for the FAC data, and model used were reported alongside the trend results from the unadjusted data (tables 10-18).

Streamflow

Trend analysis of instantaneous streamflow measurements was performed to determine if the flow measurements made at the time of sampling might be changing over time. Analysis of 22 stations indicates no significant streamflow trends (table 9).

Specific Conductance

Trend analysis of specific-conductance data indicates that two stations had significant temporal trends in unadjusted data, and two other stations had trends in flow-adjusted data (table 10). Most stations were not tested for flow-adjusted values because the regression equations did not indicate a good relation (R^2>0.5) of specific conductance to streamflow. Station 3, Green River at Greensburg, had a +34 percent of the mean per year increase in unadjusted data, with a poor regression equation. An examination of the data shows that Green River Dam (upstream) was closed for repairs in late 1981, reducing flow to less than 5 ft^3/s and causing a temporary increase in specific conductance. Thus, the 34 percent increase per year is not considered to be a true trend in the Green River. Station 6, Green River at Munfordville, had no trend in unadjusted data, but indicates a decreasing trend in flow-adjusted data. Considering the number of data points and the long period of record at this site, this decrease could reflect the reduction in oil production from the Greensburg Oil Field. Station 29, Caney Creek near Horse Branch, had no trend from 1970 to 1982, but does show a +12 percent per year increasing trend from 1979 to 1982 in the unadjusted data. Neither period had a good regression. An examination of the data reveals one high value, 520 µS/cm, was determined during extreme low flow. This is more than twice any other value, and appears to have affected the trend analysis during the shorter time period. Without this value, there appears to be no trend. Station 33, Green River at Lock 2, did not have a trend in unadjusted data, but did indicate an increase in flow-adjusted data. The Green River NASQAN station (38) did not have a trend with either unadjusted or adjusted data.

Chloride

Trend analysis of chloride data indicates that four stations had significant temporal trends in unadjusted data, and one of the four had a trend in flow-adjusted data (table 11). Most stations were not tested for flow-adjusted concentrations because the regression equations did not indicate a good relation of chloride to streamflow. Station 6, Green River at Munfordville, had a decreasing trend of about 5 percent of the mean per year from 1969 to 1982 for the unadjusted data. This decrease probably reflects

Table 9.--Instantaneous-streamflow trends in the Green River basin

Report station number	Station	Period of record	Number of measurements	Mean (ft^3/s)	Trend p	Slope (percent per year)
1	Green River near Campbellsville.	1977-82	41	1,449	0.12	-7.7
3	Green River at Greensburg	1979-82	29	1,390	.55	-27
4	Russell Creek near Columbia	1978-82	38	320	.33	-23
6	Green River at Munfordville	1969-82	160	4,754	.62	-1.0
9	Nolin River at White Mills	1979-82	63	873	.74	-5.4
10	Bacon Creek near Priceville	1979-82	85	320	.16	-1.8
12	Nolin River at Kyrock	1970-82	51	976	.68	+.3
14	Green River at Lock 6	1978-82	36	7,048	1.0	0
15	Beaver Dam Creek at Rhoda	1969-82	45	21	.26	+.4
16	Barren River near Finney	1970-82	51	1,595	.91	+.3
17	West Fork Drakes Creek near Franklin.	1979-82	54	151	.28	-2.0
18	Barren River at Bowling Green.	1979-82	54	2,716	.27	-13
20	Green River at Aberdeen	1979-82	45	8,497	.71	-36
23	Green River at Paradise	1978-81	32	14,040	.49	+7.6
25	Green River at Rockport	1979-81	26	13,942	1.0	+6.2
28	Rough River at Falls of Rough.	1978-82	40	755	.45	-12
29	Caney Creek near Horse Branch.	1978-82	40	276	.14	-4.3
31	Rough River at Dundee	1979-82	53	1,200	.44	-41
33	Green River at Lock 2	1978-82	29	17,376	.27	-25
34	Pond River near Apex	1978-82	79	620	.06	-4.3
37	Cypress Creek near Calhoun	1979-81	85	200	.15	-8.5
38	Green River near Beech Grove	1974-82	88	14,985	.18	-1.6

Table 10.--Specific-conductance trends in the Green River basin
[S indicates significant trend]

Report station number	Station	Period of record	Number of measure-ments	Concentration: Mean (µS/cm)	Concentration: Trend p	Concentration: Slope (percent per year)	Flow-adjusted concentration: R^2	Flow-adjusted concentration: Trend p	Flow-adjusted concentration: Trend direction	Flow-adjusted concentration: Type of model
1	Green River near Campbellsville	1977-82	36	148	0.25	+3.4	<0.5			
2	Green River near Greensburg	1969-77	28	154	.54	-2.3	<.5			
3	Green River at Greensburg	1979-81	27	157	.01 S	+34	<.5			
4	Russell Creek near Columbia	1970-82	35	219	1.0	0	<.5			
5	Little Barren River near Monroe	1970-73	22	435	.06	-17	<.5			
6	Green River at Munfordville	1970-82	159	280	.51	-.6	.59	0.03 S	decreasing	Log Linear
9	Nolin River at White Mills	1970-82	1/ 57	315	.46	+1.0	.72	.71	decreasing	Log Linear
10	Bacon Creek near Priceville	1971-82	63	308	.15	+1.5	<.5			
12	Nolin River at Kyrock	1970-82	49	250	.32	+.44	<.5			
14	Green River at Lock 6	1978-82	33	242	.45	+3.9	<.5			
15	Beaver Dam Creek at Rhoda	1970-82	44	186	.84	+.3	.59	.14	increasing	Log Linear
16	Barren River near Finney	1970-82	51	216	.08	+2.8	<.5			
17	West Fork Drakes Creek near Franklin	1970-82	53	250	.69	0	<.5			
18	Barren River at Bowling Green	1970-82	86	253	.70	+.4	<.5			
19	Green River at Lock 4	1970-82	38	242	.90	+.10	<.5			
20	Green River at Aberdeen	1979-82	46	253	.07	+6.7	.55	.46	increasing	Log Linear
21	Mud River near Homer	1975-82	42	369	.41	+1.5		Not determined, flow data not available.		
23	Green River at Paradise	1978-81	29	262	.18	+3.2	<.5			
25	Green River at Rockport	1979-81	19	288	1.0	+3.1	.76	.37	increasing	Log Linear
28	Rough River at Falls of Rough	1970-82	51	219	.27	-.8	<.5			
29	Caney Creek near Horse Branch	1970-82	50	166	.84	0	<.5			
29	Caney Creek near Horse Branch	1979-82	39	163	.05 S	+12	<.5			
30	Rough River near Dundee	1975-82	1/ 43	205	.38	-1.6	<.5			
31	Rough River at Dundee	1979-82	44	204	.33	+8.8	<.5			
33	Green River at Lock 2	1970-82	36	279	.07	+6.0	.58	.02 S	increasing	Log Linear
34	Pond River near Apex	1970-82	86	327	.90	+.3	<.5			
35	Pond River near Sacramento	1970-82	53	1,036	.28	-3.1		Not determined, flow data not available		
36	Pond River near Vandetta	1979-82	18	761	1.0	-18	.92	.73	increasing	Log Linear
37	Cypress Creek near Calhoun	1979-82	69	1,700	.41	+26	.79	.06	decreasing	Log Linear
38	Green River near Beech Grove	1974-82	88	308	.28	+1.3	.65	1.0	increasing	Log Linear

1/ One less measurement here than for same station in figure 4 because of poor flow data for the omitted measurement.

Table 11.--Chloride trends in the Green River basin
[S indicates significant trend]

Report station number	Station	Period of record	Number of measure-ments	Concentration: Mean (mg/L)	Concentration: Trend p	Concentration: Slope (percent per year)	Flow-adjusted concentration: R^2	Flow-adjusted concentration: Trend p	Flow-adjusted concentration: Trend direction	Flow-adjusted concentration: Type of model
3	Green River at Greensburg	1979-82	29	4.0	0.84	+3.0	< 0.5			
6	Green River at Munfordville	1969-82	124	21	.002 S	-4.9	.59	0.009 S	decreasing	Log Log
6	Green River at Munfordville	1979-82	28	17	.105	+41	<.5			
7	Green River at Mammoth Cave	1969-74	21	17	.09	-18		Not determined, flow data not available		
9	Nolin River at White Mills	1970-82	28	7.1	.17	+2.9	<.5			
10	Bacon Creek near Priceville	1979-82	23	6.1	.60	+16	<.5			
18	Barren River at Bowling Green	1969-82	46	6.8	.45	.5	<.5			
20	Green River at Aberdeen	1979-82	27	11	.10	+17	<.5			
21	Mud River near Homer	1979-82	21	19	1.0	-22		Not determined, flow data not available		
31	Rough River at Dundee	1979-82	24	4.9	1.0	+2	<.5			
34	Pond River near Apex	1979-82	33	21	.05 S	+12	.57	.60	increasing	Log Log
35	Pond River near Sacremento	1969-82	48	13	1.0	-1.5		Not determined, flow data not available		
35	Pond River near Sacremento	1979-82	33	13	.002 S	+15		Not determined, flow data not available		
38	Green River near Beech Grove	1974-82	85	6.9	-.05 S	+4.9	<.5			
38	Green River near Beech Grove	1979-82	40	7.2	.003 S	+23	<.5			

the reduction of oil production from the Greensburg Oil Field. This same station did not have a trend from 1979 to 1982, indicating that either chloride concentrations have leveled off in recent years or that there is insufficient data over this period to see the trend. Station 34, Pond River near Apex, had a +12 percent per year increase in unadjusted data but no significant trend in flow-adjusted data. Station 35, Pond River near Sacremento, showed no trend from 1969 to 1982, but had a 15 percent per year increase from 1979 to 1982 in unadjusted data. Flow data are not available at this site. The Green River NASQAN station (38) had approximately a 5 percent per year increase from the period 1974 to 1982, and a 23 percent per year increase from 1979 to 1982 in unadjusted concentrations. The station had a poor regression equation. In a trend study of NASQAN stations by Smith and Alexander (1983), the period of record from 1974 to 1981 indicated no significant chloride trend at the Green River NASQAN station (75 samples). A review of the data since that study (10 measurements) did not reveal questionable concentrations but did show that the mean of chloride concentrations had increased from 6.6 to 8.6 mg/L. Streamflow was normal during this period. These three testing periods indicate that chloride concentrations were, and may still be, increasing at the NASQAN station since 1981. The source appears to be inputs from the Pond River.

Sulfate

Trend analysis of sulfate data indicates that none of the stations had a temporal trend in unadjusted data, and only two stations had a good relation between sulfate and streamflow (table 12). Trend analysis on the flow-adjusted data at these two stations also shows no significant trend.

Total Phosphorus

Trend analysis of total-phosphorus data indicates that two stations had significant temporal trends in unadjusted data (table 13). None of the stations were tested for flow-adjusted concentrations because the regression equations did not indicate a good relation of phosphorus to discharge. Station 3, Green River at Greensburg, had a 40 percent of the mean per year increase in unadjusted concentrations from 1980 to 1982. A review of these data did not reveal the cause of this apparent increase, but because of the short period of record this trend may only be due to natural variability. The Green River NASQAN station (38) had a trend of +2.5 percent per year from 1974 to 1982. Two other reports discuss phosphorus trends at the NASQAN station. Smith and others (1982) use the period from 1974 to 1979, and show a trend of +3.9 percent at a p level greater than 0.1, which is not considered statistically significant. Smith and Alexander (1983), for the period 1974 to 1981, show a trend of +4.1 percent at a p level of 0.08, also not considered significant by the standards used for this report. The p value for this study, from 1974 to 1982, was 0.04, which is considered statistically significant. From these three period of records it appears that phosphorus concentrations are slowly increasing at the NASQAN station. It should be noted, however, that the mean value for all three tests was 0.08 mg/L, and

Table 12.--Sulfate trends in the Green River basin
[S indicates significant trend]

Report station number	Station	Period of record	Number of measure- ments	Concentration			Flow-adjusted concentration			
				Mean (mg/L)	Trend p	Slope (percent per year)	R^2	Trend p	Trend direction	Type of model
3	Green River at Greensburg	1979-82	30	17	1.0	+2.9	< 0.5			
6	Green River at Munfordville	1979-82	28	17	.06	+20	<.5			
9	Nolin River at White Mills	1979-82	24	11	.45	+22	<.5			
10	Bacon Creek near Priceville	1979-82	26	9.0	.36	+10	<.5			
18	Barren River at Bowling Green.	1979-82	25	22	.63	+13	<.5			
20	Green River at Aberdeen	1979-82	27	19	.13	+12	<.5			
21	Mud River near Homer	1979-82	23	21	1.0	+6.1		Not determined, flow data not available		
25	Green River at Rockport	1979-81	19	38	.77	+24	.59	0.37	increasing	Log Linear
31	Rough River at Dundee	1979-82	25	20	.67	-3.0	<.5			
33	Green River at Lock 2	1979-82	19	42	.20	+25	<.5			
34	Pond River near Apex	1979-82	32	38	1.0	+3.8	<.5			
35	Pond River near Sacremento	1979-82	33	440	.62	+5.7		Not determined, flow data not available		
37	Cypress Creek near Calhoun	1979-82	23	785	.57	+41	.86	.57	decreasing	Log Linear
38	Green River near Beech Grove.	1974-82	85	55	.20	-1.7	<.5			

Table 13.--Total-phosphorus trends in the Green River basin
[S indicates significant trend]

Report station number	Station	Period of record	Number of measure- ments	Concentration			Flow-adjusted concentration			
				Mean (mg/L)	Trend p	Slope (percent per year)	R^2	Trend p	Trend direction	Type of model
3	Green River at Greensburg	1980-82	22	0.05	0.03 S	+40	< 0.5			
6	Green River at Munfordville	1980-82	22	.07	.34	+43	< .5			
9	Nolin River at White Mills	1980-82	20	.12	1.0	+13	< .5			
10	Bacon Creek near Priceville	1980-82	19	.04	1.0	0	< .5			
18	Barren River at Bowling Green.	1972-82	26	.05	.40	+10	< .5			
20	Green River at Aberdeen	1979-82	20	.07	.68	+23	< .5			
21	Mud River near Homer	1979-82	16	.25	.25	+44		Not determined, flow data not available		
31	Rough River at Dundee	1979-82	19	.11	.13	+41	< .5			
34	Pond River near Apex	1979-82	29	.07	.17	+24	< .5			
35	Pond River near Sacremento	1979-82	29	.08	1.0	0		Not determined, flow data not available		
38	Green River near Beech Grove.	1974-82	87	.08	.04 S	+2.5	< .5			

that an increase of 2.5 percent of the mean is only 0.002 mg/L per year, which is less than the detection limit of 0.01 mg/L. Future trend analysis should be conducted to determine if this apparent trend is real, or possibly caused by normal sampling and analytical variations.

Dissolved Iron

Trend analysis of dissolved-iron data indicates that two stations had significant temporal trends in unadjusted data (table 14). Only two stations were tested for flow-adjusted concentrations, neither of which showed a trend. The other stations were not tested for flow adjustment because the regression equations did not indicate a good relation of dissolved iron to streamflow. Station 35, Pond River near Sacremento, had a 12 percent per year decrease in dissolved iron from 1971 to 1982. Flow data are not available at this site to test for flow adjustment, so the decreasing trend may be an effect of changing streamflow or biased sampling. This seems unlikely, however, because of the poor relation of dissolved iron to streamflow at most other sites in the basin. Station 37, Cypress Creek near Calhoun, had a 30 percent per year increase in dissolved iron from 1979 to 1981. A review of these data did not reveal the cause of this apparent increase; but because of the short period of record, this trend may only be due to natural variability. However, there is extensive mining in this basin, and the trend may be reflecting an increase in mining activity or other land disturbance.

Total Iron

Trend analysis of total-iron data shows that none of the stations had a temporal trend in unadjusted data, and only three stations indicated a relation between total iron and streamflow (table 15). Trend analysis on the flow-adjusted data at these stations did not show a significant trend.

pH

Trend analysis of pH data indicates that five stations had significant temporal trends in unadjusted pH data (table 16). None of the stations were tested for flow-adjusted concentrations because the regression equations did not indicate a good relation of pH to streamflow. Station 3, Green River at Greensburg, had a 2.4 percent of the median per year decrease in pH from 1979 to 1982. A review of these data did not reveal the cause of this trend. Station 6, Green River at Munfordville, had a 0.53 percent per year decreasing trend from 1970 to 1982, but no significant trend from 1979 to 1982. Station 34, Pond River near Apex, had a 2.4 percent per year increase from 1979 to 1982, and Station 35, Pond River near Sacremento, had a 3.0 percent per year increase from 1969 to 1982 and a 1.5 percent per year increase from 1979 to 1982. These increases probably reflect better control of acid mine drainage from surface-mining activities. The Green River NASQAN station (38) had a 0.68 percent per year increase from 1974 to 1982, and no significant trend from 1979 to 1982.

Table 14.--Dissolved-iron trends in the Green River basin
[S indicates significant trend]

Report station number	Station	Period of record	Number of measurements	Concentration: Mean (µg/L)	Trend p	Slope (percent per year)	Flow-adjusted concentration: R^2	Trend p	Trend direction	Type of model
3	Green River at Greensburg	1979-82	23	80	1.0	+6.0	< 0.5			
6	Green River at Munfordville	1980-82	22	53	.29	+57	< .5			
9	Nolin River at White Mills	1980-82	20	44	1.0	+11	< .5			
10	Bacon Creek near Priceville	1980-82	19	38	1.0	0	< .5			
18	Barren River at Bowling Green.	1979-82	18	57	.13	+35	< .5			
20	Green River at Aberdeen	1979-82	36	66	.13	+15	< .5			
25	Green River at Rockport	1979-81	17	68	.74	-22	.59	0.37	increasing	Log Log
31	Rough River at Dundee	1979-82	37	169	.15	-25	< .5			
33	Green River at Lock 2	1979-81	19	40	.73	-25	.54	.52	increasing	Hyperbolic
34	Pond River near Apex	1979-82	47	93	.11	-22	< .5			
35	Pond River near Sacremento	1971-82	38	546	.001 S	-12		Not determined, flow data not available		
36	Pond River near Vandetta	1979-81	17	296	.70	+5	< .5			
37	Cypress Creek near Calhoun	1979-81	66	1,281	.04 S	+30	< .5			
38	Green River near Beech Grove.	1974-82	33	134	.66	0	< .5			

Table 15.--Total-iron trends in the Green River basin
[S indicates significant trend]

Report station number	Station	Period of record	Number of measurements	Concentration: Mean (µg/L)	Trend p	Slope (percent per year)	Flow-adjusted concentration: R^2	Trend p	Trend direction	Type of model
3	Green River at Greensburg	1979-82	15	868	1.0	0	< 0.5			
6	Green River at Munfordville	1980-82	15	976	1.0	-5.0	.52	1.0	decreasing	Log Log
9	Nolin River at White Mills	1980-82	15	643	.25	+3.1	< .5			
20	Green River at Aberdeen	1979-82	33	1,460	.20	+15	< .5			
25	Green River at Rockport	1979-82	18	1,903	1.0	+2.4	.95	.14	decreasing	Quadratic
31	Rough River at Dundee	1979-82	33	1,906	.83	+3.5	< .5			
33	Green River at Calhoun	1979-82	18	2,105	.73	-20	.54	.73	increasing	Hyperbolic
34	Pond River near Apex	1979-82	29	2,060	.13	+24	< .5			
35	Pond River near Sacremento	1979-82	15	1,210	1.0	+8.3		Not determined, flow data not available		
36	Pond River near Vandetta	1979-81	17	4,470	1.0	-4.5	< .5			
37	Cypress Creek near Calhoun	1979-82	76	4,543	1.0	+7.7	< .5			
38	Green River near Beech Grove.	1974-82	33	2,815	.68	+4.1	< .5			

Table 16.--pH trends in the Green River basin
[S indicates significant trend]

Report station number	Station	Period of record	Number of measurements	Concentration: Median (units)	Trend p	Slope (percent per year)	Flow-adjusted concentration: R^2	Trend p	Trend direction	Type of model
3	Green River at Greensburg	1979-82	31	7.20	0.04 S	-2.4	< 0.5			
6	Green River at Munfordville	1970-82	124	7.60	.000 S	-.53	< .5			
6	Green River at Munfordville	1979-82	28	7.30	.40	-1.4	< .5			
9	Nolin River at White Mills	1979-82	27	7.40	.49	-.34	< .5			
10	Bacon Creek near Priceville	1979-82	28	7.50	1.0	0	< .5			
18	Barren River at Bowling Green.	1969-82	43	7.50	1.0	0	< .5			
20	Green River at Aberdeen	1979-81	45	7.40	1.0	-.34	< .5			
21	Mud River near Homer	1979-81	21	7.20	.47	-2.1		Not determined, flow data not available		
25	Green River at Rockport	1979-81	19	7.70	.53	+1.3	< .5			
31	Rough River at Dundee	1979-82	49	7.20	.86	0	< .5			
33	Green River at Lock 2	1979-81	19	7.80	.20	+.96	< .5			
34	Pond River near Apex	1979-82	48	7.30	.01 S	+2.4	< .5			
35	Pond River near Sacremento	1969-82	49	6.70	.000 S	+3.0		Not determined, flow data not available		
35	Pond River near Sacremento	1979-82	34	6.80	.02 S	+1.5		Not determined, flow data not available		
37	Cypress Creek near Calhoun	1979-81	65	7.30	.17	+2.3	< .5			
38	Green River near Beech Grove.	1974-82	83	7.4	.03 S	+.68	< .5			
38	Green River near Beech Grove.	1979-82	41	7.5	.53	-1.0	< .5			

Suspended Sediment

Trend analysis of suspended-sediment data indicates that two stations had significant temporal trends in unadjusted data, and none of the stations tested for flow-adjusted concentrations had a significant trend (table 17). Station 10, Bacon Creek near Priceville, had a -38 percent per year trend in unadjusted data, with a low R^2 value. A review of these data reveals that heavy flooding in December of 1978 resulted in high concentrations of suspended-sediment. Fourteen sediment samples were collected during this flood period. Similar flooding has not occured since that time, and the rises that have occurred were not sampled as extensively as the December 1978 flood. The apparent decreasing trend, therefore, is probably not a true reflection of sediment conditions in this stream, but is a result of the extensive sampling of one flood event. The Green River NASQAN station (38) had a trend of +7.2 percent per year with an R^2 value of less than 0.5. A review of these data did not reveal a specific reason for this trend. The Pond River stations (34, 36) and the Cypress Creek station (37) although not showing a trend, had much higher suspended-sediment concentrations which might have caused this trend at the NASQAN station.

Water Temperature

Two stations had significant temporal trends in unadjusted temperature data (table 18). None of the stations were tested for flow-adjusted concentrations because of the poor relation of temperature to streamflow. Station 37, Cypress Creek near Calhoun, had a 15 percent of the mean per year decrease in water temperature from 1979 to 1981. A review of these data did not indicate a reason for this apparent trend. The Green River NASQAN station (38) also had a decreasing trend (-1.8 percent per year) for the period 1974 to 1982. A review of these data also did not reveal a reason for this trend, but 1.8 percent per year decrease of the mean is 0.3 °C which is less than the ±0.5 °C precision of the measurement. This trend at Beech Grove may be the result of measurement error.

Table 17.--Suspended-sediment trends in the Green River basin
[S indicates significant trend]

Report station number	Station	Period of record	Number of measurements	Concentration			Flow-adjusted concentration			
				Mean (mg/L)	Trend p	Slope (percent per year)	R^2	Trend p	Trend direction	Type of model
4	Russell Creek near Columbia.	1977-81	39	55	0.15	-6.4	< 0.5			
6	Green River at Munfordville	1970-82	33	510	.45	-6.9	.53	0.29	decreasing	Log Log
9	Nolin River at White Mills	1977-81	37	74	.39	-27	.55	.15	decreasing	Log Log
10	Bacon Creek near Priceville	1978-81	46	228	.02 S	-38	<.5			
20	Green River at Aberdeen	1979-81	16	100	.70	+40	<.5			
25	Green River at Rockport	1979-81	20	106	.24	+100	.60	.25	increasing	Log Log
31	Rough River at Dundee	1979-81	23	394	.68	+9.9	<.5			
33	Green River at Lock 2	1979-81	18	110	1.0	-35	.51	.37	increasing	Log Log
34	Pond River near Apex	1977-81	42	326	.65	+1.4	.50	.89	decreasing	Log Log
36	Pond River near Vandetta	1979-81	25	163	1.0	+90	<.5			
37	Cypress Creek near Calhoun	1979-81	22	493	.16	+57	<.5			
38	Green River near Beech Grove.	1974-82	72	76	.02 S	+7.2	<.5			

Table 18.--Water-temperature trends in the Green River basin
[S indicates significant trend]

Report station number	Station	Period of record	Number of measurements	Concentration			Flow-adjusted concentration			
				Mean (°C)	Trend p	Slope (percent per year)	R^2	Trend p	Trend direction	Type of model
1	Green River near Campbellsville.	1977-82	41	13.0	1.0	0	< 0.5			
2	Green River near Greensburg	1969-77	33	14.0	.40	+1.1	<.5			
3	Green River at Greensburg	1979-82	31	15.0	1.0	0	<.5			
4	Russell Creek near Columbia	1970-82	43	14.0	.52	-1.1	<.5			
6	Green River at Munfordville	1969-82	179	14.0	.24	+.4	<.5			
9	Nolin River at White Mills	1970-82	71	14.0	.24	-2.8	<.5			
10	Bacon Creek near Priceville	1970-82	95	13.0	.11	+1.3	<.5			
12	Nolin River at Kyrock	1969-82	51	14.0	.19	+1.2	<.5			
14	Green River at Lock 6	1977-82	36	15.0	.19	+2.2	<.5			
15	Beaver Dam Creek at Rhoda	1969-82	43	13.5	.15	+3.0	<.5			
16	Barren River near Finney	1970-82	51	15.0	.49	-.43	<.5			
17	West Fork Drakes Creek near Franklin.	1970-82	54	17.5	.18	+1.9	<.5			
18	Barren River at Bowling Green.	1969-82	95	16.5	.27	-.73	<.5			
19	Green River at Lock 4	1970-82	42	16.5	.48	.5	<.5			
20	Green River at Aberdeen	1979-82	48	15.5	.39	+5.6	<.5			
21	Mud River near Homer	1975-82	45	15.5	.91	0	<.5			
23	Green River at Paradise	1977-81	32	17.0	.49	+1.5	<.5			
25	Green River at Rockport	1979-81	20	18.5	.14	+9.2	<.5			
28	Rough River at Falls of Rough.	1970-82	50	14.0	.78	0	<.5			
29	Caney Creek near Horse Branch.	1970-82	51	16.0	.63	+.31	<.5			
30	Rough River near Dundee	1975-82	44	15.0	1.0	0	<.5			
31	Rough River at Dundee	1979-82	56	15.0	.21	+4.5	<.5			
33	Green River at Lock 2	1970-82	37	17.5	1.0	-1.5	<.5			
34	Pond River near Apex	1970-82	101	16.0	1.0	0	<.5			
35	Pond River near Sacremento	1969-82	54	16.5	.81	0		Not determined, flow data not available		
37	Cypress Creek near Calhoun	1979-81	77	16.5	.05 S	-15	<.5			
38	Green River near Beech Grove.	1974-82	88	17.0	.03 S	-1.8	<.5			

SUMMARY

The Green River basin, the largest drainage basin in Kentucky, drains 9,229 mi^2 of Kentucky and Tennessee. Streamflow in the basin is highly variable and many streams go dry during low rainfall periods, but flooding can be severe during wet periods. There are four Corps of Engineers flood control reservoirs in the basin. Approximately 64 Mgal/d were used in 1980, and 77 percent of this was from surface-water sources. Pastureland, cropland, and forest are the principal land uses in the basin. Approximately 120 mi^2 are used for strip mining. About 40 million tons of coal were mined in 1981, and 3.9 million barrels of oil were produced in 1980 from the Western Kentucky Coal Field, most of which is in the Green River basin. Sewage wastes, oil brines, and heated wastes are the significant point-source pollution problems. Acid mine drainage, siltation, agricultural runoff, and storm drainage from urban areas are the significant non-point sources.

Streamflow and water-quality data collected since 1969 by the U.S. Geological Survey and the Kentucky Natural Resources and Environmental Protection Cabinet at 38 sites in the basin were used to compare water-quality conditions throughout the basin, and to determine if data collected from the Green River near Beech Grove NASQAN station are representative of basin conditions. Water-quality concentrations, discharges, and trends were studied. Where available, daily collected data were compared with periodically collected data.

Specific-conductance data were generally similar throughout the basin, with the exception of Little Barren River, Pond Creek, Lewis Creek, Pond River, and Cypress Creek. These streams are impacted by coal mining or oil production. Daily values of specific-conductance were found to coincide very closely with long-term periodic data, and did not add to information gained from long-term periodic measurements. Chloride data were highly variable. Chloride concentrations at the NASQAN station were less than half of those at Station 6, Green River at Munfordville. Brines from oil production cause the higher concentrations at Munfordville. The NASQAN station had the highest mean sulfate concentration in the basin except for stations directly affected by coal mining. Inflows from Pond Creek, Lewis Creek, Cypress Creek, and the Pond River affect the sulfate concentration at the NASQAN station. The pH at the NASQAN station was fairly representative of pH values throughout the basin, but some small streams had values less than 4.0 units. Phosphorous and nitrogen concentrations were similar throughout the basin except at the Nolin River at White Mills and Mud River near Homer. Causes of the higher concentrations at these stations were not determined. Total and dissolved-iron concentrations at the NASQAN station were increased by inflows from the heavily mined Pond River basin and were not representative of iron data collected throughout the basin. Water temperature increased downstream on the Green River. The lower Green River was, on the average, 2 °C higher than other river basins in Kentucky. Periodically collected suspended-sediment data were inferior to daily-collected data, and were not useful for basin comparisons. Only six stations had daily data. Based on this limited number of stations, the NASQAN station appeared to be representative of average sediment concentrations, but not of extreme values.

Discharge-estimation techniques, developed by Miller in 1951, were used to determine long term estimated discharge and yield values at stations where daily streamflow records and water quality data had been collected. Discharges at the NASQAN station, because of the lack of daily streamflow data, were computed by multiplying the average of the constituent concentration by the average of instantaneous streamflow. Yield values in tons per day per square mile were compared. Suspended-sediment yields decrease downstream on the Green River, as sediment is apparently deposited in the river channel and floodplain. Dissolved-solids yields slowly increased downstream on the Green River from Munfordville to Lock 2, but the NASQAN station showed a large increase. This large increase may be due to the different method of computation and not to an actual increase in dissolved solids loads. Sulfate yields also increased downstream on the Green River, and the highest value was recorded at the NASQAN station. Phosphorus yields were similar at the stations where enough data were available for computation. Total-iron yields gradually increased downstream on the main stem.

Trend-analysis techniques, developed by the Survey, were used to test for trends in both unadjusted and flow-adjusted data. There were no trends in instantaneous-streamflow data collected at 22 stations. Two stations indicated increasing trends in unadjusted specific-conductance data, and two other stations had trends, one increasing and one decreasing, in flow-adjusted data. Specific conductance at the NASQAN station showed no trend. Four stations had trends in chloride data. The NASQAN station had a significant increase in chloride concentration, which may be the result of inputs from the Pond River. No significant trends in sulfate data were detected. Two stations had an increasing trend in phosphorus data. One of these was the NASQAN station, but the magnitude of the trend is less than the detection limit. Two stations had trends in dissolved-iron concentrations, but none of the stations had a trend in total iron concentrations. Five stations had pH trends, including the NASQAN station, which was slowly increasing. The NASQAN station indicated an increasing trend in suspended sediment, as did one other site. The NASQAN site and one other station showed a decreasing trend in water temperature. The reasons for these various trends are considered to be caused by extreme data values, accuracy of the various measurements, and actual changes occurring in the basin.

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