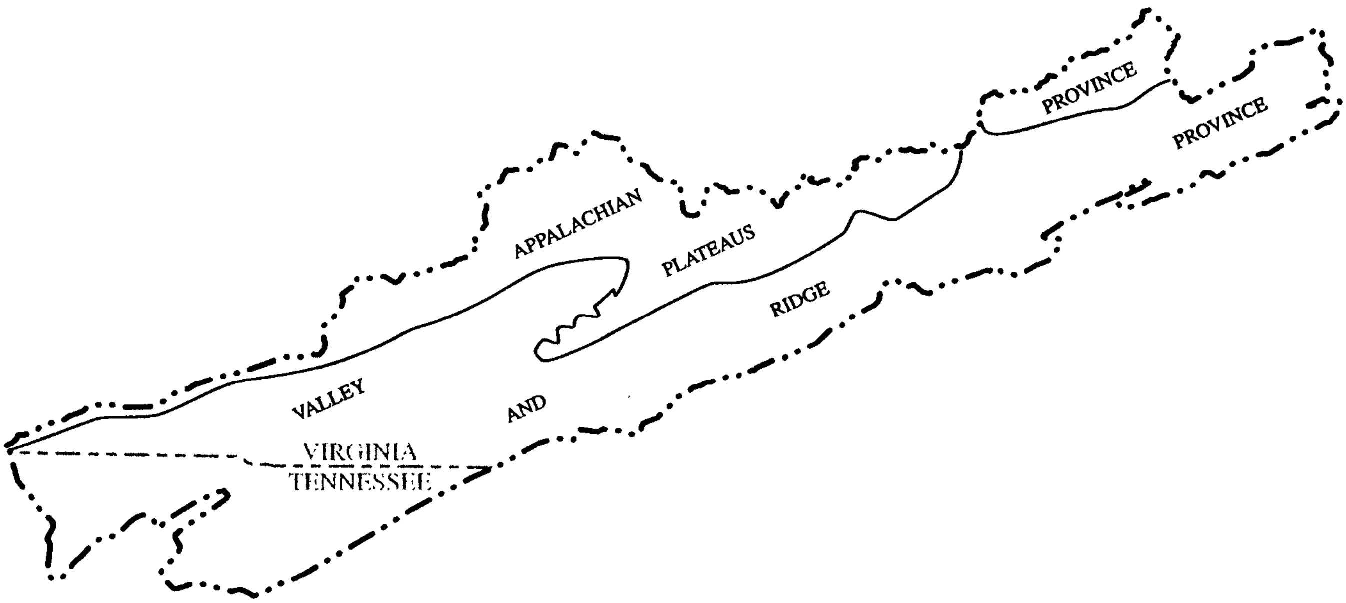
Open-File Report 96-247

Water-Quality Characteristics and Suspended Sediment of the Clinch and Powell Rivers in Northeastern Tennessee, 1989-94



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Cover illustration. See figure 2, page 4.

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by LAWRENCE M. BREDE and BRIAN L. BENHAM

U.S. Geological Survey

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Nashville, Tennessee

1996

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.30483	meter
mile (mi)	1.609	meter
square mile (mi^2)	2.590	square kilometer
cubic feet (ft^3)	0.0283	cubic meter
gallon (gal)	3.785	liter
pound (lb)	0.4536	kilogram
ton	0.9072	metric ton
tons per square mile per year [($tons/mi^2$)/yr]	0.3502	ton per square kilometer per year
microsiemens per centimeter (μS/cm) at 25° Celsius	1	micromhos per centimeter at 25° Celsius

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

$$^{o}C = (^{o}F - 32)/1.8$$

Water-quality abbreviations

mg/L	milligrams per liter
cols./100 mL	colonies per 100 milliliter

Water-Quality Characteristics and Suspended Sediment of the Clinch and Powell Rivers in Northeastern Tennessee, 1989-94

By Lawrence M. Brede *and* Brian L. Benham

Abstract

The U.S. Geological Survey, in cooperation with the Tennessee State Planning Office, conducted a 4 1/2-year water-quality study in the Clinch and Powell River drainage basins in northeastern Tennessee. An intermittent sampling program was conducted from June 1989 through January 1994. Water-quality samples were collected and analyzed for an upstream site and a downstream site on each river. The upstream sites were near the Tennessee-Virginia State line, and the downstream sites were located on the rivers upstream of Norris Lake.

At the upstream sites, fecal coliform bacteria exceeded the water-quality criteria for recreational use in 14 of 40 samples. At the downstream sites, counts exceeded the criteria limits in 2 out of 22 samples. Concentrations of nitrogen and phosphorus compounds were within the range expected for natural surface water. Nutrient discharge did not correlate well to streamflow, rainfall, and seasonal effects. Suspended-sediment discharge at the four study sites was related to streamflow, a rainfall factor, and seasonal effects. Average annual sediment yields among sites were estimated at 97 tons per square mile per year on the Clinch River and 184 tons per square mile per year on the Powell River. Concentrations of calcium, magnesium, sodium, potassium, sulfate, chloride, silica, and fluoride were all measured within the range expected for a natural carbonate system.

Instantaneous total-iron concentrations exceeded the U.S. Environmental Protection Agency criteria for fish and aquatic life at the upstream sites in 23 of 28 samples on the Clinch River, and in 38 of 44 samples on the Powell River. At the downstream sites, total iron exceeded the same criteria in 2 of 5 samples on the Clinch River, and in 1 of 4 samples on the Powell River.

INTRODUCTION

The Clinch and Powell River drainage basins contain valuable natural resources. Agricultural, grazing, and mining activities in these basins pose potential problems that may jeopardize the water quality of the basins. Data on water quality are needed to identify and quantify potentially harmful constituent levels, as well as their sources.

From June 1989 through January 1994, the U.S. Geological Survey (USGS), in cooperation with the Tennessee State Planning Office, conducted an investigation of water quality in the Clinch and Powell River basins. The purposes of the study were to characterize water quality, to identify potential water-quality problems, and to estimate annual loads of selected constituents in the Clinch and Powell Rivers.

This report presents summary statistics of the water-quality data and estimates of annual loads for suspended sediment from two sites located in each basin. Water samples were analyzed for physical properties, bacteria, nutrients, suspended sediment, major ions, and selected trace constituents. Sampling intensity varied during the study period due to differing annual study requirements. Storm flow, defined as flow during the rise, peak, and recession of a storm event, and base flow, defined as flow more than 72 hours after a precipitation event, were sampled. The annual suspended-sediment loads were estimated by extrapolating the measured suspended-sediment concentration and continuous data such as discharge and rainfall to produce a synthetic record of daily sediment loads and an estimated annual load.

Description of the Study Area

The Clinch River and Powell River drainage basins (referred to as Clinch and Powell River basins) are located in northeastern Tennessee and southwestern Virginia (fig. 1). The study includes the Clinch and Powell River basins situated upstream of the backwater of Norris Lake. The basins are adjacent, with the Clinch River basin to the east and the Powell River basin to the west. The rivers flow from northeast to southwest.

The Clinch and Powell River drainage basins occur in the Appalachian Plateaus and the Valley and Ridge Physiographic Provinces (fig. 2) (Fenneman, 1938). The Valley and Ridge Physiographic Province is characterized by parallel southwest to northeast trending valleys and ridges, with valleys having an average width of 45 miles. The valleys within the basin have slopes ranging between 0.0001 foot per foot (ft/ft) and 0.0025 ft/ft, and altitudes varying from 1,200 to 1,600 feet. The ridges bounding these valleys have altitudes of nearly 2,200 feet. The northwestern part of the Powell River basin contains a part of the Cumberland Mountain section of the Appalachian Plateaus Physiographic Province (fig. 2). It is marked by a prominent escarpment of cliffs 1,000 feet higher than the floor of the Valley and Ridge Physiographic Province.

The Clinch River drains 1,154 mi^2 in southwestern Virginia upstream of the Looney's Gap site (site 1 near the Tennessee-Virginia State line), and 320 mi^2 in northwestern Tennessee at site 2, near the backwater of Norris Lake, for a total contributing study area of 1,474 mi^2 (fig. 1, table 1). The Powell River drains 510 mi^2 in southwestern Virginia upstream of site 3 near Alanthus Hill, Tennessee, and 175 mi^2 in northeastern Tennessee above Arthur, Tennessee, at site 4 also near the backwater of Norris Lake, for a total contributing study area of 685 mi^2 (table 1). The four sampling sites used in this investigation are located in Tennessee.

The surface geology of the two river basins is similar. Both basins are primarily underlain by extensively faulted and folded limestone, dolomite, and shale of Mississippian to Cambrian age. The valleys are underlain by soft or less resistant rocks, and the ridges are underlain by hard, more resistant rocks (Floyd, 1965). The Powell River basin, however, contains a much larger area underlain by formations of Pennsylvanian age consisting of sandstones and shale with bituminous coal beds.

The study area has a mean annual temperature of 58 °F. The coldest months are December and January with an average daily minimum temperature of 30 °F, and the hottest months are July and August with an average daily maximum temperature of about 87 °F (National Oceanic and Atmospheric Administration, 1974).

Average annual precipitation is 49 inches with approximately 23 inches occurring during April through September. Average annual snowfall varies from 8 inches in the southwestern part of the watershed to 12 inches on the highland area of the Cumberland Plateau. The highest volume precipitation occurs from December through March, caused by frontal activity, and from July through August, caused by late-day convective storms (Hufschmidt and others, 1981).

Well over half of each basin is forested (table 1). The majority of forest land in the Clinch and Powell River basins is of the oak-hickory type. The Clinch River basin also contains loblolly-shortleaf pine, maple-beech-birch, oak-pine, and elm-ash-cottonwood forest types, which occupy less than 10 percent of the forested area. The Powell River basin contains small areas of eastern red cedar and maple-beech-birch forest types (U.S. Department of Agriculture, 1992a; 1992b).

Agriculture (cropland and pasture) accounts for about 19 to 37 percent of the land use (table 1). The primary crops in this region include tobacco, corn, and small grains in addition to hay. Beef cattle, horses, and sheep are the predominant livestock in both basins, followed by dairy cattle, hogs, and poultry (U.S. Department of Agriculture, 1992b).

Bituminous coal occurs in both river basins and is extracted by both deep and strip mining methods. Mining accounts for about 1 percent of the land use in the Clinch River basin and about 2 percent in the Powell River basin (table 1), but most of the mining occurs in Virginia (U.S. Department of Agriculture, 1992a).

Streamflow Characteristics of the Clinch and Powell Rivers

When compared with flood-frequency values, peak discharges recorded during sampling demonstrate the relative magnitude and range of flows

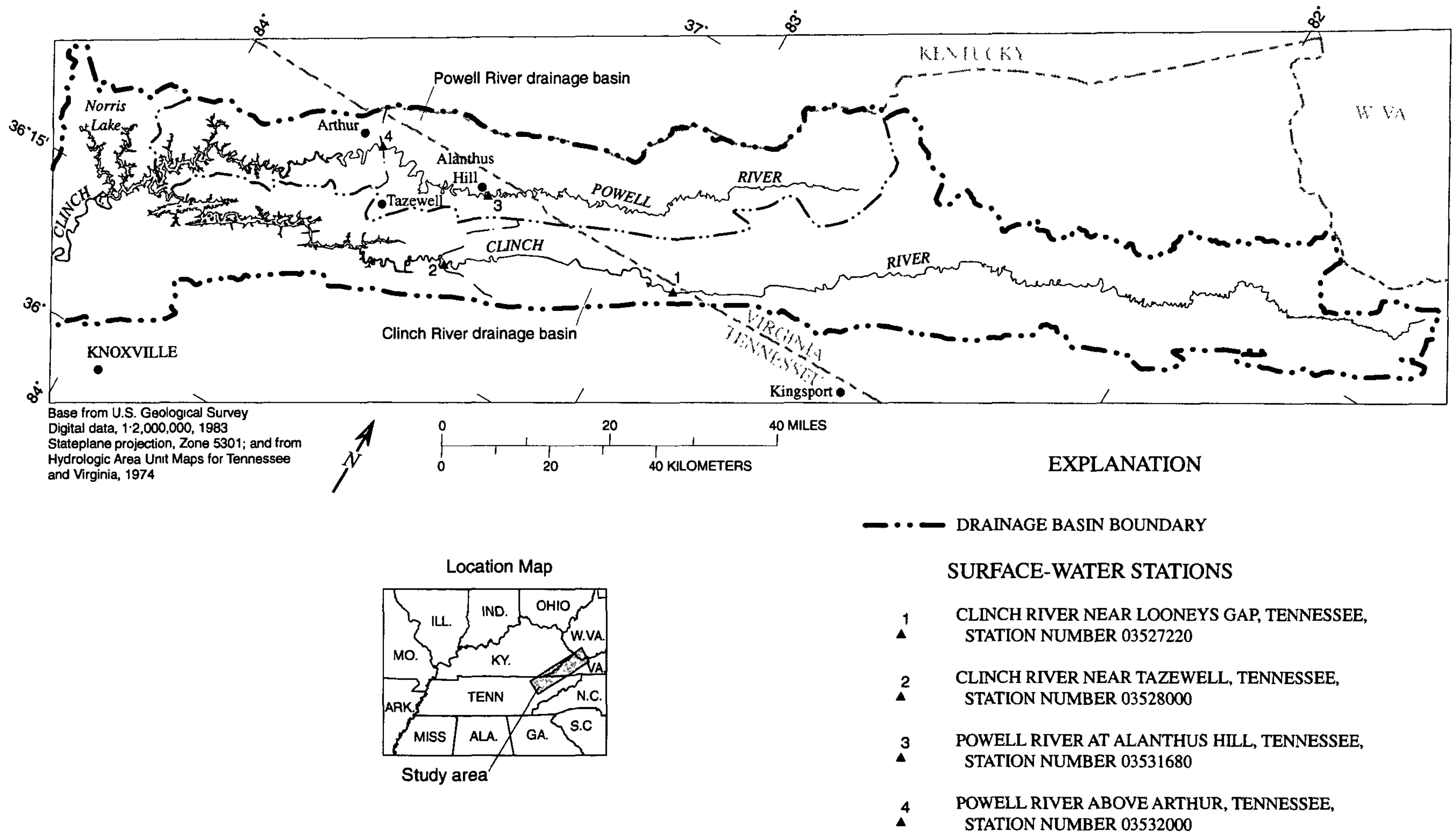
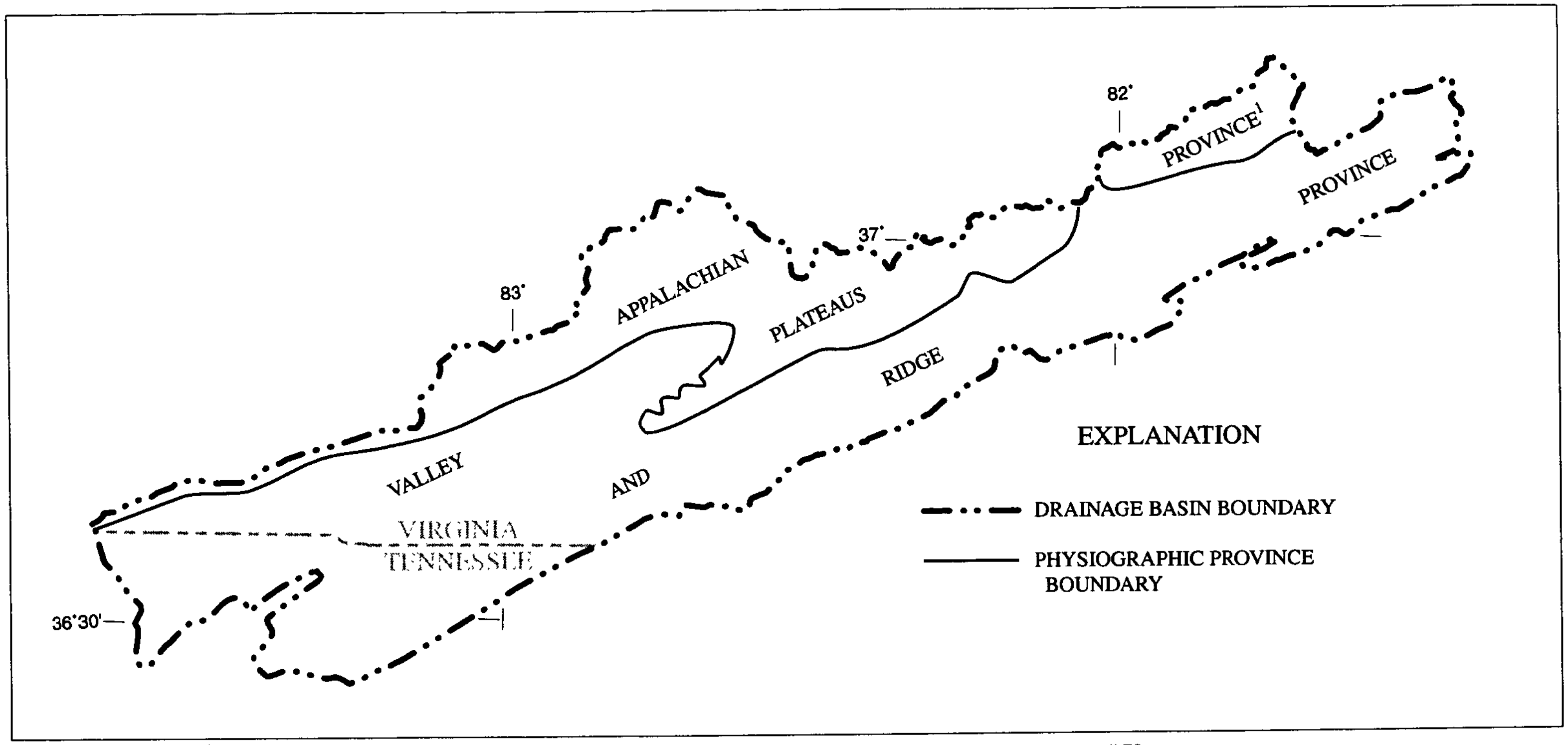


Figure 1. Location of study area and surface-water stations in the Clinch River and Powell River drainage basins, Tennessee and Virginia.



Base from U S Geological Survey
Digital data, 1:2,000,000, 1983
Stateplane projection, Zone 5301; and from
Hydrologic Area Unit Maps for Tennessee
and Virginia, 1974

[1]Cumberland Mountain section of Appalachian Plateaus province

Figure 2. Combined Clinch River and Powell River basins with physiographic provinces identified.

Table 1. Water-quality sampling sites in the study area, subbasin drainage, and land use

[from U.S. Department of Agriculture, 1992a and 1992b; and Donald L. Dotson, U.S. Department of Agriculture, Soil Conservation Service, written commun., 1993]

Station number	Subbasin location	Drainage, in square miles	Latitude	Longitude	Land use as percentage of total land area: Forest	Cropland	Pasture	Mined	Mine associated land	Other[1]
	Clinch River									
03527220	near Looney's Gap (site 1)	1,154	36° 34′ 22″	82° 56′ 20″	56.5	13.6	23.4	1.1	0.5	4.9
--	Looney's Gap to Tazewell[2]	320	--	--	78.8	5.7	13.7	0.6	0.3	0.9
03528000	above Tazewell (site 2)	1,474	36° 25′ 30″	83° 23′ 54″	61.3	11.9	21.3	1.0	0.5	4.0
	Powell River									
03531680	at Alanthus Hill (site 3)	510	36° 33′ 23″	82° 22′ 47″	61.3	15.9	13.6	2.3	0.3	6.6
--	Alanthus Hill to Arthur[2]	175	--	--	62.0	16.2	18.7	2.0	0.3	0.8
03532000	above Arthur (site 4)	685	36° 33′ 30″	83° 37′ 49″	61.5	16.0	14.9	2.2	0.3	5.1

[1] Other category includes residential, industrial, water bodies, orchard, and Christmas tree acreage.

[2] Represents subbasin drainage to the river between sampling sites.

covered by the sampling (table 2). Flood probability values, or flood-frequency curves, were defined by Weaver and Gamble (1993). The flood-frequency curves for the Clinch River near Looney's Gap, Tennessee (fig. 3a), and the Powell River at Alanthus Hill, Tennessee (fig. 3c), were calculated using Method B for ungaged sites in rural basins of Tennessee (Weaver and Gamble, 1993). The flood-frequency curves for the Clinch River above Tazewell, Tennessee (fig. 3b), and the Powell River above Arthur, Tennessee (fig. 3d), were developed using discharge data collected at those gaged sites (Weaver and Gamble, 1993).

The storms sampled during this investigation typically had a recurrence interval of less than 2 years. A flood with a 2-year recurrence interval, or average return period, is expected to be exceeded on the average of once in 2 years. Two storms had 2-year recurrence intervals: February 10-12, 1990, at Clinch River near Looney's Gap and June 15-19, 1989, at Powell River above Arthur. The storm of December 1-6, 1991, resulted in a peak discharge with a 4-year recurrence interval on the Powell River near Alanthus Hill (table 2).

Data Collection

Hydrographs for sampled storm-flow events were taken from continuous recording stations, if available, or estimated from actual observations of stream discharge made during the storm event. The accuracy of hydrograph delineation for each storm-flow event varied greatly and, therefore, a linear approximation between samples was used to estimate all hydrographs.

Rainfall data were obtained from the Tennessee Valley Authority Engineering Services (Wayne Hamburger, written commun., 1994) and from the National Oceanic and Atmospheric Administration (1988 to 1994) monthly data reports for Tennessee. These data were used in a Thiessen weighted calculation to determine a basin rainfall factor for calculating suspended-sediment loads.

Water samples were taken with a depth integrating sampler. The samples were collected manually during individual storms to characterize water quality during the rise, peak, and recession of the storm event (table 2). Comparison of peak discharges from sampled events (table 2) with flood recurrence intervals from the respective stations show that all sampled storms were of low to moderate size. Additionally, samples were collected during base-flow conditions, defined by the absence of significant rainfall in the basin during the 72 hours (or more) prior to sampling.

Properties and constituents measured in the field include pH, specific conductance, dissolved oxygen, fecal coliform and fecal streptococcal bacteria, discharge, and water temperature. Analyses for other chemical constituents and sediment particle-size determinations were made in the laboratory.

Water-quality data for the sampling sites are described using statistical measures (minimum, maximum, median, mean, 75th and 25th percentile) that summarize sample distribution. These sample distribution statistics are presented in table 3 (in back of report).

WATER-QUALITY CHARACTERISTICS OF THE CLINCH AND POWELL RIVERS

Water-quality samples were collected at four sites on the Clinch and Powell Rivers to evaluate water-quality conditions and differences between the two basins. The samples were analyzed for physical properties, bacteria, nutrients, suspended sediment, major ions, and selected trace constituents.

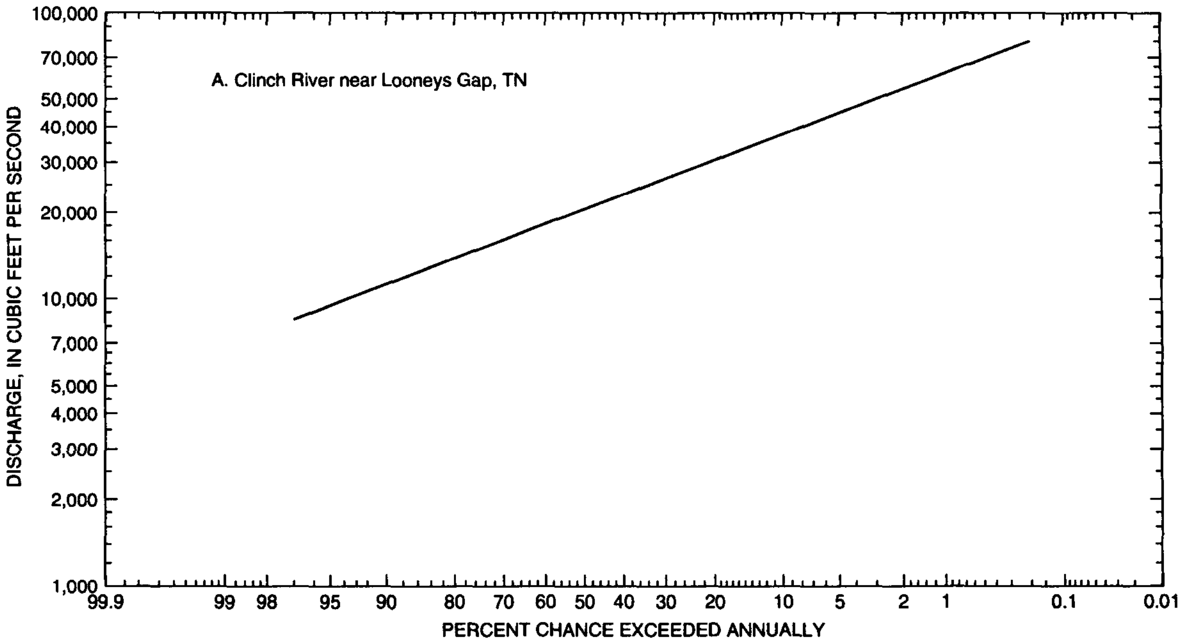
Physical properties of the Clinch and Powell Rivers were measured during each sampling event. The pH of the waters ranged from 7.2 to 8.8 at all sites. At each site, the pH decreased during storm flow (table 4). Median values of pH during stormflow were typically less than the median values observed during periods of base flow. All values were within the range expected for streams draining watersheds containing carbonate rocks. The median value of pH for all water samples from the Clinch River is 8.2, and the median from the Powell River is 8.1 (table 3, in back of report). The median value of pH for all water samples from the Powell River is less than the median value from the comparably sized Clinch River sites.

Acidity was tested at three of the four sampling sites (table 3) and ranged from 5 to 25 milligrams per liter (mg/L) as calcium carbonate ($CaCO_3$). The larger values occurred in winter months at higher discharges. Runoff rates during these months increased due to increased rainfall and decreased infiltration rates. Most of the carbonate in the system existed as bicarbonate at the observed pH range during the study. Alkalinity at the four sampling sites ranged from 62 to 157 mg/L as $CaCO_3$. However, the median at all sites varied only

Table 2. Description of storm-flow sampling for each of the study sites

[<, less than]

Date	Hydrograph period, in hours	Total number of samples	Samples on rising limb	Samples on falling limb	Samples at peak discharge	Peak discharge, in cubic feet per second	Recurrence interval
			Clinch River near Looney's Gap, Tennessee				
September 16-18, 1989	40	3	0	3	0	13,040	< 2 yr
February 10-12 1990	56	4	1	2	1	19,400	2 yr
December 19-20, 1990	28	5	2	2	1	3,350	< 2 yr
February 14-15, 1991	50	2	0	2	0	7,589	< 2 yr
March 29-April 2, 1991	93	9	4	4	1	13,300	< 2 yr
May 19-21, 1993	43	14	5	7	2	5,080	< 2 yr
			Clinch River above Tazewell, Tennessee				
June 17-19, 1989	66	25	8	10	7	17,100	< 2 yr
September 18-19, 1989	84	2	0	2	0	13,460	< 2 yr
February 10-13, 1990	73	19	5	13	1	16,600	< 2 yr
May 5-7, 1990	46	24	9	12	3	13,100	< 2 yr
			Powell River at Alanthus Hill, Tennessee				
September 16-18, 1989	41	3	1	2	0	5,235	< 2 yr
February 10-13, 1990	72	5	2	2	1	11,200	< 2 yr
May 5-7, 1990	43	4	2	1	1	7,460	< 2 yr
January 7-9, 1991	53	7	3	3	1	5,910	< 2 yr
February 18-22, 1991	91	9	4	3	2	11,400	< 2 yr
November 22-24, 1991	52	17	5	11	1	6,480	< 2 yr
December 1-6, 1991	110	21	11	8	2	18,300	4 yr
January 7-10, 1994	72	5	2	2	1	5,160	< 2 yr
			Powell River above Arthur, Tennessee				
June 7-8, 1989	15	15	4	6	5	4,670	< 2 yr
June 15-19, 1989	102	31	6	22	3	15,600	2 yr
September 17-19, 1989	57	2	0	2	0	4,965	< 2 yr
November 16-18, 1989	46	24	11	9	4	6,140	< 2 yr
February 10-13, 1990	78	26	12	10	4	11,600	< 2 yr
May 5-7, 1990	48	17	9	6	2	8,410	< 2 yr



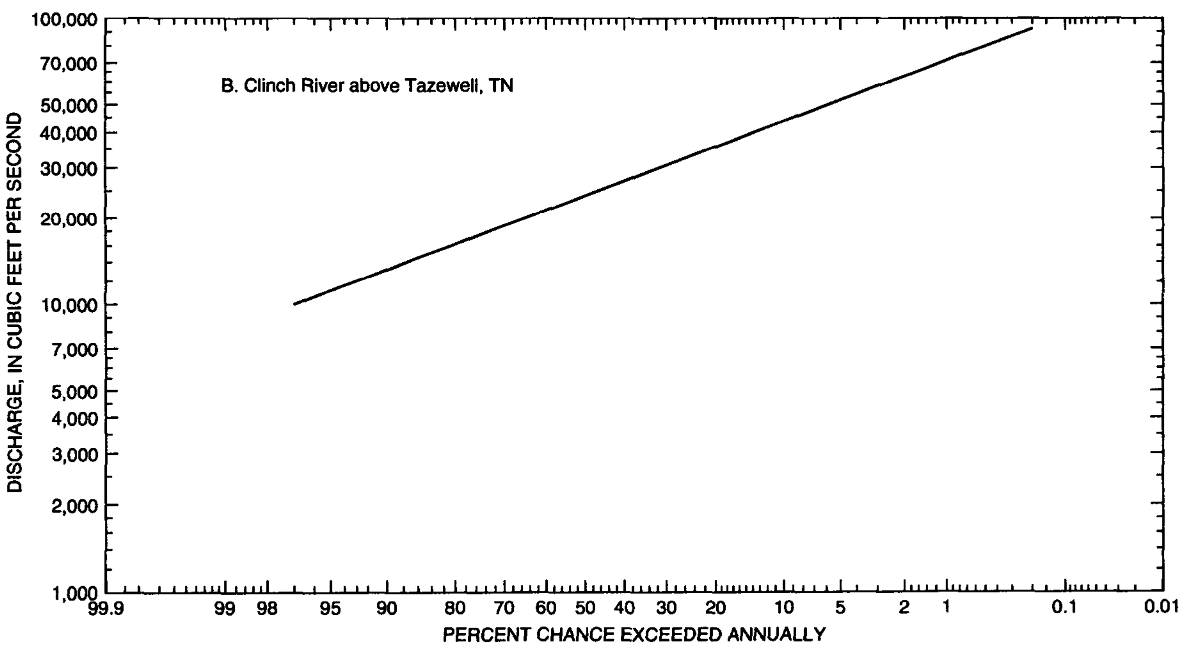
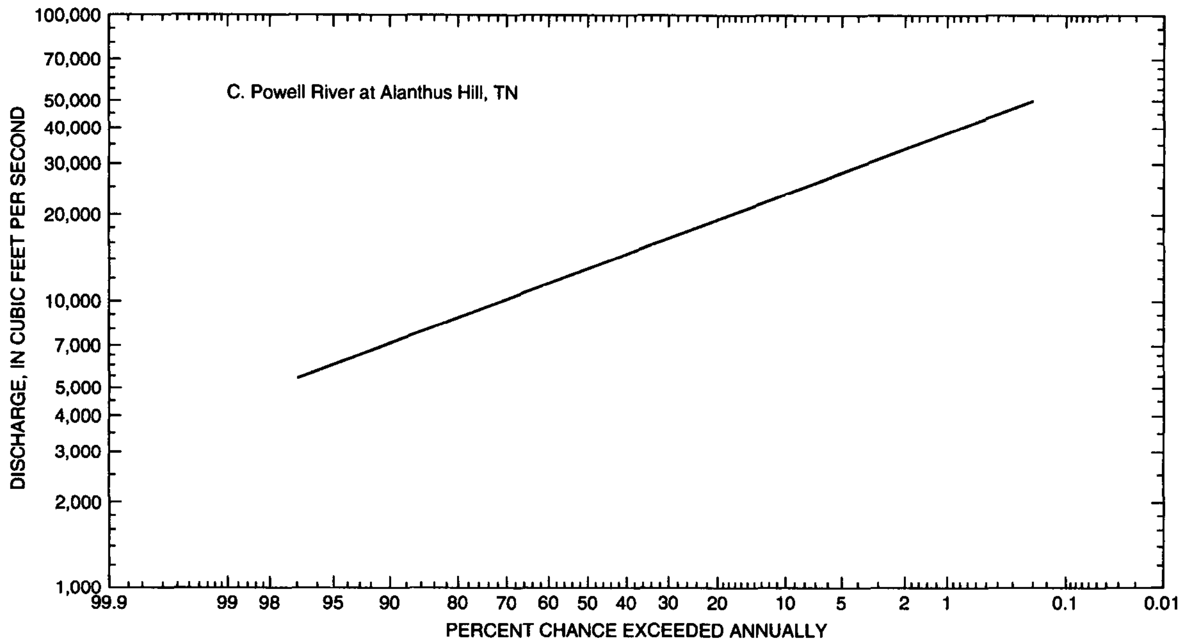


Figure 3. Flood-frequency curves for the sampling sites in the Clinch and Powell River basins.



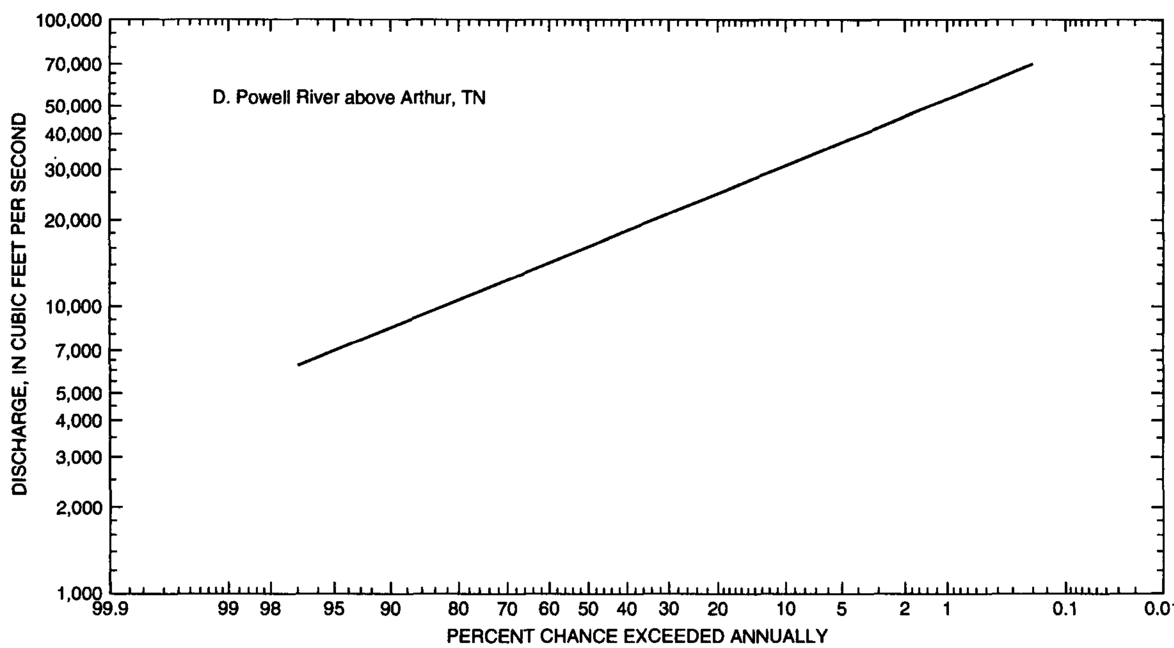


Figure 3. Flood-frequency curves for the sampling sites in the Clinch and Powell River basins—Continued.

Table 4. Comparison of pH during low flow and storm flow at the sampling sites

Site	pH, in standard units		
	Range	Base-flow median	Storm flow median
Clinch River			
near Looney's Gap	7.2-8.6	8.2	8.1
above Tazewell	8.0-8.8	8.3	8.2
Powell River			
at Alanthus Hill	7.7-8.3	8.2	7.9
above Arthur	7.8-8.4	8.0	8.0

between 83 and 119 mg/L (table 3). Specific conductance at the sites ranged from 99 to 445 microsiemens per centimeter (µS/cm), with median values ranging from 234 to 302 µS/cm (table 3). Turbidity at all sampling sites ranged from 0.6 to 140. Dissolved-oxygen concentration varied slightly among the four sites and was never below the water-quality criterion of 5 mg/L established by the Tennessee Department of Environment and Conservation for the protection of fish and aquatic life (Tennessee Department of Environment and Conservation, 1991) (table 3).

Measurement of fecal bacteria (streptococcus and coliform) was taken under varying streamflow conditions. No correlation existed between streamflow and fecal bacteria count. Fecal streptococcus ranged from 3 to 20,000 cols./100 mL (table 3). The upstream sites on both rivers showed wider ranges and higher median values than the downstream sites. Fecal coliform colonies ranged from 5 to 7,300 cols./100 mL (table 3). The upstream sites showed greater ranges and higher median values than the downstream sites. The State of Tennessee water-quality criterion for a single sample for recreational use (1,000 cols./100 mL) was exceeded for 6 of 19 samples at the upstream Clinch River site and for 8 of 21 samples at the upstream Powell River site. Additionally, the criterion for fish and aquatic life (5,000 cols./100 mL) was exceeded for 5 of 19 samples at the upstream Clinch River site and for 3 of 21 samples at the upstream Powell River site. The values for the downstream sites were, for the most part, within the criterion limits. Only 2 of 13 samples exceeded the criterion for recreation and 1 of 13 samples exceeded the fish and aquatic life criterion at the downstream Clinch River site. No values were measured in exceedance of recreation or fish and aquatic life criteria at the Powell River downstream site.

Natural sources of nitrogen include precipitation, runoff, and erosion of fertile land. Biological nitrogen fixation by microorganisms, such as blue-green algae, also contributes nitrogen to surface water. Man-made sources of nitrogen include agricultural, domestic (septic), and industrial wastewater discharge. Samples from the Clinch and Powell River sites were analyzed for nitrite, nitrate, dissolved ammonia, and total ammonia. Concentrations were typically below 1 mg/L. The concentration ranges showed little difference between river basins or upstream and downstream sites. The detected levels of total ammonia (NH_4) nitrogen did exceed the U.S. EPA criterion for fish and aquatic life (0.02 mg/L) in 44 of 124 samples collected (table 3). However, un-ionized ammonia toxicity is a function of water temperature and pH. Decreases in either of these two variables results in decreased toxicity for a given concentration of total ammonia.

Total phosphorus values ranged from <0.01 to 0.41 mg/L. These values were consistent with land use of the basins and did not exceed values expected for these uses (table 3). The median values for total phosphorus were less than 0.1 mg/L at all four sites.

Concentrations of suspended sediment in samples from the four sites ranged from 1 to 1,040 mg/L (table 3). The downstream sites on the two rivers had greater median concentrations than the upstream sites. The median percentage of suspended sediment finer than 0.062 millimeter in diameter, the break point between sand and silt, varied between 83 and 89 percent. These percentages indicate that the majority of the sediment transported by both rivers consists of silts and clays. No correlation existed between streamflow and percentage finer than 0.062 millimeter. Each river appears to have a similar content of sand versus silt between sites, with a slightly larger ratio of silt-clay to sand in the Clinch River than the Powell River (table 3).

Samples were analyzed for total dissolved solids and major constituents to determine the general water quality. Dissolved solids consist of inorganic salts, some organic matter, and dissolved constituents. The concentrations at all sampling sites were well below the water-quality criterion limit of 500 mg/L for domestic water supply (table 3). The major ions determined in the study act as "fingerprints" for the type of water which is being sampled. These ions include calcium, magnesium, sodium, potassium, sulfate, chloride, silica, and fluoride, as well as total hardness, which is expressed in milligrams per liter as calcium carbonate (table 3). Concentrations of these constituents were within the range expected for a natural carbonate system.

Total and dissolved analysis for 20 trace constituents were made on selected base-flow and storm-flow samples (table 3). Concentrations were compared on an individual basis with the most appropriate water-quality criteria (Tennessee Department of Environment and Conservation, 1991; U.S. Environmental Protection Agency, 1976). Total-iron concentrations exceeded the U.S. Environmental Protection Agency criterion for fish and aquatic life in 23 of 28 samples at the upstream Clinch River site, in 38 of 44 samples at the upstream Powell River site, in 2 of 5 samples at the downstream Clinch River site, and in 1 of 4 samples at the downstream Powell River site. No other dissolved trace-constituent concentrations exceeded established water-quality criteria for the study basins.

SUSPENDED SEDIMENT

To estimate annual loads of any water-quality constituent, the water-quality data must be used with a surrogate variable and an extrapolation technique, such as regression, to estimate concentration data for unsampled times. Regression defines a relation between a dependent variable, such as water-quality concentration, and the surrogate variable, such as streamflow, for which continuous data are available. Other independent variables, such as season and rainfall characteristics, may also be included in the regression. The coefficient of determination (r^2) and the standard error of the estimate (*SE*) measure the fit of the regression. The r^2 value represents how well the variation of the dependent variable is explained by the independent variables. The *SE* is a measure of how well estimated values agree with observed values of the dependent variable.

Concentration data for suspended sediments were regressed against streamflow, season at time of sampling, and a rainfall factor. To separate the data seasonally, each calendar year was divided into radians and the discharge was related to the sine and cosine of the radian date. The rainfall factor (*R*) was determined by the product of total rainfall in inches ($Precip_{total}$) and the maximum 6-hour storm intensity ($I_{6\text{-}hour}$), which were published by the National Oceanic and Atmospheric Administration (1974). Rainfall factor is determined by the following equation:

$$R = (Precip_{total}) \cdot (I_{6-hour})$$

The rainfall factor (*R*) was then weighted according to the Thiessen diagram results for a basin-wide rainfall factor (table 5). The final regression factor values for instantaneous discharge were computed from either actual measurements or unit-value discharge based on stage data taken during the sampling event. Calibration coefficients and error statistics for the regression at each of the four sampling sites are listed in table 6. The regression for Powell River above Arthur appears weaker (r^2=0.611 and *SE*=0.269) than those for the other sites because of a single storm that caused extremely large sediment loads.

A synthetic record of daily sediment loading was produced for each site by applying the regression relation to streamflow and rainfall data. Annual load was computed by summing the synthetic record and dividing by the number of years of record (table 7). Percentage of error is based on the regression error of the concentration estimate. The estimated annual load for the Clinch River both near Looney's Gap (upstream) and above Tazewell (downstream) was 143,000 tons. Results suggest that the Clinch River between Looney's Gap and Tazewell does not contribute to the sediment load; however, there are no impoundments to trap sediment and the contribution may be obscured in the error. The estimated annual load for the Powell River increased from 110,000 tons at Alanthus Hill (upstream) to 126,000 tons above Arthur (downstream); however, the estimated annual load for Powell River above Arthur has a percentage error of 91 due to the weak regression caused by a single storm with extremely large sediment loads. The estimated annual suspended-sediment yield from June 1989 through January 1994 was 97 and 184 (tons/mi^2)

Table 5. Rain gage locations with Thiessen weight annotated

[Data source: Wayne Hamburger, Tennessee Valley Authority Engineering Services, written commun., 1994]

Station name	Latitude	Longitude	Data type	Thiessen weight
Wise, Va.	36°58'00"	82°23'00"	Hourly	6.25
Rogersville, Tenn.	36°25'00"	82°59'00"	Hourly	0.78
Arthur, Tenn.	36°32'32"	83°37'49"	2-hour	4.69
Speedwell, Tenn.	36°27'27"	83°53'04"	6-hour	4.69
Fitt's Gap, Tenn.	36°35'20"	83°13'40"	6-hour	4.69
Church Hill, Tenn.	36°31'16"	82°44'15"	6-hour	0.78
Duffield, Va.	36°42'44"	82°47'47"	6-hour	12.5
Pennington Gap, Va.	36°44'48"	83°02'20"	6-hour	12.5
Appalachia, Va.	36°53'54"	82°47'18"	6-hour	12.5
Tazewell, Va.	37°07'33"	81°33'29"	6-hour	6.25
Coeburn, Va.	36°55'44"	82°28'53"	6-hour	6.25
Lebanon, Va.	36°54'33"	83°03'39"	6-hour	9.37
Richlands, Va.	37°05'46"	81°50'09"	6-hour	9.37
Hilton, Va.	36°38'44"	82°29'15"	6-hour	9.37

Table 6. Regression equations for estimating suspended-sediment concentration based on season, rainfall, and instantaneous discharge at the sampling sites

[ss, instantaneous concentration of suspended sediment in milligrams per liter; θ, the radian year with January 1 as θ=0; Q, the instantaneous streamflow in cubic feet per second; R, rainfall factor defined by the weighted product of the total precipitation and 6-hour intensity; r^2, coefficient of determination; SE, standard error of the regression estimate; N, number of samples used in the regression analysis; C, B, D, E, and F are regression coefficients; --, variable is not used in the model; equation form is: $\log[ss] = C + B*\sin\theta + D*\cos\theta + E*\log Q + F*R$]

Site	C	B	D	E	F	r^2	SE	N
Clinch River								
Looney's Gap	-4.013	-0.1496	--	1.8428	-0.0095	0.885	0.192	42
Tazewell	-0.5797	1.4391	--	0.3478	0.0071	0.879	0.154	78
Powell River								
Alanthus Hill	-4.8273	--	-0.2813	1.50608	0.0137	0.934	0.093	72
Arthur	-0.08105	--	--	0.7124	0.0062	0.611	0.269	120

Table 7. Estimated annual sediment loads for the Clinch and Powell Rivers in the study area

[(tons/mi^2)/year, tons per square mile per year]

Site	Total annual load (tons)	Annual load per basin area [(tons/mi^2)/year]	Percentage of error
Clinch River			
near Looney's Gap	143,000	124	50
above Tazewell	143,000	97	42
Powell River			
at Alanthus Hill	110,000	216	25
above Arthur	126,000	184	91

on the downstream sites of the Clinch and Powell Rivers, respectively. The estimated annual suspended-sediment yields at the upstream sites were also lower for the Clinch River (124 tons/mi^2) than for the Powell River (216 tons/mi^2).

SUMMARY

From June 1989 through January 1994, the USGS, in cooperation with the Tennessee State Planning Office, conducted an investigation of water quality in the Clinch and Powell River basins in northeastern Tennessee. Agriculture, grazing, and mining activities in these basins pose potential problems that may jeopardize the water quality. This report summarizes the water quality at an upstream and downstream site on both the Clinch and Powell Rivers. Water samples were analyzed for physical properties, bacteria, nutrients, suspended sediment, major ions, and selected trace constituents.

The Clinch and Powell River basins are located in northeastern Tennessee and southwestern Virginia in the Appalachian Plateau and the Valley and Ridge Physiographic Provinces. The study area is underlain by rock formations mostly of Pennsylvanian, Cambrian, and Ordovician ages.

The part of the Clinch and Powell River basins used in the study are upstream of the backwater of Norris Lake. The basins are adjacent. The Clinch River basin in the study area is 1,474 mi^2, and the Powell River basin in the study area is 685 mi^2. Flow-duration curves are characteristic of highly variable streamflow with most flow occurring during or immediately after storms.

The pH of the waters ranged from 7.2 to 8.8 at all sites. At each site, the pH decreased during storm flow. The median value of pH for all water samples from the Clinch River is 8.2, and the median from the Powell River is 8.1.

Acidity tested at three of the four sampling sites ranged from 5 to 25 milligrams per liter as calcium carbonate. Alkalinity at the four sampling sites ranged from 62 to 157 milligrams per liter as calcium carbonate. Values of specific conductance at the sites ranged from 99 to 445 microsiemens per centimeter.

Fecal coliform colonies ranged from 5 to 7,300 colonies per 100 milliliters. The State of Tennessee water-quality criterion for a single sample for recreational use (1,000 colonies per 100 milliliters) was exceeded for 6 of 19 samples at the upstream Clinch River site and for 8 of 21 samples at the upstream Powell River site. The criterion for fish and aquatic life (5,000 colonies per 100 milliliters) was exceeded for 5 of 19 samples at the upstream Clinch River site and for 3 of 21 samples at the upstream Powell River site. Only 2 of 13 samples exceeded the criterion for recreation and 1 of 13 samples exceeded the fish and aquatic life criterion at the downstream Clinch River site. No values were measured in exceedance of recreation or fish and aquatic life criteria at the Powell River downstream site.

Detected levels of total ammonia nitrogen did exceed the U.S. Environmental Protection Agency criterion for fish and aquatic life in 44 of 124 samples. Total phosphorus values ranged from < 0.01 to 0.41 milligrams per liter, were consistent with land use of the basins, and did not exceed values expected for these uses. Concentrations of suspended sediment in samples from the four sites ranged from

1 to 1,040 milligrams per liter. Sand-silt separation of samples indicated that the majority of the sediment transported by both rivers consists of silts and clays.

Major ions sampled included calcium, magnesium, sodium, potassium, sulfate, chloride, silica, and fluoride, as well as total hardness. Concentrations of these constituents were within the range expected for a natural carbonate system. Of 20 trace constituents sampled, only total-iron concentrations frequently exceeded U.S. Environmental Protection Agency criterion for fish and aquatic life. Total-iron concentration exceedances occurred in 23 of 28 samples at the upstream Clinch River site, in 38 of 44 samples at the upstream Powell River site, in 2 of 5 samples at the downstream Clinch River site, and in 1 of 4 samples at the downstream Powell River site.

Estimates of suspended-sediment loads were made using suspended-sediment concentration data, continuous streamflow data, and rainfall data. Coefficients of determination for the estimators indicate that loads can be reasonably estimated at all sites except Powell River at Arthur, Tennessee. The low confidence at Arthur is apparently due to one large storm event that created extremely large sediment loads. The estimated average annual suspended-sediment yield from June 1989 through January 1994 was 97 and 184 tons per square mile on the Clinch and Powell Rivers, respectively.

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Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994

[P75, the value of the 75th percentile sample; P25, the value of the 25th percentile sample; Number not detected, the number of samples with measured values lower than detectable levels; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mL, milliliter; <, less than; >, greater than; mm, millimeter; NTU, nephelometric turbidity unit; µg/l, micrograms/liter; n/a, no applicable criteria; n/a, not applicable; --, no data]

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
Station Number 03527220 Clinch River near Looney's Gap, Tennessee											
pH	Standard	6.5-8.5[1] 6.4-9.0[2,3]	1 0	41	8.6	7.2	--	8.2	8.2	8.1	0
Acidity	mg/L	none	n/a	8	9.9	5	5.6	5	5	5	0
Alkalinity	mg/L	<20[4]	0	18	151	76	103	101	110	91	11
Specific conductance	µS/cm @ 25 °C	none	n/a	40	445	220	281	272	309	240	0
Dissolved oxygen	mg/L	>5.0[1]	0	38	14.1	7.6	10.1	10.4	11.0	8.9	0
Fecal coliform	colonies/100 mL	5,000[1] 1,000[2]	5 6	19	6,700	5	1,755	490	3,200	87	0
Fecal streptococcus	colonies/100 mL	none	n/a	18	20,000	22	3,600	1,350	5,600	70	0
Nitrogen:											
NO_2	mg/L	none	n/a	40	0.04	<0.01	0.02	0.02	0.02	<0.01	36
NO_3	mg/L	none	n/a	4	0.96	0.68	0.81	--	--	--	0
NO_2+NO_3	mg/L	none	n/a	40	1.1	<0.05	0.69	0.70	0.82	0.6	1
$NH_{4\,(dis)}$	mg/L	none	n/a	40	0.05	<0.01	0.02	.02	0.03	0.01	5
$NH_{4\,(tot)}$	mg/L	0.02[4]	14	35	0.05	<0.01	0.02	.02	0.04	0.01	2
Total organic nitrogen	mg/L	none	n/a	30	1.5	0.15	0.59	0.52	0.67	0.36	0
Phosphorus:											
Dissolved	mg/L	none	n/a	40	0.03	<0.01	0.01	.01	0.02	<0.01	19
Total	mg/L	none	n/a	40	0.23	<0.01	0.07	.07	0.1	0.03	7
Ortho-phosphorus	mg/L	none	n/a	40	0.03	<0.01	0.01	0.01	<0.01	<0.01	26
Total organic carbon	mg/L	none	n/a	38	10	1	4.7	4.2	6.2	2.8	0

[1] State of Tennessee water-quality criteria for fish and aquatic life.

[2] State of Tennessee water-quality criteria for recreational use.

[3] State of Tennessee water-quality criteria for irrigation and livestock watering and wildlife.

[4] Federal water-quality criteria for fish and aquatic life.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
Station Number 03527220 Clinch River near Looney's Gap, Tennessee											
Suspended sediment:											
Concentration	mg/L	none	n/a	42	450.0	2.0	110.5	95.5	126.2	60.2	0
%< 0.062mm	percent	none	n/a	42	100.0	69.0	89.1	89.0	95.2	83.7	0
Turbidity	NTU	none	n/a	11	60	0.7	28	26	42	6	0
Dissolved solids[1]	mg/L	500[2]	n/a	11	239	127	160	153	167	139	0
Common ions:											
Calcium	mg/L	none	n/a	11	45	25	34	33	37	31	0
Magnesium	mg/L	none	n/a	11	14.0	7.9	9.7	8.9	12.0	8.3	0
Sodium	mg/L	none	n/a	11	21.0	4.8	7.9	7.0	8.3	5.7	0
Chloride	mg/L	none	n/a	11	5.8	3.6	4.3	4.0	5.1	3.8	0
Potassium	mg/L	none	n/a	11	2.6	1.4	1.7	1.6	1.7	1.5	0
Sulfate	mg/L	none	n/a	11	59	23	32.3	31	33	26	0
Fluoride	mg/L	none	n/a	11	0.2	<0.1	0.1	0.1	0.1	0.1	1
Silica	mg/L	none	n/a	11	6.9	0.9	4.4	4.7	6.1	2.6	0
Hardness	mg/L	none	n/a	11	170	95	125	120	140	110	0
Aluminum:											
Dissolved	µg/L	none	n/a	21	50	<10	24.3	20	30	20	1
Total	µg/L	none	n/a	28	3,300	50	1,350	1,250	2,000	702	0
Arsenic:											
Dissolved	µg/L	none	n/a	4	<1	--	--	--	--	--	4
Total	µg/L	360[3]	0	11	<1	--	--	--	--	--	11
		100[4]	0								
Barium:											
Dissolved	µg/L	none	n/a	11	43	29	35.5	35	41	30	0
Total	µg/L	none	n/a	11	<100	--	--	--	--	--	11

[1] Residue on evaporation at 180 °C.

[2] State of Tennessee water-quality criteria for domestic water supply.

[3] State of Tennessee water-quality criteria for fish and aquatic life.

[4] Federal water-quality criteria for irrigation.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
Station Number 03527220 Clinch River near Looney's Gap, Tennessee											
Beryllium:											
Dissolved	µg/L	none	n/a	4	<0.5	--	--	--	--	--	4
Total	µg/L	1.3[2] 1,100[3] 100[4]	unknown 0 0	11	<10	--	--	--	--	--	11
Cadmium:											
Dissolved	µg/L	9[1]	0	4	<1	--	--	--	--	--	4
Total	µg/L	12[3]	0	11	<1	--	--	--	--	--	11
Chromium:											
Dissolved	µg/L	none	n/a	4	1	<1	--	--	--	--	3
Total	µg/L	16[1] 670,000[2]	0 0	11	3	<1	2.2	2	2	2	7
Cobalt:											
Dissolved	µg/L	none	n/a	11	<3	--	--	--	--	--	11
Total	µg/L	none	n/a	11	4	<1	1.6	1	2	0.6	3
Copper:											
Dissolved	µg/L	34[1]	0	4	<1	--	--	--	--	--	4
Total	µg/L	none	n/a	10	11	3	5.9	7.2	5.5	3.7	0
Iron:											
Dissolved	µg/L	none	n/a	28	60	<10	20	18	25	10	4
Total	µg/L	1,000[3]	23	28	5,000	170	2,240	2,200	3,250	1,220	0
Lead:											
Dissolved	µg/L	198[1]	0	4	9	<1	3.7	--	--	--	1
Total	µg/L	none	n/a	11	10	2	4.6	4	6	3	0
Lithium:											
Dissolved	µg/L	none	n/a	11	17	<4	9.2	8.0	13.0	<4	3
Total	µg/L	none	n/a	11	30	<10	15.8	20	20	<10	3

[1] State of Tennessee water-quality criteria for fish and aquatic life.

[2] State of Tennessee water-quality criteria for recreational use.

[3] Federal water-quality criteria for fish and aquatic life.

[4] Federal water-quality criteria for irrigation.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
Station Number 03527220 Clinch River near Looney's Gap, Tennessee											
Manganese:											
Dissolved	µg/L	none	n/a	28	11	<1	2.6	<10	<10	<1	18
Total	µg/L	none	n/a	28	350	20	178	190	237	92	0
Mercury:											
Dissolved	µg/L	none	n/a	4	0.2	<0.1	--	--	--	--	2
Total, in µg/L		2.40[1] 0.15[2] 0.05[3]	0 0 0	11	0.1	<0.1	--	--	--	--	9
Molybdenum:											
Dissolved	µg/L	none	n/a	11	<10	--	--	--	--	--	11
Total	µg/L	none	n/a	11	1	<1	--	--	--	--	10
Nickel:											
Dissolved	µg/L	2,549[1]	0	11	1	<1	1	1	1	<1	5
Total	µg/L	4,600[2]	0	11	7	2	3.3	3	4	2	0
Selenium:											
Dissolved	µg/L	none	n/a	11	<1	--	--	--	--	--	11
Total	µg/L	20[1]	0	11	<1	--	--	--	--	--	11
Silver:											
Dissolved	µg/L	13[1]	0	11	<1	--	--	--	--	--	11
Total	µg/L	none	n/a	11	<1	--	--	--	--	--	11
Strontium:											
Dissolved	µg/L	none	n/a	11	300	84	121	100	120	93	0
Total	µg/L	none	n/a	11	290	50	109	100	120	60	0
Vanadium:											
Dissolved	µg/L	none	n/a	11	<6	--	--	--	--	--	11
Zinc:											
Dissolved	µg/L	210[1]	0	4	35	7	21	--	--	--	2
Total	µg/L	none	n/a	11	150	<10	30	20	30	10	2

[1] State of Tennessee water-quality criteria for fish and aquatic life.

[2] State of Tennessee water-quality criteria for recreational use.

[3] Federal water-quality criteria for fish and aquatic life.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
				Station Number 0352800 Clinch River above Tazewell, Tennessee							
pH	Standard	6.5-8.5[1] 6.4-9.0[2,3]	1 0	16	8.8	8.0	--	8.2	8.3	8.1	0
Acidity	mg/L	none	n/a	0	--	--	--	--	--	--	0
Alkalinity	mg/L	>20[4]	0	3	130	96	111	--	--	--	0
Specific conductance	µS/cm @ 25°C	none	n/a	28	417	99	301	302	340	272	0
Dissolved oxygen	mg/L	>5.0[1]	0	16	13.2	7.5	9.8	9.6	11.2	8.5	0
Fecal coliform	colonies/100 ml	5,000[1] 1,000[2]	1 2	13	6,000	61	1,010	380	770	89	0
Fecal streptococcus	colonies/100 ml	none	n/a	11	3,300	11	873	470	1,100	135	0
Nitrogen:											
NO_2	mg/L	none	n/a	14	0.03	<0.01	--	--	--	--	12
NO_3	mg/L	none	n/a	2	0.93	0.83	--	--	.--	--	0
NO_2+NO_3	mg/L	none	n/a	14	1	0.49	0.77	0.79	0.95	0.60	0
$NH_{4\,(dis)}$	mg/L	none	n/a	14	0.04	<0.01	0.02	0.01	.03	<0.01	2
$NH_{4\,(tot)}$	mg/L	0.02[4]	5	16	0.07	<0.01	0.02	0.02	.03	0.01	2
Total organic nitrogen	mg/L	none	n/a	11	1.6	0.15	0.42	0.29	0.39	0.27	0
Phosphorus:											
Dissolved	mg/L	none	n/a	15	0.04	<0.01	0.2	0.01	0.02	<0.01	5
Total	mg/L	none	n/a	16	0.13	0.01	0.46	0.03	0.07	0.02	0
Ortho-phosphorus	mg/L	none	n/a	14	0.04	<0.01	0.01	0.01	0.02	<0.01	7
Total organic carbon	mg/L	none	n/a	12	6.8	1.1	3.4	3.3	4.4	1.8	0

[1] State of Tennessee water-quality criteria for fish and aquatic life.

[2] State of Tennessee water-quality criteria for recreational use.

[3] State of Tennessee water-quality criteria for irrigation and livestock watering and wildlife.

[4] Federal water-quality criteria for fish and aquatic life.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
Station Number 03528000 Clinch River above Tazewell, Tennessee											
Suspended sediment:											
Concentration	mg/L	none	n/a	78	717	3	256	300	423	66	0
%< 0.062mm	percent	none	n/a	78	99	45	86	87	96	81	0
Turbidity	NTU	none	n/a	3	32	1	18	21	--	--	0
Dissolved solids[1]	mg/L	500[2]	n/a	3	175	141	163	173	--	--	0
Common ions:											
Calcium	mg/L	none	n/a	3	42	34	38	38	--	--	0
Magnesium	mg/L	none	n/a	3	12	7.8	9.9	9.9	--	--	0
Sodium	mg/L	none	n/a	3	7.4	3.5	6	7.1	--	--	0
Chloride	mg/L	none	n/a	3	4.3	3	3.76	4	--	--	0
Potassium	mg/L	none	n/a	3	1.8	1.4	1.56	1.5	--	--	0
Sulfate	mg/L	none	n/a	5	36	22	27.2	24	30	24	0
Fluoride	mg/L	none	n/a	5	0.1	<0.1	0.1	0.1	0.1	<0.1	1
Silica	mg/L	none	n/a	3	7.4	2.4	5.7	7.2	--	--	0
Hardness	mg/L	none	n/a	3	150	120	137	140	--	--	0
Aluminum:											
Dissolved	µg/L	none	n/a	3	30	10	20	20	--	--	0
Total	µg/L	none	n/a	3	8,140	1,260	4,717	4,750	--	--	0
Arsenic:											
Dissolved	µg/L	none	n/a	3	<0.01	--	--	--	--	--	3
Total	µg/L	360[3]	0	3	<0.01	--	--	--	--	--	3
		100[4]	0								
Barium:											
Dissolved	µg/L	none	n/a	3	38	34	35.3	34	--	--	0
Total	µg/L	none	n/a	3	<100	--	--	--	--	--	3

[1] Residue on evaporation at 180 °C.
[2] State of Tennessee water-quality criteria for domestic water supply.
[3] State of Tennessee water-quality criteria for fish and aquatic life.
[4] Federal water-quality criteria for irrigation.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
				Station Number 03528000 Clinch River above Tazewell, Tennessee							
Beryllium:											
Dissolved	µg/L	none	n/a	3	<0.5	--	--	--	--	--	3
Total	µg/L	1.3[2] 1,100[3] 100[4]	unknown 0 0	5	<10	--	--	--	--	--	5
Cadmium:											
Dissolved	µg/L	9[1]	0	3	<1	--	--	--	--	--	3
Total	µg/L	12[3]	0	5	1	<1	--	--	--	--	2
Chromium:											
Dissolved	µg/L	none	n/a	3	<1	--	--	--	--	--	3
Total	µg/L	16[1] 670,000[2]	0 0	3	<1	--	--	--	--	--	3
Cobalt:											
Dissolved	µg/L	none	n/a	3	<3	--	--	--	--	--	3
Total	µg/L	none	n/a	3	2	<1	--	--	--	--	2
Copper:											
Dissolved	µg/L	34[1]	0	3	7	2	3.7	2	--	--	0
Total	µg/L	none	n/a	5	10	<10	9.3	--	--	--	2
Iron:											
Dissolved	µg/L	none	n/a	3	23	7	13.7	11	--	--	0
Total	µg/L	1,000[3]	2	5	2,700	190	1,232	490	2,300	480	0
Lead:											
Dissolved	µg/L	198[1]	0	3	2	<1	--	--	--	--	2
Total	µg/L	none	n/a	5	8	<1	6	--	--	--	1
Lithium:											
Dissolved	µg/L	none	n/a	3	15	7	10.3	9	--	--	0
Total	µg/L	none	n/a	3	20	<10	15	--	--	--	1

[1] State of Tennessee water-quality criteria for fish and aquatic life.
[2] State of Tennessee water-quality criteria for recreational use.
[3] Federal water-quality criteria for fish and aquatic life.
[4] Federal water-quality criteria for irrigation.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
Station Number 03528000 Clinch River above Tazewell, Tennessee											
Manganese:											
Dissolved	µg/L	none	n/a	3	8	2	4	2	--	--	0
Total	µg/L	none	n/a	5	160	27	101	140	150	30	0
Mercury:											
Dissolved	µg/L	none	n/a	3	0.1	<0.1	--	--	--	--	2
Total	µg/L	2.40[1] 0.15[2] 0.05[3]	0 0 2	3	0.1	<0.1	--	--	--	--	2
Molybdenum:											
Dissolved	µg/L	none	n/a	3	<10	--	--	--	--	--	3
Total	µg/L	none	n/a	3	<1	--	--	--	--	--	3
Nickel:											
Dissolved	µg/L	2,549[1]	0	3	1	<1	--	--	--	--	1
Total	µg/L	4,600[2]	0	5	6	<1	3.3	3	--	--	2
Selenium:											
Dissolved	µg/L	none	n/a	3	<1	--	--	--	--	--	3
Total	µg/L	20[1]	0	5	<1	--	--	--	--	--	5
Silver:											
Dissolved	µg/L	13[1]	n/a	3	<1	--	--	--	--	--	3
Total	µg/L	none	0	5	<1	--	--	--	--	--	5
Strontium:											
Dissolved	µg/L	none	n/a	3	120	82	101	100	--	--	0
Total	µg/L	none	n/a	3	100	80	90	90	--	--	0
Vanadium:											
Dissolved	µg/L	none	n/a	3	<6	--	--	--	--	--	3
Zinc:											
Dissolved	µg/L	210[1]	0	3	140	4	51.3	10	--	--	0
Total	µg/L	none	n/a	5	50	<10	35	--	--	--	3

[1] State of Tennessee water-quality criteria for fish and aquatic life.

[2] State of Tennessee water-quality criteria for recreational use.

[3] Federal water-quality criteria for fish and aquatic life.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
Station Number 03531680 Powell River at Alanthus Hill, Tennessee											
pH	Standard	6.5-8.5[1] 6.4-9.0[2,3]	0 0	59	8.3	7.7	--	8.0	8.1	7.9	0
Acidity	mg/L	none	n/a	33	25	5	9.3	9.9	9.9	5	0
Alkalinity	mg/L	>20[4]	0	28	157	62	89.8	83	98.2	71	0
Specific conductance	µS/cm @ 25°C	none	n/a	63	402	165	245.6	234	270	202	0
Dissolved oxygen	mg/L	>5.0[1]	0	46	13.8	6.6	10.3	10.4	11.4	9.3	0
Fecal coliform	colonies/100 ml	5,000[1] 1,000[2]	3 8	21	7,300	14	1,850	960	3,150	150	0
Fecal steptococcus	colonies/100 ml	none	n/a	21	15,000	3	3,335	2,000	5,500	185	0
Nitrogen:											
NO_2	mg/L	none	n/a	61	0.01	<0.01	0.01	--	--	--	56
NO_3	mg/L	none	n/a	5	0.93	0.51	0.78	0.83	--	--	0
NO_2+NO_3	mg/L	none	n/a	61	1.1	0.23	0.77	0.79	0.85	0.70	0
$NH_{4\ (dis)}$	mg/L	none	n/a	61	0.04	<0.01	0.014	0.01	0.02	<0.01	26
$NH_{4\ (tot)}$	mg/L	0.02[4]	22	56	0.07	<0.01	0.02	0.02	0.03	0.01	8
Total organic nitrogen	mg/L	none	n/a	53	1.4	0.17	0.56	0.46	0.76	0.29	0
Phosphorus:											
Dissolved	mg/L	none	n/a	61	0.04	<0.01	0.02	0.01	0.02	0.01	12
Total	mg/L	none	n/a	61	0.41	0.02	0.10	0.08	0.14	0.04	0
Ortho-phosphorus	mg/L	none	n/a	61	0.03	<0.01	0.01	<0.01	0.01	<0.01	27
Total organic carbon	mg/L	none	n/a	49	19	1.1	6.2	4.9	8.8	3.1	0

[1] State of Tennessee water-quality criteria for fish and aquatic life.
[2] State of Tennessee water-quality criteria for recreational use.
[3] State of Tennessee water-quality criteria for irrigation and livestock watering and wildlife.
[4] Federal water-quality criteria for fish and aquatic life.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
Station Number 03531680 Powell River at Alanthus Hill, Tennessee											
Suspended sediment:											
Concentration	mg/L	none	n/a	79	1,040	2	226.7	192	314	81	0
%< 0.062mm	percent	none	n/a	79	96	13	78	83	88	78	0
Turbidity	NTU	none	n/a	28	140	0.6	56.7	53	86.7	19.7	0
Dissolved solids[1]	mg/L	500[2]	n/a	28	267	96	141.4	140	154	111.7	0
Common ions:											
Calcium	mg/L	none	n/a	28	49	22	31.2	31	34.7	25.2	0
Magnesium	mg/L	none	n/a	28	19	4.7	7.4	6.7	8.0	5.5	0
Sodium	mg/L	none	n/a	28	18	2.2	6.1	5.3	7.5	3.2	0
Chloride	mg/L	none	n/a	28	9.4	1	3.1	2.8	3.6	2.4	0
Potassium	mg/L	none	n/a	28	3	1.1	1.8	1.7	2.1	1.5	0
Sulfate	mg/L	none	n/a	28	74	16	29	27	34	21	0
Fluoride	mg/L	none	n/a	28	0.2	<0.01	0.08	<0.01	<0.01	<0.01	12
Silica	mg/L	none	n/a	28	6.5	0.62	5.2	5.4	5.7	4.9	0
Hardness	mg/L	none	n/a	28	200	74	108.3	100	120	87.2	0
Aluminum:											
Dissolved	µg/L	none	n/a	44	70	10	35.2	30	50	22.5	0
Total	µg/L	none	n/a	44	8,400	50	2,655	2,100	4,400	962	0
Arsenic:											
Dissolved	µg/L	none	n/a	3	<0.01	--	--	--	--	--	3
Total	µg/L	360[3]	0	28	2	<1	0.56	<1	<1	<1	22
		100[4]	0								
Barium:											
Dissolved	µg/L	none	n/a	28	49	22	34.2	34	38.7	27	0
Total	µg/L	none	n/a	28	100	<100	100	<100	<100	<100	24

[1] Residue on evaporation at 180 °C.

[2] State of Tennessee water-quality criteria for domestic water supply.

[3] State of Tennessee water-quality criteria for fish and aquatic life.

[4] Federal water-quality criteria for irrigation.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
				Station Number 03531680 Powell River at Alanthus Hill, Tennessee							
Beryllium:											
Dissolved	mg/L	none	n/a	3	<0.5	--	--	--	--	--	3
Total	mg/L	1.3^{2} $1{,}100^{3}$ 100^{4}	unknown 0 0	28	<10	--	--	--	--	--	28
Cadmium:											
Dissolved	mg/L	9^{1}	0	3	<1	--	--	--	--	--	3
Total	mg/L	12^{3}	0	28	2	<1	--	--	--	--	26
Chromium:											
Dissolved	mg/L	none	n/a	3	2	<1	--	--	--	--	2
Total	mg/L	16^{1} $670{,}000^{2}$	0 0	28	16	<1	4.4	3	7	1	5
Cobalt:											
Dissolved	mg/L	none	n/a	28	<3	--	--	--	--	--	28
Total	mg/L	none	n/a	28	10	<1	4.2	3	8	1	5
Copper:											
Dissolved	mg/L	34^{1}	0	3	2	1	1.3	--	--	--	0
Total	mg/L	none	n/a	25	9	<1	4.3	4	6	2	3
Iron:											
Dissolved	mg/L	none	n/a	44	810	5	55.2	37	56	21.5	0
Total	mg/L	$1{,}000^{3}$	38	44	16,000	140	4,985	1,000	8,700	1,425	0
Lead:											
Dissolved	mg/L	198^{1}	0	3	1	<1	2	--	--	--	1
Total	mg/L	none	n/a	28	80	2	17.6	12	26.7	6.2	0
Lithium:											
Dissolved	mg/L	none	n/a	28	26	<4	2.3	<4	<4	<4	22
Total	mg/L	none	n/a	28	20	<10	7.7	<10	<10	<10	22

[1] State of Tennessee water-quality criteria for fish and aquatic life.

[2] State of Tennessee water-quality criteria for recreational use.

[3] Federal water-quality criteria for fish and aquatic life.

[4] Federal water-quality criteria for irrigation.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
				Station Number 03531680 Powell River at Alanthus Hill, Tennessee							
Manganese:											
Dissolved	µg/L	none	n/a	44	13	<10	5.3	3	6	<10	16
Total	µg/L	none	n/a	44	890	10	301	290	470	132	0
Mercury:											
Dissolved	µg/L	none	n/a	3	<0.1	--	--	--	--	--	3
Total	µg/L	2.40[1] 0.15[2] 0.05[3]	0 0 2	28	0.2	<0.1	--	--	--	--	27
Molybdenum:											
Dissolved	µg/L	none	n/a	28	<10	--	--	--	--	--	28
Total	µg/L	none	n/a	25	2	<1	--	--	--	--	24
Nickel:											
Dissolved	µg/L	2,549[1]	0	28	2	<1	0.8	<1	1	<1	18
Total	µg/L	4,600[2]	0	28	23	1	8.8	6	14.7	3.2	0
Selenium:											
Dissolved	µg/L	none	n/a	28	<1	--	--	--	--	--	28
Total	µg/L	20[1]	0	28	<1	--	--	--	--	--	28
Silver:											
Dissolved	µg/L	13[1]	n/a	28	<1	--	--	--	--	--	28
Total	µg/L	none	0	28	<1	--	--	--	--	--	28
Strontium:											
Dissolved	µg/L	none	n/a	28	210	78	133.7	130	167.5	95.5	0
Total	µg/L	none	n/a	28	180	70	120.3	110	147.5	92.5	0
Vanadium:											
Dissolved	µg/L	none	n/a	28	<6	--	--	--	--	--	28
Zinc:											
Dissolved	µg/L	210[1]	0	3	12	<3	--	7	--	--	1
Total	µg/L	none	n/a	22	140	<10	56.7	40	80	20	3

[1] State of Tennessee water-quality criteria for fish and aquatic life.

[2] State of Tennessee water-quality criteria for recreational use.

[3] Federal water-quality criteria for fish and aquatic life.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
Station Number 03532000 Powell River above Arthur, Tennessee											
pH	Standard	6.5-8.5[1]	0	20	8.4	7.8	--	8.1	8.3	3.0	0
		6.4-9.0[2,3]	0								
Acidity	mg/L	none	n/a	2	5	5	--	--	--	--	0
Alkalinity	mg/L	>20[4]	0	2	129	109	--	--	--	--	0
Specific conductance	µS/cm @ 25°C	none	n/a	15	410	190	283.6	285	320	230	0
Dissolved oxygen	mg/L	>5.0[1]	0	17	13.0	7.5	9.8	9.8	10.4	8.8	0
Fecal coliform	colonies/100 ml	5,000[1]	0	9	730	20	275	160	520	65	0
		1,000[2]	0								
Fecal steptococcus	colonies/100 ml	none	n/a	9	2,100	34	520	160	900	49	0
Nitrogen:											
NO_2	mg/L	none	n/a	17	0.02	<0.01	--	--	--	--	16
NO_3	mg/L	none	n/a	2	0.92	0.73	0.82	--	--	--	0
NO_2+NO_3	mg/L	none	n/a	17	1.2	0.54	0.78	0.73	0.89	0.68	0
$NH_{4\ (dis)}$	mg/L	none	n/a	17	0.04	<0.01	0.02	0.02	0.03	0.01	4
$NH_{4\ (tot)}$	mg/L	0.02[4]	3	17	0.13	<0.01	0.02	0.02	0.02	0.01	4
Total organic nitrogen	mg/L	none	n/a	13	2.3	0.28	0.70	0.42	1.03	0.28	0
Phosphorus:											
Dissolved	mg/L	none	n/a	18	0.7	<0.01	0.01	<0.01	0.02	<0.01	13
Total	mg/L	none	n/a	19	0.18	0.01	0.05	0.04	0.07	0.02	0
Ortho-phosphorus	mg/L	none	n/a	17	0.05	<0.01	0.01	<0.01	0.02	<0.01	10
Total organic carbon	mg/L	none	n/a	13	17	1	4.6	3.1	6.1	1.3	0

[1] State of Tennessee water-quality criteria for fish and aquatic life.

[2] State of Tennessee water-quality criteria for recreational use.

[3] State of Tennessee water-quality criteria for irrigation and livestock watering and wildlife.

[4] Federal water-quality criteria for fish and aquatic life.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
Station Number 03532000 Powell River above Arthur, Tennessee											
Suspended sediment:											
Concentration	mg/L	none	n/a	120	871	1	335.7	333	444.7	209.7	0
%< 0.062mm	percent	none	n/a	120	98	50	84.8	86	89	82	0
Turbidity	NTU	none	n/a	2	81	0.6	40.8	--	--	--	0
Dissolved solids[1]	mg/L	500[2]	n/a	2	184	162	112.5	--	--	--	0
Common ions:											
Calcium	mg/L	none	n/a	2	40	39	39.5	--	--	--	0
Magnesium	mg/L	none	n/a	2	12	8.6	10.3	--	--	--	0
Sodium	mg/L	none	n/a	2	9.2	7.8	8.5	--	--	--	0
Chloride	mg/L	none	n/a	2	2.9	2.7	2.8	--	--	--	0
Potassium	mg/L	none	n/a	2	1.5	1.4	1.45	--	--	--	0
Sulfate	mg/L	none	n/a	2	39	30	34.5	--	--	--	0
Fluoride	mg/L	none	n/a	2	0.1	<0.1	--	--	--	--	0
Silica	mg/L	none	n/a	2	6.5	5	5.7	--	--	--	0
Hardness	mg/L	none	n/a	2	150	130	140	--	--	--	0
Aluminum:							--	--	--	--	
Dissolved	µg/L	none	n/a	2	30	10	20	--	--	--	0
Total	µg/L	none	n/a	4	3,400	50	900	525	760	50	0
Arsenic:											
Dissolved	µg/L	none	n/a	2	<1	--	--	--	--	--	2
Total	µg/L	360[3]	0	2	1	<1	--	--	--	--	1
		100[4]	0								
Barium:											
Dissolved	µg/L	none	n/a	2	39	37	38	--	--	--	0
Total	µg/L	none	n/a	2	<100	--	--	--	--	--	2

[1] Residue on evaporation at 180 °C.

[2] State of Tennessee water-quality criteria for domestic water supply.

[3] State of Tennessee water-quality criteria for fish and aquatic life.

[4] *Federal water-quality criteria for irrigation.*

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
Station Number 03532000 Powell River above Arthur, Tennessee											
Beryllium:											
Dissolved	μg/L	none	n/a	2	<0.5	--	--	--	--	--	2
Total	μg/L	1.3[2] 1,100[3] 100[4]	unknown 0 0	4	<10	<1	--	--	--	--	2
Cadmium:											
Dissolved	μg/L	9[1]	0	2	<1	--	--	--	--	--	2
Total	μg/L	12[3]	0	4	<1	--	--	--	--	--	4
Chromium:											
Dissolved	μg/L	none	n/a	2	1	<1	--	--	--	--	1
Total	μg/L	16[1] 670,000[2]	0 0	2	3	<1	2	--	--	--	2
Cobalt:											
Dissolved	μg/L	none	n/a	2	<3	--	--	--	--	--	2
Total	μg/L	none	n/a	2	5	<1	--	--	--	--	1
Copper:											
Dissolved	μg/L	34[1]	0	2	2	1	1.5	--	--	--	0
Total	μg/L	none	n/a	4	43	<10	21.3	--	--	--	1
Iron:											
Dissolved	μg/L	none	n/a	2	20	6	13	--	--	--	0
Total	μg/L	1,000[3]	1	4	5,900	130	1,510	760	1,000	130	0
Lead:											
Dissolved	μg/L	198[1]	0	2	1	<1	--	--	--	--	1
Total	μg/L	none	n/a	4	12	2	5	3	4	2	0
Lithium:											
Dissolved	μg/L	none	n/a	2	5	5	5	--	--	--	0
Total	μg/L	none	n/a	2	<10	--	--	--	--	--	2

[1] State of Tennessee water-quality criteria for fish and aquatic life.

[2] State of Tennessee water-quality criteria for recreational use.

[3] Federal water-quality criteria for fish and aquatic life.

[4] Federal water-quality criteria for irrigation.

Table 3. Statistical summary of water quality at the sampling sites, June 1989 through January 1994—Continued

Parameter	Units	Listed criteria	Number of exceedances	Number of samples	Maximum	Minimum	Mean	Median	P75	P25	Number not detected
Station Number 03532000 Powell River above Arthur, Tennessee											
Manganese:											
Dissolved	µg/L	none	n/a	2	7	1	4	--	--	--	0
Total	µg/L	none	n/a	4	420	<10	153.5	92	140	<10	1
Mercury:											
Dissolved	µg/L	none	n/a	1	0.1	--	--	--	--	--	0
Total	µg/L	2.40[1] 0.15[2] 0.05[3]	0 0 0	2	<0.1	--	--	--	--	--	2
Molybdenum:											
Dissolved	µg/L	none	n/a	2	<10	--	--	--	--	--	2
Total	µg/L	none	n/a	2	1	<1	--	--	--	--	1
Nickel:											
Dissolved	µg/L	2,549[1]	0	2	1	1	--	--	--	--	0
Total	µg/L	4,600[2]	0	4	9	1	3.2	1.5	2	1	0
Selenium:											
Dissolved	µg/L	none	n/a	2	<1	--	--	--	--	--	2
Total	µg/L	20[1]	0	4	<1	--	--	--	--	--	4
Silver:											
Dissolved	µg/L	13[1]	n/a	2	<1	--	--	--	--	--	2
Total	µg/L	none	0	4	<1	--	--	--	--	--	4
Strontium:											
Dissolved	µg/L	none	n/a	2	170	160	165	--	--	--	0
Total	µg/L	none	n/a	2	150	100	125	--	--	--	0
Vanadium:											
Dissolved	µg/L	none	n/a	2	<6	--	--	--	--	--	2
Zinc:											
Dissolved	µg/L	210[1]	0	2	16	11	13.5	--	--	--	0
Total	µg/L	none	n/a	4	40	10	25	25	40	10	0

[1] State of Tennessee water-quality criteria for fish and aquatic life.

[2] State of Tennessee water-quality criteria for recreational use.

[3] Federal water-quality criteria for fish and aquatic life.