HYDROLOGIC CONDITIONS IN THE CHICOD CREEK BASIN, NORTH CAROLINA
Before and during channel modifications, 1975-81

By Sharon A. Watkins and Clyde E. Simmons

U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS 84-4025

Prepared in cooperation with the

Soil Conservation Service

U.S. Department of Agriculture

Raleigh, North Carolina

1984

UNITED STATES DEPARTMENT OF THE INTERIOR

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GLOSSARY

The following definitions are included as a guide to the terminology used in this report:

Adjusted mean value. In analysis of covariance, an expected treatment mean based on a common independent variable value. Flow-adjusted mean concentrations before and during excavation are based on an overall mean flow rather than on individual mean flows for the two periods.

Analysis of covariance. A statistical model used to adjust mean responses of a dependent variable by an independent variable. Thus, instead of comparing mean concentration before excavation directly to mean concentration during excavation, both means are adjusted through regression to a common mean streamflow and then compared.

Aquifer. A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Bank storage. Water absorbed into banks of streams when the stage rises above the water table in the bank formations then returns to the channel as effluent seepage when the stream stages fall below the water table (Langbein and Iseri, 1960, p. 5).

Base flow. Sustained or fair-weather flow of a stream; in most streams, composed largely of ground-water effluent (Langbein and Iseri, 1960, p. 5).

Bottom material. The unconsolidated material of which a streambed, lake, pond, reservoir, or estuary bottom is composed.

Correlation coefficient. A measure of the degree to which two or more variables are linearly related. The correlation coefficient varies from -1 to 1, where -1 or 1 represents perfect linear relations and 0 represents no linear relation between variables. If the relation between variables increases, the absolute (unsigned) value of the correlation coefficient increases. The simple correlation coefficient, a measure of linear relation between two variables, is referred to as the correlation coefficient in this report.

Fecal coliform bacteria. Bacteria that are present in the intestines or feces of warm-blooded animals. They are often used as indicators of the sanitary quality of the water. In the laboratory they are defined as all organisms which produce blue colonies within 24 hours when incubated at 44.5°C ± 0.2°C on M-FC medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 mL of sample.

Fecal streptococcal bacteria. Bacteria found also in intestines of warm-blooded animals. Their presence in water is considered to verify fecal pollution. They are characterized as gram-positive, cocci bacteria which are capable of growth in brain-heart infusion broth. In the laboratory they are defined as all the organisms which produce red or pink colonies within 48 hours at 35°C ± 1.0°C on M-enterrococcus medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 mL of sample.

Level of significance. The probability of a result occurring by chance, given a specific set of conditions. Thus, a result having a level of significance of 0.02 would be expected to occur by chance approximately twice in 100 independent trials under stated conditions.

Minor elements. Constituents of natural water typically occurring in concentrations of less than 1.0 mg/L (Hem, 1970, p. 188). In this report, the term applies primarily to the metals, such as copper, lead, and mercury.

Nutrients. In water, any dissolved or suspended inorganic or organic compound, especially the various forms of nitrogen or phosphorus, used to sustain plant life.

Runoff. That part of precipitation appearing in surface streams (Langbein and Iseri, 1960, p. 17).

Student's *t* test. A standard test of significance generally applied to small samples (30 observations or less) of unknown variance. For example, it is used to test whether the means of two samples differ significantly from one another.

Trap efficiency. The ratio, expressed in percent, of the amount of sediment trapped to the amount of sediment entering the trap (Herb, 1980, p. 33).

INTERNATIONAL SYSTEM UNITS

The following factors may be used to convert inch-pound units published herein to the International System of Units (SI).

Multiply inch-pound unit	By	To obtain SI unit
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.4047	hectare
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	28.32	liter per second (L/s)
cubic foot per second per square mile ($(ft^3/s)/mi^2$)	0.01093	cubic meter per second per square kilometer ($(m^3/s)/km^2$)
	Temperature	
degree Fahrenheit (°F)	5/9(°F-32)	degree Celsius (°C)
	Mass	
ton (short, 2,000 pounds)	0.9072	megagram (Mg)
ton per square mile (T/mi^2)	0.3503	megagram per square kilometer (Mg/km^2)
	Specific Conductance	
micromho (μmho) per centimeter at 25° Celsius	1.000	microsiemen (μS)

National Geodetic Vertical Datum of 1929 is a geodetic datum derived from the average sea level over a period of many years at 26 tide stations along the Atlantic, Gulf of Mexico, and Pacific Coasts and as such does not represent local mean sea level at any particular place. To establish a more precise nomenclature, the terms "NGVD" or "NGVD of 1929" are used in place of "Sea Level Datum of 1929" or "mean sea level." NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

Beginning in late 1978, stream channels throughout the 60-square mile Chicod Creek basin underwent extensive modification to increase drainage efficiency and reduce flooding potential. Drainage modifications in this Coastal Plain basin, consisting primarily of channel excavation and clearing of channel blockages, were completed in December 1981. The hydrologic condition of the basin before and during modification was determined from observed data.

Observed data indicate hydrologic changes occurred in selected basin characteristics. For example, water levels in the surficial aquifer within 250 feet of Juniper Branch declined as much as 0.4 feet during modifications; at distances greater than 250 feet from the stream, ground-water levels did not change. Base flows increased, and suspended-sediment concentrations for high flows were several times greater than before channel modifications. Increases in selected chemical constituent concentrations in stream water during modifications were as follows: calcium, 12 percent; sodium, 18 percent; bicarbonate, 84 percent; and phosphorous, 80 percent. Significant changes were not found in either pesticide concentrations or coliform bacteria counts.

INTRODUCTION

Prior to modification, the drainage efficiency of the sluggish, low-gradient streams of the Chicod Creek basin had decreased to the extent that flood-induced crop damage and generally poor surface and subsurface drainage had become major problems for residents (Coffey, 1982). Over the years fallen trees and branches created blockages that trapped sediment and other debris, thereby filling the channel. Because of this aggradation, streams no longer had well-defined channels. Conditions which, in the past, had supported a bountiful fish population were changing. A fishery inventory conducted by the North Carolina Wildlife Resources Commission prior to modification found fewer fish species and a smaller standing crop of fish in Chicod Creek than in similar Coastal Plain streams (Wingate and Weaver, 1977).

The U.S. Soil Conservation Service (SCS) obtained approval to excavate stream channels in the Chicod Creek basin in 1966. The primary objective of the project was to increase drainage efficiency of the stream channels and reduce flooding through channel excavation and clearing operations. The project was delayed on several occasions because of delays in funding and by litigation initiated by conservation groups concerning possible adverse environmental impacts. In March 1972, the U.S. District Court granted the Natural Resources Defense Council an injunction preventing initiation of the project without an environmental impact statement. A compromise agreement was reached in September 1977. The project was begun in November 1978 and was completed in December 1981.

The case greatly increased public awareness and concern for effects of channel excavation on the environment. In 1975, the SCS requested that the U.S. Geological Survey undertake an environmental study of the Chicod Creek basin to determine the magnitude of changes in flow regimes caused by channelization and effects of channelization on surface-water quality and ground-water conditions. In late 1975, the collection of data was begun at a network of streamflow, stream-quality, and ground-water monitoring stations installed throughout the Chicod Creek basin. Hydrologic data already being collected as part of a separate on-going project in the adjacent Creeping Swamp basin would be used for control (background) purposes. Data collection was designed to define characteristics during three specific phases of the project: a 3-year period prior to channel modifications; the 3-year period during which modifications were underway; and, a 5-year period immediately following completion of channel modifications.

The progress and findings of the Geological Survey study will be presented in two interim reports and a final report. The first interim report (Simmons and Aldridge, 1980) characterizes streamflow, stream quality, and ground-water conditions prior to channel modification, which began in late 1978. This report, which is the second interim report, compares hydrologic conditions in the basin prior to and during construction, including ground water, surface water, and surface-water quality, and covers the period from late 1975 to late 1981. A final report will compare hydrologic conditions prior to and following completion of all channel modifications.

Several methods are used to identify and quantify parametric values and trends. Hydrologic data collected at sites in an adjacent, unmodified basin are used in this study for control purposes. Geologic and hydrologic characteristics of the 27 mi^2 control basin, Creeping Swamp, are similar to those of Chicod Creek prior to channel modification activities; therefore, various changes occurring in the Chicod basin as a result of channel modifications are reflected in comparisons with data for Creeping Swamp. Comparisons were made by computerized statistical programs for regression analysis, as were determinations of statistical values of various parameters, accuracy limits, and reliability tests.

Most channel-modification activities in the Chicod basin, which began in November 1978, were completed by October 1980; clearing and snagging of stream channels was completed by October 1981. All channel modifications were completed by December 1981. Data collection is planned to continue until 1986.

Special acknowledgment is given to Mr. J. C. Galloway, Greenville, N.C., for his devoted efforts in collecting daily suspended-sediment samples on Chicod Creek during the study period. Special high-flow suspended-sediment samples and weather data were provided by Mr. Larry Tucker, Grimesland, N.C., for the Juniper Branch station during 1979-80. Soil Conservation Service personnel in Greenville, N.C., under supervision of Mr. Albert Coffey, provided level data and local weather information which were critical to project operations. Technical comments on the draft of this report were provided by staff of the Soil Conservation Service including Mr. Robert Jessup, Raleigh, N.C., and Mr. Richard Folsche, Fort Worth, Tex.

DESCRIPTION OF STUDY AREA

The study area includes the Chicod Creek and Creeping Swamp basins (fig. 1). The Chicod Creek basin, an area of approximately 60 mi^2, is in the central Coastal Plain province of eastern North Carolina. Approximately 90 percent of the basin is in Pitt County and 10 percent is in Beaufort County (fig. 1). Chicod Creek originates in the western part of Beaufort County and flows north to the Tar River. Major tributaries are Cow Swamp and Juniper Branch, whose drainage areas are 18 mi^2 and 14 mi^2, respectively. The basin is characterized by sluggish, low-gradient streams and relatively flat topography. The average gradient of Chicod Creek is only about 0.3 foot per mile; land-surface altitudes in the basin range from about 10 to 50 feet above sea level. Relatively broad swamplands are abundant and stream channels are often nonexistent, poorly defined, or braided. Runoff from moderate and, in some cases, even light storms quickly fills the shallow channels, causing extensive flooding of adjacent lowlands. Short reaches of major stream channels, usually less than a mile in length, have been excavated at various times since the early 1900's; but, until late 1978, an organized, large-scale effort had not been made to improve flow and drainage conditions in the entire basin. A dense growth of trees, predominantly pine, sweet gum, poplar, and cypress, covers most of the flood plains and areas immediately adjacent to the streams.

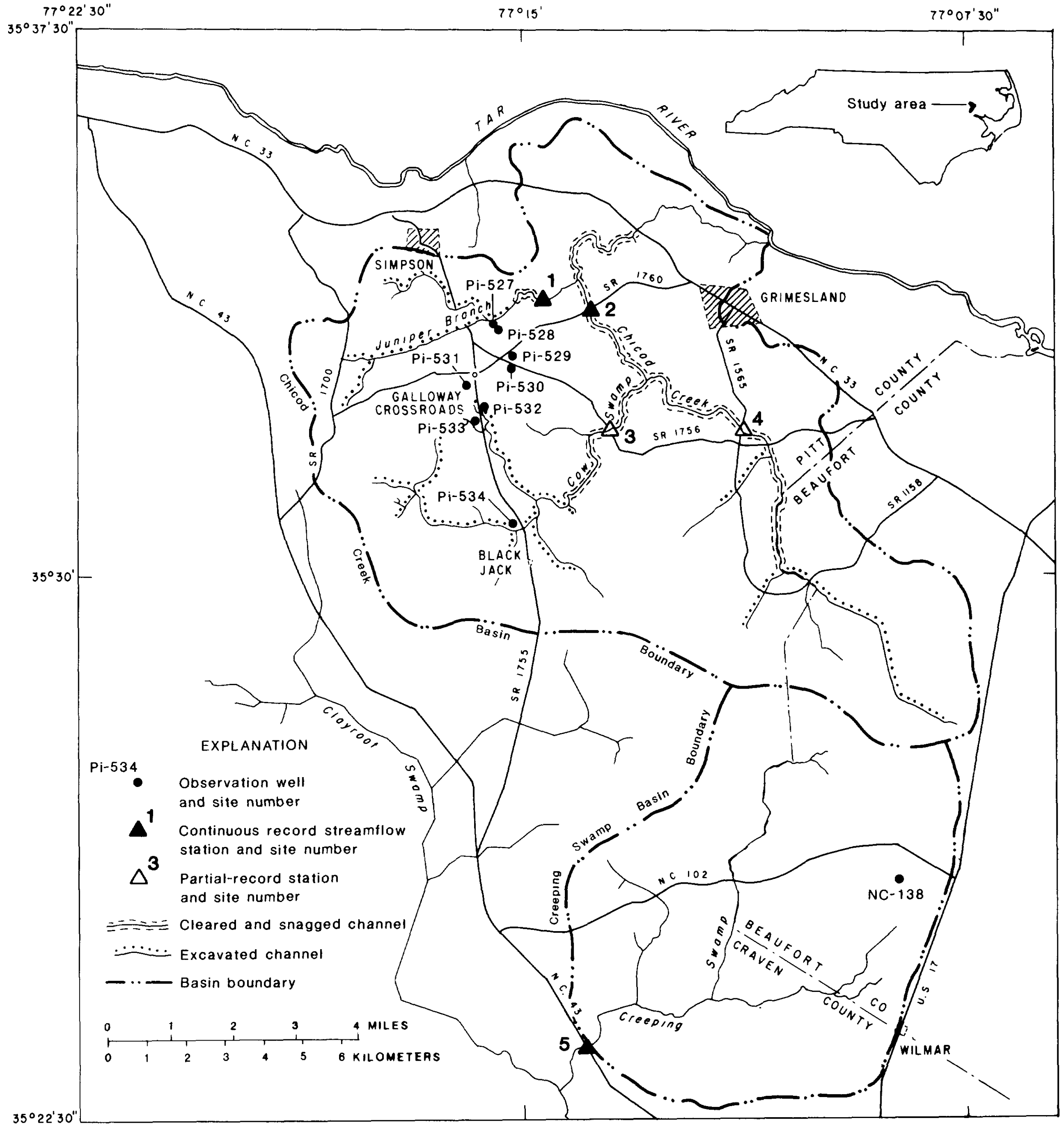

Figure 1.--Study area and location of data-collection sites and channel modifications.

Land use in the Chicod basin is dominated by agricultural lands and forests. In 1978, about 45 percent of the land area was used for crops and pastures; dense hardwood and pine covered approximately 50 percent of the basin. Residential areas, roadways, and water courses accounted for the remaining 5 percent (Simmons and Aldridge, 1980). A reconnaissance of the basin was conducted during the summer of 1978 to determine the prevalence and types of livestock and agricultural land-use activities in the basin. Although only a small number of cattle and horses were observed (less than 100), the basin contained many poultry and swine farms. Several poultry farms, each having 80,000 or more chickens, are in proximity to streams. With the exception of direct outlets to streams from holding ponds adjacent to poultry and livestock shelters, point sources of pollution were not observed in the basin. Tobacco, soybeans, and corn are the primary row crops, and numerous ponds, 1 to 4 acres in size, are located throughout the basin for irrigation purposes. Almost all agricultural fields are separated from streams by forest and heavy undergrowth.

Increases of 2 to 3 percent in housing and croplands are estimated to have occurred since 1978. Construction of 20 to 30 new houses has occurred in the headwaters of Juniper Branch alone. Several large farm ponds, ranging in size from about 2 to 10 acres, have also been constructed during the past several years. The Chicod Creek basin, however, can still be regarded as a rural basin with intense farming activities.

The Creeping Swamp basin is immediately south of and adjacent to the Chicod Creek basin (fig. 1). At the gage on Creeping Swamp (site 5), the basin is approximately 28 mi^2, of which 38 percent is in Pitt County, 37 percent is in Beaufort County, and 25 percent is in Craven County. Approximately 70 percent of the basin is forested or cut-over scrubland; row crops and other agricultural lands account for about 25 percent; and developed lands such as residential property and highways account for most of the remaining 5 percent of the basin. Channel gradients, flood plains, and other physical characteristics of streams in the Creeping Swamp basin are similar to those in the Chicod Creek basin. During the study period, land-use changes and modifications of channel and drainage systems in the Creeping Swamp basin were minor.

The study area is underlain by 900 to 1,200 feet of water-bearing sands, clays, and calcareous sediments. The uppermost sediments include Pleistocene and Holocene surficial deposits, and are underlain by the Tertiary Yorktown Formation and Castle Hayne Limestone. The surficial deposits are composed primarily of sand and silt ranging from 10 to 20 feet thick. These surficial deposits are major sources of water for shallow wells and base flow to streams. The Yorktown Formation lies immediately under the surficial deposits. Layers of gray silty clay comprise the upper part of the formation, whereas the lower part is composed of dark blue-gray sandy clay containing shells and other remains of marine organisms. The average thickness of the Yorktown Formation is about 40 feet, except where thinned by erosion. Within the study area, the Yorktown Formation and the surficial deposits comprise the surficial aquifer. The Castle Hayne Limestone underlies the Yorktown Formation, except in the extreme western part of the area where it thins to a feather edge. The Castle Hayne Limestone consists of white, calcareous sand, green clay, and gray sandy limestone and is the major artesian aquifer for deep wells in the area.

The study area has a humid moderate climate, an average January temperature of 5.5°C and an average July temperature of 26.5°C (National Oceanic and Atmospheric Administration, 1981). Based on long-term records for Greenville, located about 12 miles northwest, average annual precipitation is approximately 48 inches. Annual precipitation during the study period ranged from 39.0 inches in 1981 to 64.3 inches in 1979; however, totals during remaining years were near the annual average. Severe flooding has not occurred recently in the basin, but most of the Coastal Plain province was affected by a drought from early summer 1980 to early spring 1981. The rainfall deficiency at Greenville from July 1980 to March 1981 was over 10 inches.

CHANNEL MODIFICATION

The channel modification program was initiated in November 1978, after 12 years of planning, litigation, and contractual negotiations. Modifications continued during the next 3 years, but were interrupted periodically by inclement weather and were suspended from February 1 to June 30 each year to avoid interference with herring spawning runs. When channel modifications ended in December 1981, contractors had cleared and snagged 13 miles of channel, excavated another 58 miles, and constructed 13 instream grade-control structures and 17 sediment basins (fig. 2). Upstream of N.C. Highway 33, virtually every natural and older artificial channel in the basin had been modified.

The modification program consisted of two phases. The first phase began in November 1978 and continued through January 1979. During this period, the first 3 miles of channel, Juniper Branch at Secondary Road 1766 downstream to Chicod Creek at N.C. Highway 33, were cleared and snagged (fig. 2). The second phase began July 1979 and ended December 1981. During the second phase, remaining clearing and snagging operations and channel excavations, and construction of grade-control structures and sediment basins were completed. Clearing and snagging operations were confined mainly to stream reaches bordered by wooded swamp. Heavy equipment was used to move large obstacles such as logs, stumps, brush, and debris within the channel; but much of the clearing was done manually. Removed material was piled and bound with wire cables to prevent it from being washed into the channel during storm periods.

During the second phase, channels were excavated simultaneously in as many as four or five subbasins. Except in forested areas, one streambank was generally cleared to provide access for the surveyors and heavy equipment such as backhoes and draglines. Locations of grade-control structures,

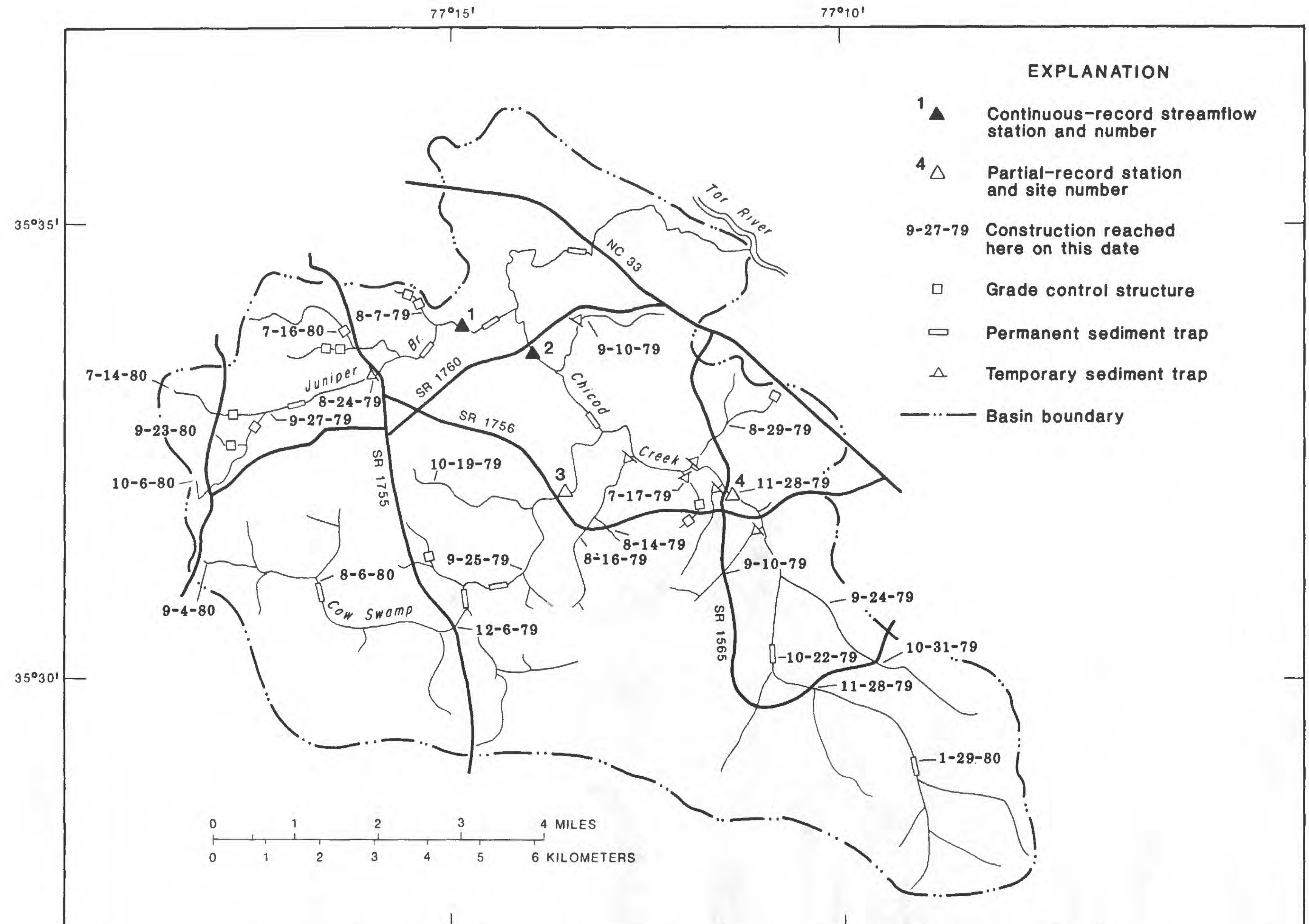

Figure 2.--Data-collection sites, dates of completed channel modifications, grade-control structures, and sediment traps in the Chicod Creek basin.

sediment basins, and channels to be excavated were surveyed. Excavation generally began at the downstream end of a prepared reach and progressed upstream (fig. 3). Excavated channel depths ranged from about 2 to 7 feet. Culverts were installed under private roads. When channel excavation conflicted with construction at grade-control structures and sediment basins, excavation operations were suspended temporarily or moved to another area until completion of the structure or basin. Spoil areas and streambanks were shaped and seeded following excavation to prevent excessive erosion.

A B

Figure 3.--Typical modification operations in the Chicod Creek basin. A, Clearing and snagging in the main stem of Chicod Creek; B, Excavation by dragline in the upstream main stem of Chicod Creek. (Photographs by Albert Coffey, U.S. Department of Agriculture.)

The type of modification varied throughout the basin. As shown in figure 1, channels were generally excavated on the smaller headwater streams, and cleared and snagged along the larger main streams. Little change was made along reaches having naturally deep pools when the streambed was already at or below design elevation. Consequently, some areas underwent more alteration than others. For example, all tributaries and main-stream channels of Juniper Branch, upstream of site 1, were excavated; whereas, the main channel of Chicod Creek for several miles upstream of site 2 was relatively unaltered.

Grade-control structures were installed on relatively high-gradient reaches to improve channel stability and reduce erosion (fig. 2). These dam-type structures generally consisted of large-diameter pipes placed lengthwise in the stream channel with earthen or concrete fill. The structures confine channel flow to the pipe, thereby preventing scour and degradation of the natural channel. The gradient of the structure is controlled by the length and slope of the pipe.

Sediment basins, or traps, were constructed to decrease sediment runoff during and following construction. Ten traps were permanent, and seven were for temporary use during construction (fig. 2). The permanent traps are generally longer than the temporary ones and are to be maintained after channel modification. Traps were constructed in the existing or design channel; lengths varied from 210 to 250 feet, widths were approximately twice as wide and depths were about 2 feet deeper than adjacent reaches. The extra width and depth of the trap caused a reduction in flow velocities and sediment transport in the stream, and suspended sediment which drops from suspension is deposited in the trap. A significant amount of sediment transported as bedload, which is composed of larger material that skips and rolls along the streambed, is also deposited in the traps. Because the bed of the trap is lower than adjacent channels, deposited sediment does not impede flow. Temporary traps were allowed to fill to the level of adjacent channel sections.

DATA COLLECTION

Locations of surface- and ground-water sites in the study area are shown in figure 1. Streamflow and water-quality data are collected at five sites, and ground-water levels are measured at nine observation wells. Discharge measurements and continuous-stage records are collected at Juniper Branch, Chicod Creek at site 2, and at Creeping Swamp for determining streamflow. Conductance, temperature, and sediment data are also collected at Chicod Creek at site 2. Sediment data are obtained by means of an automatic sampler (stage controlled) at prescheduled time intervals during flood periods, in order that suspended sediment could be monitored during floods. A suspended-sediment sample is also collected at site 2 each day by an observer for computation of daily loads. Discharge measurements are made periodically at sites 3 and 4, Cow Swamp and Chicod Creek, respectively, (fig. 1) for defining the stage-discharge relation throughout a full range of flow conditions. A complete listing of sites in the surface-water network, their locations, type of data collected, and period of record are given in table 1.

Table 1.--Surface-water network sites and types and frequency of data collection

[Data for site numbers 1 to 4 from Simmons and Aldridge (1980, table 2); Approximate sampling frequency: C, continuous; M, monthly; D, daily; Q, quarterly; T, twice yearly; Y, yearly]

Site No.[1/]	Name	Drainage area (square miles)	Period of record	Type of data and sampling frequency									
				Major dissolved constituents	Nutrients	Minor elements	Dissolved oxygen	Pesticides	Temperature	Specific conductance	Bottom material	Suspended sediment	Discharge
1	Juniper Branch near Simpson	7.5	October 1975 to December 1981	Q	Q	Q	Q	T	Q	Q	Y	M	C
2	Chicod Creek at SR 1760 Simpson	45	October 1975 to December 1981	M	M	M	M	T	C	C	Y	D	C
3	Cow Swamp near Grimesland	17	October 1975 to December 1981	Q	Q	Q	Q	T	Q	Q	Y	M	M
4	Chicod Creek at SR 1565 near Grimesland	19	October 1975 to December 1981	Q	Q	Q	Q	T	Q	Q	Y	M	M
5	Creeping Swamp near Vanceboro	27	March 1971 to September 1975 and June 1981 to December 1981	Q	Q	Q	Q	T	Q	Q	Y	Q	C

[1/]Site number refers to locations shown in figure 1.

The eight observation wells in the Chicod basin are located at distances ranging from 150 feet to 3¼ miles from Juniper Branch across the drainage divide between Cow Swamp and Juniper Branch (fig. 1). The depths of the wells range from 9 to 21 feet. Land-surface altitudes at the observation wells range from about 27 to 58 feet above sea level. Unique identification numbers assigned to the Chicod basin wells consist of a sequence number preceded by Pi-, which refers to Pitt County, where the wells are located; NC- refers to North Carolina in the identification number of the Creeping Swamp basin well. Three wells, Pi-527, -528, and -534, extend into the Yorktown Formation, and all of the others, into the shallower surficial deposits. Continuous water-level records are collected at wells Pi-527, -528, -529, -532, -533, and -534. Water levels at wells Pi-530 and -531 are measured monthly. Well NC-138 is located in the Creeping Swamp basin and is operated as part of a statewide ground-water level monitoring network. A continuous record of levels in the surficial aquifer is provided by this well. Additional information regarding the observation wells is presented in table 2.

The types of water-quality data and frequency of chemical and physical analyses for study sites are listed in table 1. Water-quality samples from observation wells (table 2) were collected July 1977 to evaluate overall chemical-quality characteristics of ground water in the study area (Simmons and Aldridge, 1980, table 6). Laboratory and field analyses are made in accordance with methods set forth by the Federal Interagency Work Group on recommended methods for water data acquisition (1977). All streamflow and water-quality data collected at study sites are published annually in U.S. Geological Survey Water-Data Reports (1976-81).

Table 2.--Ground-water network sites, physical characteristics, and frequency of data collection

[Data from Simmons and Aldridge (1980, table 6); Well number refers to locations shown in figure 1.]

Well No.	Land surface altitude (feet above sea level)	Depth (feet)	Diameter (inches)	Well screen altitude (feet above sea level)	Type of well casing	Waterbearing material	Lateral distance from Juniper Branch (feet)	Water-level records
Pi-527	27.4	14.6	6	12.8-15.8	Polyvinyl chloride	Yorktown Formation (sand and clay)	150	Continuous.
Pi-528	34.9	14.2	6	20.6-23.6	do.	do.	250	Do.
Pi-529	49.3	14.4	6	34.9-37.9	do.	Surficial sand and clay	3,100	Do.
Pi-530	51.5	21.1	2	30.4-33.4	Galvanized steel	do.	4,100	Monthly.
Pi-531	57.3	20.4	2	36.9-39.9	do.	do.	5,400	Do.
Pi-532	56.1	10.9	6	45.2-48.2	Polyvinyl chloride	do.	7,300	Continuous.
Pi-533	52.2	9.1	6	42.9-45.9	do.	do.	8,900	Do.
Pi-534	32.0	9.6	6	22.4-25.4	do.	Yorktown Formation (sand and clay)	17,300	Do.
NC-138	56.1	12.0	4	44.8-49.1	Black iron	Surficial sand and clay	Not applicable	Do.

HYDROLOGIC CONDITIONS

This study represents one of the most comprehensive studies conducted in this State to define hydrologic changes caused by channel modifications. It also is one of the first studies to use data that were actually collected prior to and during the various modification phases. A similar but less detailed study of another Coastal Plain stream, the Black River near Dunn (North Carolina), indicated that channel excavation caused significant changes in several hydrologic parameters (Simmons and Watkins, 1982). Throughout the remainder of this report, various comparative and statistical methods are used to characterize the hydrologic conditions existing in the Chicod study area prior to alterations and to compare these with subsequent changes that occurred as a direct result of channel modifications.

GROUND WATER

Observation wells in the study area monitor changes in ground-water levels in the surficial or unconfined aquifer. Water levels in the unconfined aquifer are at atmospheric pressure and are commonly referred to as "water-table" conditions. Figure 4 is a land-surface and water-table profile between Juniper Branch and Cow Swamp; the locations of observation wells are shown, along with the range and mean of ground-water levels in each well during 1977-78. Mean ground-water levels above sea level are

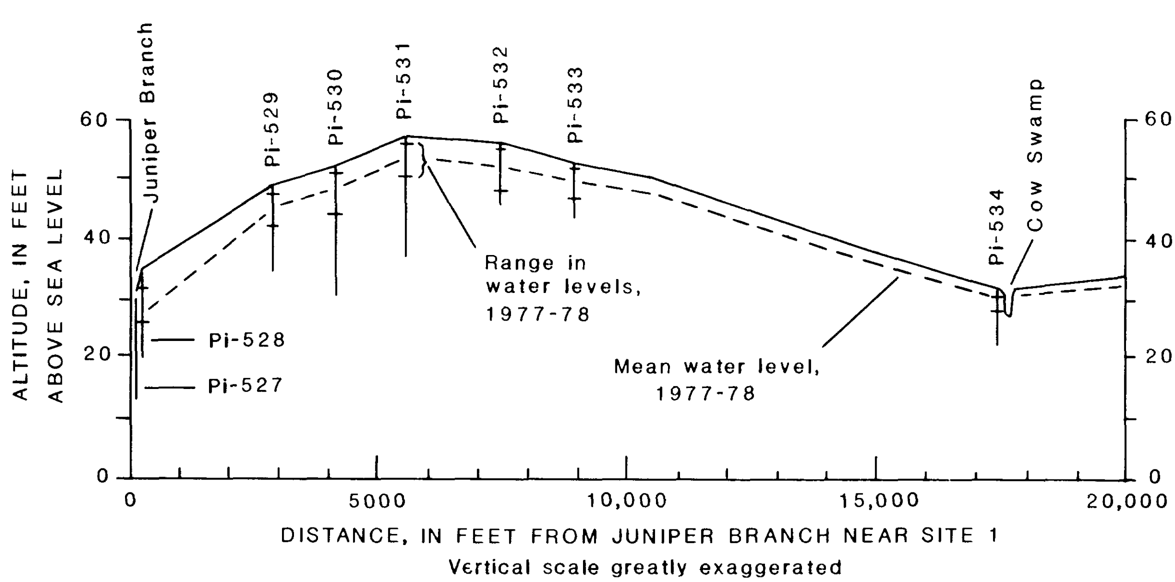

Figure 4.--Surface profile and ranges in ground-water levels between Juniper Branch and Cow Swamp, prior to modification, 1977-78 (from Simmons and Aldridge, 1980, fig. 2).

lowest near the streambeds, but increase with elevation, roughly approximating land-surface topography. Ground-water levels and surface-water levels in the adjacent streams respond directly and rapidly to climatic changes, especially rainfall. During periods of little or no precipitation, streamflow is derived mainly from ground-water discharge, and, almost always, stages in streams during these periods show a direct relation to water levels in the shallow wells. In a study of the Creeping Swamp basin, Winner and Simmons (1977, p. 19) estimated that over half of the basin runoff is derived from ground water; because of the similarity of the two basins, it is reasonable to assume this estimate is also applicable to Chicod Creek prior to modification. Most rainfall which does not appear as runoff infiltrates the surficial aquifer. Water is lost from the surficial aquifer by infiltration to the deeper artesian aquifers, by evapotranspiration, and discharge to streams. The amount of water that infiltrates the deeper artesian aquifer system is small compared to the amounts leaving the surficial aquifer by evapotranspiration and discharge to streams. Thus, the examination of hydrologic conditions required recognition of the interrelation of ground and surface water.

The hydrographs in figure 5 illustrate the relation between stream stage and ground-water levels prior to channel modifications. The sharp peaks in stream stage at site 1 on Juniper Branch, caused overland runoff following heavy rainfall, closely follow less pronounced fluctuations in well Pi-527, which is 150 feet from Juniper Branch, and in well Pi-534, which is 300 feet from Cow Swamp. Infiltration from rains have even less effect at Pi-532, which is approximately 300 feet from a tributary to Cow Swamp, and water-level changes recorded in this well following larger storms are not as abrupt as those recorded in either Pi-527 or Pi-534 for the same period. During periods of little or no precipitation, ground-water levels in these Chicod basin wells decline as discharge in the stream falls to base flow. At such times, levels in well Pi-532 decline the most, as water moves down gradient.

Annual precipitation in the study area during 1976-81, varied from about 39 to 64 inches per year. Therefore, direct comparisons of water-level records between years probably would be more indicative of changes caused by variations in rainfall than of those caused by channel modifications. Comparison of water-level records in the Chicod Creek basin with those of the Creeping Swamp basin provides an accurate accounting of resultant changes.

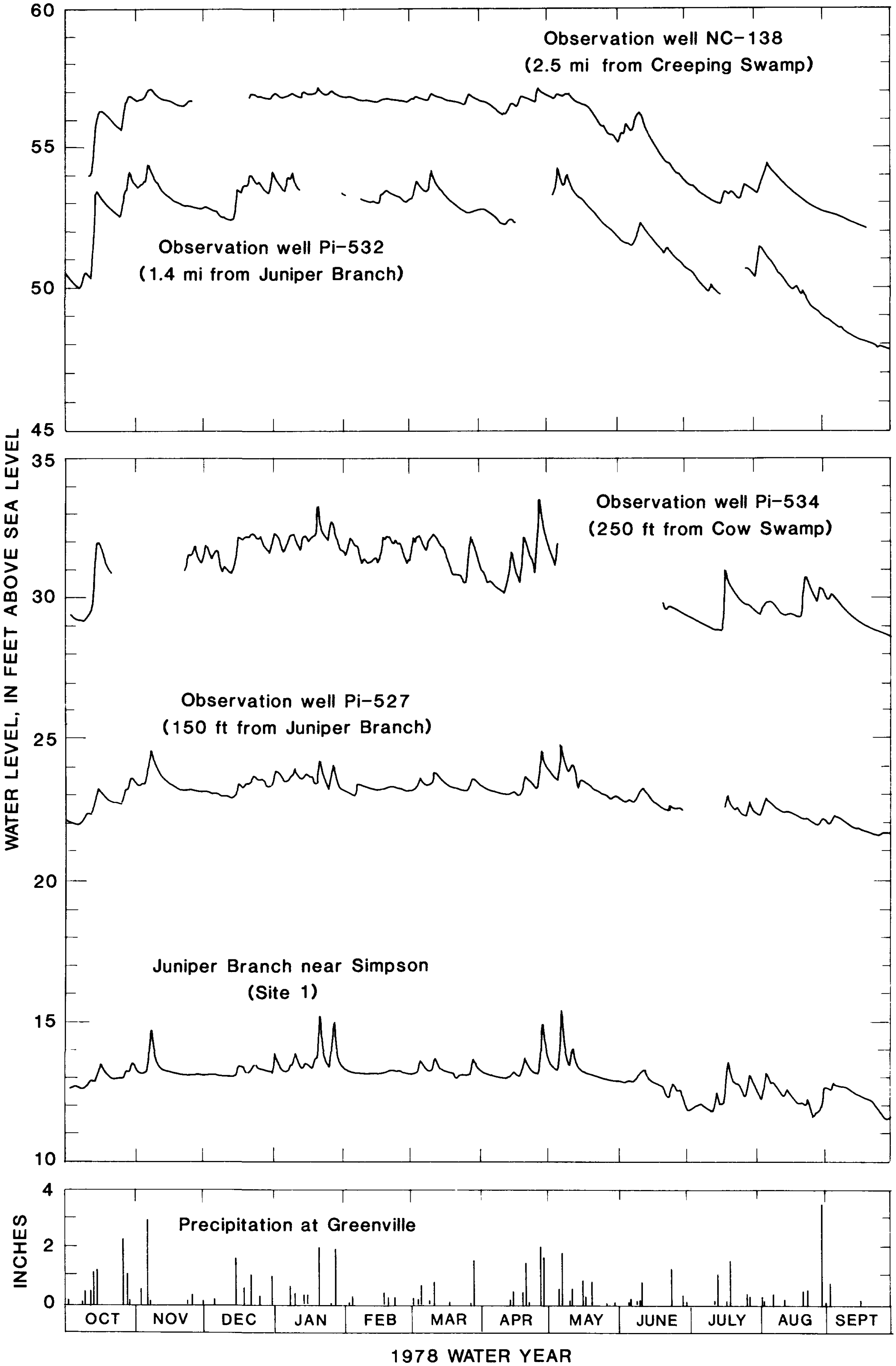

Figure 5.--Precipitation and water-level fluctuations in selected observation wells and in Juniper Branch, 1978 water year. (Site and well numbers refer to locations shown in figure 1.)

Comparisons of water-level hydrographs from well NC-138, in the Creeping Swamp basin, and those from wells in the Chicod basin prior to excavation show similar responses to climatic stresses; however, statistical analyses show that ground-water levels in NC-138 are most highly correlated with the levels in the Chicod basin wells during base-flow periods. Correlation coefficients for simultaneous water levels in well NC-138 with water levels for each observation well in the Chicod Creek basin, except Pi-529, are shown in table 3. Water-level data from Pi-529 are periodically affected by withdrawals from a nearby irrigation pond and subsequently are omitted

Table 3.--Correlation coefficients for simultaneous water levels in observation well NC-138 and Chicod Creek observation wells during base-flow periods

[Well number refers to locations shown in figure 1.]

Well No.	Correlation coefficient	Number of observations
Pi-527	0.78	793
Pi-528	.83	632
Pi-530	.93	21
Pi-531	.72	23
Pi-532	.96	701
Pi-533	.93	790
Pi-534	.80	571

from this analysis. The correlation coefficients range from 0.72 to 0.96. Data for well Pi-531 has the lowest correlation coefficient, 0.72, which differs from zero at significance level $\alpha = .0001$, but is based on only 23 observations. Approximately 600 to 800 daily values are used to calculate correlation coefficients for each well having continuous records.

Ground-water conditions during channel modifications were evaluated using a simple covariance analysis (Steel and Torrie, 1960, pp. 305-330). Ground-water levels during base-flow conditions at each of the Chicod Creek wells were analyzed as dependent variables versus water levels in well NC-138, the phase of channel modification, and their product. Where significant variation due to modifications was detected, an adjusted mean value for the appropriate Chicod Creek well was calculated for each phase. Statistically significant differences between adjusted means were found only at four wells equipped with continuous recorders: Pi-527, Pi-528, Pi-532, and Pi-533. Adjusted means and differences are shown in table 4. All four wells show statistically significant declines in ground-water level during channel modifications of from approximately 0.1 to 0.4 foot, with significance levels of $\alpha = 0.02$; but declines of 0.1 foot were probably within the limits of localized differences between the study sites and the background station and are doubtful. Analyses of data from wells Pi-530 and Pi-531, which were measured approximately monthly, showed no statistically significant change in adjusted mean ground-water levels.

Table 4.--Estimated adjusted mean ground-water levels for base-flow periods at Chicod Creek wells before and during excavation

[Well number refers to locations shown in figure 1.]

Well No.	Adjusted mean ground-water levels (feet above sea level)		Change in water level (feet)
	Before excavation	During excavation	
Pi-527	22.7	22.3	0.4
Pi-528	27.5	27.3	.2
Pi-532	51.4	51.3	.1
Pi-533	48.9	48.8	.1

In summary, changes in shallow ground-water levels resulting from excavating Juniper Branch appear to be slight and limited in lateral extent. Although the stream bottom was deepened approximately 2 feet in the vicinity of Pi-527, the excavation caused average declines of 0.4 foot in well Pi-527 and 0.2 foot in Pi-528 located 150 feet and 250 feet, respectively, from the stream. Changes of 0.1 foot or less calculated for other wells in the network might be attributed to variations in rainfall between sites or differences in evapotranspiration, infiltration, or aquifer characteristics at each well.

SURFACE WATER

As shown by Winner and Simmons (1977, p. 40), Heath (1975, p. 67), and Daniel (1981, p. 95-101), channel excavations can significantly alter streamflow characteristics. In the Chicod Creek basin, the extent of channel modifications varied between individual streams and even along reaches of the same stream (fig. 1).

The excavation of the Juniper Branch channel, the most extensively modified of the four monitored sites, further incised shallow ground-water aquifers, thereby increasing the amount of ground water available for discharge. The most obvious change that occurred in the flow of Juniper Branch was an increase in base flow as depicted by flow-duration graphs, before and during channel modifications (fig. 6). Prior to channel excavations, flows were less than 0.1 ft^3/s approximately 11 percent of the time; however, during the excavation period, minimum flows increased to 0.4 ft^3/s, although the area experienced a severe drought during the summer and fall of 1981 (fig. 6). Winner and Simmons (1977, p. 41-42) reported a similar change in flow regime of Ahoskie Creek at Ahoskie, North Carolina, following excavation in 1962-64; they hypothesized such a change for Creeping Swamp following excavation which had been proposed at that time. For comparison, flow-duration graphs for the control basin, Creeping Swamp, are also shown in figure 6. Before- and during-duration curves for Creeping Swamp are virtually parallel throughout the range of flows, indicating no change in flow regime during the period that channel modifications were made in the Chicod basin.

Similar changes in low-flow characteristics noted at Juniper Branch, also occurred at site 2 on Chicod Creek. Prior to excavation, flows at site 2 often ceased and were below 0.1 ft^3/s approximately 13 percent of the time. During the channel modification phase of the study, flows fell below 0.1 ft^3/s only 4 percent of the time. Changes in high-flow characteristics were less pronounced in Chicod Creek than those observed in Juniper Branch.

STREAM-QUALITY CHARACTERISTICS

Stream quality in the Chicod Creek basin is influenced by natural conditions such as geology, and by agricultural activities, quality of precipitation, some septic tank seepage, and other man-related activities. During channel modifications, stream quality was also affected by excavation, clearing and snagging in the channel, and by increased ground-water discharge. Water-quality data were not obtained in Creeping Swamp prior to channel modifications, and therefore, comparisons with control data are not possible. To compare many of the stream-quality characteristics before and during modifications, regression relationships were developed between individual constituents and stream discharge. Differences in mean concentrations probably attributable to the modifications were calculated and

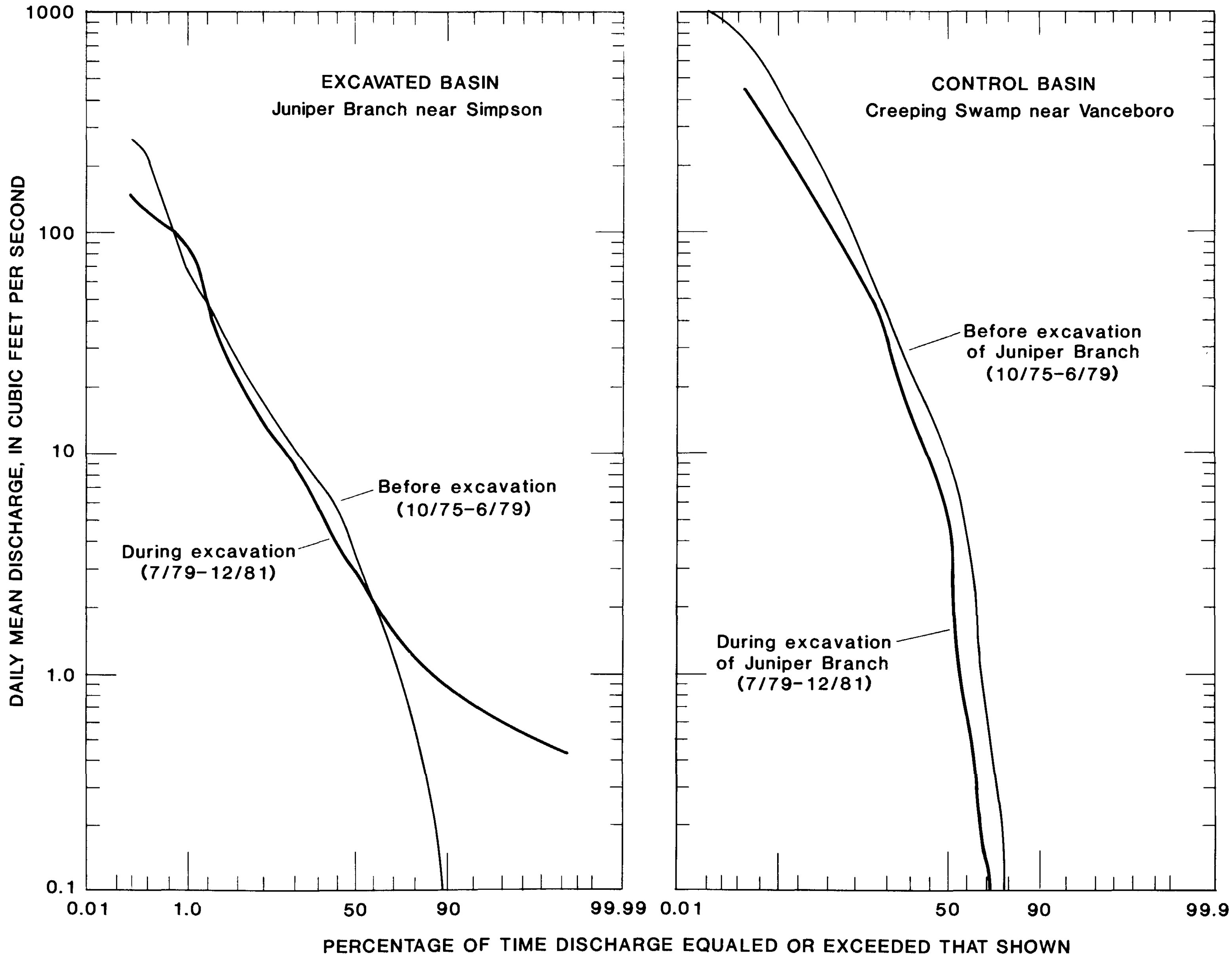

Figure 6.--Flow-duration curves for Juniper Branch and Creeping Swamp, before and during excavation of Juniper Branch.

tested using analysis of covariance (Steel and Torrie, 1960, p. 305-330). Three general areas are considered in the following discussion of stream quality: physical characteristics, chemical characteristics, and bacteria.

Physical characteristics

Physical characteristics studied include suspended sediment, dissolved oxygen, and stream temperature. Suspended-sediment concentrations in streams vary primarily with stream discharge, land use, soil type and cover, slope, and rainfall intensity. Although farming activities in the basin create large areas of exposed land, the flat topography, sluggish streams, and permeable soils tend to minimize sediment transport. Prior to channel modifications, high sediment concentrations occurred only during intense storms, when overland runoff transported sediment derived from cultivated fields, road ditches, and other exposed areas. Excavation and clearing and snagging operations disturbed the streambed itself, contributing to elevated sediment concentrations in some reaches even during periods of base flow.

Table 5 lists suspended sediment and streamflow data for Juniper Branch and site 2 on Chicod Creek. Although the daily mean water discharge was lower during modifications than before, the daily mean sediment concentrations were higher during channel modifications at both sites. The greatest instantaneous concentrations of sediment observed during either phase of the study, however, occurred prior to the modifications during the

Table 5.--Suspended-sediment and flow data for selected sites in the Chicod Creek basin before and during channel modifications

Parameter	Juniper Branch[1/] near Simpson		Chicod Creek at SR 1760[2/] near Simpson	
	Before Modifications	During Modifications	Before Modifications	During Modifications
Mean daily water discharge, in ft^3/s	9.7	5.8	75	35
Mean daily suspended-sediment concentration, in mg/L	26	70	52	77
Annual suspended-sediment yield, in T/mi^2	33	53	86	59
Ranges of instantaneous suspended-sediment concentrations, in mg/L	0-1260	0-482	0-662	0-422

1/ Site 1, figure 1.
2/ Site 2, figure 1.

floods of April and May 1978. The flows during these floods were nearly twice as great as any that occurred during the modification period and produced the greatest suspended-sediment concentrations observed during the study. Much greater concentrations would probably have occurred, however, had similar floods occurred during modifications.

Figure 7 shows sediment-transport plots for Chicod Creek at site 2 (fig. 1) before and during modifications. The lines included on the plots are estimated lines of daily mean suspended-sediment discharge versus mean daily water discharge. At site 2 on Chicod Creek, excavation does not seem to have had a great effect on suspended-sediment discharge, as indicated by the similarity of the plots. Sediment basins installed upstream of the site and natural pools apparently reduced the amount of suspended sediment in the water during excavation.

The before and during sediment-transport curves for Juniper Branch, however, are markedly different (fig. 8). Excavation was much more extensive in the Juniper Branch section of the basin and was also much nearer the sampling site than was the case at site 2 on Chicod Creek. The sediment-transport curve for Juniper Branch shows that sediment-discharge values during excavation were generally greater than those recorded for similar streamflow values before excavation, especially in the flow range from 10 to 1,000 ft^3/s (fig. 8). Excavation in the channel created unstable banks and easily eroded spoil piles which probably contributed to the increased sediment. This stream reach did not have the buffer of relatively undisturbed cleared and snagged streambed to minimize sediment. Even so, it is likely that natural deep pools and in-stream sediment traps reduced the total sediment load during construction from the level it might have attained without such features.

Dissolved-oxygen concentrations are related primarily to temperature, the biological processes of decomposition, oxidation, respiration and photosynthesis, and the reaeration capacity of the stream. Dissolved-oxygen concentrations recorded over a wide variety of flow and temperature conditions ranged from a minimum of 0.8 mg/L (milligrams per liter) at Cow Swamp during a low-flow period, to a maximum of 14.8 mg/L at Juniper Branch during a stormflow period; both values occurred before modification. During summer and fall low-flow periods, concentrations at all sampling sites (1 through 4, fig. 1) usually drop below the 5 mg/L value which is needed to support a varied fish population (U.S. Environmental Protection Agency, 1976). Statistical analysis revealed no significant differences in dissolved-oxygen concentration before and during channel modifications.

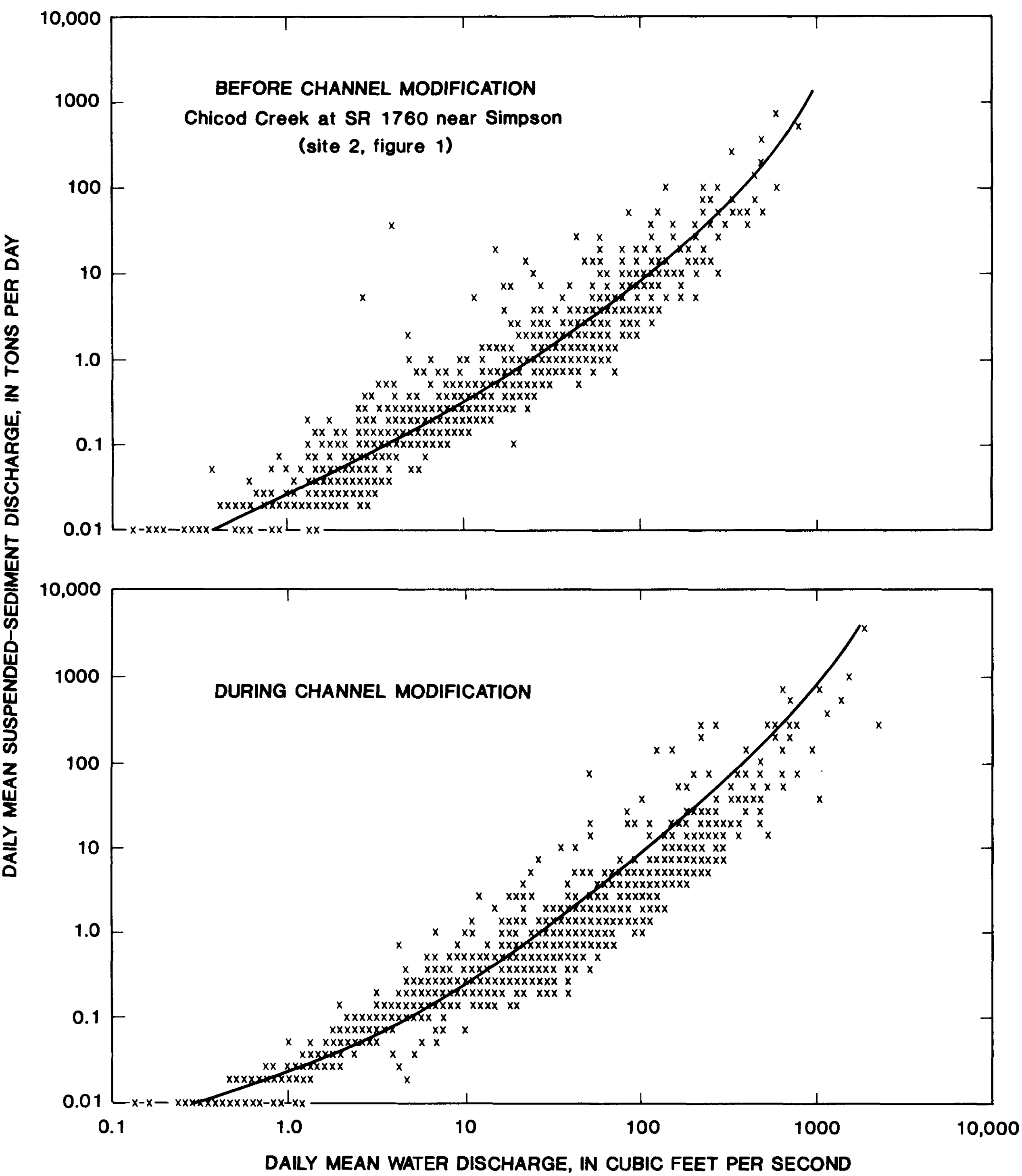

Figure 7.--Sediment-transport relations for Chicod Creek before and during channel modification.

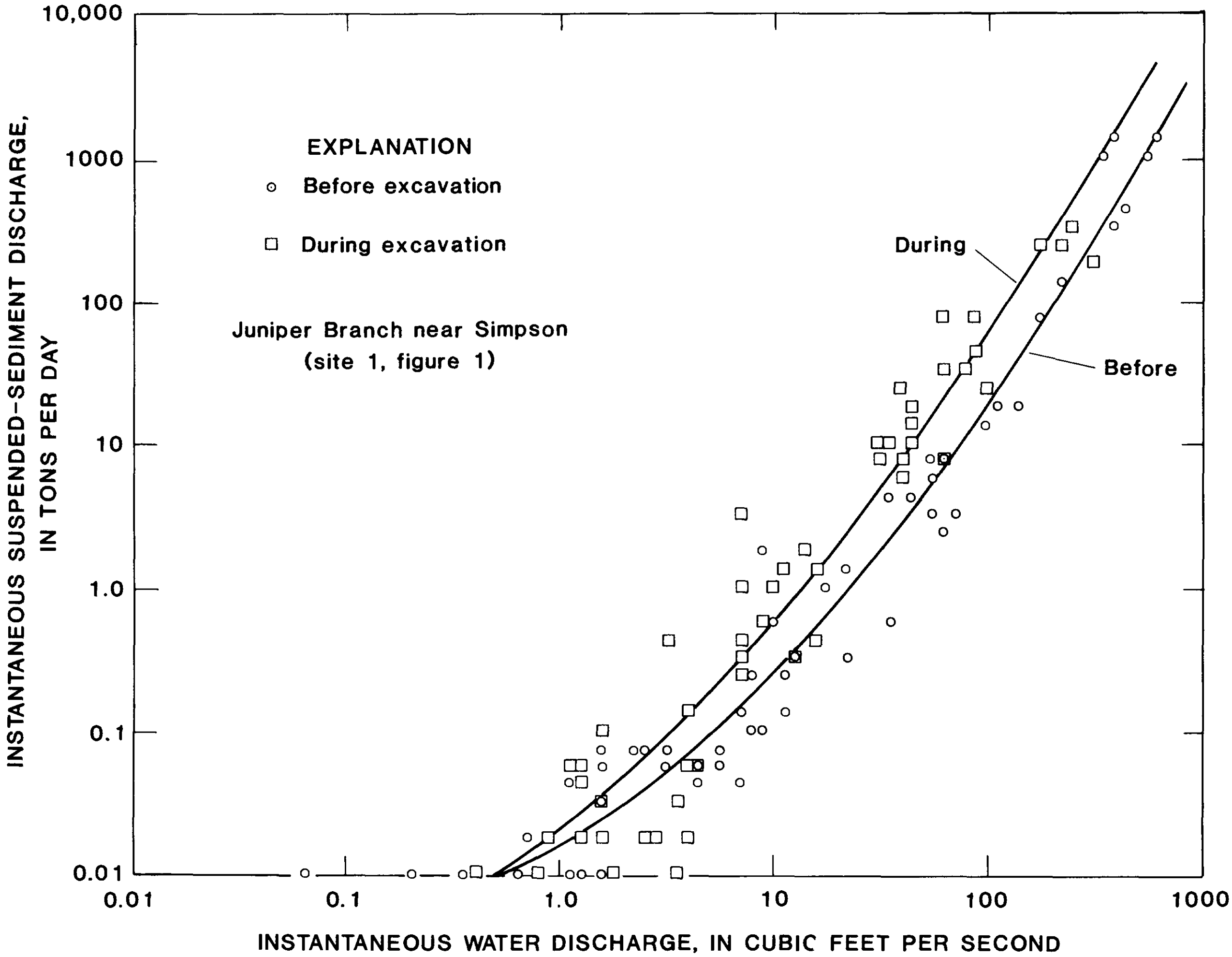

Figure 8.--Sediment-transport relations for Juniper Branch before and during channel modification.

Table 6.--Physical, chemical, and streamflow data for selected base-flow and storm periods and for all samples before and during channel modifications in the Chicod Creek basin

[Site number refers to locations shown in figure 1; N is the number of samples.]

Parameter	Site No.	Base-flow						Storm flow						All Samples					
		Before			During			Before			During			Before			During		
		Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	N
Streamflow, in ft^3/s	1	2.4	0.13-7.3	8	2.8	1.5-4.2	5	298	56-637	6	92	38-245	5	70	0.06-637	62	36	0.24-309	58
	2	7.2	.01-23	6	8.2	1.0-20	6	1240	545-2020	7	687	438-1010	8	398	.01-2020	30	221	0-1010	30
	3	1.6	.25-6.7	6	3.9	.31-8.5	5	856	404-1350	6	368	179-621	5	163	.09-1350	55	116	.31-621	30
	4	4.6	1.4-7.8	3	2.1	.11-4.3	4	441	211-606	7	178	31-350	6	125	.01-606	45	61	.11-350	29
Temperature, in °C	1	16	8.0-22	6	13	.5-25	5	15	7.5-21	6	17	6.0-21	4	13	1.5-22	20	17	.5-27	18
	2	16	11-22	6	14	.0-24	6	15	7.5-22	6	18	5.0-23	5	13	1.0-22	25	16	0-26	23
	3	14	11-25	6	12	.0-25	5	13	7.5-21	5	17	4.5-22	5	14	3.0-25	21	16	0-25	17
	4	16	9.0-21	3	9	.0-21	4	15	7.5-21	7	19	5.0-23	6	13	2.0-21	17	16	0-25	17
Dissolved oxygen, in mg/L	1	5.3	2.7-7.5	6	11	4.9-12	5	7.2	4.6-9	5	8.1	6.5-11	4	7.5	2.7-15	19	7.4	3.3-13	17
	2	6.2	1.6-11	5	7.4	3.6-13	5	6.9	4.6-10	5	8.2	5.9-12	3	7.5	1.6-13	23	7.4	1.8-13	18
	3	3.2	.8-4.9	6	10	2.9-11	5	5.9	5.0-8.0	4	7.6	5.1-12	4	5.9	.8-11	20	6.4	2.0-12	15
	4	6.4	3.6-10	3	6.4	2.8-10	4	6.2	3.6-9.5	6	7.1	5.3-11	4	7.0	2.4-13	16	7.1	2.8-12	14
Suspended sediment concentration, in mg/L	1	5	3-12	6	3	2-5	4	437	12-1260	7	194	8.5-482	5	94	2-1260	61	25	1-482	57
	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	19	7-37	5	12	5-18	5	334	12-776	6	313	54-716	5	74	4-776	54	121	2-716	30
	4	9	3-19	3	18	3-35	4	155	8-488	7	141	28-410	6	70	2-488	45	93	3-410	29
Suspended sediment discharge, in T/d	1	.05	.0-.14	6	.03	.01-.05	4	529	2.1-1400	6	79	8.7-319	5	94	0-1400	61	87	0-319	57
	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	.07	.01-.22	5	.13	.01-.41	5	1020	12-2560	6	395	26-1200	5	139	0-2560	54	122	0-1200	30
	4	.07	.04-.11	3	.06	.01-.17	4	225	7-676	7	49	12-117	6	40	0-676	45	22	.01-117	29

Means and ranges of dissolved oxygen concentrations for selected base flow and stormflow samples are presented in table 6, along with streamflow, temperature, and sediment data. These values reflect conditions during selected short-term periods and extreme flow conditions, and generally are not representative of the long-term mean and other statistical values characterizing specific study phases. Values presented in table 6, therefore, are not flow-adjusted, should not be used for determining trends, and only serve to illustrate conditions as they existed during selected low and stormflows.

Stream temperature data for Chicod Creek, site 2, were compared with air temperature data for the National Weather Service Station at Greenville. Statistical analyses of data prior to and during modifications indicate that no change in stream temperature attributable to channel modifications occurred. Although trees and brush along excavated channels were removed, the cleared areas were relatively small, and increases in stream exposure to solar radiation were insignificant.

Chemical characteristics

The chemical characteristics fall into the broad categories of major dissolved constituents, nutrients, minor elements, and pesticides. Mean concentrations and ranges of major dissolved constituents for the Chicod basin, sites 1 through 4 (fig. 1), during selected base and storm runoff conditions are listed in table 7. Table 8 lists similar information for nutrients and minor elements. Flow conditions often influence chemical quality in a stream, and maximum and minimum values of various constituents generally occur during extreme climatic events. In North Carolina, for example, concentrations of phosphorus are often greatest during floods, whereas calcium levels are usually greatest during droughts. Water-quality data representative of similar flow events must be compared, therefore, to minimize the bias caused by large variations in flow. In tables 7 and 8, data collected during extended dry periods were selected as representative of base runoff samples; those collected during the highest available flow conditions were selected as representative of storm runoff. During base-flow periods, streamflow consisted primarily of ground water; streamflow was composed primarily of overland runoff and shallow ground water during stormflow periods.

Analysis of the data was performed in three steps: base-flow and stormflow observations given in tables 7 and 8 were examined to ensure classification by type of flow; student's t-tests were determined for all data collected before versus all data collected during modifications on a site-by-site basis; and, analyses of covariance was performed only on data collected at site 2 because of the large amount of data available. Where results are termed statistically significant, the level of significance is 0.05 or less, unless otherwise stated.

Table 7.--Major dissolved solids for selected base-flow and storm periods and for all samples before and during modifications

[Site number refers to locations shown in figure 1; N is the number of samples; data in milligrams per liter except as indicated.]

Parameter	Site No.	Base-flow						Storm flow						All Samples					
		Before			During			Before			During			Before			During		
		Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	N
Calcium	1	18	11-29	6	22	14-25	5	7.0	3.3-14	5	9.6	6.9-13	5	13	3.3-29	19	17	6.9-26	19
	2	13	7.0-18	6	16	9.1-27	6	5.0	3.3-7.6	5	5.2	4.1-6.5	8	9.9	3.3-27	28	12	4.1-34	30
	3	24	12-41	6	23	17-28	5	4.2	3.2-5.0	4	5.5	4.4-6.7	5	15	3.2-41	21	16	4.4-28	17
	4	9.7	2.7-22	3	4.9	3.4-6.4	4	2.8	2.2-4.4	7	3.4	2.7-4.1	6	5.7	2.2-22	17	4.4	2.7-6.4	17
Magnesium	1	2.6	2.3-3.3	6	2.6	2.3-2.9	5	1.4	.9-2.4	5	2.2	1.6-2.6	5	2.3	.9-3.8	19	2.7	1.6-3.4	19
	2	2.2	1.6-2.8	6	2.4	1.3-3.1	6	1.0	.8-1.3	5	1.1	.9-1.4	8	1.9	.8-5.1	28	2.0	.9-3.3	30
	3	3.4	2.2-6.5	6	2.7	1.7-3.7	5	.9	.7-1.1	4	1.2	1.0-1.5	5	2.3	.7-6.5	21	2.3	1.0-4.0	17
	4	2.9	.9-6.6	3	1.7	1.2-2.3	4	.9	.7-1.6	7	1.2	1.1-1.5	6	1.7	.7-6.6	17	1.5	1.1-2.3	17
Sodium	1	7.1	6.4-8.0	6	6.6	5.9-7.4	5	3.4	2.0-5.7	5	4.7	3.7-5.4	5	5.8	2.0-8.2	19	6.4	3.7-9.5	19
	2	6.7	4.6-9.1	6	7.1	5.3-8.7	6	2.6	1.8-4.0	5	2.9	2.1-4.2	8	5.6	1.8-11	28	5.8	2.1-9.0	30
	3	8.4	6.5-12	6	8.6	6.6-11	5	2.2	1.7-3.3	4	2.8	2.2-3.8	5	6.0	1.7-12	21	6.7	2.2-15	17
	4	7.1	4.8-11	3	5.7	4.3-6.5	4	2.5	2.2-3.5	7	3.2	2.5-4.3	6	4.4	1.9-11	17	4.9	2.5-11	17
Potassium	1	3.7	2.4-7.2	6	3.1	2.3-4.0	5	2.8	2.2-3.3	5	3.5	2.5-4.4	5	3.1	2.1-7.2	19	3.7	2.3-5.6	19
	2	4.2	2.1-7.2	6	4.7	3.6-7.1	6	3.3	2.2-5.2	5	4.5	2.5-6.6	8	4.0	2.1-12	28	4.8	2.3-9.3	30
	3	7.8	3.2-20	6	7.5	3.3-17	5	2.7	2.0-3.9	4	3.6	2.7-4.5	5	5.3	1.9-20	21	6.2	2.6-17	17
	4	2.8	1.3-4.8	3	3.2	2.1-5.0	4	2.3	1.5-3.0	7	2.6	1.5-3.0	6	2.5	1.3-7.0	17	3.1	1.3-7.2	17
Bicarbonate	1	34	20-57	6	42	32-53	5	6.0	4.0-8.0	5	7.6	4.0-10	5	20	4-57	19	39	4-85	17
	2	35	15-58	6	52	26-94	5	8.0	6.0-9.0	5	14	10-24	6	21	6-59	28	37	10-94	21
	3	76	28-140	6	95	50-168	4	6.2	4.0-8.0	4	11	8.0-13	5	39	4-140	21	54	8-168	16
	4	7.0	3.0-12	3	13	9.0-28	3	4.7	3.0-9.0	7	5.8	4.0-9.0	6	8	2-39	17	12	3-49	15
Sulfate	1	26	13-61	6	24	13-35	5	15	8.8-24	5	22	17-29	5	21	8.8-61	19	21	8.5-35	19
	2	11	6.7-22	6	14	5.9-22	6	9.6	6.9-13	5	7.3	5.4-8.8	8	15	6.7-66	28	13	5.4-32	30
	3	11	2.9-22	6	19	6.5-31	5	8.4	6.0-11	4	9.3	7.3-11	5	15	2.9-49	21	17	6.5-31	17
	4	26	4.3-71	3	7.3	4.1-11	4	7.9	5.4-10	7	6.8	5.5-8.3	6	15	4.3-71	17	8.6	4.1-16	17
Chloride	1	12	11-15	6	12	11-14	5	5.7	2.8-10	5	7.1	4.7-9.1	5	10	2.8-15	19	11	4.7-14	19
	2	11	7.8-14	6	12	8.4-14	6	4.5	3.0-6.5	5	5.0	3.4-6.0	8	9.2	3.0-17	28	9.5	3.4-14	30
	3	13	9.4-19	6	14	13-16	5	3.7	2.5-5.2	4	4.6	3.3-6.4	5	10	2.5-19	20	10	3.3-16	17
	4	9.4	6.3-13	3	11	8-13	3	4.2	2.4-6.0	7	5.8	4.7-7.5	6	6.8	2.4-13	17	8.6	4.7-13	17
Fluoride	1	.2	.1-.4	6	.2	.1-.2	5	.1	.1	5	.2	.1-.2	5	.20	.10-.40	19	.20	.10-.20	19
	2	.2	.1-.8	6	.1	.1-.2	6	.1	.1-.2	5	.2	.1-.3	8	<.20	<.10-.80	28	<.20	<.10-.40	30
	3	.2	.1-.5	6	.2	.2	5	.1	.1-.2	4	.2	.1-.3	5	.20	.10-.50	21	.20	.10-.40	17
	4	.2	.1-.3	3	<.1	<.1-.1	4	<.1	<.1-.1	6	<.2	<.1-.2	6	<.10	<.10-.30	17	<.10	<.10-.20	17
Silica	1	10	5.8-14	6	10	8.9-12	5	3.8	2.0-6.0	5	4.7	3.0-6.4	5	7	2-14	19	9	3-12	19
	2	7.1	2.3-11	6	9.0	7.9-11	6	3.4	2.0-4.9	5	3.3	2.3-4.2	8	7	2-12	28	6	1.9-11	30
	3	11	8.0-13	6	9.3	6.8-12	5	2.4	1.9-2.9	4	3.0	2.6-4.2	4	7	1.9-13	21	7	2.6-12	17
	4	8.9	2.8-13	3	9.0	8.0-11	4	3.7	2.6-5.1	7	4.9	3.5-6.4	6	6	2.6-14	17	7	3.5-12	17
Dissolved solids	1	111	84-166	6	122	100-131	5	75	50-130	5	94	71-122	5	98	50-166	19	116	71-150	18
	2	98	67-157	6	104	82-130	6	65	49-93	5	64	53-75	8	85	48-206	28	97	53-152	29
	3	152	93-293	6	135	109-159	5	48	44-56	4	62	50-79	5	111	44-293	21	115	50-210	16
	4	100	50-158	3	78	62-84	4	56	45-74	7	61	49-83	6	75	45-165	17	73	49-97	17

Table 8.--Concentrations of nutrients and minor elements for selected base-flow and storm periods and for all samples before and during modifications in the Chicod Creek basin

[Site number refers to locations shown in figure 1; N is the number of samples; data in milligrams per liter except as indicated.]

Parameter	Site No.	Base-flow						Storm flow						All Samples					
		Before			During			Before			During			Before			During		
		Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	N	Mean	Range	N
Total nitrite	1	<0.02	<0.01-0.02	4	0.03	0.01-0.06	5	0.06	0.02-0.12	6	0.05	0.01-0.09	4	0.03	.01-.12	16	0.06	0.01-.43	18
	2	.02	.01-.02	5	.02	.00-.05	5	.04	.01-.07	7	.08	.01-.13	5	.04	.01-.17	26	.06	.00-.14	22
	3	.05	.01-.08	5	.03	.00-.10	4	.06	.02-.12	5	.07	.01-.11	4	.05	.01-.12	18	.07	.00-.26	16
	4	.01	.01	1	<.02	<.01-.04	4	.04	.01-.06	7	.04	.00-.07	5	.02	.01-.06	13	.03	.00-.07	16
Total nitrate	1	.54	.13-1.3	4	2.1	1.4-2.9	5	1.6	.64-4.8	6	1.8	1.1-2.3	4	1.4	.13-4.8	16	1.8	.24-3.6	18
	2	.83	.05-1.2	5	1.5	.95-2.2	5	.80	.30-1.9	7	.84	.41-1.2	5	.96	.05-3.8	26	1.3	.41-2.4	21
	3	.57	.08-1.4	5	1.3	.07-2.5	5	.60	.43-.88	5	1.1	.55-1.6	4	.82	.08-2.8	18	1.3	.07-2.5	16
	4	.17	.17	1	.67	.06-1.2	3	.50	.15-1.6	7	.70	.44-.92	5	.46	0-1.6	13	.86	.06-3.3	15
Total nitrogen	1	1.1	.49-2.0	6	3.1	2.2-4.5	5	3.5	1.8-6.2	6	3.7	2.8-5.5	5	2.3	.49-6.2	20	3.4	1.1-5.5	19
	2	1.7	.83-2.2	6	2.9	2.2-3.7	5	2.5	1.3-3.9	7	3.8	2.1-6.5	8	2.1	.83-6.5	30	3.1	.42-6.5	28
	3	6.7	.89-25	6	6.8	2.7-19	5	3.0	1.6-5.2	5	3.1	2.1-4.2	5	4.7	.89-25	22	4.7	2.1-19	17
	4	2.2	.84-5.0	3	1.9	1.3-2.7	4	2.0	.75-3.3	7	2.2	1.5-4.2	6	1.8	.75-5.0	17	2.4	1.3-5.6	17
Total kjeldahl nitrogen	1	.67	.37-1.1	8	.96	.5-1.8	5	1.9	.83-3.5	6	1.9	.9-4.3	5	1.0	.37-3.5	20	1.5	.46-4.3	19
	2	1.0	.76-1.3	6	1.2	.51-2.0	6	1.6	1.0-25	7	2.7	1.4-5.3	8	1.1	.42-2.5	30	1.8	.10-5.3	29
	3	6.3	.8-25	6	5.5	1.6-19	5	2.7	.99-4.4	6	2.0	1.5-3.0	5	3.9	.63-25	22	3.3	1.2-19	17
	4	.98	.66-1.5	3	1.1	.68-1.5	4	1.4	.60-2.8	7	1.4	.62-2.7	5	1.1	.37-2.8	17	1.4	.62-5.2	17
Total phosphorus	1	.13	.02-.20	6	.12	.08-.20	5	.49	.16-.93	6	.62	.18-2.0	5	.24	.02-.93	20	.34	.07-2.0	19
	2	.24	.16-.38	6	.37	.21-.49	6	.51	.37-.63	7	.64	.19-1.1	8	.29	.06-.87	30	.45	.15-1.1	29
	3	1.3	.60-2.6	6	.85	.35-2.2	5	.47	.37-.63	5	.84	.21-1.6	5	.66	.16-2.6	22	.85	.21-2.7	17
	4	.05	.04-.06	3	.09	.03-.15	4	.23	.05-.48	7	.20	.06-.30	6	.13	.02-.48	17	.15	.03-.30	17
Total copper, in µg/L	1	2	0-3	6	5	0-14	5	8	0-14	6	9	2-16	3	4	0-14	20	5	0-16	16
	2	5	2-14	6	9	0-20	6	7	0-22	7	7	2-13	5	6	0-23	30	7	0-20	20
	3	3	2-6	6	<3	<2-7	5	8	2-15	6	7	2-9	3	<4	<2-15	22	4	0-9	14
	4	<2	<2-2	3	<3	<2-9	4	<8	<2-<20	7	3	0-5	5	5	0-20	17	4	1-22	14
Total iron, in µg/L	1	1,000	500-1,400	6	670	300-1,400	5	5,600	1,000-13,000	6	2,800	890-5,500	3	2,400	180-13,000	20	1,400	300-5,500	16
	2	<770	<10-1,600	6	810	190-1,500	6	4,000	1,000-9,700	7	3,800	950-8.800	5	1,800	10-9,700	25	1,800	190-8,800	20
	3	1,800	920-2,700	6	1,100	530-2,100	5	4,800	1,000-9,000	6	3,800	740-6,000	3	2,400	250-9,000	22	1,800	530-6,000	14
	4	1,000	100-2,500	3	1,200	280-2,500	4	2,400	620-5,800	7	1,800	990-2,600	5	1,800	100-5,800	16	1,500	280-2,600	14
Total lead, in µg/L	1	10	2-17	6	3	0-9	5	15	4-45	6	8	0-16	3	10	2-45	19	3	0-16	16
	2	<11	<2-24	6	9	3-13	6	9	0-23	7	10	0-19	5	12	0-56	29	7	0-19	20
	3	8	0-15	6	3	0-5	5	12	0-38	5	13	1-23	3	9	0-38	21	6	0-23	14
	4	8	6-11	3	2	0-4	4	6	0-11	7	3	0-5	5	7	0-20	16	4	0-10	14
Total mercury, in µg/L	1	<.5	<.5-.5	5	<.2	<.1-<.5	5	<.5	<.5	3	<.1	<.1	3	<.5	<.5-.5	14	<.2	<.1-<.5	16
	2	<.5	<.5-.5	5	<.2	<.1-.5	6	<.5	<.5	4	<.1	<.1-.1	5	<.5	<.5-.5	21	<.2	<.1-<.5	20
	3	<.5	<.5-.5	3	<.3	<.1-<.5	5	<.5	<.5	3	<.2	<.1-.2	3	<.5	<.5-.5	15	<.2	<.1-<.5	14
	4	<.5	<.5	3	<.2	<.1-<.5	4	<.5	<.5	4	<.1	<.1-.1	4	<.5	<.5-.5	14	<.2	<.1-<.5	14
Total zinc, in µg/L	1	<30	<20-30	6	60	10-210	6	40	20-60	6	100	20-180	3	<30	<20-60	20	40	10-210	16
	2	<30	<20-50	6	50	10-110	6	<40	<20-60	7	50	10-130	5	<30	<20-100	26	40	10-140	20
	3	<20	<20-40	6	<20	<20-20	5	40	20-60	5	60	20-110	3	<30	<20-70	22	30	10-110	14
	4	<40	<20-60	3	<30	<20-30	4	<30	<20-40	7	20	10-40	5	<30	<20-60	17	30	10-110	14

1/ Analytical detection limit of mercury changed in 1979 from 0.5 µg/L to 0.1 µg/L.

Concentrations of the major dissolved constituents are usually at maximum levels during base-flow periods and tend to decrease with increased streamflow. Based on a small number of samples collected at site 1 and nearby wells during a base-flow period, Simmons and Aldridge (1980, p. 17) indicated that concentrations of most major dissolved constituents increase with depth in the ground-water system and that concentrations in the stream during base-flow periods are generally of the same order of magnitude as those in the uppermost surficial aquifer. Concentrations of these dissolved constituents in overland runoff during storm periods are generally lower, and storm runoff tends to dilute the more concentrated solution contributed by ground water.

Mean concentrations of most constituents were computed from equations derived by analysis of covariance for Chicod Creek, site 2, because this station has data in sufficient quantity to assure statistically reliable values. Of the parameters listed in table 7, the ones which showed significant changes during channel modifications were calcium, sodium, bicarbonate, and dissolved solids (table 9). At site 2, the overall increases in concentration were: calcium, 12 percent; sodium, 18 percent; bicarbonate, 84 percent; and total-dissolved solids, 18 percent. Excavations at several points along Juniper Branch and Chicod Creek intercepted fossil shell beds. Since these ancient shells are composed primarily of calcium carbonate, it is possible that the solution of these shell beds contributed to the increased concentrations of calcium, bicarbonate, and dissolved solids at the

Table 9.--Flow-adjusted mean concentrations, in milligrams per liter, of major dissolved constituents and total phosphorus for Chicod Creek, site 2, before and during channel modifications

Constituent	Flow-adjusted mean concentration		Percentage change (percent)
	Before modifications	During modifications	
Calcium	8.5	10	+12
Sodium	5.1	6.0	+18
Bicarbonate	19	35	+84
Dissolved solids	79	92	+18
Phosphorus, total	.26	.47	+80

Chicod site; and increases would be expected also in Juniper Branch. Concentrations are also influenced by ground-water discharge which contains a higher concentration of most major dissolved constituents than surface water.

Nutrients and minor elements are transported in both dissolved and suspended states. In the suspended state most of these constituents are generally attached to soil particles. During base-flow periods, these particles lie undisturbed on the ground or in the streambed. During high-flow periods or when the streambed is physically disturbed, the particles become suspended, causing concentrations of nutrients and minor elements which are readily adsorbed to increase. For this reason, these constituents often reach maximum concentrations during storm periods.

During base-flow periods, high nutrient concentrations occur, probably because of agricultural and livestock operations in the basin. In many places livestock have direct access to the stream for watering purposes, resulting in the direct input of fecal and other waste products to the stream. These wastes are a significant source of various forms of nitrogen. But in most cases, nutrient concentrations were generally higher during storm than base-flow periods. Except for phosphorus, significant differences were not found between nutrient concentrations before and during channel modifications.

Total phosphorus concentrations for storm and base-flow periods were generally much higher during than before channel modifications. Overall, the flow-adjusted mean phosphorus concentration at Chicod Creek, site 2 (fig. 1), increased about 80 percent during excavation, from a flow-adjusted average of 0.26 mg/L to 0.47 mg/L (table 9).

As expected, examination of table 8 indicates predominately higher mean concentrations of minor elements during stormflow than during base flow. Statistical analyses of concentrations before and during channel modifications, however, showed no systematic changes for any of the minor elements. The apparent change in mercury levels following excavation was actually caused by a change in laboratory analytical detection limits. The limits were decreased from 0.5 μg/L (micrograms per liter) to 0.1 μg/L in late 1979, causing the reported mean values before excavation to appear several times greater than those during excavation (table 8). Concentrations of nutrients and minor elements were well within limits recommended for domestic water supply sources (U.S. Environmental Protection Agency, 1980).

Pesticide analyses of bottom material and water samples collected at each site were performed at irregular intervals over a broad range of flow conditions. Analyses were also performed for two other groups of toxic organic compounds, polychlorinated biphenyl (PCB) and polychlorinated naphthalene (PCN). A total of 24 bottom material samples and 31 water samples were collected between February 1976 and June 1981 (tables 10 and 11). No significant differences were detected between constituent concentrations before modifications and those during modifications, except possibly during floods.

Table 10.--Concentration of selected organic compounds in bottom material samples collected at Chicod Creek basin sites

[Site number refers to locations shown in figure 1; BD denotes below detection level; concentrations in micrograms per kilogram.]

Site No.	Date	Chlordane	DDD	DDE	DDT	Dieldrin	Endrin	Heptachlor	PCB
1	February 2, 1976	BD	56	30	9.4	5.6	1.0	BD	BD
	November 22, 1976	BD	3.7	4.2	2.8	1.0	BD	BD	BD
	October 4, 1977	BD	BD	10	1.7	5.2	BD	BD	BD
	November 29, 1978	1.0	1.1	.7	BD	.7	BD	BD	BD
	April 24, 1979	BD	1.5	1.2	1.2	BD	BD	BD	BD
	October 23, 1979 1/	80	58	37	20	11	BD	BD	9
	March 7, 1980 1/	BD	15	2.5	12	4.3	.3	8.1	3
2	February 2, 1976	BD	12	15	6.5	3.4	.2	BD	BD
	November 22, 1976	BD	44	12	BD	7.6	BD	BD	BD
	October 4, 1977	BD	BD	BD	.1	.9	BD	BD	BD
	November 29, 1978	BD	4.4	1.5	.4	.9	BD	BD	BD
	April 23, 1979	1.0	BD	2.6	.5	BD	BD	BD	BD
	March 7, 1980 1/	2.0	5.8	18	2.0	2.8	BD	BD	BD
3	February 2, 1976	BD	1.5	BD	BD	BD	BD	BD	BD
	November 22, 1976	BD	5.1	3.5	BD	.8	BD	BD	BD
	October 4, 1977	BD	BD	BD	BD	2.0	BD	BD	BD
	November 29, 1978	BD	4.4	1.5	.4	BD	BD	BD	BD
	April 24, 1979	BD	.7	1.6	1.2	4.5	BD	BD	BD
	March 8, 1980 1/	BD	3.8	2.9	1.1	.8	BD	BD	3
4	February 2, 1976	BD	9.5	9.0	15	1.9	BD	BD	BD
	November 22, 1976	BD	9.0	2.5	BD	1.8	BD	BD	BD
	November 29, 1978	BD	2.5	BD	BD	1.0	BD	BD	BD
	April 23, 1979	BD	BD	.3	BD	BD	BD	BD	BD
	March 7, 1980 1/	1.0	1.8	3.2	.9	.3	BD	BD	25

1/ Sample collected during modification phase.

Table 11.--Concentration of selected dissolved pesticides, discharge and suspended-sediment concentration of in-stream samples at Chicod Creek basin sites

[Site number refers to locations shown in figure 1; BD denotes below detection level.]

Site No.	Date	Discharge (ft^3/s)	Suspended sediment (mg/L)	DDT (μg/L)	Dieldrin (μg/L)	Diazinon (μg/L)
1	February 2, 1976	56	39	BD	BD	BD
	June 2, 1976	.70	9	BD	.01	BD
	November 22, 1976	1.6	7	BD	BD	BD
	October 4, 1977	.19	12	BD	BD	BD
	November 29, 1978	1.1	3	BD	BD	BD
	April 24, 1979	3.0	9	BD	BD	BD
	October 23, 1979 1/	1.2	12	BD	BD	BD
	October 24, 1979 1/	1.5	21	BD	BD	BD
	March 7, 1980 1/	38	85	BD	BD	BD
2	February 2, 1976	375	68	.01	.01	BD
	June 2, 1976	5.6	26	BD	BD	BD
	November 22, 1976	8.2	9	BD	BD	BD
	October 4, 1977	.12	8	BD	BD	BD
	November 29, 1978	4.6	14	BD	BD	BD
	April 23, 1979	23	13	BD	BD	BD
	March 7, 1980 1/	632	53	BD	BD	BD
	June 7, 1981 1/	890	216	.01	.02	.01
3	February 2, 1976	288	128	.01	.02	BD
	June 2, 1976	.45	16	BD	BD	BD
	November 22, 1976	2.7	71	BD	BD	BD
	October 4, 1977	.39	7	BD	BD	BD
	November 29, 1978	1.8	5	BD	BD	BD
	April 24, 1979	6.7	12	BD	.01	BD
	March 7, 1980 1/	179	54	BD	BD	BD
4	February 2, 1976	70	50	BD	.01	BD
	June 2, 1976	3.5	15	BD	BD	BD
	November 22, 1976	4.6	3	BD	BD	BD
	November 29, 1978	.01	17	BD	BD	BD
	April 23, 1979	7.8	5	BD	.01	BD
	March 7, 1980 1/	212	28	BD	BD	BD
	June 7, 1981 1/	304	70	.01	.01	BD

1/ Sample collected during modification phase.

The more persistent pesticides, such as heptachlor and DDT, readily attach to clays and other fine soil particles. During intense storms, these particles are often transported from cultivated areas by erosional processes and eventually become deposited as bed materials along stream courses; thus, sediment serves as a sink for a number of chemical constituents. Exposure of these materials at later dates by excavation or by natural stream-channel degradation makes them available for fluvial transport, thereby producing elevated pesticide levels along the stream course during floods. As shown in table 11, detectable levels of several pesticides were found in the waters of Chicod Creek, site 2, and Cow Swamp during the flood of June 7, 1981. Laboratory detection limits for pesticides found in measureable concentrations during the study are given in table 12.

Table 12.--Detection limits of selected organic compounds in bottom material and water samples

Compound	Detection limit	
	Bottom material (µg/Kg)	Water (µg/L)
Chlordane	1	0.1
DDD	0.1	.01
DDE	.1	.01
DDT	.1	.01
Dieldrin	.1	.01
Endrin	.1	.01
Heptachlor	.1	.01
Polychlorinated biphenyls (PCB)	1	.10
Diazinon	.1	.01

In each sample of bottom material, at least one of the following compounds was detected: chlordane, dieldrin, endrin, heptachlor, PCB, DDT, DDD or DDE (table 11). No other pesticide or PCN was detectable, although usually several of the compounds listed above were present. Dieldrin, DDT, DDD, and DDE were most frequently detected.

While no specific pesticide was always present at detectable levels in in-stream water samples, dieldrin was found most frequently at all four sites and ranged in concentrations from less than 0.01 to 0.02 µg/L (table 11). DDT was detected at three sites, although less frequently, at concentrations up to 0.01 ug/L. No other pesticides were detected in water samples from sites 1, 3, and 4, although diazinon was detected at site 2.

Bacteria

The presence of fecal coliform and fecal streptococcus bacteria indicate fecal-waste contamination by warm-blooded animals. Biologists use the ratio of fecal coliform (FC) counts to fecal streptococcus (FS) counts to determine the source of the bacteria. A FC to FS ratio less than 0.7 indicates that the source of pollution is poultry or livestock, while a ratio greater than 4 suggests that human wastes predominate (Geldrich and Kenner, 1969). The majority of the ratios from samples taken in the Chicod Creek basin were less than 0.7 (table 13).

Table 13.--Bacteriological data for selected sites in the Chicod Creek basin before and during modifications

[FC/FS ratio: $\frac{\text{Fecal coliform, in colonies per 100 mL}}{\text{Fecal streptococcus, in colonies per 100 mL}}$]

Site No. 1/	Station Name	Modification Phase	Date	Time	Discharge (ft^3/s)	Fecal coliform (cols/100mL)	Fecal streptococcus (cols/100mL)	Ratio FC/FS
1	Juniper Branch near Simpson	Before	April 26, 1978	1645	637	3,500	7,200	0.48
			April 26, 1978	2100	398	3,700	7,400	.50
			November 29, 1978	1415	1.1	440	380	1.16
		During	November 6, 1979	1510	1.3	2,900	9,800	.30
			January 2, 1980	1330	2.9	76	510	.15
			February 13, 1980	1450	16	-	52	-
			November 17, 1980	1225	1.8	120	200	.60
			January 13, 1981	1300	4.2	1,200	210	5.71
			May 12, 1981	1430	1.6	170	88	1.03
			August 31, 1981	1700	3.8	160	220	.73
2	Chicod Creek at SR 1760 near Simpson	Before	November 8, 1977	1700	813	160	1,400	.11
			November 10, 1977	1200	260	120	1,200	.10
			April 27, 1978	0040	2,020	8,600	>2,000	-
			November 29, 1978	1300	4.6	660	770	.86
		During	November 5, 1979	1230	3.3	160	400	.40
			January 2, 1980	1100	14	120	100	1.20
			November 17, 1980	1440	3.8	72	28	2.57
			January 12, 1981	1330	20	150	980	.15
			January 13, 1981	1330	-	150	980	.15
			May 12, 1981	1345	76	700	4,100	.17
			June 7, 1981	0950	1,010	4,200	17,000	.25
			June 7, 1981	1300	890	4,900	9,600	.51
			August 5, 1981	1130	.16	96	420	.23
			August 31, 1981	1245	8.0	180	380	.47
			October 13, 1981	1515	-	20	-	-
			December 1, 1981	1450	.9	196	-	-
3	Cow Swamp near Grimesland	Before	November 8, 1977	1800	132	210	1,500	.14
			November 10, 1977	1400	47	140	1,700	.08
			April 26, 1978	1800	1,350	7,100	>2,000	-
			April 27, 1978	0000	1,070	6,100	7,800	.78
			November 29, 1978	1500	1.8	110	770	.14
		During	November 5, 1979	1400	2.6	14,000	10,000	1.4
			January 2, 1980	1255	8.5	76	400	.19
			February 12, 1980	1500	50	1,000	1,600	.62
			November 18, 1980	1015	3.0	210	320	.66
			January 13, 1981	1040	6.8	900	1,100	.82
			May 12, 1981	1000	5.0	1,200	35,000	.03
			September 1, 1981	1630	2.9	5,200	22,000	.24
4	Chicod Creek at SR 1565 near Grimesland	Before	November 8, 1977	1930	414	42	1,000	.04
			November 10, 1977	1600	119	12	600	.02
			April 26, 1978	1845	606	2,100	>2,000	-
			November 29, 1978	1600	.01	32	650	.05
		During	November 6, 1979	0900	2.0	200	240	.83
			January 2, 1980	1225	2.9	140	190	.74
			February 13, 1980	0930	58	80	60	1.33
			November 18, 1980	0845	1.0	64	260	.25
			January 13, 1981	0850	4.3	40	100	.40
			May 12, 1981	1245	46	370	2,200	.17
			June 7, 1981	1045	350	3,200	9,700	.33
			June 7, 1981	1340	304	1,900	9,000	.21
			June 8, 1981	1600	80	120	400	.30
			September 1, 1981	1400	2.5	120	790	.15

1/ Site number refers to locations shown in figure 1.

The bacteriological counts from periodic samples obtained before and during channel modification, along with instantaneous stream discharges and FC to FS ratios, are listed in table 13. In general, the counts were higher during periods having high streamflows, but occasional high counts also occurred during base-flow periods. For instance, the highest fecal coliform count, 14,000 colonies per 100 mL, was found during modification at Cow Swamp, site 3 (fig. 1), on November 5, 1979, during a low discharge of 2.6 ft^3/s; the highest fecal streptococcus count was reported at site 3 on May 12, 1981, when discharge was 5.0 ft^3/s. High coliform counts during low-flow conditions probably result from livestock operations in the basin. Fecal coliform and fecal streptococcus counts (table 13) before and during channel modifications were not significantly different. According to criteria established by the U.S. Environmental Protection Agency (1980), fecal coliform counts of streams in the Chicod Creek basin often exceed recommended limits for bathing waters and shellfish harvesting.

SUMMARY

Channel modifications caused significant changes in the hydrology of the Chicod Creek basin. Ground-water levels in shallow wells near Juniper Branch declined as much as 0.4 foot, while water levels in wells over 250 feet from the stream did not change significantly. Streamflow characteristics changed substantially during the modifications, especially at base flow. Minimum flows in Juniper Branch were less than 0.1 ft^3/s approximately 11 percent of the time before channel modification; during modification, minimum flows exceeded 0.4 ft^3/s at all times.

Stream-quality characteristics in three general categories were examined: physical characteristics, chemical characteristics, and bacteria. Only one physical characteristic, suspended sediment, showed a significant increase during channel modification. Examination of sediment-transport curves for Juniper Branch, site 1, confirmed that suspended-sediment discharge values associated with the streamflow range from 10 to 1,000 ft^3/s were generally greater during channel modifications than before. Daily mean sediment concentrations at both sites 1 and 2 were higher during construction than before.

Concentrations of the following constituents were higher during than before modifications: dissolved solids, 18 percent; calcium, 12 percent; sodium, 18 percent; bicarbonate, 84 percent; and phosphorus, 80 percent. An apparent decrease in mercury concentrations actually reflected a change in laboratory detection limits. Overall, no changes were found in pesticide concentrations in surface water or bottom material.

Bacteriological data indicate that surface water at all four sampling sites is subject to fecal contamination, most likely by domestic livestock or poultry. No significant change in bacteria counts occurred during channel modifications.

SELECTED REFERENCES

Coffey, A., 1982, Stream improvement: The Chicod Creek episode: Journal of Soil and Water Conservation, v. 37, no. 2, p. 80-82.

Daniel, C. C., III, 1981, Hydrology, geology, and soils of pocosins: A comparison of natural and altered systems, in Richardson, C. J., ed., Pocosin wetlands: Hutchinson Ross, p. 69-108.

Federal Interagency Work Group, 1977, National handbook of recommended methods for water-data acquisition: U.S. Geological Survey, Office of Water Data Coordination, 193 p.

Geldreich, E. E., and Kenner, B. A., 1969, Concepts of fecal streptococci in stream pollution: Journal of the Water Pollution Control Federation 41, part 2, p. A336-352.

Greeson, P. C., Ehlke, T. A., Irwin, G. A., Lium, B. W., and Slack, K. V., eds., 1977, Methods for collection analysis of aquatic biological and microbiological samples: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter A4, 332 p.

Heath, R. C., 1975, Hydrology of the Albemarle-Pamlico region North Carolina: U.S. Geological Survey Water-Resources Investigations 75-9, 98 p.

_____ 1980, Basic elements of ground-water hydrology with reference to conditions in North Carolina: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-40, 86 p.

Hem, J. D., 1970, Study and interpretation of the chemical constituents of natural water (2d ed.): U.S. Geological Survey Water-Supply Paper 1473, 363 p.

Herb, W. J., 1980, Sediment-trap efficiency of a multi-purpose impoundment, North Branch Rock Creek basin, Montgomery County, Maryland, 1968-76: U.S. Geological Survey Water-Supply Paper 2071, 41 p.

Langbein, W. B., and Iseri, K. T., 1960, General introduction and hydrologic definitions: U.S. Geological Survey Water-Supply Paper 1541-A, 29 p.

National Oceanic and Atmospheric Administration, 1981, Climatological data, annual summary, North Carolina, 1980: National Climatic Center, Asheville, North Carolina, v. 85, no. 13, 16 p.

Simmons, C. E., and Aldridge, M. C., 1980, Hydrology of the Chicod Creek basin, North Carolina prior to channel improvements: U.S. Geological Survey Open-File Report 80-680, 27 p.

Simmons, C. E., and Watkins, S. A., 1982, The effects of channel excavation on water-quality characteristic of the Black River and ground-water levels near Dunn, North Carolina: U.S. Geological Survey Water-Resources Investigations 82-4083, 28 p.

Steel, R.G.D., and Torrie, J. H., 1960, Principles and procedures of statistics: New York, McGraw-Hill, 481 p.

U.S. Environmental Protection Agency, 1980, Interim primary drinking water regulation, Federal Register, v. 45, no. 168, pt. IV, p. 57332-57357.

U.S. Geological Survey, issued annually for 1976-81 water years, Water resources data for North Carolina: U.S. Geological Survey, Water-Data Reports, Raleigh, North Carolina.

Wingate, P. J., and Weaver, E., 1977, Environmental assessment, Chicod Creek watershed, Pitt and Beaufort Counties, North Carolina, general report: North Carolina Wildlife Resources Commission, Raleigh, North Carolina, v. 1, p. 1-7.

Winner, M. D., and Simmons, C. E., 1977, Hydrology of the Creeping Swamp watershed, North Carolina with reference to potential effects of stream channelization: U.S. Geological Survey Water-Resources Investigations 77-26, 54 p.