THE EFFECTS OF CHANNEL EXCAVATION ON WATER-QUALITY CHARACTERISTICS OF THE BLACK RIVER AND ON GROUND-WATER LEVELS NEAR DUNN, NORTH CAROLINA

By Clyde E. Simmons and Sharon A. Watkins

U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS 82-4083

Prepared in cooperation with the
DEPARTMENT OF THE ARMY, CORPS OF ENGINEERS,
Wilmington District, North Carolina

Raleigh, North Carolina

1982

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UNITED STATES DEPARTMENT OF THE INTERIOR

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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	
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
yard (yd)	0.9144	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
	0.003785	cubic meter (m^3)
million gallon (10^6gal)	3785	cubic meter (m^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
	Flow	
cubic foot per second (ft^3/s)	28.32	liter per second (L/s)
	0.02832	cubic meter per second (m^3/s)
million gallon per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
gallon/day (gal/d)	0.0038	cubic meter per day (m^3/d)
	Temperature	
degree Fahrenheit (°F)	5/9(°F-32)	degree celsius (°C)
	Mass	
ton (short, 2000 pounds)	0.9072	metric ton (t)
	Conductance	
micromho (μmho)	1.000	microsiemen (μs)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to in this report as sea level.

THE EFFECTS OF CHANNEL EXCAVATION ON WATER-QUALITY CHARACTERISTICS OF THE BLACK RIVER AND ON GROUND-WATER LEVELS NEAR DUNN, NORTH CAROLINA

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ABSTRACT

Data were collected at three sites on the Black River near Dunn, North Carolina, to define the effects of channel excavation on water-quality characteristics and on ground-water levels in nearby areas. Background data were collected at a site upstream from the 5-mile-long excavated reach. Changes in hydrologic characteristics were determined from data collected before, during, and after the construction period 1976-81. Significant changes occurred in shallow ground-water levels, streamflow velocities, water temperatures, dissolved oxygen, and suspended sediment; little or no change occurred in pH, dissolved solids, nitrogen, phosphorus, and bacteria.

After deepening the channel more than 2 feet at site 3, water levels in observation wells within 100 feet of the stream declined a proportionate amount; however, water levels in a well 500 feet from the stream did not change. Flow velocities were 100 percent higher after construction than prior to and during construction. In-stream water temperatures were about one degree Celsius higher after removal of the trees and brush that provided shading along the channel. After construction, concentrations of dissolved oxygen also increased with the percent of saturation increasing 20 to 25 percent during periods of low streamflow. Maximum concentrations of suspended sediment increased from about 75 mg/L prior to construction to over 2000 mg/L during construction. Within a year after construction, levels of suspended sediment during stormflow had decreased but remained 5 to 10 times greater than pre-construction levels.

INTRODUCTION

Runoff from major storms has previously caused flooding of croplands, roads, and residential and commercial properties along the Black River in the vicinity of Dunn, Harnett County, North Carolina. The U.S. Army Corps of Engineers implemented flood-relief measures along the Black River consisting of channel realignment, deepening, and widening as authorized under Section 205 of the 1948 Flood Control Act. Construction work began at the downstream end of the 5.1 mile reach (fig. 1) in late 1978 and was completed in November 1979.

The effects of channel excavation on water-quality characteristics of streams and ground-water levels in nearby areas is not well known. Thus, at the request of the Corps of Engineers, the U.S. Geological Survey conducted this study to determine hydrologic conditions that existed in the excavated reach and nearby area of Black River prior to, during, and after construction. Hydrologic conditions evaluated consisted of selected water-quality characteristics of streamflow and ground-water levels in areas adjacent to the stream channel. The data-collection phase of the study began in 1976 and was completed in August 1981. An interim report by Simmons (1980) presented baseline data describing hydrologic conditions prior to construction.

Special acknowledgment is given to: E. G. Long and R. A. Phillips, Corps of Engineers, for their helpful suggestions on data collection phases of the project; C. C. Meshaw and R. M. Jackson, Corps of Engineers, for their timely and critical reviews of the text; and to Survey employees, R. G. Barker, R. G. Garrett, and S. S. Howe, who collected most of the field data.

BASIN DESCRIPTION

The Black River basin is in the western Coastal Plain region of North Carolina and drains a predominantly rural area which lies almost entirely in Harnett County (fig. 1). The Black River flows generally southward into Mingo Swamp, Cumberland County, to form the South River. For purposes of this report, the study basin is defined as the drainage area upstream from the bridge crossing on Secondary Road 1780, which is also the location of project site 3 (fig. 2). The basin above site 3 is about 49 mi^2 in size. Approximately 32 percent of the basin is in forests, 60 percent is in row crops and pastures, 6 percent is lakes and other waters, and 2 percent is urban and municipal. The small towns of Angier (population, approximately 1700), Coats (approximately 1380), Erwin (approximately 2830) and Dunn (approximately 9000) lie in or near the basin (fig. 1). Land surface elevations range from about 150 to 340 feet above sea level. The average stream gradient is about 4 1/2 feet per mile; bottom lands are generally flat and swampy.

Most of the basin is underlain by sedimentary deposits of Cretaceous age. The northern half of the basin is largely underlain by sands, silts, and clays of the Cape Fear Formation; whereas the southern half, including all of the reach scheduled for excavation, is underlain by similar deposits of the Black Creek Formation. Several small areas in the upper basin between the towns of Coats and Angier are underlain by highly weathered felsic volcanic rocks of precambrian age. Although sandy loams are predominant, soils throughout the basin range from clay loam to coarse sandy and gravelly loams. Numerous water-filled pits on the flood plain in the Dunn area are the result of commercial mining of these sand and gravel deposits. The mining operations began in the early 1960's and continue at several sites.

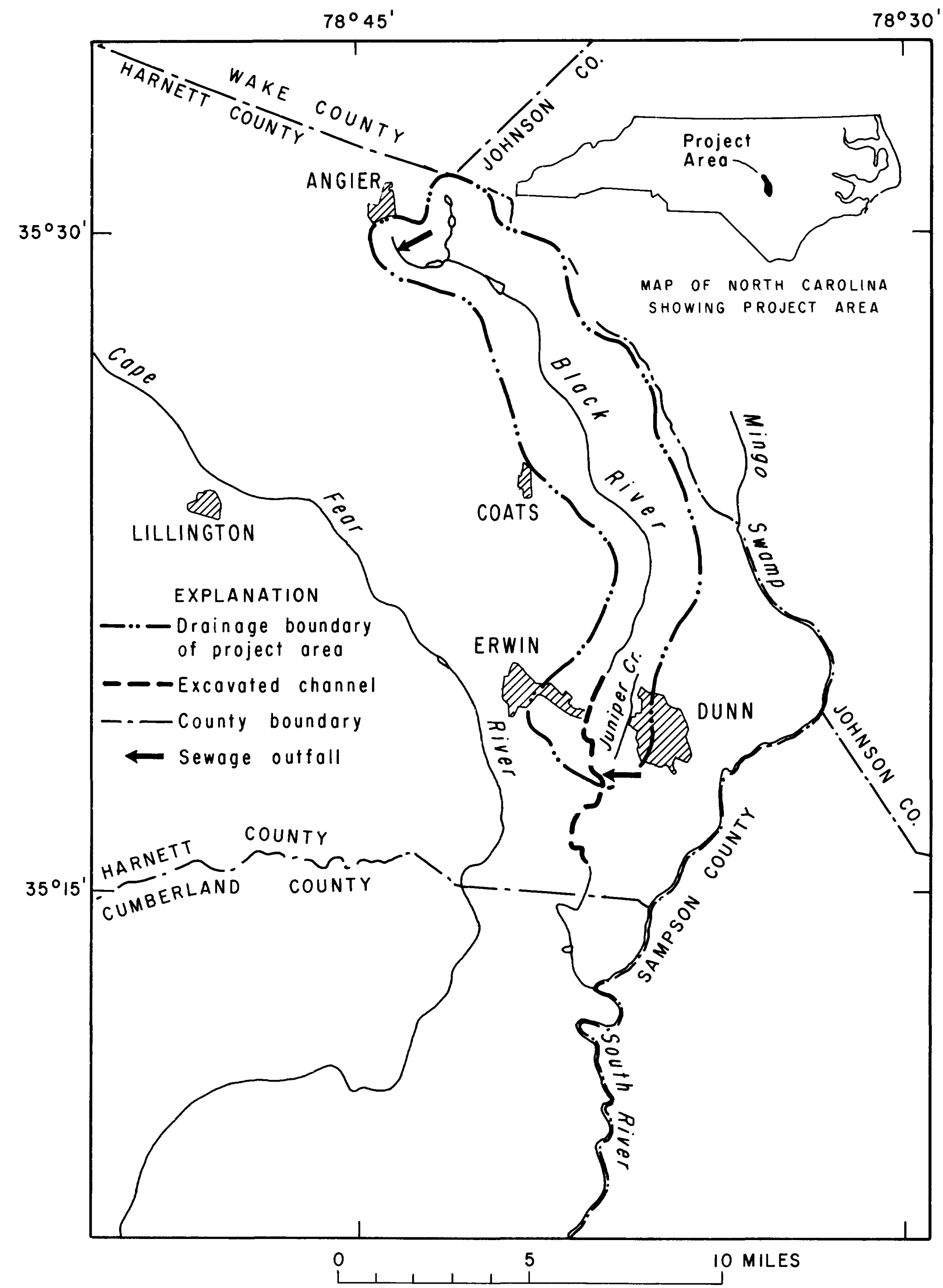

Figure 1.--Location of Black River and channel excavation project.

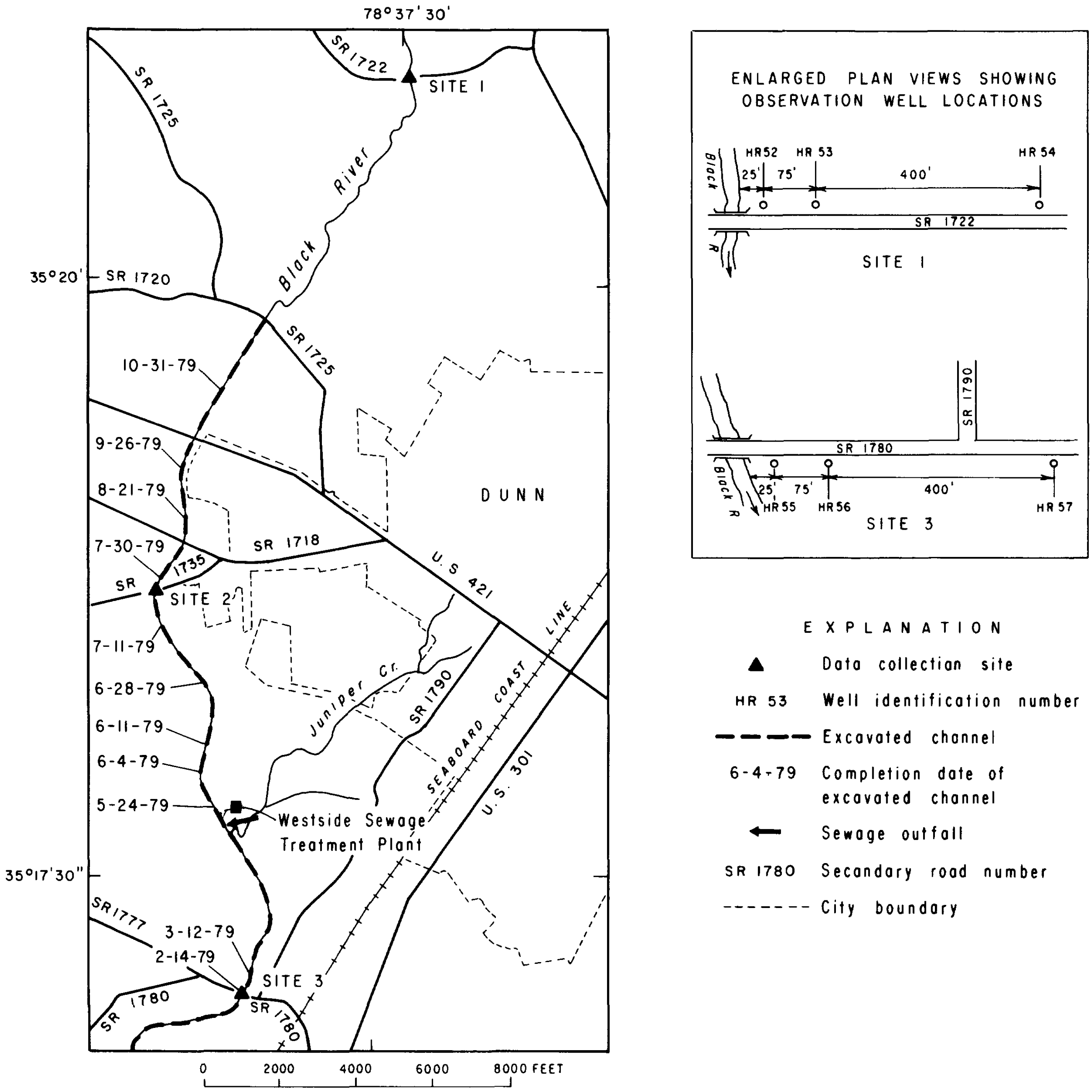

Figure 2.--Completion dates of excavated channel and data collection sites.

Urban and industrial developments influence stream quality in the basin. Municipal and industrial wastes discharge into the Black River at several points. During the study, the town of Angier discharged treated municipal sewage at an average rate of about 0.2 Mgal/d (million gallons per day) into the Black River (fig. 1). Prior to July 1980 two of three primary sewage treatment plants in Dunn also discharged into the Black River downstream from site 2 (fig. 2). Discharge from the relatively small treatment facility owned by Dunn Meat Packers averages about 0.1 Mgal/d. The city-owned Westside plant, located immediately above the confluence of Juniper Creek, discharged municipal and industrial wastes at an approximate average rate of 1.0 Mgal/d during 1978-79. The industrial wastes were primarily from two large food-processing plants and a carbon-brush plant. From October 1979 to July 1980, waste-discharge data for the Westside plant are unavailable. Construction of new facilities to replace the Westside plant began in late 1978 and was completed July 7, 1980. Effluent from the new plant is diverted to the Cape Fear River.

Farming is the primary source of income in the basin with soybeans, corn, and tobacco being the primary row crops. Pasture lands are used mostly for cattle grazing. Swine and poultry operations are numerous and are scattered rather uniformly throughout the basin. Much of the farmland is located near or adjoins water courses; consequently, runoff from these areas has an impact on stream quality.

The area has a moderate climate, an average January temperature of 6°C and an average July temperature of 26°C (National Oceanic and Atmospheric Administration, 1981). Average annual precipitation in the basin is approximately 45 inches. Annual precipitation during the study ranged from 39 inches during the 1976 WY (water year) to almost 54 inches during the 1979 WY. (A water year is the 12-month period October 1 through September 30.) Precipitation was generally well distributed throughout the study, and there were no occurrences of severe floods; however, the basin was affected by a prolonged drought during the summer and fall of 1981.

CHANNEL CONSTRUCTION

Channel construction began in October 1978 and was completed in November 1979. All timber and brush were removed from areas adjacent to the stream reach prior to construction. The clearing zone ranged from 110 to 150 feet wide (fig. 3). Approximately 280,000 cubic yards of material were excavated during construction (U.S. Army Corps of Engineers, 1976, p. 2). The new channel has a bottom width of approximately 35 feet and averages 2 to 4 feet deeper than the original channel (fig. 3). The new channel generally follows the original channel, but sharp meanders were bypassed to obtain a straighter channel. Except at bridge crossings, the excavated material was placed on the east bank. Spoil areas were shaped and seeded several months after excavation. A 4-foot low-flow channel, approximately 2 feet deep, was excavated in the bottom of the major channel (fig. 3). Channel conditions at site 3 prior to, during, and following channel excavation are shown in figure 4.

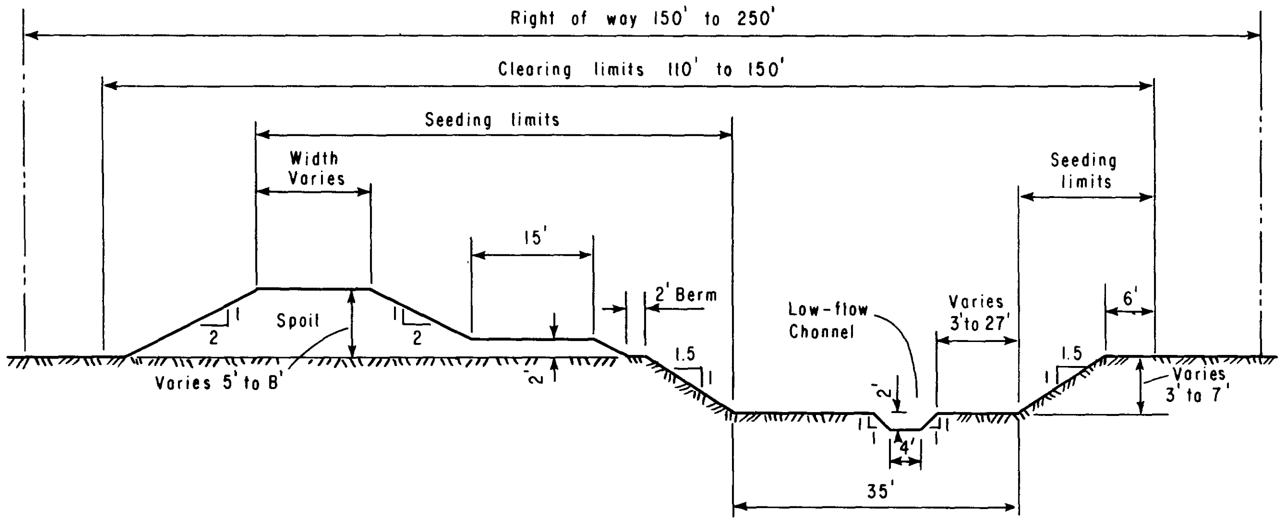

Figure 3.--Typical cross section showing channel construction and placement of excavated material (from U.S. Department of the Army, 1976).

The main channel was excavated primarily by tracked draglines which worked from timber pallets to prevent miring. Wheeled backhoes were often used for excavation of material from bridge openings, drainage ditches and culvert construction. Equipment breakdowns and high water delayed construction on several occasions. For instance, less than a quarter mile of channel was excavated during March and April 1979 because of high water. The location and dates of construction progress upstream from site 3 are shown in figure 2. Water-quality samples were collected on each date shown during construction.

DATA COLLECTION

Hydrologic data were collected at three sites in or near the study reach (fig. 2). Site 1 is located on Secondary Road 1722, approximately 1.5 miles upstream from the channelized reach. Data for site 1, which has a drainage area of 38 mi^2, are used for control, or background purposes. Three shallow observation wells, ranging in depth from 6 to 7 feet, were located at distances of 25, 100, and 500 feet from the east side of the stream at site 1 (fig. 2). All wells have 2-inch diameter polyvinyl choride casings and are screened with fiberglass opposite sand layers. Periodic water-level data for these wells were used to determine fluctuations in ground-water storage and the relation between ground-water levels and stream stage. Measurements of stream discharge were made throughout a wide range of flow conditions to establish a relation between stream stage and discharge. In-stream water-quality samples were collected for the determination of selected chemical constituents, suspended sediment, and other parameters listed in table 1. Continuous records of streamflow and ground-water levels were not collected at this site.

Figure 4.--Black River at site 3. A, Prior to construction, December 14, 1978; B, timber and brush removed, February 15, 1979; C, excavated channel, June 28, 1979; D, new vegetative cover, June 5, 1980. (Photographs by R. G. Barker and C. E. Simmons.)

Site 2, with a drainage area of 41 mi^2, is located at Secondary Road 1735 in the upper part of the excavated reach upstream from municipal and industrial waste outfalls for the Town of Dunn (fig. 2). Only in-stream water-quality data were collected at this site and they are used to evaluate the effects of channel excavation on selected parameters. Channel excavation reached this site on July 24, 1979.

Site 3 is located on Secondary Road 1780 about 1 mile upstream from the downstream end of the channelized reach (fig. 2). As at site 1, fluctuations of water levels in the shallow aquifer were determined by data obtained from three observation wells (fig. 2). Well HR55, located 25 feet from the stream, was equipped with a continuous water-level recording device, whereas periodic measurements were made at the other two wells. Periodic measurements of stream discharge and suspended-sediment samples were also obtained. Streamflow and water quality at this site are affected by variable waste discharges from municipal and industrial sources located in and near Dunn. Channel construction reached site 3 on February 14, 1979.

For comparative purposes, hydrologic data were generally collected on the same day at all three sites to minimize possible effects of variations in flow and climatic conditions. Water-quality samples were not collected during periods of zero flow. Consequently, data are not available for several months affected by severe drought conditions. Otherwise, sample collections were well distributed with respect to time and flow conditions throughout the study. Additional samples were taken to define water-quality characteristics of storm runoff.

Table 1.--Type and frequency of data collection at sites on Black River.
[Site number refers to locations shown in figure 2
Approximate frequency: C, continuous; M, monthly]

Site No.	Type and frequency of data collection											
	Stream discharge	Specific conductance	pH	Water temperature	Dissolved oxygen	Coliform bacteria	Dissolved solids	Nitrogen	Phosphorus	Organic carbon	Suspended sediment	Ground-water levels
1	M	M	M	M	M	M	M	M	M	M	M	M
2	--	M	M	M	M	M	M	M	M	M	--	--
3	M	--	--	--	--	--	--	--	--	--	M	C

In summary, data were collected at site 1 located upstream from the excavated reach, which served as a background site, and were collected at sites 2 and 3 located in the excavated reach. Data for sites 2 and 3 are compared with similar data from site 1 to define changes in hydrologic conditions during and following construction.

Hydrologic data collected for individual sites discussed in this report are contained in publications issued annually by the U.S. Geological Survey (1976-81).

METHODS OF DATA ANALYSIS

Simplified methods were used whenever possible to present comparative data describing effects or changes caused by channel excavation. In cases where changes are apparent, simple linear plots are used. All changes are verified by statistical testing.

Preliminary plots of the data indicated that for some water-quality parameters and physical characteristics, linear relationships seemed to exist between data collected at site 1 and data collected at site 2 or site 3. In addition, the grouped data collected before, during, and after construction showed apparent differences in mean value or slope in some cases. Analysis of covariance (Steel and Torrie, 1960) was used to test whether these apparent linear relationships and differences among groups were statistically significant. Where relations between data from two sites or differences between phases of construction are reported, the significance level of the overall test for fit is less than 1 percent.

CHANNEL AND FLOW CHARACTERISTICS

Prior to excavation, the Black River at Dunn was a sluggish, intermittent, black-water stream that is typical of most streams throughout the Coastal Plain region of North Carolina. The channel was frequently braided and meandering. Numerous deep pools and shallows alternated along its reach. Low-lying flood plains along its banks were swampy and generally covered with thick growths of cypress and sweetgum trees. Low, poorly defined stream banks allowed frequent flooding, and flood waters receded slowly because of impeded flow from heavy vegetation and numerous blockages by logs and debris.

After excavation, flow conditions in the new channel were significantly improved. Trees and other vegetation were removed. In most places the channel was lowered to establish a more uniform gradient, which also resulted in higher well-defined banks. Stormflow which previously would have caused overbank flooding is now confined within banks. Figure 5 shows the degree of flooding and flow velocity data for almost identical floods before and after channel excavation at site 3 (fig. 2). As shown, the flood stage for the same discharge was almost 4 feet less after excavation, and flow velocities in the new channel were more than double those in the former natural channel because cross-section areas were reduced by about 50 percent. The new channel is relatively uniform in configuration and lacks the deep pools and debris blockages that were formerly prevalent. To maximize hydraulic conveyance, the new channel was constructed as straight as possible; excavation followed the natural reach where possible but most sharp meanders were bypassed. Flow characteristics at low stages are also improved. At site 3 the new channel was excavated approximately 40 feet west of the existing channel as illustrated in figure 5.

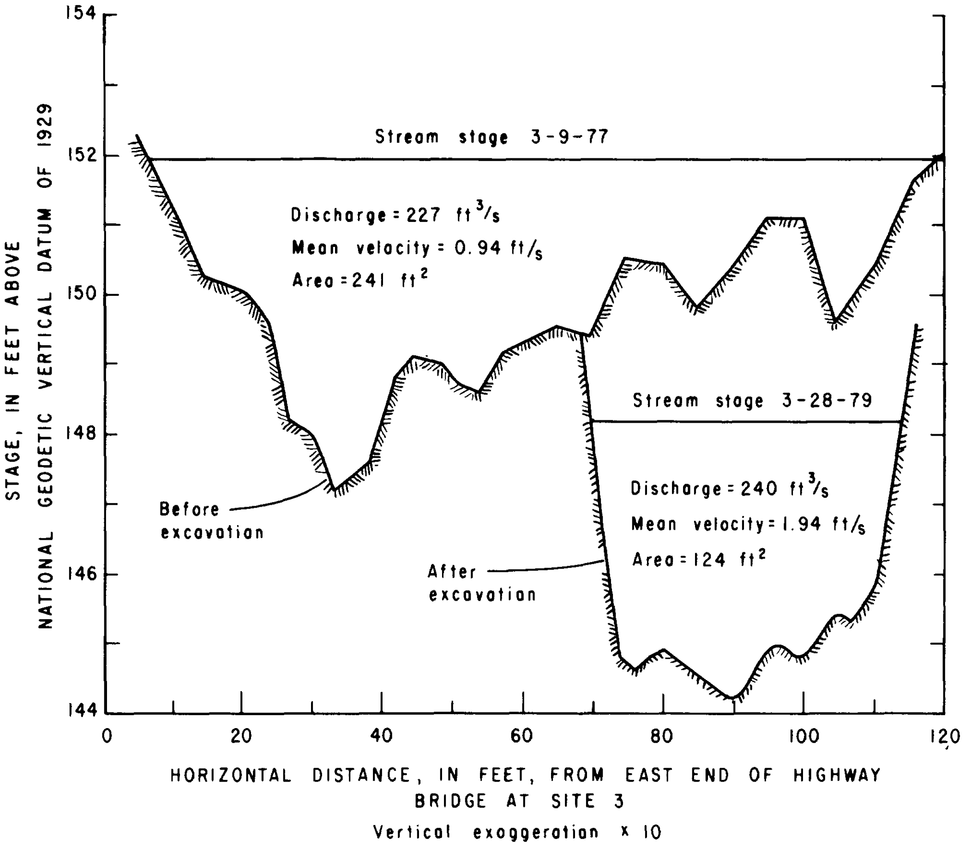

Figure 5.--Channel cross sections and streamflow characteristics at site 3 for comparable flows before and after channel excavation.

Bed-material characteristics in the excavated reach were also changed. Prior to excavation, the bed material was composed primarily of fine sand, silt and clay which was slightly cohesive. Its brownish color also indicated some organic content. The new channel was excavated into layers of unconsolidated clay, white sand and gravel. Because of the increased velocities, streamflow quickly carried off the finer materials, leaving behind a new channel bed of sand and rounded quartz gravel. Grass and other vegetation, which had begun to grow in the channel near the end of the investigation, might reverse this sandy condition, by entrapping silt and finer material if growth continues.

GROUND-WATER — SURFACE-WATER RELATION

There is a relation between flows in the Black River and ground-water levels in areas directly adjacent to the stream. Most of the valley and hillsides are underlain, at shallow depths, by highly permeable deposits of sand and gravel. The observation wells at sites 1 and 3, ranging in depth from 6.8 to 10.8 feet, are screened in these deposits, and the preconstruction channel breached the upper part of the deposits at various places throughout the basin. Ground water moves down gradient through this surficial aquifer to the stream. During periods of little or no rain, flow in the Black River is derived from ground water. Because of the high permeability of the soils in most of the basin, rainfall readily soaks into the ground and transits to the stream; consequently, a major part of high flows also is derived from ground water.

Water levels in the surficial aquifer and in the stream channel respond to climatic changes. Prior to channel excavation water-level fluctuations in wells within 100 feet of the stream were almost identical with those in the stream, but fluctuations in wells 500 feet from the stream were considerably subdued (Simmons, 1980, p. 8). On February 14, 1979, channel excavation reached site 3 and water levels in well HR55 began to decline as deepening of the channel progressed. By February 16, when construction at the site was completed, the water level in well HR55 had declined over 2 feet (fig. 6).

Although water levels in both the stream and HR55 were lowered after excavation, the magnitude and rate of change in fluctuations greatly increased. Before excavation, levels in the the stream and well responded slowly to rainfall, generally rising less than a foot in one day. Since excavation, both ground-water and stream levels often rise 2 or more feet in a few hours and also recede at a faster rate. Figure 7 shows the effects of nearly identical rainfall events on water levels in well HR55. Channel excavation did not change the physical characteristics of the surficial aquifer or the rate of recharge by downward percolation of rainfall. The excavation did, however, improve the flow characteristics of the stream channel, causing faster runoff and flood crests of shorter duration than under natural conditions. The changes in response characteristics noted in well HR55 after excavation indicate that water levels in the shallow aquifer near the stream are affected by stage of the stream, especially during stormflow. The abrupt rises in HR55 are caused by lateral recharge from the stream. This lateral recharge, or bank storage, is discussed by Rorabaugh (1964). The close relation between levels in the stream and in HR55 is shown in figure 8. An unknown but lesser effect on ground-water levels near the stream is caused by recharge from precipitation.

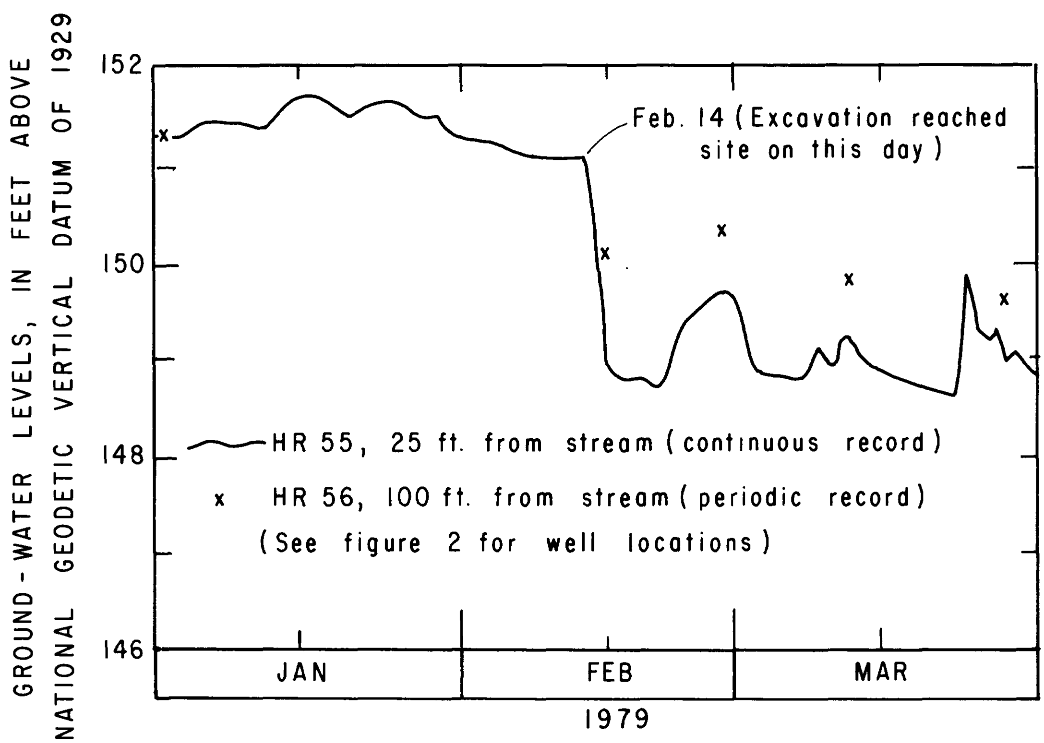

Figure 6.--Water-level fluctuations at wells HR55 and HR56 during channel excavation at site 3.

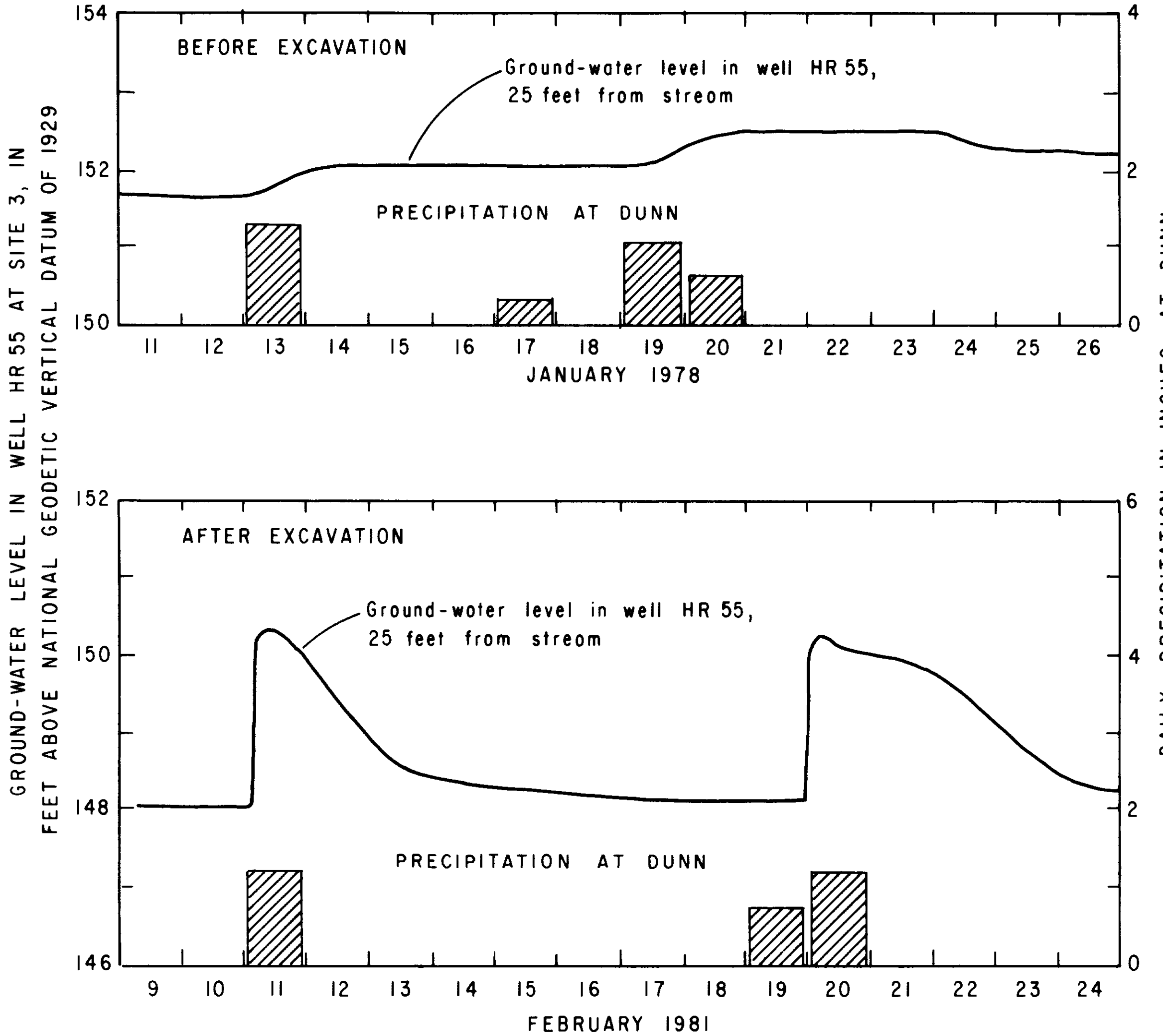

Figure 7.--Water-level fluctuations in well HR55 during similar storm periods before and after channel excavation.

Excavation also lowered the water level about 2 feet in well HR56, located 100 feet east of the stream; however, no significant change in water levels occurred in well HR57 500 feet from the stream (fig. 9). Because of the high transmissivity of the surficial aquifer, water levels in well HR56 also responded to high stages in Black River. The response characteristics in well HR56, which was measured periodically, are not as accurately defined as those in HR55, which was equipped with a continuous recorder.

The long-term impact of lowered ground-water levels on trees and other vegetation along the stream is unknown; however, numerous on-site inspections at sites 2 and 3 indicate that no apparent loss of trees or underbrush occurred through August 1981, when the project ended.

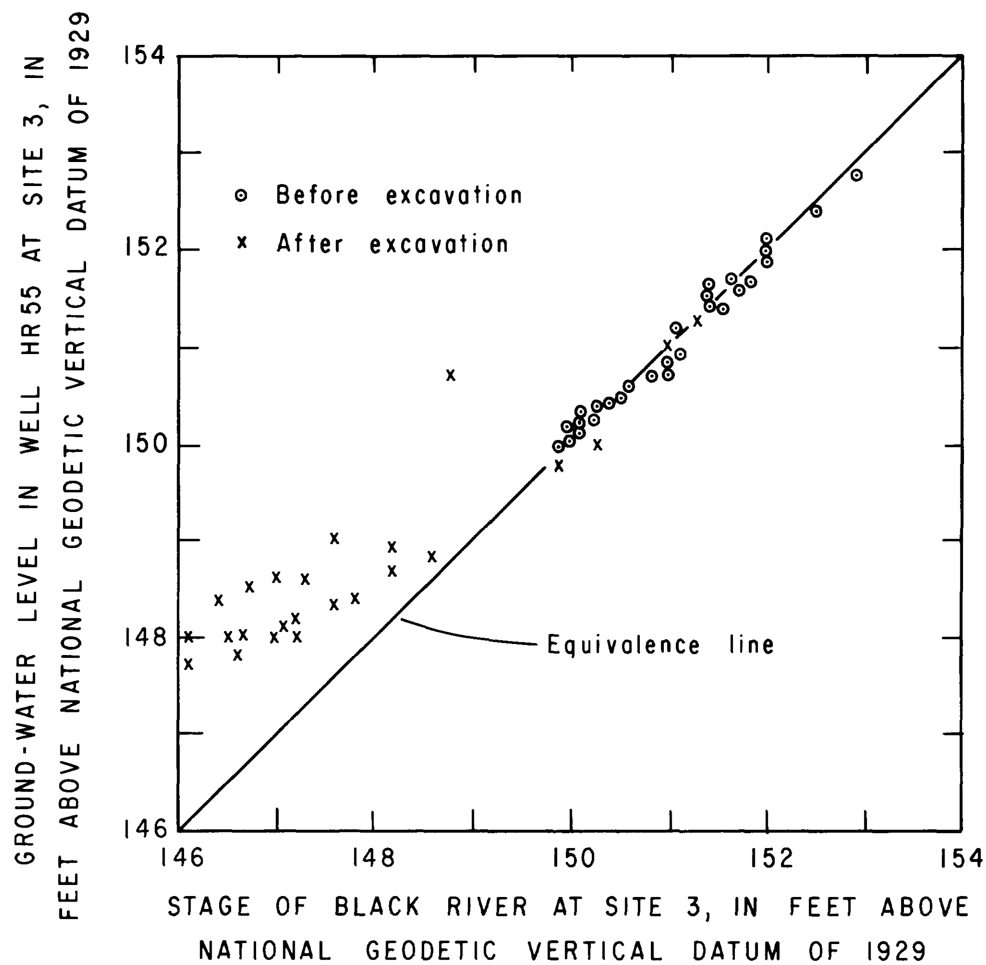

Figure 8.--Relation between stage of the Black River and water levels in observation well HR55 before and after channel excavation.

WATER-QUALITY CHARACTERISTICS

Because of the limited scope of this study, the number of water-quality parameters determined was minimal. Values of specific conductance, pH, water temperature and dissolved oxygen were determined at each site when sampled. Analyses were made on the total dissolved solids, which roughly approximate the sum of the major dissolved constituents, and on phosphorus, nitrogen and organic carbon. Characteristics of suspended-sediment transport were of special concern; therefore, a large number of suspended-sediment samples were collected for analyses. Because concentrations of most of these constituents vary with streamflow, a full range of flow conditions was sampled during each phase of the project.

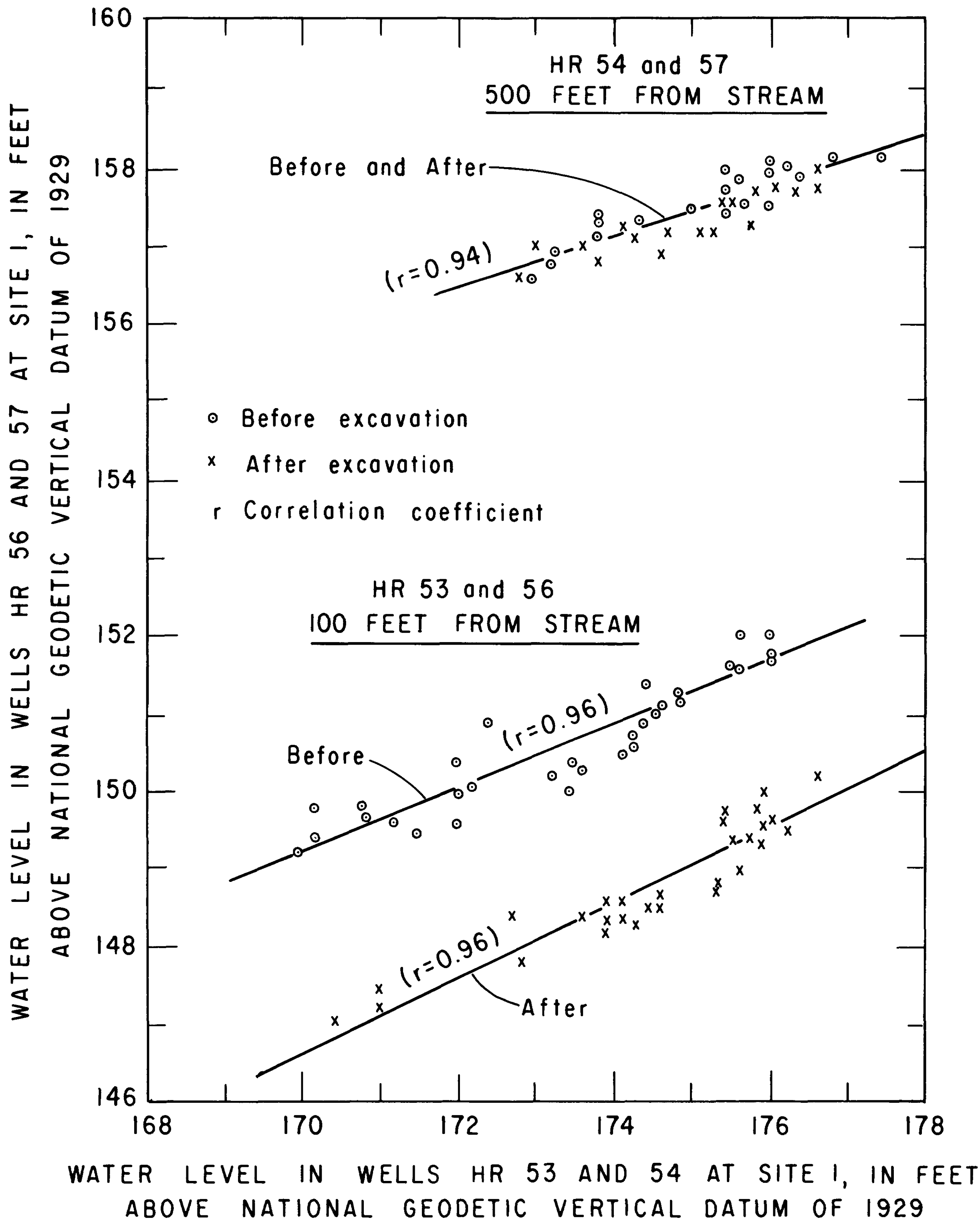

Figure 9.--Relation of ground-water levels in wells at sites 1 and 3.

Comparisons of constituent levels before and after excavation were usually stratified according to flow conditions. For example, several tables in the following sections include mean concentration values for constituents collected during base-flow and stormflow conditions. National Weather Service rainfall data, the continuous record from HR55 and records for nearby U.S. Geological Survey stream-gaging stations were used to classify flows. Base-flow samples were those collected during a steady-flow period preceded by at least seven consecutive rainless days. Only samples collected at or near the floodcrest were used in defining stormwater characteristics. A special effort was made, therefore, to determine mean concentrations for constituents sampled in each study phase that are reflective of similar flow ranges and antecedent precipitation conditions.

Again, the chemical-quality data presented in this report were collected upstream from major point sources of pollution and, therefore, do not necessarily reflect the quality of water found in the lower reaches of Black River downstream from Dunn.

Temperature

Water temperature is an important factor in water-quality studies because it not only influences both physical and chemical processes in the stream but also affects all biologic processes as well. The water temperature in the Black River is largely controlled by air temperature and direct solar radiation and, to an unknown but probably lesser degree, by the temperature of ground-water inflow. Prior to channel excavation, large trees and heavy brush formed a natural canopy over most of the study reach. The degree of shading was more pronounced during spring and summer because most of the vegetation was deciduous. During construction all vegetation within the clearing zone was removed, thereby increasing the effects of solar radiation. Comparisons of data show that daytime water temperatures at site 2 increased an average of about 1/2 to 1°C after the removal of brush and trees with maximum increases up to about 4°C (fig. 10). Simultaneous temperature data at sites 1 and 2 has a correlation coefficient of 0.74 before and after denudation. A brief summary of temperature data is given in table 2.

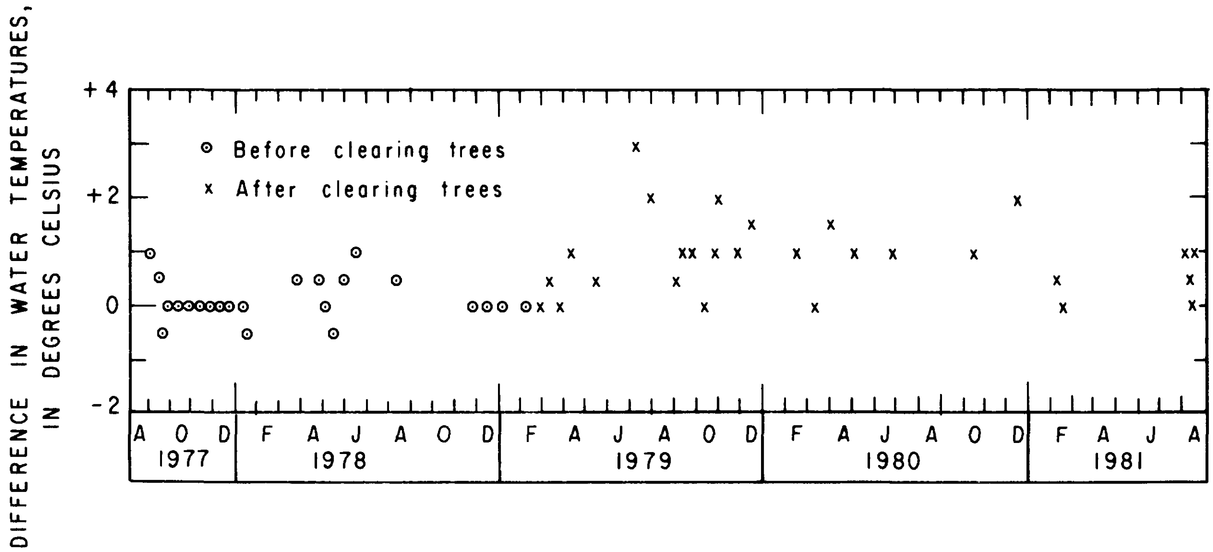

Figure 10.--Differences in simultaneous water temperatures between sites 1 and 2 before and after clearing trees and brush along excavated reach.

Table 2.--Summary of periodic streamflow and physical-quality data for the Black River before and after excavation

[Site numbers refer to locations shown in figure 2. The numerals in parentheses are the number of samples used in determining values]

Variable	Site	Base-flow conditions				Stormflow conditions				All samples			
		Mean		Range		Mean		Range		Mean		Range	
		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Streamflow	1	$29^{(4)}$	$34^{(4)}$	1.2-66	12-50	$340^{(5)}$	$290^{(8)}$	86-600	66-600	$115^{(33)}$	$160^{(23)}$	1.2-600	12-600
(ft^3/s)	3	$73^{(3)}$	$28^{(4)}$	2.4-115	0.15-56	$504^{(6)}$	$211^{(14)}$	210-900	77-505	$187^{(32)}$	$189^{(26)}$	1.4-900	0.15-505
Water temperature	1	$15^{(4)}$	$13^{(3)}$	4.0-24	3.5-20	$14^{(4)}$	$21^{(4)}$	7.5-20	15-24	$14^{(22)}$	$15^{(18)}$	0-24	2.0-24
(°C)	2	$15^{(4)}$	$15^{(3)}$	5.0-24.5	5.5-24	$14^{(4)}$	$22^{(4)}$	8.0-21	16-24	$14^{(22)}$	$13^{(18)}$	0-24.5	3.0-24
Dissolved oxygen	1	$7.4^{(4)}$	$7.5^{(3)}$	3.3-11.6	5.8-9.8	$6.6^{(4)}$	$10.6^{(3)}$	4.6-8.5	7.1-12.7	$6.9^{(22)}$	$8.3^{(14)}$	3.2-11.6	4.4-12.7
(mg/L)	2	$7.6^{(3)}$	$9.2^{(3)}$	2.6-10.8	7.7-11.0	$6.4^{(4)}$	$10.5^{(3)}$	4.1-8.6	8.0-13.2	$6.8^{(21)}$	$9.3^{(17)}$	2.6-11.4	5.5-13.2
Suspended sediment	1	$11^{(4)}$	$4^{(3)}$	5-28	3-5	$33^{(5)}$	$22^{(8)}$	15-66	4-30	$22^{(33)}$	$12^{(21)}$	1-81	2-35
(mg/L)	3	$13^{(3)}$	$18^{(4)}$	4-28	8-25	$32^{(6)}$	$202^{(14)}$	6-65	67-505	$15^{(32)}$	$117^{(26)}$	3-65	8-505

Dissolved Oxygen

Dissolved oxygen in water supports fish and other forms of aquatic life and is necessary to maintain a balanced biochemical environment. Dissolved-oxygen levels are generally a function of temperature and atmospheric pressure, with minimum concentrations usually occurring during summer and maximum values occurring during the colder winter months. The turbulence associated with rapids and other increased flow velocities also increases oxygen levels through the effects of aeration. Dissolved-oxygen concentration of 4 mg/L (milligrams per liter) is about the lowest level that will support a varied fish population (Ellis, 1937; Thompson, 1925).

As noted with the temperature data, concentrations of dissolved oxygen increased significantly at site 2 following channel excavation. Prior to the excavation, concentrations at all flow levels were about the same at sites 1 and 2 and were often less than 5 mg/L during base-flow periods (table 2). Concentrations in the new channel were seldom less than 5 mg/L, and, on the average, the percent saturation increased 20 to 25 percent in the lower ranges (fig. 11). The exact cause of this large increase is not known but is probably caused by increased turbulence from higher flow velocities throughout the new reach and by the excavation and removal of oxygen consuming organic material that had accumulated in the natural channel. The increase in stream temperatures after excavation was sufficient to lower corresponding oxygen values by 0.1 to 0.2 mg/L, although this amounts to only a few percent of the total concentration.

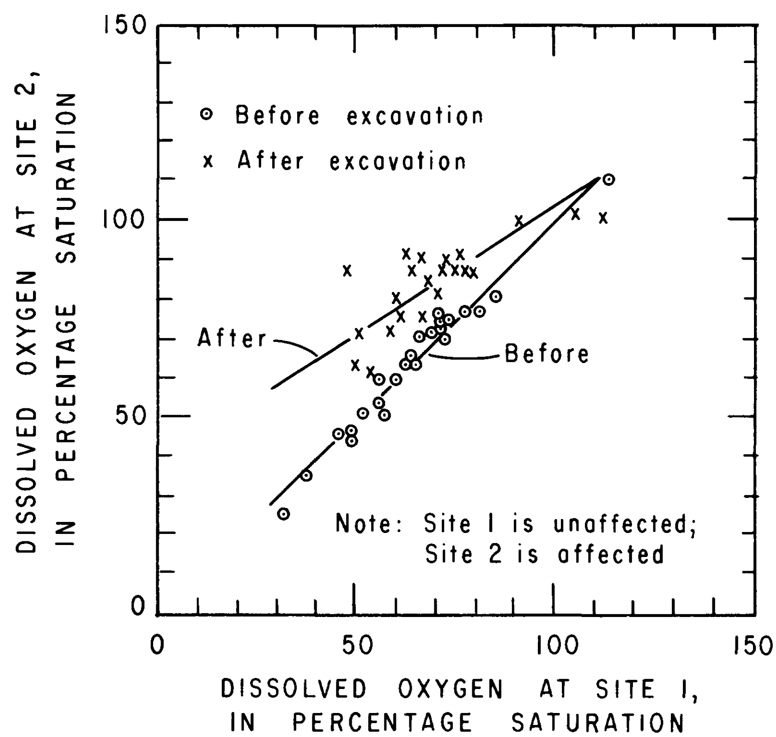

Figure 11.--Relation of dissolved oxygen at sites 1 and 2 before and after channel excavation.

Suspended Sediment

The sediment characteristics of the Black River are affected by land use, soil properties, type and degree of vegetative cover, flow velocities, channel and flood-plain characteristics, and various other factors. Channel excavation altered many of these factors and therefore impacted on sediment characteristics.

As in most North Carolina streams, suspended-sediment concentrations in the Black River vary with streamflow and reach maximum levels during floods. Prior to channel excavation, suspended-sediment concentrations at low and medium stages were generally less than 25 mg/L at site 3; concentrations during flood periods did not exceed 75 mg/L. As shown in table 2, concentrations at both sites 1 and 3 were in close agreement for similar flow conditions prior to the excavation. Although the natural channel was composed primarily of easily erodible silts and sand, flow velocities were usually insufficient to scour and transport bottom materials in large quantities. During floods, suspended material in overbank flow probably settled out of the slow moving waters that inundated the swamps and flood plains. A heavy growth of trees and brush and an intricate root system along the streambanks minimized bank scour as an added source of sediment.

During construction, concentrations at site 3 increased dramatically, and on several occasions, exceeded 2000 mg/L when flows ranged from 100 to 400 ft^3/s (cubic feet per second). Concentrations often exceeded 100 mg/L during dredging when flows were less than 10 ft^3/s. At site 3 and for at least a mile upstream, the excavated channel cut into extensive beds of sand and gravel which scour easily and cause bank failure. Large spoil piles placed within a few feet of the new channel also produced a new source of sediment by surface wash. Channel excavation increased flow velocities, which subsequently increased the transport capabilities of the stream and reduced the deposition of sediment on the flood plains by minimizing occurrences of overbank flooding. Dredging the stream channel also exposed fine material which previously had been buried and made it available for fluvial transport. Near channel completion, however, the spoil piles were reshaped and grass seeds were planted to reduce erosion.

Following excavation, suspended-sediment concentrations at site 3 decreased considerably. A year after construction, however, concentrations for comparable stormflows remained 5-10 times greater than those observed prior to excavation and concentrations ranged as high as 505 mg/L (table 2). The relation between stream discharge and suspended-sediment discharge for site 3 during the project is shown in figure 12. Because of the large amount of data available, data obtained prior to channel excavation are shown on a separate plot at the top of the page. The plots shown in figure 12 are sediment-transport curves. The suspended-sediment discharge for each data point was computed by multiplying the sediment concentration by the stream discharge at the time of sampling and by a conversion factor, 0.0027, to obtain units of tons per day. Figure 12 shows the average change in loads of suspended sediment at site 3 during and following channel excavation. Samples collected during the storm of August 12-14, 1981 are of special interest because they indicate a significant decrease in concentrations when compared to other samples collected during and after channel construction. Based on field inspections, thick grass covered the streambanks and cleared areas during early spring of 1980 and appeared to improve bank stabilization

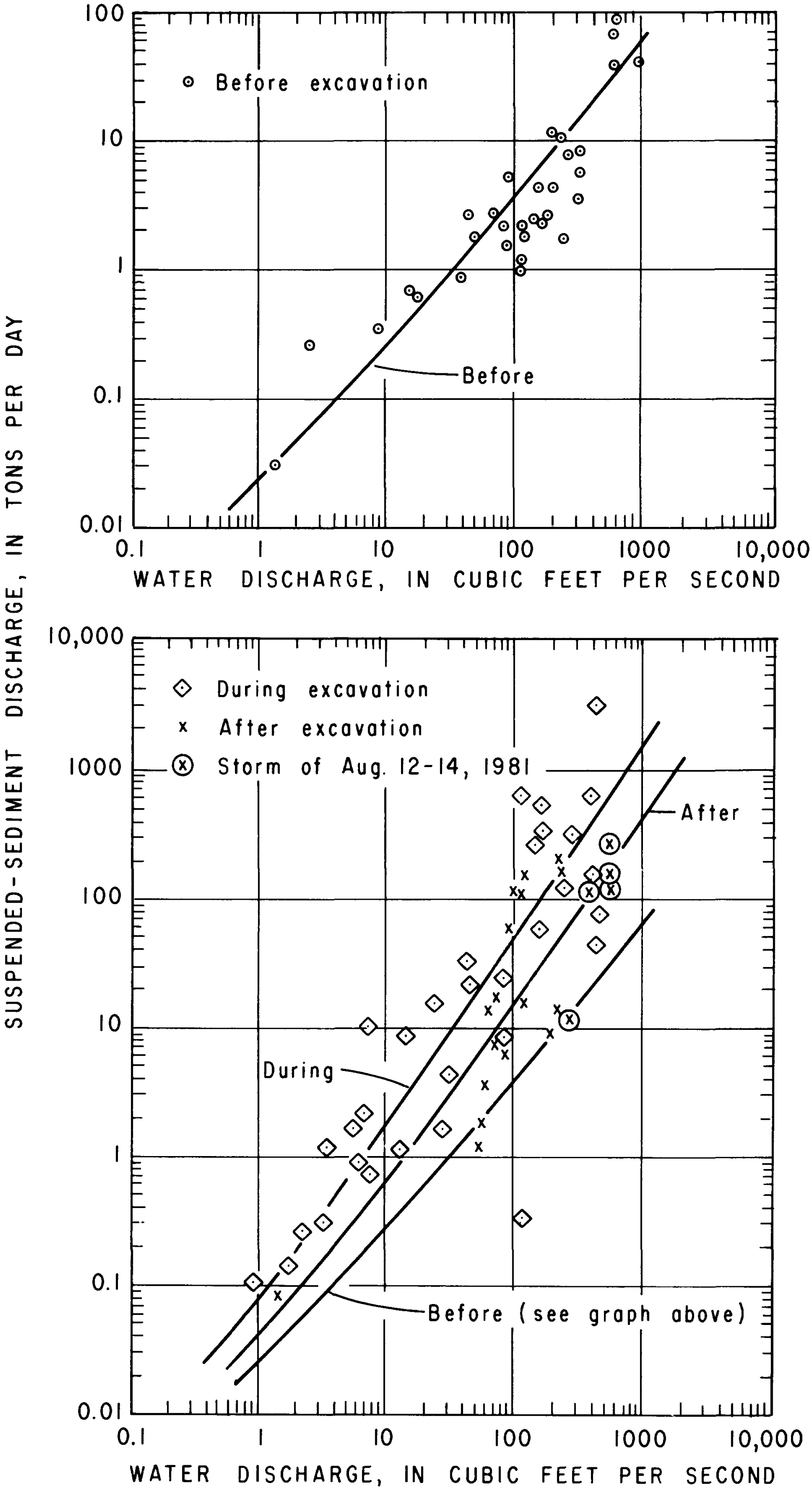

Figure 12.--Sediment-transport characteristics for site 3 before, during, and after channel excavation.

and reduce erosion. By late summer of 1980, a prolific stand of grass and small brush was also growing in much of the channel. The new vegetative cover probably influenced the reduction in sediment concentrations noted during the August 1981 flood which possibly suggests a trend towards pre-excavation conditions.

In addition to suspended material, an unknown amount of sediment was also transported as bed discharge or bedload through the new reach after construction. Unlike suspended material, bed discharge is the material that moves by rolling or bouncing along the stream bottom in the direction of flow. Conventional sampling methods only measure sediment to within about 3 1/2 inches of the stream bottom, thereby excluding bed-discharge measurement. Based on field observations and photographs of the channel, considerable movement and formation of sandbars and deltas from bed discharge movement probably occurred during and immediately following construction. Within several months following construction, the 4-foot wide low-flow channel (fig. 3) in the vicinity of sites 2 and 3 was filled with sediment and was not discernible throughout the remainder of the project.

pH, Dissolved Solids and Specific Conductance

Streams of the Coastal Plain region generally have acidic waters and the Black River, with pH values ranging from 4 to 7 units, is no exception (table 3). Statistical testing showed a strong relation between simultaneous pH values obtained at sites 1 and 2 during each phase of the project. Identical values of pH were often observed at both sites on the same day. Although subtle changes in pH may have occurred, the data collected indicate that the effects of excavation on pH were not detectable.

Values of dissolved solids (residue at 180°C) and specific conductance decrease with increases in flow (table 3). Specific conductance is affected by the chemical ions in solution, and is therefore closely related to the concentration of dissolved solids. Both parameters respond similarly to changes in streamflow. Figure 13 shows the correlation in dissolved-solids values between sites 1 and 2. Although values for same-day sampling are similar for both sites in the 40-60 mg/L range, concentrations in the 90-110 mg/L range at site 2 appear to be somewhat less than corresponding values at site 1. Because the higher-range values reflect conditions at low flow, however, this difference might be caused by significant differences in water discharge between the two sites at the time of sampling. Higher flows, generally more dilute, were often sampled at site 2. As shown in figure 13, statistical testing indicates that a strong correlation existed for dissolved solids at the two sites and that excavation probably had little or no effect on this relation.

Nutrients

The nutrients, phosphorus and nitrogen, are available from many sources throughout the basin. In heavily farmed areas, such as the Black River basin, water-quality characteristics often reflect nutrient concentrations because of storm runoff from fertilized croplands, pig farms, or grazing areas. However, detection of trends in concentration of constituents and causative factors is difficult because of the numerous variables affecting the system.

Table 3.--Summary of chemical-quality data by flow conditions for the Black River before and after excavation

[The numerals in parentheses are the number of samples used in determining values]

Variable	Site	Base-flow Conditions				Stormflow Conditions				All Samples			
		Mean		Range		Mean		Range		Mean		Range	
		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Specific conductance (µmho)	1	61(4)	103(3)	50-76	98-110	48(15)	49(4)	37-60	45-56	60(29)	67(18)	37-115	45-110
	2	62(4)	93(3)	52-75	83-105	48(15)	54(4)	35-63	53-58	61(29)	67(21)	35-117	42-110
pH	1			4.5-6.2	4.8-5.7			4.7-6.0	4.7-6.0			4.1-6.9	4.6-7.2
	2			4.7-6.4	4.7-5.7			4.9-5.6	4.8-6.0			4.1-7.3	4.6-7.0
Dissolved solids at 180°C (mg/L)	1	86(4)	96(3)	74-100	75-107	48(5)	66(4)	37-60	63-70	65(27)	69(18)	37-108	46-107
	2	87(4)	93(3)	74-104	75-108	51(5)	70(4)	40-64	62-76	67(28)	67(21)	40-104	40-108
Nitrate nitrogen (mg/L)	1	.03(3)	.04(3)	.01-.05	.02-.06	.20(5)	.11(3)	.00-.54	.08-.13	.14(23)	.17(14)	.00-.54	.01-.95
	2	.07(3)	.03(3)	.01-.08	.00-.06	.22(5)	.17(4)	.00-.46	.12-.26	.14(23)	.19(16)	.00-.46	.00-.80
Nitrite nitrogen (mg/L)	1	.01(3)	.00(3)	.00-.01	.00-.01	.01(5)	.01(4)	.01-.03	.00-.01	.01(23)	.01(17)	.00-.03	.00-.05
	2	.01(3)	.00(3)	.01	0	.01(5)	.01(4)	.01-.02	.00-.01	.01(23)	.01(21)	.00-.02	.00-.04
Ammonia nitrogen (mg/L)	1	.03(3)	.14(3)	.01-.05	.00-.38	.08(5)	.06(4)	.00-.30	.03-.09	.05(22)	.09(16)	.00-.30	.00-.38
	2	.01(3)	.03(3)	.01-.02	.00-.08	.04(5)	.07(4)	.00-.13	.03-.13	.02(23)	.05(21)	.00-.13	.00-.15
Organic nitrogen (mg/L)	1	.58(3)	.68(3)	.44-.72	.62-.73	.44(3)	.68(3)	.41-.47	.67-.70	.55(10)	.63(15)	.10-.96	.25-1.2
	2	.51(3)	.56(3)	.42-.60	.40-.71	.36(3)	.76(4)	.31-.40	.69-.87	.55(10)	.63(21)	.07-.90	.34-1.10
Total nitrogen (mg/L)	1	.67(3)	.71(3)	.54-.80	.64-.78	.74(3)	.87(3)	.51-.97	.86-.87	.68(9)	.88(16)	.33-1.0	.44-2.5
	2	.62(3)	.62(3)	.53-.71	.40-.74	.60(3)	1.0(4)	.41-.78	.93-1.2	.70(10)	.86(21)	.21-.96	.40-1.8
Ortho phosphorus (mg/L)	1	.01(4)	.01(3)	.00-.03	.00-.01	.02(4)	.05(4)	.00-.05	.03-.07	.02(26)	.03(18)	.00-.14	.00-.15
	2	.01(4)	.01(3)	.00-.03	.00-.01	.02(5)	.05(4)	.00-.05	.03-.08	.01(28)	.03(21)	.00-.05	.00-.14
Total phosphorus (mg/L)	1	.05(3)	.05(3)	.03-.09	.00-.03	.05(4)	.09(4)	.03-.10	.06-.12	.06(21)	.07(18)	.00-.30	.00-.30
	2	.03(3)	.04(3)	.02-.06	.03-.05	.07(5)	.12(4)	.03-.14	.07-.19	.05(22)	.07(21)	.01-.20	.01-.29
Organic carbon (mg/L)	1	10(4)	15(3)	7.5-16	13-19	14(5)	18(4)	7.9-31	14-19	9.9(28)	14(18)	4.9-31	4.7-22
	2	10(4)	16(3)	7.3-15	11-22	14(5)	18(4)	8.4-27	15-20	11(28)	13(21)	5.9-27	5.0-22

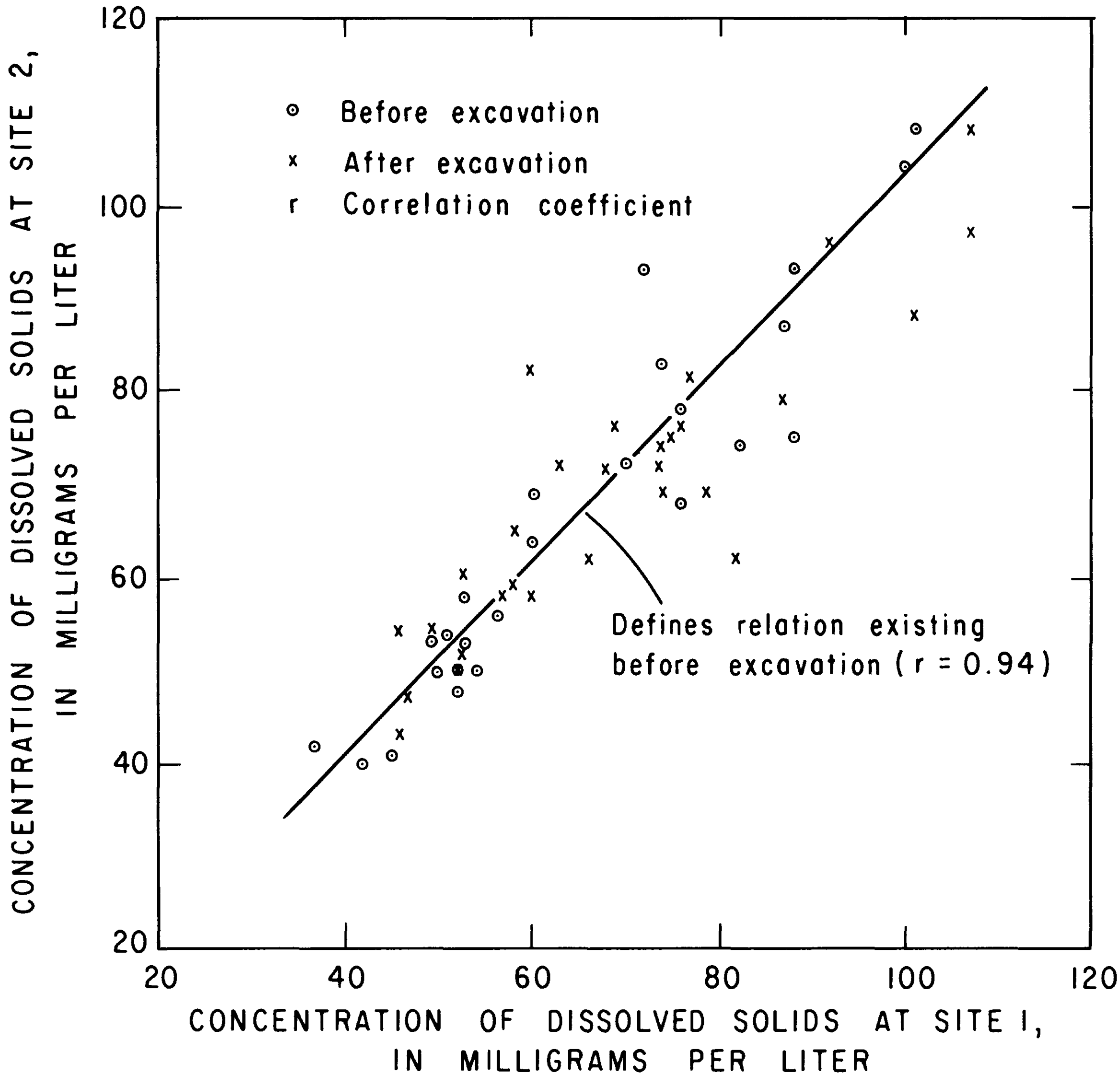

Figure 13.--Relation of concentrations of dissolved solids at sites 1 and 2 before and after channelization.

In many areas throughout the basin farm animals have direct access to the main stream and tributaries and animal wastes may affect water quality at all levels of flow. Municipal sewage from the town of Angier, located about 12 miles upstream from site 1, might also influence stream quality, particularly at site 1 (fig. 1).

Nutrient data collected are representative of flow conditions that occurred during each phase of the study; however, the variability of the data generally preclude definitive evaluation (table 3). For instance, concentrations of phosphorus and nitrogen were greatest during high flows, although on several occasions above average concentrations of phosphorus and nitrogen occurred during both storm and base-flow conditions, indicating little relation with stream discharge. Concentrations of phosphorus on May 28, 1981, during a base-flow period (16 ft^3/s at site 1), ranged from 0.29 - 0.30 mg/L and nitrogen ranged from 1.8 - 2.5 mg/L at sites 1 and 2 respectively (fig. 2). These values were several times higher than average levels and possibly reflected a short-term slugging from an upstream waste source.

Concentrations of total nitrogen, nitrate, and phosphorus collected simultanously at sites 1 and 2 are shown in plots in figure 14. Note that the diagonal line in each plot defines the line of equal fit (1:1 slope) and is not a fitted regression line of the data. Total nitrogen and phosphorus show some correlation between sites 1 and 2; however, the plot of nitrate (as nitrogen) indicates a relatively good correlation. The distribution of data points in each plot probably indicates that significant changes in nutrient characteristics have not occurred in the study reach following channel excavation.

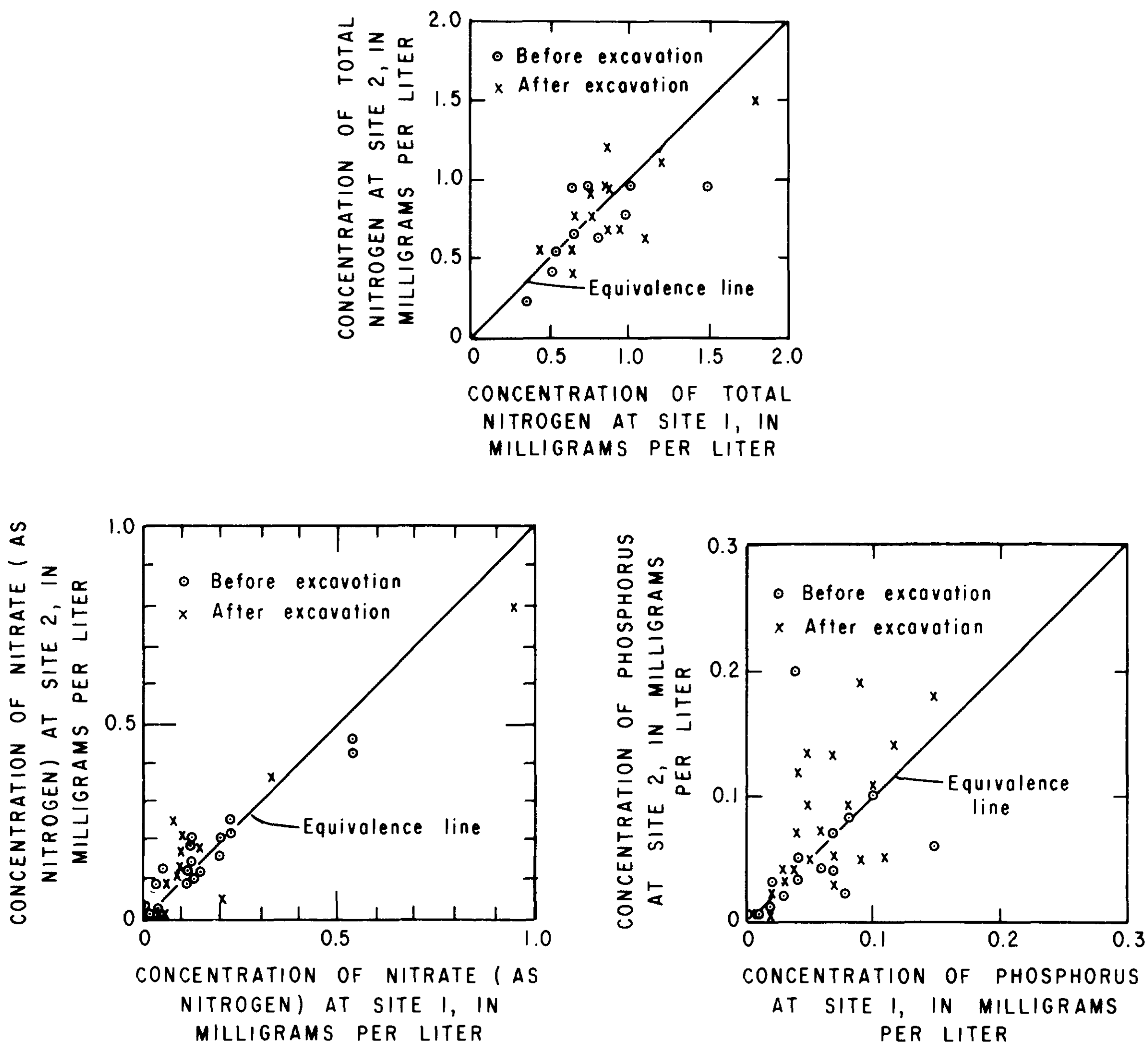

Figure 14.--Comparisons of nutrient concentrations for sites 1 and 2 before and after channel excavation.

Bacteria

In-stream values of fecal coliform and fecal streptococci are listed in table 4 for selected flows. Both forms of bacteria are found in the intestines and feces of warm-blooded animals, and their presence in water is considered to verify fecal pollution. The ratio of fecal coliform (FC) to fecal streptococci (FS) is a useful indicator of the source of the bacteria. Ratios less than or equal to 1.0 indicate pollution from livestock or poultry, whereas ratios between 2 and 4 generally suggest a presence of human wastes (Geldreich and Kenner, 1969). As shown in table 4, most ratios FC/FS, are about 1.0 or less, thereby indicating that animal wastes are the most probable source of bacteria in the study reach. Storm runoff from animal-inhabited areas, such as feedlots, probably caused the project's maximum observed bacteria levels which occurred during the flood on August 12, 1981 (table 4).

A plot of fecal coliform data collected simultaneously at sites 1 and 2 is shown in figure 15. On the average, most values compare reasonably well with the line of equality, thereby indicating similar bacterial levels at both sites. Only eight bacteria samples were collected prior to channel excavation; however, as shown in figure 15, the concentrations covered a wide range in values and compare favorably with data collected after excavation.

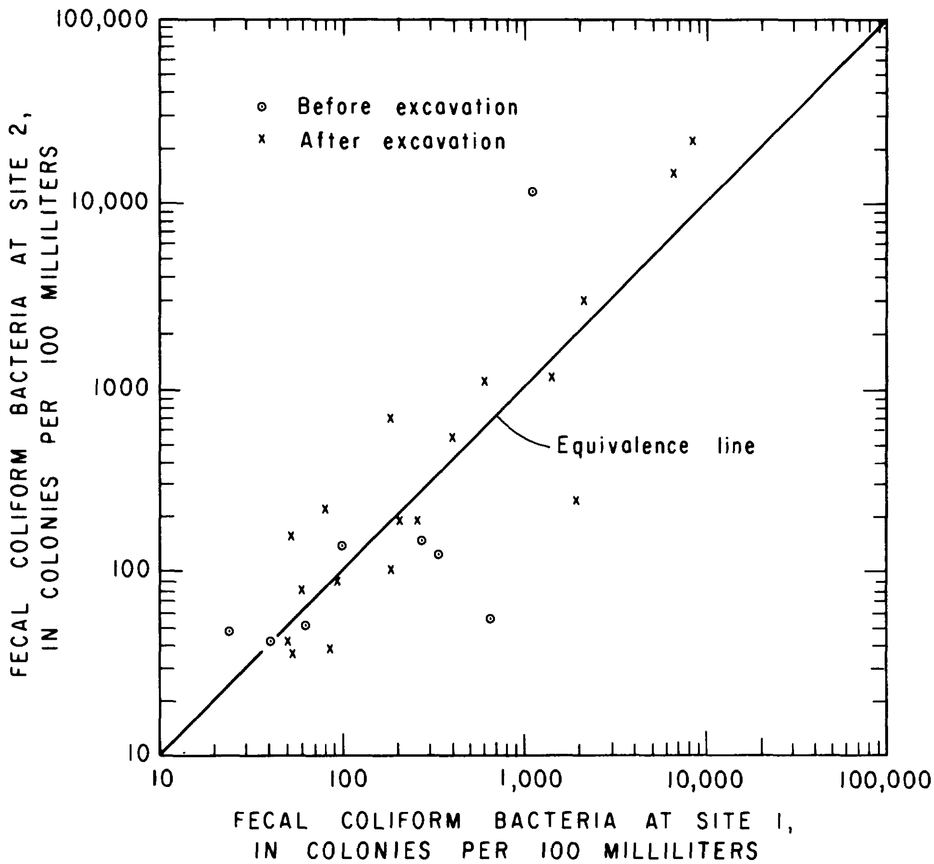

Figure 15.--Relation of fecal coliform bacteria data for sites 1 and 2 before and after excavation.

Table 4.--Bacteriological data prior to, during, and after excavation of the Black River

[Excavation reached site 2 on July 24, 1979 and was completed in November 1979]

Date	Site	Discharge (ft^3/s)	Fecal Coliform (cols./100 mL)	Fecal Streptocci (cols./100 mL)	Ratio FC/FS
		Before excavation			
May 31, 1978	1	9.0	320	470	0.68
	2		140	310	.45
June 19, 1978	1	4.8	270	440	.61
	2		150	480	.31
November 28, 1978	1	5.4	1,100	1,800	.61
	2		12,000	11,000	1.09
January 3, 1979	1	47	640	2,500	.26
	2		380	930	.41
		During excavation			
February 27, 1979	1	430	100	270	.37
	2		140	220	.64
March 12, 1979	1	130	24	88	.27
	2		48	24	2.00
March 28, 1979	1	135	40	44	.91
	2		42	28	1.50
April 10, 1979	1	60	62	60	1.03
	2		50	40	1.25
July 30, 1979	1	.36	250	300	.83
	2		190	200	.95
September 11, 1979	1	40	300	220	1.36
	2		140	290	.48
September 26, 1979	1	4.8	210	300	.70
	2		190	210	.90
October 10, 1979	1	17	52	110	.47
	2		150	320	.47
October 24, 1979	1	9.8	180	230	.78
	2		690	1,400	.49
		After excavation			
December 12, 1979	1	50	88	150	.59
	2		92	190	.48
January 21, 1980	1	86	52	103	.50
	2		40	44	.91
February 13, 1980	1	98	52	120	.43
	2		44	120	.37
March 11, 1980	1	80	60	80	.75
	2		80	32	2.50
March 27, 1980	1	92	84	48	1.75
	2		36	24	1.50
April 15, 1980	1	120	1,400	890	1.57
	2		1,200	760	1.58
April 30, 1980	1	65	390	350	1.11
	2		550	570	.96
October 6, 1980	1	28	80	260	.31
	2		210	200	1.05
December 2, 1980	1	45	180	160	1.12
	2		100	80	1.25
February 11, 1981	1	71	1,900	4,000	.48
	2		240	2,000	.12
February 12, 1981	1	12	600	1,500	.40
	2		1,200	2,500	.48
August 12, 1981	1	520	8,400	30,000	.28
(AM)	2		23,000	34,000	.68
August 12, 1981	1	600	6,800	24,000	.28
(PM)	2		15,000	18,000	.83
August 13, 1981	1	350	2,100	3,300	.64
	2		3,000	2,600	1.15
August 14, 1981	1	155	240	600	.40
	2		160	350	.46
August 15, 1981	1	81	260	790	.33
	2		180	640	.28

SUMMARY

Data were collected to define hydrologic conditions before, during and after channel excavation along the Black River near Dunn, North Carolina. Data collection sites 2 and 3 were located within the 5.1-mile-long excavated reach, and site 1 was located about 1.5 miles upstream from the new channel to define background conditions. Stream water-quality data between sites upstream and downstream were compared as were water levels for shallow water-table wells adjacent to the river to illustrate probable impacts of channel excavation.

In cooperation with the Department of the Army, Corps of Engineers, the collection of hydrologic data began in 1976. Excavation of the new channel began in late 1978 and was completed in November 1979. The collection of field data was completed in August 1981. The new 40-foot-wide channel is considerably straighter than the former natural channel and is also 2 to 4 feet deeper. The canopy of trees and heavy brush growing along the former channel was also removed. Excavated spoil material was placed along the east bank about 15 feet from the stream.

A comparison of streamflow and ground-water characteristics prior to and following construction shows significant differences. Flow velocities have increased by 100 percent or more and the magnitude of overbank flooding is reduced. After heavy storms, the stream, which previously responded slowly and remained at high stages for a week or more, now rises and recedes within several days at site 3. Ground-water levels declined over 2 feet in shallow water-table wells located within 100 feet of the excavated channel; however, changes were not detected in a well located 500 feet away. During storm periods, water levels in wells as much as 100 feet from the stream changed, both before and after excavation, almost simultaneously with changes in stream stage. Water-level fluctuations in these shallow wells continued to be almost identical to changes in stream stages, but the magnitude and rate of change in fluctuations greatly increased after excavation.

The removal of all vegetation within the clearing zone, which formerly provided shading over most of the channel, increased the opportunity of solar radiation and heating of channel water. Daytime water temperatures following construction were about 1/2 to 1°C higher than temperatures prior to construction. Dissolved oxygen also rose significantly following channel excavation, and the percent of saturation in the lower ranges increased from 20 to 25 percent.

Suspended-sediment concentrations in the Black River are flow-related, and maximum levels occur during stormflow. While high-flow concentrations did not exceed 75 mg/L prior to excavation, they increased dramatically during construction, exceeding 2000 mg/L on several occasions. Following construction, concentrations decreased considerably, but remained 5 to 10 times greater than those observed before channel excavation.

The pH values ranged from 4 to 7 units; significant changes prior to, during, and following construction were not detected. Simultaneous values of pH showed a high degree of correlation between sites during all phases of the investigation. Values of specific conductance and dissolved-solids concentrations were unaffected by the excavation.

Concentrations of phosphorus and nitrogen were highly variable throughout various phases of the study; however, significant changes in nutrient characteristics were not detected.

The presence of fecal coliform and fecal streptococci in the stream verifies fecal pollution, and the high proportion of fecal coliform to fecal streptococci indicates that animal wastes are the predominant source of these bacteria in the study reach. No significant change in bacterial levels occurred after excavation.

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