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LOW-FLOW CHARACTERISTICS AND PROFILES FOR THE DEEP RIVER IN THE CAPE FEAR RIVER BASIN, NORTH CAROLINA

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 97-4128

Prepared in cooperation with the
DIVISION OF WATER QUALITY and DIVISION OF WATER RESOURCES
of the NORTH CAROLINA DEPARTMENT OF ENVIRONMENT,
HEALTH, AND NATURAL RESOURCES

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Raleigh, North Carolina
1997

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

For additional information write to:

District Chief
U.S. Geological Survey
3916 Sunset Ridge Road
Raleigh, NC 27607

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
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CONVERSION FACTORS, TEMPERATURE, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.590	square kilometer
	Flow	
gallon per minute (gal/min)	0.06308	liter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per square mile ($[ft^3/s]/mi^2$)	0.01093	cubic meter per second per square kilometer

Temperature: In this report, temperature is given in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by using the following equation:

$$°C = (5/9)(°F - 32)$$

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

Low-flow Characteristics and Profiles for the Deep River in the Cape Fear River Basin, North Carolina

By J. Curtis Weaver

ABSTRACT

An understanding of the magnitude and frequency of low-flow discharges is an important part of protecting surface-water resources and planning for municipal and industrial economic expansion. Low-flow characteristics are summarized for 7 continuous-record gaging stations and 23 partial-record measuring sites in the Deep River Basin in North Carolina. Records of discharge collected through the 1995 water year are used. Flow characteristics included in the summary are (1) average annual unit flow; (2) 7Q10 low-flow discharge, the minimum average discharge for a 7-consecutive-day period occurring, on average, once in 10 years; (3) 30Q2 low-flow discharge; (4) W7Q10 low-flow discharge, similar to 7Q10 discharge except only flow during the months of November through March is considered; and (5) 7Q2 low-flow discharge. The potential for sustained base flows in the upper half of the basin is higher than that for streams in the lower half of the basin. Much of the decrease in base-flow potential in the lower part of the basin is attributed to the underlying rock types of the Triassic basin. Soils in the lower part of the basin consist of clays which limit the infiltration of water into surficial aquifers for later release to streams during drought conditions. Correspondingly, many streams in the lower part of the basin have minimal (defined as less than 0.1 cubic foot per second) or zero 7Q10 discharges.

Drainage-area and low-flow discharge profiles are presented for the Deep River. The drainage-area profile shows downstream increases in basin size. At the mouth, the drainage area for the Deep River is 1,441 square miles. Low-flow discharge profiles for the Deep River include 7Q10, 30Q2, W7Q10, and 7Q2 discharges in a continuous profile with contributions from major tributaries included.

INTRODUCTION

The need for a better understanding of low-flow hydrology and for improved techniques in determining low-flow characteristics of streams has become more critical as demands for sustained, high-quality water supplies and effective waste assimilation have increased. The simultaneous occurrence of higher demands and recent droughts in North Carolina have increased awareness of the importance of determining low-flow characteristics.

Low flow is defined as base flow, or sustained fair weather flow, and is composed largely of ground-water discharge from aquifers into streams. Discharges from aquifers have large spatial and temporal variations which are highly dependent on topographic, geologic, and climatic conditions in the drainage basin. The high variability of such conditions across North Carolina—and sometimes even within a drainage basin or along the same stream—results in a complex low-flow hydrology. Moreover, withdrawals, point-source discharges, impoundments, and development in the drainage basin complicate the characterization of low-flow hydrology. Low flows in North Carolina typically occur at the conclusion of the growing season in late summer and early autumn, following maximum use of ground water by crops and other plants. Additionally, temperatures during the summer and early autumn seasons cause increases in the human consumption of water, which in turn places higher demand for withdrawals from streams and reservoirs.

An understanding of low-flow characteristics is crucial in the evaluation of water-supply potential and reservoir-release requirements, the determination of allowable wastewater discharges in streams, and the maintenance of aquatic habitats in streams. Where sufficient records of discharge are available at continuous- and partial-record sites, application of statistical techniques, such as those described by Riggs (1972), form the basis for determining low-flow characteristics. However, the number of sites for which sufficient record exists to determine low-flow characteristics is far outnumbered by those locations where little or no record is available for developing estimates.

Low-flow characteristics are defined by a set of discharges that are statistically derived values having an associated duration and recurrence interval (or probability of occurrence). For example, the 7-day, 10-year low-flow discharge (hereafter referred to as 7Q10 discharge) is the annual lowest mean streamflow over a 7-consecutive-day period which, on average, is exceeded in 9 out of 10 years—or stated another way, the probability is 10 percent (the inverse of the recurrence interval) that the lowest average 7-consecutive-day flow in any year is less than the 7Q10 discharge (Giese and Mason, 1993). If the 7Q10 discharge is 5 cubic feet per second (ft^3/s), then the annual minimum average discharge for a 7-consecutive-day period would be 5 ft^3/s *or lower*, on average, 1 time in 10 years, 5 times in 50 years, or 10 times in 100 years.

In North Carolina, other low-flow statistics used by State regulatory agencies in determining permitting limits for withdrawals from and discharges into streams include the 30Q2, W7Q10, and 7Q2 discharges. The W7Q10 discharge, or "winter 7Q10," is defined in a similar manner as the 7Q10 discharge except only flow during the months of November through March is considered in the analysis.

In 1996, the Division of Water Quality (DWQ, formerly the Division of Environmental Management) of the North Carolina Department of Environment, Health, and Natural Resources (NCDEHNR), requested that a low-flow discharge profile be developed for the Deep River. Such a profile would provide consistent estimates of low-flow characteristics of the Deep River and result in better assessment and management of water quality in the Deep River by the DWQ. The U.S. Geological Survey (USGS), in cooperation with the DWQ and the Division of Water Resources (DWR), also of the NCDEHNR, conducted a study of the low-flow characteristics in the Deep River Basin to develop a low-flow discharge profile for the Deep River.

Purpose and Scope

This report presents low-flow characteristics for the Deep River Basin in North Carolina (fig. 1). Low-flow characteristics are summarized for existing gaging

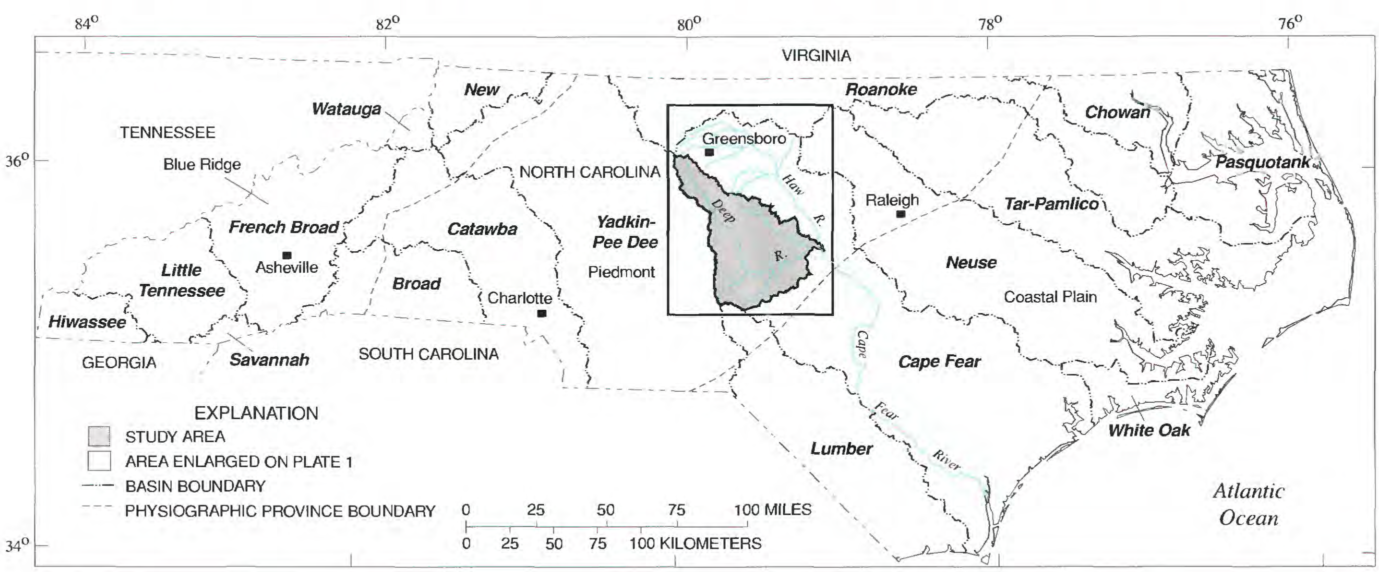

Figure 1. Locations of major river basins, the Deep River Basin study area (shaded), and physiographic provinces in North Carolina.

stations on the Deep River and selected sites on tributaries which drain to the Deep River. Drainage-area and low-flow discharge profiles for the Deep River also are presented.

Low-flow characteristics are summarized for 7 continuous-record gaging stations and 23 partial-record measuring sites. Flow characteristics included in the report are the average annual unit flow and the 7Q10, 30Q2, W7Q10, and 7Q2 low-flow discharges. Records of discharge collected through the 1995 water year were used in the analysis of low flows. For each gaging station where low-flow characteristics are summarized, the number of zero-flow days and discharge measurements for continuous-record stations and partial-record sites are included.

The drainage-area profile depicts increases in drainage area for the Deep River from the headwaters (West Fork Deep River) to the mouth, whereas the low-flow discharge profile presents estimates of low flows along the reach between the dam at High Point Municipal Lake and the mouth. The low-flow discharge profile shows the relation of 7Q10, 30Q2, W7Q10, and 7Q2 discharges to river mileage. No profiles were developed for tributaries to the Deep River.

Previous Low-Flow Studies

Prior to World War II, low-flow characteristics of North Carolina streams were determined only for sites operated as continuous-record gaging stations. With the economic expansion after World War II, the USGS began to receive an increasing number of requests for hydrologic information at sites where no data had been collected (Yonts, 1972). Thus, the USGS expanded its data-collection programs in the late 1940's to include partial-record sites where discharge measurements were made on a periodic basis. Discharge measurements made under conditions of base flow along with observations of zero flow became the foundation of data used in the initial assessments of low-flow characteristics in North Carolina. With data available from the network of partial record, the USGS began to respond to requests for low-flow characteristics on a site-specific basis, including those for ungaged sites.

Estimates of low-flow discharges continue to be provided upon request to government agencies and private corporations. These data are used in assessing the capacity of streams to receive wastewater discharges and to allow withdrawals for water supply. Data generally are provided on a site-specific basis with little consideration of previously estimated low-flow statistics upstream or downstream from the request site. In some instances, this has led to inconsistencies in estimates of low-flow discharges for adjacent sites.

Only a limited number of studies have been conducted to investigate low flows for streams in North Carolina. Goddard (1963) presented low-flow characteristics for many continuous-record gaging stations in North Carolina along with drainage-area and 7Q10-discharge profiles developed for selected mainstem rivers. Yonts (1972) reported base-flow measurements made at over 2,200 continuous-record stations and partial-record sites throughout the State.

Giese and Mason (1993) evaluated low-flow characteristics at 122 continuous-record stations and 396 partial-record sites with drainage areas between 1 and 400 square miles (mi^2) and streamflows unaffected by regulation or diversions. Sites were characterized on the basis of similarity in ranges of low-flow discharges and potential to sustain base flow. Ten hydrologic areas (HA) were delineated (fig. 2), and regression equations, which relate low flows to basin characteristics, were derived to determine flow characteristics at ungaged sites. Equations for only 4 of the 10 hydrologic areas—representing the western Piedmont and mountains (HA10), Sand Hills (HA3), and limited areas of the eastern and central Piedmont (HA5 and HA9)—had standard errors that were considered small enough to permit use of the equations in estimating low-flow characteristics at the ungaged sites. The large standard errors computed for equations in the remaining hydrologic areas reflect the complex relation between low-flow hydrology and geologic, topographic, and climatic factors. High standard errors for low-flow regression equations also were reported in a 1970 comprehensive study of low flows in which 47 USGS districts participated (each district being representative of the State in which it is located) (Riggs, 1973). Some districts reported standard errors well in excess of 100 percent, while others were unable to derive useful low-flow relations.

Evett (1994) investigated the effects of urbanization and land-use changes on low flows. Negative trends in low flows were detected from data at selected urban and rural continuous-record gaging stations in Asheville, Charlotte, Greensboro, and Raleigh (fig. 1). However, while the conclusions tended to support the investigation's hypothesis of decreasing

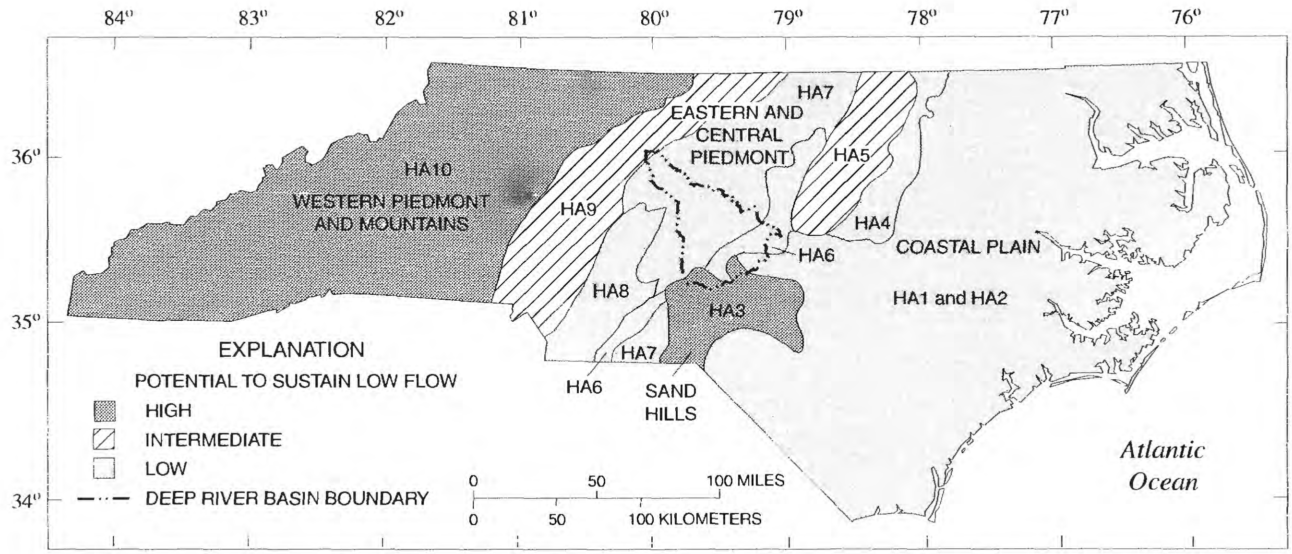

Figure 2. Hydrologic areas (HA) of similar potential to sustain low flows in North Carolina (modified from Giese and Mason, 1993).

low flows with increasing urbanization, the results were considered statistically inconclusive.

Weaver (1996) conducted a study of low-flow characteristics in the Roanoke River Basin in conjunction with the DWQ's program of basin-wide assessment and management of water quality in major river basins in North Carolina. Low-flow characteristics were summarized for 82 streamflow sites in North Carolina (79 sites) and Virginia (3 sites), and profiles of drainage area and low-flow discharge were developed for 10 selected streams, which reflect a wide range in basin size, characteristics, and streamflow conditions in the Roanoke River Basin. The streams included were Town Fork Creek, Hogans Creek, Mayo River, Buffalo Creek, Smith River, Country Line Creek, Dan River, Marlowe Creek, Hyco River, and Roanoke River. Drainage-area profiles show increases in drainage areas as streams travel their course in the basin. At the mouths, drainage areas for the streams profiled range from 22 mi^2 to about 9,700 mi^2. Low-flow discharges for each stream include 7Q10, 30Q2, W7Q10, and 7Q2 discharges in a continuous profile with contributions from major tributaries included. The methods and format used in this report are the same as those used by Weaver (1996).

DESCRIPTION OF DEEP RIVER BASIN

The Deep River Basin drains about 1,440 mi^2 of the central Piedmont Province in North Carolina and is tributary to the Cape Fear River, which discharges into the Atlantic Ocean near the southeastern tip of the State (fig. 1). The Deep River Basin occupies about 15 percent of the Cape Fear River Basin and lies within parts of eight counties—Forsyth, Guilford, Randolph, Alamance, Chatham, Montgomery, Moore, and Lee (pl. 1 at the back of the report). The Deep River Basin is characterized by rolling and hilly topography. Average ground elevations within the basin range from about 150 feet (ft) above sea level at the mouth of the Deep River to nearly 800 ft above sea level in the uppermost parts of the basin.

No percentages of land use were compiled for this study, but most of the basin is rural. The greatest extent of urban land use occurs in the headwaters of the basin in the vicinity of High Point, the largest municipality in the basin. Other smaller municipalities in the basin include Asheboro, Franklinville, Randleman, and Ramseur in Randolph County; Robbins and Carthage in Moore County; Siler City in Chatham County; and Sanford in Lee County.

Much of the Deep River Basin occupies 2 of the 10 hydrologic areas identified by Giese and Mason (1993)—the Carolina Slate Belt hydrologic area (HA7) and the Triassic basin hydrologic area (HA6) (fig. 2).

Low-flow potential for streams in these two areas is low relative to the other hydrologic areas in the State. Many streams within the Triassic basin have zero 7Q10 discharges as a result of low permeabilities associated with rock types in this area.

Drainage System

Rivers and streams within the Deep River Basin constitute one of the units defined in the system of hydrologic units in the USGS National Water Data Network (Seaber and others, 1987). The unit is identified as "03030003 Deep [River], North Carolina" and is defined as the study area for this report. Selected gaging stations and measurements from sites within this basin are the basis for the low-flow characteristics and profiles presented in this report.

Major Rivers and Tributaries

The Deep River forms at the confluence of the West Fork and East Fork Deep Rivers just upstream from the dam which impounds High Point Municipal Lake in Guilford County. The Deep River is nearly 114 miles (mi) in length from the dam to the mouth of the river. From the dam, the Deep River flows in a southeasterly direction through Guilford and Randolph Counties, turns east in Moore County then northeast along the Chatham–Lee County line before draining into the Cape Fear River (pl. 1).

At the mouth, the drainage area of the Deep River is 1,441 mi^2. The basin begins as a narrow drainage area and gradually broadens in width as the river travels its downstream course. Major tributaries draining to the Deep River include Polecat Creek (56.3 mi^2) in Guilford and Randolph Counties; Sandy Creek (60 mi^2), Richland Creek (66 mi^2), and Brush Creek (69.6 mi^2) in Randolph County; Bear Creek (145 mi^2) and McLendons Creek (100 mi^2) in Moore County; and Rocky River (243 mi^2) in Chatham County (pl. 1).

Major Flow Modifications

Previous discussions alluded to the generally complex nature of low-flow hydrology due to geologic, topographic, and climatic factors. The presence of major flow modifications adds a level of complexity to the determination of low-flow characteristics. Flow modifications can be classified into two general categories—impoundments and diversions of flow. The on-going addition and, in some instances, removal of these modifications result in continual changes to the low-flow characteristics.

Impoundments

Impoundments, the result of construction of a dam on a stream, are used to store water for a variety of purposes including supply, recreation, irrigation, flood control, power production, and cooling. The effects of impoundments on downstream low-flow characteristics vary because of the changes in streamflow patterns that result from storage, diversions of water (for supply purposes) that commonly occur within the impoundments, and to a smaller extent, evaporation from the impoundments. Post-impoundment flow durations for downstream flows, particularly below major impoundments, adjust in response to changes in flows relative to pre-impoundment conditions. The most common, and usually more obvious, adjustment in flow durations for streams downstream of impoundments is the reduction in peak flood discharges observed in post-impoundment flows. In a similar manner, some impoundments—particularly those operating under minimum-flow releases—serve to augment downstream flows during droughts and thus increase low flows observed below the dam.

Sixteen existing dams—14 of which are located on the Deep River—were identified from information provided by the DWR (North Carolina Department of Environment, Health, and Natural Resources, written commun., 1996) and from examination of USGS topographic quadrangle maps (table 1). One other dam listed in table 1 and shown on plate 1 is the proposed dam for Randleman Reservoir which, if completed, will be used primarily for water supply. The dams at Oak Hollow Reservoir and High Point Municipal Lake are the only ones which store water to the extent of causing widespread inundation of the river valley upstream from the dam. Most of the dams on the Deep River are owned by small hydroelectric power producers who typically operate on the basis of "run-of-river" mode in which outflows from the dams are approximately equal to inflows to the dams. While the dams on the Deep River can alter flow patterns in the river reaches immediately upstream and downstream from the dams, none are capable of causing the level of extensive changes in flow patterns observed downstream from the dams at Oak Hollow Reservoir and High Point Municipal Lake (Jim Meade, Division of Water Resources, written commun., 1997).

Table 1. Summary of selected dams in the Deep River Basin in North Carolina

[mi^2, square miles; ft^3/s, cubic feet per second; FERC, Federal Energy Regulatory Commission; n/a, not applicable; ---, no minimum release specified; ft, feet]

County	Dam	River mile[a]	Drainage area, (mi^2)	Minimum release[b] (ft^3/s) as mandated by: State of North Carolina	Minimum release[b] (ft^3/s) as mandated by: FERC	Remarks
Guilford	Oak Hollow Reservoir dam (02094950 West Fork Deep River at Oak Hollow Reservoir near Deep River)	n/a	32.0	---	---	
Guilford	High Point Municipal Lake dam (02099096 Deep River at High Point Dam)	113.8	61.4	---	---	
Randolph	Coltrane Mill dam	102.4	125	7.1	---	Bypass length 230 ft. Dam is not subject to licensing by FERC.
Randolph	Randleman dam [proposed] (02100083330 Deep River at proposed dam site at Randleman)	94.6	173	30	---	Dam for proposed Randleman Reservoir.
Randolph	Unnamed dam	92.2	178	---	---	
Randolph	Worthville dam (02100219 Deep River at Worthville)	90.7	236	---	---	
Randolph	Cox Lake dam	86.1	255	8	42	Bypass length 506 ft.
Randolph	Cedar Falls dam	84.8	266	8	32	Bypass length 2,112 ft.
Randolph	Franklinville dam (02100365 Deep River at dam at Franklinville)	82.2	277	11	---	Bypass length 480 ft. Dam is subject to licensing by FERC (no current license).
Randolph	Unnamed dam	81.4	279	---	---	Presence of dam noted on topographic map; however, dam has been breached.
Randolph	Ramseur dam	78.9	349	11	45	Bypass length 1,430 ft.
Randolph	Coleridge dam (02100617 Deep River at Coleridge)	70.7	401	12	35	Bypass length 500 ft.
Moore	Unnamed dam	55.5	634	---	---	Presence of dam noted on topographic map; however, only remnants of dam known to exist.
Moore	High Falls dam	51.3	792	28	108	Bypass length 2,844 ft.
Chatham	Carbonton dam (02101402 Deep River at dam at Carbonton)	29.0	1,026	---	---	
Chatham	Rocky River dam[c]	n/a	180[d]	---	---	
Chatham	Lockville dam (02102048 Deep River at dam at Moncure)	3.2	1,436	28	70	Bypass length 700 ft.

[a] Where applicable, river mile for Deep River. Zero miles is at mouth of Deep River.

[b] Minimum-release data and information (listed in Remarks) pertaining to dams from North Carolina Department of Environment, Health, and Natural Resources, written commun., 1996.

[c] Three other dams (not listed in this table) are located on the Rocky River in Chatham County. Two are operated by Town of Siler City for water supply; the third dam, dating to the pre-Civil War period, is not actively operated and merely serves as a point of interest in the local area.

[d] Approximate drainage area.

The reach of the Deep River between High Point Municipal Lake and the mouth of the river has one of the highest occurrences of dams for moderate-size river basins in North Carolina (pl. 1). The presence of these dams has made the assessment and management of water quality difficult for officials at the Federal, State, and local levels. Concurrent records of inflow, outflow, and corresponding patterns of storage at each of these dams are non-existent and thus unavailable to supplement records of streamflow collected by the USGS at selected sites on the Deep River. An indication of the complexity of river management on the Deep River can be seen from the data in table 1 where two distinct minimum-flow releases are required for some dams. At the small hydroelectric dams, minimum-flow releases required by the State are based, in part, on previous estimates of 7Q10 discharge, whereas flow releases required by the Federal Energy Regulatory Commission are based on a complex formula which addresses, in part, the maintenance of aquatic habitat. Minimum-flow releases required by the State apply to the bypass reaches (table 1) below these dams. The use of "run-of-river" mode in maintaining flows upstream and downstream from the dams applies to the reaches upstream from the dams and downstream from the dams' bypass reaches.

Diversions

Diversions, occurring as withdrawals or point-source discharges, have the effects of immediately altering downstream low flows by an amount equal to the diversion rate. Withdrawals commonly are made by municipalities for supply purposes, by major industries for manufacturing, and by farms for irrigation. Knowledge of low-flow characteristics is important when withdrawals are being made because decreased flows downstream from the withdrawals must be sufficient to sustain *downstream* uses, including the assimilation of treated effluent during drought conditions. Point-source discharges into streams are permitted through the issuance of National Pollution Discharge Elimination System (NPDES) permits. In North Carolina, as well as other States, permits that set limits for discharges of treated effluent are based, in part, on the 7Q10 discharge. In a similar manner to withdrawals, flows *upstream* from the discharge point must be sufficient to assimilate the treated effluent while maintaining other uses of the stream.

Data describing major withdrawals and point-source discharges in the study area were obtained from the different State agencies that monitor flow diversions (North Carolina Department of Environment, Health, and Natural Resources, written commun., 1996). For selected facilities, average surface-water withdrawals and return point-source discharges reported for 1995 were compiled into a summary that lists the magnitudes of streamflow changes in the affected streams (table 2). In most instances, point-source discharges were paired with a corresponding surface-water withdrawal made by a given facility. For each facility, the NPDES permit number and permitted flow rate assigned to the permit also are listed.

Eight facilities (seven municipalities and one industry) had withdrawals and/or point-source discharges to the Deep River during 1995 (table 2). The City of High Point had the highest rates of flow diversions—withdrawals averaged more than 13 million gallons per day (Mgal/d), and returns to the Deep River averaged 11.7 Mgal/d. Other significant diversions are point-source discharges made by the Cities of Asheboro and Sanford, each of which discharged about 4.5 Mgal/d into the Deep River during 1995. Return discharge by the City of Asheboro is actually an interbasin transfer from the Yadkin River Basin. Similarly, water is transferred out of the Deep River Basin by the City of High Point, which discharged an average of 5.2 Mgal/d into Rich Fork Creek in the Yadkin River Basin during the 1996 water year.

Climate

The climate in the study area, as throughout most of North Carolina, consists of long, hot, humid summers and short, mild winters with brief periods of more moderate, milder conditions during the spring and autumn seasons. Records collected by the National Weather Service at selected observation stations in and near the study area indicate that average monthly temperatures (1961–90) range from a minimum of about 38 °F in January to a maximum of about 78 °F in July (National Oceanic and Atmospheric Administration, written commun., 1994). In all areas of the Deep River Basin, temperature extremes in the summer reach levels exceeding 90 °F for long periods of consecutive days.

Average annual precipitation (1961–90) at selected observation stations in and surrounding the study area ranges from nearly 42 inches in headwaters

Table 2. Summary of selected flow diversions by surface-water withdrawals and return (point-source) discharges to streams in the Deep River Basin study area for 1995

[Mgal/d, million gallons per day (1 Mgal/d is equivalent to approximately 1.55 cubic feet per second); n/a, not applicable. Where Deep River is listed as the withdrawal source or return destination, river miles are listed in parentheses beside stream names]

County	Facility	Purpose	Source of withdrawal	Average withdrawal (Mgal/d)	Destination of return discharge	Average return discharge (Mgal/d)	NPDES permit number	Permitted NPDES discharge (Mgal/d)
Guilford	City of High Point[a]	Public water supply	High Point Municipal Lake	13.3	Richland Creek (tributary to Deep River at mile 106.8)	11.7	NC0024210	16.0
					Rich Fork Creek in Yadkin River Basin	4.9	NC0081256	10.0
Randolph	City of Randleman[b]	Public water supply	Polecat Creek	1.0	Deep River (mile 91.2)	1.03	NC0025445	1.75
Randolph	City of Asheboro[c]	Public water supply	Stream in Yadkin River Basin	n/a	Hasketts Creek (tributary to Deep River at mile 87.8)	4.73	NC0026123	6.0
Randolph	Town of Ramseur	Public water supply	Sandy Creek	.54	Deep River (mile 77.7)	.24	NC0026565	.48
Moore	Town of Robbins	Public water supply	Bear Creek, Cabin Creek, and Brooks Reservoir	.7[d]	Deep River (mile 54.7)	.77	NC0062855	1.0
Chatham	Goldston-Gulf Sanitary District	Public water supply	Deep River (mile 23.3)	.3	Deep River (mile 23.3)	.003	NC0081795	.006
Lee	Lee County Water and Sewer District[e]	Public water supply	Deep River (mile 18.0)	.81	n/a	n/a	n/a	n/a
Lee	Golden Poultry, Inc.	Food processing	n/a	n/a[f]	Deep River (mile 15.2)	.72	NC0072575	1.0
Lee	City of Sanford[g]	Public water supply	Stream in Cape Fear Basin	n/a	Deep River (mile 14.3)	4.31	NC0024147	5.0

[a] Withdrawals and return-discharge amounts reported for 1996 water year. City of High Point also supplies water and treats waste for Archdale and Jamestown municipalities.

[b] City of Randleman receives and treats some waste from City of Asheboro.

[c] City of Asheboro withdraws water from the Yadkin River Basin and discharges part of the treated waste to Hasketts Creek in the Deep River Basin.

[d] Average withdrawal reported for Town of Robbins represents total amount withdrawn from the three identified sources.

[e] Lee County Water and Sewer District supplies water to the community of Tramway; City of Sanford treats water distributed by Lee County Water and Sewer District.

[f] Golden Poultry receives water from Lee County Water and Sewer District.

[g] City of Sanford withdraws water from the middle Cape Fear Basin and discharges part of the treated waste upstream to the Deep River.

of the basin to about 47 inches in the central parts of the basin. Most rainfall occurring during the warmer months comes from isolated, convective storms which arise in the late afternoons and evenings as a result of day-time heating. Rainfall occurring during the cooler months is from more organized frontal storms which cover broad areas of the region (Kopec and Clay, 1975).

Since 1900, there have been seven major droughts in North Carolina, some of which have resulted in low flows in the Deep River Basin (Zembrzuski and others, 1991). The drought of the longest duration occurred during 1950–57; dry conditions associated with this drought initially affected streams in the Piedmont Province (including the study area) and spread statewide by 1952. Low flows having recurrence intervals of between 40 and 60 years were observed across the State. The lowest daily mean discharge (6.0 ft^3/s) and the lowest instantaneous discharge (5.5 ft^3/s) at the USGS gaging station at Deep River at Moncure (site 160) in Chatham County were recorded on October 9 and 10, 1954, respectively, for the period of record (July 1925 to September 1995) (U.S. Geological Survey, 1961–95, published annually).

Geology and Soils

An understanding of the geology and soils within the study area may provide some insight into the low-flow characteristics for streams in the Deep River Basin. Although these factors should be considered in any analysis of low flows, identification of an underlying geologic unit or the soil cannot be used solely to determine the potential for sustaining base flow during drought conditions.

A number of soil associations are present in the Deep River Basin (Lee, 1955; U.S. Department of Agriculture, 1975), but two associations cover most of the basin. Soils in the Georgeville–Herndon association cover most of the central basin (Randolph, Chatham, and upper Lee Counties). These soils are derived from Late Proterozoic metavolcanic and sedimentary rocks of the Carolina Slate Belt. Soils in this association are described as being moderately deep (28 to 40 inches over weathered slate) and characterized as firm silty clay subsoils and silty clay loam surface soils (Lee, 1955). Internal drainage of water into the soils is classified as being medium. The second major association which occurs in the lower areas of the basin in central Moore and Lee Counties is the White Store–Creedmoor association. Much of these soil associations are underlain by sedimentary rocks consisting of shales, sandstones, and mudstones of Triassic age. The most significant characteristic of these soils is the high presence of clay, which causes slow to very slow internal drainage. The presence of clay soils having slow to very slow internal drainage suggests that the potential for sustained base flow in the lower part of the basin is low. Giese and Mason (1993) also concluded that streams in the Triassic basin have very low, and in some cases zero, potential for sustained base flow during drought conditions.

Average well yields determined for different hydrogeologic units in the Piedmont and Blue Ridge Provinces in North Carolina provide yet another indicator of the potential for sustained base flow. Daniel (1989) identified 18 hydrogeologic units in the Blue Ridge and Piedmont Provinces of North Carolina and determined an average well yield for each unit. The average well yield for all 18 of the hydrogeologic units was 18.2 gallons per minute (gal/min). Seven of the 12 units, occupying 79 percent of the Deep River Basin (Daniel and Payne, 1990) (fig. 3), have well yields less than this average. Six of the seven units having less-than-average well yields are derived from igneous and metavolcanic rocks. The seventh unit, which covers 16 percent of the Deep River Basin, is underlain by Triassic sediments and has the lowest average well yield of all the hydrogeologic units studied by Daniel (1989). The low average well yield for the Triassic unit is consistent with the low to zero potential for sustained base flows for streams in this part of the Deep River Basin.

LOW-FLOW CHARACTERISTICS IN THE DEEP RIVER BASIN

Low-flow characteristics were determined for selected streamflow sites in the Deep River Basin study area in North Carolina. Records of streamflow collected through the 1995 water year from 160 sites were compiled (table 3, p. 22; pl. 1) and evaluated to identify sites where low-flow characteristics could be determined. The period of record varies from site to site. Of the total 160 sites, 8 are continuous-record gaging stations, 149 are partial-record sites, and 3 are sites having a combination of continuous- and partial-record discharges. The low-flow characteristics for selected sites in the Deep River Basin are presented in this section.

Continuous-Record Stations

Low-flow characteristics based on continuous records of discharge were developed for seven sites. Daily mean discharges were compiled for five of the eight continuous-record gaging stations and for two of the three sites that have both continuous- and partial-record discharges. Records from these sites were analyzed using frequency curves (Riggs, 1972); the magnitude and frequency of low flows for the continuous-record gaging stations are shown in table 4. The period of record at four of the continuous-record sites (30, 107, 110, and 142; table 3) was less than 10 years and was too short to determine low-flow characteristics using methods for continuous-record gaging stations.

Estimates of low-flow discharges for continuous-record sites having more than 10 years of record were developed through the use of frequency curves (Riggs, 1972) (fig. 4). The curves depict the relation between recurrence interval and the lowest average annual discharge for a specified number of days at a gaging station. Using available periods of record, frequency curves of measured annual (climatic year) 7-day and

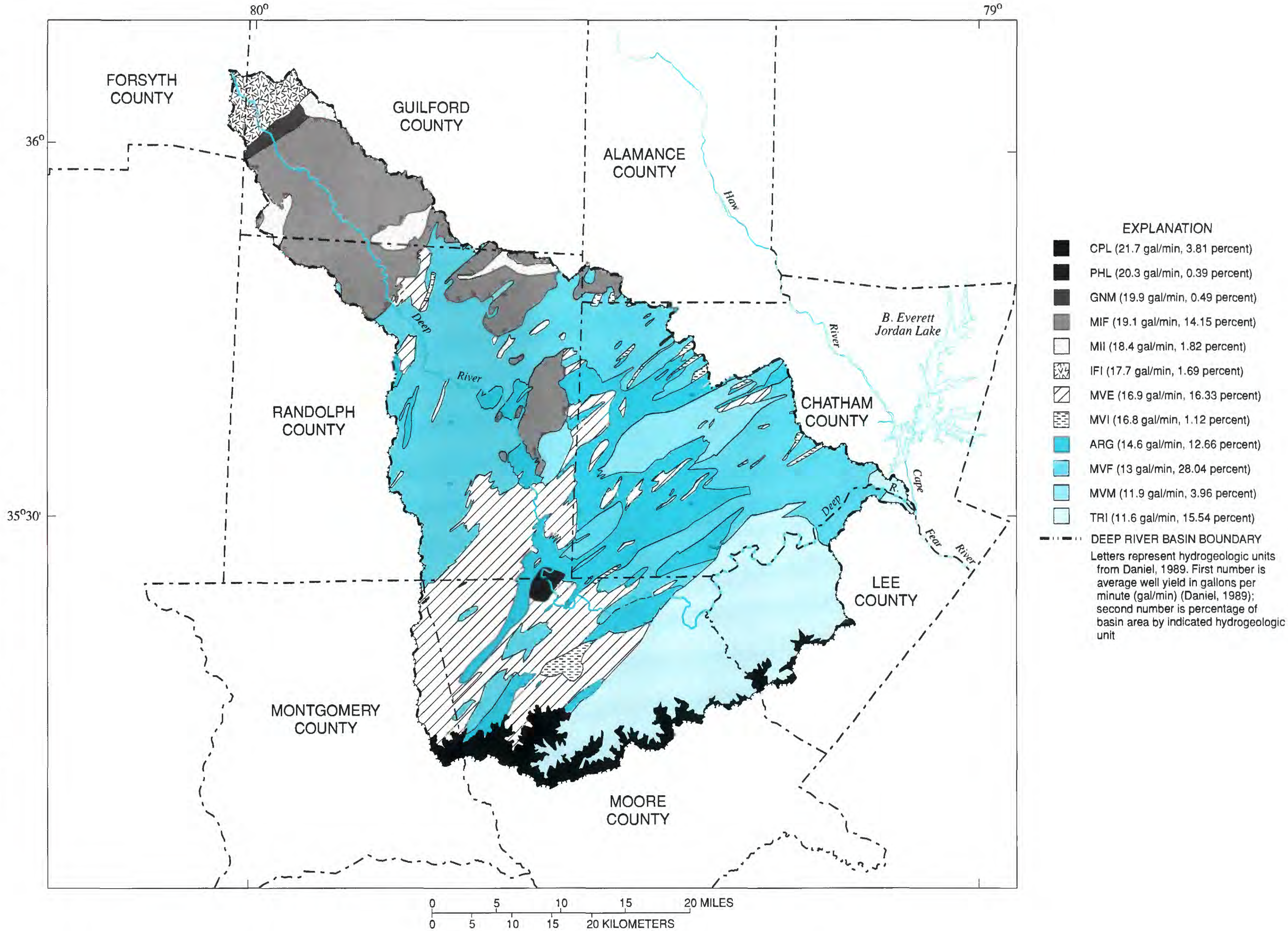

Figure 3. Hydrogeologic units in the Deep River Basin study area (modified from Daniel and Payne, 1990).

Table 4. Magnitude and frequency of annual low-flow characteristics at selected continuous-record gaging stations and partial-record sites in the Deep River Basin

[mi^2, square miles; $(ft^3/s)/mi^2$, cubic feet per second per square mile; ft^3/s, cubic feet per second; n/a, not applicable; SR, secondary road; <, less than. Period for continuous-record gaging stations (site type 1) is period of analysis in climatic years (April 1–March 31); period for partial-record sites (site type 2) is period of record in water years (October 1–September 30) during which discharge measurements were made]

Site index no. (pl. 1)	USGS downstream order number	Station name	Drainage area, (mi^2)	Site type	Period of analysis	Number of measurements for partial-record sites		Number of observed days of flow for continuous-record sites		Average annual unit flow [$(ft^3/s)/mi^2$]	Low-flow characteristics (ft^3/s)			
						Flow	Zero-flow	Equal to zero flow	Less than or equal to 7Q10		7Q10	30Q2	W7Q10	7Q2
3	02098343	West Fork Deep River near Friendship	11.5	2	1955, 1962, 1966	4	0	n/a	n/a	1.0	1.7	3.3	3.0	2.8
7	02098500	West Fork Deep River near High Point	32.5	1	1929-57	n/a	n/a	0	57	1.0	2.1	5.7	5.3	4.0
9	02099000	East Fork Deep River near High Point	14.8	1	1929-93	n/a	n/a	0	210	1.1	2.0	3.8	3.3	3.1
11	02099193	Deep River at SR 1352 near Jamestown	66.6	2	1971, 1973-74	5	0	n/a	n/a	1.0	.8	4.0	2.4	2.3
12	02099240	Bull Run at Oakdale	7.75	2	1954, 1960-67, 1969	25	1	n/a	n/a	1.0	0	.6	.2	.2
15	02099399	Deep River at Kivett Drive extension near Jamestown	77.7	2	1974-75	6	0	n/a	n/a	1.0	2 1	6 4	4.4	4 3
16	02099480	Richland Creek near Archdale	12.5	2	1954-56, 1958-60, 1962, 1966, 1971, 1973	21	0	n/a	n/a	.9	.9	2 2	2.0	1.7
21	02099490	Hickory Creek near High Point	9.60	2	1955, 1962, 1964-67, 1969-70, 1974-75	18	1	n/a	n/a	.9	< .1	.6	.4	.3
23	02099492	Reddicks Creek near Jamestown	4.90	2	1971, 1973-75	10	0	n/a	n/a	.9	0	.4	.2	.2
28	02099500	Deep River near Randleman	125	1	1929-94	n/a	n/a	0	403	1.0	7.7	18.1	12.5	13.6
34	02100096	Deep River at U.S. Highway 220 at Randleman	177	2	1971, 1973-74	5	0	n/a	n/a	1.0	7.8	22	14.3	15
38	02100180	Polecat Creek near Climax	29.1	2	1954-59, 1962-63, 1966, 1970	18	1	n/a	n/a	1.0	< .1	1.6	.9	.7
44	02100219	Deep River at Worthville	236	2	1971, 1973-74, 1976	7	0	n/a	n/a	1.0	8.0	26	14.5	17
51	02100344	Deep River at Cedar Falls	266	2	1971, 1974-75	5	0	n/a	n/a	1.0	8.5	32	18	27
60	02100500	Deep River at Ramseur	349	1	1923-94	n/a	n/a	0	384	1.0	12.0	45.6	25.1	29 5
64	02100599	Deep River near Parks Crossroads	392	2	1971, 1973-76	9	0	n/a	n/a	1.0	13.5	57	31	40
68	02100640	Richland Creek near Asheboro	36.8	2	1949-55, 1957, 1960, 1962, 1966	21	0	n/a	n/a	1.0	.1	3 0	1.9	1.5

Table 4. Magnitude and frequency of annual low-flow characteristics at selected continuous-record gaging stations and partial-record sites in the Deep River Basin—Continued

[mi², square miles; (ft³/s)/mi², cubic feet per second per square mile; ft³/s, cubic feet per second; n/a, not applicable, SR, secondary road; <, less than. Period for continuous-record gaging stations (site type 1) is period of analysis in climatic years (April 1–March 31); period for partial-record sites (site type 2) is period of record in water years (October 1–September 30) during which discharge measurements were made]

Site index no. (pl. 1)	USGS downstream order number	Station name	Drainage area, (mi²)	Site type	Period of analysis	Number of measurements for partial-record sites		Number of observed days of flow for continuous-record sites		Average annual unit flow [(ft³/s)/mi²]	Low-flow characteristics (ft³/s)			
						Flow	Zero-flow	Equal to zero flow	Less than or equal to 7Q10		7Q10	30Q2	W7Q10	7Q2
78	02100710	Brush Creek near Coleridge	67.4	2	1954-60, 1962-63, 1966	22	0	n/a	n/a	1.0	0.4	3.3	2.1	1.8
81	02100730	Fork Creek near Coleridge	38.5	2	1954-63, 1966	30	0	n/a	n/a	1.0	.1	2.6	1.6	1.3
82	02100747	Deep River at Howards Mill near Robbins	621	2	1970, 1974-77	9	0	n/a	n/a	1.0	18	75	40	48
89	02100824	Bear Creek near Spies	44.6	2	1954-55, 1971, 1973	11	0	n/a	n/a	1.1	< .1	1.8	1.0	.8
99	02101000	Bear Creek at Robbins	137	1	1940-70	n/a	n/a	36	82	1.1	.4	11.9	7.4	6.2
105	02101045	Buffalo Creek at McConnell	21.4	2	1962, 1965-68, 1970-71	12	4	n/a	n/a	1.0	0	< .1	< .1	< 1
112	02101090	McLendons Creek near Carthage	44.0	2	1949-54, 1959, 1962, 1966, 1968	22	3	n/a	n/a	1.2	0[a]	n/a[a]	n/a[a]	n/a[a]
118	02101290	McLendons Creek near Putnam	97.3	2	1963-68, 1970-71	14	0	n/a	n/a	1.0	0	1.4	.5	.3
141	02101660	Rocky River near Liberty	4.52	2	1953-55, 1960-63, 1966	18	1	n/a	n/a	.9	< .1	.4	.3	.2
152	02101800	Tick Creek near Mount Vernon Springs	15.5	1	1959-80, 1994	n/a	n/a	304	304	.9	0	.3	< .1	< 1
154	02101820	Tick Creek near Bonlee	20.0	2	1954, 1956-58, 1960-63, 1970	16	1	n/a	n/a	1.2	0[b]	n/a[b]	n/a[b]	n/a[b]
158	02101890	Bear Creek near Goldston	42.4	2	1949-71	50	2	n/a	n/a	1.0	0	4	2	1
160	02102000	Deep River at Moncure	1,434	1	1931-94	n/a	n/a	0	178	1.0	24.0	113	45.7	71.3

[a] Estimates for all low-flow characteristics cannot be determined based on available data; however, determination of zero-flow 7Q10 discharge at downstream site (site 118) allows estimate of zero-flow 7Q10 discharge at indicated site (site 112).

[b] Estimates for all low-flow characteristics cannot be determined based on available data; however, determination of zero-flow 7Q10 discharge at nearby upstream site (site 152) allows estimate of zero-flow 7Q10 discharge at indicated site (site 154).

30-day lowest average discharges and winter (November through March) 7-day lowest average discharge were developed; then a log-Pearson Type III frequency distribution was fitted to the measured values. The computed log-Pearson distribution generally corresponds closely to the distribution of annual low flows for sites having long-term periods of record (fig. 4).

Low-flow characteristics for the sites on the Deep River include the effects of the dams located on the river as reflected in the streamflow record (table 1). As discussed in a previous section, hydroelectric dams owned by small power producers typically operate in a "run-of-river" mode and only temporarily affect storage slightly by altering inflow and outflow patterns for the purposes of power production. The dams at Oak Hollow Reservoir and High Point Municipal Lake regulate the flows in the Deep River and do not operate under any requirements for minimum-flow releases (Jim Meade, Division of Water Resources, written commun., 1997). Where records of changes in storage are available, records of streamflow measured downstream from a dam typically are adjusted to reflect the changes in storage upstream from the dam. However, no adjustments were made to the measured daily mean discharges at the continuous-record gages (sites 28, 60, and 160; table 4) on the Deep River downstream from High Point Municipal Lake because records of changes in storage upstream from the dams on the Deep River were not available.

Partial-Record Sites

Using the techniques discussed by Riggs (1972), low-flow characteristics were determined for 23 of the 149 partial-record sites in the Deep River Basin (table 4). Sites having 10 or more discharge measurements, sites where low-flow characteristics previously have been published, and sites on the Deep River for which low-flow discharges were necessary to develop discharge profiles were included in the analysis of low-flow characteristics. Sites having mostly crest-gage (peak flood) partial-record measurements (sites 103, 126), sites immediately downstream from a major

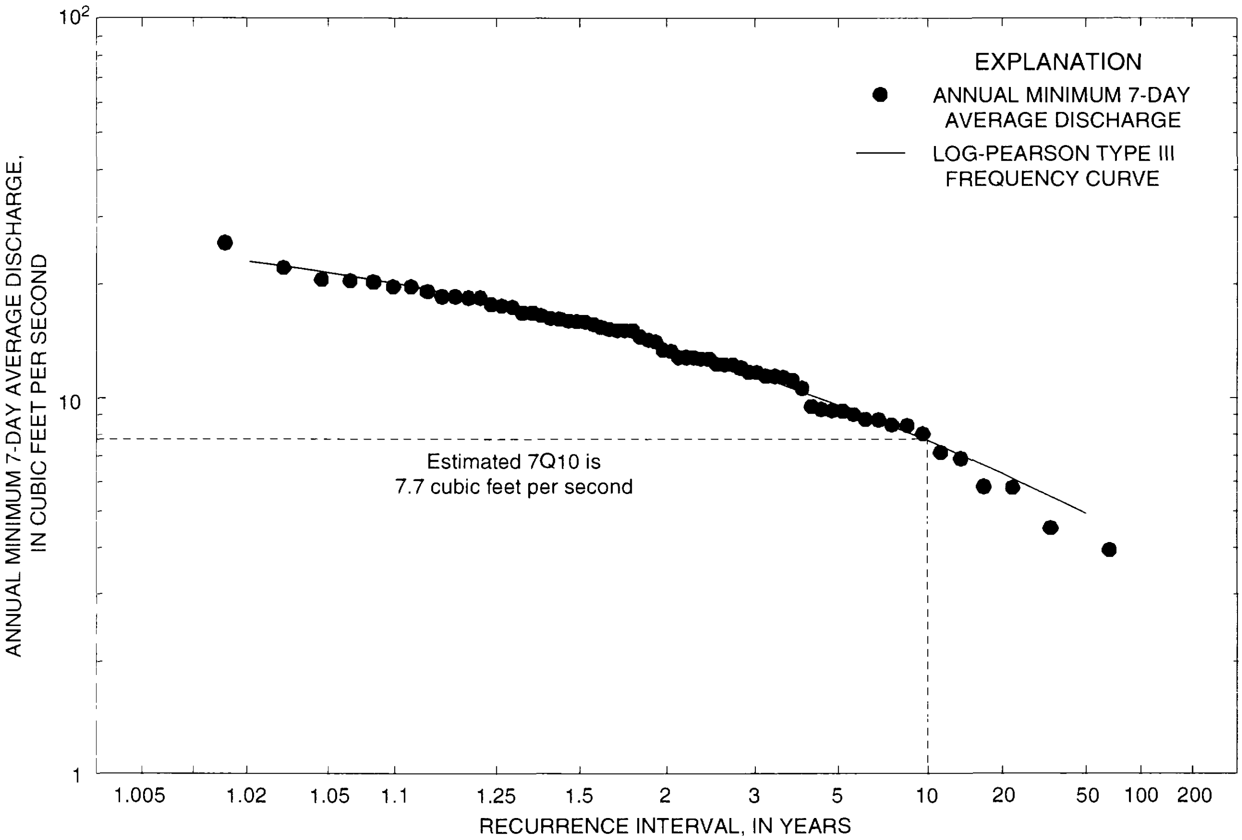

Figure 4. Low-flow frequency curve of annual minimum 7-day discharges using log-Pearson Type III frequency distribution for Deep River near Randleman, N.C. (site 28).

NPDES point-source discharge or long-term continuous-record station (sites 17, 100), and sites for which no reliable correlations could be developed (site 143) were not included in the analysis.

Discharge measurements of base flow at the partial-record sites were correlated with concurrent flows at nearby index sites (typically continuous-record gaging stations) where low-flow characteristics had been determined (fig. 5). Index sites used in the correlation analysis of concurrent flows were selected based on proximity of the partial-record and index sites, and similarity of relevant basin characteristics such as drainage area, topography, soils, and hydrogeology.

Defining the relation between concurrent flows usually is based on either statistical techniques or graphical interpretation based on a visually fitted line drawn through the concurrent flows (Riggs, 1972). In this investigation, graphical interpretation was used to establish the relation between the concurrent flows.

At most partial-record sites, correlations of the discharge measurements with concurrent flows at multiple index sites yielded several relations from which estimates of low-flow discharges could be determined. Overall estimates of low-flow discharges (7Q10, 30Q2, W7Q10, and 7Q2) for each partial-record site were determined as the average of the individual estimates derived from each correlation. However, individually derived estimates from correlations deemed unreliable were not included in the average for overall estimates.

LOW-FLOW DISCHARGE PROFILES FOR THE DEEP RIVER

Discharge profiles of low flows were developed for the Deep River. A drainage-area profile also was developed to document the relation between basin size and low-flow characteristics. Discharge profiles for the

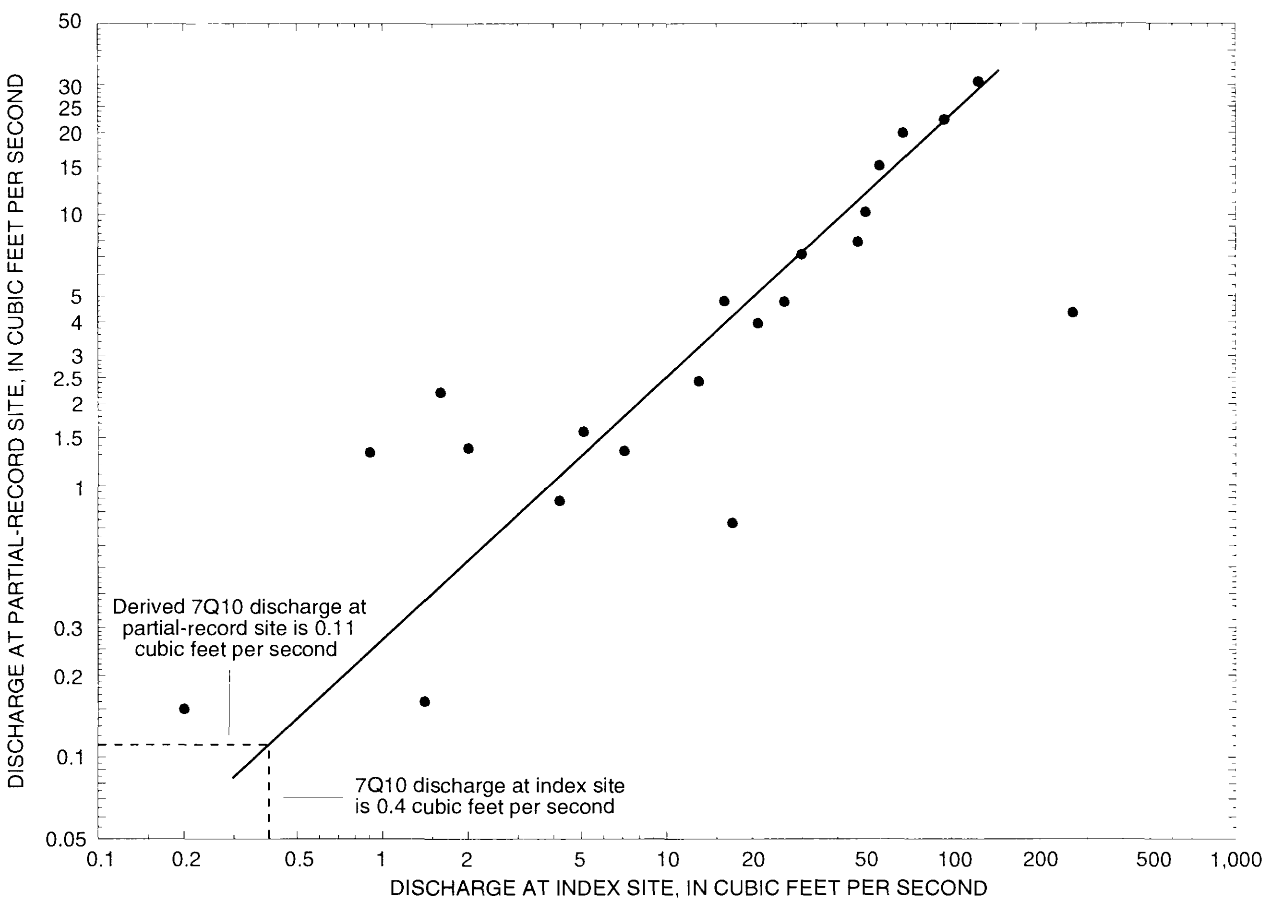

Figure 5. Correlation of concurrent discharge at the partial-record site at Richland Creek near Asheboro, N.C., (site 68) and at the index station at Bear Creek at Robbins, N.C. (site 99).

Deep River show the segment of the river between a partial-record site (site 11) downstream from High Point Municipal Lake and a continuous-record gaging station (site 160) just upstream from the mouth. The drainage-area profile shows the segment of the river from the headwaters of the West Fork Deep River to the mouth of the Deep River.

River miles shown on the profiles were determined by using the Environmental Protection Agency's (EPA) River Reach Files, which are Geographic Information System coverages of rivers and streams, digitized from 1:100,000-scale USGS topographic maps. River mileage computed for the Deep River begins at zero at the mouth and increases upstream.

The drainage-area profile (fig. 6) for the Deep River reflects the shape of the entire river basin (pl. 1). In the upper reach of the river between High Point and Coleridge, drainage-area contributions from tributary streams generally are less than 75 mi^2. Major tributaries in this reach include Muddy Creek (26.4 mi^2), Polecat Creek (56.3 mi^2), Sandy Creek (60 mi^2), Richland Creek (65.2 mi^2), Brush Creek (69.6 mi^2), and Fork Creek (48.2 mi^2). In the lower reach between Coleridge and the mouth, drainage-area increases are larger as a result of some of the major tributaries which drain to the Deep River in this reach. These tributaries include Bear Creek (145 mi^2), McLendons Creek (100 mi^2), and Rocky River (243 mi^2).

Although not shown on the drainage-area profile, the average annual discharge for the Deep River at any location can be estimated from the drainage area at the given location. Data in table 4 indicate that average annual unit flows on the Deep River are at or near 1.0 cubic foot per second per square mile [$(ft^3/s)/mi^2$]. Thus, a profile of average annual discharge would be almost identical to the drainage-area profile (fig. 6).

Discharge profiles are presented for the 7Q10, 30Q2, W7Q10, and 7Q2 discharges (fig. 7). Low-flow characteristics (table 4) developed for sites on the Deep River serve as "anchor" points in the discharge profiles. These points serve as a reference for estimating other low-flow discharges at upstream and downstream locations. Low-flow discharges at the ungaged locations on the profile were estimated using unit flows (in units of cubic feet per second per square mile) prorated on the basis of drainage area from nearby upstream or downstream anchor points. Contributions of low flows from tributaries were added to the Deep River low flows when the drainage area from a tributary was 5 percent or greater than the drainage area of the Deep River immediately upstream from the tributary. However, the estimates of W7Q10 discharges at the mouths of Bear Creek and Rocky River did not appear to be reliable. Consequently, the contributions from these two tributaries were not added to the W7Q10 profile for the Deep River, and the estimates of W7Q10 discharges between sites 82 and 160 (indicated in fig. 7 by a dotted line) probably are low relative to actual conditions.

Low-flow discharge profiles for the Deep River suggest different potentials for sustained base flow in the upper and lower reaches (fig. 7). In the upper reach between High Point Municipal Lake and Bear Creek, there are continual increases in each of the low-flow characteristics. In the lower reach between Bear Creek and the mouth, the increase in low flows with drainage area is less than that for the upper reach. The decrease in potential for sustained base flow between the upper and lower reaches most likely is a reflection of the underlying Triassic sedimentary rocks. Giese and Mason (1993) noted that low flows for many streams in this area have minimal (less than 0.1 ft^3/s) or zero 7Q10 discharge. Low-flow characteristics determined in this report confirm the low potential for sustained base flow in the lower reach of the Deep River (table 4). Another possible factor in the apparent change of low-flow characteristics as shown in the profile may be that more streamflow records are available in the upper reaches of the Deep River, and in particular on the Deep River itself, than in the lower part of the basin. However, records from tributary streams in the lower part of the basin indicate that low flows per square mile of drainage area are less than in the upper part of the Deep River Basin (table 4).

Eleven of the 14 existing dams identified on the profiles are located in the upper reach of the Deep River. Effects of the dams on low-flow characteristics could not be quantified due to lack of records of inflows, outflows, and storage patterns at each structure.

The presence of point-source discharges is reflected in the 7Q10 discharges estimated for sites on the Deep River (table 4) and shown on the low-flow discharge profiles for the Deep River itself (fig. 7). If the City of High Point is discharging wastewater into Richland Creek at the permitted flow of 24 ft^3/s, then most all flow during low-flow conditions at site 28 consists of wastewater discharge. The treatment levels

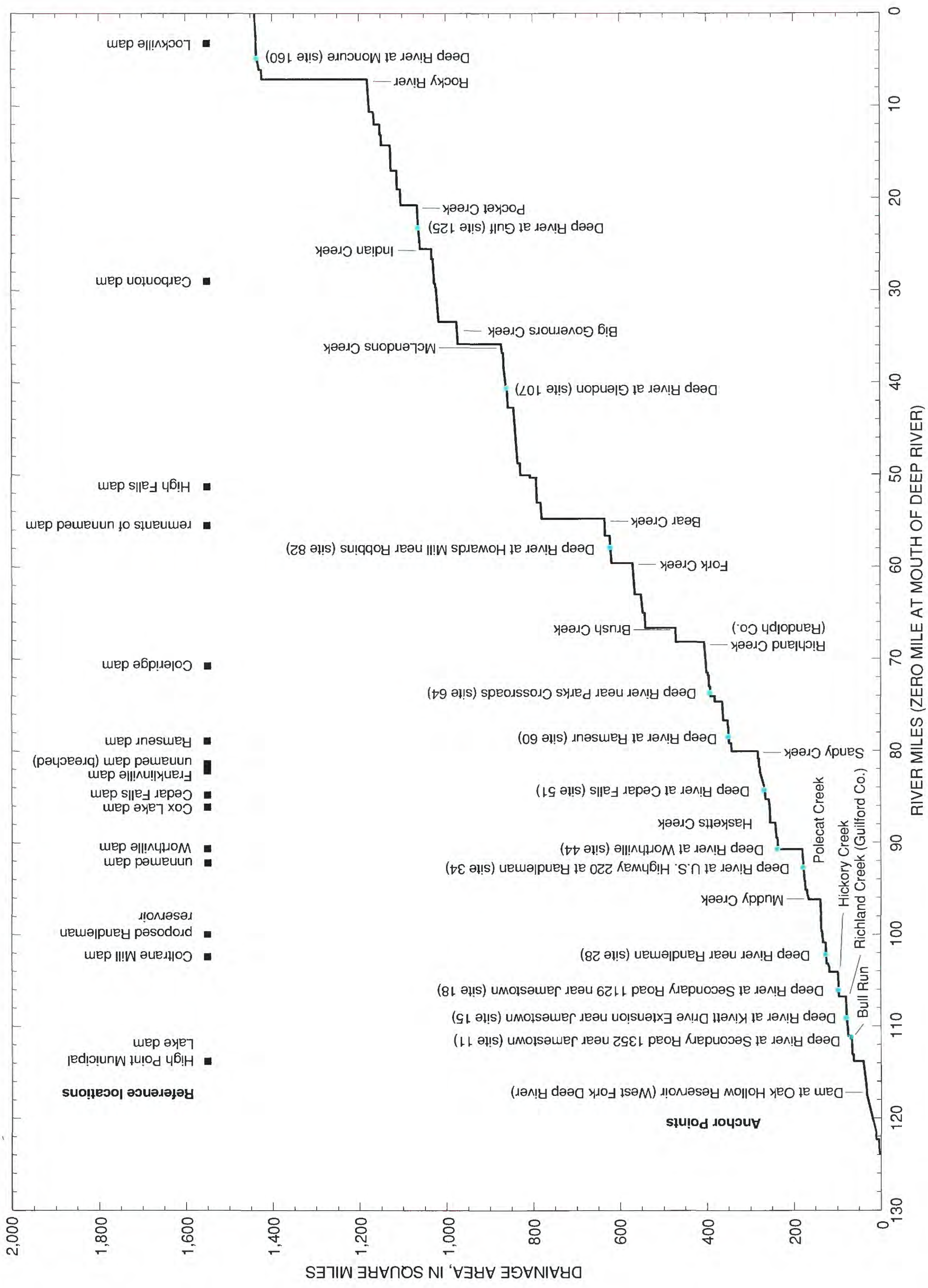

Figure 6. Relation of river miles to drainage area for the Deep River in North Carolina.

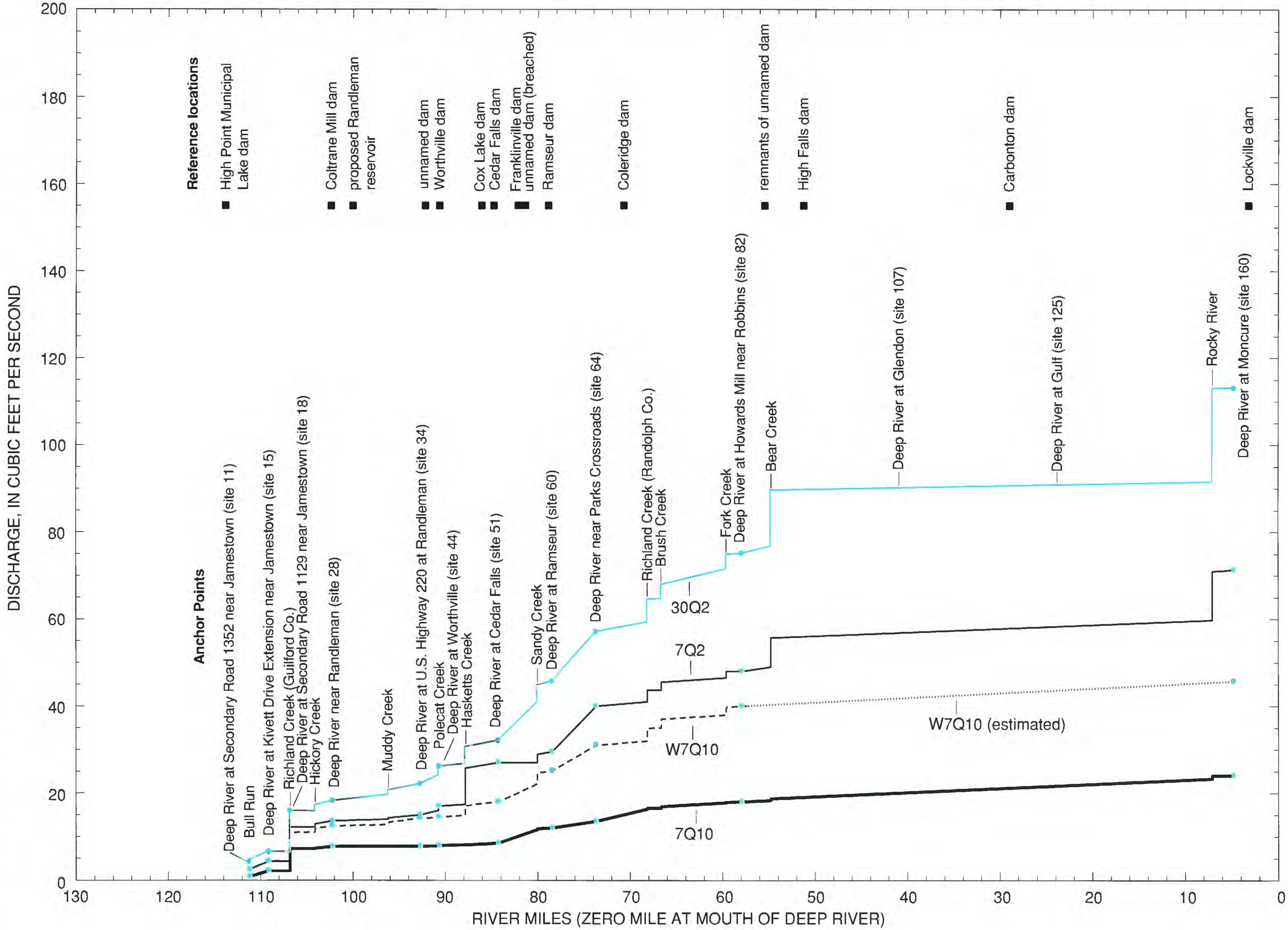

Figure 7. Relation of river miles to low-flow discharges for the Deep River in North Carolina. (Dotted line represents reach of the Deep River where estimates of W7Q10 discharges probably are low relative to actual conditions.)

which the State has required for High Point's point-source discharge to Richland Creek are due to the limited capacity of the stream to dilute wastewater by natural streamflow (Jason Doll, Division of Water Quality, oral commun., 1997).

The total of the permitted NPDES discharges to the Deep River exceeds 45 ft^3/s and is greater than the 7Q10 discharge of 24 ft^3/s estimated for site 160 (table 5). The apparent loss in water may be attributed to losses due to evaporation or to changes in flow patterns caused by operations at the impoundments. It is likely, however, that most permitted facilities are discharging less than the permitted flow, particularly during times of low flow (Jason Doll, Division of Water Quality, oral commun., 1997).

Measured Deep River flows used to determine low-flow characteristics reflect both natural streamflow and wastewater discharge as well as regulation by the impoundments. Low-flow characteristics at a site reflect streamflow conditions during the data-collection period. However, streamflow conditions at the site may change because of changes in flow diversions or changes in flow releases from impoundments. These changes in streamflow conditions resulting from increased wastewater discharges and changes in impoundment operations can only be reflected in low-flow characteristics if the low-flow characteristics are periodically updated using the most recent continuous records of streamflow.

The Deep River exemplifies the difficulty in understanding and quantifying the factors that affect low-flow discharges. Topographic, geologic, and climatic factors usually can be understood more readily because, within a given region, the effects of these factors on low-flow discharges generally do not change, other than in areas of rapid development where topographic changes may occur in conjunction with land-use changes. Likewise, climate characteristics for a given area are fairly well understood with the availability of historic climatologic records. However, human-induced flow modifications resulting from impoundments and flow diversions—withdrawals and point-source discharges—and the absence of long-term streamflow records throughout the basin complicate the quantification of low-flow characteristics. In particular, the extent to which flow diversions affect low-flow characteristics can be difficult to quantify; in some

Table 5. Comparison of permitted National Pollution Discharge Elimination System (NPDES) and 7Q10 discharges on the Deep River in North Carolina

[Mgal/d, million gallons per day (1 Mgal/d is equivalent to approximately 1.55 cubic feet per second); ft^3/s, cubic feet per second]

County	Facility	NPDES permit number	River mile	Permitted NPDES discharge (Mgal/d)	Permitted NPDES discharge (ft^3/s)	Cumulative permitted NPDES discharge (ft^3/s)	7Q10 discharge[a] (ft^3/s)
Guilford	City of High Point	NC0024210	106.8 (via Richland Creek)	16.0	24.8	24.8	2.1
Randolph	City of Randleman	NC0025445	91.2	1.75	2.7	27.5	7.8
Randolph	City of Asheboro	NC0026123	87.8 (via Hasketts Creek)	6.0	9.3	36.8	8.1
Randolph	Town of Ramseur	NC0026565	77.7	.48	.75	37.5	12.0
Moore	Town of Robbins	NC0062855	54.7	1.0	1.5	39.0	18.7
Chatham	Goldston-Gulf Sanitary District	NC0081795	23.3	.006	.01	39.0	22.0
Lee	Golden Poultry, Inc.	NC0072575	15.2	1.0[b]	1.5	40.6	23.0
Lee	City of Sanford	NC0024147	14.3	5.0	7.8	48.4	24.0

[a] 7Q10 discharges estimated from figure 7. At river miles 106.8 and 87.8 (where Richland and Hasketts Creeks, respectively, drain into the Deep River), 7Q10 discharges are for points just upstream from tributaries.

[b] NPDES discharge from the Golden Poultry facility into the Deep River is about 2.8 miles downstream from withdrawal by Lee County Water and Sewer District (0.81 Mgal/d reported for 1995, see table 2) resulting in a negligible change to flows in the Deep River.

instances, the presence of flow diversions upstream from a given location can only be acknowledged.

SUMMARY

This report describes low-flow characteristics for the Deep River Basin in North Carolina through the 1995 water year. Low-flow characteristics were summarized for a number of existing gaging stations in the study area, and drainage-area and low-flow discharge profiles were developed for the Deep River. Estimates of low flows presented in this report were prepared in cooperation with the North Carolina Department of Health, Environment, and Natural Resources (NCDEHNR). In 1991, the NCDEHNR began using a basinwide approach in its assessment of water-quality conditions in North Carolina; part of the assessment includes the simultaneous evaluation of National Pollution Discharge Elimination System (NPDES) permits for point-source discharges into streams in the basin. In 1996, the NCDEHNR requested an investigation of low flows on the Deep River. The USGS, in cooperation with the NCDEHNR, compiled low-flow characteristics for selected sites in the Deep River Basin and developed low-flow discharge profiles for the Deep River.

The Deep River Basin, which has a drainage area of 1,441 mi^2, is located in central North Carolina. The entire basin lies within the Piedmont physiographic province and is characterized by rolling and hilly topography. From the headwaters in the vicinity of High Point, the Deep River flows in a southeasterly direction through Randolph County and into Moore County where it turns east then northeast where it flows along the Chatham–Lee County line before flowing into the Cape Fear River. Land use in the Deep River Basin mostly is rural; the largest municipality is High Point in the uppermost part of the basin.

Selected basin characteristics and their known effects on low-flow characteristics are described in this report. Flow modifications—impoundments, withdrawals, and point-source discharges from and into streams—in the study area also were documented. Sixteen dams—14 of which are located on the Deep River—were identified from information provided by the NCDEHNR. With the exception of the dams on Oak Hollow Reservoir and High Point Municipal Lake, the dams on the Deep River are used primarily for power production and typically operate on the basis of "run-of-river" mode.

Withdrawals and return discharges were paired for eight facilities that use the Deep River as a source for withdrawals and/or as the receiving stream for return point-source discharges. The largest withdrawals and, correspondingly, largest return discharges were made by the City of High Point which withdrew and discharged an average of 13.3 and 11.7 Mgal/d, respectively, in 1995. Another significant return discharge from the City of Asheboro, by way of an interbasin transfer from the Yadkin River Basin, occurred on Hasketts Creek; the average discharge in 1995 was about 4.7 Mgal/d. The return discharges from High Point and Asheboro constitute much of the flow contributions shown for Richland and Hasketts Creeks, respectively.

Soils and underlying hydrogeologic units within the Deep River Basin were examined to determine any effects on low flows. Two soil associations, Georgeville–Herndon and White Store–Creedmoor, occupy much of the basin and are identified as having medium and slow to very slow internal drainage, respectively. The White Store–Creedmoor association occurs in the southern fringes of the Deep River Basin; soils in this association correspond to the underlying rock types of the Triassic basin, which occupy nearly 16 percent of the basin. These soils are noted for a high presence of clays and have slow to very slow internal drainage characteristics, which result in little or no storage of water in the surficial aquifers. Thus, streams have little or no source for sustained base flow during drought conditions. This is consistent with the presence of a number of sites in the lower half of the basin which have zero or minimal 7Q10 discharges (defined as less than 0.1 ft^3/s).

Twelve of 18 hydrogeologic units identified for the Blue Ridge and Piedmont Provinces occur within the Deep River Basin. Of these 12, seven units have average well yields below the mean average yield of 18.2 gal/min for hydrogeologic units in the Blue Ridge and Piedmont Provinces. When combined, these seven units (including the Triassic basin unit) make up nearly 79 percent of the Deep River Basin. The average well yields which fall below the mean average well yield of 18.2 gal/min correspond to the moderate to low potential for sustained base flow at streams in the lower part of the basin.

Records of surface-water data were identified and compiled for 160 sites in the study area. Low-flow characteristics (7Q10, 30Q2, W7Q10, and 7Q2) were determined for 30 sites (7 continuous-record and

23 partial-record). For the seven gaging stations with continuous records of daily mean discharge, available continuous record through the 1995 water year were used to determine low-flow characteristics.

Drainage-area and low-flow discharge profiles were developed for the Deep River. The drainage-area profile shows increases in basin size for the entire reach of the Deep River. Major tributaries to the Deep River include Polecat Creek (56.3 mi^2), Sandy Creek (60 mi^2), Richland Creek (66 mi^2), Brush Creek (69.6 mi^2), Bear Creek (145 mi^2), McLendons Creek (100 mi^2), and Rocky River (243 mi^2).

The low-flow discharge profiles depict the 7Q10, 30Q2, W7Q10, and 7Q2 discharges for the Deep River between the dam at High Point Municipal Lake and the mouth. The profiles reveal different potentials for sustained base flow between the upper and lower parts of the basin. In the upper part, flow profiles show continual increases in low-flow characteristics as a result of flow contributions from tributaries during base-flow conditions. For the lower part of the basin, the profiles show a decrease in the potential for sustained base flow as a result of little to no flow contributions from tributaries. The change in potential is partially attributed to the soils and underlying rock types which do not allow for storage in surficial aquifers, particularly in the small tributary basins which drain to the Deep River. Many streams in the lower parts of the basin have minimal (less than 0.1 ft^3/s) or zero 7Q10 discharges.

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Table 3. Summary of continuous-record gaging stations and partial-record sites in the Deep River Basin study area where records of streamflow were collected

[mi^2, square miles; SR, secondary road; n/a, not applicable; SEO, sewage effluent outfall; nd, not determined. Sites shaded in gray indicate those sites for which low-flow characteristics are presented in table 4. Period of record for continuous-record gaging stations (site type 1) shown in months and years; period of record for partial-record sites (site type 2) shown is water years in which discharge measurements were made]

Site index no. (pl. 1)	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quadrangle name	Drainage area, (mi^2)	Tributary to	Site type	Period of record	Number of measurements for partial-record sites: Flow	Zero-flow
1	02098312	West Fork Deep River tributary near Colfax	36°05'15"	80°01'25"	Guilford	Kernersville	2.18	Deep River	2	1955	1	0
2	0209831460	West Fork Deep River at SR 2602 near Kernersville	36°05'01"	80°02'33"	Forsyth	Kernersville	1.43	Deep River	2	1974-75	4	0
3	02098343	West Fork Deep River near Friendship	36°03'24"	80°01'19"	Guilford	Kernersville	11.5	Deep River	2	1955, 1962, 1966	4	0
4	02098374	West Fork Deep River tributary near Friendship	36°02'30"	80°00'05"	Guilford	Kernersville	1.95	West Fork Deep River	2	1955, 1966	2	0
5	02098437	Hiatt Branch near Deep River	36°00'50"	80°00'05"	Guilford	Kernersville	4.09	West Fork Deep River	2	1955, 1966	3	0
6	02098468	West Fork Deep River tributary No. 3 near High Point	36°00'00"	80°00'05"	Guilford	Kernersville	2.48	West Fork Deep River	2	1955, 1966	2	0
7	02098500	West Fork Deep River near High Point	36°00'15"	79°58'42"	Guilford	Guilford	32.5	Deep River	1	June 1923-Sept. 1958	n/a	n/a
									2	1960-69	27	0
8	02098833	East Fork Deep River near Friendship	36°04'50"	79°57'28"	Guilford	Guilford	3.91	Deep River	2	1955, 1962, 1966	4	0
9	02099000	East Fork Deep River near High Point	36°02'15"	79°56'46"	Guilford	Guilford	14.8	Deep River	1	July 1928-Mar. 1994	n/a	n/a
10	02099007	Long Branch near Deep River	36°02'28"	79°56'16"	Guilford	Guilford	2.21	East Fork Deep River	2	1962, 1966, 1974-75	8	1
11	02099193	Deep River at SR 1352 near Jamestown	35°58'46"	79°55'41"	Guilford	High Point East	66.6	Cape Fear River	2	1971, 1973-74	5	0
12	02099240	Bull Run at Oakdale	35°58'48"	79°55'37"	Guilford	High Point East	7.75	Deep River	2	1954, 1960-67, 1969	25	1
13	02099245	Deep River near Jamestown	35°58'44"	79°55'35"	Guilford	High Point East	74.4	Cape Fear River	2	1983	1	0
14	02099324	Deep River below SEO near Jamestown	35°58'22"	79°55'05"	Guilford	High Point East	75[a]	Cape Fear River	2	1971, 1974-75	3	0

Table 3. Summary of continuous-record gaging stations and partial-record sites in the Deep River Basin study area where records of streamflow were collected—Continued

[mi^2, square miles; SR, secondary road; n/a, not applicable; SEO, sewage effluent outfall; nd, not determined. Sites shaded in gray indicate those sites for which low-flow characteristics are presented in table 4. Period of record for continuous-record gaging stations (site type 1) shown in months and years; period of record for partial-record sites (site type 2) shown is water years in which discharge measurements were made]

Site index no. (pl. 1)	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quadrangle name	Drainage area, (mi^2)	Tributary to	Site type	Period of record	Number of measurements for partial-record sites: Flow	Number of measurements for partial-record sites: Zero-flow
15	02099399	Deep River at Kivett Drive extension near Jamestown	35°57'32"	79°54'25"	Guilford	High Point East	77.7	Cape Fear River	2	1974-75	6	0
16	02099480	Richland Creek near Archdale	35°56'28"	79°55'56"	Guilford	High Point East	12.5	Deep River	2	1954-56, 1958-60, 1962, 1966, 1971, 1973	21	0
17	02099484	Richland Creek near Groometown	35°56'26"	79°54'08"	Guilford	High Point East	16.2	Deep River	2	1971, 1973-76, 1978-95	54	0
18	0209948955	Deep River at SR 1129 near Jamestown	35°56'16"	79°53'26"	Guilford	High Point East	96.3	Cape Fear River	2	1971, 1973-75	6	0
19	0209948980	Hickory Creek tributary at SR 1129 at Groometown	35°59'30"	79°52'02"	Guilford	Pleasant Garden	nd[b]	Hickory Creek	2	1974-75	3	3
20	0209948990	Hickory Creek tributary at SR 1132 near Groometown	35°57'50"	79°50'49"	Guilford	Pleasant Garden	1.3[a]	Hickory Creek	2	1971, 1973-74	6	2
21	02099490	Hickory Creek near High Point	35°57'03"	79°52'08"	Guilford	Pleasant Garden	9.60	Deep River	2	1955, 1962, 1964-67, 1969-70, 1974-75	18	1
22	0209949155	Reddicks Creek at SR 1372 at Sedgefield	36°00'39"	79°53'02"	Guilford	Guilford	2.6[a]	Deep River	2	1971, 1973-75	8	0
23	02099492	Reddicks Creek near Jamestown	35°59'10"	79°53'36"	Guilford	High Point East	4.90	Deep River	2	1971, 1973-75	10	0
24	02099493	Reddicks Creek near Groometown	35°57'11"	79°53'09"	Guilford	High Point East	8.68	Hickory Creek	2	1966	1	0
25	02099494	Reddicks Creek near Oakdale	35°56'00"	79°52'00"	Guilford	Pleasant Garden	9.34	Hickory Creek	2	1966	1	0
26	02099495	Hickory Creek near Groometown	35°56'02"	79°52'12"	Guilford	Pleasant Garden	20.1	Deep River	2	1955, 1962, 1976	6	1
27	02099496	Deep River tributary near Randleman	35°55'17"	79°51'21"	Guilford	Pleasant Garden	2.77	Deep River	2	1966	1	0
28	02099500	Deep River near Randleman	35°54'12"	79°51'10"	Randolph	Pleasant Grove	125	Cape Fear River	1	Oct. 1928-Sept. 1995	n/a	n/a
29	02099815	Muddy Creek at SR 1916 at Archdale	35°53'55"	79°55'38"	Randolph	High Point East	8.53	Deep River	2	1974	3	0

Table 3. Summary of continuous-record gaging stations and partial-record sites in the Deep River Basin study area where records of streamflow were collected—Continued

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Site index no. (pl. 1)	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quadrangle name	Drainage area, (mi^2)	Tributary to	Site type	Period of record	Number of measurements for partial-record sites: Flow	Number of measurements for partial-record sites: Zero-flow
30	02100000	Muddy Creek near Archdale	35°52'35"	79°52'43"	Randolph	High Point East	16.5	Deep River	1	May 1934-Jan. 1942	n/a	n/a
									2	1962-63	4	0
31	02100028	Bob Branch near Randleman	35°51'15"	79°51'20"	Randolph	Randleman	2.85	Muddy Creek	2	1955, 1962	4	1
32	02100056	Muddy Creek near Randleman	35°50'55"	79°50'00"	Randolph	Randleman	26.4	Deep River	2	1955, 1962	3	1
33	02100082	Deep River tributary 7 near Randleman	35°50'05"	79°49'10"	Randolph	Randleman	0.81	Deep River	2	1971, 1975	3	1
34	02100096	Deep River at U.S. Highway 220 at Randleman	35°49'24"	79°48'12"	Randolph	Randleman	177	Cape Fear River	2	1971, 1973-74	5	0
35	0210017155	Polecat Creek at SR 3428 near Pleasant Garden	35°57'12"	79°48'43"	Guilford	Pleasant Garden	7.34	Deep River	2	1974-75	5	0
36	0210017165	Polecat Creek tributary at SR 3433 at Pleasant Garden	35°58'17"	79°46'54"	Guilford	Pleasant Garden	nd[b]	Polecat Creek	2	1974-75	4	2
37	02100172	Polecat Creek near Pleasant Garden	35°55'10"	79°47'47"	Guilford	Pleasant Garden	15.6	Deep River	2	1962, 1966	3	0
38	02100180	Polecat Creek near Climax	35°53'15"	79°46'13"	Randolph	Pleasant Garden	29.1	Deep River	2	1954-59, 1962-63, 1966, 1970	18	1
39	02100181	Polecat Creek near Level Cross	35°51'37"	79°46'09"	Randolph	Randleman	31.9	Deep River	2	1966	1	0
40	02100193	Little Polecat Creek near Randleman	35°52'18"	79°45'17"	Randolph	Randleman	11.6	Polecat Creek	2	1955, 1962, 1966	4	1
41	02100194	Polecat Creek tributary No. 3 near Salem	35°51'15"	79°46'46"	Randolph	Randleman	8.21	Polecat Creek	2	1962, 1966	2	1
42	02100197	Polecat Creek tributary No. 2 near Salem	35°50'15"	79°45'50"	Randolph	Randleman	3.52	Polecat Creek	2	1962, 1966	2	1
43	02100209	Polecat Creek tributary near Randleman	35°48'40"	79°46'20"	Randolph	Randleman	2.46	Polecat Creek	2	1960, 1962	3	0
44	02100219	Deep River at Worthville	35°48'09"	79°46'37"	Randolph	Randleman	236	Cape Fear River	2	1971, 1973-74, 1976	7	0

Table 3. Summary of continuous-record gaging stations and partial-record sites in the Deep River Basin study area where records of streamflow were collected—Continued

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45	02100244	Hasketts Creek above Penwood Branch near Asheboro	35°45'25"	79°47'45"	Randolph	Asheboro	5.62	Deep River	2	1954	3	0
46	02100262	Penwood Branch near Asheboro	35°44'12"	79°47'09"	Randolph	Asheboro	2.92	Hasketts Creek	2	1966	1	0
47	02100294	Hasketts Creek below Penwood Branch near Asheboro	35°45'33"	79°47'35"	Randolph	Randleman	9.86	Deep River	2	1971, 1973-75	7	0
48	02100307	Hasketts Creek at Central Falls	35°46'05"	79°46'45"	Randolph	Randleman	10.6	Deep River	2	1966, 1971, 1973-74	5	0
49	02100319	Deep River at Central Falls	35°45'45"	79°46'20"	Randolph	Randleman	254	Cape Fear River	2	1974	1	0
50	02100338	Gabriels Creek tributary near Asheboro	35°43'22"	79°46'40"	Randolph	Asheboro	0.91	Gabriels Creek	2	1966	1	0
51	02100344	Deep River at Cedar Falls	35°45'04"	79°43'56"	Randolph	Grays Chapel	266	Cape Fear River	2	1971, 1974-75	5	0
52	02100357	Bush Creek near Cedar Falls	35°45'10"	79°43'19"	Randolph	Grays Chapel	13.2	Deep River	2	1955, 1962	3	0
53	02100369	Deep River at Franklinville	35°44'33"	79°42'07"	Randolph	Ramseur	277	Cape Fear River	2	1973-74	3	0
54	02100407	Sandy Creek tributary near Liberty	35°52'27"	79°37'47"	Randolph	Grays Chapel	3.11	Sandy Creek	2	1953	3	0
55	02100419	Sandy Creek tributary No. 3 at Liberty	35°52'27"	79°35'33"	Randolph	Liberty	0.94	Sandy Creek	2	1953-54, 1970	9	0
56	02100432	Sandy Creek tributary No. 2 near Melanchton	35°51'53"	79°36'59"	Randolph	Liberty	5.43	Sandy Creek	2	1953, 1966, 1970	7	0
57	02100463	Sandy Creek near Whites Chapel	35°47'07"	79°39'57"	Randolph	Grays Chapel	45.1	Deep River	2	1962, 1966	2	0
58	02100464	Mount Pleasant Creek at Whites Chapel	35°47'16"	79°39'00"	Randolph	Grays Chapel	8.07	Sandy Creek	2	1962, 1966	2	0
59	02100469	Sandy Creek near Ramseur	35°46'30"	79°39'52"	Randolph	Grays Chapel	55.2	Deep River	2	1954, 1960, 1962, 1966	4	0
60	02100500	Deep River at Ramseur	35°43'34"	79°39'20"	Randolph	Ramseur	349	Cape Fear River	1	Nov. 1922-Sept. 1995	n/a	n/a
61	02100536	Reed Creek near Ramseur	35°43'21"	79°38'24"	Randolph	Ramseur	9.65	Deep River	2	1955, 1962	3	1

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Site index no. (pl. 1)	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quadrangle name	Drainage area, (mi^2)	Tributary to	Site type	Period of record	Number of measurements for partial-record sites	
											Flow	Zero-flow
62	02100554	Mill Creek near Ramseur	35°41'00"	79°38'00"	Randolph	Ramseur	16.5	Deep River	2	1955, 1962	3	0
63	02100572	Millstone Creek near Ramseur	35°41'00"	79°38'00"	Randolph	Ramseur	10.1	Deep River	2	1955, 1962	3	1
64	02100599	Deep River near Parks Crossroads	35°40'20"	79°37'39"	Randolph	Ramseur	392	Cape Fear River	2	1971, 1973-76	9	0
65	0210063677	Richland Creek near Ulah	35°39'00"	79°45'00"	Randolph	Ramseur	23.2	Deep River	2	1962, 1966	2	0
66	02100638	Panther Creek near Michfield	35°37'48"	79°44'03"	Randolph	Ramseur	3.35	Richland Creek	2	1962, 1966	2	1
67	02100639	Squirrel Creek near Michfield	35°39'00"	79°44'00"	Randolph	Ramseur	7.14	Richland Creek	2	1962, 1966	2	0
68	02100640	Richland Creek near Asheboro	35°38'22"	79°42'50"	Randolph	Ramseur	36.8	Deep River	2	1949-55, 1957, 1960, 1962, 1966	21	0
69	02100664	Bachelor Creek near Coleridge	35°35'39"	79°40'27"	Randolph	Erect	10.5	Richland Creek	2	1962, 1966	3	0
70	02100674	Richland Creek near Coleridge	35°36'30"	79°37'10"	Randolph	Bennett	65.2	Deep River	2	1954, 1960, 1962	4	0
71	02100694	Brush Creek near Siler City	35°42'32"	79°32'27"	Chatham	Coleridge	19.1	Deep River	2	1960, 1962, 1966	4	0
72	0210070125	Blood Run Creek at U.S. 421 near Siler City	35°45'05"	79°28'50"	Chatham	Crutchfield Crossroads	0.13	Brush Creek	2	1974-75	5	0
73	0210070165	Blood Run Creek at SR 1108 near Siler City	35°44'30"	79°29'10"	Chatham	Siler City	1.14	Brush Creek	2	1974-75	4	0
74	02100702	Bloodrun Creek near Siler City	35°42'15"	79°32'14"	Chatham	Coleridge	7.59	Brush Creek	2	1962, 1966	3	1
75	02100703	Brush Creek at Coleridge	35°38'29"	79°34'36"	Randolph	Coleridge	39.8	Deep River	2	1962	1	0
76	02100704	Little Brush Creek near Coleridge	35°37'50"	79°33'26"	Randolph	Coleridge	17.1	Brush Creek	2	1960, 1962, 1966	4	0
77	02100706	Little Brush Creek tributary near Coleridge	35°38'04"	79°33'34"	Randolph	Coleridge	1.20	Little Brush Creek	2	1962	1	1
78	02100710	Brush Creek near Coleridge	35°36'05"	79°35'00"	Randolph	Bennett	67.4	Deep River	2	1954-60, 1962-63, 1966	22	0
79	02100714	Richardson Creek near Erect	35°33'43"	79°41'18"	Randolph	Erect	7.02	Fork Creek	2	1960, 1962	3	0

Table 3. Summary of continuous-record gaging stations and partial-record sites in the Deep River Basin study area where records of streamflow were collected—Continued

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Site index no. (pl. 1)	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quadrangle name	Drainage area, (mi^2)	Tributary to	Site type	Period of record	Number of measurements for partial-record sites: Flow	Zero-flow
80	02100719	Reedy Creek near Coleridge	35°31'37"	79°38'39"	Randolph	Erect	7.29	Deep River	2	1954, 1966	2	1
81	02100730	Fork Creek near Coleridge	35°31'38"	79°38'31"	Randolph	Erect	38.5	Deep River	2	1954-63, 1966	30	0
82	02100747	Deep River at Howards Mill near Robbins	35°30'02"	79°34'53"	Moore	Bennett	621	Cape Fear River	2	1970, 1974-77	9	0
83	02100769	Bear Creek above SEO at Seagrove	35°31'57"	79°46'09"	Randolph	Asheboro	0.54	Deep River	2	1971, 1973-75	7	4
84	02100771	Bear Creek at NC 705 at Seagrove	35°31'55"	79°45'54"	Randolph	Asheboro	0.63	Deep River	2	1971, 1973-74	5	0
85	02100772	Bear Creek at SR 2859 near Seagrove	35°31'45"	79°45'48"	Randolph	Asheboro	0.7[a]	Deep River	2	1971, 1973	4	0
86	02100787	Bear Creek tributary near Whynot	35°31'33"	79°45'44"	Randolph	Seagrove	0.53	Deep River	2	1954, 1966	3	1
87	02100806	Bear Creek near Dover	35°27'12"	79°40'24"	Moore	Spies	28.7	Deep River	2	1962, 1966	3	0
88	02100818	Wolf Creek near Spies	35°26'37"	79°40'49"	Moore	Spies	11.3	Bear Creek	2	1962	2	2
89	02100824	Bear Creek near Spies	35°26'58"	79°38'47"	Moore	Spies	44.6	Deep River	2	1954-55, 1971, 1973	11	0
90	02100842	Cabin Creek below SEO at Candor	35°18'37"	79°44'21"	Montgomery	Candor	1.33	Bear Creek	2	1971, 1974-75	7	0
91	02100843	Cabin Creek near Candor	35°18'42"	79°44'23"	Montgomery	Candor	1.56	Bear Creek	2	1971-72, 1974	5	0
92	02100859	Cotton Creek at SR 1369 near Star	35°23'15"	79°45'55"	Montgomery	Troy	0.92	Cabin Creek	2	1971, 1974-75	6	1
93	02100862	Mill Creek at Biscoe	35°21'38"	79°45'48"	Montgomery	Biscoe	1.38	Lick Creek	2	1971-72, 1974-75	8	3
94	02100872	Cabin Creek near Dover	35°23'47"	79°42'11"	Moore	Spies	24.2	Bear Creek	2	1962	2	0
95	02100911	Mill Creek near Spies	35°23'17"	79°40'39"	Moore	Spies	15.7	Cabin Creek	2	1962, 1966, 1968	4	0
96	02100921	Wet Creek near Robbins	35°23'25"	79°39'28"	Moore	Spies	15.9	Cabin Creek	2	1962, 1966, 1968	4	0
97	02100929	Dry Creek near West Philadelphia	35°23'50"	79°37'34"	Moore	Spies	9.65	Cabin Creek	2	1962, 1966, 1968	4	2
98	02100939	Cabin Creek above mine near Robbins	35°25'00"	79°37'00"	Moore	Robbins	78.0	Bear Creek	2	1954, 1962	3	0
99	02101000	Bear Creek at Robbins	35°26'03"	79°35'39"	Moore	Robbins	137	Deep River	1	Oct. 1939-Sept. 1971	n/a	n/a
100	02101001	Bear Creek at NC 705 at Robbins	35°26'26"	79°35'20"	Moore	Robbins	139	Deep River	2	1973-74, 1985-95	38	0

Table 3. Summary of continuous-record gaging stations and partial-record sites in the Deep River Basin study area where records of streamflow were collected—Continued

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Site index no. (pl. 1)	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quadrangle name	Drainage area, (mi^2)	Tributary to	Site type	Period of record	Number of measurements for partial-record sites	
											Flow	Zero-flow
101	02101005	Bear Creek below SEO near Robbins	35°27'08"	79°34'53"	Moore	Robbins	141	Deep River	2	1971, 1974-75	4	0
102	02101016	Deep River tributary No. 3 near High Falls	35°30'16"	79°32'21"	Moore	Bennett	6.26	Deep River	2	1966	1	1
103	02101030	Falls Creek near Bennett	35°33'20"	79°29'56"	Chatham	Bennett	3.43	Deep River	2	1953, 1961-73	15	2
104	02101042	Falls Creek near High Falls	35°29'51"	79°31'01"	Moore	Robbins	12.6	Deep River	2	1955, 1962	3	3
105	02101045	Buffalo Creek at McConnell	35°28'14"	79°31'00"	Moore	Robbins	21.4	Deep River	2	1962, 1965-68, 1970-71	12	4
106	02101061	Tysons Creek at SR 1600 near Glendon	35°29'54"	79°27'05"	Moore	Putnam	12.7	Deep River	2	1962	2	2
107	02101066	Deep River at Glendon	35°29'20"	79°25'15"	Moore	Putnam	859	Cape Fear River	1	July 1993-Sept. 1995	n/a	n/a
108	02101078	Deep River tributary No. 5 at Glendon	35°29'43"	79°25'17"	Moore	Putnam	2.23	Deep River	2	1966	1	1
109	02101084	McLendons Creek near Harris	35°18'28"	79°32'35"	Moore	Zion Grove	14.5	Deep River	2	1962, 1966, 1968	4	1
110	0210108450	Suck Creek tributary near Zion Grove	35°20'17"	79°33'57"	Moore	Zion Grove	0.67	Suck Creek	1	Apr. 1986 - Sept. 1988	n/a	n/a
111	02101087	Big Juniper Creek near Harris	35°19'17"	79°30'29"	Moore	Zion Grove	9.01	McLendons Creek	2	1962, 1968	3	1
112	02101090	McLendons Creek near Carthage	35°22'23"	79°27'30"	Moore	Carthage	44.0	Deep River	2	1949-54, 1959, 1962, 1966, 1968	22	3
113	02101179	Killetts Creek at SR 1240 near Carthage	35°20'03"	79°26'13"	Moore	Carthage	2.15	McLendons Creek	2	1971, 1973-74	7	3
114	02101183	Killetts Creek near Carthage	35°21'16"	79°27'18"	Moore	Carthage	8.94	McLendons Creek	2	1971, 1973	3	0
115	0210128859	McLendons Creek near Hallison	35°24'00"	79°26'00"	Moore	Putnam	62.8	Deep River	2	1954	3	0
116	02101277	Richland Creek at NC 27 near Carthage	35°22'59"	79°29'08"	Moore	Putnam	11.0	McLendons Creek	2	1952, 1962	3	3
117	02101283	Richland Creek near Putnam	35°25'58"	79°25'58"	Moore	Putnam	24.9	McLendons Creek	2	1962-63, 1966, 1971	6	5
118	02101290	McLendons Creek near Putnam	35°27'01"	79°25'22"	Moore	Putnam	97.3	Deep River	2	1963-68, 1970-71	14	0

Table 3. Summary of continuous-record gaging stations and partial-record sites in the Deep River Basin study area where records of streamflow were collected—Continued

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Site index no. (pl. 1)	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quadrangle name	Drainage area, (mi^2)	Tributary to	Site type	Period of record	Number of measurements for partial-record sites: Flow	Zero-flow
119	02101308	McLendons Creek near Glendon	35°27'37"	79°24'07"	Moore	Putnam	99.7	Deep River	2	1954-55	4	0
120	02101358	McIntosh Creek near Carthage	35°24'33"	79°21'27"	Moore	White Hill	2.69	Big Governors Creek	2	1962	2	2
121	02101371	Big Governors Creek near Glendon	35°27'28"	79°22'12"	Moore	White Hill	31.4	Deep River	2	1954, 1963, 1966	4	3
122	02101387	Little Governors Creek near Carbonton	35°27'53"	79°21'16"	Lee	White Hill	8.21	Deep River	2	1962	2	2
123	02101388	Big Governors Creek near Hawbranch	35°28'24"	79°21'25"	Moore	White Hill	40.8	Deep River	2	1962	1	0
124	02101433	Indian Creek near Carbonton	35°32'18"	79°20'09"	Chatham	Goldston	25.4	Deep River	2	1955, 1960, 1962	4	2
125	0210146350	Deep River at Gulf	35°33'18"	79°17'14"	Chatham	Goldston	1,063	Cape Fear River	2	1970, 1973, 1976, 1979-80	7	0
126	02101480	Sugar Creek near Tramway	35°25'28"	79°14'50"	Lee	Sanford	0.9[a]	Pocket Creek	2	1953, 1955, 1961-73	15	1
127	02101484	Pocket Creek near Cumnock	35°29'25"	79°16'24"	Lee	White Hill	23.2	Deep River	2	1960, 1962	3	0
128	02101488	Little Pocket Creek near Cumnock	35°30'17"	79°17'32"	Lee	Goldston	9.52	Pocket Creek	2	1960, 1962	3	1
129	02101502	Cedar Creek tributary at U.S. 421 near Gulf	35°34'37"	79°18'35"	Chatham	Goldston	0.02	Cedar Creek	2	1974-75	7	3
130	02101504	Cedar Creek at SR 2142 at Gulf	35°34'00"	79°17'05"	Chatham	Goldston	4.42	Deep River	2	1974-75	5	1
131	02101506	Cedar Creek at SR 2145 near Gulf	35°34'05"	79°14'45"	Chatham	Colon	13.0	Deep River	2	1974-75	5	1
132	02101513	Big Buffalo Creek near Sanford	35°28'55"	79°12'03"	Lee	Sanford	9.73	Deep River	2	1954, 1962, 1971	6	2
133	02101524	Big Buffalo Creek at SR 1100 near Sanford	35°29'19"	79°12'08"	Lee	Sanford	8.64	Deep River	2	1970, 1972-73	4	0
134	02101539	Big Buffalo Creek near Colon	35°30'40"	79°12'12"	Lee	Colon	12.5	Deep River	2	1970, 1972-75	8	0
135	02101540	Big Buffalo Creek tributary at U.S. 1-15-501 near Sanford	35°30'44"	79°11'16"	Lee	Colon	0.31	Big Buffalo Creek	2	1974-75	6	2
136	02101542	Purgatory Branch at U.S. 421 near Cumnock	35°31'44"	79°14'03"	Lee	Colon	1.27	Big Buffalo Creek	2	1970, 1973-74	4	0

Table 3. Summary of continuous-record gaging stations and partial-record sites in the Deep River Basin study area where records of streamflow were collected—Continued

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Site index no. (pl. 1)	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quadrangle name	Drainage area, (mi^2)	Tributary to	Site type	Period of record	Number of measurements for partial-record sites: Flow	Number of measurements for partial-record sites: Zero-flow
137	02101552	Big Buffalo Creek near Cumnock	35°32'30"	79°13'47"	Lee	Colon	19.7	Deep River	2	1962, 1970, 1972-73	7	0
138	02101571	Georges Creek at SR 2145 at Farmville	35°34'23"	79°12'55"	Chatham	Colon	11.8	Deep River	2	1962, 1966	3	3
139	02101612	Little Buffalo Creek near Colon	35°31'54"	79°10'27"	Lee	Colon	4.79	Deep River	2	1960-62, 1964-65	7	0
140	02101631	Rocky River at Liberty	35°49'30"	79°34'24"	Randolph	Liberty	2.18	Deep River	2	1954	3	1
141	02101660	Rocky River near Liberty	35°49'09"	79°33'24"	Randolph	Liberty	4.52	Deep River	2	1953-55, 1960-63, 1966	18	1
142	0210166029	Rocky River near Crutchfield Crossroads	35°48'25"	79°31'41"	Chatham	Liberty	7.42	Deep River	1	May 1988-Sept. 1995	n/a	n/a
143	02101686	North Prong Rocky River near Liberty	35°51'51"	79°32'34"	Randolph	Liberty	2.70	Rocky River	2	1971, 1973-74, 1976-81	16	0
144	02101719	Mud Creek near Siler City	35°47'43"	79°27'47"	Chatham	Crutchfield Crossroads	7.99	Rocky River	2	1960, 1962	3	1
145	02101723	Nick Creek near Siler City	35°45'58"	79°26'13"	Chatham	Crutchfield Crossroads	5.01	Rocky River	2	1966	1	1
146	02101739	Loves Creek above SEO near Siler City	35°43'43"	79°26'19"	Chatham	Siler City	7.51	Rocky River	2	1954-55, 1974	6	0
147	02101752	Loves Creek below SEO near Siler City	35°43'49"	79°25'37"	Chatham	Siler City	8.14	Rocky River	2	1973	3	0
148	0210175555	Loves Creek at mouth near Siler City	35°43'57"	79°25'23"	Chatham	Siler City	7.99	Rocky River	2	1973-75	5	0
149	02101779	Varnell Creek at U.S. 64 near Siler City	35°44'04"	79°24'08"	Chatham	Siler City	9.74	Rocky River	2	1955, 1960, 1962	4	4
150	02101792	Rocky River near Mount Vernon Springs	35°41'54"	79°22'35"	Chatham	Siler City	94.7	Deep River	2	1970, 1973-74	5	0
151	02101793	Meadow Creek near Bonlee	35°41'27"	79°22'20"	Chatham	Siler City NE	5.33	Rocky River	2	1966	1	1
152	02101800	Tick Creek near Mount Vernon Springs	35°39'37"	79°24'08"	Chatham	Siler City	15.5	Rocky River	1	June 1958-Sept. 1981, Jan. 1994-Sept. 1995	n/a	n/a
									2	1984-89	13	3
153	02101808	Tick Creek near Bear Creek	35°39'57"	79°23'08"	Chatham	Siler City	17.0	Rocky River	2	1961	1	0
154	02101820	Tick Creek near Bonlee	35°40'24"	79°21'59"	Chatham	Siler City NE	20.0	Rocky River	2	1954, 1956-58, 1960-63, 1970	16	1
155	02101848	Landrum Creek near Pittsboro	35°41'16"	79°16'32"	Chatham	Siler City NE	14.5	Rocky River	2	1955, 1962, 1966	4	0

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											Flow	Zero-flow
156	02101862	Holland Creek near Pittsboro	35°41'30"	79°14'40"	Chatham	Pittsboro	12.7	Rocky River	2	1955, 1962	3	1
157	02101884	Bear Creek near Bonlee	35°35'57"	79°23'59"	Chatham	Bear Creek	21.7	Rocky River	2	1960, 1962	3	2
158	02101890	Bear Creek near Goldston	35°37'33"	79°17'54"	Chatham	Siler City NE	42.4	Rocky River	2	1949-71	50	2
159	02101946	Rocky River near Coalglen	35°37'20"	79°11'17"	Chatham	Colon	237	Deep River	2	1974, 1976, 1979	6	0
160	02102000	Deep River at Moncure	35°37'38"	79°06'58"	Chatham	New Hope Dam	1,434	Cape Fear River	1	July 1930-Sept. 1995	n/a	n/a

[a] Approximate drainage area.

[b] Site located just downstream from drainage-basin boundary; drainage area not determined, but probably less than 0.01 mi^2.