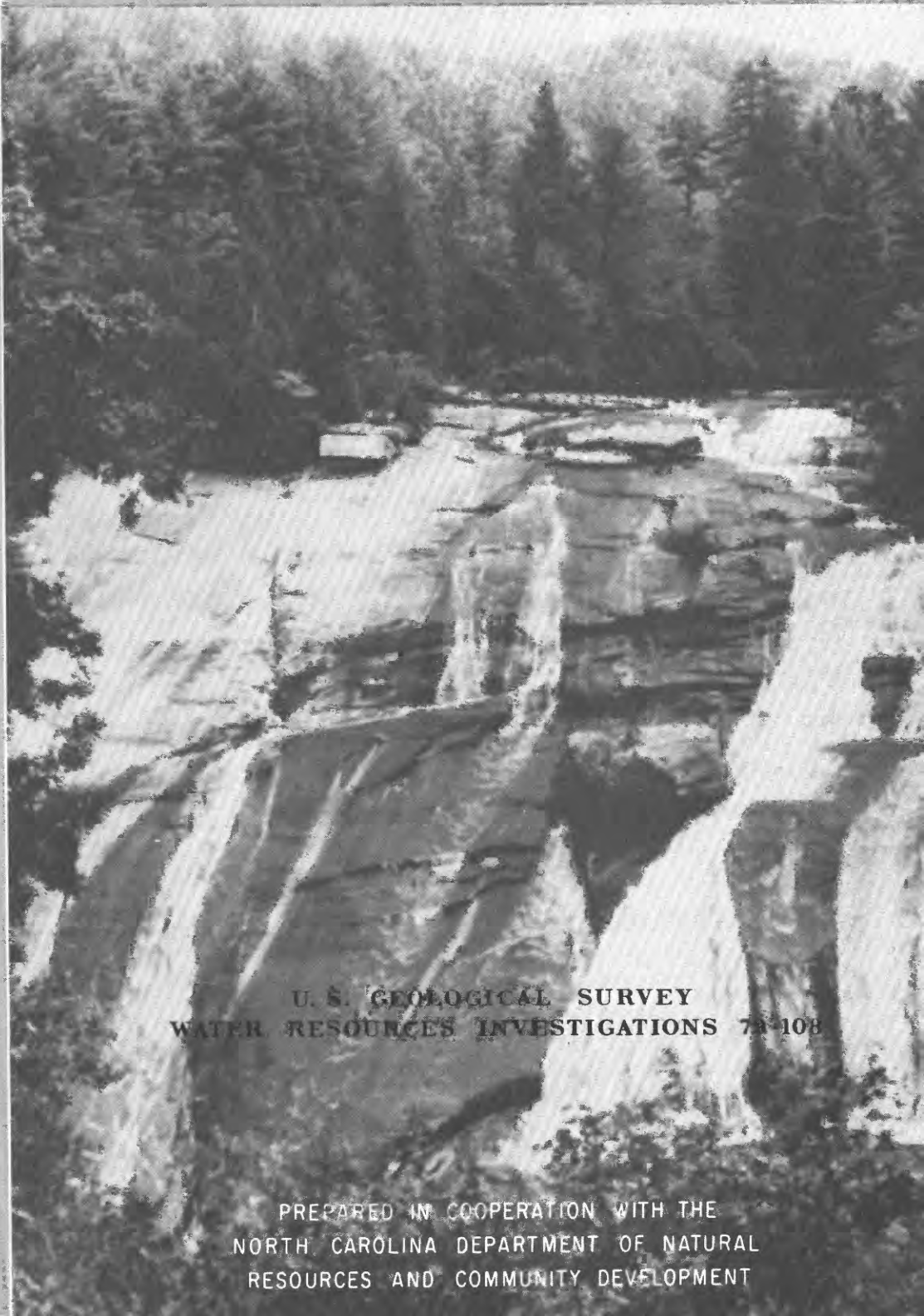




STEINKAMP

WATER-QUALITY CHARACTERISTICS OF STREAMS IN FORESTED AND RURAL AREAS OF NORTH CAROLINA



U. S. GEOLOGICAL SURVEY
WATER RESOURCES INVESTIGATIONS 7A-10B

PREPARED IN COOPERATION WITH THE
NORTH CAROLINA DEPARTMENT OF NATURAL
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North Carolina Department of Natural Resources
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1979

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CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

For additional information write to:

U. S. Geological Survey

Post Office Box 2857

Raleigh, North Carolina 27602

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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 Units | By | To obtain SI units |
|---|------------|--|
| <u>Length</u> | | |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| <u>Area</u> | | |
| square mile (mi ²) | 2.590 | square kilometer (km ²) |
| <u>Volume</u> | | |
| cubic foot (ft ³) | 0.02832 | cubic meter (m ³) |
| <u>Flow</u> | | |
| cubic foot per second (ft ³ /s) | 28.32 | liter per second (L/s) |
| | 0.02832 | cubic meter per second (m ³ /s) |
| <u>Temperature</u> | | |
| degree Fahrenheit (°F) | 5/9(°F-32) | degree celsius (°C) |
| <u>Mass</u> | | |
| ton (short, 2000 pounds) | 907.2 | kilogram (kg) |
| pound (lb avoirdupois) | 0.4536 | kilogram (kg) |

WATER-QUALITY CHARACTERISTICS OF STREAMS IN FORESTED AND RURAL AREAS OF NORTH CAROLINA

By Clyde E. Simmons

and

Ralph C. Heath

ABSTRACT

From late 1973 through 1978 water-quality samples were collected from a statewide network of rural stream sites. Data obtained from 39 of these sites, whose basins are 90 to 100 percent forested, were used to define unpolluted or baseline conditions. Stream quality at 20 other sites are believed to be affected by farming activities, which range from 15 to 55 percent of the land area of the basins. Data from these 20 sites were used for comparison with data from the 39 forested sites to determine the increase in constituent levels caused by man.

Baseline stream quality is largely influenced by basin geology and the quality of bulk precipitation. Concentrations of major dissolved constituents are greatest during low base runoff and are related primarily to the minerals comprising the soils and underlying rock in the basins. As a result of this study, five distinct geochemical zones were delineated. The chemical characteristics of surface waters in each zone are similar.

Mean and other statistical values for major dissolved constituents, nutrients and minor elements in base runoff and storm runoff for baseline conditions are presented in tabular and graphical format. Data from these forested basins indicate wide areal variations in concentrations of many constituents. Mean concentrations of dissolved solids range from 12 milligrams per liter (mg/L) in geochemical zone III to 61 mg/L in zone II. Mean nitrogen values, which are generally greater during storm runoff, range from 0.19 mg/L in zone I to 0.68 mg/L in zone V; whereas phosphorus

values are less variable, ranging only from 0.01 to 0.03 mg/L. Arsenic, mercury, and selenium are generally below detection limits. Although chromium, copper, lead and zinc occur in most baseline streams, quantities are often near detection limits and seldom exceed 15 micrograms per liter.

Significant increases in concentrations of major dissolved constituents and nutrients occurred, especially during storm runoff, at most of the 20 sites affected by farming activities. During storm runoff, concentrations of several major constituents were two to three times those determined for baseline conditions. Also, in basins where farm activities accounted for 20 or more percent of total land use, phosphorus levels during storm runoff were 2 to 13 times greater than from forested basins. Concentrations of minor elements were essentially the same in both forested and developed basins.

Future plans to continue the study of baseline stream characteristics include an intensified collection of data throughout a full range of flow and seasonal variations at up to ten sites having totally forested basins.

INTRODUCTION

In 1972, the U. S. Geological Survey, as a part of its State cooperative water-resources program, activated a water-quality monitoring program in North Carolina designed to determine variations in stream quality and to determine pollution loads and trends at key locations on the State's major rivers. To accomplish these objectives, two different networks of stations were established in late 1973; (1) a baseline-quality network consisting of stations at points on small streams relatively unaffected by man's activities, and (2) an accounting network consisting of stations located on major streams whose quality is affected by wastes from municipalities, industries, and agricultural developments (fig. 1).

A recent report by Wilder and Simmons (1978) describes methods for using data collected from these stations to determine pollution loads and other chemical characteristics of streams. The report also includes a detailed discussion of the program's design, operations, and objectives. One of the basic concepts described by Wilder and Simmons is that substances transported by streams are derived from both natural sources and wastes generated by man's activities. The primary purpose of the baseline-quality network is to determine the concentration of constituents in water derived from natural sources; however, it must be realized that even "natural sources" have been modified, such as by the fallout of air-borne constituents added to the atmosphere by man's activities. These concentrations can be used in conjunction with discharge data collected at the accounting-network stations on the major rivers to estimate the loads of dissolved substances in the rivers that are derived from natural sources.

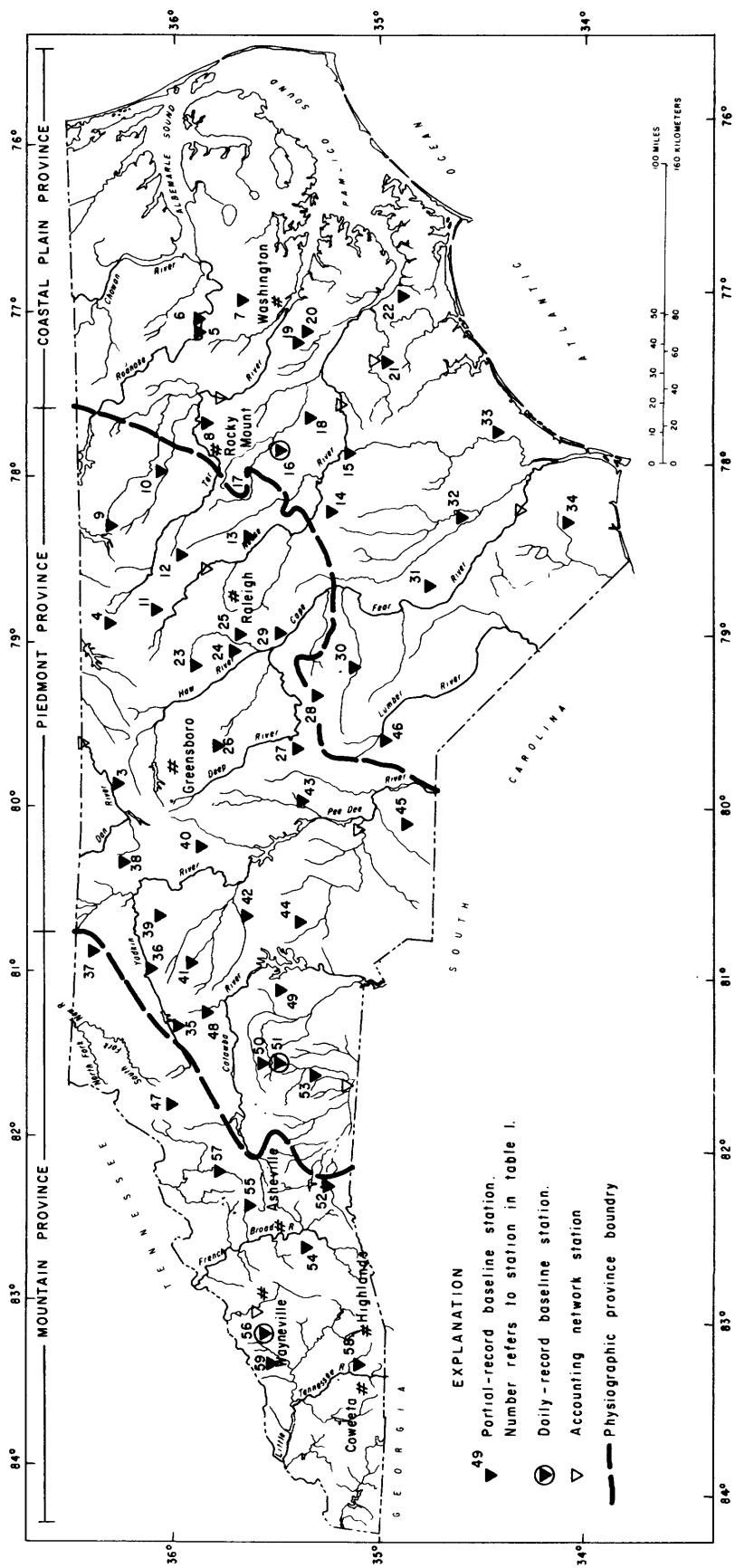


Figure 1.--Location of stations in the baseline quality and accounting networks in North Carolina.

The difference between total loads determined at the sites on the major rivers and the natural loads estimated from data collected at the baseline network stations is a measure of man's impact on stream quality.

This report presents the preliminary findings obtained from the baseline network through 1978. For North Carolina, it represents the first known attempt to determine the concentrations of major chemical and trace constituents and nutrients contributed to the State's streams by natural processes. Thirty-nine rural streams, whose basins were 90 to 100 percent forested, were used to characterize baseline stream conditions during periods of base runoff and storm runoff. Except for the effects of air pollution, which currently cannot be quantified, the sites are believed to show minimal effects of man's activities. Using geochemical zones, areas underlain by soil and rock types having the same or similar chemical characteristics, mean values were determined, where possible, for the concentrations of various chemical constituents.

During the early phases of this study, 20 additional rural stations were in the baseline network but farming activities accounted for 15 to 55 percent of the total land area in these basins. Initially the effects of runoff from the farm areas on stream quality were unknown; however, chemical data collected during base and storm runoff periods quickly indicated concentrations which were considerably greater than those obtained from forested basins. Data from these 20 sites, therefore, are not used in the definition of baseline characteristics; rather, the data are used in a separate part of this report to illustrate the effects of the basins inhabitants and especially agricultural activities on baseline stream quality.

It should be noted that this report is a summary of the results of numerous hydrologic data; the chemical and related data for individual baseline stations are contained in publications issued annually by the U.S. Geological Survey (1974-78).

ESTABLISHMENT OF THE BASELINE NETWORK

As a first step in establishing the baseline network, topographic maps and aerial photographs were inspected to identify streams whose quality might not be affected by man's activities. This search was concentrated on forested basins drained by perennial streams. From the available maps and photographs it was not possible to clearly determine whether some areas were completely forested and the point at which perennial flows begin. Therefore, the initial selection process included about 200 sites relatively evenly distributed over the State. Each of these was visited to determine if the upstream areas were completely forested and, if not, the level of development (that is, the number of houses and the acreage in farms and pastures).

During the field study, specific conductance was determined for streams draining both undeveloped areas and for those draining areas in which it appeared the development would have a negligible effect on water quality. Conductivity was used as the primary screening parameter because it provides an easily measured estimate of most of the total dissolved mineral matter. Therefore, it was assumed that the effect of significant development would be reflected by higher conductivity values. The fact that such values reflected man's effects rather than a natural condition, was confirmed from review of the field notes on activities upstream from the sampling sites. As a result of this evaluation, only 47 of the initial 200 sites were determined to be essentially free of man's influence and were retained in the baseline network. These sites are on streams which are as free of man's effects as possible in that (1) they have no known upstream point sources of pollution, (2) the streams are unchanneled, and (3) the basins in most cases are unpopulated. In a few areas no suitable sites were found in the first attempt, and new sites were located on the basis of additional map review and field inspections. As shown in figure 1, the final network resulted in a relatively uniform geographic distribution of 59 stations.

Table 1, at the back of this report, includes all stations that have been operated as a part of the baseline network. As noted in the remarks section, data collection activities were terminated at nearly half of the stations listed in table 1 because preliminary analysis of the data indicate effect from agricultural activities or because major changes, such as the initiation of timber cutting, occurred in the basin after data collection began. The location of all baseline network stations listed in table 1 are shown in figure 1.

The drainage areas of the baseline sites, as shown in table 1, range in size from 0.04 to 49.2 mi² and all streams are perennial except possibly during severe droughts. Table 1 also shows a breakdown of land use into forest and agriculture. Forest includes both mature forest and previously cleared areas that are being returned to forest. Agriculture includes both pastures, small grain, hay and row crops. Because of the absence of large, totally wooded basins in several areas, especially in the heavily-farmed Coastal Plain region, it was necessary to include in the network a few basins that contain active agricultural operations of significant size. To minimize the possibility of using values influenced by agriculture, data from sites where agricultural operations exceeded ten percent of the area were not used in determining the water-quality characteristics of unpolluted streams that are discussed in a following section of this report.

DATA COLLECTION PROGRAM

Two types of sampling operations were conducted at the stations in the baseline network (table 2). At a majority of the stations, samples were collected only under extreme flow conditions; that is, (1) during low flows caused by long dry periods when the streams were at "base" flow, and (2) during high flows caused by rains resulting from the passage of major weather fronts. For convenience, these stations will be referred to as partial-record stations. The purpose of this sampling schedule was to determine the quality of both the ground-water inflow to the streams and overland flow if it occurred. It was logistically impossible to sample all sites during any one sampling period. Thus, different groups of stations were sampled at different times as suitable flow conditions occurred. Over the several years that samples were collected, both low-flow and high-flow samples were obtained at most of the sites during all seasons of the year.

Table 2.--Data-collection operations at stations in the baseline network.

| Type of station | Number of stations | Flow conditions sampled | | Type of data available and frequency | | | | | | |
|-----------------|--------------------|-------------------------|---------------------------------|--------------------------------------|-------------------|----------------------|--------------------|-----------|----------------|------------|
| | | Full flow range | Extreme low and high flows only | Stream discharge | Water temperature | Specific conductance | Major constituents | Nutrients | Minor elements | Biological |
| Daily record | 3 | Yes | No | C | D | D | M | M | M | M |
| Partial record | 56 | No | Yes | none | S | S | S | S | S | none |

C, continuous; D, once-daily; M, monthly; S, semiannually

We recognized that the "grab" samples obtained at the partial-record stations, as described above, left much to be desired. For example, we could not determine from such samples whether we ever succeeded in obtaining samples composed exclusively of overland runoff. If funds and manpower had permitted, we would have preferred to operate a continuous-record gaging station at each site and to obtain, in addition to daily

flows, hourly measurements of conductivity and temperature. Although this was not feasible, five of the sites were located at existing stream-gaging stations (Nos. 16, 30, 51, 55, and 56 in table 1). At three of these, sites 16, 51, and 56, which represent each of the major physiographic provinces, daily values of conductivity and temperature were obtained and water samples were collected at about monthly intervals, depending on the flow conditions. For convenience, the latter three sites will be referred to as daily-record stations. Data from these stations were extremely valuable in the interpretation of data from the partial-record sites.

Brief descriptions of the basins sampled at the daily-record stations are contained in the following paragraphs:

Site No. 16, Turner Swamp near Eureka. - The Turner Swamp station is located in the west-central part of the Coastal Plain, two miles north of Eureka, Wayne County. Turner Swamp is the smallest stream in the daily-record group and at the sampling point has a drainage area of only 2.2 mi². Topography of the basin is gently rolling hills with elevations ranging from 90 to 130 feet. Average stream gradient is 17 ft/mi.

The basin is sparsely populated and has only 20 homes which are mostly on the perimeter of the basin. Dense forests and underbrush account for approximately 60 percent of the land use, and cleared land accounts for the remaining 40 percent. Of the cleared land, about half is under active cultivation while the remainder is used for pasture and idle croplands. Most of the forest land is along the water courses, thereby serving as buffer zones between the streams and cleared areas. A lightly traveled paved road encircles most of the basin. During the 1974-75 sampling period, no concentrated sources of significant pollution such as livestock feeding pens, pig farms, or intensive agricultural operations were present in the basin.

Site No. 51, Jacob Fork at Ramsey. - The Jacob Fork station is located about 0.4 miles north of Ramsey, Burke County. Most of the upper headwaters, comprising about 60 percent of the 25.4 mi² basin, is in the protected South Mountains Management Area. Typical of the western Piedmont region, the land is steep and average stream gradient is 120 ft/mi.

Although the basin is 96 percent forested, approximately 40 residences are located in the lower part of the basin. Approximately two percent of the land area is used periodically for crop cultivation and two percent is used for cattle pastures. Several paved and unpaved roads are in the lower part of the basin. There were no known point sources of stream pollution during the sampling period (1975-76). During 1974, an attempt to construct a mountain resort community about a mile upstream from the station failed because of economic reasons. Several homes were completed before construction ceased, but occupancy of these homes is mostly during the summer and weekends.

Site No. 56, Cataloochee Creek near Cataloochee. - The Cataloochee Creek sampling station is located in western North Carolina, about two miles north of Cataloochee, Haywood County. The drainage basin lies entirely in the Great Smoky Mountains National Park and has an area of 49.2 mi² at the station.

Cataloochee Creek is completely surrounded by mountains with elevations ranging from 2,460 feet on the valley floor to mountain peaks exceeding 5,500 feet. The average gradient of the main stream is 160 ft/mi. The basin is 98 percent forested and a ranger station at Cataloochee, located about 2-1/2 miles upstream from the gage, is the basin's only permanent residence. There is no farming in the basin but it is a popular hiking and horseback riding area from mid April to September. Most of the recreation occurs in the upper headwaters. According to the National Park Service (Mr. Thomas Kloos, personal comm., 1977), several thousand horseback riders and hikers visited the area each year during the sampling period (1974-77). A narrow paved road crosses the headwaters region and terminates at a small wilderness campground. A sand and gravel road, State Highway 284, parallels the creek at a distance of a few hundred feet for about a mile upstream from the station. Both roads are lightly traveled.

SAMPLING AND LABORATORY PROCEDURES

To ensure the collection of representative water samples and consistency in sampling techniques, all samples were collected using depth-integrating methods as discussed by Guy and Norman (1970). A hand-held aluminum DH-48 sampler (Guy and Norman, 1970, p. 16) was used to obtain samples from shallow, wadable streams. A weighted sampler capable of holding up to four 1-liter bottles was used on deeper, slow moving streams. Samples from deep, swift streams were obtained using a bronze, 24-lb sampler, the DH-59; and a much heavier sampler, the 62-lb D-49, was used during high-flow conditions when complete depth integration was not possible with lighter samplers. To prevent contamination, the samplers used to collect samples for trace-metal analyses were coated with epoxy resin.

Water samples obtained for determination of dissolved constituents were filtered through a 0.45 μ m membrane immediately after collection. All filtering was performed using a Skougstad filtration unit and compressed air or nitrogen (Skougstad and Scarboro, 1968). To minimize loss of solutes by oxidation and (or) precipitation, trace-metal samples were treated with nitric acid immediately after filtering. Samples collected for nutrients were chilled immediately after collection and were kept in this condition until analyzed.

Except for determinations of unstable parameters such as pH, dissolved oxygen, specific conductance and alkalinity, all of which were determined at the time of sampling, all chemical analyses were performed in the USGS Central Laboratory at Doraville, Georgia. The methods and procedures used by the Central Laboratory are in compliance with guidelines established in Chapter 5, National Handbook of Recommended Methods for Water-Data Acquisition (Federal Interagency Work Group, 1977). Analyses of suspended sediment were made in the district sediment laboratory located in Raleigh.

FACTORS AFFECTING BASELINE WATER QUALITY

The quality of water at the sites in the baseline network depends primarily on the quality of the precipitation and on the changes in quality that occur as the precipitation moves over and percolates through the ground. Every effort was made to identify areas free of agricultural and other human-related activities so that the quality of the water leaving the areas would be dominated by natural processes with man's effects at a minimum. As is apparent in table 1, however, it was necessary to include several sites in the network that were partly affected by some development in order to obtain adequate areal coverage. Because of air-borne pollution, however, even data from sites completely free of all development cannot, strictly speaking, be assumed to reflect only natural water quality.

Particles and gases released to the atmosphere by man's activities affect even the most remote parts of earth and clearly have an important effect on the water quality at the baseline sites. For this reason the term "baseline" quality is generally used in this report rather than the term "natural" quality. The following sections deal with several of the most important factors affecting the water quality at baseline sites.

PRECIPITATION

North Carolina is located in the humid temperate zone and receives abundant rainfall distributed rather uniformly throughout the year. Based on long-term weather records, rainfall amounts range from about 37 inches per year at Asheville to about 80 inches at Highlands. The statewide yearly average is about 50 inches.

Precipitation contains constituents of local origin and some that have been transported by winds from distant sources. Also, during rainless periods, there is a "dry" fallout of mineral and organic dust from the atmosphere. Because precipitation is the source of water in North Carolina streams, its chemical composition must be considered in any water-quality study which has as one of its objectives the identification of sources of constituents. It was not feasible to collect data on the

chemical composition of precipitation as a part of this study but enough data exist to show that significant quantities of the major ions, except silica, are contained in precipitation. Data from other studies for selected sites located across the State are presented in table 3. The data in table 3 are referred to as "bulk precipitation" because the analyses include constituents deposited both by rainfall and by dry fallout. These data show the variability of the chemical composition of rainwater. Concentrations of several of the major constituents, such as chloride, sodium and magnesium, are greatest along the coast and decrease inland, thereby indicating that the ocean is a primary source. Relatively uniform values of other major constituents, however, indicate apparent contribution from land or non-marine sources. Gambell and Fisher (1966) and others also show that concentrations of many constituents in rainwater vary seasonally and from one storm to another.

Table 3.--Chemical composition of bulk precipitation in North Carolina.

| Location | Dissolved constituent (mean concentrations, in mg/L) | | | | | | | | |
|--------------------------|--|------|------|------|------------------|-----------------|------|-----------------|----------------------------------|
| | Ca | Mg | Na | K | HCO ₃ | SO ₄ | Cl | NO ₃ | NH ₄ |
| Hatteras ¹ | 0.41 | 0.59 | 4.36 | 0.10 | - | 1.97 | 8.20 | 0.23 | Generally less than 0.05 mg/L |
| Washington ¹ | .73 | .20 | .82 | .10 | - | 2.02 | 1.15 | .34 | |
| Rocky Mount ¹ | .57 | .18 | .74 | .10 | - | 1.91 | .74 | .70 | |
| Raleigh ¹ | .41 | .13 | .39 | .10 | - | 1.99 | .34 | .63 | |
| Greensboro ¹ | .52 | .13 | .36 | .10 | - | 2.56 | .37 | .69 | |
| Waynesville ² | .85 | .10 | .52 | .17 | 2.0 | 2.26 | .20 | - | |
| Coweeta ³ | .19 | .04 | .21 | .07 | - | - | .35 | .12 | |

¹Gambell and Fisher (1966). Means of monthly samples collected August 1962 through July 1963.

²Unpublished data (USGS). Means of nine periodic samples collected July 1962 through March 1963.

³Swank and Henderson (1976). Means of weekly samples collected June 1972 through May 1973.

In addition to contributing major chemical constituents, precipitation also serves as an indirect source of minor elements and nutrients. Most of these constituents probably enter the atmosphere as gaseous or particulate matter generated during man's activities and return to earth absorbed or suspended in raindrops and snow flakes. Of recent concern are the quantities and forms of the nutrients, nitrogen and phosphorus, which are contributed by both wet and dry precipitation. Gambell and Fisher (1966) showed that concentrations of nitrate in precipitation increased in a westward direction across North Carolina with lowest values occurring along the coast and highest values in the mountains. By comparing annual constituent loads derived from precipitation with loads in four major eastern North Carolina rivers, Gambell and Fisher estimated that the total nitrate load could have been derived entirely from precipitation. In a recent study of seven eastern North Carolina streams, Kuenzler, Mulholland, Ruley and Sniffen (1977) reported weighted-mean concentrations of 0.36 and 0.06 mg/L respectively for total nitrogen and phosphorus in bulk precipitation. Other studies, such as Joyner (1974) and Ellis, Erickson, and Wolcott (1978) also show that concentrations of nitrogen and phosphorus are often greater in precipitation than in unpolluted natural streams.

SOILS AND ROCKS

Prior to reaching the land surface, precipitation becomes slightly acidic as a result of absorption of carbon dioxide and other gases from the atmosphere. After precipitation reaches the land surface its chemical composition is modified as it comes in contact with plants, decaying organic matter, soils, and rocks below the soil zone. The rate and extent of this modification depends on the chemical composition of the precipitation and on the solubility characteristics of the soil and rock particles.

The rocks underlying North Carolina are described by Stuckey (1965). These range from relatively soluble beds of limestone and mollusk shells, which underlie parts of the Coastal Plain region, to relatively insoluble rocks such as granite, mica schist, and slate, which underlie large areas in the Piedmont and mountain regions. A generalized geologic map of the State is shown in figure 2. The geology of the State is far more complex than indicated on figure 2 which shows only major rock types and formations. The generalized map is used, however, because it is not within the scope of this report to relate stream quality characteristics to complex localized geologic conditions but rather to relate, where possible, these characteristics to large-scale regional geologic properties.

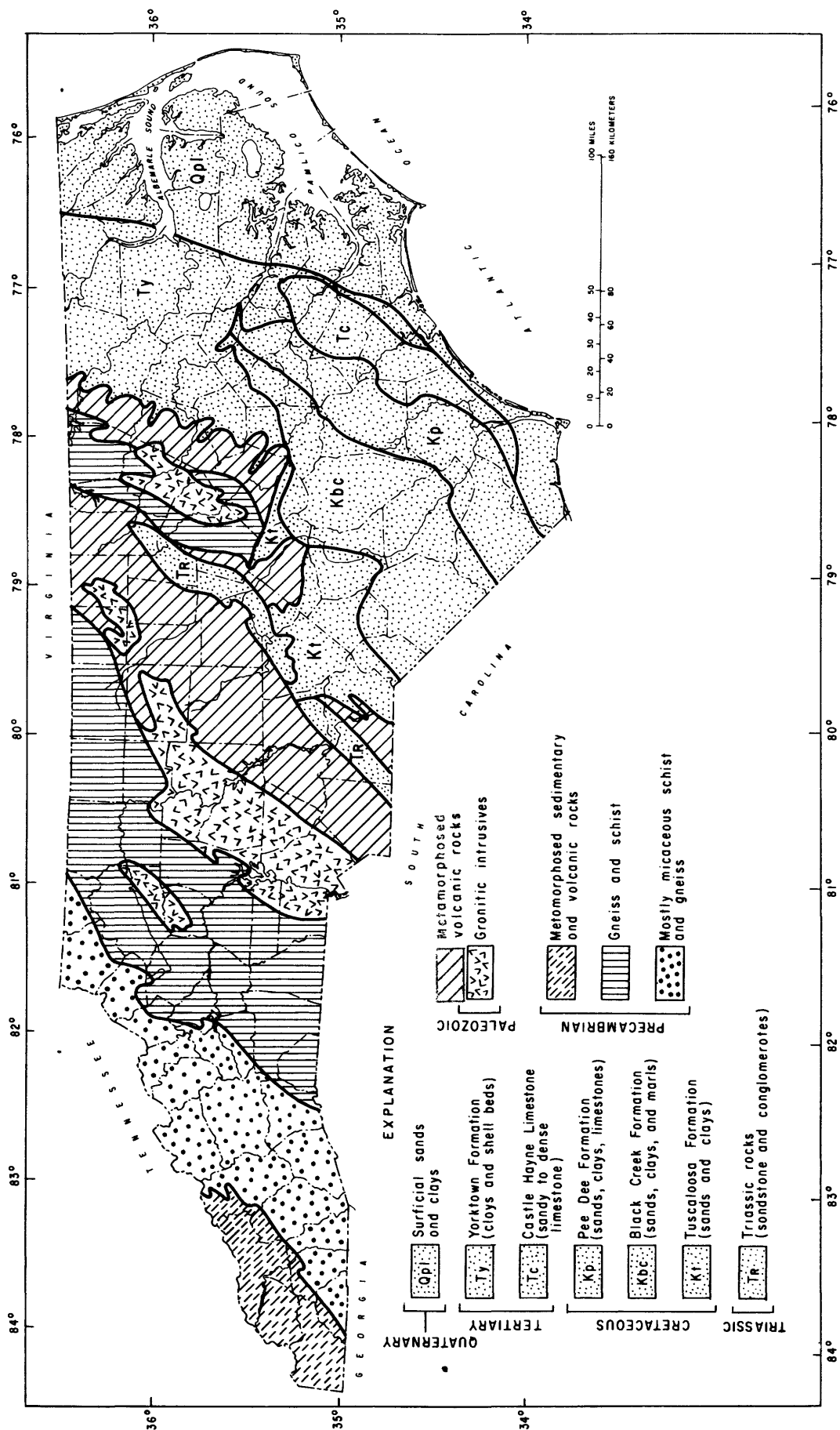


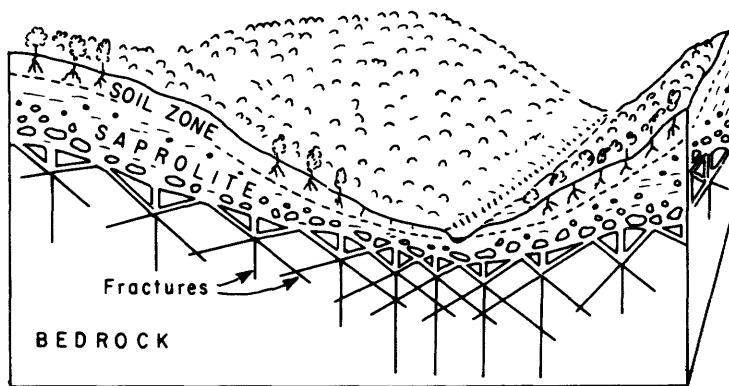
Figure 2.--Generalized geologic map of North Carolina (modified from North Carolina Department of Conservation and Development, 1958).

Because of the wide range in lithology and solubility of the rocks underlying North Carolina, it is reasonable to expect a wide range in the concentration of substances dissolved in water that reaches streams, especially during low-flow periods. The most soluble rocks underlie parts of the Coastal Plain region, and, as might be expected, baseflow in these areas contains relatively large concentrations of substances that are dissolved as the water percolates through the ground-water system. The rocks underlying the Piedmont and mountain regions are less soluble but, as LeGrand (1958) pointed out, there are significant differences in solubility between the different rocks underlying these regions. Using chemical analyses of water from wells and springs, he showed that the igneous and metamorphic rocks underlying the Piedmont and mountain areas form two distinct groups. One group, referred to as the granite group and composed of granite, granite gneiss, mica schist, slate, and rhyolite flows and tuffs, yields a soft, slightly acidic water that contains a low concentration of dissolved constituents. The other group, referred to as the diorite group and composed of diorite, gabbro, hornblende gneiss, and andesite flows and tuffs, yields a harder slightly alkaline water relatively high in dissolved constituents.

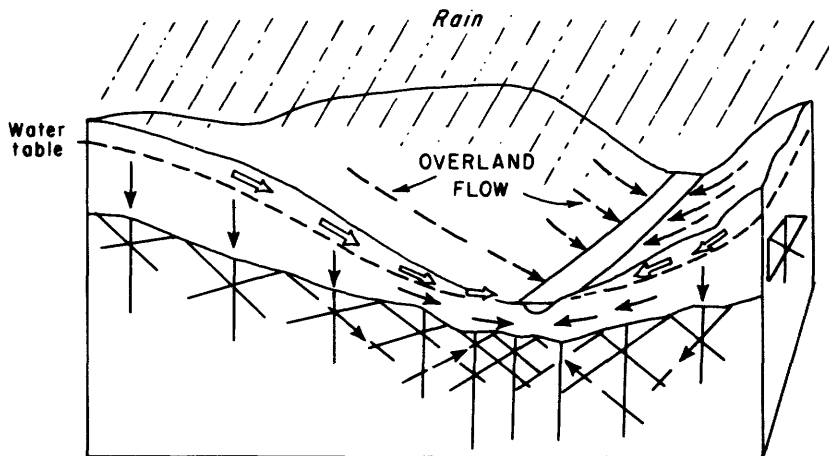
RUNOFF CONDITIONS

It is apparent from the preceding discussions that the chemical content of water in the streams of the baseline network depends primarily on the chemical content of precipitation and on the amount of material added to the water from vegetation, surface litter, and the soils and rocks with which it comes in contact. Thus, the water quality is often dependent upon runoff conditions and the path taken by runoff in reaching the stream system. It is, therefore, necessary to consider, at least briefly, these paths or sources of water in the baseline streams.

Runoff conditions are quite variable across the State and, to a large degree, are controlled primarily by various characteristics of the underlying soils and rocks, topography, and ground cover. Figure 3 shows runoff conditions during storms and during baseflow from a hypothetical wooded area located in the Piedmont or mountains. Both the Piedmont and mountains are underlain by bedrock that has been broken along an intricate network of fractures (fig. 3A). The bedrock is overlain, except where exposed at the surface, by a layer of disintegrated (weathered) rock referred to as saprolite or residuum. The upper zone of saprolite, generally ranging in thickness from a few inches to several feet, forms the soil zone. The soil zone of wooded areas in the Piedmont and mountains is covered by a layer of forest litter averaging several inches in thickness which is capable of absorbing water at a relatively high rate.



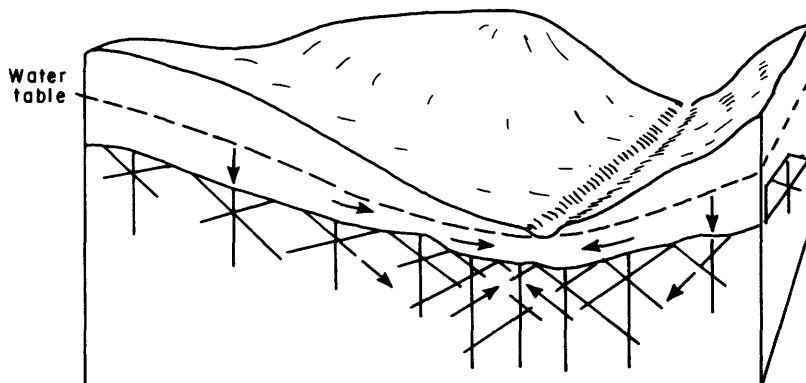
A. Forested area in the Piedmont and Mountains.



B. Runoff conditions during storms

↔ Seepage through surface litter and soil zone.

← Seepage through lower part of saporolite and bedrock



C. Runoff conditions during base flow.

← Seepage through saporolite and bedrock

Figure 3.--Basin cross section showing idealized runoff conditions from wooded areas in the Piedmont and mountain regions.

During storm runoff as depicted in figure 3B, rain infiltrates into the highly permeable surface litter and soil zone and moves quickly down-slope to discharge into the nearest stream. In forested basins, overland runoff is rare and occurs only during intense rainfall (1) when the rainfall exceeds the infiltration capacity of the soil zone and (or) (2) only near streams and along depressions where the water table is at or near the land surface. In forested areas of North Carolina, most soluble materials have previously been leached from the shallow soil zone and waters flowing in this zone usually contain low concentrations of dissolved matter. Concentrations of solid particles and constituents sorbed on particles, however, often reach maximum levels during storm runoff as a result of being swept into suspension by increased stream velocities.

During periods following rains, the lateral movement of water through the soil zone in the Piedmont and mountains ceases and water reaching the streams is ground water that has moved through the deeper saprolite and bedrock (fig. 3C). As these deeper zones are less weathered than the soil zone, they generally contain more soluble materials, and waters draining these zones most often contain greater concentrations of dissolved mineral matter than waters that move only through the shallow zones. During base-flow conditions, concentrations of suspended solids are minimal because stream velocities are most often insufficient to transport significant amounts of material in suspension.

LeGrand (1958, fig. 1) presented the following chemical data obtained from springs and wells located in the Piedmont and mountains:

| <u>Type of rock</u> | <u>Source of water</u> | <u>Dissolved-solids median concentration (mg/L)</u> |
|---------------------|------------------------|---|
| Granite | springs | 39 |
| Granite | wells | 71 |
| Diorite | springs | 99 |
| Diorite | wells | 233 |

Data obtained from springs are indicative of shallow ground-water conditions whereas the wells are generally representative of much deeper saprolite and (or) bedrock conditions. LeGrand's data illustrates large differences in ground-water chemistry between major rock types and further shows that water derived from shallow surficial materials are the least mineralized.

Runoff conditions in the Coastal Plain region differ from those in the Piedmont and mountains primarily because of differences in geology and topography. The relatively flat surface slopes of the Coastal Plain result in a slow movement of water both on the surface and underground. Unlike the mountains and Piedmont, which are generally underlain by bedrock at relatively shallow depth, most of the Coastal Plain region is underlain by surficial deposits of sands and at greater depths by layers of clay, sand, marl, and limestone. Runoff derived from the deeper marls and limestone contains greater concentrations of dissolved substances than does runoff which comes from the shallow and less soluble soil zone. In general, however, most of the hydrologic and geochemical processes evident in the mountains and Piedmont are also characteristic of streams in the Coastal Plain.

WATER-QUALITY CHARACTERISTICS OF UNPOLLUTED STREAMS

As has already been mentioned, water samples were collected at the baseline stations both during or immediately after storms and during fair weather periods when no rain had fallen for at least several days. In addition, daily measurements of conductivity were made at three of the stations. The results of this sampling program provide information on three important aspects of baseline (unpolluted) water quality. These are:

1. Areal differences in water quality resulting both from differences in the chemical composition of precipitation and from differences in soil and rock solubility.
2. Differences in the chemical quality of streams during periods of high flow and baseflow.
3. The effect of agricultural land use on water quality.

DEFINITION OF SURFACE-WATER GEOCHEMICAL ZONES

During the early phases of the study, the data collected at baseline sites were analyzed to determine the extent to which the water quality differed from one part of the State to another. This analysis indicated a high degree of variability between many constituents when viewed on a Statewide basis. However, it was observed that the chemical quality of streams underlain by the same rock type was notably similar. Figure 4 shows the sites at which data are representative of baseline conditions. The fractions near the symbols for each site show the mean total dissolved solids of (1) samples collected during periods of high flow (upper number), and (2) samples collected during periods of baseflow (lower number). The boundaries of the five geochemical zones were drawn on the basis of the contacts of the major geologic units shown on figure 2 and, where available, the similarity of the chemical composition in both high flow and low flow.

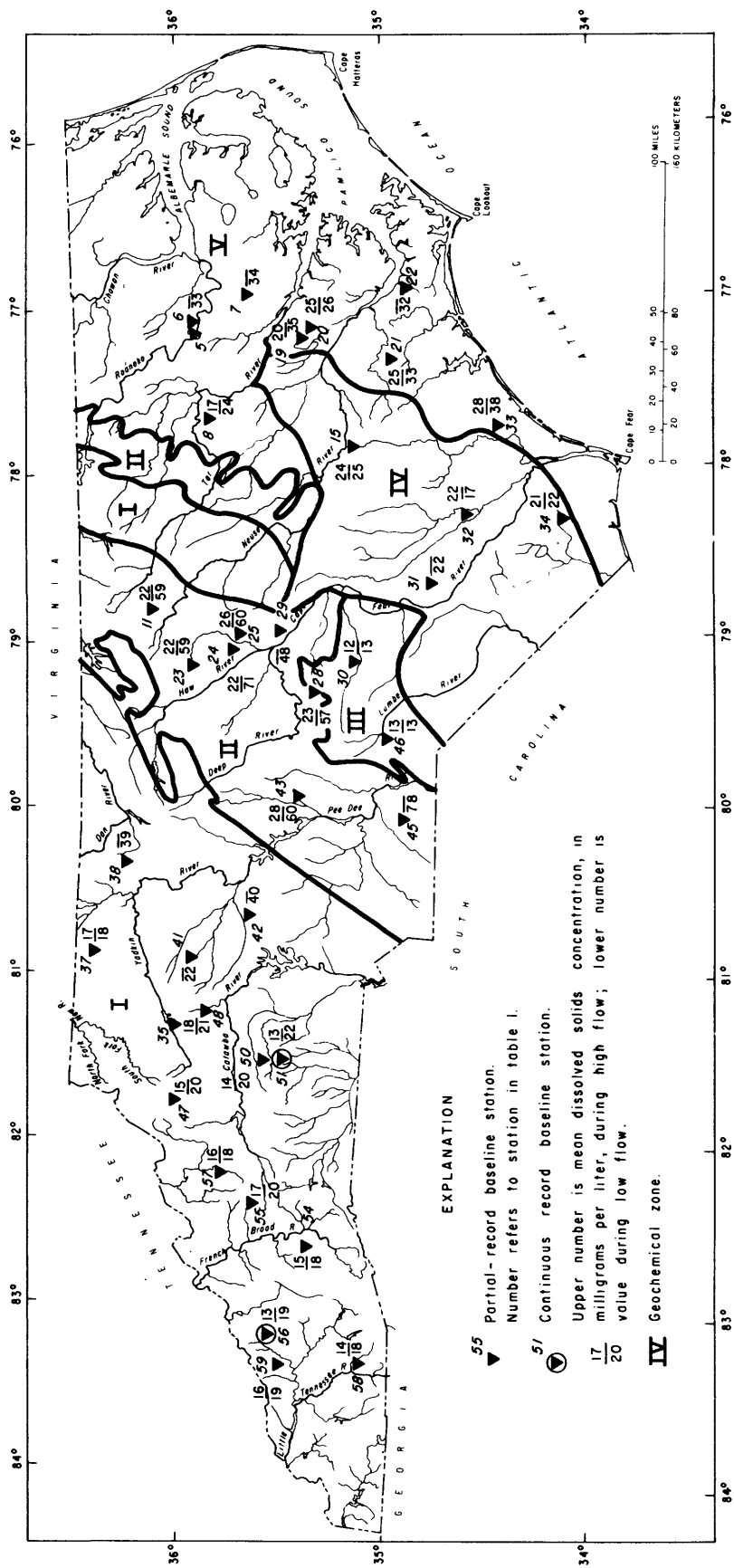


Figure 4.--Locations of unpolluted baseline quality stations, mean dissolved-solids concentrations, and major geochemical zones.

Although several methods can be used to substantiate the locations of the geochemical boundaries, a computerized multiple group discriminant analysis program, BMD-07M (University of California, 1974), gives one of the best visual displays of these differences. This program uses a number of complex statistical procedures to group sites having similar characteristics. For each sampling site, mean concentrations of total dissolved solids, sulfate, chloride, sodium, and calcium were used in the program as input variables. Along with various statistical values, the program produces a multidimensional plot that is converted to a two-dimensional plot of these data which shows optimal separation of similar groups. Figure 5 is a plot derived from using the above major constituents for unpolluted sites in the baseline network. Each number on the plot represents a baseline site. Its position was determined by evaluating the first two canonical variables, which are those linear combinations of the input variables that yield the greatest and second greatest statistical separations among the five geochemical zones. As shown in figure 5, the close grouping of stations which lie in the same geochemical zones indicates (1) that the boundaries of the zones are logically located, and (2) that in regards to the major dissolved constituents used in the comparison, the chemical characteristics of unpolluted streams within each zone are generally similar.

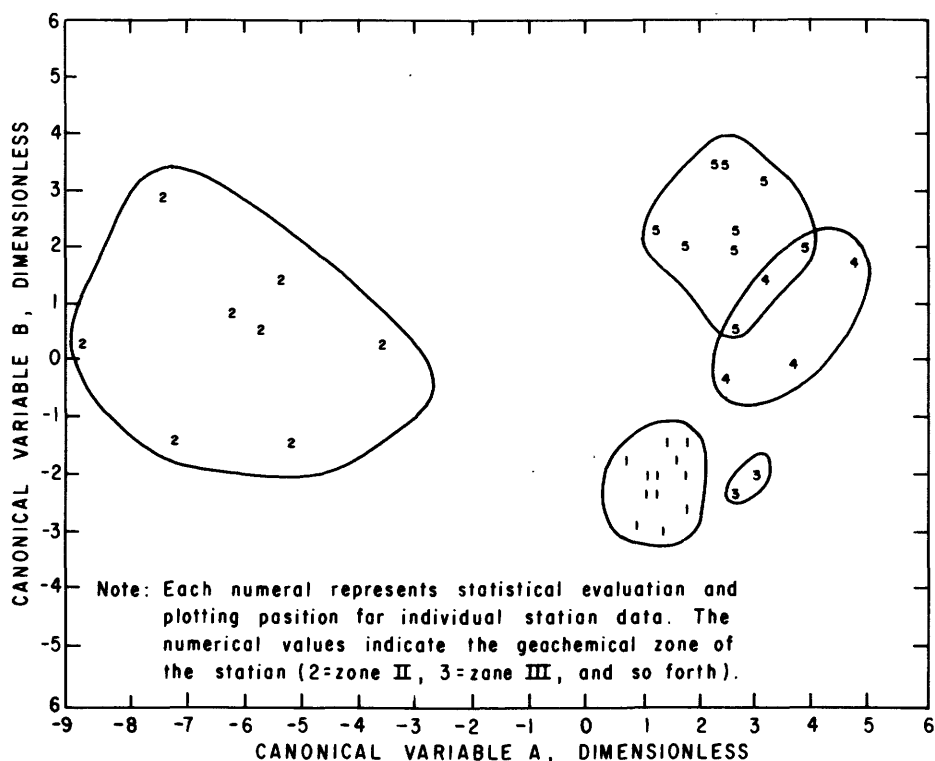


Figure 5.--Computer plot showing ideal close grouping of baseline sites obtained from comparing stream-quality data and geochemical zones of sites by multiple group analysis.

As will be shown later in this report, many constituents show little or no variations between zones and therefore appear to be unrelated to differences in geology or soil types. Enough of the major constituents show a correlation with geology, however, to justify the zone boundaries; and, to facilitate the discussion of constituents, the geochemical zones are used throughout the report regarding references to geographic locations. A brief discussion of major characteristics of individual zones follows:

Geochemical zone I is probably the most complex from the standpoint of rock composition. Although it includes the four major rock units shown on figure 2, the composition of the rocks underlying this zone is far more complex than shown. On the large-scale geologic map referred to earlier the four major rock units are subdivided into 21 units. However, the similarity of water quality at the 16 baseline sites in this zone suggests that the different rock units produce waters of very similar chemical composition. The largest differences in water quality are observed between the granite and diorite groups described by LeGrand (1958).

Of the baseline sites in zone I on figure 4, all are in granite-group rocks except site 42. Site 42 is in rocks of the diorite group. As shown on figure 4, water at this site contains significantly more dissolved mineral matter than does water at sites in the granite group. It might have been appropriate to divide zone I into two or more zones composed respectively of these rock groups. We chose not to do this because, as shown on figure 6, diorite-group rocks underlie only about ten percent of the area, and most of the areas underlain by these rocks are relatively small and are surrounded by extensive areas of granite-group rocks. Consequently, on an areal scale relatively little streamflow originates from the diorite-group rocks.

Geochemical zone II coincides with the Carolina Slate Belt and the Durham and Wadesboro Triassic basins. The Slate Belt is underlain by metamorphosed volcanic and metamorphosed sedimentary rocks. The Triassic basins are underlain by cemented conglomerates, sandstones, siltstones, and shales. Although high flows originating in zone II are only slightly more mineralized than those in zone I, concentrations during low flows are considerably greater in zone II.

The Coastal Plain region of the State is divided among three zones, III, IV, and V. Geochemical zone III coincides with the Sand Hills section of Cumberland, Harnett, Hoke, Moore, Richmond, and Scotland Counties. This area is underlain by a surficial layer of quartz sand ranging in thickness from a few feet to about 150 feet. Because of the highly permeable nature of this sand, water readily infiltrates into it and little overland flow occurs. Thus, as shown on figure 4, there is no significant difference in dissolved solids of high flow and low flow. Also, because quartz is relatively insoluble, the water in this zone is less mineralized than water from any other zone.

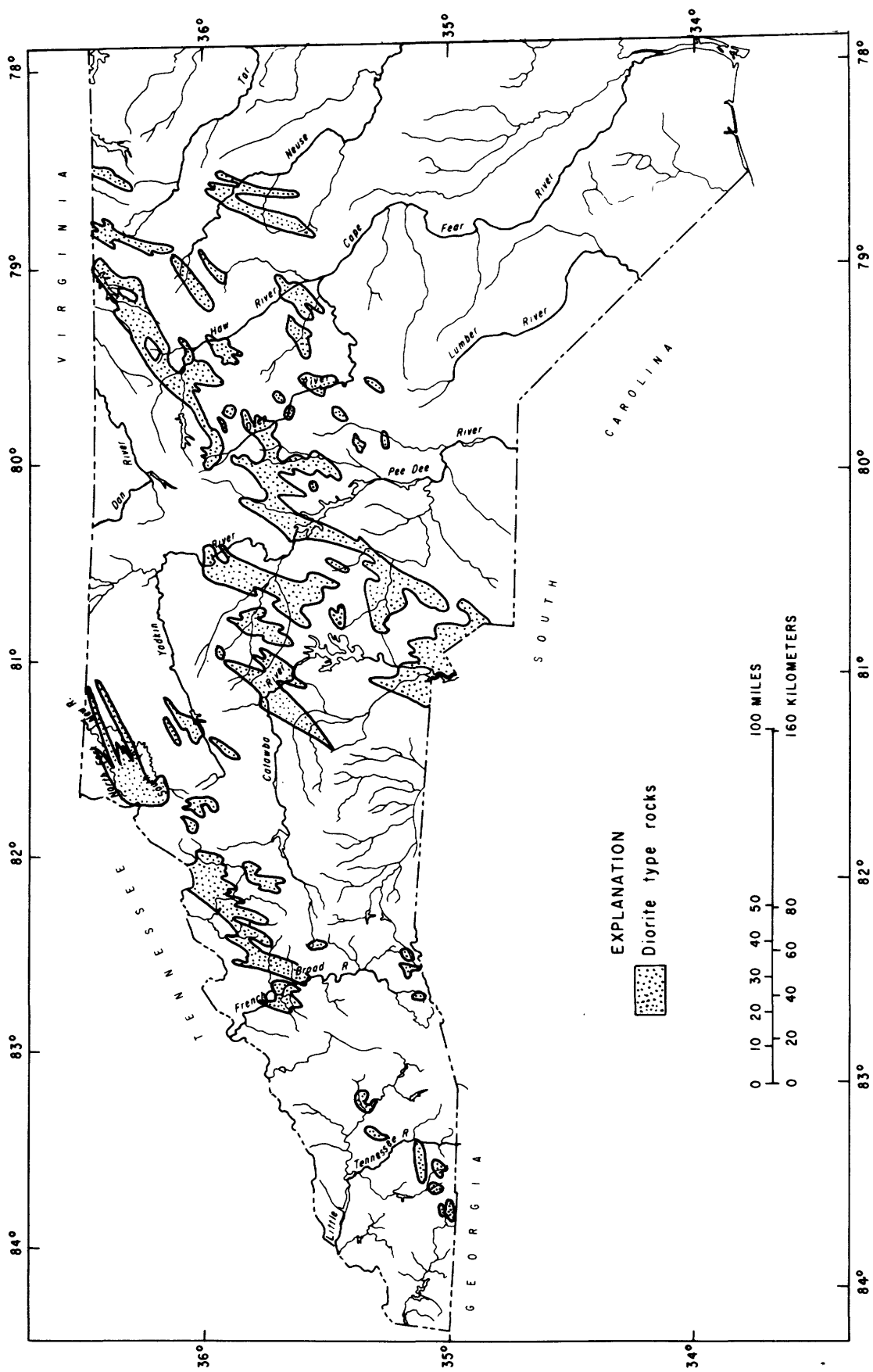


Figure 6.--Areas underlain by rocks of the diorite group.

Geochemical zone IV coincides with the outcrop area of the Black Creek and Pee Dee Formations of Cretaceous age. These formations consist of interbedded layers of sand, clay, and marl. Much of the area is underlain by a surficial layer of quartz sand. As a result, little or no overland runoff occurs and the chemical quality of both high flows and low flows are very similar. Furthermore, because most of the water moves only through the surficial quartz sand, the dissolved solids are relatively low compared to that originating in most of the other geochemical zones.

Geochemical zone V encompasses the remainder of the Coastal Plain and includes the areas underlain by the Castle Hayne Limestone and the Yorktown Formation of Tertiary age, and the surficial sands, shell beds, and clays of Quaternary age. Both the limestone and the shell beds are relatively soluble with the result that water in this zone tends to be somewhat more mineralized than water in zone IV. However, because neither the Castle Hayne nor the shell beds in the Yorktown Formation are continuous over the area, dissolved solids in water from this zone tend to vary more widely than in most other zones of the Coastal Plain region.

CHEMICAL CHARACTERISTICS

The chemical composition of water from the baseline sites is summarized in tables 4-6 at the end of this report. The values shown include the number of samples, mean, range, standard error of the mean, and standard deviation of constituents in both high flow and baseflow. These values also indicate the reliability of the data, which in some cases might be doubtful primarily because of an insufficient data base in some zones. Because the number of samples were different for different stations, mean values for a geochemical zone were computed from mean values for stations located within the zone rather than from individual sample analyses. Data for the three daily-record stations are shown separately in table 4 to permit comparison of the site data with the mean values for zones in which the sites are located. It should be noted that the data for Turner Swamp was not averaged with the other data from zone V because of the significant level of agricultural land use in the Turner Swamp basin.

The areal variations in baseline quality are most readily apparent from figures 7 and 8 which show the mean values for selected constituents during both high flow and baseflow for each geochemical zone. The major inorganic constituents and total dissolved solids are shown in figure 7 and nutrients are shown in figure 8. For those constituents such as magnesium, potassium, and phosphorus, which show little variation in concentrations between geochemical zones and (or) different flow conditions, it might be appropriate to determine a single representative value for the entire State. For purposes of this report, however, individual constituents values have been determined for each zone and flow condition, and presented accordingly to show the presence and extent of regional variations.

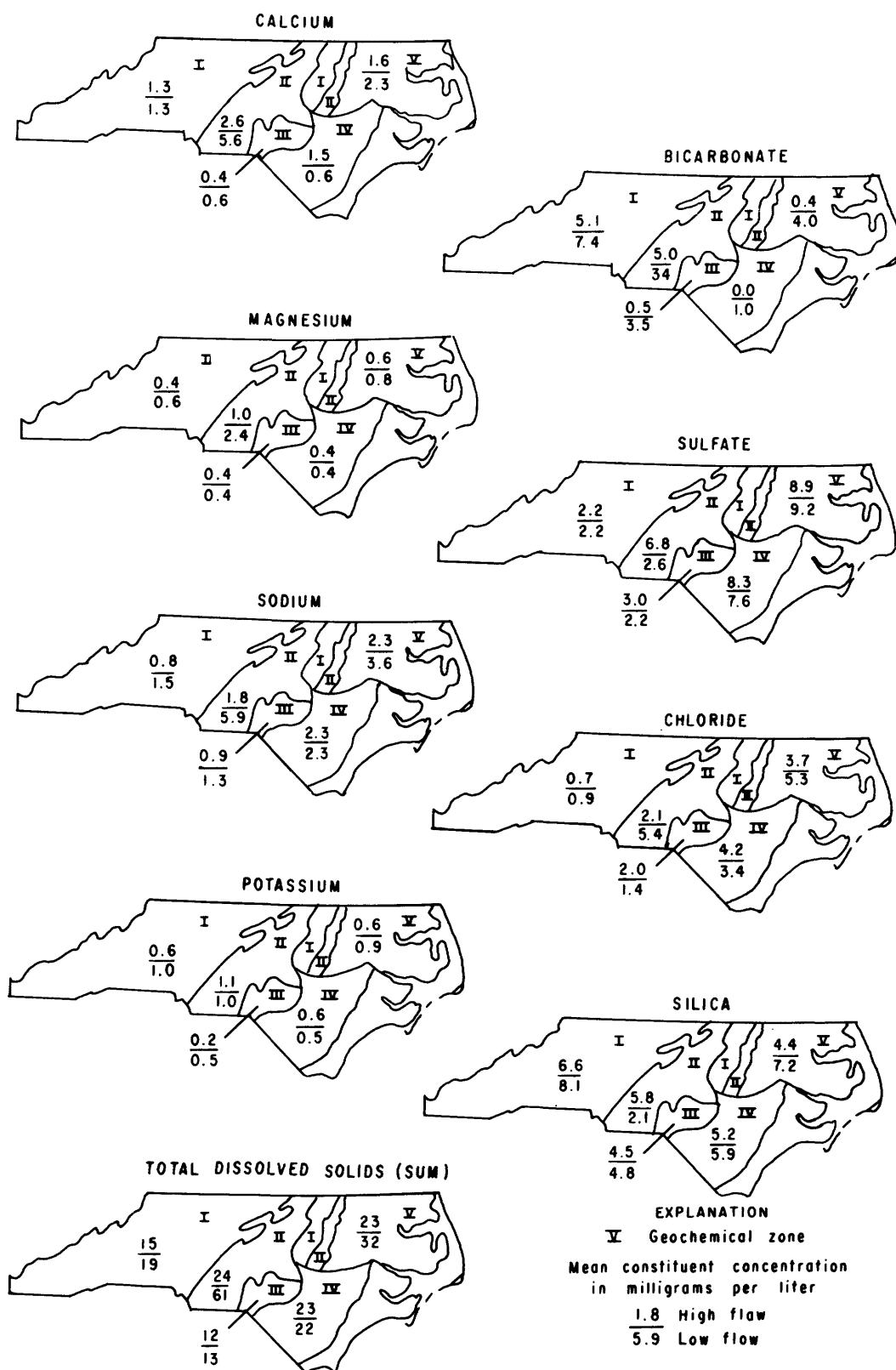


Figure 7.--Mean concentrations of major dissolved inorganic constituents and total dissolved solids in unpolluted streams of North Carolina.

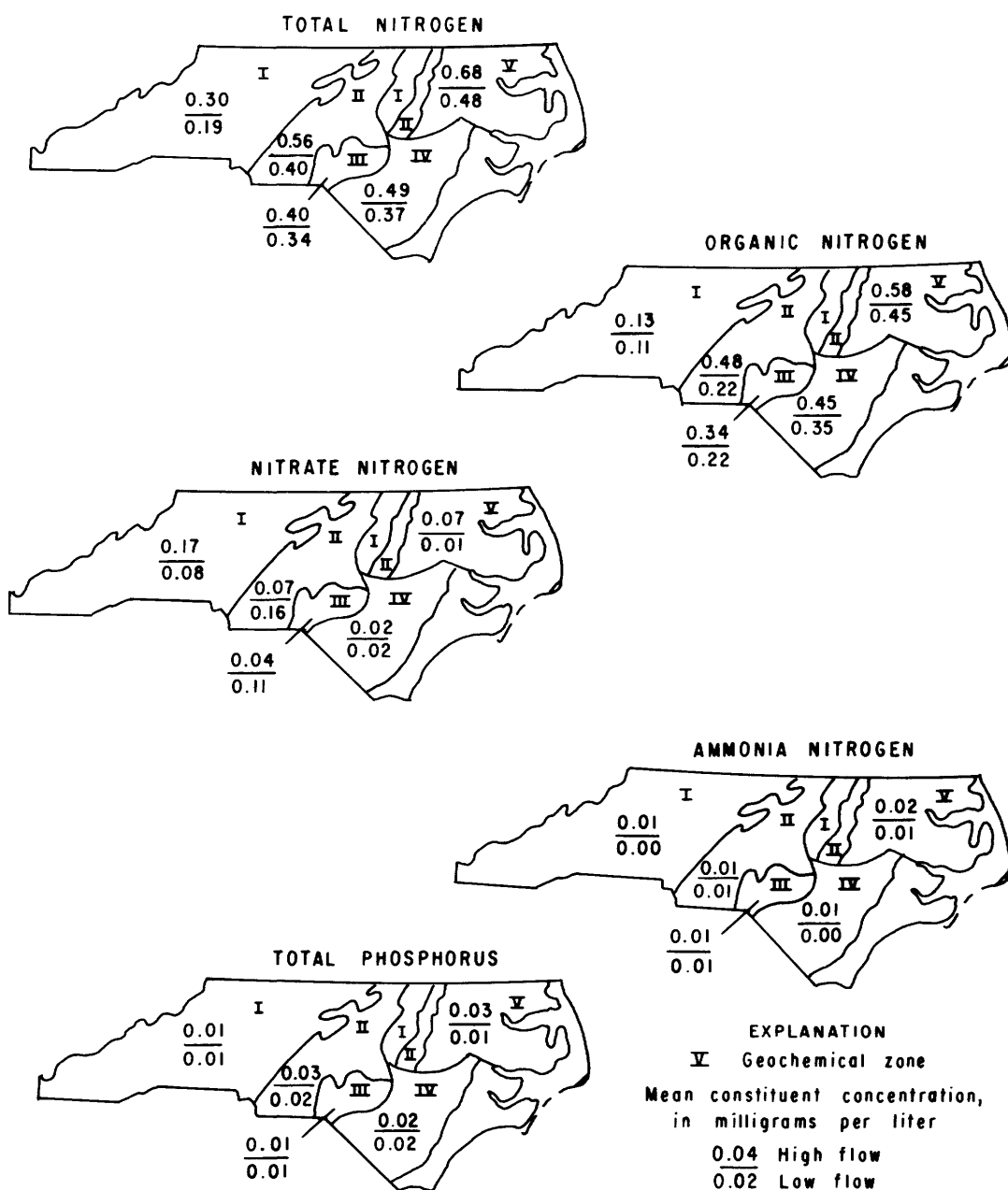


Figure 8.--Mean concentrations of nutrients in unpolluted streams of North Carolina.

The most significant aspect of the data presented in tables 4-6 is the small concentration of substances found in the water. It is not surprising that the smallest values occur in waters of zone III which, as previously noted, coincides with the Sand Hills. Because of the highly permeable nature of the sand underlying this area, nearly all precipitation infiltrates into the ground. However, because the sand is composed almost entirely of relatively-insoluble quartz, there is little opportunity for the water to dissolve additional material. Thus, there is no significant difference in quality between high-flow and baseflow conditions.

The largest concentration of most substances is in waters of zone II. This zone includes the Carolina Slate Belt and the Triassic basins. The explanation for the larger concentrations in this zone is not readily apparent. The constituents showing the largest increases, when compared with data from the other zones, are bicarbonate and silica. The bicarbonate may be derived from solution of calcite and other carbonates which are relatively common as fracture fillings in the Slate Belt. The higher silica content may indicate the presence in zone II of relatively decomposable forms of silicate minerals. Also, zone II is located in the most populated and industrialized area of the State and it is possible that air pollution has a greater effect on water quality in this zone than in the other zones.

Comparison of the data shows that the chemical quality of the runoff from forested areas is remarkably similar for both high-flow and baseflow conditions in all zones. This is consistent with the runoff conditions depicted on figure 3 where it is postulated that nearly all water reaching streams in these areas has either percolated through the soil zone or through the ground-water system. The concentration of some major inorganic substances tends to be somewhat higher in baseflow than in high flow (table 4), indicating that a larger proportion of the streamflow during baseflow conditions is derived from deeper aquifers where waters are generally more mineralized than in the soil zone and shallow aquifers.

The concentrations of nutrients, as shown in table 5 and figure 8, differ from the major inorganic substances in that they tend to increase during high flow. This is consistent with observations that precipitation and organic matter on the surface and in the soil zone, which are the primary paths of flow during storm runoff, are also the primary sources of nutrients in forested areas. Figure 9 shows mean concentrations of total and organic nitrogen in both baseflow and high flow for each geochemical zone.

As shown in table 6, the occurrence of most minor elements, except iron, appears to be unrelated to flow conditions or geographic location. Maximum concentrations of iron in the State's baseline streams occur in storm runoff in zones I and II. Selenium was not found in detectable quantities at any of the baseline sites. Levels of the remaining constituents shown in table 6 are similar across the State thereby indicating a uniform distribution from a single source such as air pollution.

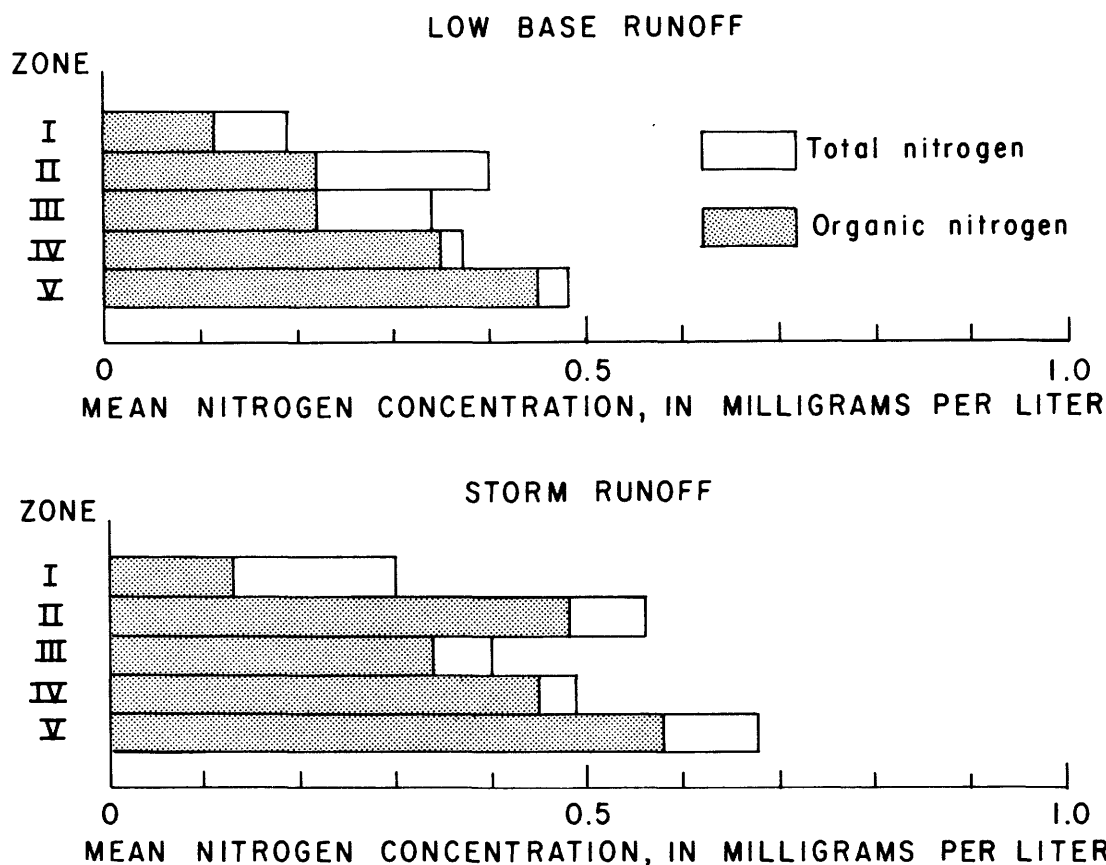


Figure 9.--Mean concentrations of total and organic nitrogen during periods of base and storm runoff in unpolluted streams of North Carolina.

The relation between streamflow and water quality is obviously more complex than indicated by the mean values of different constituents in high flow and baseflow. Figure 10 shows the daily discharge and daily specific conductance for 1975 for Cataloochee Creek and Jacob Fork. The flow of the streams tends to be largest during the winter and spring and smallest during the summer and fall. These pronounced seasonal differences in flow are caused primarily by differences in the loss of water withdrawn by evapotranspiration processes. Specific conductance is a measure of the amount of substances dissolved in water; thus, increases in concentrations produce larger values of specific conductance. Comparison of streamflow and conductivity shows the conductivity is smallest when the flows are the largest.

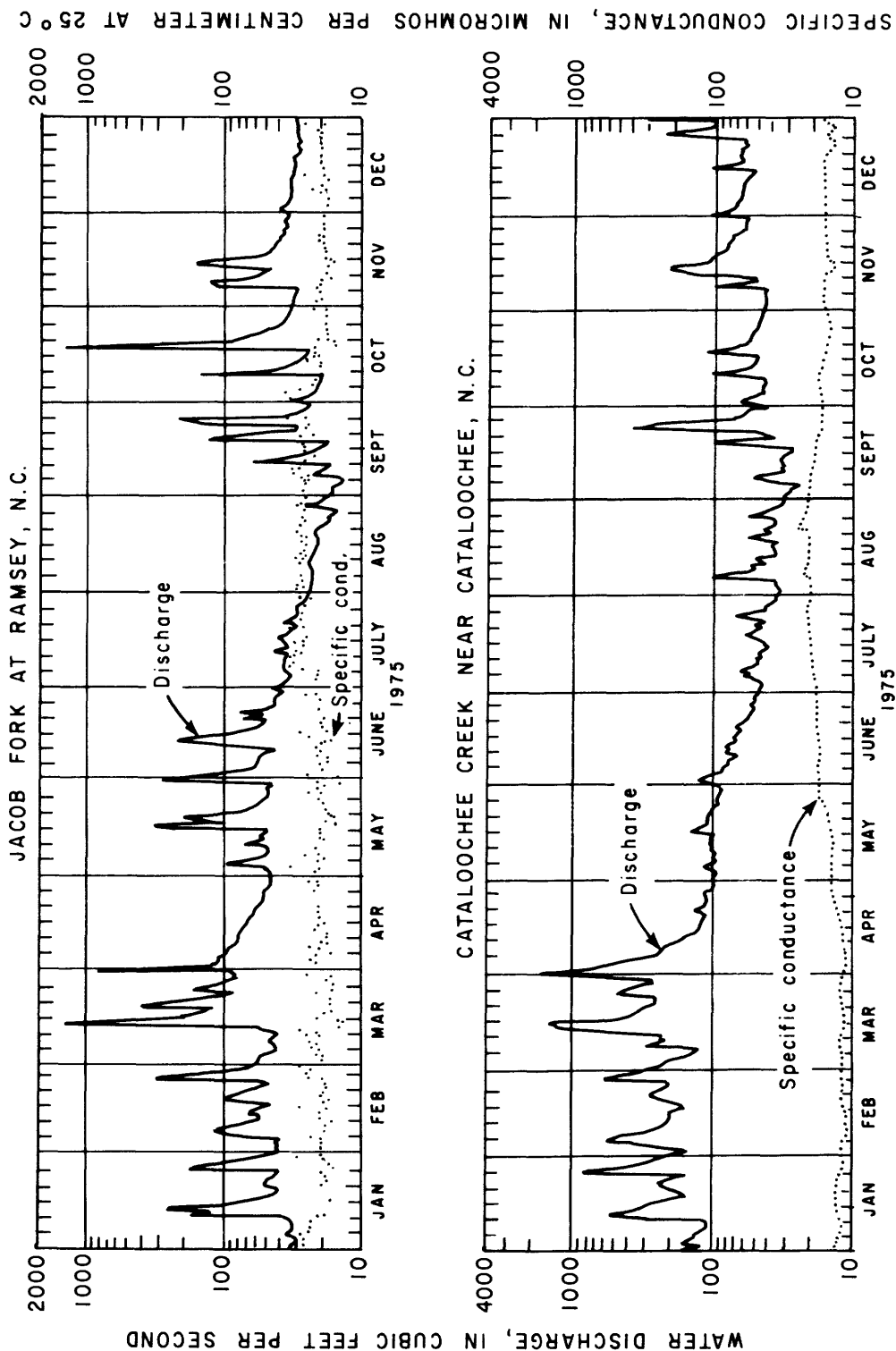


Figure 10.--Daily values of water discharge and specific conductance for Jacob Fork and Cataloochee Creek during 1975.

In order to determine how the concentrations of chemical constituents vary during floods, a series of samples were collected at the three daily stations in the baseline network during several storms. Figure 11 shows the changes in stream discharge and concentrations of selected inorganic constituents observed during storms at two of these stations. As expected, the concentrations decreased rather abruptly when the flow started to increase. Minimum concentrations occur at or slightly ahead of the peak flow and as the flow begins to decline the concentrations begin a rapid return to pre-flood levels. It is apparent from these graphs that, because of their small drainage areas, floods on the streams in the baseline network are short-period events and that samples showing extreme effects of storm runoff on many chemical constituents must be collected at or very shortly before the time of peak flow.

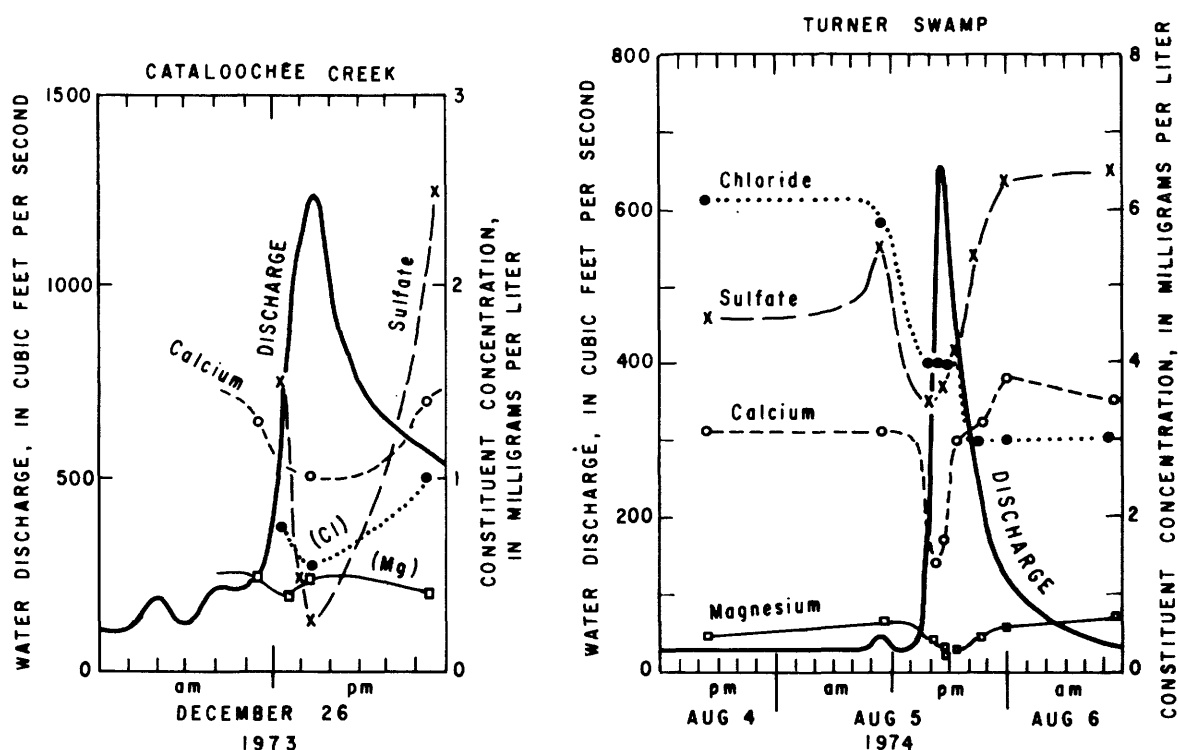


Figure 11.--Concentrations of several major dissolved constituents and discharge during varying flow conditions in Cataloochee Creek and Turner Swamp.

The role of bulk precipitation as a source of chemical constituents has already been briefly discussed. Using constituent concentrations from table 3 and ET (evapotranspiration) data presented by Heath, Thomas, and Dubach (1975, p. 151, fig. 8.2), the amounts of certain constituents contributed by precipitation can be roughly estimated. In making these estimates it is necessary to assume that the chemical constituent for which the estimate is to be made remains in solution in the water, that is,

the constituent is not affected by chemical and biological processes that would affect its concentration and that the concentration of the constituent is increased by the return of water to the atmosphere by evaporation and plant transpiration. Using calcium as an example, the computational procedure is shown in the following table:

| Location | Geochemical zone | (a) | (b) | (c) | (d) |
|-------------|------------------|----------------------------|--------------------------|-----------------------------------|--|
| | | Runoff (100-ET*) (percent) | Quality factor [100÷(a)] | Calcium in precipitation** (mg/L) | Calcium in runoff from bulk precipitation [(b)×(c)] (mg/L) |
| Waynesville | I | 45 | 2 | 0.85 | 1.7 |
| Raleigh | I | 35 | 3 | .41 | 1.2 |
| Washington | V | 35 | 3 | .73 | 2.2 |

*From Heath, Thomas and Dubach (1975, p. 151, fig. 8.2).

**From table 3.

Comparisons of the concentrations of calcium shown above with those determined at baseline sites (fig. 7) indicate that bulk precipitation may be the major source of calcium in streams in geochemical zones I and V and presumably also in the other three zones. The importance of bulk precipitation as the source of a large part of the dissolved material in streamflow from forested basins is further illustrated in figure 12 which shows estimated quantities of major dissolved constituents contributed by bulk precipitation in the Waynesville area as compared to quantities determined in nearby baseline streams. It should be noted that the constituents shown in figure 12 as contributed by bulk precipitation have been increased using the method illustrated in the preceding table to account for the effects of evapotranspiration.

SUSPENDED-SEDIMENT RUNOFF

The collection of suspended-sediment samples was begun during early 1977 to determine the concentration of sediment in runoff from those basins in the baseline network in which there has been little or no disturbance of the natural soil cover. Thus, samples were obtained only from basins that do not contain roads, timber cutting operations, active grazing and agricultural lands, or other possible sources of sediment which are related to man's activities. In the forested basins sampled for suspended sediment, leaf litter and vegetation cover the forest floor, and, except in the stream channel itself, little soil material is exposed to erosion. Also, little, if any, overland runoff occurs in these basins except possibly during very intense rainfall. Thus, except during unusual storms, none of which occurred during the sampling period, the stream channels are believed to be the primary source of suspended sediment.

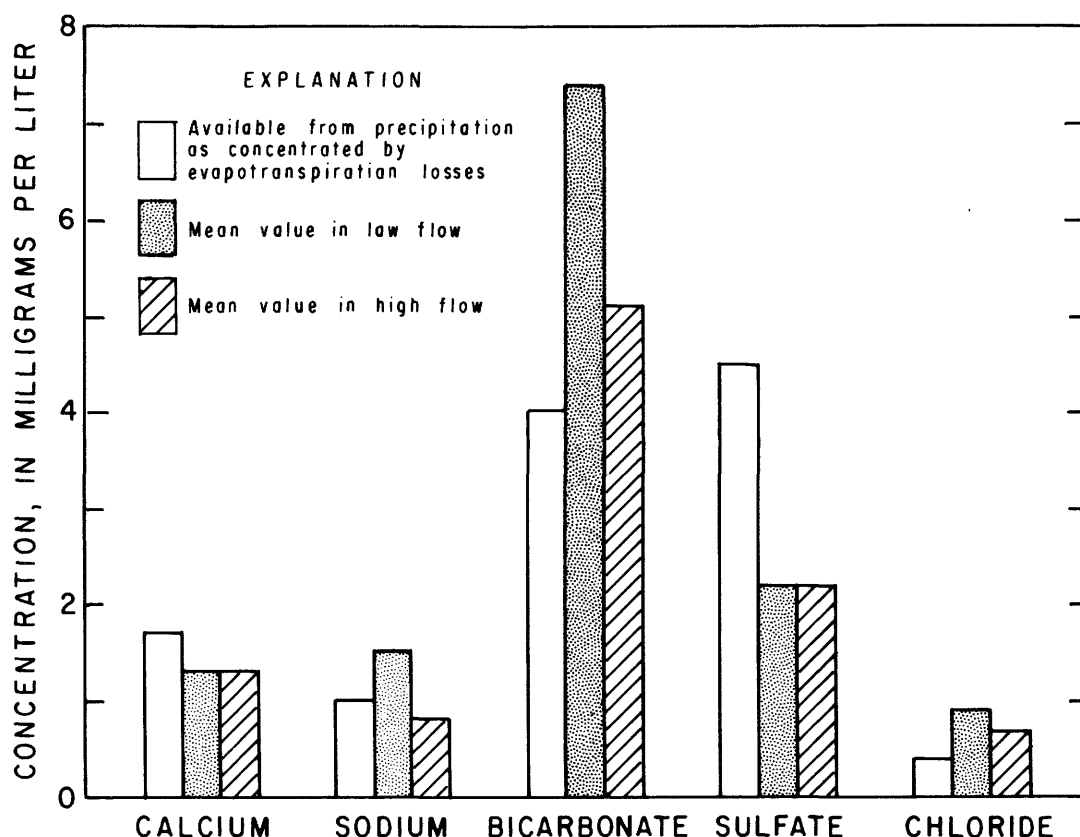


Figure 12.--Estimated quantities of major dissolved constituents derived from precipitation compared with mean concentrations determined for unpolluted streams in the vicinity of Waynesville, geochemical zone I.

Suspended-sediment concentrations vary considerably with flow conditions and reach maximum levels during intense storm runoff. Concentrations also vary from one geochemical zone to another as a result of differences in topography, stream gradients, and the characteristics of the material composing the sides and bottoms of the channels. The results of suspended-sediment samples collected during storm runoff in forested basins are shown in the following table:

| Geochemical zone | No. sites sampled | No. samples | Range in concentration (mg/L) | Mean concentration (mg/L) |
|------------------|-------------------|-------------|-------------------------------|---------------------------|
| I | 7 | 8 | 6-58 | 19 |
| II | 6 | 6 | 39-235 | 110 |
| III | 1 | 5 | 81-145 | 119 |
| IV & V | 7 | 10 | 5-25 | 13 |

Because no severe storms occurred during the collection period the values are representative of flows which, on the average, were near or less than the mean annual flood (that flood flow which is expected to occur, on the average, about every 2.3 years). Greater concentrations than those shown in the table are expected to occur during severe flooding when stream velocities and erosion are at a maximum. Concentrations during low base runoff seldom exceed 10 mg/L and a representative statewide average is about 6 mg/L.

Suspended sediment transported by the baseline streams includes both rock particles and organic matter. Organic matter is readily available in the baseline basins in the layer of litter that covers the forest floor. The relation between suspended-sediment concentration and percent of organic matter at baseline sites is shown in figure 13. It should be noted that the smaller the concentration of suspended sediment, the larger the proportion of organic matter.

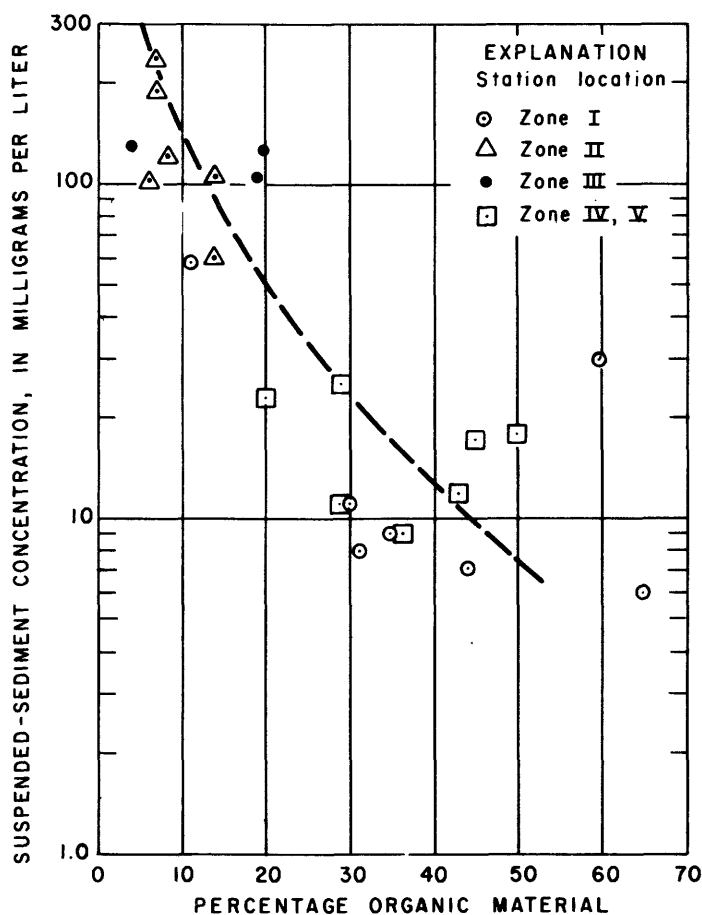


Figure 13.--Relation of percentage organic material in suspended sediment to suspended-sediment concentration for streams in forested basins during storm flow.

As expected, both the range in concentration of suspended sediment and the mean concentration were smallest in zones IV and V in the Coastal Plain where the topography is relatively flat and stream gradients are small. The differences in concentration between zone I in the mountains and western Piedmont and zone II in the central Piedmont was not expected. However, zone II coincides with the Carolina Slate Belt and the Triassic Basins, both of which are underlain by relatively impermeable clayey soils. The larger concentration of suspended sediment being produced from the forested basins in this zone, therefore, may indicate more overland runoff and more easily-eroded soils in this zone than in zone I, which is underlain by coarser-grained and more permeable soils.

The concentration of suspended sediment in zone III, which coincides with the Sand Hills area, also appears, at first glance, to be unusually large. The relatively large concentration in this area, however, may result from the relatively steep gradients of the small, tributary streams whose channels are composed of fine-grained sand.

EFFECTS OF AGRICULTURAL ACTIVITIES ON WATER-QUALITY CHARACTERISTICS

As mentioned previously, 20 of the basins sampled as a part of the baseline network contained agricultural activities that occupied more than ten percent of the area which we suspected might significantly affect water quality. This suspicion was confirmed during analysis of the data and, as a consequence, data from these basins were not used to define baseline water quality. The areas in these basins occupied by houses and by farming operations range from about 15 percent to about 50 percent of the total area (see table 1). Although the data from these basins could not be used to define baseline quality, the data were useful in showing the effect of rural land use on water quality.

Activities in the 20 basins that most likely affect water quality include:

1. The use of fertilizers, pesticides, and herbicides on row crops and pastures,
2. Pollution from farm animals, especially cattle and poultry,
3. Pollution originating from septic tanks used for the disposal of domestic wastes, and
4. Exposure of the land to erosion during the cultivation of fields and land clearing for buildings, roads, or other developments.

The first three items were expected to increase the concentrations of substances dissolved in water leaving the basins. The last item was expected to increase concentrations of suspended sediment and constituents sorbed on or in some way associated with sediment.

Figure 14 shows mean concentrations of selected dissolved constituents in high-flow samples from forested basins in zone I (ten percent or less of the areas affected by agricultural land use) and from basins in which agricultural land use affects more than ten percent of the total area. Streams draining basins where agricultural activities exceed ten percent of the basins land area are generally more mineralized than the baseline streams; and, as shown in figure 14, concentrations of major dissolved constituents are often two to three times greater than those determined for baseline streams.

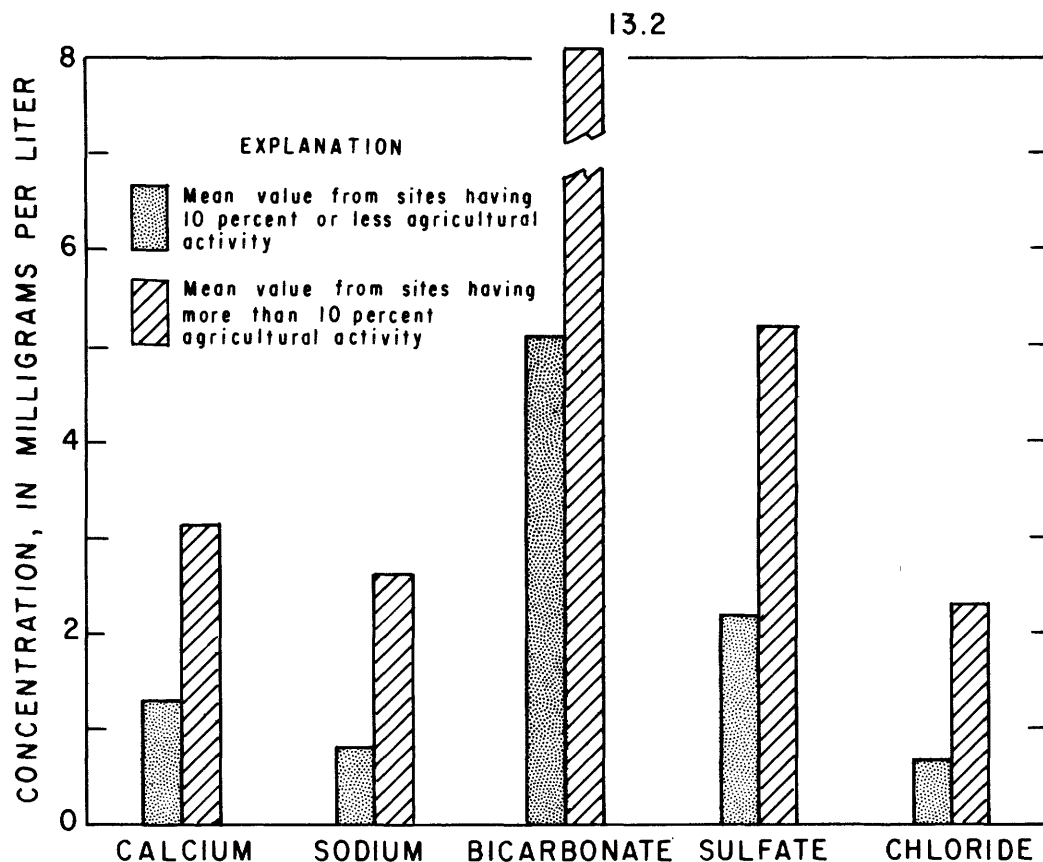


Figure 14.--Comparison of mean constituent concentrations in zone I during storm runoff at unpolluted streams with those for sites where agricultural activities exceed 10 percent of basin land use.

The 20 basins that include significant land use occur in all the geochemical zones except zone III. Therefore, to determine the effect of the land use on water quality, a method was needed which would eliminate the differences in quality between the different zones. Figure 15 shows one method that partly solves this problem. Each of the 59 basins is represented by two points on each graph; one relating to the total nitrogen and

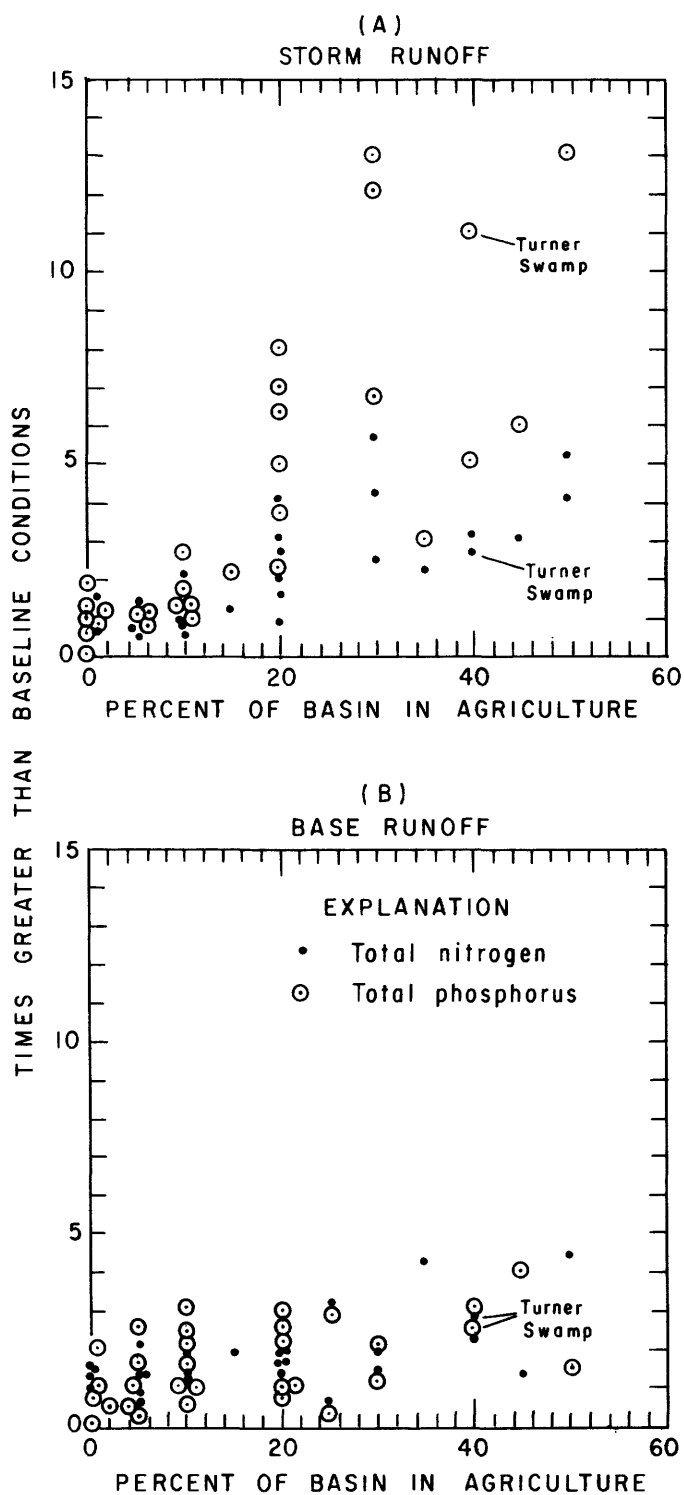


Figure 15.--Relation of percent of basin used for agriculture as compared to increase in nutrients over baseline levels.
A, storm runoff; B, base runoff

the other to total phosphorus. As has previously been discussed, the 39 basins in which non-forest land uses were ten percent or less were used to calculate the mean baseline concentration of different constituents in each zone. In figure 15, the mean concentrations of nitrogen and phosphorus for each of these basins were divided by the mean concentration for the zone in which the basin occurs. The result is plotted on figure 15 versus the percent of the basin in agriculture. Because the basins in which agricultural land use was ten percent or less were used in calculating the zone values, the points for these basins tend to cluster around the factor of one on the vertical axis.

It may be noted in figure 15A that in basins in which agricultural land use was 20 percent or more, total phosphorus was increased by a factor ranging from 2 to 13 times above baseline levels during periods of storm runoff. The increase in total nitrogen was less, ranging from no increase (a factor of one) to about 5 1/2 times. As shown in figure 15B, during base runoff the increases in nutrient concentrations related to land use are much smaller than those in storm runoff.

Concentrations of minor elements remained near baseline levels at the 20 sites affected by agricultural activities. This suggests that few or no minor elements are applied in the study basins or that, if applied, the elements are bound up by soils or biologic processes in such a manner that little escapes. If increases occurred, they were below analytical detection limits.

FUTURE PLANS

Although data collection activities were discontinued at baseline stations during late 1978, efforts to characterize unpolluted stream conditions will continue. A modified baseline data program is scheduled to begin operation in late 1979. Whereas the data used in this report were obtained largely from grab samples obtained at partial-record stations, the revised data network will be composed of approximately ten continuous-record stations located in totally forested basins. Operations at three of these planned stations will begin during October 1979. Other new stations will be added to the network as funds permit. The collection of data will be intensified and will include continuous records of streamflow and specific conductance and a sufficient number of water samples to define a full range of flow conditions.

The new program also contains plans to better define the major contributors of stream runoff. Networks of ground-water wells are planned for installation in several forested basins, thereby, providing information needed to determine the quantity and quality of ground-water runoff.

In the future better information on atmospheric contributions to stream quality will be obtained from the National Atmospheric Deposition Program (NADP). Established in 1978, the NADP is a nationwide program supported by several Federal and State agencies, universities, and private groups from both the United States and Canada. Five of the network's 46 precipitation stations (as of 1978) are located in North Carolina. Data obtained at these stations over the next several years should greatly enhance our knowledge of precipitation as a source of chemical constituents in streams.

Although we do not expect data obtained from the new network to invalidate the findings of this preliminary study, some adjustments in constituent values may result from the more intensive data coverage.

SUMMARY

Data obtained on 39 rural streams, whose basins were 90 to 100 percent forested, were used to characterize baseline stream conditions during periods of base runoff and storm runoff. Except for the effects of air pollution, which currently cannot be quantified, the sites are believed to be relatively free of man's activities. Baseline stream quality is primarily influenced by the quality of precipitation and by the types of rocks and soils underlying the stream basin. To facilitate comparisons of water-quality characteristics on a statewide basis, the State was divided into five geochemical zones in which baseline quality within individual zones is similar. Each geochemical zone is underlain by one or more major rock types having the same or similar chemical characteristics.

The sources of flow often play a prominent role in baseline stream quality. Although the differences might only be slight, water derived from overland runoff and (or) the shallow soil zone generally contains lower concentrations of major dissolved constituents and higher concentrations of nutrients than waters derived from deeper subsurface sources. When compared statewide, the chemical characteristics of baseline streams are surprisingly similar during intense storm runoff; however, large differences in concentrations of major constituents and nutrients often exist during base runoff. Except for iron, concentrations of minor elements, when in detectable quantities, are relatively uniform in streams across the State and remain relatively constant throughout changing flow conditions.

Data obtained from an additional 20 rural sites, which were affected by farming activities, show significant increases above baseline levels in concentrations of major dissolved constituents and nutrients. The effects of farming were most pronounced during intense storms. At most of these 20 sites, concentrations of several major dissolved constituents during storm runoff averaged 2 to 3 times greater than those determined for baseline conditions while total phosphorus levels were 2 to 13 times greater and total nitrogen as much as five times greater.

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TABLES

Table 1.--Names, locations, and physical characteristics of baseline sampling sites.

| Map number (fig. 1) | Station number and name | Location | Drainage area (mi ²) | Geochemical zone (See fig. 4) | Land use, in percent of total drainage area | | Remarks |
|---------------------|--|---|----------------------------------|-------------------------------|---|-------------|---|
| | | | | | Forest | Agriculture | |
| 1 | 02053021. Jacks Swamp near Pleasant Hill | Lat 36°30'55", long 77°32'35", Northampton County, at Secondary Road 1203, 1.2 miles south-south east of Pleasant Hill. | 6.10 | V | 80 | 20 | U.S. Highway I-95 crosses upper part of basin. Sampling discontinued in 1977. |
| 2 | 02053249. Deep Creek near Coffield | Lat 36°22'25", long 76°56'00", Hertford County, at State Highway 45, 1.7 miles northwest of Coffield. | 3.00 | V | 75 | 25 | Sampling discontinued in 1977. |
| 3 | 02070806. Huffines Mill Creek near Bethany | Lat 36°20'00", long 79°51'26", Rockingham County, at Secondary Road 2359, 1.8 miles north of Bethany. | 1.60 | I | 80 | 20 | Sampling discontinued in 1977. |
| 4 | 02077629. Mayo Creek Trib. near Allensville | Lat 36°23'55", long 78°54'05", Person County, at bridge on Secondary Road 1520, 1.0 mile northwest of Allensville. | 0.68 | II | 80 | 20 | Paved county road crosses basin. Sampling discontinued in 1977. |
| 5 | 02081026. Indian Creek Trib. near Cahaba | Lat 36°01'02", long 77°10'38", Bertie County, at Secondary Road 1123, 2.0 miles southwest of Cahaba | 0.50 | V | 100 | 0 | Station established in March 1978. |
| 6 | 02081031. Coniott Creek near Cahaba | Lat 36°00'41", long 77°08'05", Bertie County, at Secondary Road 1108, 2.4 miles southwest of Cahaba. | 2.80 | V | 95 | 5 | Station established in October 1977, but abandoned because of farm activities immediately upstream from sampling point. |
| 7 | 02081082. Hardison Creek near Roberson Store | Lat 35°43'20", long 76°57'30", Martin County, at Secondary Road 1543, 1.6 miles southeast of Roberson Store. | 14.00 | V | 95 | 5 | Large-scale timber clearing operation underway since 1973. |

Table 1.--Names, locations, and physical characteristics of baseline sampling sites.--Continued

| Map number (fig. 1) | Station number and name | Location | Drainage area (mi ²) | Geochemical zone (See fig. 4) | Land use, in percent of total drainage area | | Remarks |
|---------------------|---|---|----------------------------------|-------------------------------|---|-----------------|--|
| | | | | | Forest | Agriculture | |
| 8 | 02082625. Walnut Creek at Kingsboro | Lat 35°55'35", long 77°40'34", Edgecombe County, at Secondary Road 1225, 0.6 mile north of Kingsboro. | 0.80 | V | 100 | 0 | Station established in March 1978. |
| 9 | 02082824. Fishing Creek near Middleburg | Lat 36°23'06", long 78°19'05", Vance County, at Secondary Road 1501, 1.1 miles south-southwest of Middleburg. | 3.30 | I | 55 | 45 ^a | Railroad and major highway cross extreme upper part of basin. Sampling activities discontinued in 1978. |
| 10 | 02082920. White Oak Swamp near Action | Lat 36°09'59", long 78°00'05", Nash County, at Secondary Road 1004, 3.2 miles west-northwest of Aventon. | 4.10 | II | 75 | 25 | Farming activities increased in basin during spring-summer 1976. Sampling activities discontinued in 1976. |
| 11 | 02086300. Rocky Creek near Bahama | Lat 36°10'30", long 78°49'20", Durham County, at Secondary Road 1616, 3.3 miles northeast of Bahama. | 2.40 | II | 90 | 10 | Military rifle range and living quarters constructed in basin during late 1976. Paved county road crosses upper part of basin. Sampling activities discontinued. |
| 12 | 02087173. Horse Creek Trib. near Pocomoke | Lat 36°02'33", long 78°31'03", Franklin County, at Secondary Road 1140, 2.7 miles southeast of Pocomoke. | 1.1 | I | 80 | 20 ^a | Sampling discontinued in 1977. |
| 13 | 02087499. Neuse River Trib. near Clayton | Lat 35°39'05", long 78°24'11", Johnston County, 0.2 mile above Secondary Road 1705, 3.0 miles east of Clayton. | 1.30 | I | 80 | 20 ^a | Sampling discontinued in 1977. |
| 14 | 02088314. Beaverdam Creek near Dobbersville | Lat 35°17'56", long 78°15'57", Wayne County, at Secondary Road 1009, 5.3 miles north-northwest of Dobbersville. | 2.60 | IV | 50 | 50 | Major increase in agriculture in 1976. Paved county road crosses upper part of basin. Sampling activities discontinued in 1977. |

Table 1.--Names, locations, and physical characteristics of baseline sampling sites.--Continued

| Map number (fig. 1) | Station number and name | Location | Drainage area (mi ²) | Geochemical zone (See fig. 4) | Land use, in percent of total drainage area | | Remarks |
|---------------------|---|--|----------------------------------|-------------------------------|---|-----------------|--|
| | | | | | Forest | Agriculture | |
| 15 | 02089168. Mill Creek near Seven Springs | Lat 35°14'14", long 77°52'57", Wayne County, in Cliffs of the Neuse State Park, 2.0 miles west of Seven Springs. | 0.79 | IV | 95 | 5 | Located in Cliffs of the Neuse State Park. |
| 16 | 02090625. Turner Swamp near Eureka | Lat 35°34'10", long 77°52'40", Wayne County, at Secondary Road 1505, 2.0 miles north of Eureka. | 2.2 | V | 60 | 40 ^a | Continuous-record station. Sampling activities discontinued in 1976. |
| 17 | 02090666. White Oak Swamp near Mount Pleasant | Lat 35°48'55", long 78°04'42", Nash County, at Secondary Road 1956, 1.8 miles east of Mount Pleasant. | 1.00 | V | 45 | 55 ^a | Lightly-travelled county road crosses upper part of basin. Sampling activities discontinued in 1978. |
| 18 | 02091476. Rainbow Creek near Browntown | Lat 35°24'00", long 77°34'50", Greene County, at U.S. Highway 258, 1.5 miles north of Browntown. | 5.00 | IV | 60 | 40 ^a | Lightly-travelled county road encircles basin. Sampling discontinued in 1977. |
| 19 | 02091949. Clayroot Swamp near Shelmerdine | Lat 35°27'16", long 77°13'12", Pitt County, at bridge on Secondary Road 1786, 2.4 miles east of Shelmerdine. | 0.60 | V | 90 | 10 | Approximately 25 percent of wooded area is covered with underbrush and young timber. |
| 20 | 02091961. Creeping Swamp near Wilmar | Lat 35°25'42", long 77°10'40", Beaufort County, on Sutton Road, 2.7 miles northwest of Wilmar. | 0.2 | V | 100 | 0 | Station established 1978. |
| 21 | 02092551. Crooked Run near Trenton | Lat 35°02'25", long 77°22'07", Jones County, at Secondary Road 1123, 2.1 miles south-southwest of Trenton. | 17.00 | V | 90 | 10 | Most of basin drains from Hoffman State Forest. |

Table 1.--Names, locations, and physical characteristics of baseline sampling sites.--Continued

| Map number (fig. 1) | Station number and name | Location | Drainage area (mi ²) | Geochemical zone (See Fig. 4) | Land use, in percent of total drainage area | | Remarks |
|---------------------|---|---|----------------------------------|-------------------------------|---|-----------------|---|
| | | | | | Forest | Agriculture | |
| 22 | 02092569. Brice Creek at Croatan | Lat 34°57'56", long 76°58'26", Craven County, at Secondary Road 1100, 0.4 mile southwest of Croatan. | 0.80 | V | 100 | 0 | Located in Croatan National Forest. |
| 23 | 02096845. Cane Creek near Buckhorn | Lat 36°01'19", long 79°10'29", Orange County, at Secondary Road 1126, 2.5 miles southeast of Buckhorn. | 1.00 | II | 95 | 5 | Approximately 45 percent of wooded area is young timber and underbrush. |
| 24 | 02096975. Ward Creek near Bynum | Lat 35°46'40", long 79°05'44", Chatham County, at Secondary Road 1700, 1.7 miles east of Bynum. | 1.29 | II | 90 | 10 | Large housing development started in basin in early 1977. Sampling activities discontinued. |
| 25 | 02097715. New Hope Creek Trib. near Farrington | Lat 35°47'08", long 79°01'50", Chatham County, at bridge on Secondary Road 1715, 1.5 miles southwest of Farrington. | 0.30 | II | 95 | 5 | Site now (1979) affected by land-clearing operations for B. Everett Jordan reservoir. |
| 26 | 02100459. Sandy Creek Trib. at Melancton | Lat 35°50'26", long 79°39'17", Randolph County, at Secondary Road 2261, 0.8 mile southeast of Melancton. | 3.30 | II | 80 | 20 ^a | Sampling discontinued in 1977. |
| 27 | 02100749. Grassy Creek near Jugtown | Lat 35°29'13", long 79°37'30", Moore County, at Secondary Road 1003, 2.2 miles southeast of Jugtown. | 3.20 | II | 70 | 30 ^a | Several dairy and poultry farms in basin. Sampling activities discontinued in 1977. |
| 28 | 02101357. Big Governors Creek Trib. near Carthage | Lat 35°23'05", long 79°19'56", Moore County, at bridge on Secondary Road 1660, 5.2 miles northeast of Carthage. | 2.90 | II | 90 | 10 | State Highway crosses upper part of basin. |

Table 1.--Names, locations, and physical characteristics of baseline sampling sites.--Continued

| Map number (fig. 1) | Station number and name | Location | Drainage area (mi ²) | Geochemical zone (See fig. 4) | Land use, in percent of total drainage area | | Remarks |
|---------------------|---|--|----------------------------------|-------------------------------|---|-------------|--|
| | | | | | Forest | Agriculture | |
| 29 | 02102237. Parkers Creek Trib. near Cokesbury | Lat 35°32'19", long 78°55'17", Harnett County, at mouth, 0.1 mile below Secondary Road 1450, 1.2 miles northwest of Cokesbury. | 0.45 | II | 98 | 2 | Station established in December 1977. |
| 30 | 02102908. Flat Creek near Inverness | Lat 35°10'54", long 79°10'40", Hoke County, at culvert on Manchester Road, 3.6 miles east of Inverness. | 7.65 | III | 100 | 0 | Isolated section of Fort Bragg Military Reservation. Continuous-record streamflow station. |
| 31 | 02105524. Ellis Creek Trib. near White Oak | Lat 34°46'02", long 78°41'24", Bladen County, at Secondary Road 1325, 1.4 miles northeast of White Oak. | 1.6 | IV | 100 | 0 | |
| 32 | 02107154. South River Trib. at Tomahawk | Lat 34°42'15", long 78°20'25", Sampson County, at N.C. Highway 41, 0.9 mile southwest of Tomahawk. | 2.80 | IV | 95 | 5 | |
| 33 | 02108608. Lillington Creek near St. Helena. | Lat 34°30'27", long 77°48'57", Pender County, at Secondary Road 1520, 5.9 miles east-southeast of St. Helena. | 7.60 | V | 90 | 10 | Most of basin lies in Holly Shelter State Game Management Area. |
| 34 | 02109481. Juniper Creek near Prospect | Lat 34°06'07", long 78°18'25", Brunswick County, at State Highway 211, 4.2 miles north-north-east of Prospect. | 6.40 | IV | 100 | 0 | |
| 35 | 02111275. Big Warrior Creek Subtributary near Boomer. | Lat 36°03'04", long 81°15'47", Wilkes County, at Secondary Road 1116, 1.2 miles southwest of Boomer. | 0.30 | I | 95 | 5 | |

Table 1.--Names, locations, and physical characteristics of baseline sampling sites.--Continued

| Map number (fig. 1) | Station number and name | Location | Drainage area (mi ²) | Geochemical zone (See fig. 4) | Land use, in percent of total drainage area | | Remarks |
|---------------------|---|--|----------------------------------|-------------------------------|---|-----------------|---|
| | | | | | Forest | Agriculture | |
| * 36 | 02112202. Grays Creek near Clingman | Lat 36°10'27", long 80°58'03", Wilkes County, at Secondary Road 2318, 2.2 miles west-southwest of Clingman. | 2.20 | I | 60 | 40 ^a | State highway crosses part of basin. Sampling discontinued in 1977. |
| 37 | 02112401. Endicott Creek near Blevins Store. | Lat 36°28'15", long 80°50'06", Surry County, at Secondary Road 1338, 1.4 miles northwest of Blevins Store. | 3.20 | I | 98 | 2 | |
| 38 | 02114256. East Prong Little Yadkin River Trib. near Capella | Lat 36°21'49", long 80°21'08", Stokes County, at Secondary Road 1166, 1.9 miles west of Capella. | 0.50 | I | 90 | 10 | |
| 39 | 02115496. Little Forbush Creek near Forbush | Lat 36°11'13", long 80°34'59", Yadkin County, at Secondary Road 1584, 0.9 mile southwest of Forbush. | 1.70 | I | 80 | 20 ^a | Sampling discontinued in 1975. |
| 40 | 02115946. Fries Creek Trib. near Midway | Lat 35°57'30", long 80°14'32", Davidson County, at Secondary Road 1506, 1.4 miles west of Midway. | 0.40 | I | 50 | 50 ^a | Lightly-travelled paved road transverses mid-basin. Sampling activities discontinued in 1977. |
| 41 | 02117485. Olin Creek near Union Grove | Lat 35°59'15", long 80°55'16", Iredell County, at Secondary Road 1868, 4.0 miles southwest of Union Grove. | 2.00 | I | 90 | 10 ^a | Several dairy farms throughout basin. |
| 42 | 02120507. Tributary to Third Creek Trib. near Barber | Lat 35°44'02", long 80°39'04", Rowan County, 0.4 mile above Secondary Road 1741, 1.0 mile northwest of Barber. | 0.04 | I | 99 | 1 | Station established in December 1977. |

Table 1.--Names, locations, and physical characteristics of baseline sampling sites.--Continued

| Map number (fig. 1) | Station number and name | Location | Drainage area (mi. ²) | Geochemical zone (See fig. 4) | Land use, in percent of total drainage area | | Remarks |
|---------------------|--|---|-----------------------------------|-------------------------------|---|-----------------|--|
| | | | | | Forest | Agriculture | |
| 43 | 02123532. Spencer Creek at Uwharrie | Lat 35°25'22", long 79°59'53", Montgomery County, at Secondary Road 1303, 0.6 mile northeast of Uwharrie. | 6.90 | II | 99 | 1 | Located in Uwharrie National Forest. Station established in October 1977. |
| 44 | 02124193. Park Creek near Kannapolis | Lat 35°29'53", long 80°42'58", Cabarrus County, at Secondary Road 1624, 4.3 miles west of Kannapolis. | 5.20 | I | 70 | 30 ^a | Active dairy farming at several places in basin. Paved county road crosses part of basin. Sampling discontinued in 1977. |
| 45 | 02127228. Goulds Fork near Wadesboro | Lat 34°57'23", long 80°07'23" Anson County, at Secondary Road 1205, 2.7 miles southwest of Wadesboro. | 3.80 | II | 99 | 1 | Station established in October 1977. Lightly-travelled, unpaved road crosses part of basin. |
| 46 | 02129028. Bones Fork Creek near Hoffman | Lat 35°01'26", long 79°38'02", Richmond County, at bridge on Secondary Road 1487, 4.8 miles west of Hoffman. | 6.96 | III | 95 | 5 ^a | Located primarily in Sandhill Game Management Area. |
| 47 | 02140304. Wilson Creek near Gragg | Lat 37°05'49", long 81°48'28", Avery County, at bridge on U.S. Highway 221, 2.7 miles northwest of Gragg | 0.74 | I | 100 | 0 | |
| 48 | 02142122. Lower Little River Trib. near Taylorsville | Lat 35°53'24", long 81°13'52", Alexander County, at Secondary Road 1124, 3.4 miles southwest of Taylorsville. | 2.60 | I | 90 | 10 | Small dairy farm in lower part of basin. |
| 49 | 02142692. Killian Creek near Denver | Lat 35°32'10", long 80°03'13", Lincoln County, at Secondary Road 1349, 1.4 miles west of Denver. | 2.60 | I | 70 | 30 ^a | Paved secondary road encircles basin. Permanent pastures and cattle (less than 100 head) in upper part of basin. Sampling activities discontinued in 1978. |

Table 1.--Names, Locations, and physical characteristics of baseline sampling sites.--Continued

| Map number (fig. 1) | Station number and name | Location | Drainage area (mi ²) | Geochemical zone (See fig. 4) | Land use, in percent of total drainage area | | Remarks |
|---------------------|--|---|----------------------------------|-------------------------------|---|-----------------|---|
| | | | | | Forest | Agriculture | |
| 50 | 02142988. Henry Fork Trib. near Pleasant Grove | Lat 35°39'07", long 81°36'28", Burke County, at Secondary Road 1924, 1.9 miles northwest of Pleasant Grove. | 3.20 | I | 95 | 5 | Most of basin in South Mountains Management Area. |
| 51 | 02143040. Jacob Fork at Ramsey | Lat 35°35'26", long 81°34'02", Burke County, at Secondary Road 1924, 0.6 mile north of Ramsey. | 25.4 | I | 96 | 4 | Continuous-record streamflow station. Sampling discontinued in 1977. |
| 52 | 02149716. Silver Creek near Mill Spring | Lat 35°18'35", long 82°12'10", Polk County, at Secondary Road 1138, 2.4 miles west-northwest of Mill Spring. | 1.20 | I | 98 | 2 | |
| 53 | 02152514. Little Harris Creek near Campbell | Lat 35°22'34", long 81°35'45", Cleveland County, at Secondary Road 1821, 1.3 miles east of Campbell. | 1.20 | I | 65 | 35 ^a | Most of cleared land is inactive pasture. Sampling activities discontinued in 1977. |
| 54 | 03445376. North Fork Mills River above Mills River | Lat 35°24'25", long 82°38'47", Henderson County, at bridge on Natural Forest Road, 4.7 miles west-northwest of Mills River. | 18.60 | I | 100 | 0 | Located in Pisgah National Forest. |
| 55 | 03450000. Beetree Creek near Swannanoa | Lat 35°39'11", long 82°24'20", Buncombe County, 1,000 feet above Beetree Reservoir, 3.8 miles north of Swannanoa. | 5.46 | I | 100 | 0 | Located in protected municipal watershed area. |
| 56 | 03460000. Cataloochee Creek near Cataloochee | Lat 35°40'02", long 83°04'23", Haywood County, at bridge on State Highway 284, 2 miles north of Cataloochee. | 49.2 | I | 98 | 2 ^a | Continuous-record streamflow station. Located in Great Smoky Mountains National Park. |

Table 1.--Names, locations, and physical characteristics of baseline sampling sites.--Continued

| Map number (fig. 1) | Station number and name | Location | Drainage area (mi. ²) | Geochemical zone (See fig. 4) | Land use, in percent of total drainage area | | Remarks |
|---------------------|--------------------------------------|---|-----------------------------------|-------------------------------|---|----------------|---|
| | | | | | Forest | Agriculture | |
| 57 | 03463292. Locust Creek near Celo | Lat 35°48'42", long 82°11'52", Yancey County, at Secondary Road 1158, 3.0 miles south of Celo. | 1.80 | I | 95 | 5 ^a | |
| 58 | 03500741. Peaks Creek near Gneiss | Lat 37°07'08", long 83°17'40", Macon County, at Secondary Road 1678, 1.3 miles southeast of Gneiss. | 2.00 | I | 97 | 3 ^a | |
| 59 | 03510815. Mingus Creek at Ravensford | Lat 35°31'12", long 83°18'30", Swain County, at bridge on U.S. Highway 441, 0.9 mile northwest of Ravensford. | 4.70 | I | 100 | 0 | Located in Great Smoky Mountains National Park. |

a - Partly inactive.

Table 4.--Statistical summary of major inorganic constituents, in milligrams per liter, in unpolluted streams.
[SD, standard deviation; SE, standard error of mean; ND, not determined]

| Geo-chemical zone | Base-line site(s) | Runoff condition and number of analyses | Calcium | | | | Magnesium | | | | Sodium | | | | Potassium | | | | Bicarbonate | | | |
|-------------------|-------------------|---|---------|---------|-----|-----|-----------|---------|-----|-----|--------|---------|-----|-----|-----------|---------|-----|-----|-------------|---------|-----|-----|
| | | | Mean | Range | SD | SE | Mean | Range | SD | SE | Mean | Range | SD | SE | Mean | Range | SD | SE | Mean | Range | SD | SE |
| I | All | Storm(13) | 1.3 | 0.5-3.0 | 0.8 | 0.2 | 0.4 | 0.3-.9 | 0.2 | 0.1 | 0.8 | 0.4-1.3 | 0.3 | 0.1 | 0.6 | 0.4-.9 | 0.2 | 0.1 | 5.1 | 2.0-8.0 | 1.8 | 0.5 |
| | | Baseflow(31) | 1.3 | .7-2.1 | .4 | .1 | .6 | .3-.9 | .2 | .1 | 1.5 | 1.0-2.2 | .4 | .1 | 1.0 | .3-1.9 | .5 | .1 | 7.4 | 6.0-9.5 | 1.2 | .4 |
| | Cataloo-chee Cr. | Storm(2) | 2.3 | .6-1.9 | ND | ND | .4 | .2-.5 | ND | ND | .4 | .4 | ND | ND | .7 | .6-.8 | ND | ND | 3.5 | 3.0-4.0 | ND | ND |
| | Jacob Fork | Baseflow(8) | 1.8 | .9-2.6 | ND | ND | .5 | .1-1.1 | ND | ND | 1.4 | .9-2.0 | ND | ND | .6 | .2-.8 | ND | ND | 6.7 | 5.0-8.0 | ND | ND |
| II | All | Storm(2) | 1.2 | .7-1.7 | ND | ND | .3 | .3 | ND | ND | .4 | .4 | ND | ND | .8 | .7-.8 | ND | ND | 3.5 | 3.0-4.0 | ND | ND |
| | | Baseflow(8) | 1.7 | .7-2.9 | ND | ND | .5 | .2-.9 | ND | ND | 1.4 | 1.1-1.8 | ND | ND | .9 | .7-1.3 | ND | ND | 9.4 | 6.0-16 | ND | ND |
| | | Storm(6) | 2.6 | 2.1-3.2 | .4 | .2 | 1.0 | .7-1.1 | .2 | .1 | 1.8 | 1.3-2.5 | .5 | .2 | 1.1 | .3-1.8 | .6 | .2 | 5.0 | 3.0-6.0 | 1.1 | .4 |
| | | Baseflow(12) | 5.6 | 2.9-10 | 2.1 | .7 | 2.4 | 1.1-4.1 | 1.0 | .3 | 5.9 | 4.7-7.3 | 1.1 | .4 | 1.0 | .3-1.8 | .5 | .2 | 34 | 21-44 | 7.4 | 2.6 |
| III | All | Storm(3) | .4 | 1-8 | ND | ND | .4 | .3-.5 | ND | ND | .9 | .8-1.0 | ND | ND | .2 | .1-.2 | ND | ND | .5 | 0-1.0 | ND | ND |
| | | Baseflow(4) | .6 | .5-.6 | ND | ND | .4 | .3-.4 | ND | ND | 1.3 | 1.0-1.5 | ND | ND | .5 | .5 | ND | ND | 3.5 | 3.0-4.0 | ND | ND |
| | | Storm(5) | 1.5 | 1.1-1.9 | .5 | .4 | .4 | .3-.6 | .2 | .2 | 2.3 | 2.1-2.5 | .3 | .2 | .6 | .4-.7 | .2 | .2 | 0 | 0 | 0 | 0 |
| | | Baseflow(7) | .6 | .4-.7 | .1 | .1 | .4 | .3-.8 | .2 | .1 | 2.3 | 2.0-2.5 | .2 | .1 | .5 | .1-1.0 | .4 | .2 | 1.0 | 0-4.0 | 2.0 | 1.0 |
| V | *All | Storm(7) | 1.6 | .4-3.7 | 1.2 | .6 | .6 | .5-.7 | .1 | .1 | 2.3 | 1.8-2.7 | .4 | .2 | .6 | .1-1.1 | .4 | .2 | .4 | 0-1.0 | .5 | .2 |
| | | Baseflow(14) | 2.3 | .2-4.0 | 1.2 | .4 | .8 | .3-1.5 | .4 | .1 | 3.6 | 2.8-4.8 | .7 | .2 | .9 | .4-1.9 | .5 | .2 | 4.0 | 0-7.5 | 2.8 | 1.0 |
| | Turner Swamp | Storm(4) | 2.4 | 1.4-3.2 | ND | ND | .3 | .3-.5 | ND | ND | .4 | .2-.7 | ND | ND | 1.2 | 1.2-1.3 | ND | ND | 4.0 | 3.0-4.0 | ND | ND |
| | | Baseflow(6) | 3.4 | 1.8-4.8 | ND | ND | .9 | .5-1.2 | ND | ND | 5.7 | 5.2-6.0 | ND | ND | 1.2 | .9-1.5 | ND | ND | 10 | 7.0-14 | ND | ND |

| Geo-chemical zone | Base-line site(s) | Runoff condition and number of analyses | Sulfate | | | | Chloride | | | | Fluoride | | | | Silica | | | | Total dissolved solids (sum) | | | |
|--------------------------------|-------------------|---|---------|---------|-----|-----|----------|---------|-----|-----|----------|---------|-----|-----|--------|---------|-----|-----|------------------------------|-------|-----|-----|
| | | | Mean | Range | SD | SE | Mean | Range | SD | SE | Mean | Range | SD | SE | Mean | Range | SD | SE | Mean | Range | SD | SE |
| I | All | Storm(13) | 2.2 | 0.8-5.7 | 1.4 | 0.4 | 0.7 | 0.0-1.9 | 0.5 | 0.2 | 0.1 | 0.0-0.5 | 0.2 | 0.1 | 6.6 | 3.6-8.6 | 1.6 | 0.5 | 15 | 12-18 | 1.9 | 0.6 |
| | | Baseflow(31) | 2.2 | 1.0-3.9 | .9 | .3 | .9 | .1-2.0 | .6 | .2 | .1 | .05-.15 | .0 | .0 | 8.1 | 5.9-9.5 | 1.1 | .3 | 19 | 16-22 | 1.8 | .5 |
| | Cataloo-chee Cr. | Storm(2) | 2.2 | 1.8-2.5 | ND | ND | .6 | .3-.8 | ND | ND | 0 | 0 | ND | ND | 4.8 | 4.2-5.4 | ND | ND | 13 | 12-14 | ND | ND |
| | | Baseflow(8) | 1.7 | .6-2.7 | ND | ND | .8 | .4-2.0 | ND | ND | .1 | 0-.2 | ND | ND | 8.5 | 7.5-9.2 | ND | ND | 19 | 17-21 | ND | ND |
| II | Jacob Fork | Storm(2) | 3.6 | 3.2-4.0 | ND | ND | 1.2 | .9-1.4 | ND | ND | 0 | 0 | ND | ND | 3.6 | 3.2-3.7 | ND | ND | 12 | 11-14 | ND | ND |
| | | Baseflow(8) | 1.9 | 1.4-2.8 | ND | ND | 1.1 | 1.0-1.3 | ND | ND | .1 | 0-.1 | ND | ND | 9.4 | 8.1-11 | ND | ND | 22 | 18-24 | ND | ND |
| | All | Storm(6) | 6.8 | 5.5-8.1 | 1.1 | .5 | 2.1 | 1.4-2.9 | .5 | .2 | .1 | 0-.2 | .1 | .0 | 5.8 | 3.1-8.8 | 2.3 | .9 | 24 | 22-28 | 2.6 | 1.0 |
| | | Baseflow(12) | 2.6 | 1.2-8.2 | 2.3 | .8 | 5.4 | 3.1-10 | 2.4 | .8 | .1 | 0-.1 | .1 | .0 | 22 | 12-29 | 6.1 | 2.1 | 61 | 48-78 | 9.8 | 3.5 |
| III | All | Storm(3) | 3.0 | 2.6-3.4 | ND | ND | 2.0 | 1.5-2.5 | ND | ND | .2 | .1-.3 | ND | ND | 4.5 | 4.5-4.6 | ND | ND | 12 | 12-13 | ND | ND |
| | | Baseflow(4) | 2.2 | 2.0-2.5 | ND | ND | 1.4 | 1.1-1.8 | ND | ND | .1 | 0-.1 | ND | ND | 4.8 | 4.5-5.1 | ND | ND | 13 | 13 | ND | ND |
| IV | All | Storm(5) | 8.3 | 7.8-8.8 | .7 | .5 | 4.2 | 3.1-5.4 | 1.6 | 1.2 | .2 | .1-.3 | .1 | .1 | 5.2 | 1.6-8.7 | 5.0 | 3.5 | 23 | 22-25 | 2.5 | 1.8 |
| | | Baseflow(7) | 7.6 | 5.2-12 | 3.4 | 1.7 | 3.4 | 2.7-4.2 | .7 | .3 | .1 | 0-.1 | 0 | 0 | 5.9 | 1.9-9.0 | 3.1 | 1.6 | 22 | 17-25 | 3.3 | 1.7 |
| V | *All | Storm(7) | 8.9 | 5.7-12 | 2.5 | 1.1 | 3.7 | 1.9-5.3 | 1.3 | .6 | .2 | 0-.5 | .2 | .1 | 4.4 | 3.5-5.6 | .8 | .4 | 23 | 17-28 | 4.4 | 2.0 |
| | | Baseflow(14) | 9.2 | 5.6-12 | 2.5 | .9 | 5.3 | 3.6-7.6 | 1.1 | .4 | .1 | 0-.2 | .1 | 0 | 7.2 | 5.2-11 | 1.9 | .7 | 32 | 24-38 | 4.9 | 1.7 |
| | Turner Swamp | Storm(4) | 4.0 | 3.5-5.4 | ND | ND | 3.0 | .8-5.1 | ND | ND | .1 | 0-.1 | ND | ND | 1.5 | 1.4-2.4 | ND | ND | 16 | 12-18 | ND | ND |
| | | Baseflow(6) | 3.5 | 1.8-5.4 | ND | ND | 7.5 | 6.4-8.7 | ND | ND | .1 | 0-.3 | ND | ND | 11 | 8.8-12 | ND | ND | 40 | 31-44 | ND | ND |
| *All sites except Turner Swamp | | | | | | | | | | | | | | | | | | | | | | |

*All sites except Turner Swamp

Table 5.--Statistical summary of nutrient values by geochemical zone and flow condition in unpolluted streams.
[SD, standard deviation; SE, standard error of mean, ND, not determined]

| Geo-chemical zone | Runoff condition and number of analyses | Nitrate nitrogen | | | Ammonia nitrogen | | | Organic nitrogen | | | Total nitrogen | | | Total phosphorus | | |
|-------------------|---|------------------|----------|------|------------------|------|----------|------------------|------|------|----------------|------|------|------------------|----------|------|
| | | Mean | Range | SD | SE | Mean | Range | SD | SE | Mean | Range | SD | SE | Mean | Range | SD |
| I | Storm (18) | 0.17 | 0.01-.62 | 0.18 | 0.06 | 0.01 | 0.00-.01 | 0.00 | 0.06 | 0.13 | 0.02-.29 | 0.07 | 0.02 | 0.30 | 0.14-.92 | 0.23 |
| | Baseflow(21) | .08 | .00-.17 | .07 | .02 | .00 | .00-.01 | .00 | .00 | .11 | .00-.27 | .10 | .00 | .19 | .00-.36 | .13 |
| II | Storm (9) | .07 | .00-.26 | .10 | .04 | .01 | .01-.02 | .00 | .00 | .48 | .37-.69 | .11 | .05 | .56 | .34-.73 | .14 |
| | Baseflow(10) | .16 | .00-1.00 | .34 | .12 | .01 | .00-.07 | .03 | .01 | .22 | .07-.51 | .15 | .05 | .40 | .07-1.50 | .47 |
| III | Storm (5) | .04 | .04-.05 | .01 | .01 | .01 | .00-.01 | .00 | .00 | .34 | .31-.38 | .05 | .04 | .40 | .37-.43 | .04 |
| | Baseflow(3) | .11 | .04-.19 | .11 | .08 | .01 | .00-.01 | .01 | .01 | .22 | .20-.24 | .02 | .02 | .34 | .28-.40 | .09 |
| IV | Storm (10) | .02 | .01-.07 | .03 | .01 | .01 | .01-.02 | .01 | .00 | .45 | .23-.66 | .18 | .09 | .49 | .30-.69 | .16 |
| | Baseflow(9) | .02 | .00-.03 | .03 | .01 | .00 | .00-.01 | .00 | .00 | .35 | .15-.51 | .15 | .08 | .37 | .21-.51 | .13 |
| V | Storm (10) | .07 | .00-.15 | .06 | .03 | .02 | .01-.04 | .01 | .00 | .58 | .34-.99 | .22 | .09 | .68 | .49-1.19 | .25 |
| | Baseflow(11) | .01 | .00-.05 | .02 | .01 | .01 | .00-.06 | .02 | .01 | .45 | .15-.72 | .18 | .07 | .48 | .15-.72 | .20 |

Table 6.--Statistical summary of minor elements, in micrograms per liter, by geochemical zone and flow conditions in unpolluted streams.
[SD, standard deviation; SE, standard error of mean, ND, not determined]

| Geochemical zone | Runoff condition and number of analyses | Arsenic | | | Chromium | | | Copper | | | Iron | | |
|------------------|---|---------|-------|-----|----------|------|-------|--------|-----|------|--------|-----|-----|
| | | Mean | Range | SD | SE | Mean | Range | SD | SE | Mean | Range | SD | SE |
| I | Storm(18) | 0 | 0 | 0.0 | 0.0 | 11 | 10-20 | 3.5 | 1.3 | 4 | 1.5-12 | 3.8 | 1.3 |
| | Baseflow(22) | .1 | 0-1 | .3 | .1 | 13 | 10-20 | 6.5 | 2.1 | 4 | 0-9 | 2.6 | .8 |
| II | Storm(10) | 1.2 | 0-3 | 1.1 | .4 | 12 | 10-20 | 4.1 | 1.7 | 4 | 2-11 | 3.4 | 1.4 |
| | Baseflow(9) | .6 | 0-2 | .8 | .3 | 12 | 10-20 | 4.1 | 1.7 | 4 | 0-10 | 2.9 | 1.1 |
| III | Storm(2) | .5 | 0-1 | ND | ND | 10 | 10 | ND | ND | 1 | 1 | ND | ND |
| | Baseflow(2) | 0 | 0 | ND | ND | 15 | 10-20 | ND | ND | 2 | 0-4 | ND | ND |
| IV | Storm(6) | .7 | 0-1 | .5 | .3 | 10 | 10 | 0 | 0 | 2 | 1-2 | .9 | .7 |
| | Baseflow(6) | 0 | 0 | 0 | 0 | 15 | 10-20 | 5.8 | 2.9 | 4 | 3-5 | .8 | .4 |
| V | Storm(8) | .9 | 0-2 | .7 | .3 | 10 | 10 | 0 | 0 | 3 | 0-5 | 2.1 | .9 |
| | Baseflow(12) | .3 | 0-1 | .5 | .2 | 11 | 10-15 | 2.3 | .8 | 2 | 1-4 | 1.0 | .3 |

| Geochemical zone | Runoff condition and number of analyses | Lead | | | Mercury | | | Selenium | | | Zinc | | |
|------------------|---|------|-------|-----|---------|------|--------|----------|-----|------|-------|----|----|
| | | Mean | Range | SD | SE | Mean | Range | SD | SE | Mean | Range | SD | SE |
| I | Storm(18) | 9 | 2-25 | 7.1 | 2.5 | 0.4 | 0.3-.5 | 0.1 | 0.0 | 0 | 0 | 0 | 0 |
| | Baseflow(22) | 5 | 0-16 | 4.3 | 1.4 | .3 | 0-.5 | .2 | .1 | 0 | 0 | 0 | 0 |
| II | Storm(10) | 7 | 4-10 | 2.2 | .9 | .3 | 0-.5 | .2 | .1 | 0 | 0 | 0 | 0 |
| | Baseflow(9) | 6 | 4-11 | 2.5 | 1.0 | .4 | 0 | .2 | .5 | 0 | 0 | 0 | 0 |
| III | Storm(2) | 7 | 7-8 | ND | ND | 0 | 0 | ND | ND | 0 | 0 | ND | ND |
| | Baseflow(2) | 4 | 1-8 | ND | ND | .1 | 0-.1 | ND | ND | 0 | 0 | ND | ND |
| IV | Storm(6) | 6 | 5-6 | .9 | .7 | .2 | 0-.3 | .2 | .2 | 0 | 0 | 0 | 0 |
| | Baseflow(6) | 4 | 1-7 | 2.5 | 1.3 | .4 | .1-.5 | .2 | .1 | 0 | 0 | 0 | 0 |
| V | Storm(8) | 4 | 0-11 | 4.1 | 1.7 | .3 | 0-.5 | .3 | .1 | 0 | 0 | 0 | 0 |
| | Baseflow(12) | 6 | 4-14 | 3.4 | 1.2 | .4 | .3-.5 | .1 | 0 | 0 | 0 | 0 | 0 |

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W R I 72 108 WATER-QUALITY CHARACTERISTICS OF STREAMS IN FORESTED AND RURAL AREAS OF NORTH CAROL
By C. E. Simmons and R. C. Heath