Selected Aquatic Ecology, Surface-Water Quality, and Ground-Water Studies in the Santee River Basin and Coastal Drainages, North and South Carolina, 1996

By Thomas A. Abrahamsen, W. Brian Hughes, Eric J. Reuber, *and* Terry L. Sicherman

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U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For addtional information write to:

District Chief
U.S. Geological Survey
Stephenson Center-Suite 129
720 Gracern Road
Columbia, SC 29210-7651

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0268

FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
square foot per day (ft^2/d)	0.0929	square meter per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
gallon per min (gal/min)	3.785	liter per minute
million gallons per day (Mgal/d)	3.785	million liters per day
gallon (gal)	3.785	liter
gallon per day per foot [(gal/d)/ft]	12.41	liter per day per meter
parts per million (ppm)	1.0	milligrams per liter

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

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Abstract

A literature search of aquatic ecology, surface-water quality, and ground-water studies in or near the Santee River Basin and coastal drainages in North and South Carolina was conducted to facilitate current and future water-quality assessments for the U.S. Geological Survey National Water-Quality Assessment Program. This report summarizes 30 selected studies and provides an extensive bibliography of nearly 400 ecologic and hydrologic studies in North and South Carolina. Reference materials were provided by private organizations, universities, and Federal, State, and local agencies.

INTRODUCTION

At the request of Congress, the U.S. Geological Survey (USGS) began a National Water-Quality Assessment (NAWQA) Program in 1991. The goals of the NAWQA program are to report the status and trends in quality of a large, representative part of the Nation's surface- and ground-water resources, and to identify the major factors that affect the quality of these resources (Gilliom and others, 1995). In meeting these goals, the program provides water-quality information that will be useful to policy makers and managers at National, State, and local levels.

The emphasis of the NAWQA program is on regional-scale water-quality conditions. Currently (1996), there are many smaller-scale studies and monitoring programs designed and conducted by Federal, State, and local agencies to meet their individual needs. The NAWQA program, however, emphasizes a large-scale water-quality assessment. The understanding of regional and national water-quality conditions is expected to provide a framework for in-depth, small-scale water-quality studies.

The NAWQA program consists of 60 hydrologic systems (study-unit investigations) that include parts of most of the major river basins and aquifer systems in the United States. The 60 study units range in size from 1,000 mi^2 to more than 60,000 mi^2, and represent 60 to 70 percent of the Nation's water use and population served by public water supplies. Twenty study-unit investigations were started in 1991. Fifteen additional investigations were started in 1994, and 20 are planned to start in 1997. The Santee River Basin and Coastal Drainages (SANT) study unit was one of 15 units that began assessment activities in 1994 (fig. 1).

Purpose and Scope

The purpose of this report is to provide summaries of selected ecologic and hydrologic studies that were conducted in or near the SANT study area, or of studies that are pertinent to an understanding of ecologic and hydrologic conditions in the study area. Additional sources of information, such as Federal, State, and local databases, are presented in table format. The lists of bibliographies (appendixes 1-3) include citations related to water quality and ecology, but are not all-inclusive. The lists, organized alphabetically by author's last name or organizational name, are available on computer diskettes. The diskettes are

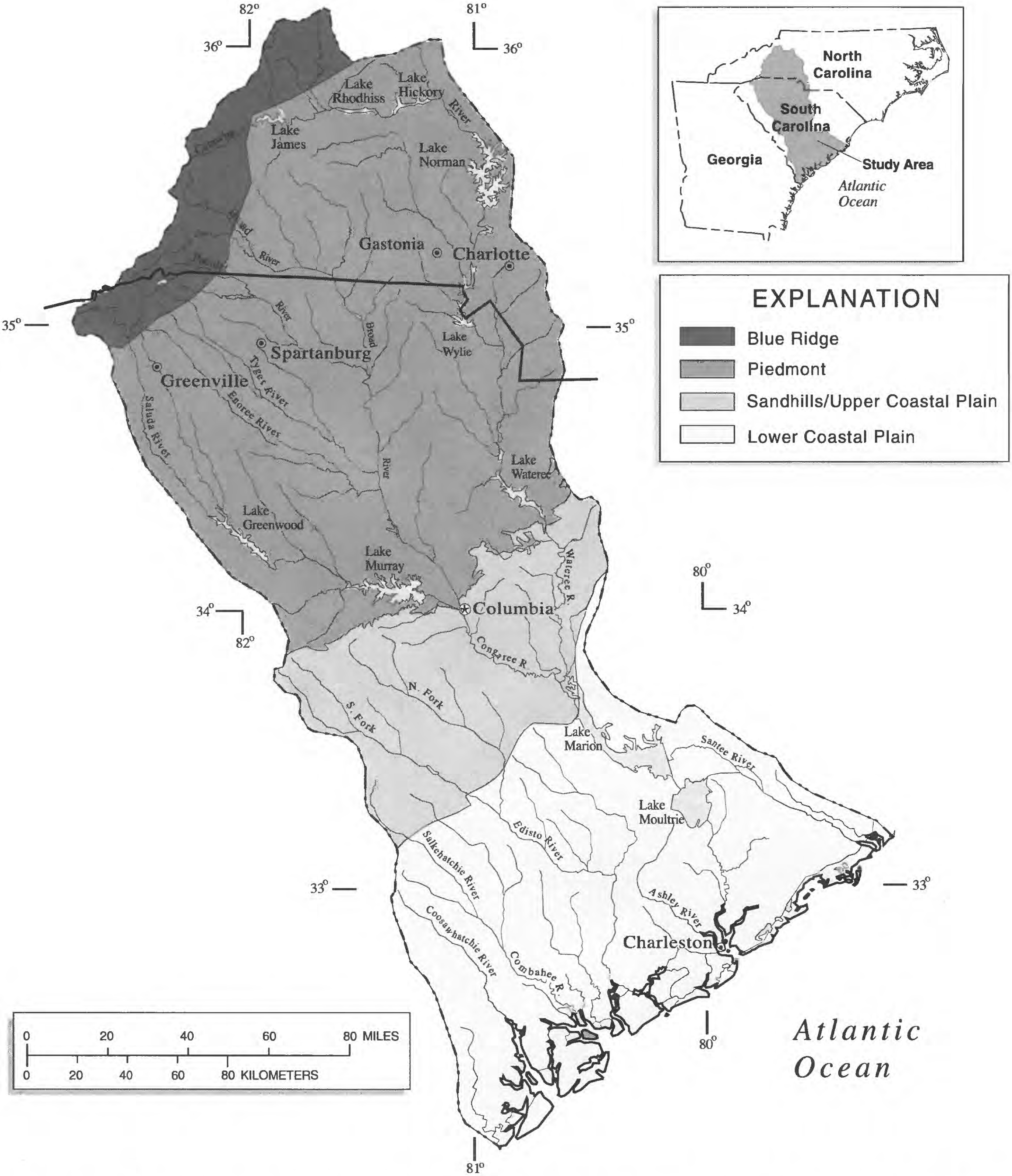

Figure 1. Physiographic provinces of the Santee River basin and coastal drainages study area.

in American Standard Code for Information Interchange (ASCII) format for ease in retrieval by most computer systems, and are available from the USGS office in Columbia, S.C. Charges for the diskette include the cost of the diskette and the labor to transfer the files to the diskette.

Description of Study Area

The Santee River Basin and coastal drainages study area is approximately 23,600 mi^2 and covers parts of western North Carolina and much of South Carolina (fig. 1). The study area extends from the mountainous part of western North Carolina to the Atlantic Ocean in South Carolina and includes three physiographic provinces--the Blue Ridge, Piedmont, and Coastal Plain. The 1990 population of the study area was about 3.6 million, with the most densely populated areas located in the northern Piedmont Province (Charlotte and Gastonia, N.C.; Greenville and Spartanburg, S.C.), along the Fall Line (Columbia, S.C.), and near the coast (Charleston, S.C.). According to USGS land-use data from the 1970's, about 63 percent of the land area was forested, 25 percent was cropland and pasture, and 7 percent was urban. Textiles, paper, and chemicals are the major industries in the study area. Farming, feed lots, orchards, meat processing, and mining constitute the current vital economic activities. These activities can affect water quality to various degrees.

The major tributaries of the Santee River are the Saluda, Broad, and Catawba Rivers; their headwaters are located in the Blue Ridge, a forested, mountainous region that changes rapidly to agricultural and urban lands in the upper Piedmont Province. Many man-made reservoirs are located in the tributaries to the Santee River, especially a string of reservoirs in the Catawba River. Downstream, the middle and lower Piedmont Province is dominated by natural second growth hardwood and intensively managed pine forests.

The headwaters of the Edisto, Salkahatchie, and Coosawhatchie Rivers are located in the Coastal Plain. The most intensive agricultural region in the study area is located in a belt that extends from east to west across the central part of the Edisto, Salkahatchie, and Coosawhatchie Basins. The lower parts of these basins are dominated by intensive pine silviculture, forested wetlands, and, near the Atlantic Ocean, by saltwater marshes. Brackish estuaries are located all along the shore, and tides affect river stage as far as 30 mi inland.

Surface-water quality for much of the study area is good, with about 60 percent of the rivers and streams in South Carolina meeting the state's water-quality standards (S.C. Department of Health and Environmental Control, 1995).Water quality is locally affected by agriculture, forestry, industry and other activities. The most common water quality problem in lotic waters in the state is the presence of fecal coliform bacteria (S.C. Department of Health and Environmental Control, 1995). Nonpoint sources of pollution such as agricultural and urban runoff introduce trace metals, pesticides, nutrients, and other organic compounds into surface-water bodies. Airborne pesticides, metals, and nutrients can be transported from one area to another, and can enter the hydrologic system through precipitation or dry deposition. Point sources such as industrial and municipal waste-water treatment plants are regulated, but can contribute nutrients and toxic chemicals to the surface-water system.

The study area includes parts of four major ecoregions (J.M. Omernik, U.S. Environmental Protection Agency, oral commun., 1996; Omernik, 1987): the Blue Ridge Mountains, the Piedmont, the Southeastern Plains, and the Middle Atlantic Coastal Plain (fig. 2). These ecoregions are roughly coincident with the similarly-named physiographic provinces; the Southeastern Plains and Middle Atlantic Coastal Plains ecoregions being included within the Coastal Plain physiographic province.

Streams of the Blue Ridge physiographic province are typically high-gradient (varying to greater than 20 percent) and densely shaded, and their biological communities depend upon allochthonous sources (leaves and woody debris) to supply energy in the form of organic carbon. The vertebrate niche is dominated by salamanders in the headwaters of small streams and fish, particularly brook trout (*Salvelinus fontinalis*), in the downstream sections. Dominant aquatic invertebrates are among the collector-gatherer groups (oligochaetes, mayflies, stoneflies, crustaceans) and collector-filterer groups (mayflies, caddisflies, and mollusks). High current velocities elevate the mosses and liverworts to the dominant macrophyte niche by excluding rooted plants (Wallace and others, 1992). Bed composition is typically bedrock, boulders, cobbles, pebbles, and coarse sand, depending upon the

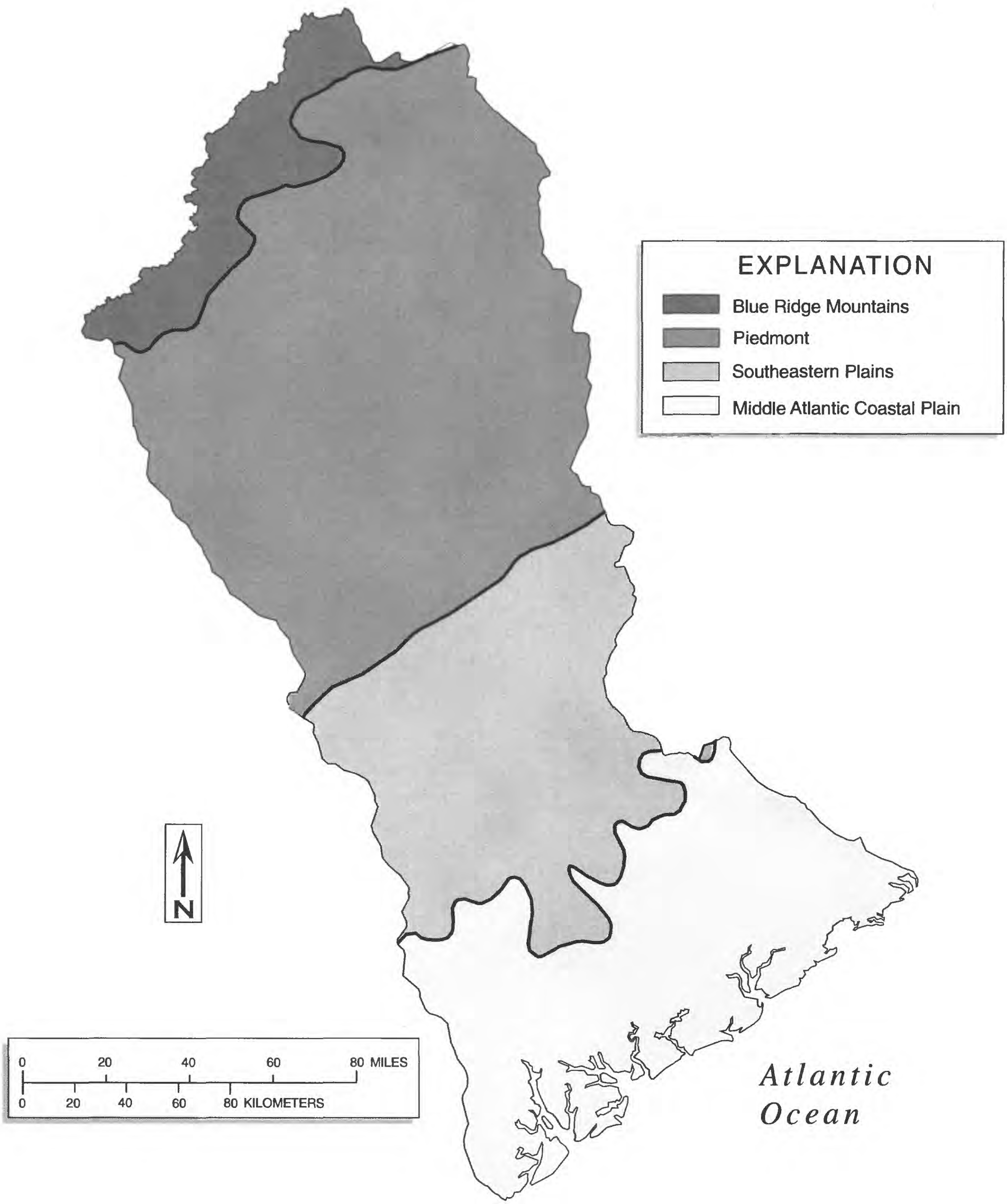

Figure 2. Ecoregions within the Santee River Basin and coastal drainages study area, North and South Carolina (Modified from Omernick, 1996).

gradient and consequent water velocity. Important habitats include the undersides of rocks and bedrock ledges. Woody debris provides habitat and contributes to stream structure by affecting water flow.

The Piedmont ecoregion and the Southeastern Plains ecoregion include portions of both the Piedmont physiographic province and the upper Coastal Plain physiographic province. Streams in these ecoregions are generally of lower gradient (0.2 percent to 2.0 percent in the Piedmont ecoregion and 0.02 percent to 0.1 percent in the Southeastern Plains ecoregion) than streams in the Blue Ridge Mountains ecoregion and are variable in channel morphology. The flood plains tend to be relatively narrow, but flood plain swamp forests are common and extensive. These forests serve as important sources of organic carbon and contribute significantly to secondary production. Fishes are the dominant vertebrates in the upper stream reaches. Invertebrate communities are numerically dominated by the mayflies (Ephemeroptera) and the true flies (Diptera) (Mulholland and Lenat, 1992). In general, streams in both the Piedmont and Southeastern Plains ecoregions are variable in structure, ranging from those with relatively stable bedrock/cobbles/pebble substrates to sandy, shifting bottoms, which predominate. Woody snags and debris dams are important features of streams in these ecoregions, and, especially where there is an unstable substrate, provide critical habitat and refugia for aquatic biota. These streams tend to carry greater suspended solids loads than streams in the other ecoregions in this study. Agricultural activities generate suspended sediments that limit the penetration of sunlight and, consequently, primary production. Biota in these streams depend upon allochthonous energy sources.

The Middle Atlantic Coastal Plain ecoregion extends from the first Pleistocene-age marine terrace to the Atlantic Ocean. Blackwater streams dominate in this ecoregion. The physical, biological, and chemical characteristics of blackwater streams differ from those of streams in the Southeastern Plains, the Piedmont, and the Blue Ridge Mountains ecoregions. The pH in blackwater streams is generally lower because of their complement of organic or mineral acids. These rivers carry low suspended solids loads and their buffering capacity and nutrient concentrations are generally lower than that of streams in the ecoregions cited above. The designation, "blackwater stream," is derived from the color of the water, because of the presence of humic and fulvic acid complexes and lactic acid components (Livingston, 1992). The streams are generally shallow and braided, and sediments range from loose, shifting sands to highly organic soils. Although some streams in the northwestern section of this ecoregion have riffles, the dominant geomorphic channel units in the Middle Atlantic Coastal Plain are reaches and pools. The very low slope of streams in the ecoregion (0.04 percent to 0.1 percent) exerts a major influence on their biological community structures and hydrologic characteristics. These streams experience large seasonal variations in flow, and their extensive flood plains serve as functional headwaters when they are flooded. The lower sections of main-stem streams in this ecoregion are tidally influenced. Fish species are numerous and collector-gatherer (chironomids, oligochaetes, mayflies) and filter-gatherer groups (true flies and caddisflies) dominate the macroinvertebrate community. The most important habitats in these streams are woody snags, debris dams, and root masses. (Smock and Gilinsky, 1992).

The structure and health of aquatic communities are determined by stream-water quality and habitat stability. The primary water-quality factors that affect aquatic communities are nutrient loading, the presence of toxic substances, dissolved-oxygen concentrations, current velocity, temperature, and suspended-sediment loads. Organic compounds, metals, and nutrients (such as phosphorus and nitrogen) are present in urban and agricultural runoff, and some point-source discharges to surface waters. Such substances also can enter bodies of water through atmospheric deposition. Toxic substances can shift community structure by causing a decrease in the number of intolerant species and an increase in the populations of more-tolerant species. High nutrient loading caused by runoff of fertilizers from agricultural and urban sites, and from point-source discharges, can cause algal blooms or dense growths of aquatic macrophytes. Blooms of algae demand large quantities of dissolved oxygen (DO) and can deplete DO concentration at night to levels below those required for life support of other stream organisms. Fish kills can result from dramatic decreases in DO concentration caused by algal blooms. The presence of dead fish triggers an increase in bacterial populations and additional demand for dissolved oxygen.

Natural habitats are altered when land use changes prompt clearing of vegetation, channelizing of streams, the creation of impoundments or changes in flow conditions in the stream. For instance, an increase in the concentration of suspended sediments may drive changes in community structure by burying material that serves as the primary energy source, or may alter habitat such that a change in species composition occurs. Removal of riparian cover leads to a decrease in allochthonous contributions to the stream-energy budget and increases in the amount of sunlight reaching the water. Consequent increases in daily mean temperature within the stream reach affected by clearing can occur. These changes may drive a shift from secondary to primary production by permitting the establishment of a photosynthetic community and concomitant changes in energy processing (feeding) groups within the macroinvertebrate community (Neubold and others, 1980), as well as changes in fish-community structure. The construction of an impoundment leads to changes in the downstream plant, macroinvertebrate, and fish communities because of the impoundment's effect upon the size range of particulate organic material, scouring of the substrate by the periodic release of water, water temperature changes, nutrient concentration, and DO content.

The SANT study area can be divided into two hydrogeologic regions - the Blue Ridge/Piedmont and the Coastal Plain. In the Blue Ridge/Piedmont hydrogeologic region, ground water is present in fractures in the crystalline metamorphic bedrock and in pore spaces in the overlying saprolite, or weathered bedrock. Ground water in the Coastal Plain hydrogeologic region is derived from clastic sedimentary rocks and limestone aquifers. Shallow aquifers in the study area are recharged at land surface and discharge into streams, lakes, and deeper aquifers. Flowpaths are generally short in the shallow system. In fractured-rock aquifers, recharge is from the overlying saprolite and flowpaths are longer than in the shallower system. In the confined aquifers of the Coastal Plain hydrogeologic region, ground water is recharged where the aquifers crop out, generally near the Fall Line, and pre-development flow in the shallower aquifers is toward the coast. However, the direction of ground water flow within the deeper hydrologic units is toward the northeast.

Although most ground water in the SANT study area meets drinking water standards, under natural conditions, some ground water contains high concentrations of dissolved minerals. Along the coast, saltwater is present in many aquifers because of natural flow conditions and subsequent depletion of freshwater supplies by humans. Spills and leaks of chemicals have contaminated ground water in numerous but relatively small areas. Some pesticides and nutrients are found in ground water associated with agricultural areas.

Acknowledgments

Many agencies and organizations provided publication lists and abstracts that were used to produce this report. The authors wish to thank Federal and State agencies and the members of the Santee River Basin and Coastal Drainages Liaison Committee for their cooperation in providing information for this report. Their contributions have helped to make this report a useful tool.

SELECTED DATA SOURCES

As part of the NAWQA program, information from Federal, State, and local government agencies, universities, and private companies was compiled to produce a list of environmental databases that contain information on the SANT study area (table 1). The emphasis was placed on computerized databases that covered a large part of the study area and could be readily obtained. The list is not exhaustive. Many small databases and data that are only available in print are not listed. The intent is to provide a list of the major databases that can be used as starting points for additional data sources. The information contained in the list was collected in 1995 and was current at that time.

Table 1. Selected environmental databases--Santee River Basin and coastal drainages study area, North and South Carolina

[GIS, Geographic Information System; NCDEHNR, North Carolina Department of Environment, Health, and Natural Resources; SCDHEC, South Carolina Department of Health and Environmental Control; SCDNR, South Carolina Department of Natural Resources]

Agency name	Type of database	Telephone numbers
Aquacoustics	Hydroacoustic fish density and distribution	(704) 664-7737
Catawba Regional Planning Council	Catawba River Basin GIS coverages	(803) 327-9041
Clemson University	Pesticides in ground water	(864) 656-2150
Duke Power Company	Catawba River largemouth bass health assessment	(704) 875-5455
	Electrofishing data, Lee Steam Station, Saluda River	(704) 875-5460
	Fish entrainment studies	(704) 875-5453
	Fish tissue--metals, pesticides, polychlorinated biphenyls, aromatic hydrocarbons	(704) 875-5236
	Species composition in reservoirs	(704) 875-5459
	Surface-water chemical data	(704) 875-5202
	Tailwater macroinvertebrate density estimate	(704) 875-5425
Greenville County Soil and Water Conservation District	Soils information	(864) 467-2756
National Acid Deposition Program/ National Trends Network	Precipitation chemistry	(970) 491-3608
NCDEHNR Division of Land Quality	Surface-mine locations	(919) 733-4574
	Dam locations	(919) 733-4574
NCDEHNR Western Region	Water intakes and withdrawals; finished water quality	(919) 733-2321
NCDEHNR Division of Environmental Health - Public Water Supply Section	Drinking-water analysis results	(919) 733-2321
	Water-quality compliance and monitoring	(919) 715-3243 (919) 734-5422
NCDEHNR Division of Water Resources	Water withdrawals and water-supply system data	(919) 715-5441
NCDEHNR Division of Water Quality	Surface-water quality	(919) 733-9960
	National Pollutant Discharge Elimination System	(919) 733-5083

Table 1. Selected environmental databases--Santee River Basin and coastal drainages study area, North and South Carolina--Continued

[GIS, Geographic Information System; NCDEHNR, North Carolina Department of Environment, Health, and Natural Resources; SCDHEC, South Carolina Department of Health and Environmental Control; SCDNR, South Carolina Department of Natural Resources]

Agency name	Type of database	Telephone numbers
NCDEHNR Division of Waste Management	Comprehensive Environmental Response, Compensation, and Liability Act and Resource Conservation and Recovery Act sites	(919) 733-2801
	Permitted hazardous-waste sites	(919) 733-2178
NCDEHNR Division of Ground Water	Ambient ground-water quality monitoring	(919) 733-3221
	Ambient ground-water-level monitoring	(919) 733-3221
	Geophysical logs	(919) 733-3221
	Incident-management database	(919) 733-1315
	Injection-well database	(919) 733-3221
	Well construction	(919) 733-3221
NCDEHNR Division of Epidemiology	Private-well pesticide contamination	(919) 715-6430
NCDEHNR Division of Biological Assessment	Benthic macroinvertebrate survey data	(919) 733-6946
	Fish, macroinvertebrates, phytoplankton, community structure, and tissue	(919) 733-9960
Resources for the Future	Pesticide usage inventory	(916) 978-4645
SCDHEC Office of Ocean and Coastal Resource Management (OCRM)	Permits required in coastal areas	(803) 744-5838
SCDHEC	South Carolina GIS coverages	(803) 734-4833
SCDHEC Environmental Monitoring	Surface-water quality monitoring	(803) 734-4631
SCDHEC	Water use	(803) 734-5283
SCDHEC Drinking Water Quality Enforcement	Water-quality compliance and monitoring database	(803) 734-5310
SCDHEC Water Pollution Control	Water-quality station locations; National Pollutant Discharge Elimination System; wastewater infrastructure	(803) 734-5300
SCDHEC Solid and Hazardous Waste	Sites covered by the Comprehensive Environmental Response, Compensation, and Liability and Resource Conservation and Recovery Acts	(803) 896-4000
	Landfills; hazardous-waste facilities	(803) 896-4000

Table 1. Selected environmental databases--Santee River Basin and coastal drainages study area, North and South Carolina--Continued

[GIS, Geographic Information System; NCDEHNR, North Carolina Department of Environment, Health, and Natural Resources; SCDHEC, South Carolina Department of Health and Environmental Control; SCDNR, South Carolina Department of Natural Resources]

Agency name	Type of database	Telephone numbers
SCDHEC Drinking Water Protection	Contamination sites; drinking-water infrastructure	(803) 734-5310
SCDHEC Ground Water Protection	Ambient ground-water database	(803) 734-5328
SCDNR Land Resources Division	Wetland inventory; land use/land cover	(803) 734-9100
SCDNR Water Resources Division	South Carolina Climatology	(803) 737-0800
SCDNR Geological Survey	Geologic maps; shallow drill logs	(803) 896-7708
University of North Carolina--Charlotte	Land cover, turbidity indices	(704) 547-4248 (704) 547-2294
	Land use and water-quality data for Mecklenburg and Gaston Counties, North Carolina	(704) 547-2293
University of South Carolina Department of Environmental Health Sciences	Santee-Cooper reservoir water quality	(803) 777-6994
U.S. Department of Agriculture	State soil geographic database (STATSGO)	(800) 672-5559
	Agricultural Best Management Practices and crop data	(803) 727-4671
U.S. Environmental Protection Agency	National sediment inventory	(202) 260-7301
	Permit compliance system (PCS)	(202) 260-6057
	Storage and retrieval of U.S. waterways parametric data (STORET)	(800) 424-9067
	Toxic release inventory (TRI)	(202) 260-1531
U. S. Geological Survey	Fertilizer use in 1987	(703) 648-6854
	Ground-water data from North Carolina	(919) 571-4000
	National Pollution Discharge Elimination System (NPDES) coverage	(202) 260-6057
	Nitrogen and phosphorus from manure 1992	(703) 648-5842
	Surface- and ground-water quality	(803) 750-6100
	Surface-water flow	(803) 750-6100
	Water use	(803) 750-6100
	Well inventory	(803) 750-6100
Western Piedmont Council of Government	Upper Catawba River Basin GIS coverages	(704) 322-9191

SELECTED STUDY DESCTIONS: AQUATIC ECOLOGY

Fourteen publications from appendix 1 were reviewed in depth. Summaries of these studies are included in this section. Some authors cited in this section make no distinction among the terms ecoregion and physiographic province, using them interchangeably or not at all. Where possible, the appropriate designations are employed in the review.

Adams, T.O., Hook, D.D., and Floyd, M.A., 1995, Effectiveness monitoring of silvicultural best management practices in South Carolina: Southern Journal of Applied Forestry, v. 19, no. 4, p. 170-176.

Rapid Bioassessment Protocols were evaluated for use in monitoring the effectiveness of silvicutural best management practices (BMP) at harvested sites in South Carolina. The authors employed studies of habitat and macroinvertebrate-community structure in streams adjacent to and within timber-harvested areas to evaluate the effectiveness of BMP compliance. Through these methods, the effect of logging upon the health of the stream community was assessed. The study concludes that silvicultural BMP are capable of reducing the effect of logging operations on adjacent streams. Data on habitat type and macroinvertebrate-community structure in South Carolina streams are provided.

Barton, M.C., Jr., and O'Brien-White, S.K., eds., 1995, Fishes of the Edisto River Basin: Columbia, Fisheries Habitat Committee, Edisto River Basin Project, South Carolina Department of Natural Resources, Report no. 6, 57 p.

Following a brief description of the Edisto River Basin in South Carolina, this report provides lists of freshwater, estuarine, and saltwater fishes in the basin. Several detailed drainage area maps indicate collection sites for biological surveys and the types of collection devices employed at each site. A comprehensive bibliography accompanies each major section of the report.

Eighty-seven species, representing 25 families of freshwater fishes, had been collected from the basin as of March 1995. The South Carolina Department of Natural Resources (SCDNR) periodically stocks the North Fork and South Fork Edisto Rivers with redbreast sunfish (*Lepomis auritus*), bluegill sunfish (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), and channel catfish (*Ictalurus punctatus*). In addition, the U.S. Fish Hatchery at Orangeburg, S.C., releases striped bass (*Morone saxatilis*) as well as sunfish, bass, and catfish. In fish collections conducted from 1988-90, the spotted sucker (*Minytrema melanops*) constituted the greatest biomass. The other most numerous fishes (by weight) included: bowfin (*Amia calva*), largemouth bass, flat bullhead (*Ameiurus platycephalus)*, longnosed gar (*Lepisosteus osseus*), and American eel (*Anguilla rostrata*). A creel census indicated that the redbreast sunfish was the most sought-after freshwater fish, accounting for 45 percent of the fishes captured by anglers (32 percent by weight). The flat bullhead and the channel catfish were the next most popular species.

Berra, T. M., 1981, An atlas of the distribution of freshwater fish families of the world: Lincoln, Nebr., University of Nebraska Press, 197 p.

Useful information on the darters in the southern United States is provided. Cousins of the perch and walleye, the darters fill a very important role as secondary consumers in streams and rivers. They are bottom dwellers and generally feed upon insects and crustaceans. Darters that likely will be found within the SANT study area include: the Savannah Darter (*Etheostoma fricksium oligocephalus*) - Broad and Edisto River drainages; the fantail darter (*E. flabellare*) - first order through eighth order streams, North Carolina only, Catawba and Broad River drainages; the carolina darter (*E. collis collis*) - Catawba River drainage; the swamp darter (*E. fusiforme barratti*) - Catawba, Broad and Edisto River drainages; the saluda darter (*E. saluda*) - listed as a species of concern (threatened) - narrowly confined to the Saluda and Broad River drainages above the Fall Line; and the sawcheek darter (*E. serriferum*) - a Coastal Plain species.

Hocutt, C.H., and Wiley, E.O., eds, 1986, The zoogeography of North American freshwater fishes: New York, John Wiley and Sons, Inc., 866 p.

This book details the distribution of freshwater fish populations of North America and includes a description of the Edisto and Santee drainage basins. The Santee River drains major areas of upland and montane habitat and supports 90 species, giving this basin the largest fish fauna assemblage on the Atlantic Slope.

There are five endemic species in the Santee Basin: the santee chub (*Hybopsis zanema*), *Notropis chloristius* (common name not given), the greenhead shiner (*Notropis chlorocephalus*), the seagreen darter (*Etheostoma thalassinum*), and the saluda darter (*Etheostoma saludae*). All except the saluda darter are upland, montane species. The saluda darter is found in the Saluda and Broad River systems of the Piedmont physiographic province.

The Edisto River drainage in South Carolina, with headwaters near the Fall Line, contains Coastal Plain fish fauna, with a total of 35 freshwater species. Most of these have arrived in the river by lateral capture. Although the Edisto River is a blackwater Coastal Plain stream, it contains a few upland and montane species, probably from the Santee and Savannah Rivers. These upland species include: the yellowfin shiner (*Notropis lutipinnis*), the striped jumprock (*Moxostoma rupiscartes*), the turquoise darter (*Etheostoma inscriptum*), and the bluehead chub (*Nocomis leptocephalus*).

Kuehne, R.A., and Barbour, R.W., 1983, The American Darters: Lexington, University of Kentucky Press, 177 p.

This work indicates that several darter species are likely to be within the confines of the SANT study area. These include: piedmont darter (*Percina crassa*) in the upper Broad and Catawba River drainages; seagreen darter (*Etheostoma thalassinum*) in the Congaree and Santee Rivers, and a subspecies of the tessellated darter (*Etheostoma olmstedi maclaticeps*) in the Columbia, S.C., area. The turquoise darter (*Etheostoma inscriptum*) may be present in the Coosawhatchie system. The greenside darter (*E. blennioides*), olive darter (*P. squamata*), gilt darter (*P. evides*), and redline darter (*E. rufilineatum*) may be present in parts of the North Carolina drainage.

Lacy, C.M., 1992, Assessment of zooplankton dynamics in response to nonpoint source loadings to the Santee-Cooper Lake System: Columbia, South Carolina Department of Health and Environmental Control Report SCP 002-92, 96 p.

Lacy's study shows that increased turbidity levels in the Santee River are the result of nonpoint source runoff from agricultural and silvicultural areas. The increased turbidity forces a change in the structure of the zooplankton community, favoring the rotifers over larger crustacean species, such as the cladoceran waterfleas, a primary food source for juvenile fishes. This decrease in the favored prey of fishes that are visual hunters (such as striped bass) could have an adverse effect upon their fisheries. Lacy suggests that the implementation of best management practices (BMPs) may decrease nonpoint-source turbidity contributions and drive reversion to a community structure with greater numbers of cladocerans, thus encouraging fishery growth. Lacy also suggests that zooplankton community structure may better characterize sediment effect on water quality, as it relates to fisheries, than methodologies currently in use.

Mulholland, P.J., and Lenat, D.R., 1992, Streams of the southeastern Piedmont, Atlantic Drainage, *in* Hackney, C.T., Adams, S.M., and Marshall, W.H., eds., Biodiversity of the southeastern United States aquatic communities: New York, John Wiley and Sons, Inc., p. 193-269.

Following a brief discussion of the climate, geology, and land use of the Piedmont physiographic province in the southeastern United States, the physical, chemical, and morphological characteristics of Piedmont streams are presented. The influence of hydrology on water chemistry is mentioned, as are effects of human-mediated disturbances. The effects of human activities on the water quality of streams in the southeastern Piedmont physiographic province are extensive. The major effect of agriculture on Piedmont streams is to contribute to increased nutrient concentrations in the water column. Observed increases in suspended-sediment loads are the direct result of urbanization. Low dissolved-oxygen concentrations, and higher levels of toxic metals and nutrients are secondary contributions from the urbanization process.

Heavy erosion caused by past farming practices has resulted in increased sediment sinks, such that, in reforested areas, stream valleys are major sources of suspended sediment during storms. Stream substrates in the Piedmont physiographic province are sand, generally, and are too unstable for prolific algal growth except under long-term low-flow conditions. High suspended-sediment loads prevent the growth of periphyton by blocking sunlight. Macrophytes are generally rare in Piedmont streams, their absence being attributable to unstable substrates, large variations in stream flow, and high or moderate gradients. An exception is the river weed, *Podostomeum ceratophyllum*, which grows on rock surfaces and is generally unaffected by shifting substrates. Aquatic bryophytes (mosses) also are rare in streams of the Piedmont physiographic province. The mosses may be competitively excluded by algae during long-term low-flow conditions. High silt loads may provide an unsuitable habitat.

In the macroinvertebrate communities of the Piedmont physiographic province, taxa richness is roughly comparable with that found in streams of the Blue Ridge Province and Coastal Plain Province. However, streams of the Piedmont physiographic province are generally poorer in mayfly, stonefly, and caddisfly taxa, while richer in beetles, dragonflies, damselflies, mollusks, and crustaceans than streams of the Blue Ridge Province. In comparison, streams of the Coastal Plain Province generally have much lower numbers of mayfly taxa than those of the Piedmont physiographic province.

Among the fishes found in streams of the Piedmont physiographic province, the shiners, members of the minnow family (Cyprinidae), are the most abundant. Few of the shiners are omnipresent, but the family is well-represented by a number of species, especially *Notropis* spp. The most widespread of all the minnows is the golden shiner (*Notemigonus crysoleucas*), which owes its extensive geographic range to fishermen who transport it for use as bait. The game fishes important to the Piedmont physiographic province include: redbreast sunfish (*Lepomis auritus*), bluegill (*L. macrochirus*), warmouth (*L. gulosus*), and largemouth bass (*Micropterus salmoides*).

Patterson, G.G., and Davis, B.A., 1991, Distribution of aquatic macrophytes in 15 lakes and streams in South Carolina: U.S. Geological Survey Water-Resources Investigations Report 89-4132, 57 p.

South Carolina has been invaded by a number of exotic aquatic plants that have become significant nuisances because of their prolific growth. A decreased rate of sediment transport in streams of the Piedmont, resulting in deeper light penetration of the water column, has been suggested as a contributory factor in the rapid spread of these plants. The plants present a hazard to boaters and industries by clogging river and lake channels and by impinging on water-intake structures. Large masses of the plants in lakes and streams deplete the dissolved oxygen content of the water. Concomitantly, fish kills and fish population structure degradation occur when the dissolved oxygen level is depleted. Exotic invaders, which are listed in the report include: Brazilian elodea (*Egeria densa*), Hydrilla (*Hydrilla verticillata*), alligator-weed (*Alternanthera philoxeroides*), and water hyacinth (*Eichornia crassipes*).

Pickett, J.R., 1992, Sources and accumulation of trace metals in sediments and the Asiatic clam, *Corbicula fluminea*, in two South Carolina watersheds: South Carolina Department of Health and Environmental Control, Santee Cooper River Basin Water Quality Management Study, 93 p.

Metal concentrations found in sediments and the water column at two sites in the basin were compared with metal concentrations found in a benthic bivalve, the Asiatic clam (*Corbicula fluminea*), collected from sediments at both sites. The sites were the Congaree River upstream of the U.S. Highway 601 bridge, and the Wateree River at the South Carolina Electric & Gas steam plant near Wateree, S.C. Both sites are upstream from the confluence of the two rivers, which combine to form the Santee River.

The major source of total suspended solids in the Congaree River was attributed to runoff associated with storms; reservoir releases were not implicated. Point sources contributed significantly larger total nutrient loading to the Congaree River than to the Wateree River. The Congaree River had significantly larger water-column concentrations of chromium, manganese, lead, iron, nickel, aluminum, zinc, and copper than the Wateree River, which contained larger concentrations of cadmium in the water column than the Congaree. Water-column mercury levels were similar in both rivers.

Concentrations of cadmium, zinc, and copper were high in clams in both rivers. Concentrations of aluminum were higher in clams from the Wateree River. Mercury concentrations were similar in both clams and sediment in each river. Sediment in both rivers had greater mean concentrations of aluminum, chromium, iron, manganese, nickel, and lead than the clams. *Corbicula fluminea* does not appear to accumulate trace elements from sediment to any large extent. Point-source pollution accounted for less than 20 percent of the total nutrient load and less than 40 percent of the total metals. Nonpoint-source runoff is the primary method of introduction of trace metals and nutrients to both rivers.

Smock, L.A., 1988, Life histories, abundance and distribution of some macroinvertebrates from a South Carolina, USA Coastal Plain stream: Hydrobiologia, v. 157, p. 193-208.

Cedar Creek is a second-order blackwater stream in the Congaree Swamp National Monument. This stream is fully canopied with water tupelo (*Nyssa aquatica* L.), bald cypress, (*Taxodium distichum* L.), and other hardwoods. Three sites in the stream were sampled to determine the macroinvertebrate-community structure. The first site was at the entrance to the swamp; the second site was outside of the swamp, about 3 mi upstream from the first; and the third site was about 3 mi downstream of the first, in the swamp proper.

Smock found that the three species of elmid beetles (Coleoptera) which were collected exhibited univoltine (1 year) life histories. The most abundant beetle was *Ancyronix variegata* (Germar). *Ancyronix variegata* and *Macronychus glabratus* (Say) were found on snags, while *Dubiraphia quadrinotta* (Say) was found in the stream sediments.

Most species of mayflies (Ephemeroptera) collected were univoltine except *Stenonema modestum* (Banks), which was at least bivoltine. *Eurylophella temporallis* (McDonough) emerged in April in all habitats except sandy bottoms. *Hexagenia munda* (Eaton) emerged from early summer through August from silty main-channel sediment in the swamp. *Paraleptophlebia volitans* (McDonnough) was found in all habitats where detritus accumulated. *Stenonema modestum* was the most abundant mayfly in Cedar Creek and was found in snag and leaf pack habitats. The insect was rare at the downstream site in the swamp.

Caddisflies (Trichoptera) exhibited univoltinism, partial bivoltinism, and complete bivoltinism. *Macrostemum carolina* (Banks), and *Nyctiophylax affinis* (Banks) were found on snags. *Chimarra florida* (Ross) and *Cheumatopsyche* spp. were found in leaf packs as well as snags. *Pycnopsyche laculenta* (Betten) was the only abundant shredder and was found in leaf packs and on the undersides of logs. *Hydropsyche decalda* (Ross) exhibited bivoltinism and was both free-living and found living on the stems of the aquatic macrophyte, *Sparganium americanum*. The adults of the bivoltine *Phylocentropus placidus* (Banks) emerged during March through June and again during August through October. Larvae of this insect were found along muddy banks.

The Megalopteran, *Sialis aequilis* (Banks), was found in the muddy sediment of the swamp and exhibited a univoltine life cycle. The Isopod, *Asellus laticaudatus* (Williams), was found on snags and muddy banks.

Among the dragonflies and damselflies (Odonates), *Calopteryx dimidiata*, *Enallagma divagans* (Selys), and *Epitheca cynosura* were all univoltine. *Gomphus lividus* (Selys), the most abundant odonate in the stream, resided in the sandy substrate; *Boyeria vinosa* (Say) resided on snags; and *Macromia georgina* (Selys), resided in the mud substrate: they were all semivoltine. Adults emerged in late spring and early summer. *Epitheca cynosura* (Say) was found in mud habitats, and *Calopteryx dimidiata* (Burmeister) was found in snags: both emerged in May. *Enallagma divagans* was found in mud and its emergence was completed by June.

The Dipteran, *Simulium taxodium* (Snoddy & Beshear), was the most abundant blackfly and produced at least 6 generations per year. It was found in leaf packs, on woody snags, and on leaves of the aquatic plant *Sparganium americanum* (Nutt).

Smock, L.A., and Gilinsky, Ellen, 1982, Benthic macroinvertebrate communities of a flood plain creek in the Congaree Swamp National Monument: Atlanta, National Park Service, Final Report, Contract Number CX5000-0-0945, 82 p.

Smock and Gilinsky determined the macroinvertebrate species composition of Cedar Creek, a blackwater stream flowing into the Congaree Swamp National Monument near Columbia, S.C. They enumerated 142 separate taxa of macroinvertebrates in five major habitats (benthic sediment, stream banks, snags, allochthonous leaf packs, and leaf blades of the aquatic macrophyte, *Sparganium americanum)*. The macroinvertebrate fauna of Cedar Creek were found to be typical of southeastern Coastal Plain blackwater streams. Woody snags and tree trunks were the richest habitat overall, in terms of density and species diversity. The dominant macroinvertebrates were: the mayfly (*Stenonema modestum*); the caddisflies (*Macronema carolina*, *Cheumatopsyche* spp., and *Oecetis* spp.); and the elmid (riffle) beetle (*Ancryonix variegate)*. Woody snags and submerged tree trunks supported in excess of 90 percent of the standing crop of macroinvertebrates, even though they represented only 20 percent of the available surface area in the stream. Species richness and composition, and diversity indicated that the water quality of Cedar Creek was good. There was no indication of any form of pollution, including organic matter, toxic wastes, or excessive loads of suspended material.

Smock, L.A., and Gilinsky, Ellen, 1992, Coastal Plain blackwater streams, *in* Hackney, C.T., Adams, S.M., and Marshall, W.H., eds., Biodiversity of the southeastern United States aquatic communities: New York, John Wiley and Sons, Inc., p. 271-313.

The authors discuss blackwater streams, the most common type of freshwater habitats present throughout the Southeastern Coastal Plains ecoregion. The physical, biological, and chemical characteristics of blackwater streams differ markedly from those of the rocky, higher-gradient streams of the Blue Ridge Mountains and the Piedmont ecoregions.

Blackwater streams in the southeastern United States exhibit large seasonal variation in flow. High-flow volumes in November and December, as a result of winter rains, increase the aquatic habitat by causing the inundation of the flood plains. The flood plains serve as water-storage areas for Coastal Plain river systems. Low-flow periods in summer and autumn are caused by an increase in evapotranspiration rates, not by a decrease in precipitation. One study, cited by the authors, indicated that upwards of 61 percent of the total annual precipitation in some North Carolina Coastal Plain streams was lost through evapotranspiration, while only 37 percent was discharged to streams.

High concentrations of dissolved organic carbon (DOC) impart a dark color and high acidity to the water. Most of the organic matter in stream water is dissolved, rather than particulate. Humic and fulvic acids, derived from the leaching of swamp soils, are prevalent. Whereas most of the lotic systems in the world have a typical dissolved inorganic carbon to dissolved organic carbon ratio of 10:1, blackwater streams exhibit a ratio of 1:1.

The inorganic chemistry of blackwater streams is based on sodium sulfate, rather than calcium carbonate. Consequently, buffering capacity and nutrient concentrations are low, as compared to other types of streams. The highly leached soils (very poor in soluble minerals) of the Coastal Plain yield few dissolved or particulate-associated inorganic ions. Concentrations of dissolved solids tend to increase from upper to lower Coastal Plain streams. Nitrogen and phosphorus concentrations are low due to bacteria mediated denitrification and phosphorus uptake by algae. Low concentrations of dissolved oxygen (DO) occur during summer and autumn low-flow periods, because of the inverse relationship between DO concentration and water temperature, and an increase in microbial respiration coinciding with autumnal leaf fall.

Plant communities of Coastal Plain stream flood plains are important energy sources. Primary productivity in blackwater streams is low and the streams are highly heterotrophic. Measured photosynthesis/respiration ratios typically range from 0.2 to 0.7. Instream algal communities are dominated by episammic diatoms and filamentous algae on stable substrates. Light penetration, rather than nutrient availability, is the limiting factor in the growth of aquatic vegetation. In addition, low productivity is due to lack of stable substrate and high rates of respiration due to the presence of allochthonous material from extensive flood plains. During periods of flooding, detritus on the flood plains is within the functional stream system.

The benthic macroinvertebrate community is varied but typically poor in scraper and shredder groups due to the absence of a stable substrate and consequent low leaf-litter retention on the sandy bottoms. Woody snags and debris dams comprise the richest habitats. Macroinvertebrate production is based on allochthonous detritus, specifically, fine particulate organic material. The filter-feeder group, occurring mostly on snags, is well-represented by blackflies and caddisflies. Snags and debris dams also harbor the collector-gatherer group, represented by chironomids and oligochaetes.

Among the mollusks, the fingernail clams (Sphaeridae) are the most abundant and seem to have a higher tolerance of acidic conditions than other molluscan families. Fishes are abundant in blackwater streams of the Coastal Plain. Endemism and processes of subspeciation have contributed to a diverse and interestingly varied community.

These streams are in heavy use by the public as fishing waters, with approximately 50 to 70 percent of the standing-stock biomass of fishes being composed of gamefish. Many fish species use the flood plain as forage areas during periods of high water. The flood plains also serve as important spawning and nursery areas for other species of fish. Most fish species found in the blackwater streams are typical of slow-flowing, deepwater habitats.

South Carolina Department of Parks and Recreation, 1991, Animals and plants of South Carolina's Catawba River corridor: Columbia, 30 p.

This report is a list of the animal and plant species that are present, or likely to be present in the Catawba River corridor in South Carolina. It provides the common and scientific names of the organisms and indicates whether the plant or animal is native or introduced, common or uncommon. There are at least 67 species of fishes living in the Catawba River corridor. Among the more common fishes of public interest listed in the report: channel catfish, white catfish, yellow bullhead, white bass, striped bass, largemouth bass, yellow perch, redbreast sunfish, bluegill sunfish, and black crappie. Other fishes of interest, but listed as not commonly seen, include: the fantail darter, the seagreen darter, bowfin, American eel, and the longnose gar.

Wallace, J.B., Webster, J.R., and Lowe, R.L., 1992, High-Gradient streams of the Appalachians, *in* Hackney, C.T. Adams, S.M., and Marshall, W.H., eds., Biodiversity of the Southeastern United States aquatic communities: New York, John Wiley and Sons, Inc., p. 133-191.

This document includes a well-rounded discussion of the geography, geology, and climatology of the southern Appalachian Mountains, followed by a description of the aquatic life forms and characteristics of high-gradient montane streams. The southern Appalachian Mountains (also called the Crystalline Appalachians) encompass part of what is known as the Blue Ridge physiographic province. In the Blue Ridge physiographic province riparian vegetation inhibits the growth of vegetation in streams, and the high current velocity of the streams limits the autotrophic community. In undisturbed streams draining the Blue Ridge physiographic province, baseflow concentrations of most ions [chloride (Cl^-), potassium (K^+), sodium (Na^+), calcium (Ca^{++}), magnesium (Mg^{++}), sulfate (SO_4^{--})] are usually less than 1 part per million (ppm). Nutrient concentrations are very low, ranging from 0.001 to 0.004 ppm for nitrate nitrogen (NO_3-N), ammonia nitrogen (NH_4-N), or phosphate (PO_4-P). Most of the streams are circumneutral in pH. Compared with other Appalachian regions, southern Blue Ridge Mountains ecoregion streams have lower acid neutralizing capacity and lower concentrations of dissolved organic carbon, bicarbonates, nitrates, sulfates, and total base cations.

A dense deciduous, hardwood forest covers most of the Blue Ridge Mountains ecoregion, but the ridgecrests support a coniferous community of frazier fir (*Abies fraseri*) and red spruce (*Picea rubens*). These coniferous and hardwood forests provide a major portion of the energy input to the streams (through litterfall and lateral movement of leaves and wood). Primary production in shaded stream reaches is only about one third of that in unshaded reaches. Woody debris from forest litterfall contributes to the stream-energy budget and habitat definition. Such debris provides habitat for fishes and invertebrates, retains particulate material, provides food for xylophagous organisms, and helps dissipate stream mechanical energy.

In turbulent streams, the dominant macrophytes are the mosses and the liverworts (bryophytes). Highly turbulent flow insures saturation with carbon dioxide (CO_2), and these bryophytes are able to use free CO_2 as a carbon source. Four species of bryophytes dominate the high-gradient streams of the southern Appalachians: *Fontinalis dalecarla*, *Hygroamblystegietum fluviatile*, *Sciaromium lescurii,* and *Scapania undulata*.

Algal dominants include the filamentous red algae (*Nemalionopsis shawii f. caroliniana* and *Boldia erythrosiphon*) and the filamentous green algae, and diatoms, specifically, genera such as *Acnanthes, Eunota, Meridon*, and *Diatoma*. Among the invertebrate fauna, the collector-gatherer and the collector-filterer groups are well-represented. They process fine, particulate organic material back to coarse, particulate organic material as metabolic waste products, making the carbon available to more species.

The vertebrate fauna are dominated by salamanders (especially the black bellied salamander, *Desmognathus quadramaculatus*) and fish; brook trout (*Salvelinus fontinalis*), sculpins (*Cottus* spp.), darters (*Etheostoma* spp.) and dace (*Rhynichthes* spp.) are the taxa most noted. Because there is limited primary production in these well-canopied mountain streams, plant feeders such as the stoneroller minnows (*Campostoma* spp.) are absent and detritivorous species are rare.

The authors conclude that the fish community, especially the brook trout, is heavily dependent upon allochthonous energy sources and this dependency is directly linked to feeding on terrestrial insects and indirectly linked to the dependence of aquatic invertebrates on allochthonous material. Four biologically important characteristics of small, high-gradient streams are cited in the article. They are: (1) invertebrate production is generally low in most small, high-gradient Appalachian streams, especially those draining areas dominated by crystalline rock, (2) the greater portion of invertebrate production is used by predacious invertebrates in the streams, (3) salamanders dominate secondary production in small fishless headwater streams, and that production tends to be similar to production of fishes in larger downstream areas, and (4) the availability of food resources may strongly influence the secondary production of carnivorous vertebrates.

SELECTED STUDY DESCRIPTIONS: SURFACE-WATER QUALITY

Eight publications from appendix 2 were reviewed in depth. Summaries of these studies are included in this section.

Bates, R.D., and Marcus, J.M., 1990, Hydrologic dynamics and water-quality characteristics of the Santee Swamp and the factors involved in fish kill episodes in upper Lake Marion, South Carolina: Columbia, South Carolina Department of Health and Environmental Control, Report SCP 001-90, 49 p.

This report describes a study designed to characterize water quality in the Santee Swamp, and to identify correlations between water quality and other environmental factors. Between March 1988 and February 1989, an intensive study showed significant variability in the physical and chemical characteristics of surface waters in the Santee Swamp. Several fish kills occurred in the swamp and upper lake area in 1986 and 1989, which were associated with low concentrations of dissolved oxygen in the water column and high water temperatures. Low dissolved-oxygen concentrations were attributed to the decomposition of naturally occurring organic material flushed into the swamp after a rain that followed a period of drought. Flow patterns through the swamp were determined and river and lake stages were related to various flow patterns.

The report provides a physical description of the Santee Swamp in upper Lake Marion and of the sampling stations used for the study. Water levels in the river, swamp, and the lake are listed, and water-quality data are discussed. Recommendations are made to prevent the occurrence of fish kills, including: monitoring rainfall events, tracking the stage of the Wateree River, monitoring water-quality conditions in upper Lake Marion and the Santee Swamp during summer and fall months, and surveying fish populations in the swamp and the upper lake area for evidence of effects from exposure to poor water-quality conditions.

Cooney, T.W., 1990, Concentrations of metals in bed material in the area of Congaree Swamp National Monument and in water in Cedar Creek, Richland County, South Carolina: U.S. Geological Survey Open-File Report 90-370, 18 p.

This report documents a water-quality study to measure concentrations of selected metals in the bed material of streams in the Congaree Swamp National Monument and in the water column of Cedar Creek. The study area is 120 mi^2 and includes the drainage areas of Toms and Cedar Creeks. The Monument is preserved as a significant tract of southern old-growth river-bottom forest. The study was conducted in response to concern that plant and animal life in the preserve may be endangered by trace metals. Levels of trace metals in bed material and surface water are listed in tables in the report.

Results indicate that metals that occur naturally in soils in the watershed are present in a wide range of concentrations. Bed material in Toms Creek contained significantly lower metal concentrations than were measured in the sediments of the lower reaches of Cedar Creek. Concentrations of lead and manganese were larger at upstream sites, possibly indicating an effect from runoff. Relatively large concentrations of most metals in the bed material in the Monument indicate that the flood plain of the Congaree River may act as a sink for metals. No correlation between particle size and sample concentrations was found. Concentrations that exceeded the 1990 U.S. Environmental Protection Agency drinking water standards for cadmium and manganese were found in the surface-water samples from Cedar Creek.

Jaynes, M.L., 1994, Hydrologic, water-quality, and meteorologic data from selected sites in the upper Catawba River Basin, North Carolina, January 1993 through March 1994: U.S. Geological Survey Open-File Report 94-509, 76 p.

This report presents data collected in an intensive study, conducted from January 1993 through March 1994, to characterize the water quality of Rhodhiss Lake, Lake Hickory, and three tributary streams. The headwaters of the upper Catawba River Basin, N.C., are in the Blue Ridge physiographic province, and the basin extends into the Piedmont physiographic province.

The report describes the mean precipitation, geologic formations, topography, land use, and natural resource development of the area. Water-quality problems such as algal blooms and elevated nutrient concentrations have been observed in the reservoirs during 1992 and 1994. Rhodhiss Lake has been classified as eutrophic by the U.S. Environmental Protection Agency.

Water samples were analyzed for biochemical oxygen demand, fecal coliform bacteria, hardness, alkalinity, total and volatile suspended solids, suspended sediment, nutrients, total organic carbon, chlorophyll, iron, calcium, and magnesium from three sites in each reservoir and from the three tributary sites. Monthly water-level statistics and daily mean values of discharge are presented in the report. Water-quality data are provided in tables and graphics.

Marshall, W.D., ed., 1993, Assessing change in the Edisto River Basin: an ecological characterization: Columbia, South Carolina Water Resources Commission Report no. 177, 149 p.

This report is a comprehensive review of the conditions in the Edisto River Basin, with suggestions for future goals and planning efforts. The physical setting is described in detail, including the climate, precipitation patterns, geology, vegetation, population, and economy of the basin. Historical land use patterns are discussed, with subbasins showing various changes. Native wetland vegetation conversions to pine plantations or agricultural land were more common and prevalent in some areas, such as Four Hole Swamp, where 34 percent of wetland areas were being converted between 1968 and 1989.

An assessment of the hydrology in the Edisto River Basin is also included, with streamflow and precipitation data evaluated for spatial and temporal trends. An analysis of single-mass curves showed no significant change in precipitation between 1939 and 1990, and few temporal streamflow trends were found. Changes in streamflow were likely related to changes in precipitation.

Historical water-quality patterns were assessed as they related to hydrology and land use patterns. Data collected from 1975 to 1991 indicated that water quality in the watershed was generally acceptable, with declining total phosphorus concentrations and biochemical oxygen demand loads. Concerns over disturbance in the North Fork Edisto River were expressed; for example, poor forest management and nonpoint source effects from farming. Breeding-bird surveys were used to assess trends in species richness and composition in the Edisto River Basin. The breeding-bird survey indicated trends associated with landcover and land use changes.

North Carolina Department of Environment, Health and Natural Resources, and South Carolina Department of Health and Environmental Control, 1992, Water quality investigation of Lake Wylie April 1989 - September 1990: Report no. 92-04, 135 p.

An in-depth study of the water quality of Lake Wylie is detailed in the report. Lake Wylie is located on the Catawba River and straddles the boundary between North Carolina and South Carolina. This lake has been the subject of public concern because of the effect of nutrient loading on water quality in the lake and the embayments of the lake. Lake Wylie is used extensively for recreation and as a drinking water source. A study was conducted to assess the physical, chemical, and biological characteristics of the lake. Results indicated that Lake Wylie is threatened by eutrophic conditions. A modeling analysis of eutrophication response was made, with results indicating the need for point-source and nonpoint-source control of nutrient loading to the lake and tributaries.

Eutrophic conditions in the embayments were among the problems identified. Elevated nutrient concentrations and algal blooms were discovered in several tributaries. Modeling indicated that control of point and nonpoint sources would be necessary to reduce nutrient loading to Lake Wylie and its tributaries, specifically, South Fork Catawba River, Catawba Creek, and Crowders Creek. Modeling also indicated that with decreased phosphorus concentrations, a significant amount of wastewater could be assimilated.

South Carolina Department of Health and Environmental Control, 1975?, Edisto-Combahee River Basin water quality management plan, 133 p.

This report represents a long-term basin plan for the Edisto-Combahee Basin and is a required planning document for other basins in South Carolina. It describes the basin's climate, physiography, and geology, as well as economic, social, and political conditions. Surface- and ground-water resources are assessed, with point-source and nonpoint-source pollution addressed as they relate to resource development. The basin's existing wastewater-treatment facilities are discussed, with recommendations for meeting the needs of economic development and protection of water quality through current standards. The status of government-funded projects to meet these needs is described, along with wasteload allocations for the discharges in the basin.

Water-quality data assessment during 1970-74 indicated that there were many water-quality standards violations for dissolved oxygen, pH, and fecal coliform bacteria. Individual stream segments were assessed with problem areas mapped and locations of point-source discharges shown. By identifying those stream segments with standards violations and correlating the violations with point-source discharges, appropriate effluent limitations could be recommended to bring the streams back into compliance through the wasteload allocation process.

South Carolina Water Resources Commission, 1976, Lower Santee River environmental quality study: Columbia, Report no. 122, 60 p.

This report details water-quality parameters from May 1974 to February 1975. Four intensive sampling periods included diurnal studies to characterize water quality. The study included 87 river miles of the Santee River from Wilson Dam to the river's mouth. Significant findings included high levels of dissolved oxygen in the lower Santee River, with lower percentages of saturation in the warmer months. Biochemical oxygen demand was generally low, indicating good water quality. Ammonia nitrogen and nitrate nitrogen concentrations were high in areas affected by industrial effluents. Phosphorus levels were generally low, with a gradual increase downstream, perhaps due to agricultural runoff or municipal wastewater. The concentrations of metals in analyzed samples were below drinking-water standards. Pesticides were detected at all stations in the water column and in sediment samples. Phytoplankton biomass decreased downstream, but then increased again. Seasonal variability in phytoplankton biomass was observed. This report also includes a vascular plant survey of the flood plain, and a small mammal survey of the delta.

U.S. Environmental Protection Agency, 1973, Santee River Basin - a review and summary of available information on physical, chemical and biological characteristics and resources: Athens, Georgia, U.S. Environmental Protection Agency Ecology Branch, 129 p.

Concern over potential effects on the aquatic environment in the lower part of the river caused by the diversion of the flow to the Santee River prompted the state of South Carolina to request a review of available data. The U.S. Environmental Protection Agency produced this summary of the data and reports available at that time. The information continues to be of value as the question of flow diversion to the Cooper and Santee Rivers is an on-going concern due to sedimentation, point-source discharge permit issuance, salt-wedge encroachment, and freshwater supply issues.

The report describes basin characteristics, including morphology, geology, climate, demography, and land use. Ground water, surface water, and biota are also discussed. Water quality and biological monitoring data are reviewed, including reports prepared by Bears Bluff Laboratory, Inc., the U.S. Geological Survey, the South Carolina Department of Health and Environmental Control, the U.S. Department of Agriculture, and the U.S. Fish and Wildlife Service. Data on streamflow, water quality, and a list of fish, plant, and invertebrate species collected in the basin are presented in tables. Municipal and industrial point sources of pollution are reviewed.

Multiple recommendations are given to relieve the silt deposition and shoaling in Charleston Harbor. One recommended action is the diversion of all flows greater than 3,000 ft^3/s to the Santee River or to Prices Inlet. The intensive study conducted by the U.S. Fish and Wildlife Service concludes that alternatives existed that would not be detrimental to fishes and wildlife resources in the basin.

SELECTED STUDY DESCRIPTIONS: GROUND WATER

Eight publications from appendix 3 were reviewed in depth. Summaries of these studies are included in this section.

Aucott, W.R., 1988, The predevelopment ground-water flow system and hydrologic characteristics of the Coastal Plain aquifers of South Carolina: U.S. Geological Survey Water-Resources Investigations Report 86-4347, 65 p.

The Regional Aquifer System Analysis (RASA) program of the U.S. Geological Survey developed a comprehensive analysis of ground-water flow and availability in the Coastal Plain aquifers of South Carolina and parts of Georgia and North Carolina prior to development for human use. A ground-water flow model was created to aid in understanding and describing ground-water conditions in the Coastal Plain aquifers. The quasi-three-dimensional model simulated deep, regional ground-water flow, that did not include local shallow-flow systems, and consisted of five layers and a (48 by 63) uniform square grid of 4 mi on a side.

In the lower Coastal Plain, ground-water flow patterns among individual aquifers differed substantially. Ground water in the Floridan aquifer system and the Tertiary sand aquifer generally flowed perpendicular to the coastline in the lower Coastal Plain. However, the flow in the Cretaceous-age aquifers in the lower Coastal Plain was nearly parallel to the coast and toward the northeast. This northeasterly flow was due to the less effective confining units, lower altitude of the upstream rivers, and the closeness of Cretaceous-age aquifers to land surface in the east.

Simulations of the ground-water flow indicate that total recharge and discharge in the deep ground-water- flow system is 825 ft^3/s. Simulated direct recharge in outcrop areas is 789 ft^3/s. The remainder of the total recharge is from leakage of the overlying source-sink beds (15 ft^3/s) and inflow across boundaries (21 ft^3/s). Discharge to the upper Coastal Plain rivers is 735 ft^3/s, whereas the remaining discharge is by upward leakage to the overlying source-sink beds (64 ft^3/s) and by outflow across lateral boundaries (26 ft^3/s). Aquifer transmissivities of all aquifers ranged from less than 1,000 to 30,000 ft^2/d. On the basis of an assumed average confining unit thickness of 100 ft, vertical hydraulic conductivities of the confining units ranged from $2x10^{-7}$ to $5x10^{-2}$ ft/d.

Harrigan, J.A., 1985, Water use in South Carolina, July-December 1983: South Carolina Water Resources Commission Report no. 148, 18 p.

The Water Use Reporting and Coordination Act of 1982 provided the South Carolina Water Resources Commission with the authority to collect and report water-usage data. This report presents the compilation of information on all water users who withdraw, divert, obtain, or discharge a single-day maximum of 100,000 gal, and who are responsible for quarterly reporting of their water use to the South Carolina Water Resources Commission. Not all water users have complied with the Act.

Water withdrawals for July-December 1983 averaged 6,456 Mgal/d, which is 11.7 percent more than in 1980. Surface water was reported to be the source for 6,347 Mgal/d, or 98.3 percent, and 109 Mgal/d was withdrawn from ground-water sources.

Thermoelectric-power generation accounted for 77.1 percent of the water use; industry, 17.1 percent; public supply, 5.2 percent; and agricultural irrigation, about 0.6 percent. Golf course irrigation, heated wastewater evaporation, and wastewater return are reported uses, but that data has not yet been added to the database.

LeGrande, H.E., and Mundorff, M.J., 1952, Geology and ground-water resources in the Charlotte area, North Carolina: North Carolina Department of Conservation and Development, Division of Mineral Resources Bulletin no. 63, 88 p.

The Charlotte area is in the south-central part of North Carolina, bordering South Carolina, and includes the counties of Cabarrus, Cleveland, Gaston, Lincoln, Mecklenburg, Polk, and Rutherford. The area totals 2,833 mi^2 and, according to the 1950 census, had a population of 505,638. The Piedmont Province dominates the relief with mountainous and sharp features. Slopes are commonly precipitous in the area, and major streams have steep to gentle gradients toward the southeastern Coastal Plain.

The area is underlain by igneous and metamorphic rocks, consisting chiefly of schists, gneisses, granites, and slates. The slates and volcanic rocks to which they are related have a restricted occurrence in the extreme eastern part of the area. The mica schists, and the mica and hornblende gneisses represent the chief country rocks that have been pervaded by granite. Local variations in types of rocks are common, and large homogenous masses of a single type are rare. The rocks trend northeastward and are tipped on edge.

Ground-water supplies are obtained through drilled wells, bored wells, dug wells, and springs. The drilled wells tap into fractures in the bedrock, while bored and dug wells obtain water from the porous saprolite layer. Springs occur at all levels above the valley floors except near the hilltops.

Municipal and industrial wells drilled in schist have a slightly larger average yield, 31 gal/min, than wells in other rock units. The average yield of the remaining rock units is about 28 gal/min. Topographic location, spacing of wells, thickness of saprolite, and the presence or absence of joints and fractures also have an important bearing on the amount of water yielded by a well. The average yield of wells drilled in valleys and draws is more than twice as much as that of wells drilled on hills.

Several tables shown in the report relate yield to rock type, topographic location, and to depth of wells. The report also contains a discussion of the ground-water resources, tables of well data and chemical analysis, and a geologic map for each of the seven counties located in the Charlotte area.

Newcome, Roy, Jr., 1989, Ground-water resources of South Carolina's Coastal Plain -- 1988, an overview: Columbia, South Carolina Water Resources Commission Report no. 167, 127 p.

The Atlantic Coastal Plain of South Carolina makes up two-thirds (28 counties) of the State. Cretaceous-age and younger sediment, containing a large amount of ground water, are thinnest at the Fall Line and thicken to about 4,000 ft near the State's southern coast. Nearly 200 Mgal/d are pumped from industrial and municipal wells in the Coastal Plain. Some aquifers contain saline water that was trapped when the sediment was deposited. In some areas the trapped seawater has been flushed by infiltration of fresh ground water over millennia. Freshwater can be found along the coast and on the coastal islands.

Most of the fresh ground water is found in the Cretaceous and Floridan aquifers. The limestone Floridan aquifer contains harder, more mineralized water than that found in most of the older clastic aquifers. Some of the sand aquifers yield concentrations of dissolved solids comparable to rainwater.

Southwestern South Carolina has great potential for developing large supplies of good quality ground water. The greatest use of ground water is in the Myrtle Beach and Beaufort areas. Although these areas can support a greater demand, potential problems have led to their designation as capacity use areas for the purposes of conservation and regulation.

Newcome, Roy, Jr., 1990a, The 100 largest public water supplies in South Carolina: Columbia, South Carolina Water Resources Commission Report no. 169, 57 p.

The use of South Carolina public water supplies averages 400 Mgal/d. Of this amount, 80 percent is obtained from public surface water and 20 percent from ground water. The five largest public suppliers are the cities of Charleston, Greenville, Columbia, Spartanburg, and the Beaufort-Jasper County Water Authority. Sumter, the largest supplier using only ground water, and Anderson, which uses surface and ground water, share sixth place. The range in ground-water withdrawals for the 100 largest public supplies is from about 0.6 Mgal/d to 50 Mgal/d.

Newcome, Roy, Jr., 1993, Pumping tests of the Coastal Plain aquifers in South Carolina, with a discussion of aquifer and well characteristics: South Carolina Water Resources Commission Report no. 174, 52 p.

Pump tests from 474 wells are used for determining aquifer and well characteristics in the Coastal Plain aquifers of South Carolina. All of the tests provide values for transmissivity, with most of the tests providing information about specific capacity and efficiency. The Coastal Plain counties are unevenly represented in numbers of pump tests. However, all of the significant aquifers are represented, including the sandy Middendorf and Black Creek Formations of Cretaceous age and the limestone Floridan aquifer of Eocene age.

Nearly all the tests were made in confined aquifer wells. The highest yielding well was in the Floridan aquifer, which also had the highest transmissivity, reaching 500,000 (gal/d)/ft. The second-highest yielding water-bearing unit, and the one having the greatest areal extent, is the Middendorf aquifer. Tests of multiscreened wells in the Middendorf aquifer have produced transmissivity values with a median of 21,000 (gal/d)/ft. In pumping tests of the Black Creek aquifer, the median transmissivity was 12,000 (gal/d)/ft. Median values for the remaining aquifers were generally less than 5,000 (gal/d)/ft.

Patterson, G.G., and Padgett, G.G., 1984, Quality of water from bedrock aquifers in the South Carolina Piedmont: U.S. Geological Survey Water-Resources Investigations Report 84-4028, 24 p.

This report contains a series of maps that show bedrock-aquifer water quality in 12 geographic regions. The sampling was conducted by the South Carolina Department of Health and Environmental Control and was restricted to aquifers of the South Carolina Piedmont. The maps are based on analyses of water samples collected from 442 public and private wells from 1972 to 1982. In general, the Carolina Slate Belt showed higher alkalinity and hardness, and larger concentrations of sodium, magnesium, and chloride than the other geologic belts of the Piedmont.

Speiran, G.K., and Aucott, W.R., 1994, Effects of sediment depositional environment and ground-water flow on the quality and geochemistry of water in aquifers in sediments of Cretaceous age in the Coastal Plain of South Carolina: U.S. Geological Survey Water-Supply Paper 2416, 53 p.

Cretaceous sediments in the South Carolina Coastal Plain have been deposited in fluvial, delta-plain, marginal-marine, and marine environments. Depositional environments of sediment within a single aquifer may grade from nonmarine, fluvial, or upper-delta plain near the updip limit of the aquifer to transitional, lower-delta plain and to marine toward the coast. These environments significantly affect the water quality and geochemistry in samples taken from aquifers in Cretaceous-age sediment.

The decomposition of organic material is the major source of inorganic carbon found in nonmarine sediment. The major aqueous geochemical processes involved are the dissolution and alteration of silicate minerals. Silica is a major fraction of the dissolved constituents in water from nonmarine sediment.

Aquifers consisting of transitional and marine sediments contain various amounts of calcium carbonate and sodium-rich clay minerals. The geochemistry of these aquifers is dominated by the dissolution of calcium carbonate and the exchange of calcium for sodium on the sodium-rich clay minerals. The freshwater-saltwater interface in the aquifers in Cretaceous sediments is seaward of the present coast, and only dilute saltwater is present onshore. Although the interface may be intruding landward, the dilute saltwater of the transition zone is being flushed seaward.

SUMMARY

At the request of Congress, the U.S. Geological Survey began a National Water-Quality Assessment [NAWQA] Program in 1991. The Santee River Basin and Coastal Drainages [SANT] study area was one of 20 study units that began assessment activities in 1994. This report provides extensive bibliographies and summaries of several studies that were conducted in or near the SANT study area, prior to 1996. A table of additional sources of information from Federal, State, and local databases is presented. The bibliographies are available on computer diskette, in ASCII format.

The SANT study area encompasses approximately 23,600 mi^2, and includes three physiographic provinces (Blue Ridge, Piedmont, and Coastal Plain) and four major ecoregions - the Blue Ridge Mountains, the Piedmont, the Southeastern Plains, and the Middle Atlantic Coastal Plain. There are four major metropolitan centers in the study area, with a combined population in excess of 3.6 million. Textiles, paper, and chemicals are the major industries in the study area. Feed lots, meat processing, orchards, farming, and mining constitute current vital economic activities in the study area.

Streams in each of the four ecoregions differ in their physical, chemical, and biological characteristics. They range from high-gradient, narrow, densely shaded mountain streams in the Blue Ridge ecoregion, to lower gradient, wider, uncanopied streams with extensive flood-plain forests and small well-canopied tributaries in the Piedmont and Southeastern Plains ecoregions, to very low gradient, slow-flowing, heavily canopied blackwater streams in the Middle Atlantic Coastal Plain ecoregion.

Surface-water quality for much of the study area meets state and Federal water-quality standards. Point sources are regulated, but nonpoint sources of pollution such as agricultural and urban runoff introduce pesticides, nutrients, trace metals, and organics into surface water. The primary water-quality factors that

affect aquatic communities are current velocity, water temperature, toxic substances, dissolved-oxygen concentration, and suspended-sediment load.

The SANT study area can be divided into two hydrogeologic regions, the Blue Ridge/Piedmont and the Coastal Plain. Ground-water quality in the SANT study area generally meets state and Federal standards. However, spills and leaks of chemicals have contaminated ground water in numerous but relatively small areas. Some pesticides and nutrients are found in ground water associated with agricultural areas.

A bibliography of nearly 400 publications pertaining to aquatic biology, surface-water quality, and ground-water studies in the SANT study area is presented in 3 appendices. From this bibliography, 30 reports were selected for in-depth descriptions of their contents.

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APPENDIX 1

Aquatic Ecology Bibliography

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APPENDIX 2

Surface-Water Quality Bibliography

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APPENDIX 2 - SURFACE-WATER QUALITY BIBLIOGRAPHY

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APPENDIX 3

Ground-Water Bibliography

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APPENDIX 3. GROUND-WATER BIBLIOGRAPHY

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