Environmental Setting and Factors That Affect Water Quality in the Georgia-Florida Coastal Plain Study Unit

By Marian P. Berndt, Edward T. Oaksford, Melanie R. Darst, *and* Richard L. Marella

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NATIONAL WATER-QUALITY ASSESSMENT PROGRAM--
GEORGIA-FLORIDA COASTAL PLAIN STUDY UNIT

Tallahassee, Florida
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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

Multiply	By	To obtain
inch (in)	2.54	centimeter
foot (ft)	0.3048	meter
acre (ac)	4,047	square meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
inches per year (in/yr)	2.54	centimeters per year
million gallons per day (Mgal/d)	3,785	cubic meters per day
gallons per minute (gal/min)	0.0631	liters per second
feet per day (ft/d)	0.3048	meters per day
feet squared per day (ft^2/d)	0.0929	meters squared per day
cubic feet per second (ft^3/sec)	28.316	liters per second

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°C = (5/9) \times (°F - 32)$$

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

ACRONYMS AND ABBREVIATIONS USED IN REPORT

MSA = Metropolitan Statistical Area
NAWQA = National Water-Quality Assessment Program
USGS = U.S. Geological Survey
mg/L = milligrams per liter
ug/L = micrograms per liter

Environmental Setting and Factors That Affect Water Quality in the Georgia-Florida Coastal Plain Study Unit

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Abstract

The Georgia-Florida Coastal Plain study unit covers an area of nearly 62,000 square miles in the southeastern United States, mostly in the Coastal Plain physiographic province. Land resource provinces have been designated based on generalized soil classifications. Land resource provinces in the study area include: the Coastal Flatwoods, the Southern Coastal Plain, the Central Florida Ridge, the Sand Hills, and the Southern Piedmont. The study area includes all or parts of seven hydrologic subregions: the Ogeechee-Savannah, the Altamaha-St.Marys, the Suwannee, the Ochlockonee, the St. Johns, the Peace-Tampa Bay, and the Southern Florida. The primary source of water for public supply in the study area is ground water from the Upper Floridan aquifer. In 1990, more than 90 percent of the 2,888 million gallons per day of ground water used came from this aquifer.

The population of the study area was 9.3 million in 1990. The cities of Jacksonville, Orlando, St. Petersburg, Tallahassee, and Tampa, Florida, and parts of Atlanta and Savannah, Georgia, are located in the study area. Forest and agricultural areas are the most common land uses in the study area, accounting for 48 percent and 25 percent of the study area, respectively. Climatic conditions range from temperate in Atlanta, Georgia, where mean annual temperature is about 61.3 degrees Fahrenheit, to subtropical in Tampa, Florida, where mean annual temperature is about 72.4 degrees Fahrenheit. Long-term average precipitation (1961-90) ranges from 43.9 inches per year in Tampa, Florida, and 44.6 in Macon, Georgia, to 65.7 inches per year in Tallahassee, Florida. Floods in the study area result from frontal systems, hurricanes, tropical storms, or severe thunderstorms. Droughts are not common in the study area, especially in the Florida part of the study area due to extensive maritime exposure.

The primary physical and cultural characteristics in the study area include physiography, soils and land resource provinces, geologic setting, ground-water systems, surface-water systems, climate, floods, droughts, population, land use, and water use. Factors affecting water quality in the study area are land use (primarily urban and agricultural land uses), water use in coastal areas, hydrogeology, ground-water/surface-water interaction, geology, and climate. Surface-water quality problems in urban areas have occurred in the Ogeechee, Canoochee, Ocmulgee, St. Marys, Alapaha, Withlacoochee (north), Santa Fe, Ochlockonee, St. Johns, and Oklawaha Rivers and include nitrogen and phosphorus loading, low dissolved oxygen, elevated bacteria, sediment, and turbidity, and increased concentrations of metals. In agricultural areas, surface-water quality problems include elevated nitrogen and phosphorus concentrations, erosion, and sedimentation and have occurred in the Ocmulgee, St. Marys, Santa Fe, Ochlockonee, St. Johns, Oklawaha, Withlacoochee (South), Hillsborough, and Alafia Rivers. Ground water-quality problems such as saltwater intrusion have occurred mostly in coastal areas and were caused by excessive withdrawals.

INTRODUCTION

The Georgia-Florida Coastal Plain study unit is one of the twenty NAWQA study units located throughout the nation selected to begin assessment activities in 1991 (fig. 1). Located on the southeastern coast of the United States, this study area encompasses all or part of seven major hydrologic subregions and is an area where a large population lives and relies chiefly upon ground water as its source of public water supply.

The primary source of water in the study area is the Floridan aquifer system, which is one of the major sources of ground-water supply in the nation. Although large drawdowns have occurred in several high pumpage areas, the major constraint on increased development of the Floridan aquifer system is most likely to be degradation of water quality and not limitation of quantity (Bush and Johnston, 1988). Surface-water resources are also abundant in the study area but are not extensively used for water supply.

The seven major hydrologic subregions within the study area include the Ogeechee-Savannah, the Altamaha-St.Marys, the Suwannee, the Ochlockonee, the St. Johns, the Peace-Tampa Bay, and the Southern Florida hydrologic subregions. Only the Ogeechee River is included in the Georgia-Florida Coastal Plain from the Ogeechee-Savannah subregion and only the Withlacoochee (south), Hillsborough, and Alafia River are in the study area from the Peace-Tampa Bay hydrologic subregion.

The study area for the Georgia-Florida Coastal Plain was originally delineated to encompass most of the area underlain by the Floridan aquifer system. This original study area was about 54,000 square miles (mi^2), and extended to the northernmost extent of the Floridan aquifer system, and part of the Georgia and South Carolina border (fig. 1). The initial sampling design from the project was developed based on this boundary. This boundary cut across some major river basins, such that only the lower parts of some basins were included in the study area. To characterize the surface-water hydrology and water quality for the entire river basins (including area north of this original study area), the boundary was revised in 1993 to include the upper parts of the Ogeechee River basin and the upper parts of river basins of two major tributaries to the Altamaha River. The area of the present study area is approximately 62,000 mi^2. The sampling design for surface-water studies of the study unit includes sampling in this new section of the study area, but the sampling design for ground-water studies does not extend into this new section, because there is little ground water withdrawn in this new section.

Purpose and Scope

The purpose of this report is to describe the environmental setting of the Georgia-Florida Coastal Plain National Water-Quality Assessment (NAWQA) Program study unit and its effects on water-quality conditions in surface- and ground-water resources. The effects of the water-quality conditions on the ecosystems they support are described. This report is also intended as a reference document for future studies and topical water-quality reports produced as a part of the NAWQA program within the Georgia-Florida Coastal Plain study unit. Future studies will focus on determining the effects of some aspects of the environmental setting, such as land uses, on water quality and the effects of ground-water/surface-water interaction on ground- and surface-water quality.

This report describes the entire geographical area of the Georgia-Florida Coastal Plain study unit in terms of physical and cultural characteristics. The physical and cultural characteristics of the study area, including physiographic districts, climate, soils, geology, ground-water systems, surface-water systems, land use, population and water use are addressed as well. Factors that affect water quality in the study area, such as climate, geology, hydrogeology, ground-water/surface-water interaction, land use and water use in coastal areas, are also discussed.

ENVIRONMENTAL SETTING

The study area includes all or parts of 135 counties in Florida and Georgia (fig. 1). The total areal extent is approximately 62,000 mi^2 and extends from north-central Georgia to central Florida. Approximately 52 percent of the study area is in Georgia and 48 percent is in Florida. The topography varies from gently rolling topography in the north, to altitudes near sea level in coastal areas in the south. River basins also vary in form in the study area, with deep and narrow stream valleys in the north to poorly organized drainage systems in the south.

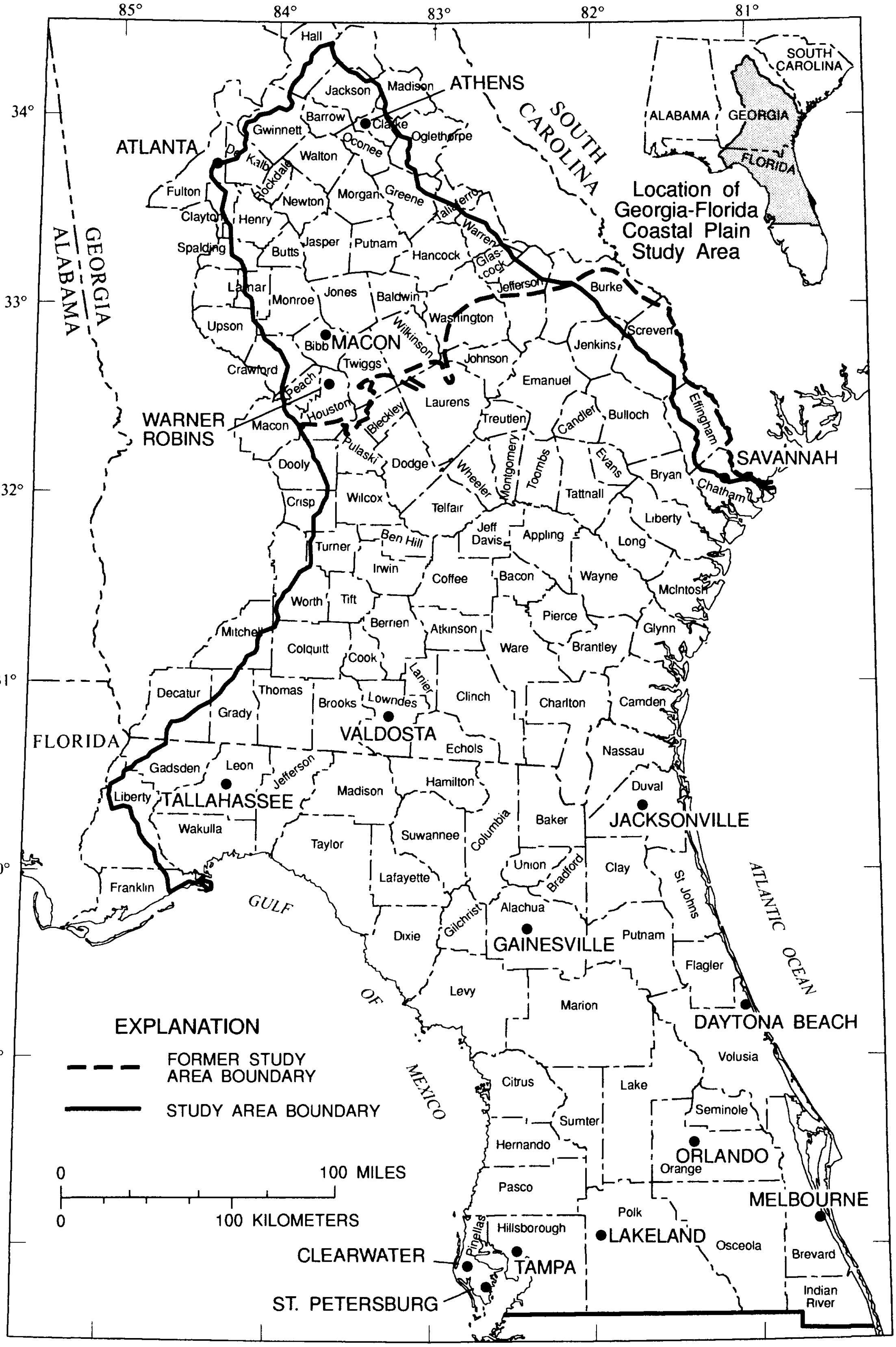

Figure 1. Location of the Georgia-Florida Coastal Plain study area.

The study area includes all or parts of two physiographic provinces, five land resource provinces, four ecoregions, two major aquifer systems as well as several other aquifer systems, and seven hydrologic subregions.

Climate

The study area has a climatic range from temperate in the north, to subtropical in the south and along the Gulf Coast. Mean annual temperatures range from about 61.3 degrees Fahrenheit (°F) in Atlanta, Ga., to about 72.4 °F in Tampa, Fla. (table 1). In Georgia, the highest temperatures normally occur in July and the lowest in January (Hodler and Schretter, 1986).

Table 1. Long-term average temperature for selected cities in the Georgia-Florida Coastal Plain, 1961-90

[Owenby and Ezell, 1992a, b]

Location	Average temperature 1961-90, in degrees Fahrenheit
Athens, Ga.	61.7
Atlanta, Ga.	61.3
Macon, Ga.	64.4
Savannah, Ga.	66.3
Daytona Beach, Fla.	70.4
Gainesville, Fla.	68.6
Jacksonville, Fla.	68.0
Melbourne, Fla.	71.9
Orlando, Fla.	72.3
Tallahassee, Fla.	67.2
Tampa, Fla.	72.4

Climatic conditions within the study area vary seasonally, annually, and areally and are influenced primarily by latitude and proximity to the Gulf of Mexico and the Atlantic Ocean. Principle sources and patterns of moisture delivery to the study area are derived from subtropical air masses from the Gulf of Mexico and air masses from the Atlantic Ocean (Bridges and Franklin, 1991; Golden and Hess, 1991). Maximum precipitation occurs during the summer as a result of convective storms from surface heating of moist air converging inland along the coastlines or being advected onshore by prevailing winds from the southwest or southeast. In northern Florida and central and southern Georgia there is a secondary maximum in late winter due to frontal systems moving through the area. Precipitation along the southeastern coast of Georgia can frequently be greatest in September whenever extremely intense rains accompany tropical storms. The driest month in much of southeastern Georgia is generally November (Golden and Hess, 1991).

Long-term average precipitation in south-central Georgia and peninsular Florida is about 53 inches per year (in/yr) (Bush and Johnston, 1988). Yearly total precipitation varies greatly, and in extremely wet years, precipitation quantities commonly occur at twice the amount measured in dry years (fig.2) (Carter, 1969; Bradley, 1972). Long-term average precipitation (1951-80) ranges from about 48 in/yr in Tampa, Fla., and central Georgia to 64 in/yr south of Tallahassee, Fla.

Estimated annual evapotranspiration rates for most of the study area range from 31 to 39 in/yr and increase from north to south (Carter and Hopkins, 1986; Bush and Johnston, 1988). Some swampy areas in southeastern Georgia and coastal Florida have estimated evapotranspiration rates of 40 to 41 in/yr (Bush and Johnston, 1988).

Concentrations of major ions are relatively low in precipitation in the study area (less than 2 mg/L) (table 2) and the pH ranges from 4.51 to 4.81 (National Atmospheric Deposition Program, 1993). These values were measured at seven sites which are a part of the National Atmospheric Deposition Program or the National Trends Network for measurement of precipitation chemistry are within or adjacent to the study area (table 2). Sea salt is the most significant source of chloride in precipitation in coastal areas, with a sharp decrease in chloride concentrations in precipitation collected in inland areas. Much of the recharge to the Upper Floridan aquifer occurs inland.

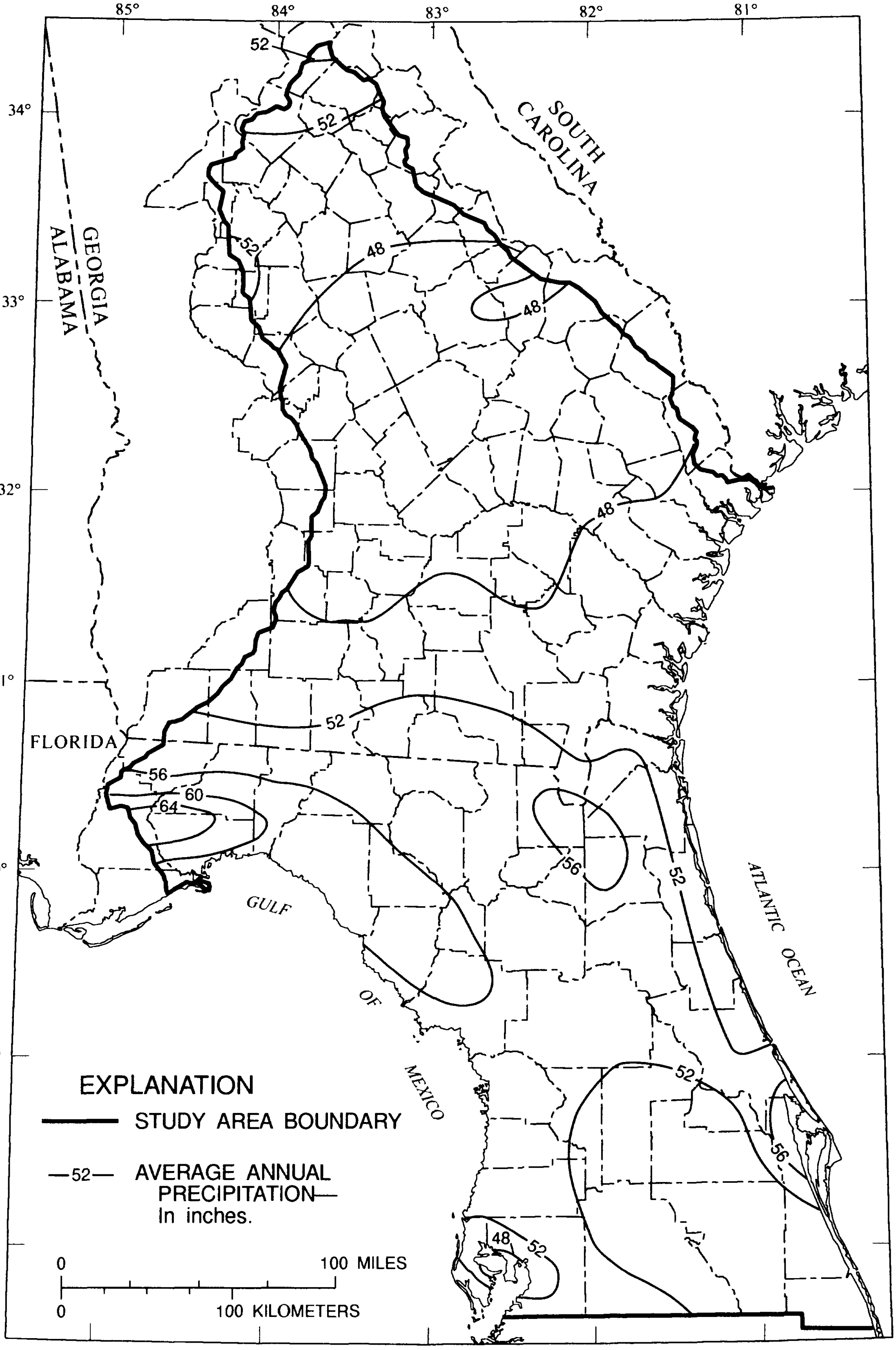

Figure 2. Average annual preciptation in the Georgia-Florida Coastal Plain, 1951-80 (from Bridges and Foose, 1986; Carter and Hopkins, 1986).

Table 2. Precipitation-weighted mean concentration of selected constituents in and near the Georgia-Florida Coastal Plain, 1992

[Data from National Atmospheric Deposition Program, 1993; Concentrations are in milligrams per liter; ranges are based on weekly samples]

Constituent	Range in concentration
Calcium	0.05 - 0.12
Magnesium	0.02 - 0.13
Sodium	0.10 - 1.09
Potassium	0.02 - 0.11
Chloride	0.18 - 1.93
Sulfate	0.75 - 1.52
Nitrate as nitrogen	0.12 - 0.20
Ammonia as nitrogen	0.02 - 0.04

Physiography

The study area is located in the Piedmont and Coastal Plain physiographic provinces (Fenneman, 1938) in the southeastern United States (fig. 3). The Fall Line separates the Piedmont and Coastal Plain provinces, and is the area where crystalline (igneous and metamorphic) rocks of the Piedmont contact the sedimentary rocks of the Coastal Plain province. Physiographic provinces in Georgia have been divided into districts by Clark and Zisa (1976) and in Florida by Brooks (1981) (fig. 3). District boundaries are not contiguous across the State boundary.

The Winder Slope and Washington Slope Districts are located in the Piedmont Province. Topography in the Winder Slope has gently rolling topography with altitudes ranging from 700 to 1,000 ft. River valleys are fairly deep and narrow and are about 100-200 ft below the narrow, rounded stream divides. A sharp break in the regional slope of land surface occurs on the southern boundary of the Winder Slope. Topography in the Washington Slope is also gently rolling, with altitudes ranging from 700 ft on the northern edge to 500 ft on the Fall Line. Most rivers in the Washington Slope have broad, shallow valleys with gentle side slopes and are separated by broad, rounded divides; however, the Ocmulgee River flows in a steep-walled valley 150-200 ft deep. The Fall Line is the southern boundary of the Washington Slope.

The part of the Coastal Plain Province in the study area in Georgia is divided into 7 districts: Fall Line Hills, Fort Valley Plateau, Vidalia Upland, Barrier Island Sequence, Bacon Terraces, Okefenokee Basin, and Tifton Upland (Clark and Zisa, 1976) (fig. 3). The Coastal Plain Province in Florida has been divided into 7 districts in the study area: Tifton Upland, Apalachicola Delta, Ocala Uplift, Sea Islands, Central Lake, Eastern Flatwoods, and Southwestern Flatwoods (fig. 3).

The Fall Line Hills is an area of contact between the older, crystalline rocks of the Piedmont and the younger sediments of the Coastal Plain. River characteristics change as they flow south through this district with rapids and shoals common near the Fall Line. Flood plains in the Coastal Plain Province become wider and meanders are more frequent than in the Piedmont. Altitudes generally range from about 500 ft along the Fall Line to about 250 ft on the southern boundary. The district is highly dissected with river valleys 50 to 250 ft below the adjacent ridge tops.

The Fort Valley Plateau is a small district within the Fall Line Hills that is less dissected than the Fall Line Hills and is characterized by flat-topped interfluvial areas. Altitudes range from 550 to 250 ft with a regional dip to the southeast (Clark and Zisa, 1976). Rivers flow in narrow, steep-walled valleys about 50-150 ft deep.

The Vidalia Upland is a moderately dissected area in gravelly, clayey sands (Clark and Zisa, 1976). Flood plains of the Ogeechee, Oconee, and Ocmulgee Rivers that are located in this district have a wide expanse

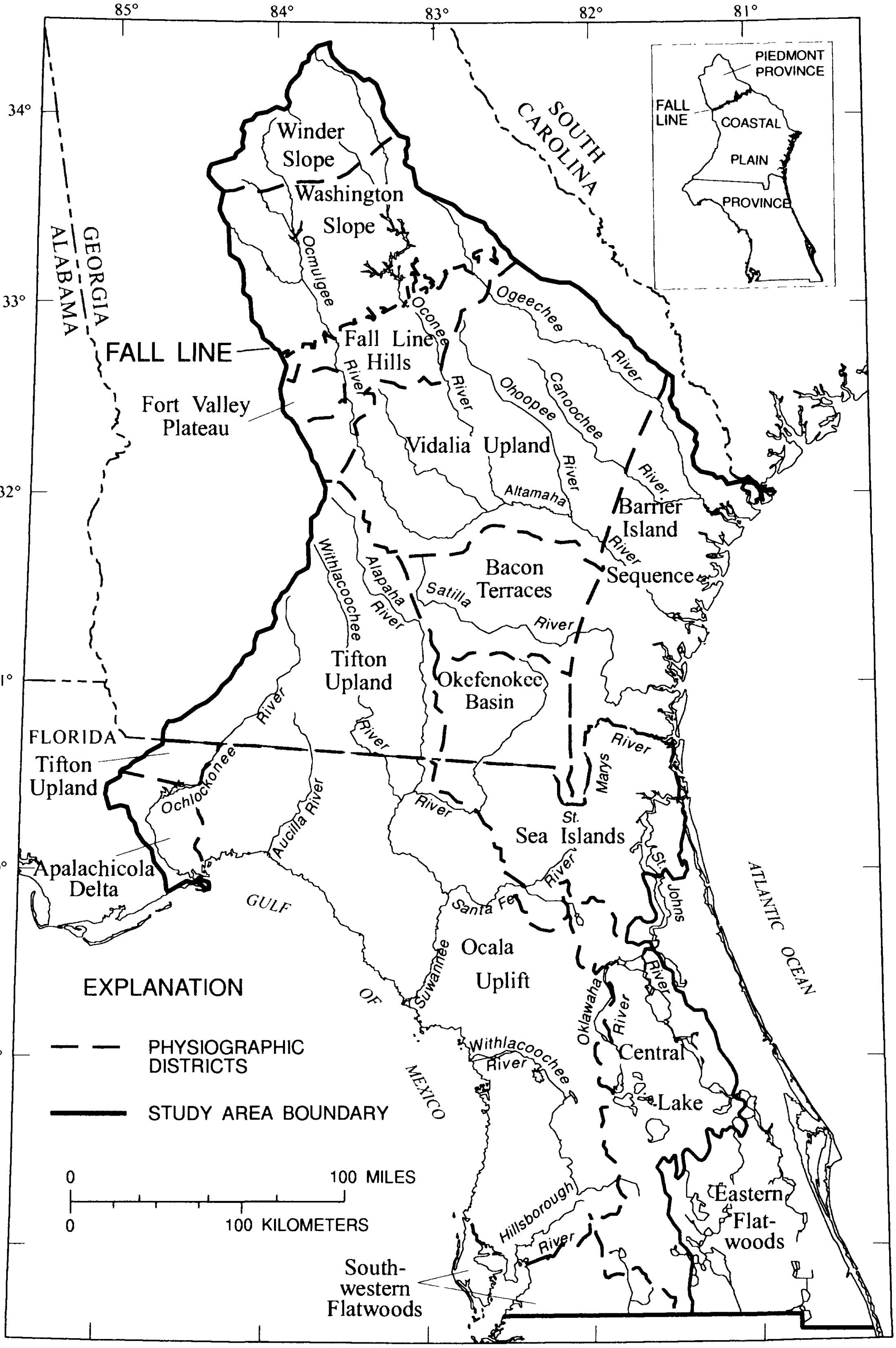

Figure 3. Physiographic provinces and districts in the Georgia-Florida Coastal Plain (from Brooks, 1981 and Clark and Zisa, 1976).

of swamp bordering both sides of the channel. Altitudes in this district range from 100 to 500 ft. The southeastern boundary is 50-70 ft above the adjacent Barrier Island Sequence.

The Barrier Island Sequence extends along the entire coast of Georgia inland for 40-50 miles (mi) from the barrier islands (Clark and Zisa, 1976). This district contains a step-like progression of terraces of decreasing altitude toward the sea formed by the advance and retreat of Pleistocene sea levels. Altitudes range from 160 ft on the western boundary of this district to sea level on the coastline. This district has been slightly to moderately dissected by rivers with marshes existing in poorly drained low areas.

The Bacon Terraces contains several terraces parallel to the Georgia coastline with eastern facing scarps. The altitudes of the terraces range from 160-330 ft (Clark and Zisa, 1976). The northern, western, and southern boundaries of the Bacon Terraces correspond to basin boundaries of the Satilla River that drains this district. The district is bounded on the east by a ridge that is a relict dune system trending north-south and also forms the eastern boundary of the Okefenokee Basin.

The Okefenokee Basin is an inland area of low relief with numerous swamps including the Okefenokee Swamp. The eastern part of this district is drained by the St. Marys River. The northern boundary of the Okefenokee Basin coincides with the Suwannee River basin boundaries. Altitudes in this district vary from 240 ft in the northwest to 75 ft in the southeast (Clark and Zisa, 1976).

The Tifton Upland in Georgia has a well developed, dendritic drainage pattern. Interfluvial areas are narrow and rounded, rising 50-200 feet above narrow stream valley floors. Altitudes in this district range from about 150-480 ft (Clark and Zisa, 1976). The Tifton Upland in Florida has thick residual silty and clayey soils with relief features sculptured by surface drainage (Brooks, 1981).

The Apalachicola Delta is a clastic terrain with no karst features. Clastic sediments are present from deposition in deltaic and flood-plain areas (Brooks, 1981). Altitudes range from sea level to about 200 ft. The Ochlockonee River is located in this district.

The Ocala Uplift is an area where broad uplift in middle and late Tertiary has produced an area with limestone at or near the surface in most places in an area of rolling plains with karst features (Brooks, 1981). Altitudes in this district range from about 170 ft to sea level.

The Sea Island in Florida is adjacent to the Barrier Island Sequence and Okefenokee Basin of Georgia. Surface features include upland terraces and separating ridges with sluggish to poorly organized surface drainage systems, an area of subdued beach ridges eastward of Trail Ridge, and an area of erosional and depositional features related to sea level changes. Altitudes in this district range from sea level to 150 ft.

The Central Lake is an area with altitudes slightly higher than other areas in Florida. In this district, sands overlie uplifted limestone and altitudes in this district range from about 60 to 300 ft (Brooks, 1981). The Central Lake is the most active area in Florida for the development of collapsed sinkholes. This district is also a principal recharge area for the Upper Floridan aquifer.

The Eastern Flatwoods originated as a sequence of barrier islands and lagoons (Brooks, 1981). Altitudes are generally less than 90 ft. This district includes much of the eastern coast of Florida within the study area and a large part of the St. Johns River Basin.

The Southwestern Flatwoods is a small province of Miocene and Pliocene sediments and rocks overlain by a thin layer of Quaternary deposits. Altitudes range from sea level to 170 ft. The Alafia River Basin is in this district.

Land Resource Provinces

Land resource areas in Florida (Caldwell and Johnson, 1982) and soil provinces in Georgia (Perkins and Shaffer, 1977), based on the generalized soils maps, have been combined and generalized and are referred to as land resource provinces. Land resource provinces provide a useful subdivision of the study area to examine the effects of generalized soils on observed water quality. The North Florida Flatwoods, Central and South Flatwoods (Caldwell and Johnson, 1982), and Atlantic Coast Flatwoods (Perkins and Shaffer, 1977) have been combined into one unit and referred to as "Coastal Flatwoods." The Black Lands, an area of about 136 mi^2 located in parts of Houston, Macon, and Twiggs Counties, Ga., has been incorporated into the Southern Coastal Plain. Land resource provinces in the study area include: the Coastal Flatwoods, the Central Florida Ridge, the Southern Coastal Plain, the Sand Hills, and the Southern Piedmont (fig. 4).

The Coastal Flatwoods includes the coastlines of Georgia and Florida within the study area and extends inland about 5 to 100 miles (fig. 4). This area consists of nearly level plains, marshes, and barrier islands, along with a set of low terraces. The altitude ranges from sea level to about 300 ft. Rivers in this area have high dissolved organic matter (black water), low gradients, wide flood plains, and frequently originate in or flow through wetlands. The dominant soil types in the Coastal Flatwoods are spodosols and ultisols. Spodosols in the study area are wet soils that occur mostly in the nearly level parts of the lower Coastal Plain Province (Soil Conservation Service, 1975). These soils developed in sandy and clayey marine sediments under forested conditions. Most of the vegetation remains forest, although areas in south-central Florida are in citrus cultivation. Some spodosols in Florida are seasonally saturated (Brady, 1984). Ultisols in the study area are also wet soils and occur on the nearly level parts of the middle and lower Coastal Plain Physiographic Province (Soil Conservation Service, 1975). These soils developed under warm humid climates with forest vegetation (Brady, 1984). The soils are frequently poorly drained and swamp conditions are present in many parts of the Coastal Flatwoods.

The Central Florida Ridge comprises much of the central uplands of Florida (fig. 4). This area is characterized by hills, ridges, terraces, and many lakes, and is marked by karst topography--numerous sinks, sinkhole lakes, sinking streams, and springs (Caldwell and Johnson, 1982). In spite of abundant precipitation, some parts of the area have very few streams, with most of the precipitation recharging ground water. Altitudes range from 40 to 250 ft. The dominant soil types in the Central Florida Ridge are entisols and spodosols (Soil Conservation Service, 1975). Entisols in the study area consist of mostly quartz sand that are mostly acidic and may be phosphatic. Few of these soils are cultivated for crops except in Florida. These soils are characterized by low water-holding capacity and high permeability (Soil Conservation Service, 1975).

The Southern Coastal Plain occurs in Georgia and the panhandle of Florida, ranges from approximately 50 to 100 miles wide (fig. 4). This area consists of broad interstream areas with gentle and deeply incised valleys. The altitude ranges from 200 to 500 ft (Perkins and Shaffer, 1977 and Caldwell and Johnson, 1982). The dominant soils in the Southern Coastal Plain are ultisols (Soil Conservation Service, 1975). These soils cover an extensive area in eastern and southeastern parts of the U.S. on the gentle and moderately slopes of the middle and upper Coastal Plain Province. These soils developed in unconsolidated sand, silt and clay. Large parts of these soils in the study area are in forest, with lumber and some pulpwood production (Soil Conservation Service, 1975).

The Sand Hills is a narrow band located between the Southern Coastal Plain and the Southern Piedmont (fig. 4). The area consists of marine sand and clay, and gentle to steep slopes. Altitudes range from about 350 to 500 ft (Perkins and Shaffer, 1977). The dominant soil type is entisols (Soil Conservation Service, 1975).

The Southern Piedmont is an area characterized by mountain ridges with steep slopes, some foothills, and narrow valleys. The area is underlain by crystalline, metamorphic rocks. Altitudes in this area range from about 700 to about 1200 ft in the study area (Perkins and Shaffer, 1977). The dominant soils are ultisols (Soil Conservation Service, 1975).

Ecoregions

Ecoregions have been defined by Omernik (1987a) to identify areas of relatively homogeneous ecological systems based on land use, topography, potential natural vegetation, and soils. Four ecoregions are present in the Georgia-Florida Coastal Plain study area; Southeastern Plains, Middle Atlantic Coastal Plain, Southern Coastal Plain, and Southern Florida Coastal Plain (fig. 5). Ecoregions differ from land resource provinces because land resource provinces are based primarily on general soil characteristics and ecoregions are based mostly on natural vegetation.

The Southeastern Plains occur mostly in the Georgia part of the study area and consists of smooth to irregular plains, and oak/hickory/pine forests and southern mixed forests (beech, sweetgum, magnolia, pine, and oak) (Omernik, 1987b). The land use is a mixture of cropland, pasture, woodland, forest, and urban areas. The dominant soil type is ultisols (Omernik, 1987b; Soil Conservation Service, 1975).

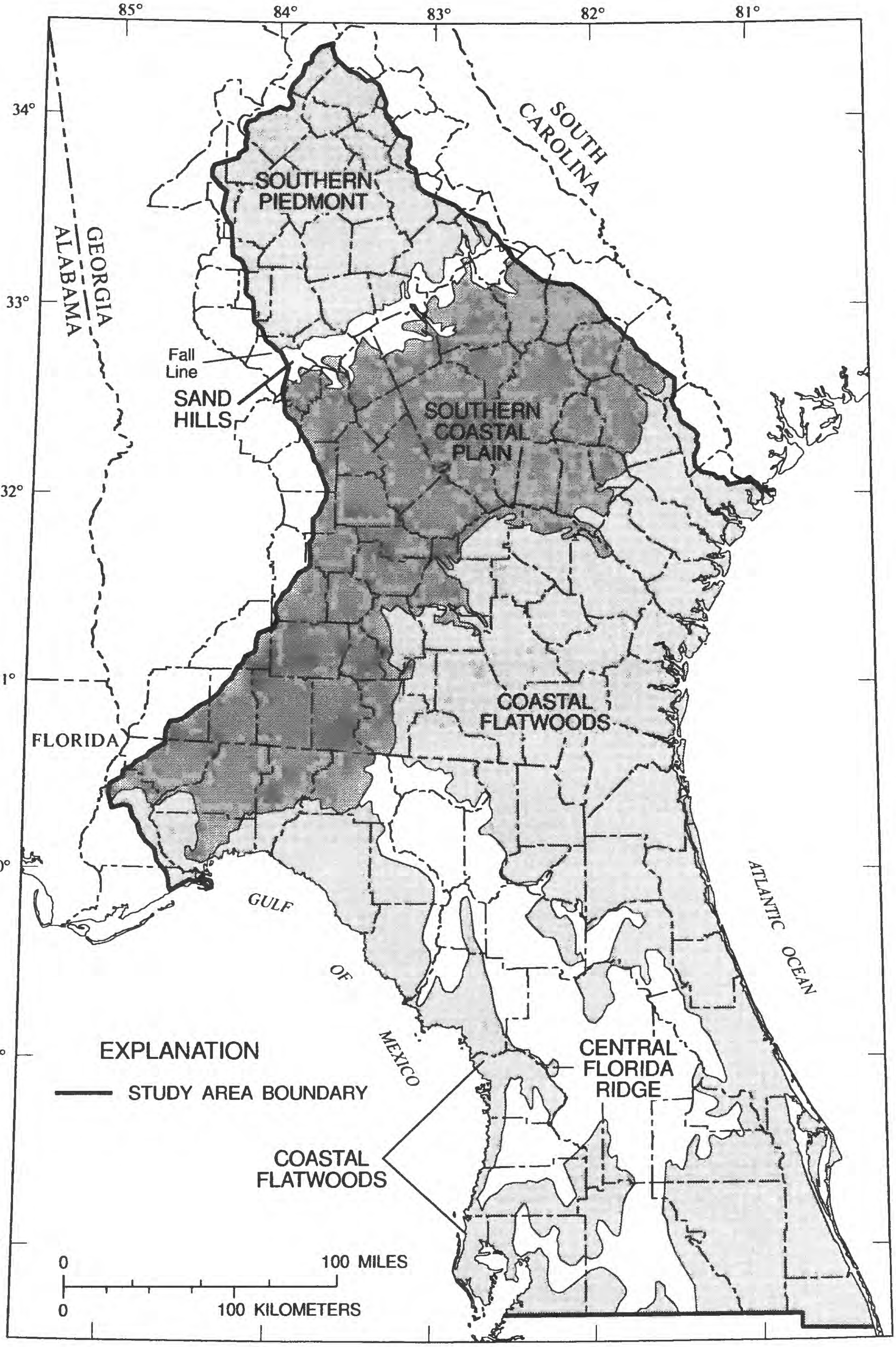

Figure 4. Land resource provinces in the Georgia-Florida Coastal Plain (from Perkins and Shaffer, 1977 and Caldwell and Johnson, 1982).

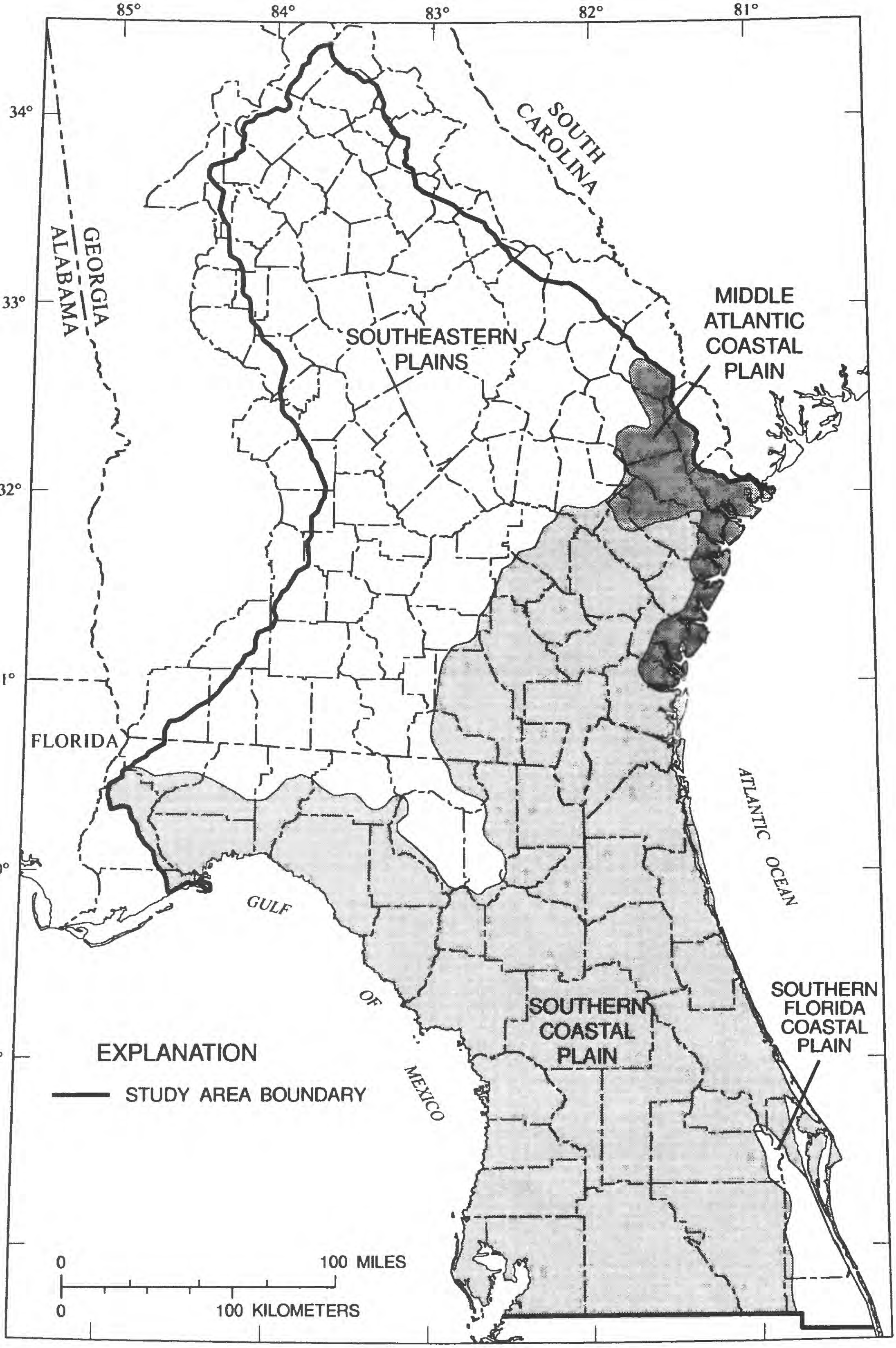

Figure 5. Ecoregions in the Georgia-Florida Coastal Plain (from Omernik, 1987a).

The Southern Coastal Plain occurs mostly in the Florida part of the study area but includes the Okefenokee Swamp area in southeastern Georgia (fig. 5). This ecoregion consists of mostly flat plains with standing water covering 10 to 50 percent, and southern mixed forest and southern floodplain forest (oak, tupelo, bald cypress) (Omernik, 1987b). The land use is forest and grazed woodland, woodland and forest with some cropland and pasture, and swamp. The dominant soil types are entisols and spodosols (Soil Conservation Service, 1975).

The Middle Atlantic Coastal Plain covers a small area within the study area in southeastern and coastal Georgia (fig. 5), and consists of flat plains and a variety of forest types. The land use includes woodland and forest with some cropland and pasture, and swamp (Omernik, 1987b). The dominant soil type is ultisols (Soil Conservation Service, 1975).

The Southern Florida Coastal Plain occurs in the southeastern part of the study area (fig. 5) and consists of flat plains with more than 50 percent covered by standing water. The land use is mostly marshland and swamp and the vegetation is palmetto prairie (saw palmetto and three-awn) and everglades (sawgrass, magnolia, and persea) (Omernik, 1987b). The dominant soil type within the study area in spodosols (Soil Conservation Service, 1975).

Geologic Setting

Much of the Georgia-Florida Coastal Plain is underlain by a thick sequence of unconsolidated to semiconsolidated sedimentary rocks that range in age from Cretaceous to Recent (fig. 6). These sediments thicken seaward from a thin edge where they crop out against older metamorphic and igneous rocks of the Piedmont province to as thick as 25,000 ft in southern Florida. Coastal plain rocks generally dip toward the Atlantic Ocean or Gulf of Mexico, except where they are structurally altered on a local to subregional scale.

The Piedmont province is underlain by many crystalline (metamorphic and igneous) rocks including granite, gneiss, quartzite, and schist (Lawton, 1977). The rocks range in age from Lower Paleozoic to Precambrian and consist of metamorphic rocks that have been intensely deformed and intruded by small to large bodies of igneous rocks (table 3) (Miller, 1990).

The Coastal Plain sedimentary rocks are separated into two general facies: (1) predominantly clastic rocks containing small amounts of limestone that extend southward and eastward toward the Atlantic Ocean and the Gulf of Mexico from the Fall Line that marks the inward limit of the Coastal Plain; and (2) a thick, continuous sequence of shallow-water platform carbonates that underlie southeastern Georgia and all of the Florida peninsula. The clastic and carbonate rocks interfinger with one another and facies changes are complex in north-central Florida and southeastern Georgia. Generally, the limestone facies of successively younger rocks encroached upon the clastic rocks to the northwest until the end of Oligocene time. Miocene and younger rocks comprise another clastic facies that, except where they have been removed by erosion, cover the older carbonate rocks (table 3). The poorly consolidated carbonate sediments of the Coastal Plain are easily eroded and dissolved by downward-percolating water. Karst topography has developed where these carbonate sediments are at or near land surface. A series of sandy, marine terraces were deposited during the Pleistocene age. The topography in much of the Coastal Plain is characterized by: (1) extensive, slightly dissected plains; (2) low, rolling hills; and (3) widely spaced drainage. (The above discussion is modified from Miller, 1986.) Names and ages of geologic formations in the study area and adjacent Alabama and South Carolina are shown in table 3.

Ground-Water Systems

The Floridan aquifer system is the principal ground-water source used in the study area (fig. 7). Some of the coastal areas in eastern Florida rely on the surficial aquifer system, and the intermediate aquifer system, both situated above the Floridan aquifer system, for water supply. Throughout the study area in Georgia and Florida, the

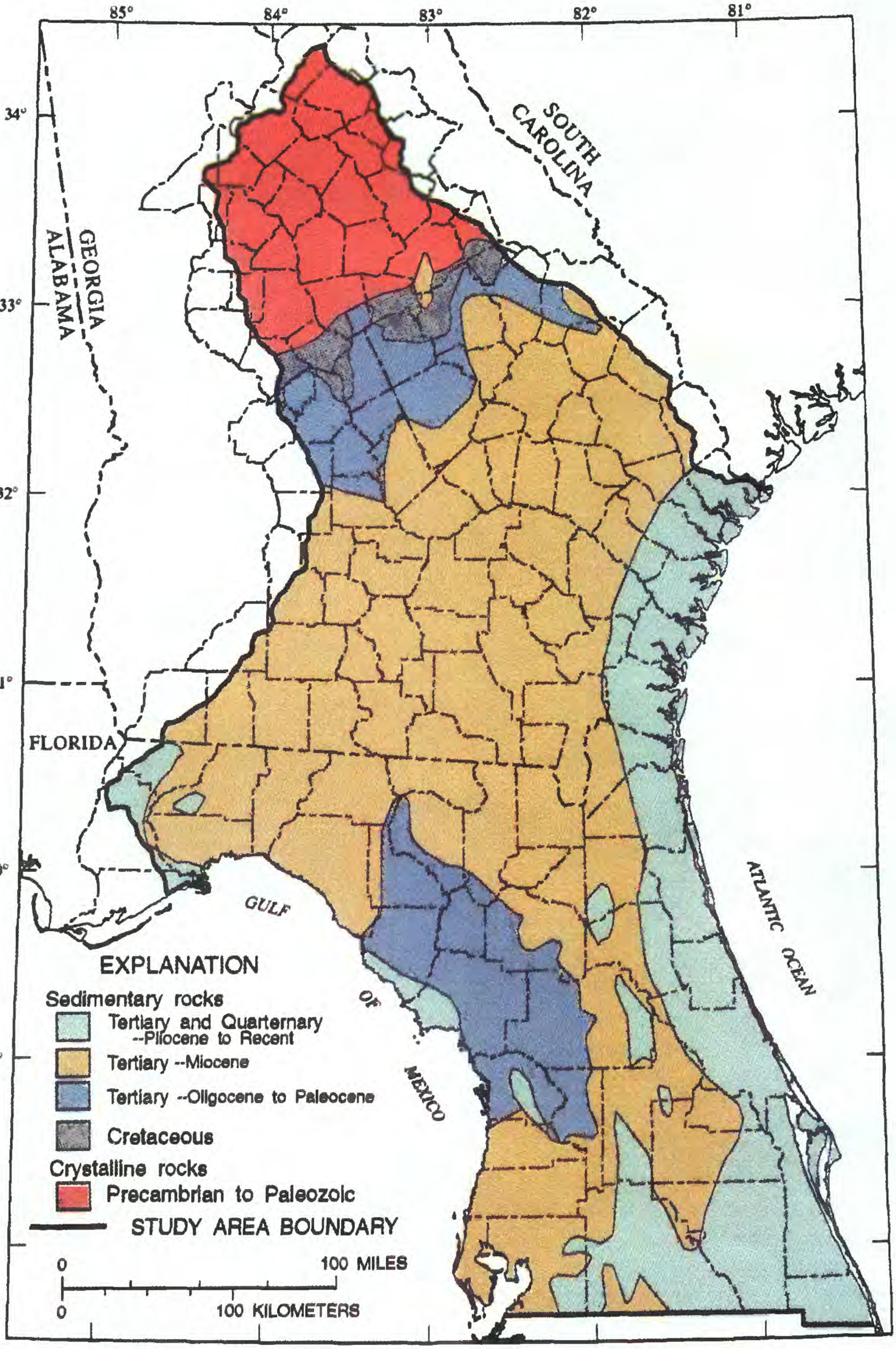

Figure 6. Generalized geologic map of the Georgia-Florida Plain (from Miller, 1986).

Table 3. Geologic units and aquifers in Florida and Georgia

[Modified from Miller, 1990, McFadden and Perriello, 1983]

			GEOLOGIC UNITS		AQUIFER	
ERA	SYSTEM	SERIES	FLORIDA Formations	GEORGIA Formations	FLORIDA	GEORGIA
CENOZOIC	QUATERNARY	RECENT TO PLEISTOCENE	Undifferentiated deposits	Undifferentiated deposits	Surficial aquifer system	Unnamed surficial aquifers
	TERTIARY	PLIOCENE				
		MIOCENE	Alum Bluff Group		Intermediate aquifer system	
			Hawthorn	Hawthorn		Brunswick
			Tampa Limestone			
		OLIGOCENE	Suwannee Limestone		Floridan aquifer system	Floridan aquifer system
		EOCENE	Ocala Limestone	Ocala Limestone		
				Clinchfield Sand		
			Avon Park	Lisbon		Claiborne
			Lake City	Tallahatta		
			Oldsmar	Hatchetigbee		
		PALEOCENE		Tuscahoma		
			Cedar Keys	Nanafalia		
				Cedar Keys		
MESOZOIC	CRETACEOUS	GULFIAN	Lawson Limestone	Providence Sand		Cretaceous aquifer system
				Ripley		
				Cusseta Sand		
				Blufftown		
				Eutaw		
PALEOZOIC TO PRE-CAMBRIAN				Many different units of granite, gneiss, quartzite, and schist		Crystalline rock

surficial aquifer system and unnamed surficial aquifers also supply water for domestic use. The intermediate aquifer system and Upper Brunswick aquifer consist of similar Miocene age deposits and are used for supplies in some limited areas in the study area. Other aquifers used in small quantities in the study area where the Floridan aquifer system is not present are the Claiborne aquifer, Cretaceous aquifer system, and crystalline rock aquifers. The Claiborne aquifer is used for some water supply in the western part of the study area in south Georgia and the other aquifers are used for limited supplies in north-central Georgia (fig. 7).

Surficial Aquifer System

The surficial aquifer system is present over much of the study area and are important sources of water supply when depths to the underlying Floridan aquifer system make drilling costs prohibitive, or when the Floridan aquifer system contains nonpotable water. Areas dependent on the surficial aquifer system for limited municipal or commercial uses include the coastal counties of St. Johns, Flagler, Brevard, and Indian River, Fla. (fig. 7). The surficial aquifer system is an important source of water for domestic use throughout the study area.

The surficial aquifer system generally consists of sand, silt, clay, and shell units, with some minor limestone beds. Units that make up the surficial aquifer range from late Miocene to Holocene age (table 3) (Miller, 1990). The thickness of the surficial aquifer system is generally less than 50 ft, but its thickness in eastern, coastal areas

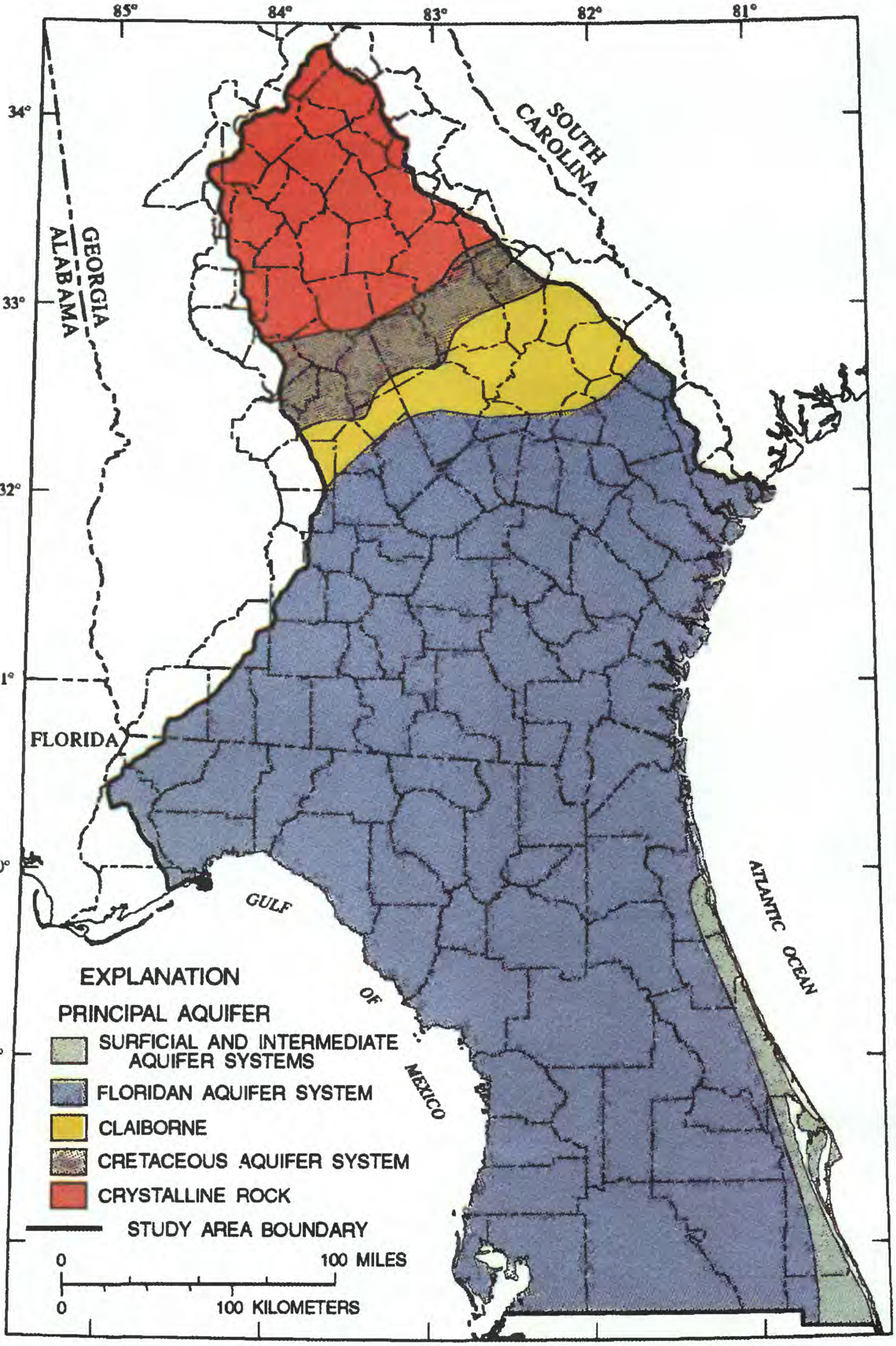

Figure 7. Principal aquifers in the Georgia-Florida Coastal Plain (from Clarke and Pierce, 1985 and Vecchioli and Foose, 1985).

of the study area can be much greater. Thicknesses of 100 to 200 ft are common in Indian River County in the southeastern part of the study area (Schiner and others, 1988). Thicknesses of 60 feet are recorded for areas of southeastern Georgia.

Water in the surficial aquifer system is usually unconfined, although semiconfined conditions may exist locally where thin clay beds are present. Generally, the surficial aquifer system includes zones of confined conditions where the thickness of the aquifers are greatest (Clarke and others, 1990). Water enters the system as precipitation and a large part is lost to the atmosphere by evapotranspiration due to the proximity of the water table to the land surface. The remaining water that does not run off recharges the aquifer. Some of this water moves laterally through the system to nearby surface-water bodies or the ocean. Locally, where heads in the surficial aquifer are higher than they are in the underlying Floridan aquifer system, surficial aquifer water recharges the underlying aquifer. Alternatively, in discharge areas of the Floridan aquifer system near the coast where its heads are higher than those in the surficial aquifer, water from the Floridan aquifer system moves upward into the surficial aquifer.

The water-table of the surficial aquifer system is generally a subdued reflection of the land surface topography, with steep gradients between ridges and streams and gentle gradients in broad interstream areas. In coastal areas, water moves toward the coast or to the nearest adjacent surface-water body. However, locally, the water-table surface can be very complex with the direction of ground-water flow changing markedly within a short distance.

Transmissivities of the surficial aquifer system are extremely variable. Reported values range from 1,000 to 10,000 feet squared per day (ft^2/d). Well yields range from 2 to 180 gallons per minute (gal/min) in Georgia (O'Connell and Davis, 1991), 450 gal/min in St. Johns County, Fla., and 1,200 gal/min in Indian River County, Fla. (Schiner and others, 1988).

Intermediate Aquifer System

The intermediate aquifer system is the name given to the Miocene age deposits between the surficial and Upper Floridan aquifers in the Florida part of the study area (Southeastern Geological Society, 1986). The Upper Brunswick aquifer is the name given to these same deposits in Georgia. The surficial aquifer system and the intermediate aquifer system act as the confining unit for the underlying Floridan aquifer system. However, where more permeable layers persist in Miocene deposits they are utilized as a water supply. These deposits consist of shell, limestone, and sand with discontinuous layers of clay. In Georgia, the Miocene age deposits overlying the Floridan aquifer system are referred to as the upper and lower Brunswick aquifers (O'Connell and Davis, 1991). This aquifer is of some importance in coastal Georgia and consists of poorly sorted, slightly phosphatic and dolomitic quartz sand that ranges in thickness from 10 to 150 ft (Clarke and others, 1990).

In areas where the intermediate aquifer system is thin or absent, including a large area in the study area in north-central Florida and part of south Georgia, the Floridan aquifer system is unconfined to semiconfined. Generally, in areas where the intermediate aquifer system is greater than 100 feet thick it is used as a supplemental source of water. The intermediate aquifer system is of greatest importance south of the study area where it is a significant source of public water supply.

Transmissivities of the intermediate aquifer are variable because of the range in type of deposits. Reported values range from 200 to 13,000 ft^2/d (Ryder, 1985). Well yields for most wells in the intermediate aquifer system are 200 gal/min or less, although well yields as high as 1,800 gal/min have been reported for some wells (Miller, 1990).

Floridan Aquifer System

The Floridan aquifer system is defined by Miller (1986) as "a vertically continuous sequence of carbonate rocks of generally high permeability that are mostly of middle and late Tertiary age and hydraulically connected in varying degrees and whose permeability is, in general, an order to several orders of magnitude greater than that of those rocks that bound the system above and below". Thickness of the Floridan aquifer system ranges from less than 200 ft in the northern part of the study area to more than more than 3,000 ft in the southern part of the study area. A confining unit is present in the middle of the Floridan aquifer system over most of the study area, hydraulically separating the system into the Upper and Lower Floridan aquifers. In places, no middle confining unit exists and the aquifer system is highly permeable throughout its vertical extent and is known as the Upper Floridan aquifer. In most places, water in the Lower Floridan aquifer is brackish to saline and is not used as a water supply. Little is known about the Lower Floridan aquifer because there has been no reason to drill into it, when an adequate shallower source of better quality water exists. Because the Upper Floridan aquifer is the part of the aquifer system used for water supply, hereafter in this report, discussion will be primarily concerned with the Upper Floridan aquifer.

The degree of confinement of the Upper Floridan aquifer is the major hydrogeologic control on the distribution of recharge, discharge, and ground-water flow. Areas of unconfined, semiconfined, and confined conditions for the Upper Floridan aquifer are shown in figure 8.

Transmissivities in Upper Floridan aquifer are variable because of variations in confinement, lithology, aquifer thickness and paleokarst.The highest transmissivity values occur in the karstic areas of central and northern Florida where the Upper Floridan is generally unconfined or semiconfined. Transmissivities in excess of 1,000,000 ft^2/d occur in this area and the upper part of the aquifer contains numerous caves, sinkholes, pipes, and other types of solution openings (Bush and Johnston, 1988). Where the Upper Floridan aquifer is confined, the transmissivity is generally less than 250,000 ft^2/d. The lowest transmissivities in the Upper Floridan aquifer of less than 50,000 ft^2/d are in the updip areas of Georgia (Bush and Johnston, 1988). Well yields for the Upper Floridan aquifer are generally greater than 250 gal/min and less than 2,000 gal/min (Pascale, 1975). Potentiometric surface maps for the Upper Floridan aquifer indicate that water generally flows from topographic high areas and inland areas toward the Gulf of Mexico and the Atlantic Coast (fig. 9).

Springs are a prominent hydrologic feature of the Upper Floridan aquifer flow system. Central Florida contains over 20 first-magnitude springs (flows greater than 100 cubic feet per second (ft^3/s)). Most of these springs are located within the study area and are concentrated along major rivers and along the coast of west-central Florida. The springs are also located in or near areas of high recharge (greater than 10 in/yr) (fig. 10) where the Upper Floridan aquifer is unconfined to semiconfined, indicating a vigorous and well-developed shallow flow system in this area (Bush and Johnston, 1988).

Claiborne Aquifer

The Claiborne aquifer consists of middle Eocene age calcareous and glauconitic clayey sand, limestone, and sandy limestone that underlies the Floridan aquifer system on the western edge of the study area in Georgia. The sediments that comprise the Claiborne aquifer generally thicken to the south and southwest. Thicknesses in the study area are about 100 to 200 ft (McFadden and Perriello, 1983). Within the study area, water in this aquifer is generally confined. Transmissivities within the study area range from 2000 to 5,000 ft^2/d and well yields of properly constructed wells can be 200 to 2,000 gal/min. (McFadden and Perriello, 1983).

Cretaceous Aquifer System

The Cretaceous aquifer system consists of sand and gravel that contain discontinuous clay layers that function as confining layers (Clarke and Pierce, 1985). In southwestern Georgia this aquifer system contains the Providence aquifer. In east-central Georgia, interlayered sand and clay of Pleistocene and late Cretaceous age have been named the Dublin and Midville aquifer system (Clarke and others, 1985). Thickness of this aquifer system ranges from 80 to 645 ft and contains discontinous clay layers that result in local zones of confinement. Transmissivities range from 800 to 39,000 ft^2/d and well yields are up to 3,400 gal/min.

Crystalline Rock Aquifers

The crystalline rock aquifers are generally used only for rural supply, because individual aquifers are not laterally extensive (Clarke and Pierce, 1985). The rocks that comprise these aquifers include granite, gneiss, schist, and quartzite. In these aquifers, ground water is generally unconfined and occurs in the regolith and in joints, fractures, and other secondary openings. Water levels show rapid response to precipitation (Clarke and Pierce, 1985). Typical well yields in these aquifers are about 15 to 20 gal/min (Miller, 1990).

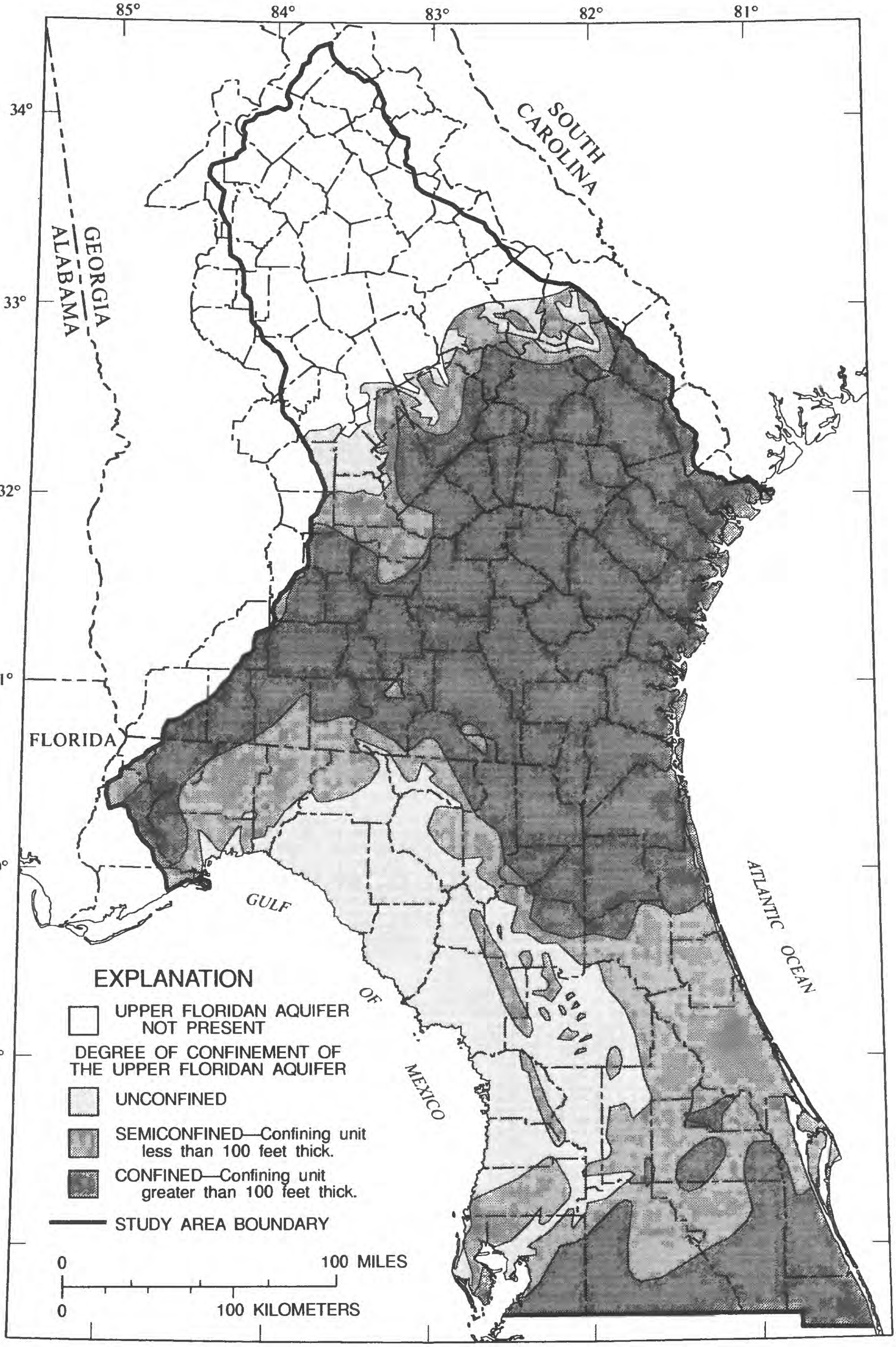

Figure 8. Areas of confined, semiconfined, and unconfined conditions for the Upper Floridan aquifer in the Georgia-Florida Coastal Plain (from Miller, 1986).

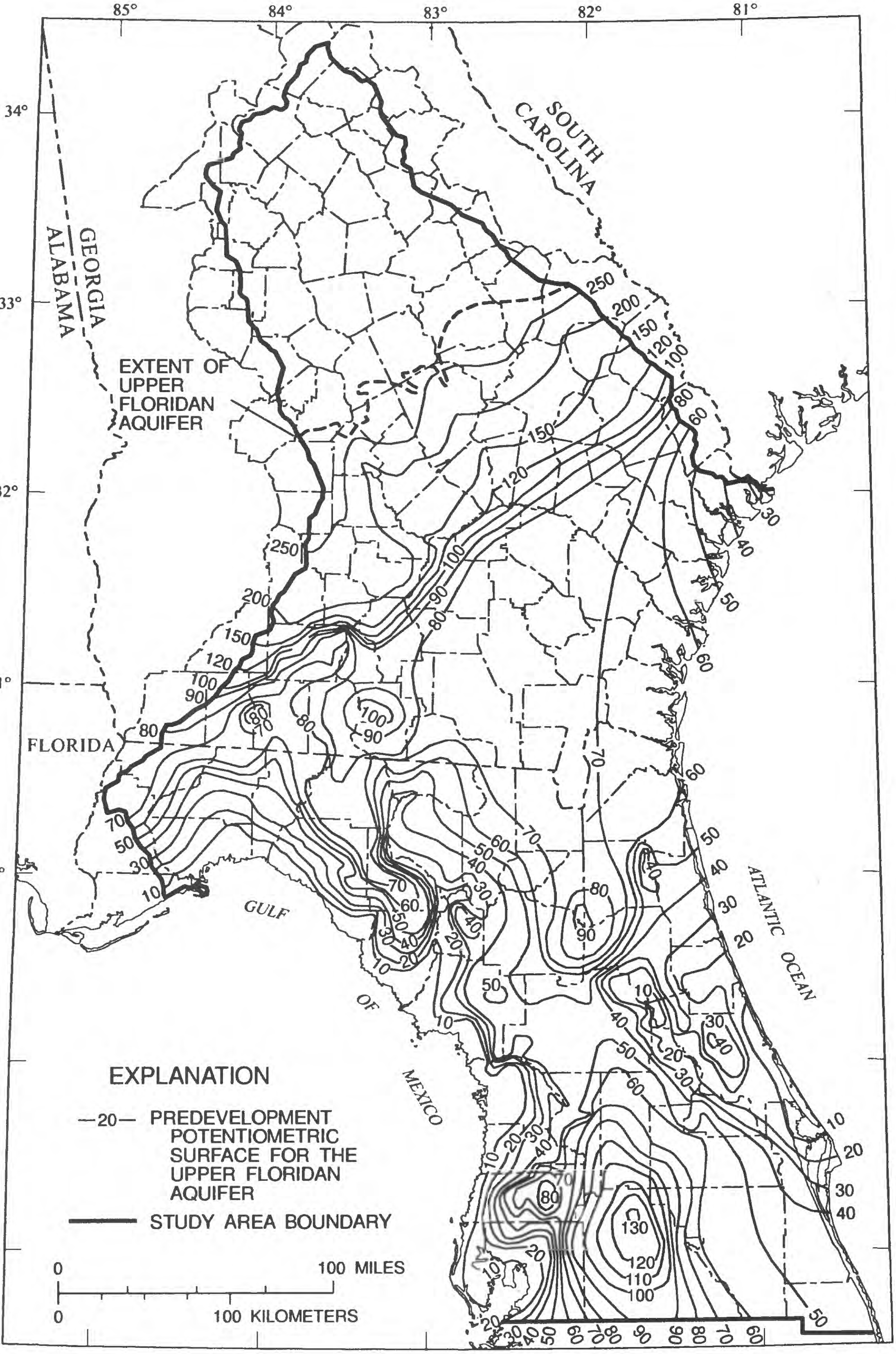

Figure 9. Predevelopment potentiometric surface map for the Upper Floridan aquifer in the Georgia-Florida Coastal Plain (modified from Bush and Johnston, 1988).

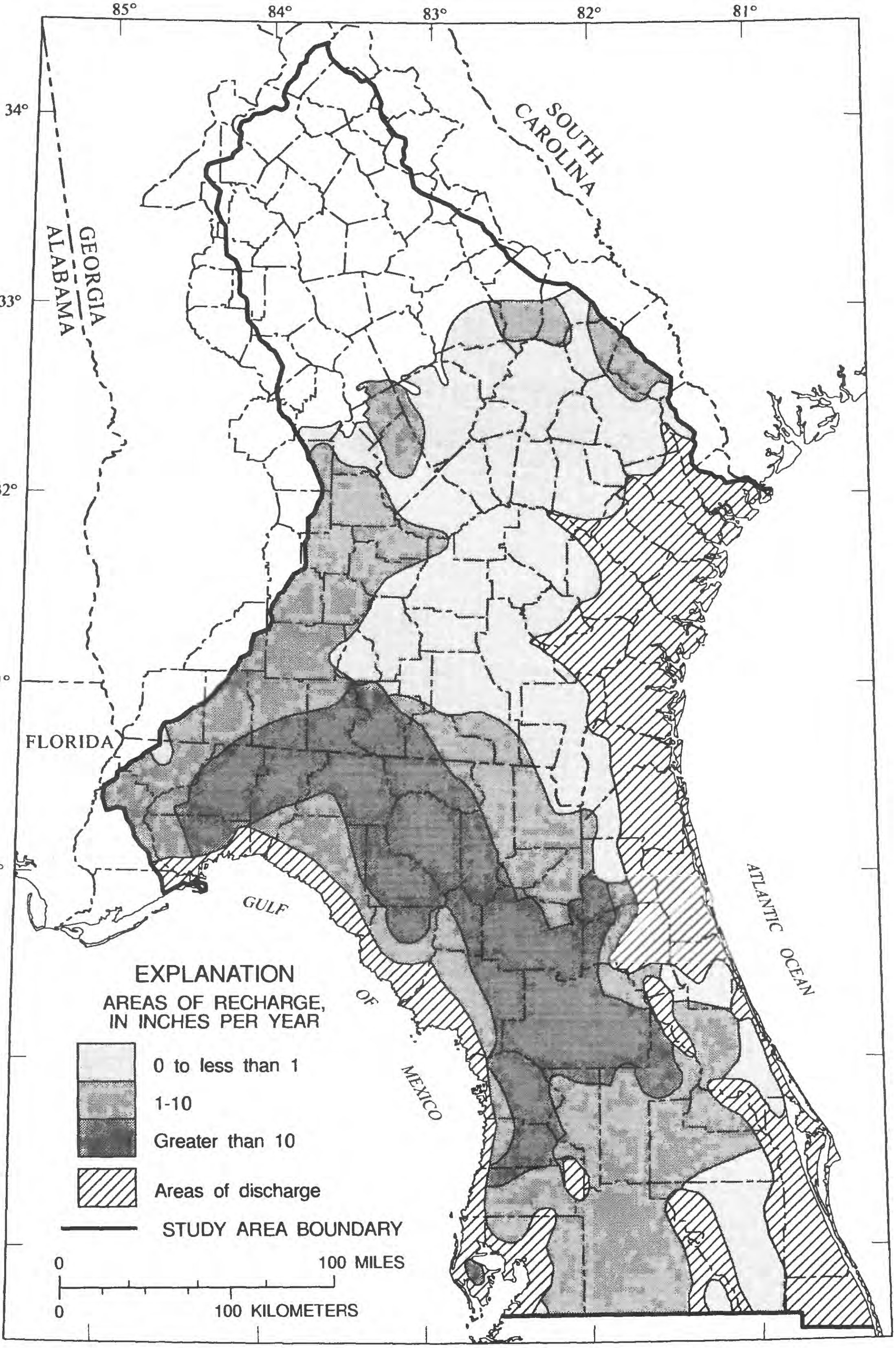

Figure 10. Locations of recharge and discharge areas for the Upper Floridan aquifer (modified from Bush and Johnston, 1988).

Surface-Water Systems

The study area is located in the South Atlantic-Gulf Water Resource Region and includes all of the Altamaha-St.Marys, Ochlockonee, and Suwannee subregions; all but a small part of the St. Johns Subregion; and parts of the Ogeechee-Savannah, Peace-Tampa Bay, and Southern Florida subregions (fig. 11). Major rivers in the study area discharging to the Atlantic Ocean include the Altamaha, St. Marys, Ogeechee, and St. Johns Rivers (fig. 11). The parts of the Ogeechee-Savannah Subregion in the study area only include the Ogeechee River and its major tributary, the Canoochee River. Major rivers in the Peace-Tampa Bay Subregion in the study area include the Hillsborough River and the Withlacoochee River (southernmost of the two Withlacoochee Rivers in the study area). A small part of the Southern Florida Subregion is also included within the study area, but is not studied in this project and is only included in this report for discussion of water use. Major rivers that discharge to the Gulf of Mexico include the Suwannee, Ochlockonee, Aucilla, Hillsborough, and Withlacoochee (south) Rivers (fig. 11). The drainage basins of major rivers in each subregion are described in table 4.

Rivers in the study area can generally be described as alluvial, blackwater, or spring-fed; although some rivers, such as the Aucilla, St. Johns, and Santa Fe Rivers, cannot be classified as a single type. Alluvial rivers in the study area typically originate in upland areas such as the Piedmont Province and carry sediment and inorganic nutrients to coastal sounds or bays and usually have relatively neutral pH (about 6.7). Detritus washed from the floodplain and shed from vegetation on the river system is the primary source of nutrients for organisms in alluvial rivers. Nutrients may largely reside in the suspended organic matter and clay particles of sediment load of alluvial rivers (Clewell, 1991). The flood plains of alluvial rivers are usually broad and support large tracts of bottomland hardwoods such as overcup oak, laurel oak, red maple, and water hickory. Gum-cypress communities are found on alluvial flood plains along sloughs, ox-bows, or in depressional areas (Clewell, 1991).

Low-gradient rivers which drain coastal plains and typically contain water that is dark-colored are referred to as blackwater rivers. Blackwater rivers have acidic water with a comparatively high content of organic nutrients and may be low in minerals such as calcium that are important components of mollusks and certain other organisms. Fallen leaves and other detrital remains accumulate in blackwater river basins causing formation of peat above mineral soil (Clewell, 1991). The high amount of organic matter in blackwater rivers strongly affects water chemistry. Blackwater rivers are lower in pH (4.6) than alluvial rivers (Wharton, 1978). Some disagreement exists concerning the relative productivity of habitats of blackwater rivers. Freeman and Freeman (1985) report productivity values for an Okefenokee Swamp marsh that exceeded those reported for some other blackwater river and river habitats. Blackwater rivers often have narrow flood plains bordered by swampy gum-cypress forests.

Spring-fed rivers are most common in karst areas in north-central Florida and south-central Georgia. Interactions between surface water and ground water are also common in this area. These rivers usually have relatively neutral pH and may have a relatively high concentration of dissolved solids from dissolution of carbonates (Clewell, 1991). After storms, surface runoff in large drainage basins may increase the color and turbidity of surface water and cause temporary changes in temperature or concentrations of ions (Clewell, 1991). Because spring-fed rivers have a more constant base flow and carry little sediment, their flood plains lack the topographic features of alluvial rivers and are usually narrow, flat, and dominated by cypress, ash, tupelo, and other species which can tolerant long periods of inundation.

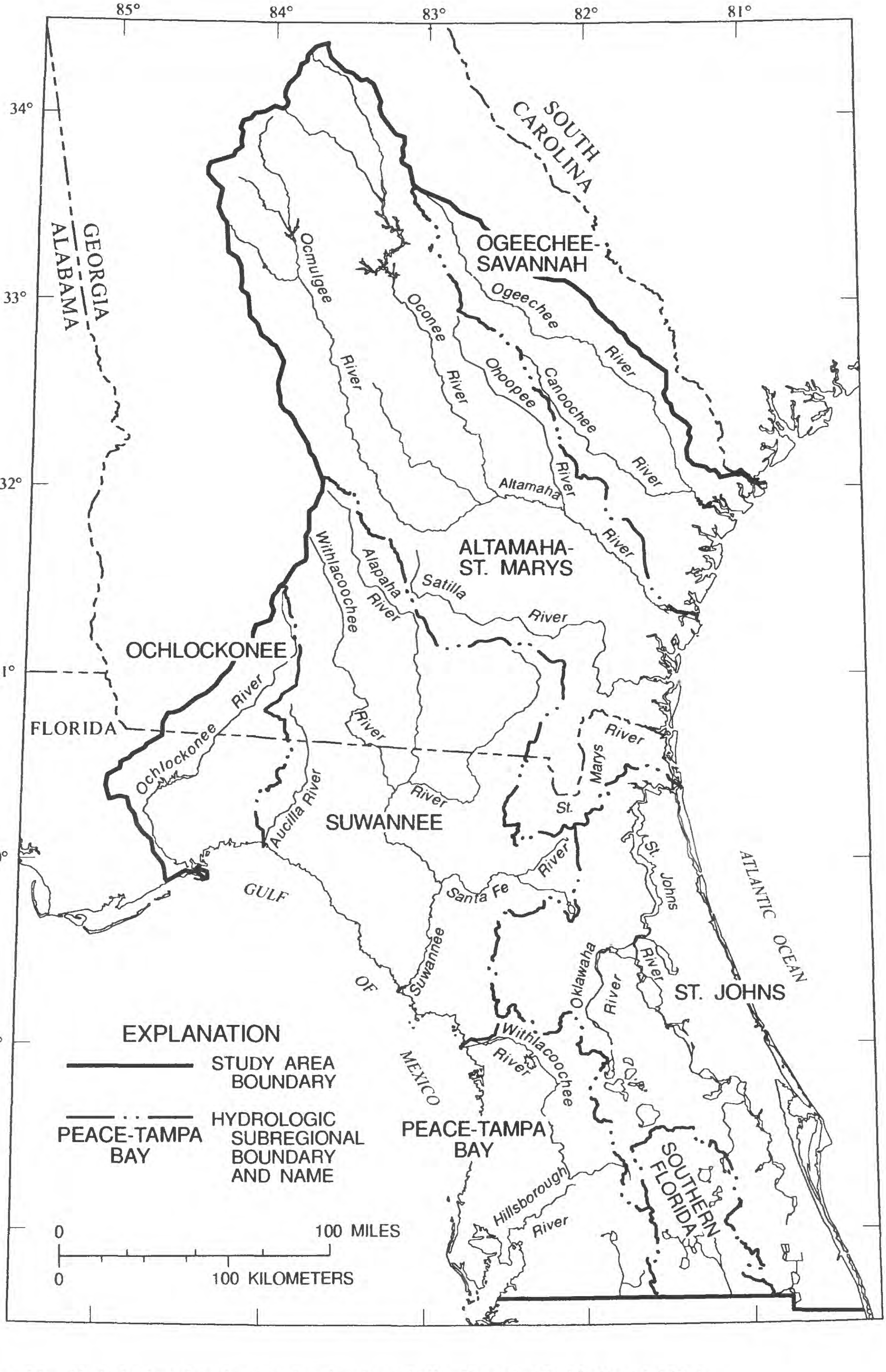

Figure 11. Hydrologic subregions and major rivers in the Georgia-Florida Coastal Plain.

Table 4. Description of major drainage basins and gaging stations in the Georgia-Florida Coastal Plain

[Data from Seaber and others, 1984; Bridges and Foose, 1986; Carter and Hopkins, 1986; Meadows and others, 1991; Stokes and others, 1991; and U.S. Geological Survey, 1991a,b; Refer to figure 12 for site numbers]

Site no.	Gaging station name and USGS site number	Major land uses	Drainage area of river at gage in square miles	Drainage area of river in square miles at mouth	Period of record	Average discharge in cubic feet per second
	Ogeechee-Savannah Subregion (16,300 square miles) (5,830 in study area), Population 334,900					
1	Ogeechee River near Eden, Ga. 02202500	Grazed forest and woodland; cropland with pasture; woodland	2,650	4,410	1938-90	2,280
2	Canoochee River near Claxton, Ga. 02203000	Cropland with pasture; woodland and forest; wetland	555	1,420	1938-90	460
	Altamaha-St. Marys Subregion (20,500 square miles), Population 2,130,400					
3	Ocmulgee River at Lumber City, Ga. 02215500	Cropland with pasture; woodland and forest	5,180	5,260	1937-90	5,461[A]
4	Oconee River at Dublin, Ga. 02223500	Cropland with pasture, woodland and forest; urban areas	4,400	5,320	1898-90	4,898[A]
5	Altamaha River at Doctortown, Ga. 02226000	Woodland and forest with some cropland and pasture; wetland	13,600	14,200	1932-90	13,490
6	Satilla River at Atkinson, Ga. 02228000	Grazed forest and woodland; wetland	2,790	3,400	1931-90	2,240
7	St. Marys River near Macclenny, Fla. 02231000	Grazed forest and woodland; and forest with some cropland and pasture	700	1,480[B]	1927-90	663
	Suwannee Subregion (13,800 square miles), Population 486,400					
8	Alapaha River at Statenville, Ga. 02317500	Woodland and forest with some cropland, pasture, and woodland grazed	1,400	1,840	1932-90	1,042
9	Withlacoochee River (north) near Pinetta, Fla. 02317500	Cropland with pasture, woodland and forest; wetland	2,120	2,360	1932-90	1,669
10	Santa Fe River near Fort White, Fla. 02317500	Woodland and forest with some cropland and pasture; wetland	1,017	1,360	1928-29, 1933-90	1,608
11	Suwannee River at Branford Fla. 02320500	Wetland; cropland with pasture, woodland and forest;	7,880	9,950[B]	1932-90	6,939
12	Aucilla River near Scanlon, Fla. 02326512	Grazed forest and woodland; wetland; woodland and forest with some cropland and pasture	805	952	1977-90	547
	Ochlockonee Subregion (3,650 square miles), Population 312,000					
13	Ochlockonee River near Havana, Fla. 02329000	Cropland with pasture, woodland and forest; wetland	1,140	2,250	1927-90	1,037
	St. Johns Subregion (11,600 square miles) (9,360 square miles in study area), Population 3,087,300					
14	Oklawaha River near Conner, Fla. 02329000	Cropland with pasture, woodland and forest; wetland; urban areas	1,196	2,769	1931-46, 1978-90	1,130
15	St. Johns River at Deland, Fla. 02236000	Grazed forest and woodland; woodland and forest with some cropland and pasture; urban areas	3,066	9,168	1934-90	3,043[C]
16	St. Johns River at Jacksonville, Fla. 02246500	Grazed forest and woodland; woodland and forest with some cropland and pasture; urban areas	8,754	9,168	1955-74, 1981 1988	5,687[D]
	Peace River-Tampa Bay Subregion (10,000 square miles) (4,492 square miles in study area), Population 2,643,500					
17	Withlacoochee River (south) near Holder, Fla. 02313000	Woodland and forest with some cropland and pasture; wetland	1,825	2,059	1932-90	1,061
18	Hillsborough River near Zephyrhills, Fla. 02303000	Woodland and forest with some cropland and pasture; urban areas	220	690	1940-90	248

[A] Flow regulated by reservoir

[B] Includes part of watershed in Okefenokee Swamp which is indeterminate

[C] Gage is located 142 miles upstream from mouth, but flow is occasionally reversed as a result of tide and wind. Maximum daily reverse flow is 3,030 cubic feet per second.

[D] Flow affected by tides. Discharge value is based on daily net discharge values that represent the difference between much larger upstream and downstream discharges.

Ogeechee River

The Ogeechee River originates in the Piedmont Province (fig. 1). The Ogeechee River is approximately 245 miles in length from its source to where it empties into the Atlantic Ocean (fig. 12). The tidal reach of the river extends upstream for about 44 mi (McConnell and Buell, 1993). The western, upstream parts of the Ogeechee River Basin lie in the Vidalia Upland, and the coastal, downstream part of the Ogeechee River basin is in the Barrier Island Sequence (fig. 2). No large cities (population greater than 50,000) are located directly on the river and water quality in the basin is deemed adequate for most uses (Carter and Hopkins, 1986). The Canoochee River is the largest tributary of the Ogeechee River (fig. 12).

The Ogeechee River is an important river for anadromous fish species, such as the federally protected shortnose sturgeon. Tributaries of the Ogeechee River provide critical refuge for striped bass. Below the Fall Line, the flood plain of the river is a wide expanse of wetland bordering both sides of the channel. The Ogeechee River is usually considered a blackwater river although the headwaters are located in the Piedmont Province. According to Wharton (1978), the Ogeechee River is intermediate between alluvial and blackwater rivers with flood-plain soils containing a higher content of sands than those of the Oconee or Ocmulgee Rivers, but Benke and Meyer (1988) and Meyer (1990) consider the Ogeechee River to be a blackwater river. The Ogeechee River has a long-term average discharge of 2,650 cubic feet per second (ft^3/sec) (table 4).

The Canoochee River, a tributary to the Ogeechee River, is located to the southwest of the Ogeechee River. The headwaters of the Canoochee River are located in the Vidalia Upland. The river channel is moderately incised; the floodplain becomes broader and more well developed after the river flows through the Barrier Island Sequence, which has less relief than the Vidalia Upland (fig. 3). The Canoochee River is also a blackwater river and the flood plain is wide near the headwaters, but has topographic features more typical of an alluvial river (Wharton, 1978). The Canoochee River is similar to the Ogeechee River in river channel biology, but on a smaller scale. No major cities are located on the Canoochee River and no dams, reservoirs, or channel alterations of importance have altered the Canoochee River. The Canoochee River has a long-term average discharge of 460 ft^3/s (table 4).

Altamaha and St. Marys Rivers

The Altamaha and St. Marys River basins extend from northwestern Georgia to the Georgia and Florida coast on the Atlantic Ocean. The basin includes several major tributaries to the Altamaha River, the Ocmulgee, Oconee, and Ohoopee Rivers, as well as the Satilla and St. Marys Rivers, and includes parts of nine physiographic districts in Georgia and Florida (figs. 3 and 12). The Altamaha River has an average discharge of 13,490 ft^3/s, the largest discharge in the study area (table 4). Its major tributaries, the Ocmulgee and Oconee Rivers, originate at altitudes 400-500 feet above the Atlantic Coast outlet of the river. The Ocmulgee, Oconee, and Altamaha Rivers are alluvial rivers and the Satilla and St. Marys Rivers are blackwater rivers. The diverse nature of the rivers included in these river basins causes variation in the seasonality of high and low flows among river basins.

The Ocmulgee River is located in central Georgia and is a tributary to the Altamaha River.The Ocmulgee River has the fourth largest discharge in the study area (table 4). The headwaters of the Ocmulgee River are located within the city limits of Atlanta, Ga., and the city of Warner Robins, Ga., is located on the Ocmulgee River. The river has been dammed for two thermoelectric and one hydroelectric power plants. Flood plain soils are silt or clay loams overlying mottled silty clay subsoils. A large underwater spring is located in a slough of the Ocmulgee River in Wilcox County, Ga., and striped bass congregate near the spring (Wharton, 1978). The Ocmulgee River has a long term average discharge of 5,461 ft^3/sec (table 4).

The Oconee River is the northernmost tributary river to the Altamaha River and has its headwaters in north-central Georgia. The river flows across Winder Slope, Washington Slope, Fall Line Hills, the Vidalia Upland, and the Barrier Island Sequence on a southeasterly course. Dams on the river form two large lakes in the Piedmont Province where the river is deeply incised (Wharton, 1978) (fig. 3).The river is not dammed or significantly altered south of the Fall Line (fig 2); however, attempts have been made to drain the swampy floodplain of the Oconee River in the Fall Line Hills (Wharton, 1978). The Oconee River flood plain is up to 4.5 miles wide at some points below the Fall Line. The Oconee River has a long term average discharge of 4,898 ft^3/sec (table 4).

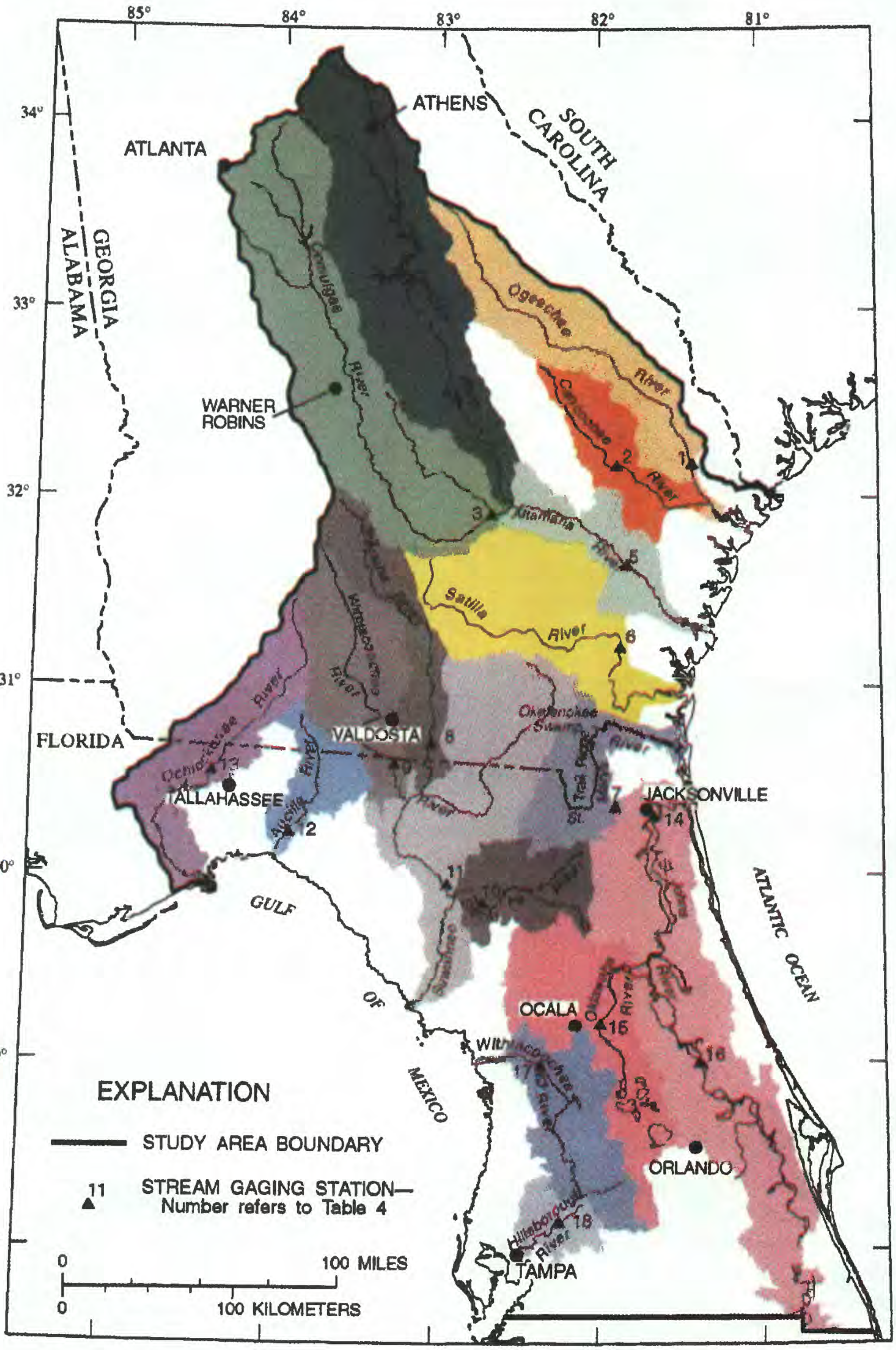

Figure 12. Major river basins in the Georgia-Florida Coastal Plain.

The Altamaha River is formed by the convergence of the Ocmulgee and Oconee Rivers in central Georgia. The Altamaha is an alluvial river that runs east and southeast to the Atlantic Ocean. Tidal influence extends upstream for approximately 24 miles (Wharton, 1978). Vast forests of cypress and gum were cleared in the tidal reach of the floodplain in the 1800's for rice plantations and some of the dike systems are still maintained in some areas for wildlife refuges (Wharton, 1978). No dams or other significant alterations have been made to the Altamaha River. The Altamaha River receives large contributions of water from underlying aquifers in the coastal plain during low-flow periods (Carter and Hopkins, 1986). The Altamaha River has a long term average discharge of 13,490 ft^3/sec, the largest discharge in the study area (table 4).

The wetland located within Altamaha River flood plain is considered to be the most diverse and productive river wetland in Georgia (U.S. Fish and Wildlife Service, 1992). The flood plain is usually under water from January through June. Six species of clams are endemic to the Altamaha River including the spiny clam, *Elliptio spinosa*, and the rare species, *Alasmidonta arcula*. This endemism indicates that the river habitat is very old and may have been isolated in the Pleistocene (Wharton, 1978). Other species of importance include the endangered shortnose sturgeon.

The Satilla River is a blackwater river that originates in the Bacon Terraces District, gathers the outflows of coastal wetlands, and is joined by many southeast-trending rivers as it meanders to the Atlantic Coast (figs. 3 and 12). The approximate length of the Satilla River is 225 mi (Benke and others, 1984) and the river is tidally influenced for approximately 67 miles above the mouth. No dams or other significant alterations have been made in the course of the river. The headwaters of the Satilla River are not as elevated as the headwaters of the more northern Ogeechee, Oconee, and Ocmulgee Rivers, resulting in a lower gradient. The river carries little sediment and has a sandy, shifting substratum in the river bottom and finer deposits collect in backwaters. During winter, tannic acids and oil wastes are often flushed into the Satilla River by industry (Wharton, 1978). The Satilla River has a long term average discharge of 2,240 ft^3/sec (table 4).

The broad flood-plain forest of the Satilla River is dominated by swamp tupelo with scattered cypress. Benke and others (1985) reported that snag habitat in the sandy main channel bottom and in muddy benthic habitat of backwaters supported 60 percent of total invertebrate biomass although snags represented only 4 percent of total habitat surfaces. Freshwater mollusks, crustacea, and fishes in the Satilla River are listed by Wharton (1978). The lower Satilla River includes habitat for a number of federally protected species and the largest bird rookery along the Georgia coast.

The St. Marys River is a blackwater river that originates in the southeastern part of the Okefenokee Swamp and forms part of the boundary between Georgia and Florida. The river flows north along the western side of a relict barrier island, then flows through the ridge and flows eastward to the Atlantic Ocean. The river is approximately 175 miles in length and is tidally influenced for approximately 60 miles upstream from the mouth (Bridges and Foose, 1986). The St. Marys River flows through no large cities and has not been dammed or significantly altered. The river includes habitat for a number of federally protected species, including anadromous fish (U.S. Fish and Wildlife Service, 1992). The St. Marys River has a long term average discharge of 663 ft^3/sec (table 4).

Suwannee River

The Suwannee River hydrologic subregion includes the Suwannee River and its major tributaries, the Withlacoochee (north), Alapaha, and Santa Fe Rivers. The hydrologic subregion is located in south-central Georgia and north-central Florida (fig. 11).The tributaries of the Suwannee River that originate in the Tifton Upland carry little sediment, are not deeply incised, and do not have dependable low flows. Extensive wetlands are found in north-central Florida. The river basin has a low stream density in Florida because porous limestone of the Upper Floridan aquifer is at or near the surface and facilitates a rapid infiltration of precipitation. The Suwannee River basin is an area of high recharge to the Upper Floridan aquifer (Bridges and Foose, 1986) and solution holes and springs are common. Several large springs along the Suwannee River in Florida contribute to the flow and further change the characteristics of the river so that it cannot be classified as either a blackwater or spring-fed river, although it is generally considered a blackwater river.

The Suwannee River has a long-term average discharge of 6,939 ft^3/sec, the second largest discharge of rivers in the study area (table 4). The main stem of the Suwannee River originates on the western side of the

Okefenokee Swamp in Georgia, as a blackwater river, and is joined by several large tributaries before it discharges into the Gulf of Mexico in Florida. From the outlet of the Okefenokee Swamp to the Gulf, it is approximately 245 miles long (Florida Board of Conservation, 1966). The Suwannee River is tidally influenced for about 27 miles upstream of the mouth (McPherson and Hammett, 1991). Sixty-two springs occur along the river and its flood plain; five of them are first magnitude (flow greater than 100 ft^3/s) (Suwannee River Water Management District, 1989). During low flow, the springs contribute a substantial percent of the total river flow (Rosenau and Faulkner, 1975; Lynch, 1984). At high flow, some springs receive flow from the river. The direction of exchange is dependent on river stage and the potentiometric surface of ground water in the Upper Floridan aquifer along the river (Stringfield, 1966).

Most of the lower flood plain of the Suwannee River is undisturbed wet hardwood swamps and prime habitat for many wetland plants and animals. The basin includes habitat for the federally protected bald eagle, wood stork, and Eastern indigo snake (uplands). The Alapaha River flows from south-central Georgia for 155 miles to its confluence with the Suwannee in north Florida (Florida Board of Conservation, 1966). Most of the basin is located in the Tifton Upland. The river carries some sediment, but is primarily a blackwater river. No major cities are located on the Alapaha River and it has not been dammed or channelized. At least five sinkholes are located within the river corridor and the flow is captured by sinkholes for about forty percent of the year (usually summer and fall) (Florida Department of Natural Resources, 1989). The Alapaha River has a long term average discharge of 1,042 ft^3/sec (table 4).

Dwarf cypresses are common on the headwaters of the Alapaha River, suggesting low nutrient availability. Most of the flood plain is narrow and inundated for long periods of time. Flood-plain forests are dominated by swamp tupelo. The Alapaha River flows through limestone strata in southern Georgia and has some limestone shoals but has low calcium concentration. The river is less acidic than most other blackwater rivers, especially in the lowest reaches. Freshwater mollusks, crustacea, and fishes found in the Alapaha River are listed by Wharton (1978).

The Withlacoochee River (north) originates in south-central Georgia and flows for 115 miles before it joins the Suwannee River (Florida Board of Conservation, 1966). No major cities are located on the Withlacoochee River and no major alterations have occurred. The long term average discharge of the Withlacoochee River is 1,669 ft^3/s (table 4). The Withlacoochee River (north) has characteristics of both a blackwater and an alluvial river. The water is highly colored, but the river carries more sediments than most rivers in north Florida (Hand and Paulic, 1992). The lower part of this river flows over limestone strata of the Upper Floridan aquifer, sinkholes have formed in the river bed (McConnell and Hacke, 1993), and significant exchanges of water occur between the river and the aquifer. The direction of exchange depends upon river stage and potentiometric surface of the aquifer (Stringfield, 1966). The river also has input from several springs in the lower course.

The Santa Fe River originates in a lake in north-central Florida (fig. 12) and flows westward for 70 miles to its confluence with the Suwannee River (Florida Board of Conservation, 1966). There are no dams or significant alterations of the channel. The Santa Fe River has an average discharge of 1,608 ft^3/s (table 4). The Santa Fe River disappears into a sinkhole and re-emerges three miles later (Florida Department of Natural Resources, 1989) with the streamflow increased with ground water from the Upper Floridan aquifer (Stringfield, 1966). After the river re-emerges, the water is clearer, has a higher pH, and higher conductivity (Hand and Paulic, 1992). The flow characteristics differ considerably between the upper and lower parts of the basin. In the upper part of the basin, the Santa Fe River is a blackwater river with a sandy bottom; further downstream karst features become more apparent. The lower course of the river flows through karst areas of the limestone of the Upper Floridan aquifer. The average runoff is 21.5 in/yr in the lower part of the basin, is much higher than runoff of most rivers in the study area and is more than twice the runoff of 10.27 in/yr for the upper river (Meadows and others, 1991). This results from ground water discharges into the river from the Upper Floridan aquifer in the lower part of the river. Because of the dual character of the basin, a diverse population of plants and animals are associated with the river and flood plain. The river has been declared an Outstanding Florida Water (Florida Department of Natural Resources, 1989).

The Aucilla River is a blackwater river located in southwestern Georgia and north Florida. The total length of the Aucilla River is about 69 miles (Florida Board of Conservation, 1966). Long term average discharge for the

Aucilla River is 547 ft^3/s (table 4). The Aucilla River receives much of its flow from ground water and is joined by a spring-fed tributary about 4 miles from the outlet to the Gulf of Mexico, which causes increases in pH and dissolved oxygen levels. No major cities are located in the Aucilla River basin and population density is very low in the basin.

Ochlockonee River

The Ochlockonee River originates in southwestern Georgia and flows to the Gulf of Mexico in Florida (fig 11). The Ochlockonee River is located in the Tifton Upland in Georgia and the Tifton Upland and Apalachicola Delta in Florida (fig. 3). This river is an alluvial river although some of the color typical of blackwater rivers is present (Hand and Paulic, 1992). The river is approximately 160 miles in length from its source in Georgia to its point of discharge to the Gulf of Mexico (Florida Board of Conservation, 1966). In Georgia, the Ochlockonee River channel is moderately incised in the rolling Tifton Upland District. There is little flood plain development and areas near the river are frequently cleared and farmed in row crops. The flood plain of the Ochlockonee River in Florida has the well-developed topographic features -- natural levees, ridges, terraces, depressions, sloughs, and oxbow lakes--which are characteristic of alluvial rivers (Leopold and others, 1964). The basin has a well-developed dendritic system of rivers that join the main stem in Georgia. A large reservoir was created in 1929 west of Tallahassee, Fla., by construction of a dam for hydroelectric power generation. No major cities are located on the Ochlockonee River and it has a long term average discharge of 1,037 ft^3/sec (table 4).

The topographic relief of the flood plain allows diverse habitats to develop (Mitsch and Gosselink, 1986). Four main ecological communities are found in the flood plain in Florida: sand bars, dominated by willows and river birch; depressions, dominated by tupelos and bald cypress, low terraces, dominated by swamp laurel oaks and red maple; and high terraces, dominated by a mixed pine-oak-sweetgum forest (Leitman and others, 1991). Ogeechee limes are the dominant trees on the lowest altitudes of the Ochlockonee River and cypress trees are common but less dominant due to logging (Light and others, 1993). Freshwater mollusks and crustacea in the Ochlockonee River are listed by Wharton (1978) and Swift and others (1977) described the distribution and natural history of Ochlockonee River fishes.

St. Johns River

The St. Johns River basin covers a large part (11,600 mi^2) of northeastern Florida and all but a small part of the southern river basin is included in the study area (fig. 12). The St. Johns River has one major tributary, the Oklawaha River. Three physiographic districts are included in the river basin: Sea Islands, Central Lake, and Eastern Flatwoods (fig. 3). Springs are common in the St. Johns River basin and flow is from slightly higher coastal areas to the lower marshes and swamps of the St. Johns River floodplain. The water draining many marshes and swamps is high in organic acid content and gives some blackwater characteristics to rivers. The St. Johns River basin is more highly populated (more than 3 million people) than the other river basins in the study area (table 4), and water quality has been affected by development and industry.

The St. John River is a unique river because of its long tidal reach with an extensive area of brackish influence, its size, the physiographic areas which it drains, the varied sources of streamflow, and the low gradient of the river. The St. Johns River flows northward for 273 miles, paralleling the Atlantic Coast, never flowing more than 30 miles inland. The river originates in a broad, marshy area in Indian River and St. Lucie Counties that is intermittently flooded (Heath and Conover, 1981). The river flows through marshland and a number of natural lakes, and is joined by many creeks and rivers, including the Oklawaha River, before discharging into the Atlantic Ocean at Jacksonville, Fla. The river has a tidal reach of about 160 miles upstream from the mouth. The headwaters have been channelized and some flow has been diverted to coastal drainages. During the last 50 years, more than 60 percent of the flood plain in the upper river has been ditched, diked, and drained for rangeland and agriculture (Fernald and Patton, 1984). Long term average discharge for the St. Johns River is 5,687 ft^3/sec (table 4).

The Oklawaha River begins in a chain of lakes in central Florida and flows northward and then eastward for approximately 75 miles before joining the St. Johns River (Florida Board of Conservation, 1966). No major cities are located directly on the river, but the headwaters are in a highly developed agricultural area. A number of control structures have been built in the Oklawaha River course. Several large lakes in the headwaters are regulated by canals and control structures constructed in 1950's and 1960's. Average discharge for the Oklawaha River is 1,130 ft^3/s (table 4), over half of which is discharge from a first magnitude spring near Ocala, Fla.

The Oklawaha River flows through a wetland forest over a sand bottom, and the water is clear, although sometimes stained with tannin from organic sources. Submerged plant communities are well-developed in the translucent water and provide support and cover for aquatic invertebrates, turtles, fish, alligators, and other riverine animals. The higher altitude of the hardwood swamp are dominated by swamp red bay, water oak, loblolly pine, bay, Florida elms, sweet gum, and cabbage palms. The more flooded areas support swamp tupelo, water ash, water locust, red maple and water hickory.

Withlacoochee (South) and Hillsborough Rivers

The Withlacoochee (south), Hillsborough, and Alafia rivers are located on the central Gulf coast of Florida, mostly in the Ocala Uplift District (fig. 3). The Withlacoochee River, the southern river of the two Withlacoochee Rivers included in the study area, begins in swamp to the northeast of Tampa, Fla. The eastern parts of the Withlacoochee and Hillsborough River basins are in the Central Lake District, and the southern part of the river basin, including the Alafia River Basin, is in the Southwestern Flatwoods (figs. 3 and 12). These rivers have some blackwater characteristics and some spring-fed characteristics. Many of these rivers have been altered by canals and dams, but intermittent flows and low gradients limit river usage. These river basins are moderately to heavily populated and intensively developed in many areas.

The Withlacoochee River (south) is approximately 157 miles in length, flowing northward from the swamp through the eastern marshes of a lake, and then westward to the outlet on the Gulf of Mexico. No major cities are located directly on the river, but the basin area is heavily populated because of suburban developments. Many alterations have been made in the mainstem and tributaries, including a diversion of the river near the mouth. The river is tidally influenced. The Withlacoochee River (south) has an average discharge of 1,061 ft^3/s (table 4). Base flow is augmented by ground water discharges and slow drainage from the many lakes and swamps that provide temporary storage of flood runoff in the river basin. The Withlacoochee River (south) is in hydraulic contact with Upper Floridan aquifer along much of its length (Sinclair, 1978).

The headwaters of the Hillsborough River are located in west-central Florida (fig. 12). The upper river receives discharge from a spring. The Hillsborough River flows for about 55 miles to Hillsborough Bay at Tampa, Fla. The river is dammed 10 miles inland from the bay to form a reservoir which supplies much of the municipal water supply for the city of Tampa. Below the dam, the river is brackish and the floodplain is completely developed. The Hillsborough River drainage basin is characterized by very low stream gradients and poorly defined basin divides. Long term average discharge for the Hillsborough River is 248 ft^3/sec (table 4).

Floods and Droughts

Floods in the study area result from frontal systems, hurricanes, tropical storms, or severe thunderstorms. Major floods on larger rivers are usually associated with frontal systems, hurricanes, or tropical storms that generate intense precipitation over large areas for an extended period. Floods on smaller rivers and large streams occur as a result of thunderstorms that produce intense precipitation over localized areas. Floods in coastal areas are commonly caused by hurricanes and tropical storms during the summer and early fall. Frontal systems are influential in the northern parts of the study area and large thunderstorms and hurricanes are commonly associated with coastal areas especially in peninsular Florida. Table 5 is a listing of all major floods in the study area between 1881 and 1989 (Bridges and Franklin, 1991; Golden and Hess, 1991)

Droughts can develop when large high-pressure systems stagnate in the region for weeks or months inhibiting cloud formation and development of rain. Alternatively or simultaneously, a ridge in the large scale wave pattern of the jet stream can develop just west of the study area and deflect storm tracks eastward or westward. These features can persist during any season of the year but are usually in the fall months.Droughts in the Florida part of the study area, especially peninsular Florida, are much less common due to its extensive maritime exposure. Table 6 is a listing of all major droughts in the study area between 1903 and 1989 (Bridges and Franklin, 1991; Golden and Hess, 1991).

Table 5. Major floods in the Georgia-Florida Coastal Plain, 1881-1989

[Bridges and Franklin, 1991; and Golden and Hess, 1991]

Date	Area affected	Recurrence interval (years)	Remarks
August 1881	Coastal areas near Savannah, Ga.	> 100	Hurricane.
August 1893	Coastal area at Savannah, Ga.	> 100	Hurricane.
January 1925	Central and southern Georgia	25 to > 100	Produced by 8-11 inches of rain.
March 17, 1929	Northwest Florida	> 100	Largest flood since about 1850.
September 1929	Central and southern Georgia	25 to > 100	Produced by 10-18 inches of rain.
October 1929	Ogeechee and Altamaha Rivers, Ga.	25 to > 100	Produced by 6-10 inches of rain.
September 7-9, 1933	Peninsular Florida	75 to > 100	Produced by 17.8 inches of rain.
April 1936	Oconee and Ogeechee Rivers, Ga.	> 50	Produced by 5-10 inches of rain.
August 1940	Coastal areas of Ogeechee River, Ga.	10 to 75	Hurricane.
October 1947	Coastal area near Savannah, Ga.	25	Hurricane.
April 1948	North Florida and southern Georgia	25 to > 100	Produced by 6-13 inches or rain.
October 3, 1951	West-central Florida	5 to > 100	Produced by 15.7 inches of rain.
March 23, 1960	Central Florida	25 to > 100	Twelve counties declared disaster areas.
September 10-11, 1960	Central Florida	10 to > 100	Hurricane.
September 13-14, 1964	North Florida	5 to > 100	Hurricane.
September 20-23, 1969	Ochlockonee River basin, Ga., Fla.	5 to > 100	Produced by 23.4 inches of rain.
April 1973	North Florida	25 to > 100	Damage to agriculture, roads, and bridges.

Table 6. Major droughts in the Georgia-Florida Coastal Plain, 1903-1989

[Bridges and Franklin, 1991 and Golden and Hess, 1991]

Date	Area affected	Recurrence interval (years)	Remarks
1903-05	Statewide in Georgia	25 to 50	A few gages indicated severe drought.
1930-35	Statewide in Georgia, except Ogeechee River basin	10 to > 25	Severe drought affected much of U.S.
1932-35	Panhandle and south-central, Florida	10 to > 50	Less than normal runoff for 1-2.5 years.
1937-41	North and northwest Florida	10 to 50	Less than normal runoff for 2.5-4.5 years.
1938-44	Statewide in Georgia	10 to > 50	Regional drought.
1949-57	Statewide in Florida	10 to 55	Less than normal runoff for 2-5 years in peninsular Florida and 3-9 years in Northern Florida.
1950-57	Statewide in Georgia	10 to >25	One of the most severe regional droughts of this century.
1960-63	Statewide in Florida	5 to 25	Less than normal runoff for 1.5-3 years.
1967-69	North Florida and panhandle	10 to 30	Less than normal runoff for 2-4 years.
1968-71	Southern and central Georgia	10 to > 25	Severity extremely variable.
1980-82	Statewide in Florida and Georgia	5 to 55	Less than normal runoff for 2-3 years.

Population

The total population in the study area in 1990 was estimated at 9.3 million (Akioka, 1992; University of Florida, 1991). The population in the study area is heavily concentrated in coastal areas and near Orlando, Fla., and Atlanta, Ga. (fig. 13). All or part of 4 of the Nation's top 50 most populated metropolitan statistical areas (MSA) in 1990 are located in the study area. These include the Tampa-St. Petersburg-Clearwater, Fla., MSA (2.1 million people), Orlando, Fla., MSA (1.1 million people), the Jacksonville, Fla., MSA (0.91 million people), and part of the Atlanta, Ga., MSA (2.8 million people) (U.S. Bureau of the Census, 1990). The population of major cities (population greater than 50,000) in the study area are listed in table 7.

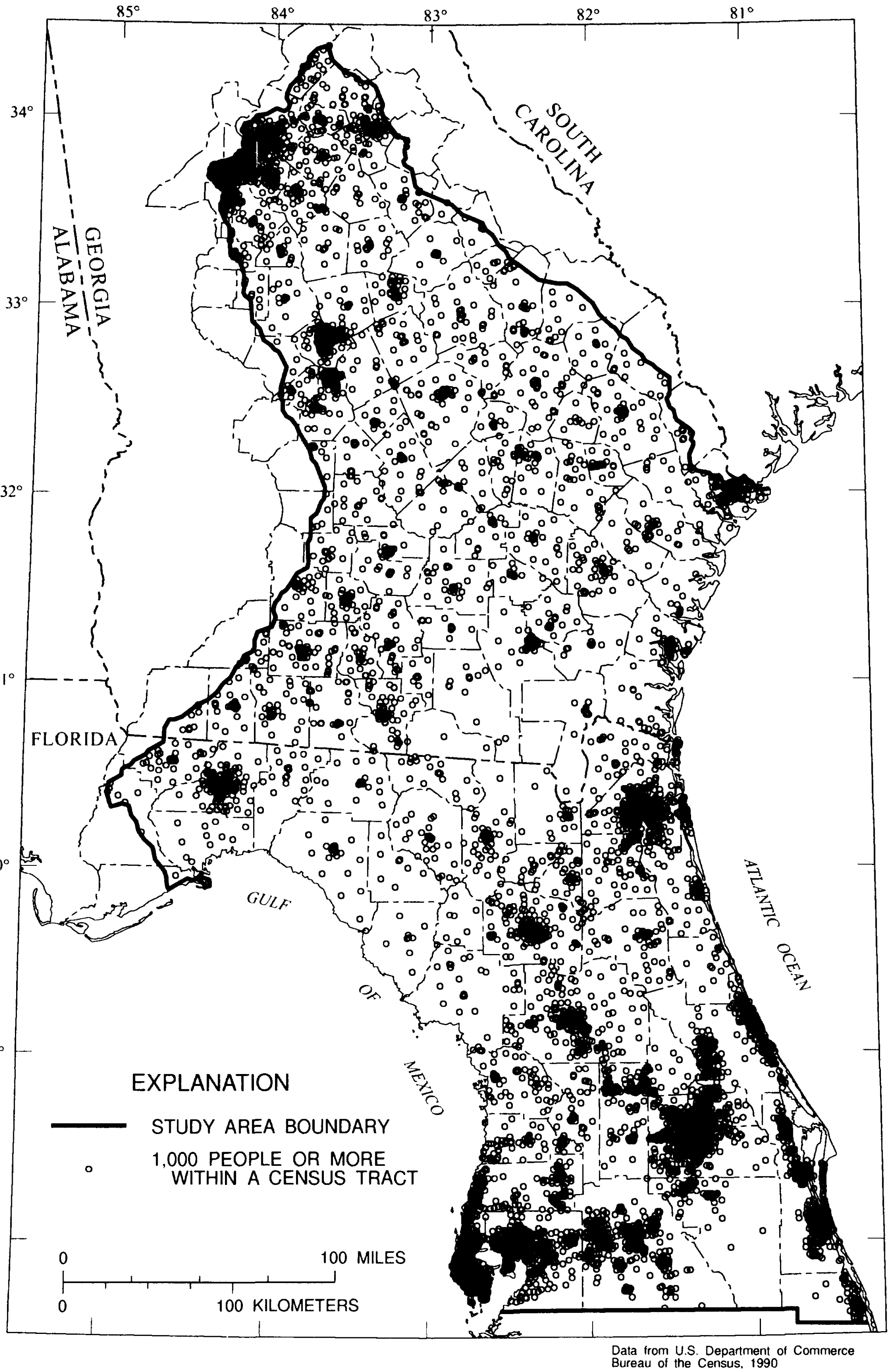

Figure 13. Population distribution in the Georgia-Florida Coastal Plain, 1990.

Table 7. Population of major cities in the Georgia-Florida Coastal Plain, 1990

[From Akioka, 1992; University of Florida, 1991]

City	Population, 1990
Jacksonville, Fla.	635,000
Atlanta, Ga.	394,000[1]
Tampa, Fla.	280,000
St. Petersburg, Fla.	239,000
Orlando, Fla.	165,000
Savannah, Ga.	138,000[1]
Tallahassee, Fla.	125,000
Macon, Ga.	107,000
Clearwater, Fla.	99,000
Gainesville, Fla.	85,000
Lakeland, Fla.	71,000
Daytona Beach, Fla.	62,000
Melbourne, Fla.	60,000

[1] Population figures from part of city that is in the study area

Land Use

The land uses of significance within the study area include forest, agriculture (citrus and row crops), wetlands, urban, and rangeland (fig. 14, table 8). Land uses for the 1970's were obtained from the USGS classification system for land use and land cover (Anderson and others, 1976; Mitchell and others, 1977). Nearly half of the study area is covered by forest (table 8), much of which is planted by the paper industry for silviculture. Agricultural land use in the study area is nearly 25 percent (table 8), occurs primarily within the Southern Coastal Plain and the Central Florida Ridge (fig. 14), and includes the growth of citrus, vegetables, cotton, peanuts, and nursery stock. Additionally, pasture lands and confined feeding operations are used for livestock grazing and dairy and poultry production, and many are located in counties in the northeastern part of the study area and in counties along the Suwannee River in Florida. Much of the wetlands are located along the coastal areas of the Atlantic Coast and the Gulf of Mexico and in southeastern Georgia (fig. 14). Barren includes mining and transitional areas.

Much of the forest lands in the study area are softwood pines which are used to manufacture paper products, including facial tissue, toilet paper, hand towels, bags, and boxes. Dominant trees in the study area include loblolly, shortleaf, longleaf, slash, and pond pines and some deciduous oaks, mostly turkey oaks (Hodler and Schretter, 1986; Fernald and Purdum, 1992). In Georgia, the highest production of pulpwood in 1989 was in Appling, Charlton, Clinch, Echols, Glynn, Long, Lowndes, Ware, and Wayne Counties (Akioka, 1992, p. 265-68). In Florida, the highest production of pulpwood was in Alachua, Baker, Bradford, Clay, Columbia, Levy, Nassau, and Taylor Counties (Shermyen and others, 1991, p. 293-94). Several national forests are located in the study area, including the Oconee National Forest (114,300 acres in parts of Greene, Jasper, Jones, and Putnam Counties) in Georgia, the Ocala National Forest (381,300 acres in Lake, Marion, and Putnam Counties), the Osceola National Forest (157,200 acres in Baker and Columbia Counties), and parts of the Apalachicola National Forest in Florida (558,900 total acres in Franklin, Leon, Liberty, and Wakulla Counties) (National Geographic Society, 1984). The Okefenokee National Wildlife Refuge includes large areas of wetlands and forested wetlands and covers nearly 396,000 acres in southeastern Georgia (National Geographic Society, 1984).

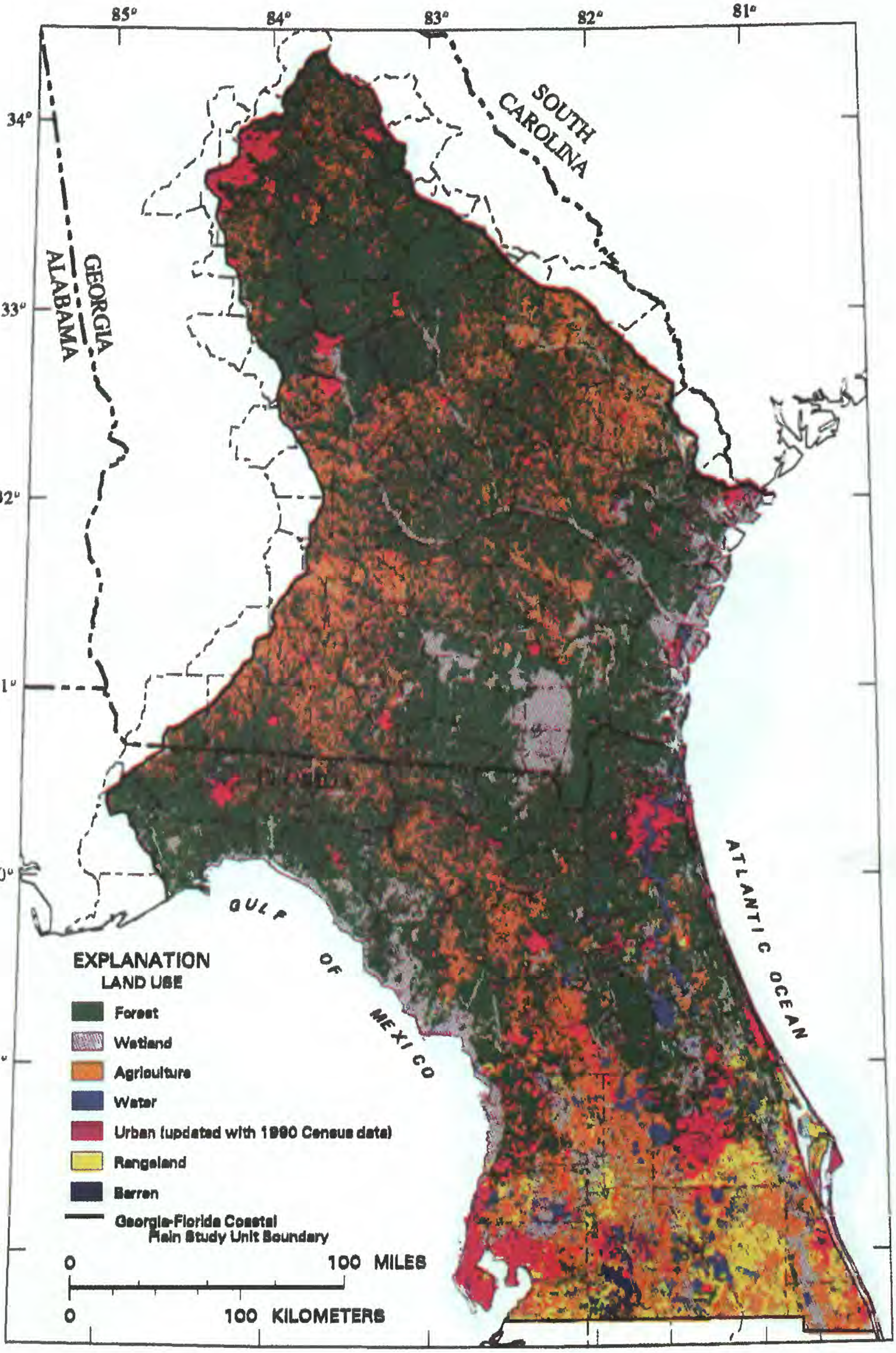

Figure 14. Land use in the Georgia-Florida Coastal Plain, 1972-76.

Table 8. Land use percentages in the Georgia-Florida Coastal Plain, 1972-76

[Anderson and others, 1976; Mitchell and others, 1977]

Land-use, and land-cover classifications	Percentage of land area covered, 1972-76
Forest	47.9
Agriculture	24.9
Wetland	15.8
Urban	4.4
Rangeland	2.9
Water	2.7
Barren	1.4

Agricultural areas account for nearly 28 percent of the study area (fig. 14) and include cultivation of field crops, fruits (including citrus), vegetables, cattle, dairy and poultry operations. Field crops grown in the study area include corn, cotton, peanuts, sorghum, soybeans, tobacco, and wheat (Florida Agricultural Statistics Service, 1991). Central and northern Florida and southern Georgia produce a wide variety of crops because of the relatively flat terrain, warm climate, sandy soils, proximity to markets, and availability of water for irrigation. Fruit crops are dominated by citrus production which occupies nearly 250,000 acres and is heavily concentrated in Hillsborough, Indian River, and Polk Counties, Fla. (Florida Agricultural Statistics Service, 1992a). Vegetable-growing areas are primarily in Flagler, Lake, Orange, Putnam, and St. Johns Counties, Fla. (Florida Agricultural Statistics Service, 1992c), and in Colquitt, Crisp, Decatur, Macon, Mitchell, Tift, and Turner Counties, Ga. Large numbers of livestock, dairy, and poultry farms are also present in the study area, primarily located in Alachua, Baker, Clay, Hillsborough, Gilchrist, Lafayette, Osceola, Polk, Suwannee, and Union Counties, Fla. (Florida Agricultural Statistics Service, 1992b) and Brantley, Colquitt, Hall, Jackson, Jenkins, Macon, Madison, Mitchell, Morgan, and Putnam Counties in Ga. (Georgia Agricultural Statistics Service, 1993).

Water Use

Estimated freshwater (water with dissolved solids less than 1,000 mg/L) withdrawn in the study area during 1990 was nearly 5,082 million gallons per day (Mgal/d) (Marella and Fanning, 1995). Ground water is the primary source of freshwater in the study area and accounted for more than 57 percent (2,888 Mgal/d) of the water withdrawn in 1990 and supplied nearly 77 percent (5.8 million) of the population served by public supply. Surface water accounted for nearly 43 percent (2,187 Mgal/d) of the water withdrawn and supplied 33 percent (1.7 million) of the population served by public-supply. Approximately 72 percent of the freshwater withdrawn was returned to ground- and surface-water sources for possible reuse.

The Floridan aquifer system provided nearly 91 percent (2,635 Mgal/d) of the ground water withdrawn in the study area during 1990 (Marella and Fanning, 1995). The surficial aquifer system supplied about 3 percent of the ground water withdrawn. Other aquifers, including the intermediate aquifer system, the Claiborne aquifer, Cretaceous aquifer system, and crystalline rock aquifers, accounted for 6 percent of the ground water withdrawn in 1990. During 1990, twelve individual facilities (public supply or industry) withdrew more than 25 Mgal/d of ground water, all from the Floridan aquifer system.

A large part of the 2,187 Mgal/d of surface water withdrawn in 1990 was withdrawn from the Altamaha, Hillsborough, Ocmulgee, Oconee, St. Johns, and Suwannee Rivers. Nearly half of the surface water was withdrawn from the Oconee River. In 1990, 1,338 Mgal/d of surface water were withdrawn from the Altamaha-St. Marys subregion, 458 Mgal/d from the St. Johns, 177 Mgal/d from the Peace-Tampa Bay, and 162 Mgal/d from the Suwannee (fig. 15). The Altamaha-St. Marys subregion is the only subregion in which surface-water withdrawals exceeded ground-water withdrawals in 1990 (fig. 15). Eight individual facilities (public supply and power generation) withdrew more than 25 Mgal/d of surface water during 1990. Nearly 430,000 people in Tampa, Fla. obtained their drinking water from the Hillsborough River in 1990 (Marella, 1993).

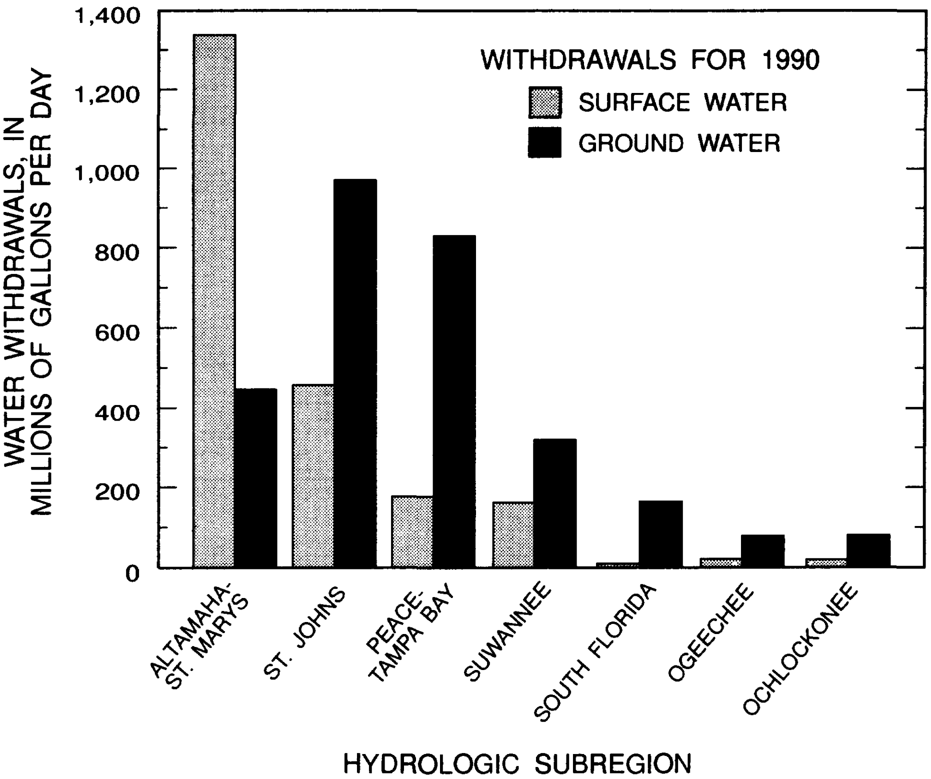

Figure 15. Ground-water, and surface-water withdrawals by hydrologic subregion in the Georgia-Florida Coastal Plain for 1990.

Freshwater withdrawals by water-use categories for 1980, 1985, and 1990 are shown in figure 16. Water withdrawals for public supply increased 49 percent from 1980 to 1990 and withdrawals for power generation decreased 26 percent, whereas withdrawals for most categories changed less than 10 percent from 1980 to 1990 (fig. 16) (Marella and Fanning, 1995). Withdrawals for public supply in 1990 totaled 1,145 Mgal/d; 83 percent ground water and 17 percent surface water. Nearly 95 percent of the ground water was from the Floridan aquifer system.Withdrawals for self-supplied domestic use in 1990 totaled 231 Mgal/d and were derived almost exclusively from ground water. The Floridan aquifer system supplied 65 percent (151 Mgal/d) of the withdrawals, the surficial aquifer system 21 percent, and other aquifers 14 percent. Withdrawals for self-supplied commercial-industrial uses (including mining) in 1990 totaled 862 Mgal/d; 93 percent from ground water and 7 percent from surface water. Withdrawals for agricultural use in 1990 totaled 1,293 Mgal/d; 69 percent from ground water and 31 percent from surface water. Most of the ground water withdrawn was from the Floridan aquifer system (93 percent).Withdrawals for thermoelectric power generation in 1990 totaled 1,552 Mgal/d, nearly all was surface water. The majority (98 percent) of water was used for once-through cooling purposes and is returned to its surface source after use (Marella and Fanning, 1995).

Wastewater discharged within the study area in 1990 was estimated at nearly 1,215 Mgal/d (Marella and Fanning, 1995). Domestic (municipal) wastewater facilities discharged nearly 820 Mgal/d and industrial wastewater facilities discharged 210 Mgal/d (industrial wastewater discharges were not available for Georgia in 1990). Releases of wastewater to septic tanks and drainfields was estimated at nearly 185 Mgal/d for the study area in 1990. Of the wastewater treated, 728 Mgal/d was discharged directly into surface water and 302 Mgal/d was discharged to the ground. Surface-water disposal includes effluent discharges into bays, rivers, streams, ditches, and wetlands. Releases to ground water include effluent discharges through drainfields, injection wells, land application systems (sprayfields and reuse systems), and percolation ponds. The actual amount of water released to ground water or surface water from these discharges is affected by runoff, evaporation, evapotranspiration, and other biological and chemical processes.

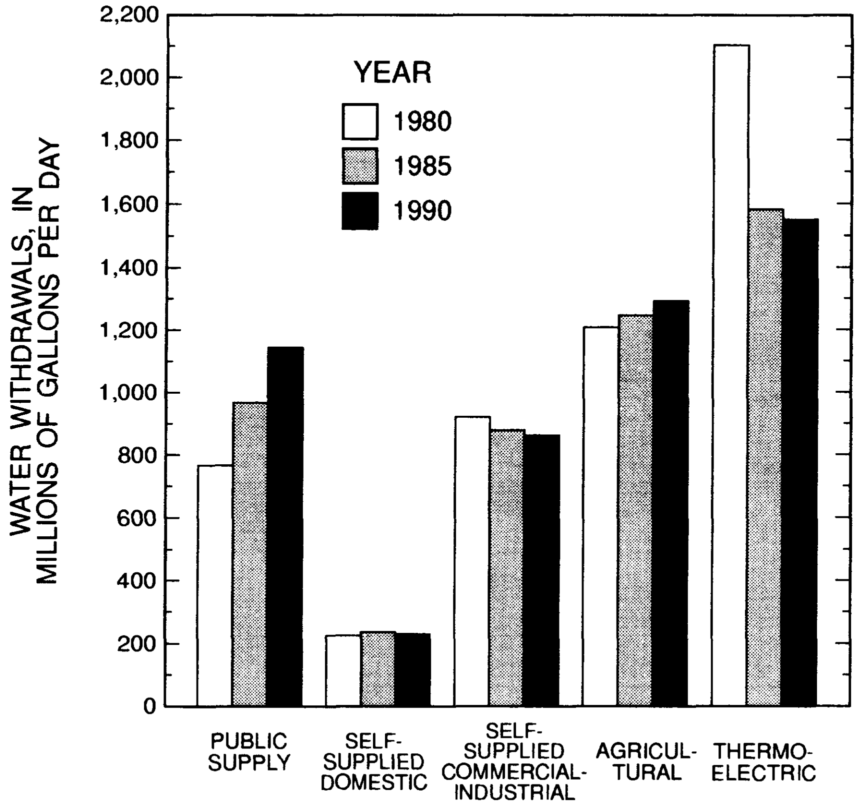

Figure 16. Water withdrawals by water-use category in the Georgia-Florida Coastal Plain study unit for 1980, 1985, and 1990.

FACTORS THAT AFFECT WATER QUALITY

Both surface- and ground-water resources are plentiful and generally of good quality in the study area. Water quality is affected by many natural factors, including climate (temperature, precipitation, and evapotranspiration), geology, hydrogeology, and ground-water/surface-water interaction, and by many human activities, including urban and agricultural land uses and water use. Constraints on the future use of these water resources probably will be caused by degradation of water quality rather than by limited quantity of water (Bush and Johnston, 1988). The factors most influential in affecting natural ground-water quality are the geologic environment, hydrologic conditions, and chemical reactions occurring in aquifers (Johnston, 1988).

Climate

Climate is an important factor affecting natural water quality of ground water and surface water. The temperature, amount and quality of precipitation and runoff, and the amount of evapotranspiration affect the amount and quality of recharge to ground water and runoff to surface water. Ground-water chemistry is determined by interaction with aquifer materials. The processes of rock weathering are strongly affected by temperature and amount and distribution of precipitation. Climatic patterns also tend to produce characteristic plant communities and soil types which affect the composition of water in a drainage basin (Hem, 1985). Effects of vegetation are most readily observed in surface water, because most runoff that enters surface water has spent some time within soils and may contain fallen leaves and other plant debris (Hem, 1985). In the study area, temperatures are mild and warm (long-term average ranges from 61 to 72 °F) (table 3), precipitation ranges from about 44 to 66 in/yr (table 3), and estimated evapotranspiration is about 30 to 39 in/yr in most areas (Carter and Hopkins, 1986; Bush and Johnston, 1988).

The chemical quality of ground water in the surficial, Upper Floridan and other aquifers is derived initially from the chemical quality of recharge. The quality of ground water at any point has evolved from a sequence of chemical reactions between the recharge water and aquifer materials. The chemistry of infiltration recharge is affected by processes such as evaporation and dissolution of natural and man-made salts in soils, that tend to increase the concentrations of major ions in ground water above those of rainwater. Estimates of the initial quality of recharge waters can be made from the chemistry of precipitation.

Geology and Hydrogeology

Hydrogeology and geology are important factors affecting ground-water quality. The natural ground-water chemistry in most aquifers in the study area reflects the sources of water recharging the aquifers, the residence time of water, and the mineralogy and lithology of deposits comprising the aquifers. In the surficial aquifer system, the major source of recharge is precipitation, the residence time is relatively short, and the mineralogy and lithology are siliceous and calcareous sand and clays. Water quality in the surficial aquifer system is generally good. The dominant ions are calcium and bicarbonate and dissolved solids concentrations generally are less than 1000 mg/L; however, concentrations of several thousand milligrams per liter have been detected in some areas (Berndt and Katz, 1992). Drinking water standards for fluoride are exceeded in water from the surficial aquifer system in some areas, although these areas appear to be limited in areal extent. The secondary drinking-water standard for iron concentrations of 300 micrograms per liter (μg/L) is commonly exceeded in water from the surficial aquifer system.

Water quality in the intermediate aquifer system is similar to the surficial aquifer system, with major ions of calcium and bicarbonate and dissolved solids concentrations less than 1,000 mg/L (Berndt and Katz, 1992). In the intermediate aquifer system, the median dissolved solids concentration was 624 mg/L in southwestern Florida.

The major-ion composition of water in the Upper Floridan aquifer is affected predominantly by mineral equilibria, degree of confinement, and mixing of freshwater with seawater (Katz, 1992). Major minerals are calcite and dolomite. In some local areas, gypsum may be present in sufficient amounts to influence water chemistry. The degree of confinement has a profound influence on amount of recharge and the major-ion chemistry. In areas where the aquifer is confined, such as south-central Florida, a closed-system evolution of ground-water occurs (Katz, 1992). There is also the potential for remnant seawater in these confined areas to persist because of the inability of freshwater to flush out this residual saline water. In unconfined areas, large amounts of recharge are likely and this recharge water contains low concentrations of major ions from precipitation and from leakage from the overlying surficial aquifer system (Katz, 1992). Areas of high recharge include north-central Florida (Aucott, 1988; Swancar and Hutchinson, 1992) (fig. 10). The aquifer is extremely vulnerable to contamination in these unconfined, high recharge areas.

The dissolved-solids concentration of water from the Upper Floridan aquifer is generally less than 250 mg/L, although concentrations greater than 25,000 mg/L occur in coastal areas in Florida where the Upper Floridan aquifer contains seawater (Sprinkle, 1989). Most major cation and anion concentrations are higher in confined areas and increase in concentration with depth (Katz, 1992). The major cation in ground water is calcium with the concentration controlled primarily by calcite saturation. Magnesium is also present and concentrations generally increase downgradient because of dolomite dissolution in the aquifer. Principal anions are bicarbonate, chloride, and sulfate. Carbonate buffering maintains the pH between 7.0 to 8.5. Bicarbonate is the principal anion throughout most of the study area. Chloride and sulfate concentrations are near zero in recharge areas. Highest concentrations of chloride are present where seawater is present in the Upper Floridan aquifer. Along the St. Johns River and the eastern coast of Florida, high chloride concentrations are present in the Upper Floridan aquifer and may be the result of incomplete flushing of Pleistocene seawater.

Nutrient concentrations in the Upper Floridan aquifer are generally low. Approximately 75 percent of 601 water samples collected from throughout the Upper Floridan aquifer had phosphorus concentrations below 0.1 mg/L (as phosphorus) (Sprinkle, 1989). In the same study, nitrogen analyses were not available for nearly as many samples, but statistical analyses indicated that total concentrations of nitrogen were similar in recharge and discharge areas and in confined and unconfined areas. But, statistical tests implied there was a quantitative decrease in oxidized nitrogen species and a quantitative increase in reduced nitrogen species from recharge to discharge areas (Sprinkle, 1989).

Water in the Upper Floridan aquifer has some water-quality problems caused by naturally occurring substances. Water from some wells in Wheeler, Montgomery, Tift, and Berrien Counties, Ga. has contained excessive levels of naturally occurring radioactivity that exceeded drinking-water standards and rendered the water unsuitable for public supply. From 1980-85, new community supply wells had to be reconstructed to eliminate pumping from specific zones within the Upper Floridan aquifer that yielded high radioactivity. In Ben Hill County, in south-central Georgia, barium concentrations as high as 2.1 mg/L have been detected in some wells installed in the Upper Floridan aquifer (Clarke and McConnell, 1988).

Samples collected throughout the extent of the Claiborne aquifer in Georgia had median dissolved solids concentrations of 160 mg/L and median chloride and iron concentrations were below secondary drinking water standards (Clarke and McConnell, 1988, p. 218). Nitrate concentrations were below the established primary drinking water standard of 10 mg/L (as nitrogen). Concentrations of dissolved solids increase to several hundred milligrams per liter and the dominant ions become calcium and bicarbonate as the relative amount of calcareous material increases in the aquifer. Dissolved solids concentrations in the Cretaceous aquifer system are generally low, with a median concentration of 35 mg/L in 25 samples (Clarke and Pierce, 1985). Median nitrate and chloride were 0.15 and 2.4 mg/L, respectively. Iron concentrations had a median of 40 μg/L, but several values in east-central Georgia had concentrations which exceeded the MCL for iron of 300 μg/L (Clarke and Pierce, 1985). In the Crystalline rock aquifers in Georgia, median dissolved solids were 87 mg/L, median chloride was 2.7 mg/L, and median nitrate was 0.25 mg/L (Clarke and Pierce, 1985). Water-quality problems are generally limited to naturally occurring iron concentrations, with concentrations as high as 14 mg/L in some cases (Clarke and Pierce, 1985).

Ground-Water/Surface-Water Interaction

Ground-water/surface-water interaction affects both ground-water and surface-water quality in the karst areas of south-central Georgia and north-central Florida. In Georgia, north of Valdosta, the channel of the Withlacoochee River (north) contains sinkholes and some flow directly recharges the Upper Floridan aquifer. Significant levels of color and organic matter have been introduced into ground water (McConnell and Hacke, 1993) and two of the city's wells had to be abandoned after 1975 because the color exceeded drinking-water standards. Hydrogen sulfide was also present and ranged in concentration up to 3.0 mg/L. Analysis of ground water in 1982-85 indicated that conditions had not improved. Recharge of ground water by surface water may cause problems in other areas as well. For example, unconfined or semiconfined areas of the Upper Floridan aquifer in Florida can be affected by surface-water recharge, especially near the Suwannee River which at times flows into and at other times receives discharge from the Upper Floridan aquifer. Also, in the Orlando, Fla., area, direct discharge of stormwater runoff to the Upper Floridan aquifer occurs through drainage wells throughout the city, and elevated concentrations of calcium, potassium, sodium, chloride, ammonia, and total organic carbon have been detected (Bradner, 1991).

Surface-water quality has been altered in several places, and in many cases improved, by ground-water/surface-water interaction. The Suwannee River receives inputs from ground water below the confluence with the Santa Fe River which causes the acidity to decrease. The Santa Fe and Oklawaha Rivers are enriched in nutrients by runoff from intensive row-crop agriculture that affects lake water-quality in their headwaters (Hand and Paulic, 1992). Ground-water quality in the Upper Floridan aquifer is generally of excellent quality with very low nutrient concentrations (Katz, 1992), thus large influxes of ground water dilute and improve water quality in these two rivers.

Land Use

Land use is the dominant feature of the environmental setting that affects water quality in the study area. The greatest effects are from the use of agricultural chemicals in agriculture areas, from urban runoff, wastewater discharges, leaking underground storage tanks, septic tanks, and landfills in urban areas, and from discharges from areas of mining land uses and from animal manure from livestock in rangeland areas.

Surface-water quality is affected by many urban land uses, including discharges from wastewater treatment plants, urban runoff, discharges from septic tank drainfields, and landfills and other waste-disposal sites. Wastewater discharges and disposal affect both ground water and surface water in the study area but discharges to surface water are more prevalent. Surface-water quality problems associated with wastewater discharges and stormwater runoff include nitrogen and phosphorus loading, low dissolved oxygen, elevated bacteria, increased sediment, and turbidity, and increased concentrations of metals (Hand and Paulic, 1992). Nearly all of the rivers described in this report have been affected by wastewater discharges. Water-quality problems related to wastewater discharges have occurred in the Ogeechee, Canoochee, Ocmulgee, St. Marys, Alapaha, Withlacoochee (north), Santa Fe, Ochlockonee, St. Johns, and Oklawaha Rivers (Florida Department of Environmental Regulation, 1987; Georgia Department of Natural Resources, 1989; Stokes and others, 1991; Hand and Paulic, 1992; McConnell and Buell, 1993). Water-quality problems related to urban runoff have occurred in the St. Johns, Oklawaha, Withlacoochee (south), Hillsborough, and Alafia Rivers (Hand and Paulic, 1992).

Land applications of wastewater discharge and urban runoff generally affect ground-water quality in the Upper Floridan aquifer only directly beneath application sites, such as sprayfields near Tallahassee and Tampa, Fla., and golf courses in central and west-central Florida (Berndt, 1990; Trommer, 1992). Where these sources are located in areas where contaminants can directly enter the Upper Floridan aquifer, degradation of ground-water quality can occur more quickly. In some areas, direct recharge of urban runoff to the Upper Floridan aquifer occurs through sinkholes and through thin or absent confining units, such as in south-central Georgia and most of the Florida part of the study area. Direct recharge also occurs through drainage wells which allow large amounts of recharge to flow into the Upper Floridan aquifer in parts of the Suwannee River basin and in the Orlando, Fla., area (Bradner, 1991).

Several instances of ground-water contamination by leaks from underground storage tanks have been detected in Florida. Common contaminants in ground water near such leaks include benzene, alkylbenzenes, toluene, and xylene. In Marion County, Fla., about 20 supply wells in the Upper Floridan aquifer were contaminated by a 10,000-gallon gasoline leak in late 1979 to early 1980 (Irwin and Bonds, 1988). At forty sites in adjacent Alachua County where underground petroleum storage tanks were located, layers up to 3 ft thick of "free floating product" were found floating on the water table (Schert, 1989). Statewide in Florida, several thousand of the approximately 28,000 gasoline stations with underground storage tanks have reported some contamination of soils and ground water from leaks.

Ground water in the study area is vulnerable to contamination by fertilizers and pesticides because in many areas aquifers are unconfined to semiconfined. The Upper Floridan aquifer is also highly porous in south-central Georgia and north-central Florida, with large conduits through which ground water can be transported rapidly. In addition, this area contains sinkholes which allow water from the surface to recharge directly to the Upper Floridan aquifer.

In agricultural areas, sources of nutrients to ground water and surface water include fertilizers and runoff from livestock feedlots. Nitrate is highly mobile in water and is a common contaminant of ground water in agricultural areas. In Georgia, several sites in the study area have shown upward trends in nutrient concentrations in surface water, including nitrate in the Oconee River, and phosphorus in the Ocmulgee and Oconee Rivers (McConnell and Buell, 1993).

Contamination of ground water by pesticides is a concern in the study area. In Florida, ethylene dibromide (EDB) was detected in more than 1000 private wells and other public supply wells throughout Florida's agricultural regions (Irwin and Bonds, 1988). The distribution was extensive and covered 22 of 66 counties tested throughout the State. Within the study area, the most detections were in Lake and Polk Counties. Aldicarb has also been detected at many study sites within the study area in Polk, St. John, Seminole, and Volusia Counties. The transport of pesticides to the Upper Floridan aquifer is dependent on processes occurring in the overlying the surficial aquifer system and confining units where they occur. Where water in the Upper Floridan aquifer is unconfined or semiconfined, pesticides can directly enter the aquifer and may threaten major drinking water supplies.

Surface-water quality problems in agricultural areas include elevated nitrogen and phosphorus concentrations, erosion and increased sedimentation. Water quality problems associated with agricultural areas have been described for the Ocmulgee, St. Marys, Santa Fe, Ochlockonee, St. Johns, Oklawaha, Withlacoochee (south), Hillsborough, and Alafia Rivers (Hand and Paulic, 1992; McConnell and Buell, 1993). An upward trend in total phosphorus concentration was noted from 1980 to 1989 for the Ocmulgee River (McConnell and Buell, 1993).

Several river basins in the study area have been affected by a combination of land uses, including urban, industrial, and agricultural. The Suwannee River and its tributaries receive discharges from municipal sewage treatment plants, livestock feedlots, a paper mill, and a phosphate mine (Hand and Paulic, 1992). In this river basin, surface water interacts directly with the Upper Floridan aquifer because the aquifer is unconfined to semiconfined, and is highly porous; also the area contains numerous springs which allow water to move back and forth from surface water to ground water, depending on river or lake stage and ground-water levels.

Many ground- and surface-water quality problems have been detected in the St. Johns River basin. In the Orlando, Fla., area, water-quality problems have been mostly due to discharges from numerous wastewater-treatment plants and urban runoff. Two lakes in the river basin have been very eutrophic and nutrient and bacteria concentrations remain high in the two tributaries to the St. Johns River (Florida Department of Environmental Regulation, 1988). In the Jacksonville, Fla., area, surface-water bodies (streams and lakes) receive discharges from paper mills, wire, chemical, and paper industries and packaging plants, as well as runoff from wastewater treatment plants, urban and stormwater runoff, and runoff from the Jacksonville shipyards. Surface-water quality problems associated with these discharges include low dissolved oxygen, and elevated metals, nutrient, and bacteria concentrations. Also, a tributary receives a large volume of effluent from a paper mill, has very low dissolved oxygen concentration, and high color and nutrient concentrations.

Water Use in Coastal Areas

Large ground-water withdrawals in urban, coastal areas are largely responsible for saltwater intrusion problems within the study area. Excessive pumpage has resulted in saltwater intrusion and upconing of saline waters in coastal communities and certain inland areas. Saltwater intrusion in the Upper Floridan aquifer has been detected in Savannah and Brunswick, Ga., and Jacksonville and Tampa-St. Petersburg, Fla. In a broad area centered around Savannah, Ga., that includes part of adjacent South Carolina, water levels in the Upper Floridan aquifer have declined more than 150 feet since pumping began in the late 1800's. The direction of ground-water flow has been reversed in some areas causing saltwater to move toward coastal areas, such as Hilton Head Island, S.C. In Brunswick, Ga., area, water levels have declined less than in the Savannah area, but water levels did decrease by approximately 65 feet since the late 1800's. Three public-supply wells in the city of Brunswick were abandoned because chloride exceeded the drinking-water standard. The Georgia Environmental Protection Division worked with industries in the area in the early 1980's to reduce industrial water use. Voluntary decreases in water use resulted in a 10 Mgal/d decrease in pumping. The chloride concentrations in the area began to decrease by 1984 and the water level had risen 6 feet in one coastal well (Clarke, 1987).

SUMMARY

The Georgia-Florida Coastal Plain study unit is an area of nearly 62,000 square miles located on the eastern coast of the United States. The population of the study area was approximately 9.3 million in 1990. Major cities located within the study unit include Jacksonville, Orlando, St. Petersburg, Tallahassee, and Tampa, Florida, and parts of Atlanta and Savannah, Georgia. Most of the study area is in the Coastal Plain physiographic province. A small part in the north is in the Piedmont physiographic province. Land resource provinces were designated based on generalized soil classifications. Land resource provinces in the study area include: the Coastal Flatwoods, the Southern Coastal Plain, the Central Florida Ridge, the Sand Hills, and the Southern Piedmont.

The primary source of water in the study area is ground water from the Upper Floridan aquifer. In 1990, more than 90 percent of the 2,888 million gallons per day of ground water used came from this aquifer. The Upper Floridan aquifer is the uppermost unit of the Floridan aquifer system which is a highly productive aquifer composed of a sequence of carbonate rocks that includes aquifer units of high permeability and confining units of low permeability. The rocks that make up this aquifer system reach a thickness of more than 3,000 feet along parts of the southern boundary of the study area. The Upper Floridan aquifer is considered confined where the thickness of confining units are greater than 100 feet, semiconfined where the confining units are less than 100 feet thick and may be breached, and unconfined where the units are virtually absent and the Upper Floridan aquifer is at or near land surface.

The study area includes all or parts of seven hydrologic subregions, including the Ogeechee-Savannah, the Altamaha-St.Marys, the Suwannee, the Ochlockonee, the St. Johns, the Peace-Tampa Bay, and the Southern Florida hydrologic subregions. Only the Ogeechee River is included in the Georgia-Florida Coastal Plain from the Ogeechee-Savannah subregion and only the Withlacoochee (south), Hillsborough, and Alafia River are in the study area from the Peace-Tampa Bay hydrologic subregion. Only a small part of the upper part of the Southern Florida subregion is within the study area, thus this subregion was not included for study.

The study area has a climatic range from temperate in the north to subtropical in the south and along the Gulf Coast. Mean annual temperatures range from about 61.3 degrees Fahrenheit in Atlanta, Ga to about 72.4 degrees Fahrenheit in Tampa, Fla. Long-term average precipitation (1951-80) ranges from 48 inches per year in Tampa, Fla., and central Georgia to 64 inches per year south of Tallahassee, Fla. Floods in the study area result from frontal systems, hurricanes, tropical storms, or severe thunderstorms. Major floods on larger rivers are usually associated with frontal systems, hurricanes, or tropical storms that generate intense precipitation over large areas. Floods on smaller rivers and large streams occur as a result of thunderstorms that produce intense precipitation over localized areas. Droughts can develop when large high-pressure systems stagnate in the region for weeks or months inhibiting cloud formation and development of rain. Droughts in the Florida part of the study area, especially peninsular Florida, are much less common due to its extensive maritime exposure.

The land uses of significance within the study area include forest, agriculture (citrus and row crops), wetlands, urban, and rangeland. Forest areas, much of which are in silviculture, cover approximately 48 percent of the study area. Much of the forest lands are softwood pines used to manufacture paper products (facial tissue, toilet paper, hand towels, bags, and boxes). Agricultural areas account for nearly 28 percent of the study area, are concentrated in several areas, and include growing of field crops, fruits (including citrus), vegetables and cattle, dairy and poultry operations.

Estimated freshwater (water with dissolved solids less than 1,000 mg/L) withdrawn in the study area during 1990 was nearly 5,082 Mgal/d. Ground water is the primary source of freshwater in the study area and accounted for more than 57 percent (2,888 Mgal/d) of the water withdrawn in 1990. Surface water accounted for nearly 43 percent (2,187 Mgal/d) of the water withdrawn during 1990.

Land use affects ground- and surface-water quality. Most effects are seen in urban and agricultural areas. Surface-water quality is affected by many urban land uses, including discharges from wastewater-treatment plants, urban runoff, discharges from septic tank drainfields, and landfills and other waste-disposal sites. Wastewater discharges and urban runoff generally affected ground-water quality in the Upper Floridan aquifer only directly beneath application sites. Several instances of ground-water contamination from leaks from underground storage tanks were detected in Florida, including benzene, alkylbenzenes, toluene, and xylene, but no widespread problems have been noted. Surface-water quality problems in agricultural areas include excessive nitrogen and phosphorus concentrations, erosion and sedimentation. Water quality problems associated with agricultural areas were described for the Ocmulgee, St. Marys, Santa Fe, Ochlockonee, St. Johns, Oklawaha, Withlacoochee (south), Hillsborough, and Alafia Rivers, and for ground water throughout agricultural regions in Florida.

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