Analysis of Nutrients in the Surface Waters of the Georgia–Florida Coastal Plain Study Unit, 1970–91

By Lisa K. Ham and Hilda H. Hatzell

U.S. Geological Survey

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Multiply	By	To obtain
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.59	square kilometer
ton per square mile (ton/mi^2)	0.3503	ton per square kilometer
million gallons per day (Mgal/d)	0.04381	cubic meter per second
degree Fahrenheit (°F)	(1)	degree Celsius (°C)

(1) Temperature: °C = (temp °F-32)/1.8

Chemical concentration and water temperature are given only in metric units. Chemical concentration in water is given in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Abbreviations and Acronyms

ESTREND = Estimate trend
FDEP = Florida Department of Environmental Protection
GAFL = Georgia–Florida Coastal Plain
GIRAS = Geographic Information Retrieval and Analysis System
huc = hydrologic unit code
LOWESS = Locally weighted scatterplot smoothing
MCL = maximum contaminant level
mg/L = milligrams per liter
NAWQA = National Water Quality Assessment
NPDES = National Pollutant Discharge Elimination System
NWIS = National Water Information system
STORET = Storage and Retrieval System
PVC = polyvinal chloride
USEPA = U.S. Environmental Protection Agency
USGS = U.S. Geological Survey

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 area 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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By Lisa K. Ham *and* Hilda H. Hatzell

Abstract

During the early phase of the Georgia–Florida National Water Quality Assessment study, existing information on nutrients was compiled and analyzed in order to evaluate the nutrient concentrations within the 61,545 square mile study unit. Evaluation of the nutrient concentrations collected at surface-water sites between October 1, 1970, and September 30, 1991, utilized the environmental characteristics of land resource provinces, land use, and nonpoint and point-source discharges within the study unit. Long-term trends were investigated to determine the temporal distribution of nutrient concentrations. In order to determine a level of concern for nutrient concentrations, the U.S. Environmental Protection Agency (USEPA) guidelines were used—(1) for nitrate concentrations, the maximum contaminant level in public-drinking water supplies (10 mg/L); (2) for ammonia concentrations, the chronic exposure of aquatic organisms to un-ionized ammonia (2.1 mg/L); (3) for total-phosphorus concentrations, the recommended concentration in flowing water to discourage excessive growth of aquatic plants (0.1 mg/L); and (4) for kjeldahl concentrations, however, no guidelines were available.

For sites within the 10 major river basins, median nutrient concentrations were generally below USEPA guidelines, except for total-phosphorus concentrations where 45 percent of the medians exceeded the guideline. The only median ammonia concentration that exceeded the guideline occurred at the Swift Creek site (3.4 mg/L), in the Suwannee River basin, perhaps due to wastewater discharges. For all sites within the Withlacoochee, Aucilla, and St. Marys River basins, median concentrations of nitrate, ammonia, and total phosphorus were below the USEPA guidelines.

Nutrient data at each monitoring site within each major basin were aggregated for comparisons of median nutrient concentrations among major basins. The Ochlockonee and Hillsborough River basins had the highest median nutrient concentrations, the Aucilla River basin had the lowest. Median concentrations of nitrate and ammonia among all major basins were below USEPA guidelines. The median total-phosphorus concentrations for the following river basins exceeded the USEPA guideline—Hillsborough, St. Johns, Suwannee, Ochlockonee, Satilla, Altamaha, and Ogeechee.

Although nutrient concentrations within the study unit were low, long-term increasing trends were found in all four nutrients. All 18 study-unit wide nitrate trends had increasing slopes ranging from less than 0.01 to 0.07 (mg/L)/yr. The range in slope for the 13 ammonia trends was -0.03 to 0.01 (mg/L)/yr with 6 increasing trends in the northern part of the study unit. Of the 17 total-phosphorus trends found in the study unit, 10 were found at sites where the median concentration exceeded the USEPA guideline. At these 10 sites, 4 sites had increasing trends with slopes ranging from less than 0.01 to 0.07 (mg/L)/yr, 5 sites had decreasing trends with slopes ranging from -0.01 to -0.24 (mg/L)/yr, and one site showed a seasonal concentration trend.

Median nutrient concentrations were significantly different among the four land resource provinces—Southern Piedmont, Southern Coastal Plain, Coastal Flatwoods, and Central Florida Ridge. As a result, nutrient concentrations among basins with similar nutrient inputs but located within different land resource provinces are not expected to be the same due to differences in the combination of factors such as soil permeability, runoff rates, and stream channel slopes. This concept is an important consideration in designing a surface-water quality network within the study area. For the most part, the Coastal Flatwoods showed the lowest median nutrient concentrations and the Southern Coastal Plain had the highest median nutrient concentrations.

Lower median nitrate concentrations in surface-water basins were associated with the forest/wetland land-use category and higher median concentrations of nitrate and ammonia with the urban category when land-use percentages were classified into four land-use categories (agriculture, forest/wetland, mixed, and urban). These results were reasonable based on expected high nutrient inputs from urban areas and low inputs from forested and wetland areas. However, the lack of association between high nutrient concentrations and the agricultural land-use category was not expected since high nutrient inputs are generally needed for agriculture production.

INTRODUCTION

The GAFL study unit is 61,545 mi^2 in area and encompasses 10 major river basins (fig. 1). The environmental setting of the GAFL study unit has been described in a report entitled *Environmental setting and implications for water quality in the Georgia–Florida Coastal Plain* by Berndt and others (1995) and includes a description of the important environmental influences on water quality in the study unit. A report entitled *Sampling design and procedures for fixed surface-water sites in the Georgia–Florida Coastal Plain study unit, 1993* by Hatzell and others (1995) describes the surface-water sampling network in the context of these environmental influences and lays the groundwork for a design to evaluate data gathered during the study. This report examines historical data in the same environmental context with particular emphasis on nutrients in surface waters in the GAFL study unit.

Nutrients, such as nitrogen and phosphorus, in surface water may be in solution or adsorbed to sediments. Species of nitrogen discussed in this report are nitrate, ammonia, and organic nitrogen plus ammonia (kjeldahl). Total phosphorus is the only species of phosphorus included in this report. Nitrate is very soluble in water, and although ammonia may occur in solution to some extent, the ammonium ion often is bound to sediment (Jordan and Stamer, 1991). Nitrate can be the oxidized end product of nitrogenous fertilizer and human and animal wastes, and most of the organic nitrogen is probably derived from degraded plant and animal material (Jordan and Stamer, 1991). Phosphorus is a common element in igneous rock and is also fairly abundant in sediments, but concentrations present in solution in natural water generally are not more than a few tenths of a milligram per liter (Hem, 1985). Sources of phosphorus in the GAFL study unit include: discharges from wastewater-treatment facilities, livestock operations, mining activities, agricultural runoff, fertilizer storage, and the breakdown and erosion of phosphorus-bearing minerals in sediments.

Nutrients in surface water, although present naturally, can increase because of human activity. Nutrient concentrations are relatively low in areas considered pristine, such as forests and wetlands. Generally, elevated levels of nutrients can be attributed to point sources or nonpoint sources, usually associated with land use practices, and to tributary flow with higher nutrient concentrations. Conversely, wetlands can decrease nutrient concentrations by decreasing the sediment and contaminant load in the water that filters through the wetland (Carter, 1986). Also, decreases in nutrient concentrations can be a result of dilution from the interaction of surface water with ground water or from tributary flow with lower nutrient concentrations.

In order to determine a level of concern for nutrient concentrations, the USEPA guidelines and standards were used as a point of reference. The MCL for nitrate concentrations in public-drinking water supplies is 10 mg/L, which is the USEPA standard (U.S. Environmental Protection Agency, 1986). The USEPA also has recommended upper concentration limits for ammonia concentrations in surface water based on chronic and acute exposure of aquatic organisms to un-ionized ammonia (U.S. Environmental Protection Agency, 1986). Within the ranges of pH (6.5-9.0) and temperature (0-30ºC) for most natural surface waters, total ammonia concentrations greater than about 2.1 mg/L exceed the guideline for chronic concentration. At high pH (about 9.0) and temperature (about 30ºC), the guideline can be exceeded by total ammonia concentrations as low as 0.07 mg/L. There are no USEPA or state guidelines for kjeldahl concentrations. To discourage excessive growth of aquatic plants in flowing waters that do not discharge directly into lakes or impoundments, the USEPA (1986) recommended upper concentration limit for total-phosphorus concentrations is 0.1 mg/L as phosphorus. The median total-phosphorus concentration in U.S. rivers (1974-81) was 0.13 mg/L (Smith and others, 1987). The median total-phosphorus concentrations in Florida streams was 0.11 mg/L (Friedemann and Hand, 1989).

Purpose and Scope

The purpose of this report is to describe and evaluate historical surface-water nutrient concentrations within the GAFL study unit. Nutrient concentrations are analyzed and presented in relation to land resource provinces, land-use categories, nonpoint and point sources, major hydrologic basins, changes in nutrient concentrations along the river (river miles), and long-term trends. However, the data used in this report were not specifically collected for this type of analysis, but were compiled from surface-water sampling networks that were designed to meet various state and local needs.

For purposes of analysis in this report, the study unit is divided into 10 major river basins and noncontributing coastal areas (fig. 1). The major river basins included are the: Altamaha, Hillsborough, Withlacoochee, Ochlockonee, Ogeechee, St. John, St. Mary, Satilla, Suwannee, and Aucilla. Water-quality data collected between October 1, 1970, and September 30, 1991, were used in this report. Ground-water nutrient information for the GAFL study unit is addressed in a separate USGS report (Berndt, 1995).

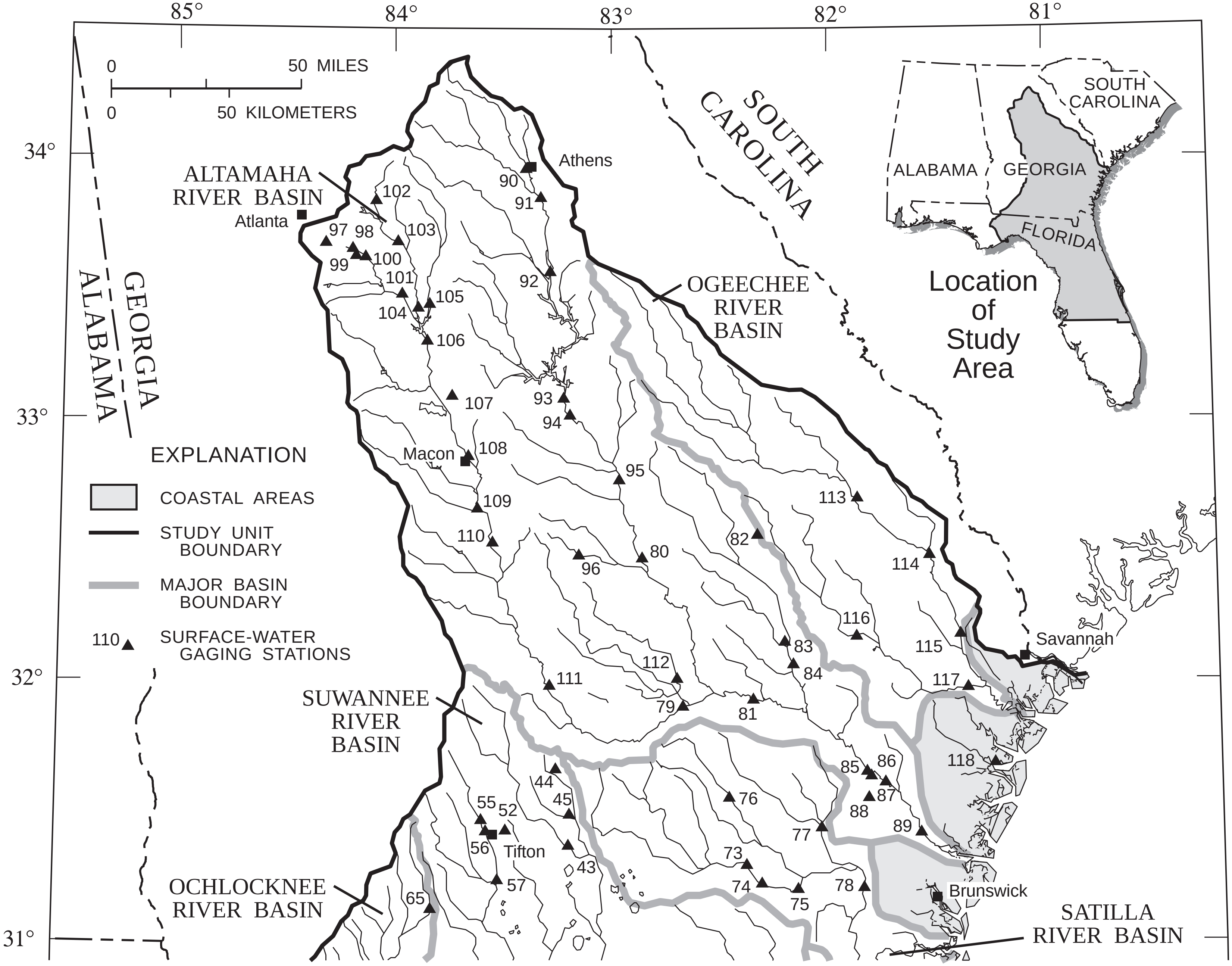
Description of the Study Unit

Rivers in the study unit can generally be described as either alluvial, blackwater, or springfed, although some rivers are combinations of these types. Alluvial rivers typically originate in upland areas and carry sediment and inorganic nutrients to coastal sounds or bays. In a natural system, the primary source of nutrients for organisms in alluvial rivers is detritus from vegetation that is washed from the floodplain. Nutrients may be bound up with suspended organic matter and clay particles of sediment load of alluvial rivers (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 naturally occurring organic compounds. Fallen leaves and other detrital remains accumulate in blackwater rivers (Clewell, 1991). springfed rivers are most common in karst areas in north-central Florida and south-central Georgia.

Land resource provinces provide a useful subdivision of the study unit to examine the effects of generalized soils on observed water quality (Berndt and others, 1995). The land resource provinces present in the study unit include the Coastal Flatwoods, the Southern Coastal Plain, the Central Florida Ridge, the Southern Piedmont, and the Sand Hills (fig. 2).

Land uses within the study unit include: forest, agriculture (citrus and row crops, orchards, and hay), wetland, urban, rangeland, and mining (fig. 2). Nearly half of the study unit is covered by forest (47.9 percent); much of this is planted by the paper industry for silviculture. Agricultural land, which occurs primarily within the Southern Coastal Plain and the Central Florida Ridge, accounts for 27.8 percent. Much of the wetlands, 15.8 percent study-unit wide, are located along the coastal areas, the Okefenokee Swamp in southeastern Georgia, and along major rivers in the study unit. Major urban areas account for 4.4 percent of land use in the study unit and aside from Atlanta, Ga., are located mainly along the Atlantic Coast and in Orlando and Tampa, Florida. The remaining land uses relate to the actual land cover—water with 2.7 percent and barren areas with 1.4 percent. Figure 2 is a composite of 1972 land use (Anderson and others, 1976) with 1990 urban land use (Hitt, 1994) superimposed over it.

Wastewater discharges within the study unit in 1990 were estimated at nearly 1,215 Mgal/d (Marella and Fanning, 1995). Surface-water disposal includes effluent discharges in bays, rivers, streams, ditches, and wetlands. The amount of water released to ground- and surface-waters from these discharges is affected by runoff, evaporation, and evapotranspiration.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34°
33°
32°
31°
0
50 MILES
0
50 KILOMETERS
ALTAMAHA RIVER BASIN
Atlanta
Athens
SOUTH CAROLINA
GEORGIA
ALABAMA
OGEECHEE RIVER BASIN
SUWANNEE RIVER BASIN
OCHLOCKNEE RIVER BASIN
SATILLA RIVER BASIN
Macon
Tifton
Savannah
Brunswick
SOUTH CAROLINA
ALABAMA
GEORGIA
FLORIDA
Location of Study Area
EXPLANATION
COASTAL AREAS
STUDY UNIT BOUNDARY
MAJOR BASIN BOUNDARY
110 SURFACE-WATER GAGING STATIONS
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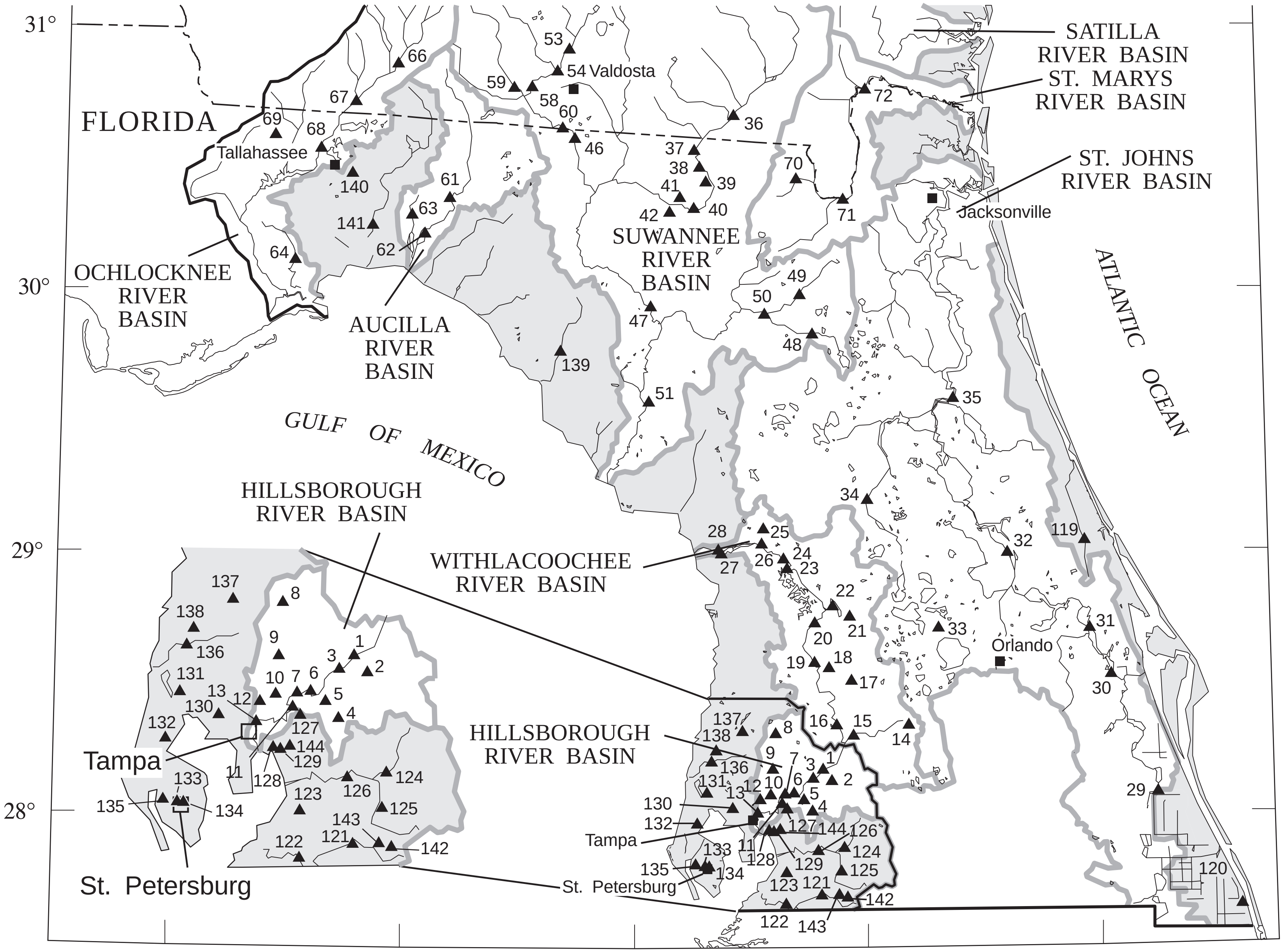

Figure 1. Location of major basins and surface-water quality sites.

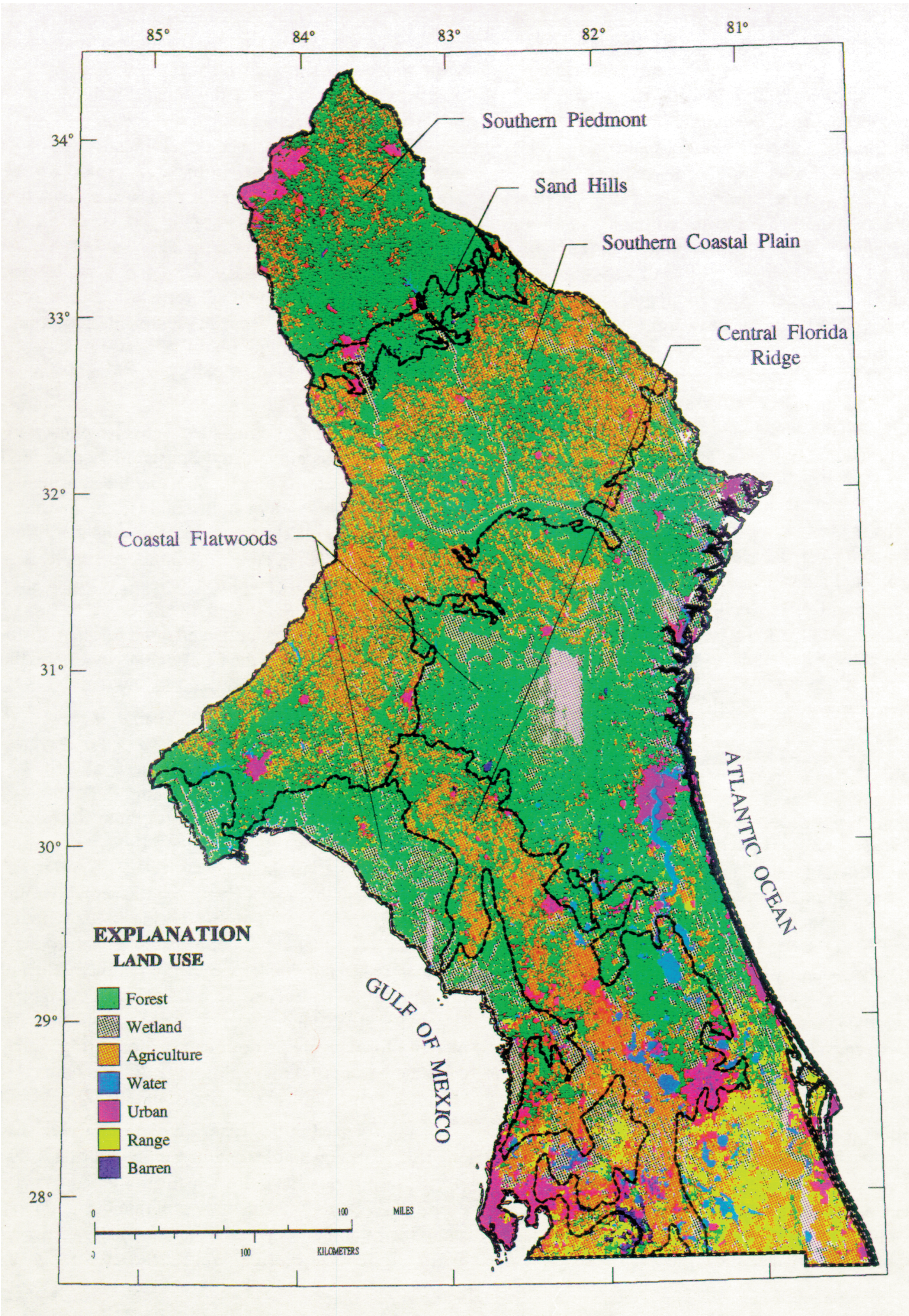

Figure 2. Land use and land resource provinces within the study unit.

Methods of Analysis

Nitrate nitrogen, ammonia nitrogen, and kjeldahl nitrogen will be referred to as nitrate, ammonia, and kjeldahl, respectively, throughout the remainder of this report. Nutrient concentrations were modified by aggregating data for related parameters which were not statistically different between samples when replicate samples were analyzed (Mueller and others, 1995). For example, the term ammonia refers to the aggregate of total and dissolved ammonia. The term nitrate refers to the aggregate of total nitrite-plus-nitrate, dissolved nitrite-plus-nitrate, total nitrate, and dissolved nitrate. Since kjeldahl is a measurement of ammonia and organic nitrogen, the amount of organic nitrogen can be derived from the figures used in this report by subtracting the ammonia concentrations from the kjeldahl concentrations; however, analysis of organic nitrogen is not included in this report.

River basins are used as a major theme throughout this report. Major river basins were obtained using the accounting hydrologic code. The hydrologic-unit code (huc) consists of four groups. For example, the huc of 03110204 is divided into a regional (03), a subregion (11), an accounting unit (02), and a cataloging unit (04). Major basins for this report are the: Hillsborough (huc 03100205), Withlacoochee (huc 03100208), St. Johns (huc 03080101-03), Suwannee (huc 03110201-06), Aucilla (huc 03110103), Ochlockonee (huc 03120002-03), St. Marys huc 03070204), Satilla (huc 03070201-02), Altamaha (huc 03070101-07), Ogeechee (huc 03060201-03). Coastal areas were excluded in the data analysis of major basins because coastal areas in Georgia differ hydrologically from the coastal areas in Florida. However, sites in coastal areas were included in data analysis of all other sections of this report. For river mile analyses, within each major basin, sites were selected on the basis of location, number of samples, and drainage area (the most downstream site was selected if too many sites existed on the same tributary). Generally, the length of each major river was divided into three segments from the headwaters to the mouth—upper, middle, and lower.

Throughout the report the Kruskal-Wallis (Chi-square approximation) test was performed to determine if median nutrient concentrations were significantly different between groups at an alpha level of 0.05. In addition, the Tukey studentized range test on the mean of the ranks by group concentrations was used in pairwise comparisons to determine which groups were significantly different at an alpha level of 0.05. The results of the pairwise comparisons are interpreted such that any two boxplots that are the same color are not significantly different statistically whereas any two boxplots that are not the same color are statistically different (see fig. 3 for example). If two colors are shown for one boxplot, the mean rank was not significantly different from other mean ranks identified by either one of those colors.

To distinguish nutrient concentrations of concern from concentrations that are not of concern the USEPA (1986) guidelines and standards were used as a point of reference. Gray shading was used to highlight areas in the boxplot diagram above the USEPA guideline or standard and white areas in the diagram represent concentrations below the guideline. According to USEPA (1986), the MCL for nitrate in public-drinking water is 10 mg/L; therefore, gray shading was used for concentrations greater than 10 mg/L and the white area is for concentrations less than 10 mg/L. Even when concentrations are below the guideline or standard, evaluation of the differences among data groups is informative.

Florida land resource areas (Caldwell and Johnson, 1982) and Georgia soil provinces (Perkins and Shaffer, 1977) were combined and generalized to produce the study unit land resource provinces. A monitoring station within a river basin was included in the analysis of the land resource provinces if at least 90 percent of the basin was within a single land resource province. Additionally, more than 90 water-quality samples per basin were required for inclusion in data analysis to exclude data from short-term sampling programs. Data from 59 basins met the criteria and were composited to represent the 4 land resource provinces.

Using the intersection of USGS digital land-use data from 1972 (Anderson and others, 1976) with individual site locations within basins provided the percent agriculture, percent forest, percent urban, and percent wetland for each basin. The following algorithm was used to create land-use categories in each basin: agricultural if percent agriculture was greater than 40 and percent urban was less than 10; forest if percent agriculture was less than 20 and percent urban was less than 10 and percent forest plus percent wetland was greater than 60; urban if percent agriculture was less than 15 and percent urban was greater than 20; mixed if the basin was not already considered agriculture, forest, or urban. Forested and wetland categories were combined and will be referred to as forested/wetland for the remainder of this report. From the initial group of 144 basins, 62 basins were selected for land-use data analysis because the basins were independent of one another (non-nested) and were considered to be representative of the predominant land use. One site was dropped from the 62 basins because the area is a small forested basin that has a large phosphate mine effecting the nutrient concentrations. The median concentrations for land-use categories were calculated for each site using samples collected over time, resulting in one statistic for each nutrient per site. Median concentrations for each land-use category were calculated from the median concentrations for each site.

Nonpoint sources of discharge (animal wastes, fertilizer application, atmospheric deposition, and septic-tank discharges) have been compiled and normalized by county size to estimate the amount of nitrogen and phosphorus inputs in tons per square mile applied to the land (Berndt, 1995). Population data were obtained from the U.S. Census Bureau and identify census block centroids with greater than 1,000 persons for 1990 (U.S. Bureau of Census, 1991a,b). Point-source data from NPDES provided average domestic (municipal) wastewater discharges per day for 1990 (Marella and Fanning, 1995).

Long-term trends were determined for each site using the program ESTREND. A hierarchical system was used to report flow-adjusted concentration trends and unadjusted concentration trends for each site. If both a flow-adjusted concentration and a concentration trend existed for a particular site then only the flow-adjusted concentration trend was reported. In addition to these trends, seasonal trends are reported. A minimum of eight years of continuous nutrient and discharge data were required for the selection of a site.

The Seasonal Kendall test was used to test for concentration and flow-adjusted concentration trends. For data sets with less than 15 percent censored data (values less than the reporting limit), all censored values are assigned one half of their reporting limit. For data sets with more than 15 percent censored data, all values that are less than the reporting limit are considered tied. The Seasonal Kendall test is a nonparametric test for monotonic trends in water quality and is a generalization of the Mann-Kendall test. The null hypothesis for the Mann-Kendall test is that the probability distribution of the random variable has not changed over time (Schertz and others, 1991).The Seasonal Kendall test statistic is calculated as a summation of the Mann-Kendall test statistics for each month (Hirsch and others, 1982). For data sets with less than 15 percent censored data, flow-adjusted and concentration trends were calculated. The model used for calculating the flow-adjusted trends was the LOWESS smooth fit to log transformed concentration and flow (Cleveland, 1979). For data sets with greater than 15 percent censored data, only concentration trends were calculated.

According to Schertz and others (1991), the rate of change over time (trend slope) is computed by the method described by Sen (1968). The trend slope, expressed as change in original units per year, is the median slope of all pairwise comparisons (each pairwise difference is divided by the number of years separating the pair of observations). The trend slope is also expressed as a percent of the mean water-quality concentration by dividing the slope (in original units per year) by the mean and multiplying by 100. For water-quality constituents that are log transformed, the slope, expressed as change in original units per year, is computed as:

$$\text{Slope} = (e^b - 1)\,C \qquad (1)$$

where b is the Seasonal Kendall slope estimate in log units and C is the mean concentration.

The rate of change in percent per year for log transformed constituents is computed as:

$$\text{Slope} = (e^b - 1)\,100 \qquad (2)$$

where b is the Seasonal Kendall slope estimate in log units.

Equations 1 and 2 provide an exponential rather than a linear estimate of the rate of change in water-quality constituent. Hence, values for the trend measured for the log-transformed data represent only the amount of change for 1 year.

A trend was considered to be significant at an alpha level of 0.05. A trend was considered increasing if the slope was positive, considered decreasing if the slope was negative, and no trend existed if the p value (probability of incorrectly rejecting the null hypothesis) was greater than 0.05. Seasons are defined as: winter (January through March), spring (April through June), summer (July through September), and fall (October through December). These seasonal definitions were selected based on weather patterns over the entire study unit.

Available Surface-Water Nutrient Data

In 1992, historical nutrient data were retrieved from USEPA's STORET data base for water years (October 1-September 30) 1981 through 1990, and from USGS's NWIS data base for water years 1970 through 1991. STORET data includes data collected by Federal, State, and local agencies. NWIS data includes data collected by USGS personnel only. NWIS data only were used for data analysis because the number of samples from NWIS data were adequate for data analysis and NWIS data has known sampling and analytical techniques.

The Altamaha River basin had the largest number of NWIS samples for nitrate (5,235 samples), ammonia (5,167 samples), and total phosphorus (5,051 samples) (table 1). The Hillsborough/ Withlacoochee River basin had the largest number of NWIS samples for kjeldahl (1,926 samples). The smallest number of NWIS samples were obtained from the Ogeechee River basin for nitrate (742 samples), kjeldahl (183 samples), ammonia (702 samples), and total phosphorus (741 samples).

Table 1. Summary of STORET and NWIS nutrient data

Major basin (see fig. 1 for location of major basins)	Number of samples		Median value	
	STORET (1981–90)	NWIS (1971–91)	STORET (1981–90)	NWIS (1971–91)
Nitrate nitrogen				
Altamaha	7,099	5,235	0.47	0.38
Hillsborough/Withlacoochee	1,194	2,445	0.21	0.08
Ochlockonee	1,034	1,008	0.21	0.40
Ogeechee	4	742	0.08	0.09
St. Johns	16,794	1,705	0.07	0.03
St. Marys/Satilla	368	966	0.02	0.06
Suwannee/Aucilla	1,982	2,716	0.15	0.19
Kjeldahl nitrogen				
Altamaha	1,902	1,057	0.40	0.40
Hillsborough/Withlacoochee	2,382	1,926	0.60	0.90
Ochlockonee	662	417	0.63	0.60
Ogeechee	564	183	0.45	0.50
St. Johns	9,480	1,084	1.10	1.00
St. Marys/Satilla	818	306	0.79	0.71
Suwannee/Aucilla	3,342	1,106	1.00	0.78
Ammonia nitrogen				
Altamaha	9,756	5,167	0.07	0.06
Hillsborough/Withlacoochee	2,482	2,433	0.12	0.03
Ochlockonee	2,294	945	0.10	0.07
Ogeechee	1,896	702	0.05	0.04
St. Johns	19,086	1,699	0.12	0.04
St. Marys/Satilla	3,094	940	0.05	0.04
Suwannee/Aucilla	6,494	2,664	0.07	0.05
Total phosphorus				
Altamaha	7,291	5,051	0.10	0.09
Hillsborough/Withlacoochee	[a] 0	2,292	--	0.11
Ochlockonee	[a] 0	969	--	0.22
Ogeechee	[a] 0	741	--	0.07
St. Johns	90	1,665	0.05	0.06
St. Marys/Satilla	[a] 0	964	--	0.06
Suwannee/Aucilla	[a] 0	2,646	--	0.21

[a] The retrieval of STORET data could be incomplete.

Acknowledgments

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FACTORS INFLUENCING NUTRIENT CONCENTRATIONS

Factors that were analyzed to examine their relationship with water quality include: basin size, land resource provinces, land-use categories, and point and nonpoint discharges. No relationship was found between basin size and nutrient concentrations. There was some evidence that smaller basins (less than 200 mi^2) tended to have higher nutrient concentrations; however, because of the small number of basins larger than 200 mi^2, a relationship could not be established. Therefore, basin size was not used as a factor in the analysis of nutrient concentrations.

Point sources are locations at which pollutants are released at a managed rate (Wanielista, 1976). Nonpoint sources are locations or land uses not requiring an NPDES permit and from which pollutants are usually dispersed, and are released at an unmanaged rate (Wanielista, 1976). Both point and nonpoint sources may degrade water quality. In this report, point sources of discharge are defined as domestic wastewater discharges. Nonpoint sources include animal wastes, fertilizers applied to the land, and septic-tank discharges. Population density influences nonpoint source discharges.

Land Resource Provinces

Land resource provinces are regional areas created by generalizing soil properties over large areas. Soil properties are formed by the following environmental factors acting over time: parent material, climate, living organisms, and topography (Brady, 1984). These environmental factors also influence the hydrologic characteristics of land areas. Thus, soils and hydrology are often closely associated and can interact to influence nutrient concentrations in water. Specific soil and hydrologic characteristics that affect water quality include soil permeability, solubility of minerals in the soil, time of contact of soils with the water, runoff rate, and the stream-channel slope.

The land resource provinces represent various combinations of the environmental factors expressed over regional areas. The purpose of evaluating nutrient concentrations by land resource province was to determine whether regional areas such as land resource provinces should be a factor in surface-water site selection and nutrient data analysis for the study unit. For instance, when comparing nutrient concentrations between two surface-water sites, each in a different land resource province, differences in nutrient concentrations might be related to differences in the environmental factors that influence the two provinces. Within the study unit, 59 basins were included for data analysis of the relationship between nutrient concentrations and land resource provinces (see methods section of this report).

The land resource provinces present in the study unit include: the Coastal Flatwoods, the Southern Coastal Plain, the Central Florida Ridge, the Southern Piedmont, and the Sand Hills (fig. 2). The Sand Hills is not included in this data analysis due to lack of river basins with available nutrient data. The Coastal Flatwoods consists of nearly level plains, marshes, and barrier islands, along with a set of low terraces. The soils in this area are frequently poorly drained; streams have dissolved organic matter (blackwater), low gradients, wide flood plains, and originate in or flow through wetlands. The Southern Coastal Plain consists of broad interstream areas with gentle and deeply-incised valleys. Large areas of these soils in the study unit are in forests, with lumber and some pulpwood production (Soil Conservation Service, 1975). The Central Florida Ridge is characterized by hills, ridges, terraces, and many lakes, and is marked by the characteristics of karst topography, such as, numerous sinks, sinkhole lakes, sinking streams, and springs (Caldwell and Johnson, 1982). In spite of abundant rainfall, some parts of the area have very few streams, with most of the precipitation recharging ground water. The soils in this province are characterized by low water-holding capacity and high permeability (Soil Conservation Service, 1975). The Southern Piedmont is an area characterized by mountain ridges with steep slopes, some foothills, and narrow valleys.

A general association exists between land resource provinces and land use (fig. 2). For example, the Southern Coastal Plain and the Central Florida Ridge tend to be dominated by agriculture. The Coastal Flatwoods is dominated by forests and wetlands in the central part of the study area and by agriculture in the southern part. The Sand Hills is mostly forest whereas the Southern Piedmont is a mixture of forest, agriculture, and urban settings. This association of land uses with land resource provinces occurs because the soil-forming environmental factors are important in both. However, as factors influencing water quality, land resource provinces are not synonymous with land uses. The land resource provinces are influenced by the soil and hydrologic properties. In contrast, land uses are influenced by the soils and hydrology, as well as other conditions, such as economics and traditions, conventions, and lifestyles of the people in the area.

Median nitrate concentrations among land resource provinces were less than 0.50 mg/L, which is far below the USEPA's MCL of 10 mg/L (U.S. Environmental Protection Agency, 1986). Pairwise comparisons of mean ranks showed that nitrate concentrations in land resource provinces were significantly different (at an alpha level of 0.05), indicating that land resource provinces are a contributing factor in explaining differences in nitrate concentrations (fig. 3). The highest median nitrate concentration occurred in the Southern Piedmont (0.44 mg/L). The lowest median nitrate concentration occurred in the Coastal Flatwoods (0.09 mg/L).

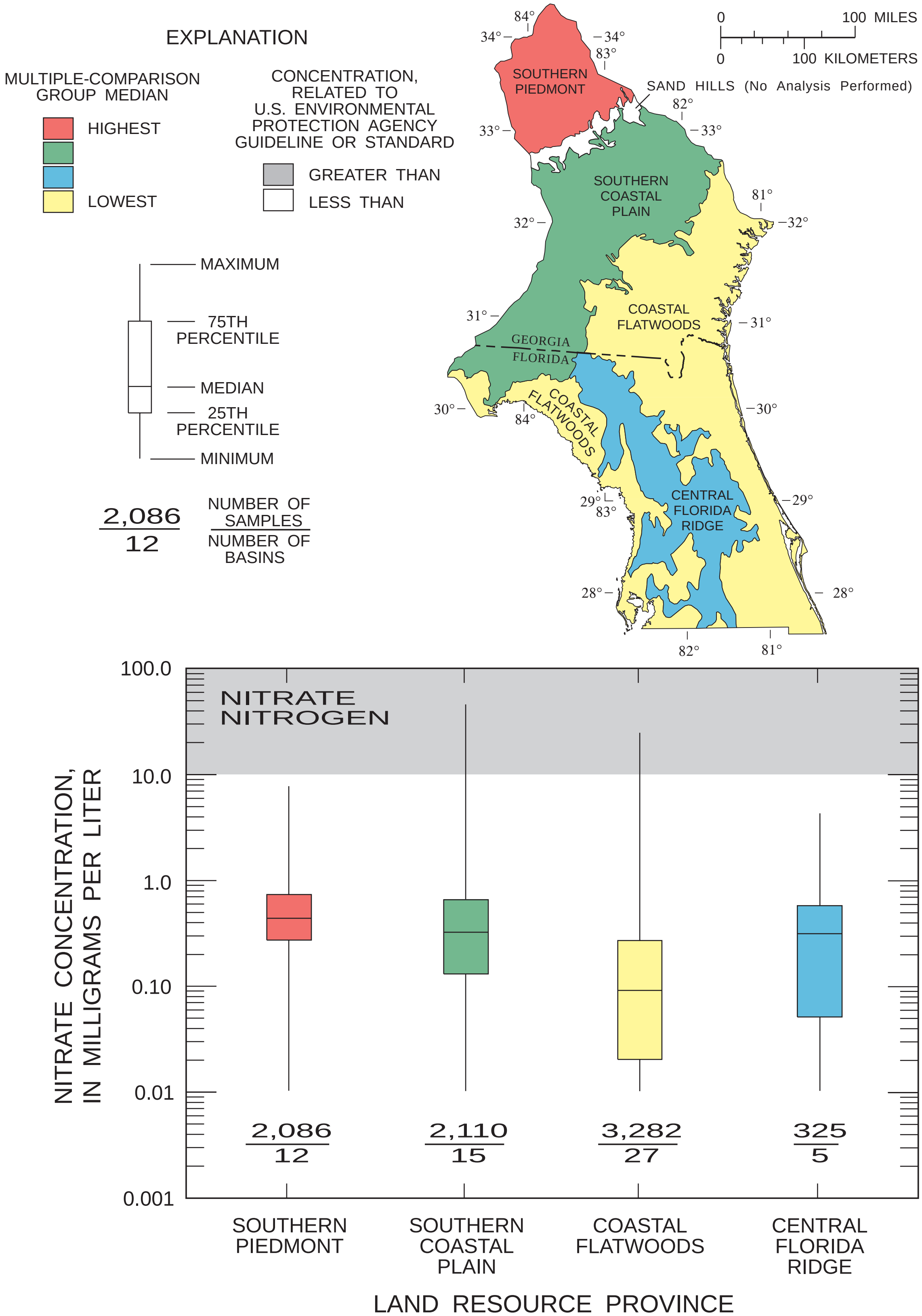

Figure 3. Nitrate concentrations among land resource provinces.

Median kjeldahl concentrations among land resource provinces were low. All pairwise comparisons of mean ranks resulted in significantly different kjeldahl concentrations among the land resource provinces indicating that land resource provinces are a contributing factor in explaining differences in kjeldahl concentrations (fig. 4). The highest median kjeldahl concentration occurred in the Central Florida Ridge (1.15 mg/L) where the organic nitrogen component in the kjeldahl concentration is an influencing factor. The lowest median kjeldahl concentration occurred in the Southern Piedmont (0.32 mg/L).

Median ammonia concentrations among land resource provinces were less than 2.1 mg/L, which is the USEPA maximum concentration for chronic exposure to aquatic organisms (U.S. Environmental Protection Agency, 1986). Pairwise comparisons of mean ranks showed no significant difference in ammonia concentrations between the Coastal Flatwoods and the Central Florida Ridge; however, a significant difference was found between the Southern Piedmont, the Southern Coastal Plain, and a group consisting of the Coastal Flatwoods and the Central Florida Ridge (fig. 5). This indicates that for comparisons of ammonia concentrations between sites in the Central Florida Ridge and the Coastal Flatwoods, land resource provinces are not a contributing factor. Land resource provinces are a contributing factor for comparisons among sites in the Southern Piedmont, Southern Coastal Plain, and the Central Florida Ridge and Coastal Flatwoods group. The highest median ammonia concentration occurred in the Southern Coastal Plain (0.07 mg/L). Sites located in Coastal Flatwoods and Central Florida Ridge showed the lowest median ammonia concentration (0.04 mg/L).

Median concentrations of total phosphorus for the Southern Coastal Plain (0.18 mg/L) and Central Florida Ridge (0.13 mg/L) were greater than 0.1 mg/L, which is the recommended upper concentration limit to control eutrophication (U.S. Environmental Protection Agency, 1986). Pairwise comparisons of the mean ranks resulted in all land resource provinces having significantly different total-phosphorus concentrations indicating that the land resource provinces are a contributing factor in explaining differences in total phosphorus concentrations (fig. 6).

In general, the median nutrient concentrations are significantly different among land resource provinces. Thus, the land resource provinces, and environmental factors that define them, should be considered in the design of surface-water sampling schemes that cover large areas. Lower nutrient concentrations were found in the Southern Piedmont and Coastal Flatwoods than in the Southern Coastal Plain and Central Florida Ridge, perhaps due to higher runoff rates. The Southern Piedmont is characterized by steep mountain slopes and the Coastal Flatwoods is characterized by poorly drained soils, these factors could result in higher runoff rates. Higher nutrient concentrations were found in the Southern Coastal Plain and Central Florida Ridge than the other two land resource provinces. The Southern Coastal Plain and Central Florida Ridge tend to be dominated by agriculture. In addition, the topography of the Southern Coastal Plain and the high soil permeability of the Central Florida Ridge may result in higher nutrient concentrations.

Land-Use Categories

The purpose for evaluating nutrient concentrations by land-use category was to determine whether land-use categories should be a factor in surface-water site selection and nutrient data analysis. For instance, when comparing nutrient concentrations between two surface-water sites within two different land-use categories, differences in nutrient concentrations could be attributed to differences in the land-use categories. An algorithm for classifying basins to represent a particular land use was used because within the study unit there were only two basins with 100 percent of a single land use (see methods section of this report). Forested/wetland areas were considered to be the land-use category with the lowest level of human activities whereas the agricultural and urban categories were the highest.

Agricultural practices, including livestock production and fertilizer application, can cause an increase in nutrient concentrations in runoff. A large variability in nutrient concentrations may be a result of seasonal application of fertilizers and variations in surface-water discharge. The water chemistry of runoff from agricultural land depends on a number of factors including specific agricultural use, topography, soil type, climate, and hydrologic conditions (Terrio, 1995). According to several studies (Dornbush and others, 1974; Uttormark and others, 1974; Donigian and Crawford, 1976; and Roseboom and others, 1990), the range of total-phosphorus concentrations in agricultural runoff is 0.02 to 3.45 mg/L. These studies also indicated that nutrient concentrations from feedlot runoff can be orders of magnitude greater than concentrations from field runoff.

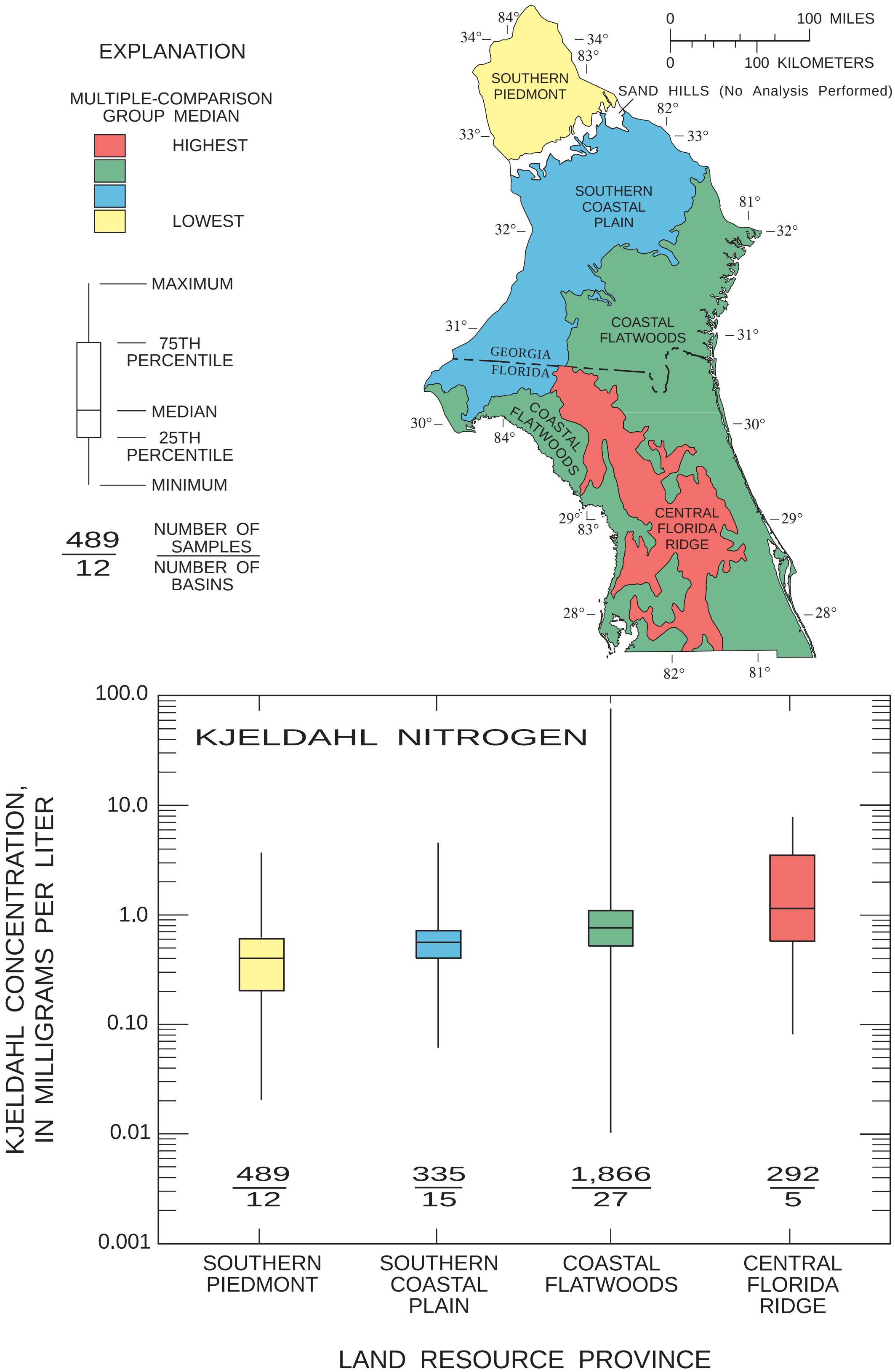

Figure 4. Kjeldahl concentrations among land resource provinces.

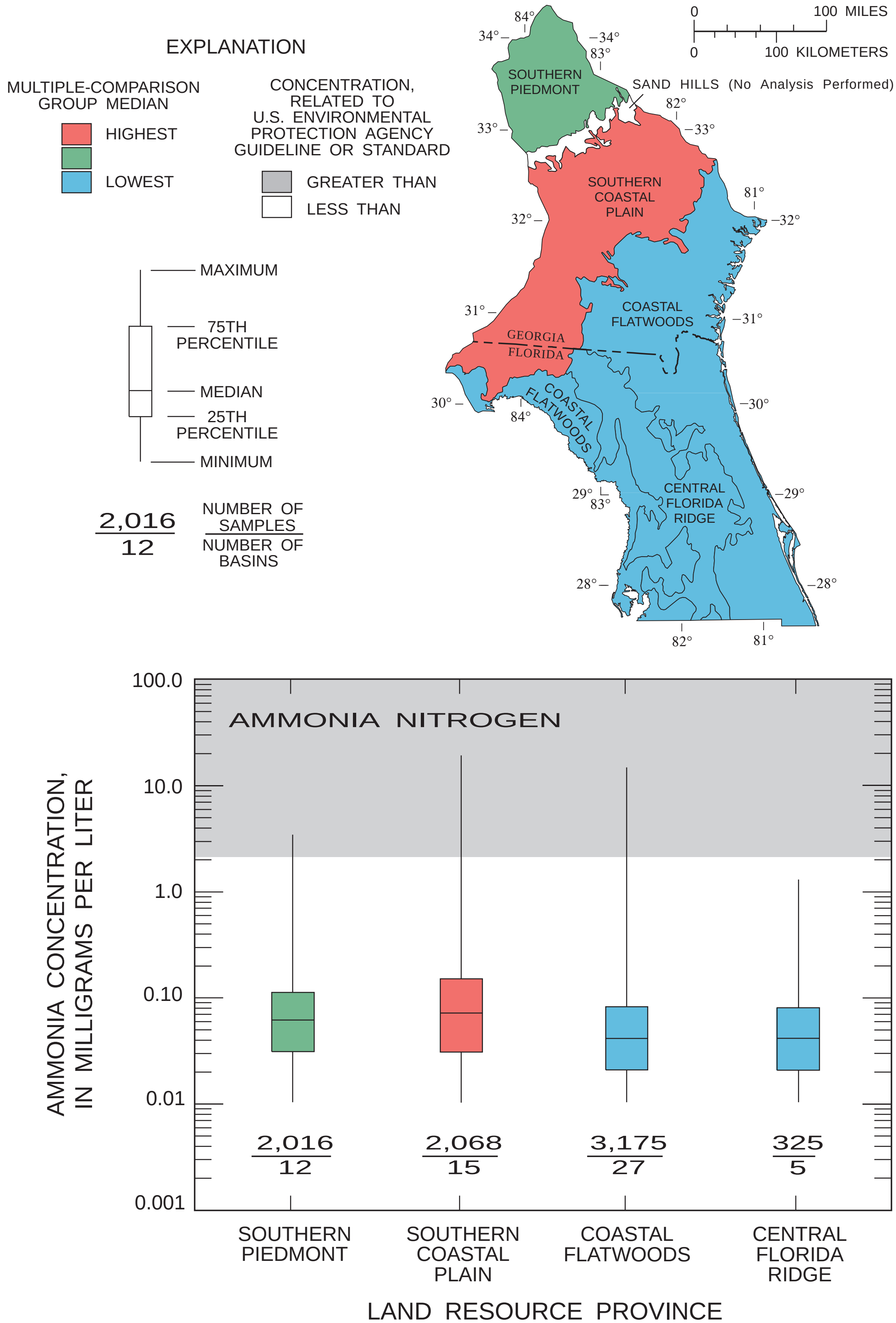

Figure 5. Ammonia concentrations among land resource provinces.

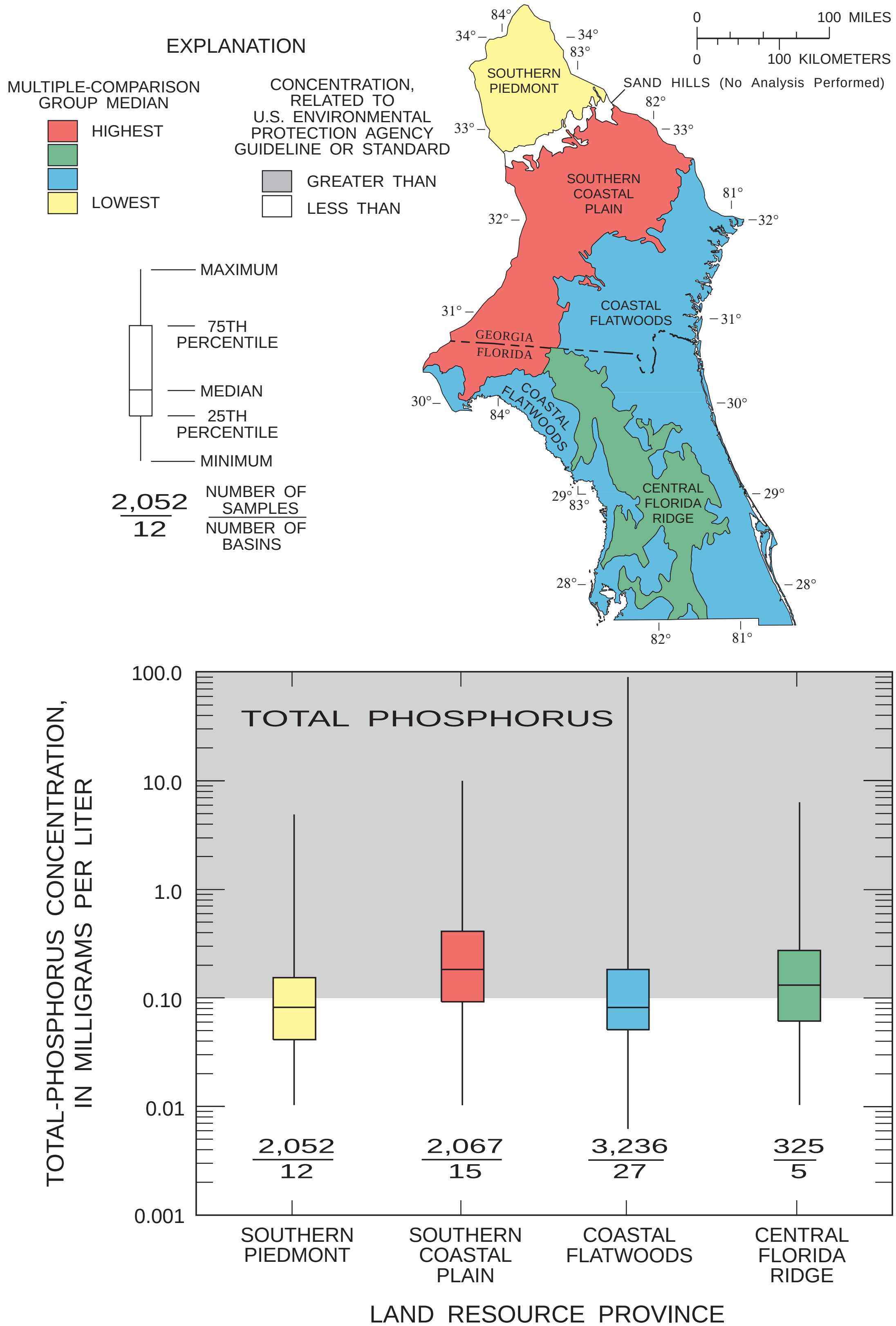

Figure 6. Total-phosphorus concentrations among land resource provinces.

Urban areas are also nutrient sources, including sewage effluent, lawn fertilizer, and storm runoff. Most domestic and industrial wastewaters have relatively large concentrations of ammonia, nitrate, and total phosphorus in comparison to concentrations found in surface waters (Terrio, 1995). Typical nutrient concentrations in wastewater vary according to level of treatment. Nutrient concentrations in runoff from urban areas are affected by many factors, including antecedent conditions, local land use, drainage-system design, climatic season, and street-cleaning practices. Although runoff and natural erosion mobilize nutrients, land disturbances such as construction may exacerbate these processes (Tornes and Brigham, 1994). According to several studies (Uttormark and others, 1974; Donigian and Crawford, 1976; and Manning and others, 1977), the range of total-phosphorus concentrations found in runoff from urban areas is 0.2 to 5.0 mg/L.

Median nitrate concentrations among land-use categories in the study area were less than 0.30 mg/L, which is well below the USEPA drinking water guideline of 10 mg/L for the maximum nitrate concentrations (U.S. Environmental Protection Agency, 1986). Pairwise comparisons of mean ranks showed a significant difference between forested/wetland basins and urban basins; mean ranks among other land-use category pairs were not significantly different (fig. 7). This indicates that the urban and the forested/wetland land-use categories are a contributing factor in explaining differences in nitrate concentrations. The lowest median nitrate concentration of 0.04 mg/L was found in the forested/wetland basins; the median nitrate concentration in urban basins was 0.29 mg/L.

Median kjeldahl concentrations among land-use categories were less than 1.0 mg/L. Pairwise comparisons of the mean ranks of kjeldahl concentrations resulted in no significant differences among land-use categories, indicating that these land-use categories are not a contributing factor in explaining differences in kjeldahl concentrations (fig. 8).

Median ammonia concentrations were less than 0.20 mg/L, which is well below the recommended maximum concentration of 2.1 mg/L for chronic exposure of aquatic organisms (U.S. Environmental Protection Agency, 1986). Pairwise comparisons of mean ranks of ammonia concentrations resulted in no significant difference among agricultural, forested/wetland, and mixed basins, but there was a significant difference between the aforementioned land-use categories and urban basins (fig. 9). This indicates that the urban land-use category is a contributing factor in explaining differences in ammonia concentrations. The highest median concentration was found in urban basins (0.12 mg/L).

Median total-phosphorus concentrations in urban (0.35 mg/L) and agricultural (0.11 mg/L) land-use categories were above the recommended upper concentration limit of 0.1 mg/L (U.S. Environmental Protection Agency, 1986). Pairwise comparisons of mean ranks among land-use categories resulted in no significant difference in total-phosphorus concentrations, indicating that the land-use categories are not a contributing factor in explaining differences in total-phosphorus concentrations (fig. 10).

In general, lower concentrations of nitrates in surface water are associated with the forest/wetland category and higher concentrations are associated with the urban category. In addition, higher ammonia concentrations are associated with the urban category. These results are reasonable based on expected high inputs from urban areas and low inputs from forested and wetland areas. No other associations between nutrient concentrations and the land-use categories were found. However, the lack of a statistical relation between nutrient concentrations and land-use categories does not mean that an association does not exist between land use and nutrient concentrations. The lack of association between nutrient concentrations and the agricultural category was not expected since the removal of nutrients in runoff from agricultural production has been documented (Legg and Meisinger, 1982; Taylor and Kilmer, 1980). If a correlation exists between nutrient concentrations and agricultural land use in the study unit, then perhaps a different algorithm for the land-use categories is needed in order to be more representative of land use in the study area. Other approaches to the lack of association include using a different statistical technique, such as multiple regression, or eliminating large basins from the data set that have a mosaic of land uses.

Nonpoint- and Point-Source Discharges

In any given location, both nonpoint and point-source discharges may contribute to water-quality characteristics. Nonpoint sources can include agricultural runoff (including animal wastes), logging operations, mining, construction runoff, urban runoff, atmospheric deposition, leachates from septic tanks or landfills, salt water intrusion, and hydrologic modifications that alter flow patterns. Nonpoint sources included in this report (fertilizer application, animal wastes, atmospheric deposition, and septic-tank

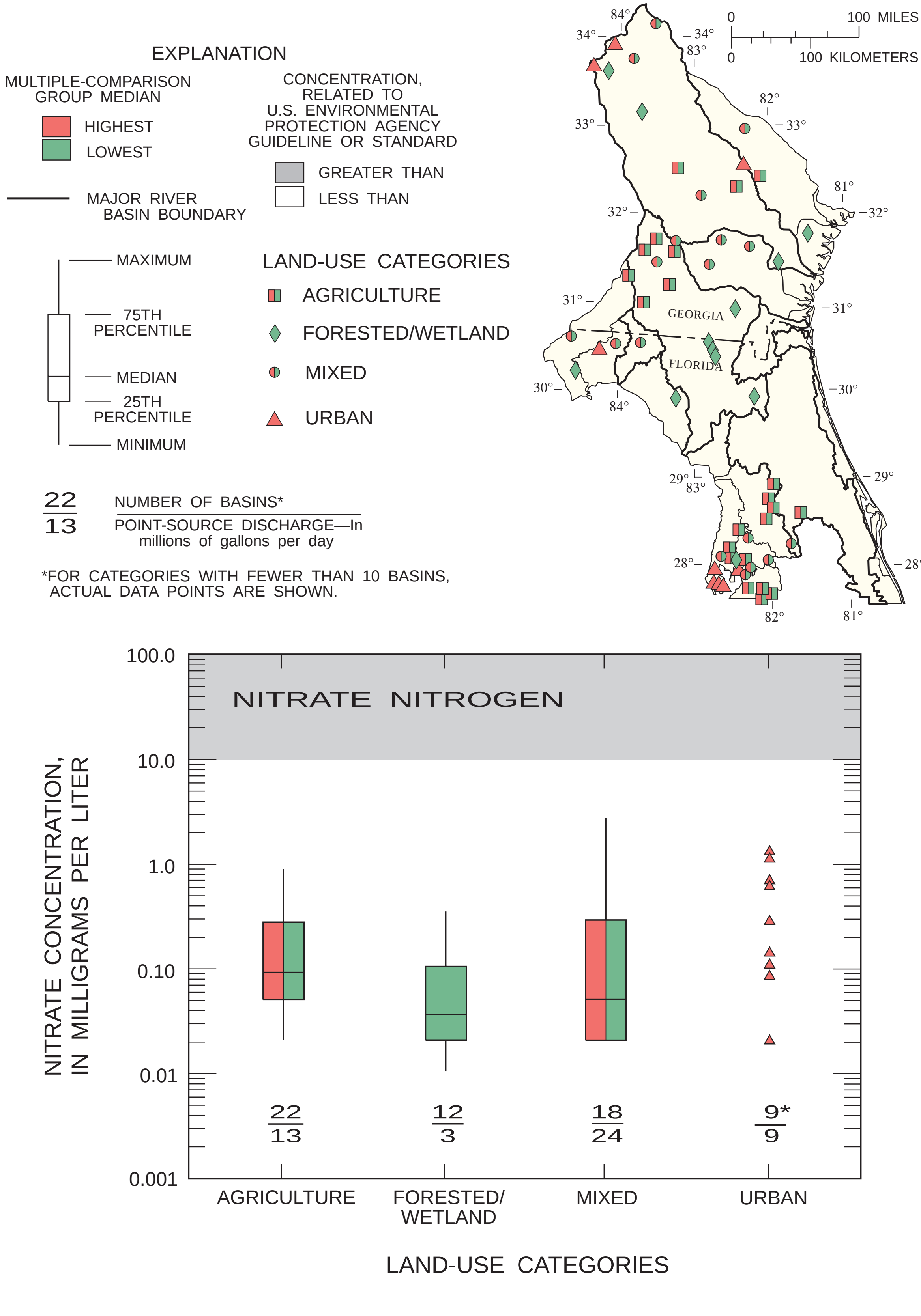

Figure 7. Nitrate concentrations among land-use categories.

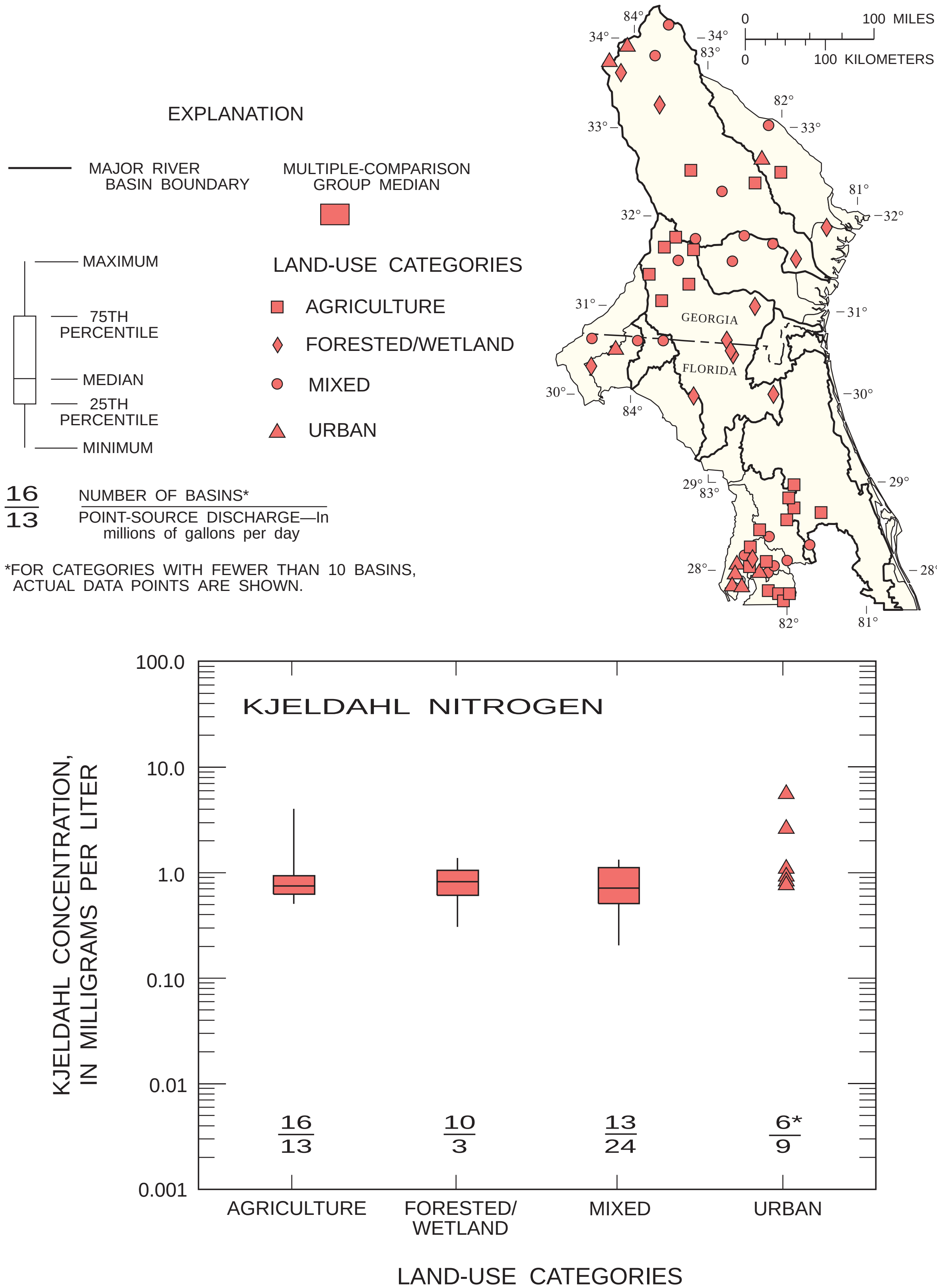

Figure 8. Kjeldahl concentrations among land-use categories.

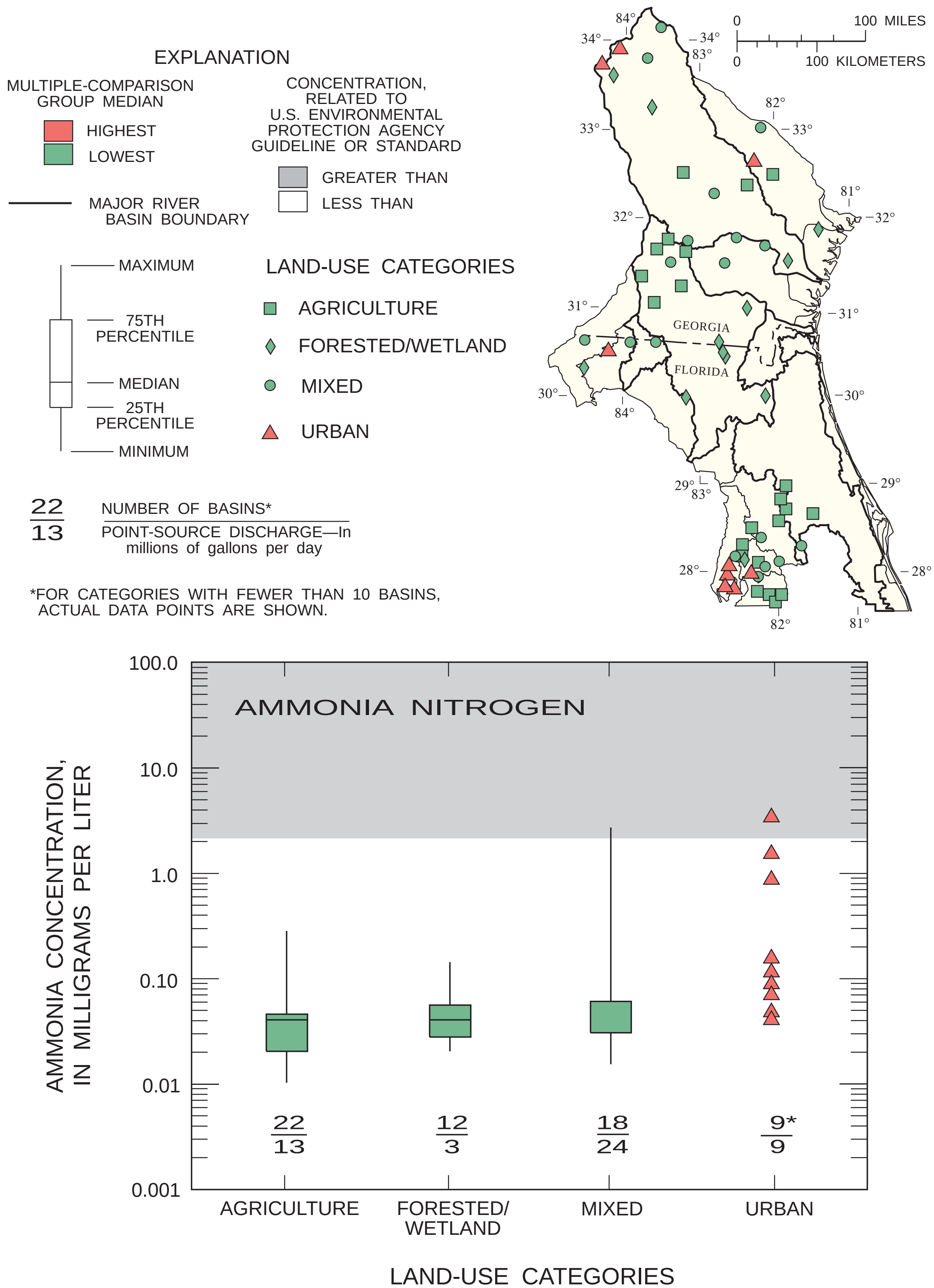

Figure 9. Ammonia concentrations among land-use categories.

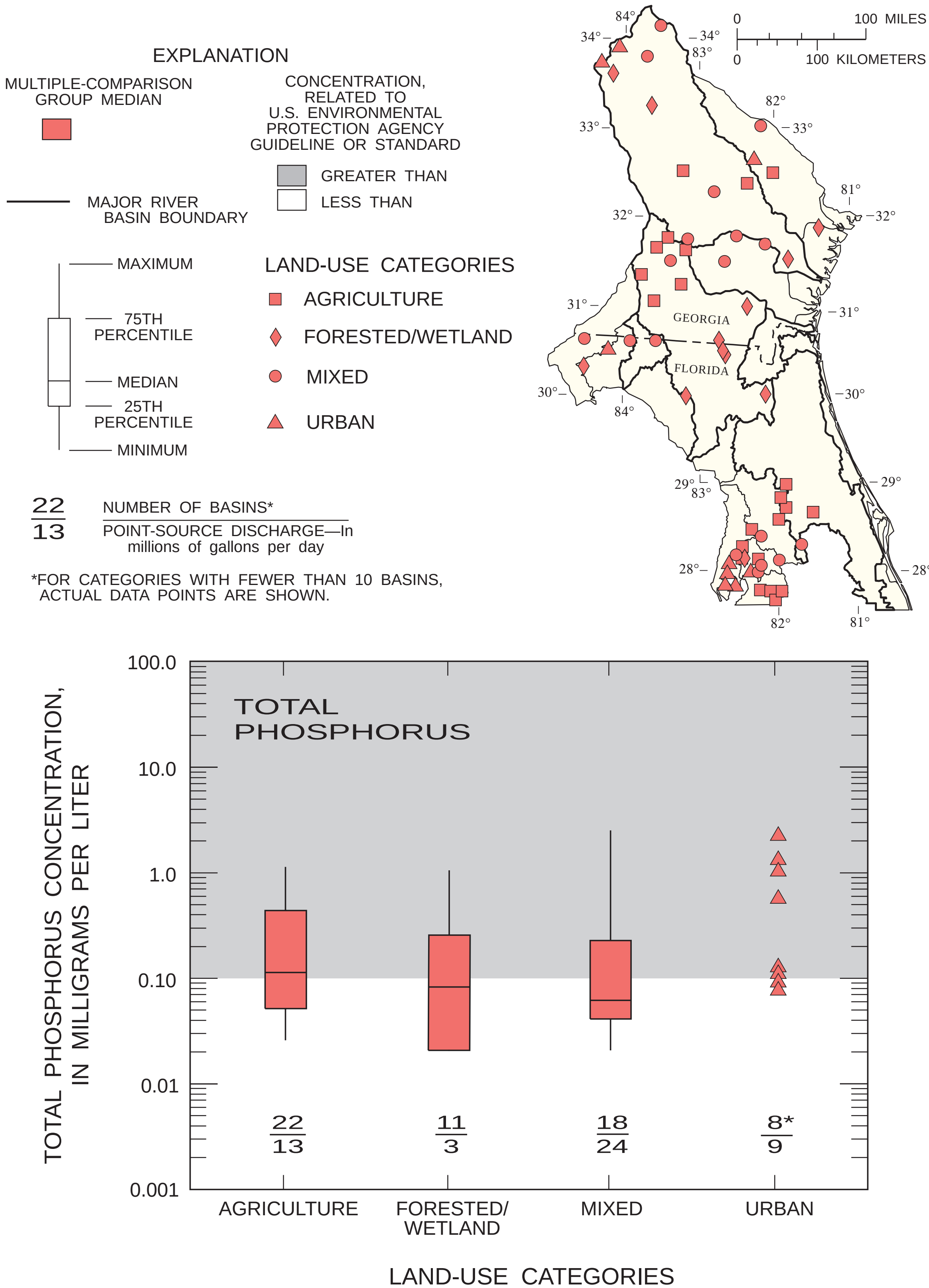

Figure 10. Total-phosphorus concentrations among land-use categories.

discharges) are presented as inputs of nitrogen and phosphorus (Berndt, 1995). Because point-source discharges are more readily determined, they are more easily identified as the source of changes in water quality. In this report, point-source discharges in Georgia include only domestic (municipal) wastewater discharges and in Florida include both domestic and industrial wastewater discharges.

Within the GAFL study unit there were 201 wastewater treatment facilities with discharges of less than 1.0 Mgal/d; 86 facilities with discharges between 1.0 and 10 Mgal/d; and 11 facilities with discharges greater than 10 Mgal/d (fig. 11). The totals from domestic wastewater discharges range from 126 Mgal/d in the Altamaha River basin to 3.9 Mgal/d in the Satilla River basin. Other basins with large wastewater discharges include the St. Johns River basin (71.6 Mgal/d) and the St. Marys River basin (33.7 Mgal/d). River basins with minimal amounts of wastewater discharge include the Aucilla River basin (4.0 Mgal/d), the Ogeechee River basin (6.3 Mgal/d), and the Ochlockonee River basin (8.8 Mgal/d).

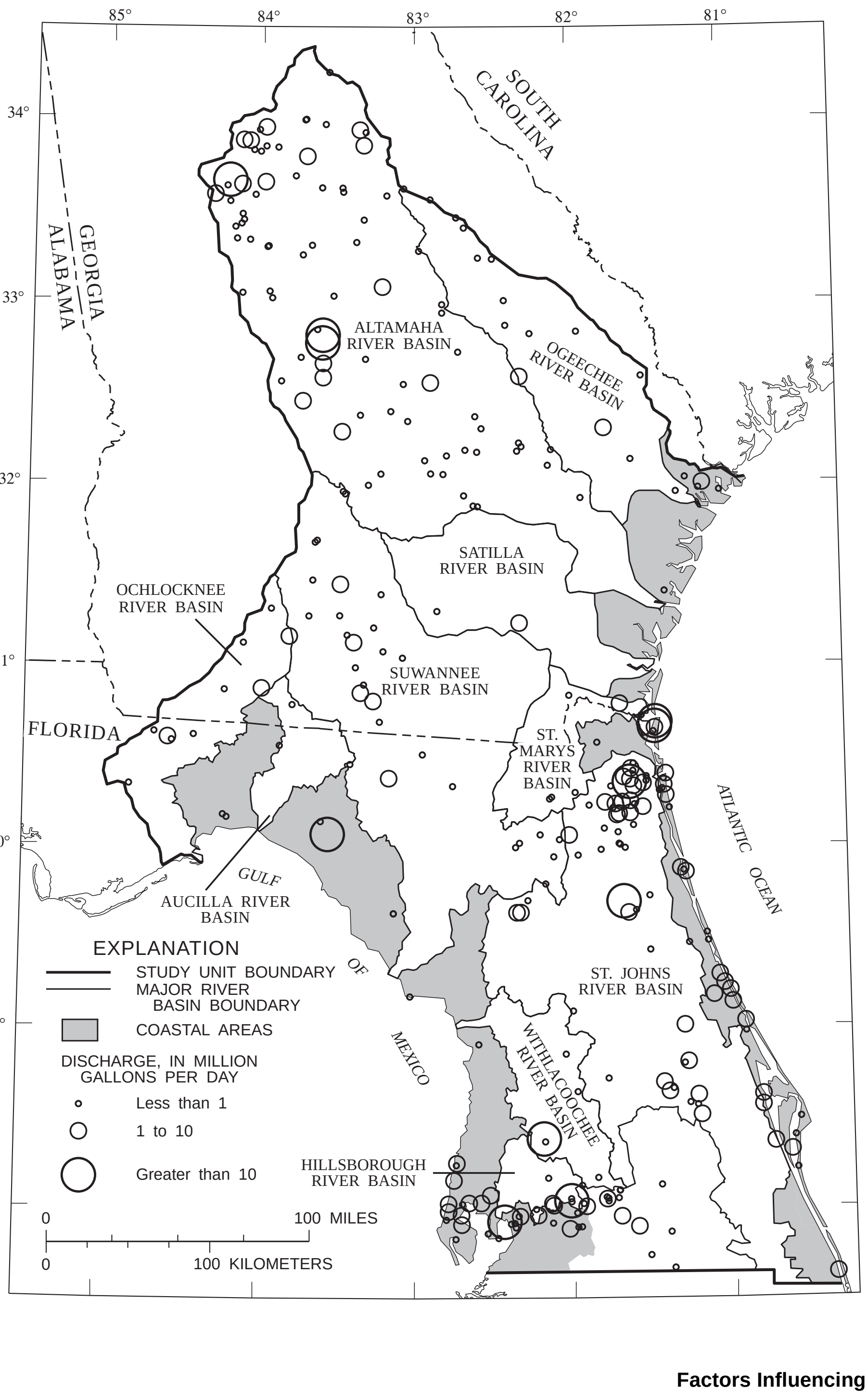

Figure 11. Location of domestic wastewater discharges and their relative amounts of discharge.

NUTRIENT CONCENTRATIONS WITHIN MAJOR BASINS

The major basins in the GAFL study unit include the: Altamaha, Hillsborough, Withlacoochee, Ochlockonee, Ogeechee, St. Johns, St. Marys, Satilla, Suwannee, and Aucilla Rivers (table 2). Data analysis was performed on major basins because they reflect changes within hydrologic systems. The analysis of river miles from the mouth of the river indicates where water quality changes in the river system and, together with other spatial data, gives indications as to why those changes might have occurred. River segments (upper, middle, and lower) were established to identify changes locally and basin wide.

When data for each river basin were aggregated and summarized, the highest median nutrient concentrations were found in the Ochlockonee and Hillsborough River basins. Agricultural runoff, wastewater treatment plant effluent, and strip mining each affect the Ochlockonee River and its tributaries (Hand and others, 1990). Development and construction have increased nutrient loading in the Hillsborough River basin (Hand and others, 1990). Overall, the lowest median nutrient concentrations were found in the Aucilla River basin. The Ogeechee and St. Marys River basins also had low nutrient concentrations.

Median nitrate concentrations among major basins were less than 1.0 mg/L, which is below the USEPA MCL of 10 mg/L (U.S. Environmental Protection Agency, 1986). Pairwise comparisons among river basins identified several basins where the mean ranks of the nitrate concentrations were significantly different (fig. 12). The highest median nitrate concentrations occurred in the Ochlockonee River basin (0.46 mg/L) and the Altamaha River basin (0.38 mg/L). There is little development in the flood plain of the Ochlockonee River basin and areas near the river are frequently tilled and farmed in row crops (Berndt and others, 1995). The amount of wastewater discharge entering rivers within the Altamaha River basin totals 126 Mgal/d. The lowest median nitrate concentrations occurred in the Withlacoochee River basin (0.02 mg/L), the St. Marys River basin (0.04 mg/L), and the Aucilla River basin (0.07 mg/L).

Pairwise comparisons of mean ranks in kjeldahl concentrations resulted in no significant difference in concentrations among the Suwannee, Aucilla, Ochlockonee, St. Marys, and Satilla River basins and no significant difference in concentrations between the Altamaha and Ogeechee River basins (fig. 13). The highest median kjeldahl concentration occurred in the St. Johns River basin (1.24 mg/L), followed by the Hillsborough River basin (1.02 mg/L) and the Withlacoochee River basin (0.90 mg/L). The St. Johns River and Hillsborough River basins are heavily populated. The lowest median kjeldahl concentrations occurred in the Altamaha River basin (0.40 mg/L) and the Ogeechee River basin (0.50 mg/L).

Median ammonia concentrations among major basins were less than 0.1 mg/L, which is well below the recommended upper concentration limit of 2.1 mg/L (U.S. Environmental Protection Agency, 1986). Pairwise comparisons of mean ranks of ammonia concentrations among river basins identified no significant differences between the Hillsborough, St. Johns, St. Marys, Satilla, and Ogeechee River basins (fig. 14). The highest median concentration occurred in the Ochlockonee River basin (0.08 mg/L), followed by the Altamaha River basin (0.06 mg/L). The effluent from the various wastewater treatment plants in the Ochlockonee River basin (8.8 Mgal/d) may contribute to the higher ammonia values. The 126 Mgal/d of wastewater discharge entering the Altamaha River basin may influence the ammonia concentrations. The lowest median ammonia concentrations occurred in the Withlacoochee and Aucilla River basins (0.02 mg/L for both).

The highest median total-phosphorus concentration occurred in the Hillsborough River basin (0.42 mg/L), followed by the Ochlockonee River basin (0.26 mg/L) and the Suwannee River basin (0.21 mg/L) (fig. 15). Median total-phosphorus concentrations for these three basins were greater than the recommended upper concentration limit of 0.1 mg/L (U.S. Environmental Protection Agency, 1986). Phosphate mining occurs in both the Hillsborough and Suwannee River basins, perhaps explaining the high median total-phosphorus concentrations (Florida Department of Natural Resources, 1989). The lowest median total-phosphorus concentrations occurred in the Withlacoochee (0.04 mg/L), Aucilla (0.06 mg/L), St. Marys (0.05 mg/L), and the Ogeechee (0.07 mg/L) River basins.

The remainder of this section is a description of the individual major river basins. Reference to land use in this section applies to USGS digital land-use data (Anderson and others, 1976), not the land-use categories previously described in this report. Because of the quantity of the information contained on the figures, the text includes a brief description of the basin hydrology, historical water-quality characteristics, and general patterns in nutrient concentrations, including

Table 2. Environmental characteristics of major basins

[SP, Southern Piedmont; SCP, Southern Coastal Plain; CFR, Central Florida Ridge; SH, Sand Hills; CFW, Coastal Flatwoods; NPDES, National Pollutant Discharge Elimination System; Mgal/d, million gallons per day; mi^2, square miles]

QUADRANGLES REPRESENT CONSTITUENTS INDICATED

Nitrate Nitrogen — Ammonia Nitrogen

Kjeldahl Nitrogen — Total Phosphorus

HIGHEST — LOWEST

Striping indicates that the mean ranks of that constituents concentration in that basin were not significantly different from two other mean ranks.

Median concen-trations	Basin	Land resource provinces (in percent)					Land use (in percent)					NPDES volume (Mgal/d)	River type	Drain-age area (mi^2)
		SP	SCP	CFR	CFW	SH	Agricul-ture	Forest	Urban	Wet-lands	Other [2]			
	Hillsborough	0.0	0.0	71.5	28.5	0.0	24.83	3.53	24.53	29.38	17.73	18.1	blackwater	690
	Withlacoochee	0.0	0.0	59.1	40.9	0.0	38.62	19.17	8.39	24.81	9.01	11.4	blackwater/ springfed	2,059
	St. Johns	0.0	0.0	43.4	56.6	0.0	20.51	35.90	11.26	18.34	13.99	104.4	blackwater	9,168
	Suwannee	0.0	30.9	26.2	42.9	0.0	30.90	50.03	1.87	16.45	0.75	22.1	blackwater/ springfed	[1] 9,950
	Aucilla	0.0	78.8	0.0	21.2	0.0	25.13	54.87	2.72	16.56	0.72	4.0	springfed	952
	Ochlockonee	0.0	77.9	0.0	22.1	0.0	30.04	57.64	2.63	8.11	1.58	8.8	alluvial	2,250
	St. Marys	0.0	0.0	0.0	100.0	0.0	2.98	67.56	2.24	26.35	0.87	33.7	blackwater	[1] 1,480
	Satilla	0.0	12.4	0.0	87.6	0.0	26.12	55.92	1.28	16.32	0.36	3.9	blackwater	3,400
	Altamaha	40.6	46.8	0.0	6.3	6.3	26.04	62.87	5.17	5.17	0.75	126.1	alluvial	14,200
	Ogeechee	6.4	62.3	0.0	24.9	6.4	35.83	47.54	1.72	13.92	0.99	5.6	blackwater	4,410

[1] Includes part of the watershed in Okeefenokee Swamp, which is indeterminate.
[2] Includes barren, rangeland, and water.

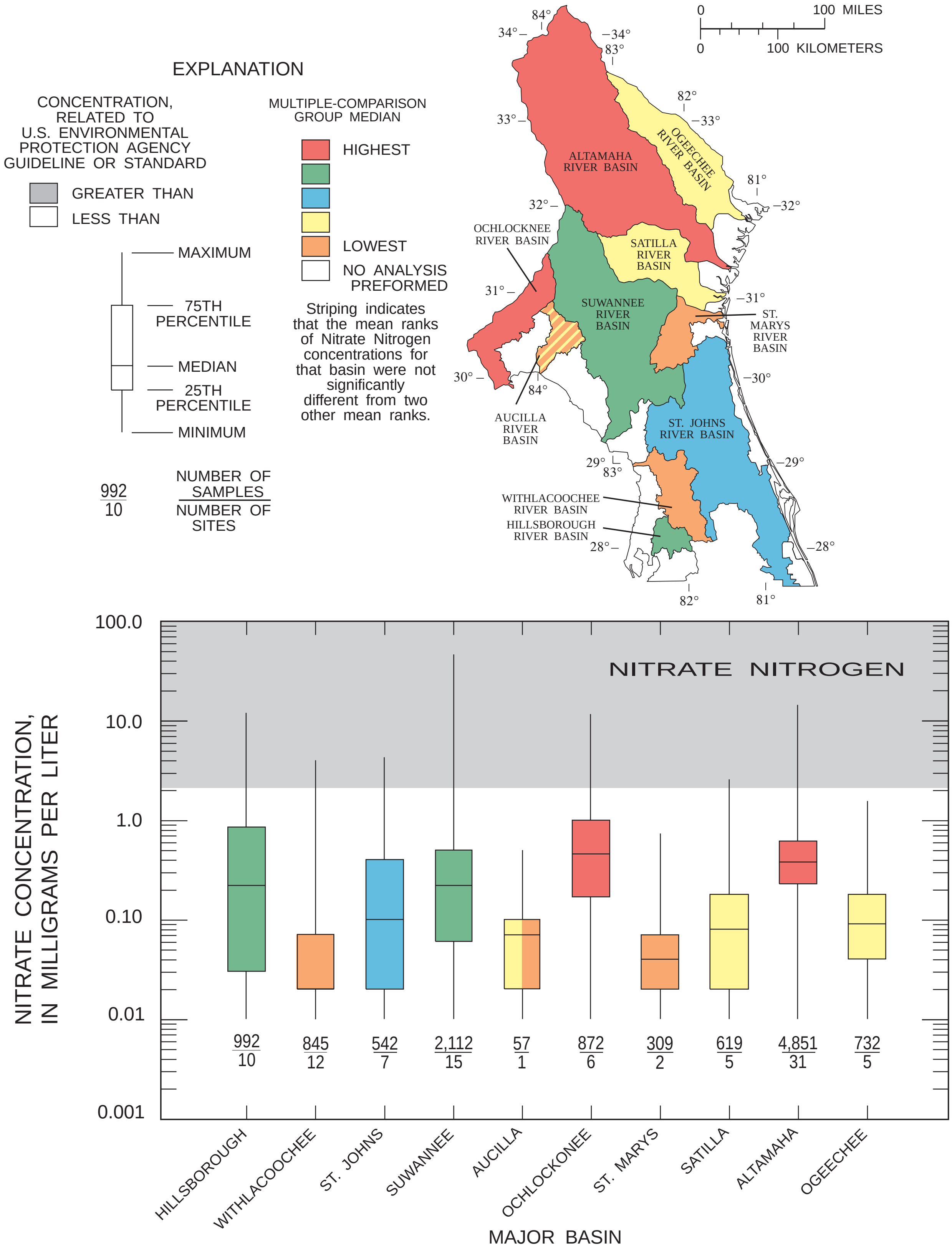

Figure 12. Nitrate concentrations among major river basins.

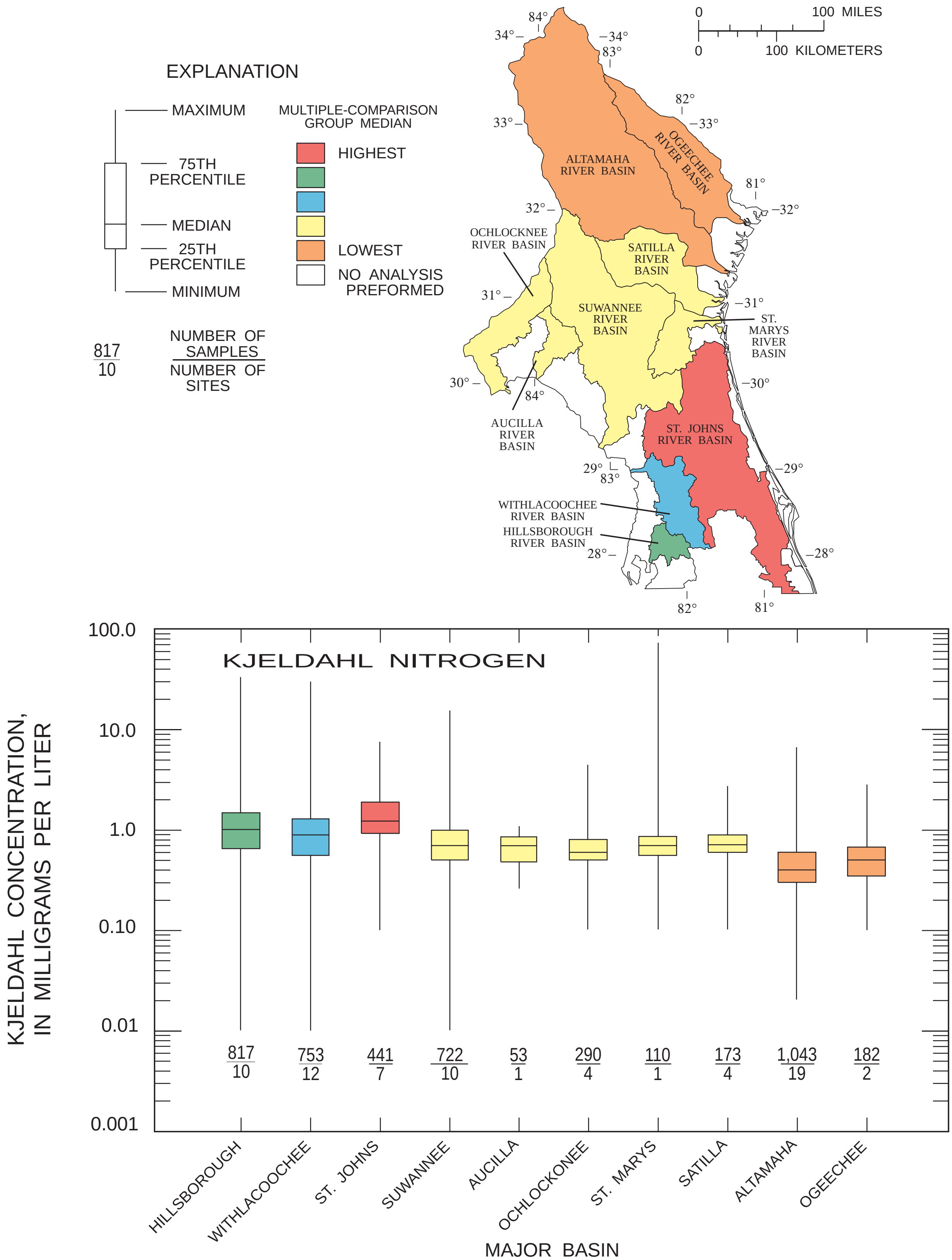

Figure 13. Kjeldahl concentrations among major river basins.

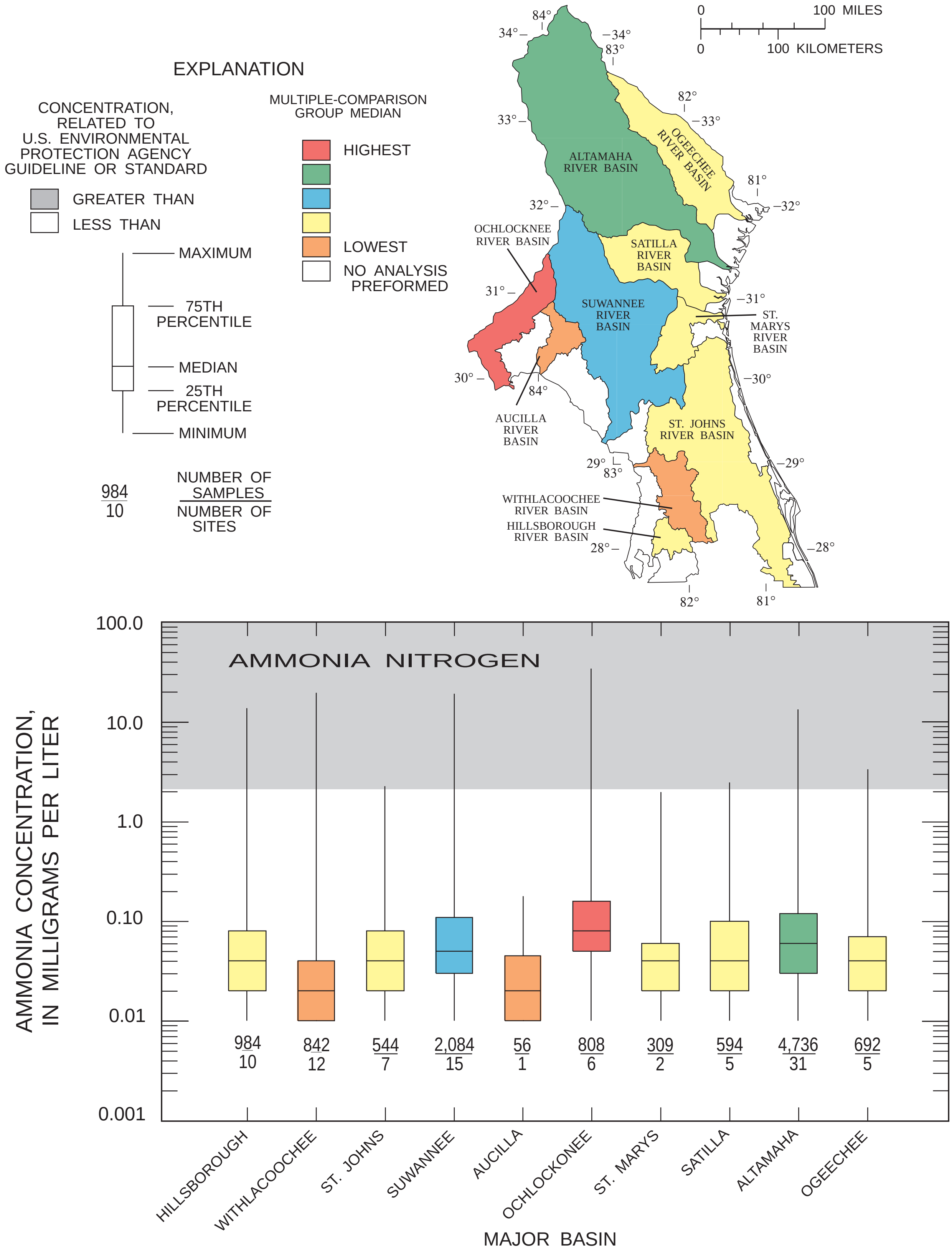

Figure 14. Ammonia concentrations among major river basins.

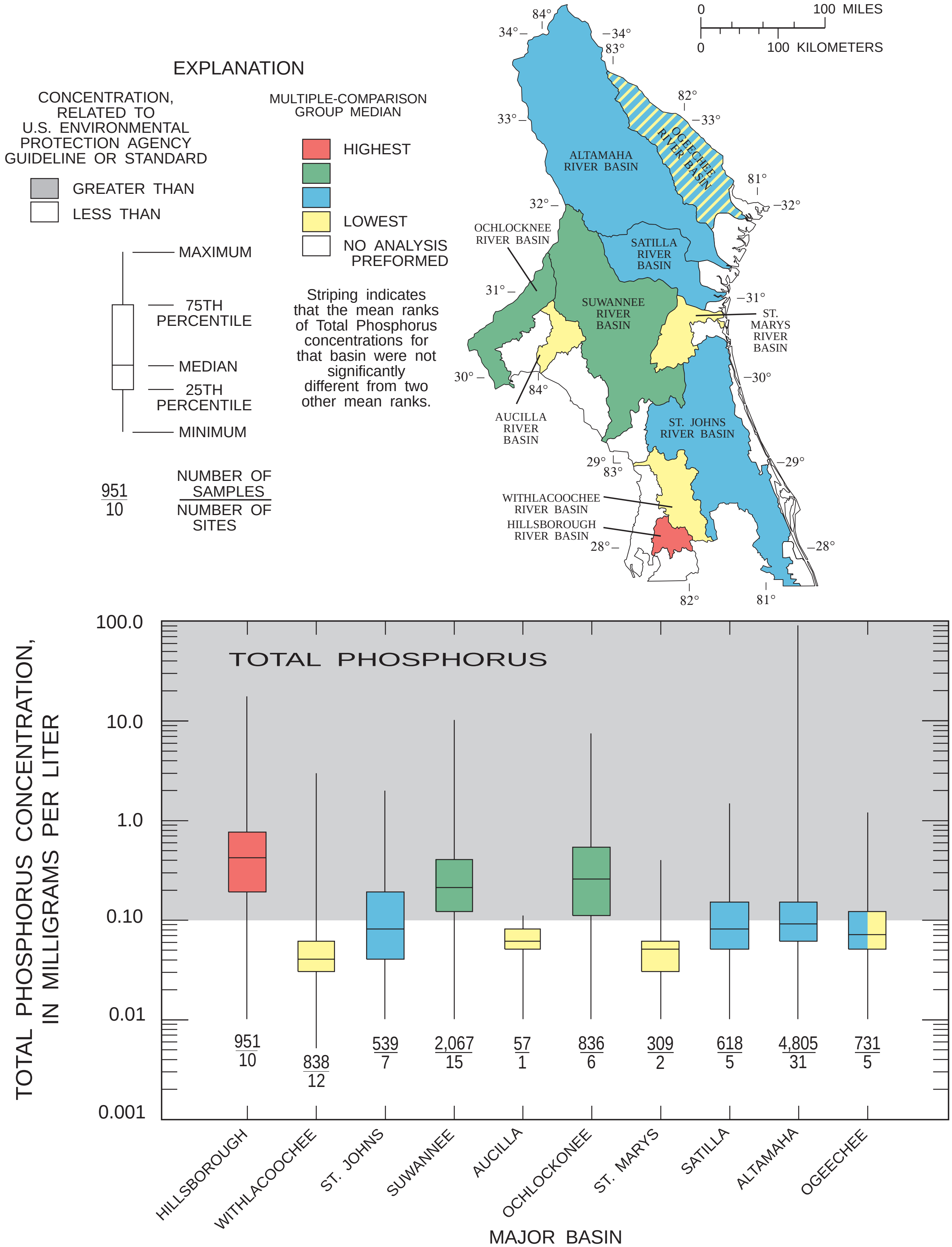

Figure 15. Total-phosphorus concentrations among major river basins.

extremes and changes in concentrations. Included on the first figure for each major basin are—surface-water site locations, color-coded multiple-comparison group medians, wastewater treatment sites, nitrogen and phosphorus inputs (Berndt, 1995), and population density (U.S. Bureau of Census, 1991a,b). The second figure for each major basin contains the nutrient concentrations (shown as color-coded boxplots) and their approximate location, expressed in river miles, from the mouth of the river. The color-coding for both the group medians and the boxplots is the result of the statistical tests performed to determine differences in the median concentration of a nutrient among sites.

Hillsborough River Basin

The Hillsborough River, with a drainage area of 690 mi^2, is a blackwater river with springfed influences that originates in the Green Swamp and flows southward for about 55 mi to Hillsborough Bay in the center of Tampa, Fla. The river basin includes the land resource provinces of the Central Florida Ridge and the Coastal Flatwoods (fig. 2). Predominant land use in the basin is agriculture, urban, and wetland (table 2). The Hillsborough River basin is characterized by very low stream gradient and poorly defined basin divides (Berndt and other, 1995).

According to Hand and others (1990), water quality in the Hillsborough River basin is generally fair with generally poor quality in several tributaries. Water quality is affected by discharges from wastewater treatment plants, phosphate and citrus processing plants, and runoff from urban, agricultural, rangeland, and phosphate- mining areas (Hand and others, 1990). Development and construction have increased sedimentation and nutrient loading in the system (Hand and others, 1990). Median nitrate and ammonia concentrations did not exceed USEPA standards and guidelines; however, median total-phosphorus concentrations were above the USEPA recommended upper concentration limit (0.1 mg/L) at all sites in the Hillsborough River basin.

In general, higher nutrient concentrations were found in the northeastern part of the river basin (figs. 16 and 17). Higher nutrient concentrations were found on Blackwater Creek (site 2), located in the upper part of the basin, than elsewhere in the basin. Water quality in Blackwater Creek has been generally poor, historically, due to mining and rangeland runoff (Hand and others, 1990). Another potential source of increased nutrient concentrations on Blackwater Creek could be wastewater discharges of 10.9 Mgal/d upstream. Some of the highest median kjeldahl (1.4 mg/L) and ammonia (0.12 mg/L) concentrations were found at site 13, an area that has a very high population density. Various sites in the western part of the basin (sites 7, 8, 12 and 13) are ranked higher in ammonia and/or kjeldahl concentrations than nitrate and total phosphorus, indicating that point-source discharges could be influencing the water quality rather than nonpoint-source discharges. Higher total-phosphorus concentrations were found on tributaries—Blackwater Creek (site 2), Pemberton Creek (site 4), and Flint Creek (site 5)—than anywhere else in the basin.

The river segment from site 3 to the confluence with Flint Creek has been considered to have generally the best water quality within the Hillsborough River basin (Hand and others, 1990). The median concentration of nitrate and total phosphorus decreases between sites 3 and 7 on the main stem, a distance of 13 river miles. The lowest median nitrate concentrations occurred at Flint Creek (sites 5) and Cypress Creek (site 8), which enters the middle Hillsborough River. There was no significant difference in mean ranks for kjeldahl and ammonia concentrations for sites on the main stem of the Hillsborough River (sites 1, 3, 7, and 11).

Nitrate, kjeldahl, and ammonia concentrations evaluated in this report in the Hillsborough River basin were low, whereas total-phosphorus concentrations exceeded USEPA guidelines. In general, the spatial distribution of the higher nutrient concentrations was in the northeast part of the river basin. Specifically, higher nutrient concentrations were found on Blackwater Creek (site 2) where, historically, water quality has been generally poor.

Withlacoochee River Basin

The Withlacoochee River (the southern stream of the two Withlacoochee Rivers included in the study unit) drains 2,059 mi^2. It begins in the Green Swamp and flows northward approximately 157 mi to the Gulf of Mexico. The Withlacoochee River basin is in the land resource provinces of the Coastal Flatwoods and Central Florida Ridge (fig. 2). Land use in the basin is primarily forest, agriculture, and wetland (table 2). Although no major cities are located directly on the river, several suburban housing developments are located within the basin. Many alterations have been made in the mainstem and tributaries, including a complete diversion of the river near the mouth into the Cross-Florida Barge Canal in 1969. The river is tidally influenced (Berndt and others, 1995). Streams in the basin have a mix of blackwater characteristics and springfed influences.

Median concentrations of nitrate, ammonia, and total phosphorus were generally low and were below the USEPA's upper concentration limit in the Withlacoochee River basin (figs. 18 and 19). All median kjeldahl concentrations are less than 2.0 mg/L in the basin. The water quality in the Withlacoochee River basin is generally very good; however, the water quality in the basin is affected by discharges from wastewater-treatment plants, phosphate and citrus processing plants, septic tank leachate, and runoff from urban, agricultural, and phosphate-mining areas (Hand and others, 1990).

Nutrient concentrations were low throughout the basin, with median ammonia and total-phosphorus concentrations showing little variability. The consistently low median total-phosphorus concentrations throughout the basin are reflective of the low levels of phosphorus input. Median nitrate concentrations were lower in the upper Withlacoochee River basin, perhaps due to ground water inputs, and higher in the lower part of the river basin.

Increased nitrate and ammonia concentrations at site 19, located in the middle Withlacoochee River basin, may have been caused by the elevated nutrient concentrations from the Little Withlacoochee River (site 18) and the 10.2 Mgal/d of wastewater discharge. The Little Withlacoochee River is influenced by agriculture, forest, and runoff from residential areas and septic tanks (Hand and others, 1990). Increased total-phosphorus concentrations at site 19 may have been caused by the high level of phosphorus inputs entering the Withlacoochee River upstream. High median kjeldahl concentrations found in the upper part of the Withlacoochee River may be attributed to the Green Swamp. The highest median nitrate concentrations were found in the lower Withlacoochee River basin at Rainbow Springs (site 25) and Blue Run (site 26).

St. Johns River Basin

The St. Johns River is the longest river within Florida, draining approximately 9,168 mi^2. It flows northward for 273 mi, through a number of natural lakes and is joined by many creeks and streams before emptying into the Atlantic Ocean east of Jacksonville. Springs are common and flow is from slightly higher coastal areas to lower marshes and swamps. 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). The St. Johns River basin is heavily populated (fig. 20). The land resource provinces included in the St. Johns River basin are the Central Florida Ridge and the Coastal Flatwoods (fig. 2). Land use within the river basin includes forest, agriculture, and urban areas (table 2).

The St. Johns River basin is an important resource in Florida and is the subject of numerous environmental studies by state and local agencies. However, within this section of this report the river is represented by only three sites and will, therefore, have limited interpretation.Of these three sites, one is located on a canal (site 33), one on a tributary (site 34), and one on the main stem of the St. Johns River (site 35).

Water quality has been impacted by development and industrial contamination. In the Jacksonville area, the most industrialized region in Florida, the river receives discharges from: paper mills; wire, chemical, and paper industries; packaging plants; wastewater treatment plants; urban and stormwater runoff; and runoff from shipyards (Hand and others, 1990). The three sites in the St. Johns River basin are upstream from Jacksonville. The median concentrations of nitrate, ammonia, and total phosphorus for the three sites in the St. Johns River basin did not exceed USEPA guidelines, except for the median total-phosphorus concentration at site 33 (0.27 mg/L) (figs. 20 and 21). The highest median kjeldahl concentration was found at site 33 on the Apopka-Beauclair Canal (4.0 mg/L), followed by the concentration at site 35 on the St. Johns River (1.03 mg/L).

Suwannee River Basin

The main stem of the Suwannee River has its headwaters in the Okefenokee Swamp in Georgia, flows southward for approximately 245 mi to the Gulf of Mexico, and has a drainage area of approximately 9,950 mi^2 (Florida Board of Conservation, 1966). The waters of the Suwannee River are usually acidic, reflecting the contribution of the Okefenokee and other swamp drainages, and high in organic content (Wharton and others, 1977). During low-flow periods much of the river's flow is from tributary springs and during high-flow periods some river water discharges into

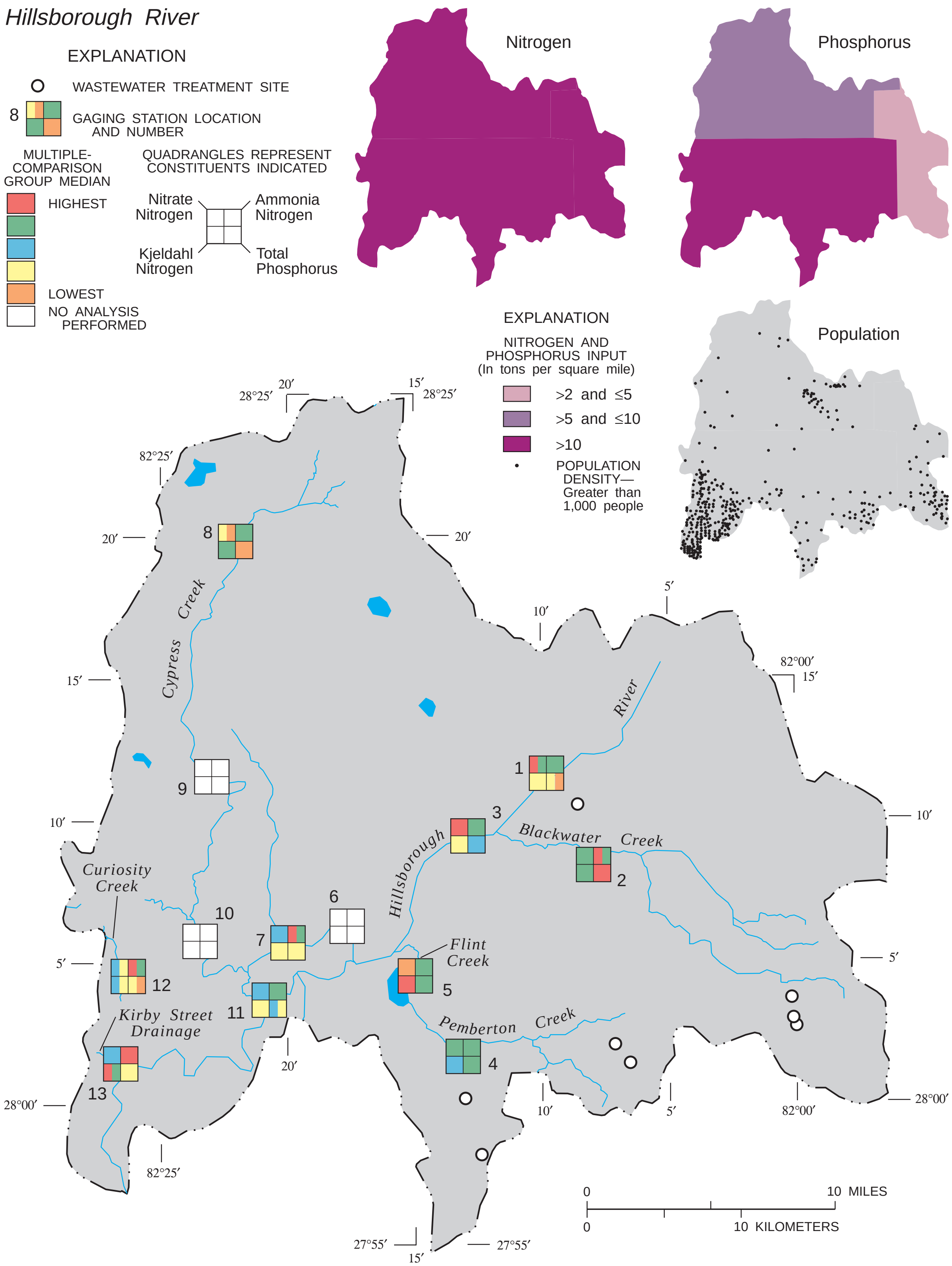

Figure 16. Distribution of population, nitrogen and phosphorus inputs, wastewater discharge locations, and site locations in the Hillsborough River basin.

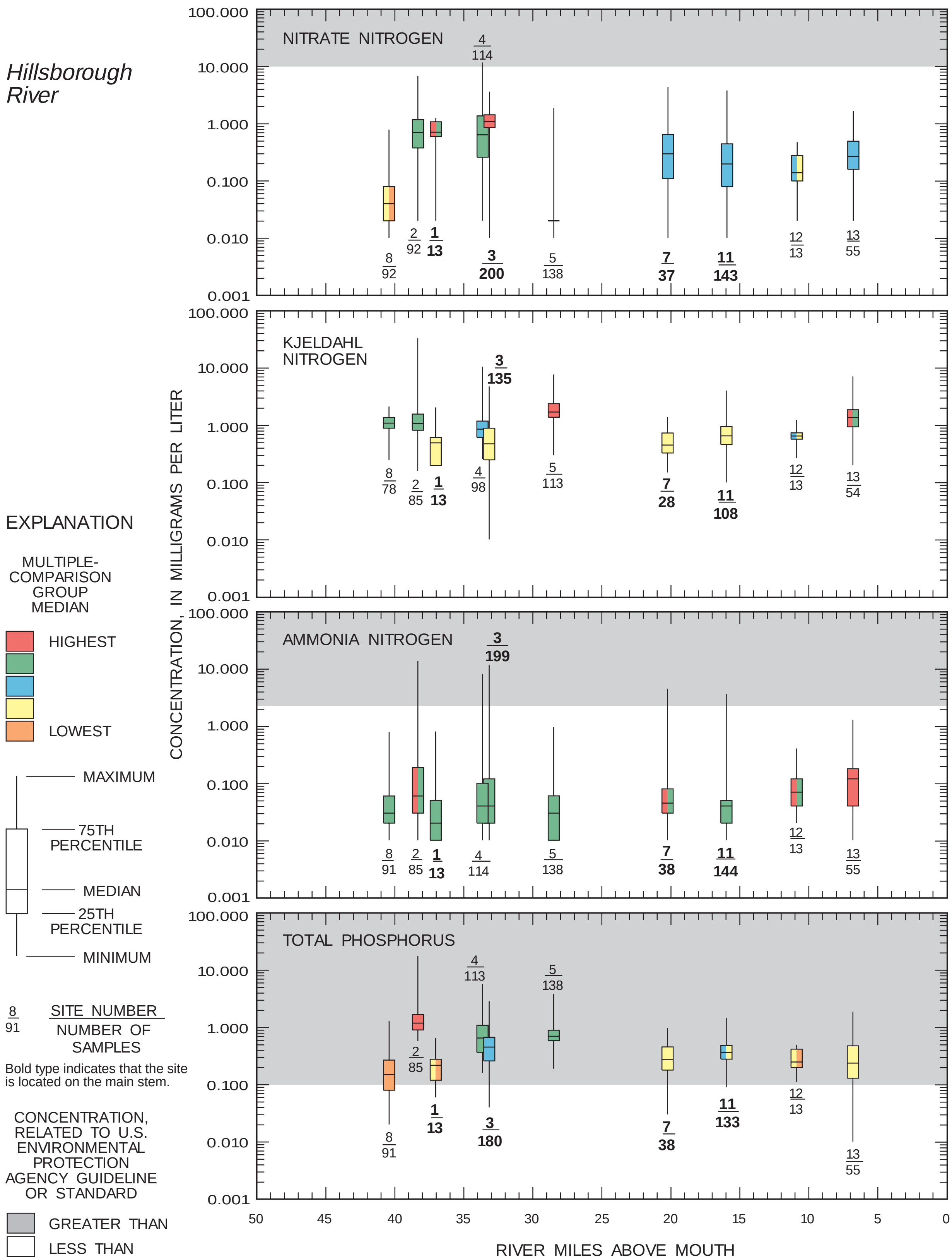

Figure 17. Nutrient concentrations along river miles in the Hillsborough River basin.

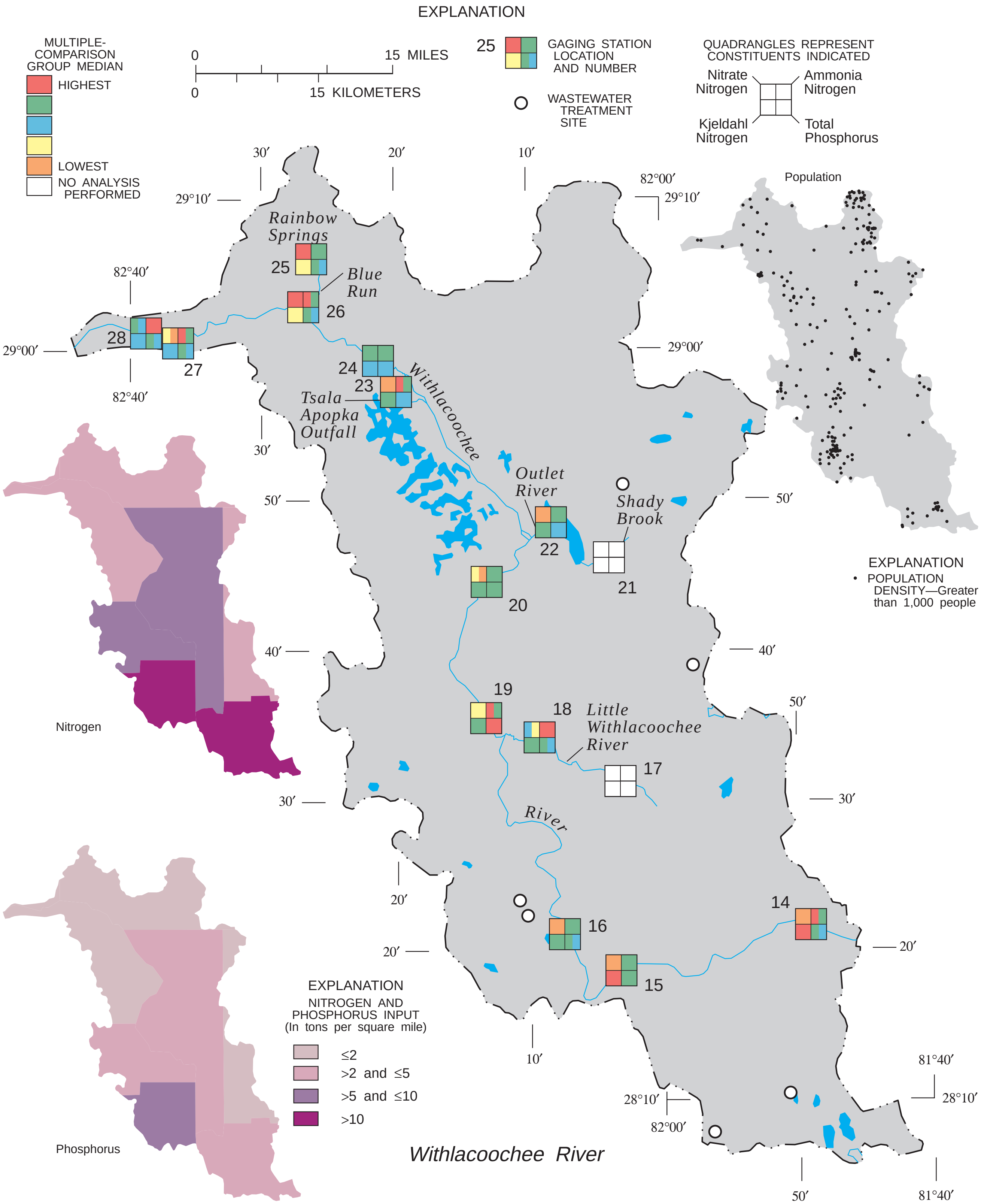

Figure 18. Distribution of population, nitrogen and phosphorus inputs, wastewater discharge locations, and site locations in the Withlacoochee River basin.

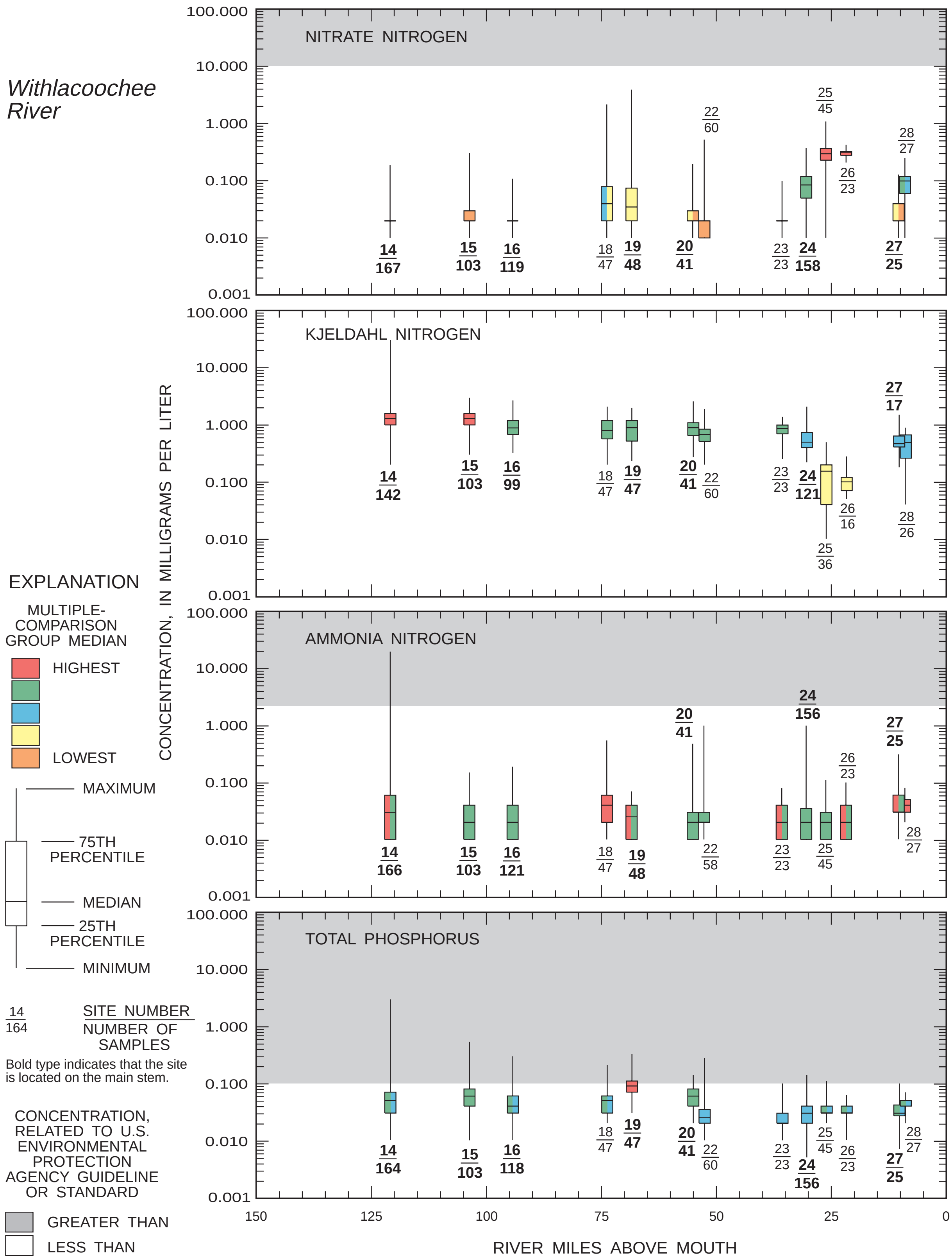

Figure 19. Nutrient concentrations along river miles in the Withlacoochee River basin.

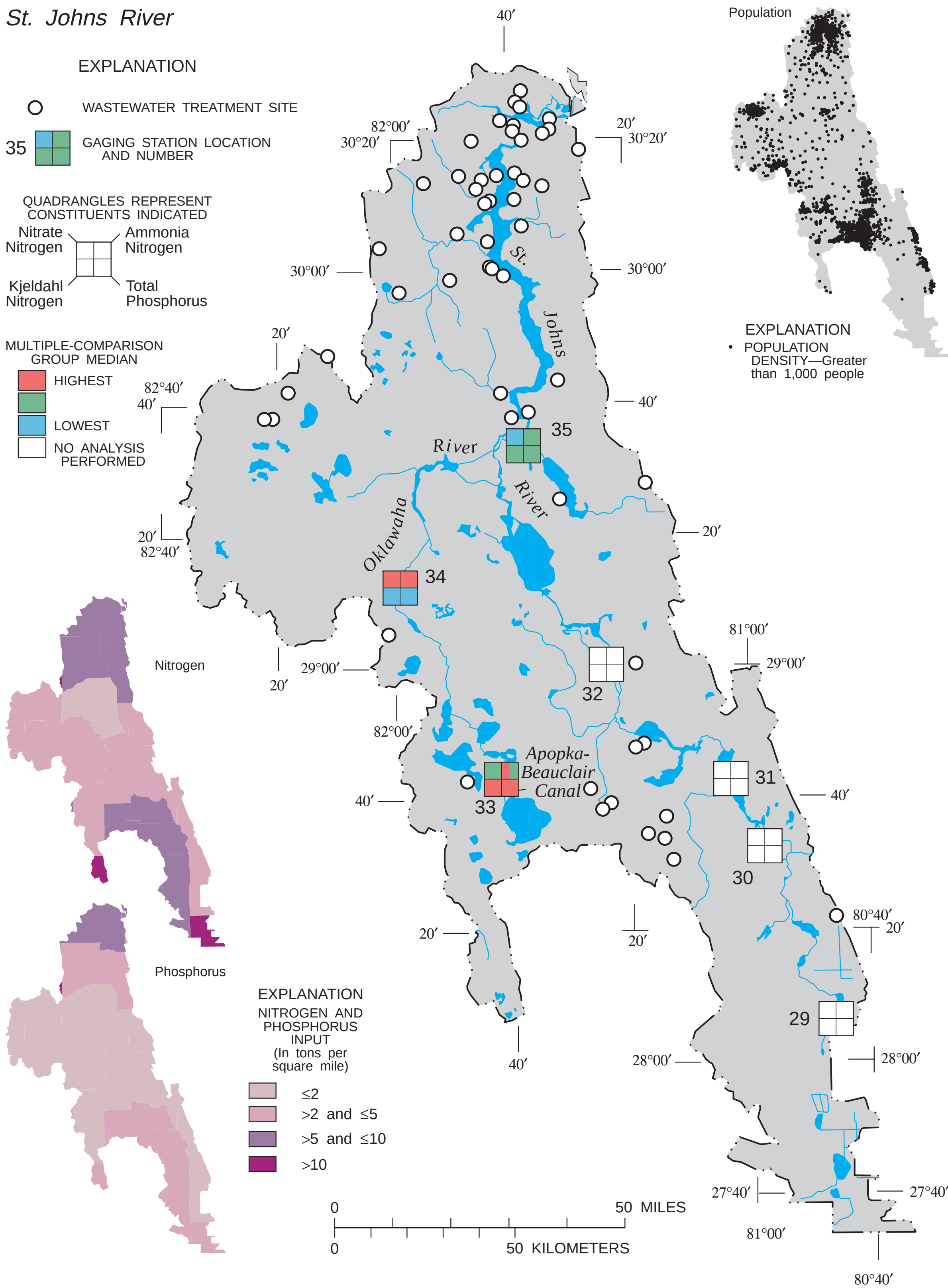

Figure 20. Distribution of population, nitrogen and phosphorus inputs, wastewater discharge locations, and site locations in the St. Johns River basin.

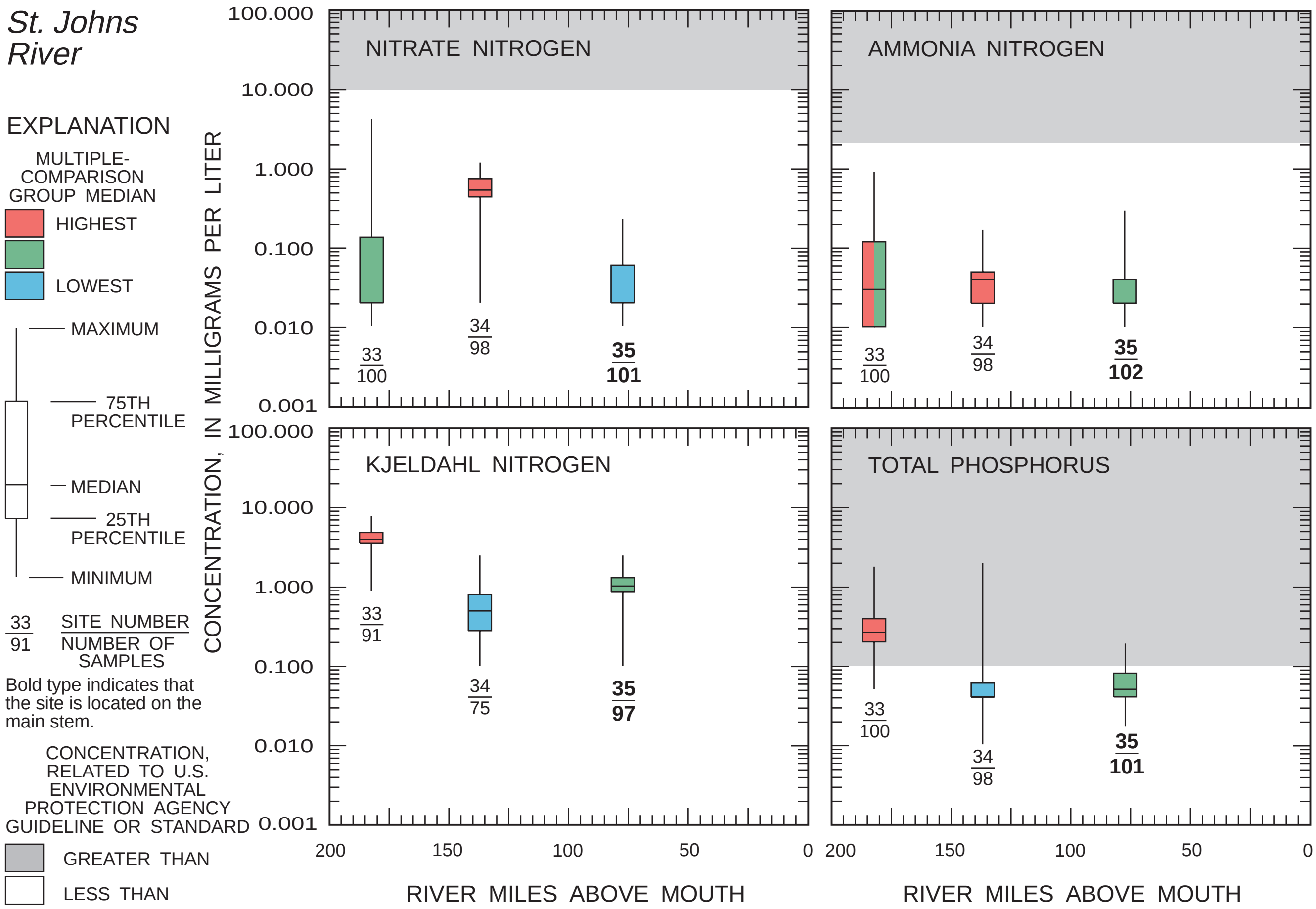

Figure 21. Nutrient concentrations along river miles in the St. Johns River basin.

springs. However, the Suwannee River is generally considered a blackwater river. Within the Suwannee River basin there is karst topography and naturally occurring phosphate deposits resulting in relatively high background phosphorus concentrations. Predominant land uses in the basin are forest, agriculture, and wetland (table 2). The land resource provinces represented in the Suwannee River basin are the Southern Coastal Plain, Coastal Flatwoods, and Central Florida Ridge (fig. 2). Major tributaries to the Suwannee River include the Alapaha, Withlacoochee (the northern stream of the two in the study unit), and Santa Fe Rivers.

Most sections of the Suwannee River have generally very good water quality, although the river and its tributaries receive discharges from wastewater-treatment plants, livestock feedlots, paper mills, and phosphate mines (Hand and others, 1990). Discharges from mining areas are sometimes high in phosphates, sulfates, organic nitrogen, and fluorides. Water quality below the confluence with the Withlacoochee River is generally good and water quality in the upper Suwannee (above the confluence with the Withlacoochee River) is generally fair to good (Hand and others, 1990). Most sources of contamination are located in the three major tributaries—the Alapaha, Withlacoochee, and Santa Fe Rivers (Hand and others, 1990). One source of concern for water quality is increasing development along the Suwannee River corridor and the increase in septic tank fields in the basin. Median concentrations of nitrate and ammonia for sites in the Suwannee River basin were below USEPA standards and guidelines (10 and 2.1 mg/L; respectively), except for the median ammonia concentration at site 41 on Swift Creek (figs. 22 and 23). Only 4 of the 15 sites (sites 36, 37, 43, and 48) did not exceed the USEPA guideline for total-phosphorus concentrations (0.1 mg/L).

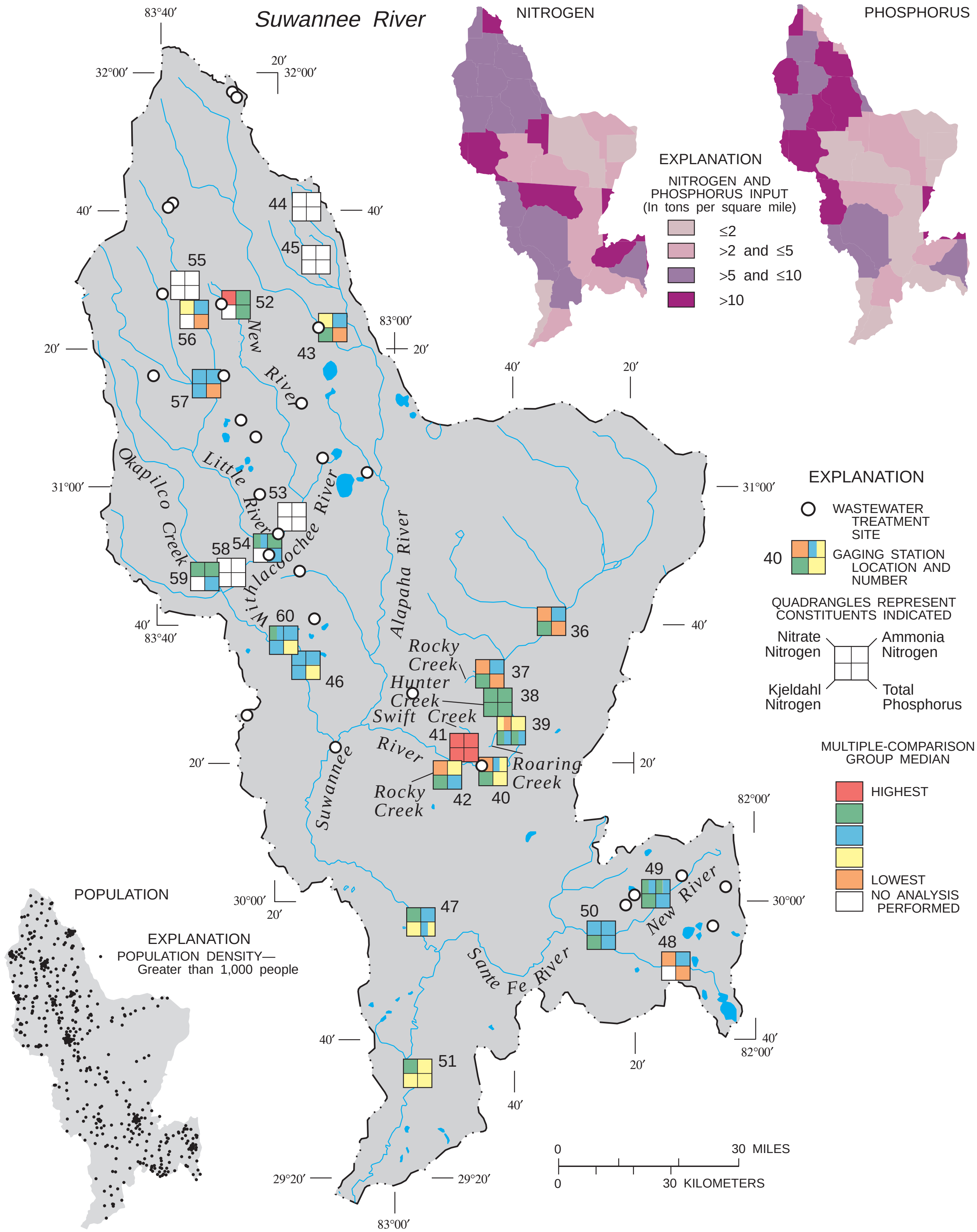

Figure 22. Distribution of population, nitrogen and phosphorus inputs, wastewater discharge locations, and site locations in the Suwannee River basin.

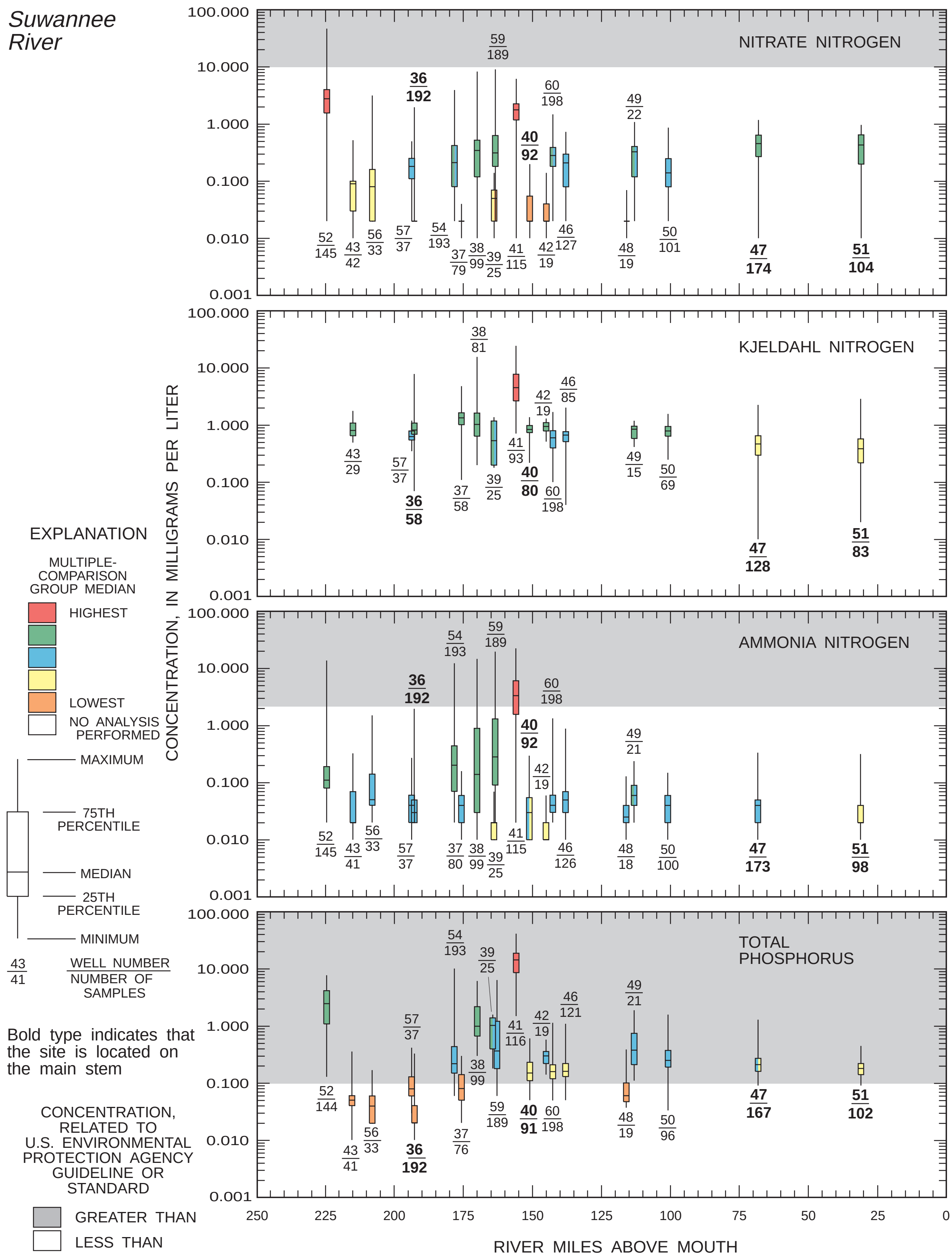

Figure 23. Nutrient concentrations along river miles in the Suwannee River basin.

Swift Creek (site 41), in the middle Suwannee River basin, has the highest median values for nitrate of 1.8 mg/L (not statistically different from the median concentration of 2.8 mg/L at site 52), for kjeldahl of 4.6 mg/L, for ammonia of 3.4 mg/L, and for total phosphorus of 14.5 mg/L among the sites in the Suwannee River basin. According to Hand and others (1990), the area in the basin with generally the worst water quality is Swift Creek. Within the Withlacoochee River subbasin, which enters the middle Suwannee River, elevated nutrient concentrations in the New River (site 52) may be attributable to the wastewater discharges totaling 4.3 Mgal/d (Marella and Fanning, 1995). Another site with consistently high nutrient concentrations is site 38 on Hunter Creek, which is located in the upper basin. Both Hunter and Swift Creeks (sites 38 and 41, respectively) are located in phosphate-mining and phosphate-processing areas. The higher kjeldahl, ammonia, and total-phosphorus concentrations found in the New River (west; site 52), Withlacoochee River (site 54), and Okapilco Creek (site 59) may be attributed to wastewater discharges (figs. 22 and 23).

Pairwise comparisons of the mean ranks of nitrate, kjeldahl, and ammonia concentrations from sites 36 and 40 in the upper Suwannee River, a distance of 42 river miles, produced no significant differences even though higher concentrations were seen at Hunter Creek (site 38). Apparently, flows from the Withlacoochee and Alapaha Rivers and several springs dilute nutrient concentrations between sites 40 and 47 on the Suwannee River.

In summary, nutrient concentrations are low in the Suwannee River basin; however, total-phosphorus concentrations at most of the sites within the basin exceeded USEPA guidelines. Swift Creek (site 41) had the highest nutrient concentrations among all of the sites.

Aucilla River Basin

The Aucilla River, about 69 mi long with a 952 mi^2 drainage area, originates in Georgia and is joined by a springfed stream, the Wacissa River, about 4 mi from the outlet in the Gulf of Mexico (Florida Board of Conservation, 1966). The Aucilla River is a blackwater river and is characterized by karst topography. The Aucilla River is in the Southern Coastal Plain and Coastal Flatwoods land resource provinces (fig. 2). Predominant land uses within the river basin are forest, agriculture, and wetland. Population density is very low in the river basin (table 2).

Water quality in the Aucilla River system is generally very good (Hand and Paulic, 1992). Silviculture and cattle access to the Wacissa River are sources of contamination in the basin (Hand and others, 1990). For the three sites in the Aucilla River basin, the median concentrations of nitrate, ammonia, and total phosphorus were below the USEPA guidelines (figs. 24 and 25). Site 62 had the highest median concentrations for all four nutrients.

Nutrient concentrations vary little in the Aucilla River basin. An increase in the median nitrate and total-phosphorus concentration occurred on the Aucilla River between site 61 and site 62, a distance of 15 river miles, perhaps due to agricultural practices. There is no significant difference between the mean ranks for concentrations of nitrate, ammonia, and total phosphorus on the Wacissa River (site 63) and site 62 in the lower Aucilla River.

Ochlockonee River Basin

The Ochlockonee River originates in clay hills of southwestern Georgia, flows 162 mi to its mouth in Ochlockonee Bay on the Gulf of Mexico, and drains an area approximately 2,250 mi^2 (Florida Board of Conservation, 1966). The Ochlockonee River is classified as an alluvial river although some of the color typical of blackwater rivers is present (Hand and Paulic, 1992). The land resource provinces represented in the basin are the Southern Coastal Plain and the Coastal Flatwoods (fig. 2). Primary land uses in the basin are forest and agriculture (table 2). The Sopchoppy River is a major tributary of the Ochlockonee River. There is little development in the flood plain, but areas near the river are frequently tilled and farmed in row crops (Berndt and others, 1995). No major cities are located directly on the Ochlockonee, but the river passes within 10 mi of Thomasville, Ga., and Tallahassee, Fla. Erosion and sedimentation problems in the basin are probably a result of the conversion of forests to cropland in southwest Georgia that has been occurring since the 1940's. The rate of conversion accelerated in the mid-1970's and is expected to continue at accelerated rates.

The lower Ochlockonee River is considered to have generally good water quality (Hand and others, 1990); inputs of nitrogen and phosphorus are low in this part of the basin (figs. 26 and 27). A study by Florida Department of Environmental Regulation (1987) identified several domestic and industrial discharges in Georgia that caused nutrient enrichment of the river in

Florida. The major sources of nutrients in the Ochlockonee River basin are from agricultural runoff, wastewater discharges, and strip mining (Hand and others, 1990). The median concentrations for the four sites in the river basin were less than 1.0 mg/L for all nutrients, but median total-phosphorus concentrations were above the USEPA recommended upper concentration limit (0.1 mg/L) for all sites on the Ochlockonee River (sites 66, 67, and 68).

Site 66, located in an area of high nitrogen and phosphorus input (fig. 26), had the highest median concentrations of nitrate, ammonia, and total phosphorus. This may be related to the 3.7 Mgal/d of wastewater discharged to the river upstream from site 66 (Marella and Fanning, 1995). Due to dilution, median nutrient concentrations gradually decrease downstream. Median concentrations of nitrate, ammonia, and total phosphorus were higher on the Ochlockonee River (sites 67 and 68) than on the Sopchoppy River (site 64). Most of the Sopchoppy River runs through the Apalachicola National Forest and is undeveloped forest, resulting in excellent water-quality conditions (Hand and Paulic, 1992).

St. Marys River Basin

The St. Marys River forms part of the Florida-Georgia border, has headwaters in the Okefenokee Swamp, and drains approximately 1,480 mi^2. The St. Marys River is a blackwater river that is approximately 175 mi in length with a tidal influence of approximately 60 mi upstream from the mouth (Bridges and Foose, 1986). It flows through no large cities and has not been dammed or significantly altered. The population density in this basin is low (fig. 28). The river basin is encompassed in the Coastal Flatwoods land resource province (fig. 2). Agriculture, forest, and wetland are the primary land uses in the St. Marys River basin (table 2).

Water quality in the main stem of the St. Marys River is generally good throughout its course until it reaches the estuarine part of the river near the Atlantic Ocean where contamination from industrial discharges and urban development result in water-quality problems (Hand and others, 1990). Water in the upper part of the river flows from headwater swamps and is unsuitable for some uses due to its acidity and dark color. The waters of the St. Marys River further downstream are used for agricultural irrigation, industrial supply, and public-water supply. Some contamination from wastewater treatment plants in the South Prong subbasin has been reported (Hand and Paulic, 1992). Levels of nitrogen and phosphorus input are higher on the south side of the river than the north.

For the three sites in the St. Marys River basin, the median concentrations for nitrate, ammonium, and total phosphorus were low, fairly uniform, and below USEPA guidelines (figs. 28 and 29). The median kjeldahl concentrations for the Middle Prong (site 70) and the St. Marys River (site 71) were less than 1.0 mg/L. An increase in the median nitrate concentration occurred between the Middle Prong (site 70) and the St. Marys River (site 71), a distance of 16 river miles. The median ammonia concentration increased slightly on the main stem between sites 71 and 72.

There was no significant difference in the mean ranks for ammonia and total-phosphorus concentrations in the mid-regions of the basin between site 70 and site 71. The mean ranks for concentrations of nitrate and total phosphorus were not significantly different between sites 71 and 72, a distance of 37 river miles along the St. Marys River. According to Hand and others (1990), generally the best water quality area in the St. Marys River basin is in the middle parts of the St. Marys River.

Satilla River Basin

The Satilla River is a blackwater river, approximately 225 mi long, originating in coastal wetlands and draining approximately 3,400 mi^2 (Benke and others, 1984). The river has a tidal influence of approximately 67 mi. No dams or other significant alterations have been made in the river's course. The Coastal Flatwoods land resource province encompasses the Satilla River basin (fig. 2). Primary land use in the basin includes forest, agriculture, and wetland (table 2).

For the five sites in the Satilla River basin (figs. 30 and 31), the median concentrations for nitrate and ammonia were below USEPA guidelines, but the median total-phosphorus concentration exceeded the upper concentration limit at site 75 (0.17 mg/L). The highest median concentrations of nitrate, ammonia, and total phosphorus are found at site 75. A source for these nutrients could be the City of Waycross, located between sites 74 and 75, with a discharge of 2.8 Mgal/d into the Satilla River (Marella and Fanning, 1995). Since site 75 has higher nutrient concentrations than sites 73, 74, and 76, nitrogen and phosphorus inputs from nonpoint sources do not appear to be the major

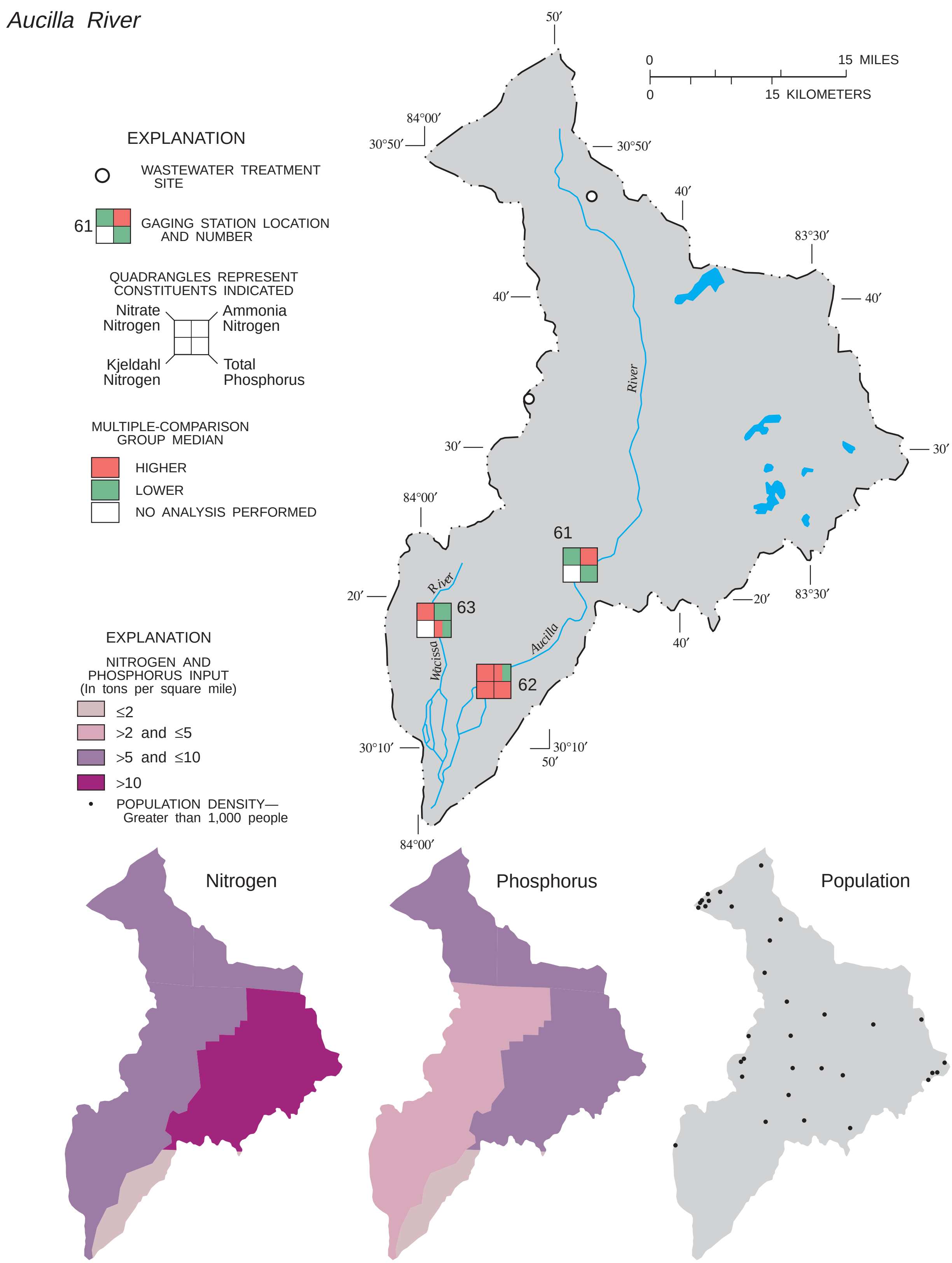

Figure 24. Distribution of population, nitrogen and phosphorus inputs, wastewater discharge locations, and site locations in the Aucilla River basin.

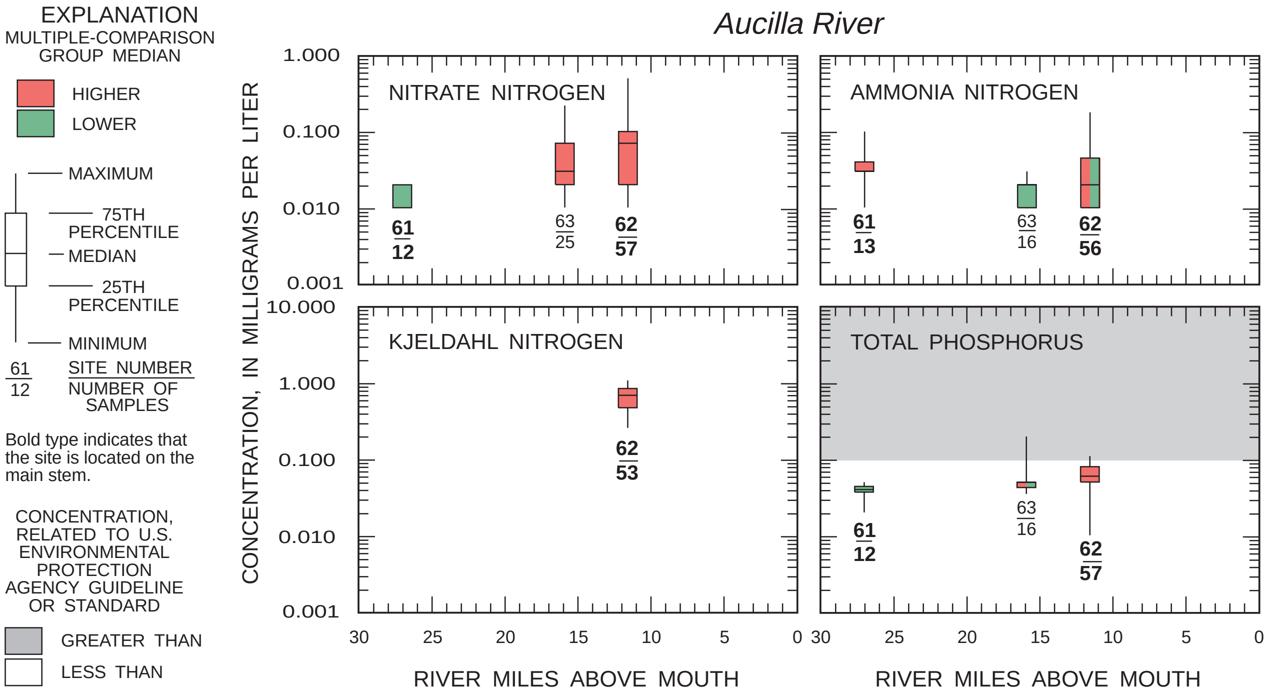

Figure 25. Nutrient concentrations along river miles in the Aucilla River basin.

influence on nutrient concentrations at these locations in the Satilla River basin. For the two sites (75 and 78) for which kjeldahl concentrations were analyzed there were no significant differences in mean ranks. Decreases in median concentrations for nitrate, ammonia, and total phosphorus between sites 75 and 78, a distance of 32 river miles, on the main stem may be a result of dilution.

Altamaha River Basin

The Altamaha River along with its primary tributaries, the Ocmulgee and Oconee Rivers, is considered alluvial and drains 14,200 mi^2. The main stem of the Altamaha River, which is approximately 119 mi in length, is formed by the confluence of the Ocmulgee and Oconee Rivers (196 and 204 mi in length, respectively). The Altamaha River is tidally influenced for 24 mi and receives large contributions of water from underlying aquifers in the coastal plain during periods of low flow (Carter and Hopkins, 1986). The land resource provinces represented in the river basin include the Southern Piedmont, the Sand Hills, the Southern Coastal Plain, and the Coastal Flatwoods (fig. 2). Primary land use in the Altamaha River basin includes forest, agriculture, and urban areas whereas wetlands line the banks of the river (table 2).

Water quality in the Altamaha River basin is considered adequate for agricultural irrigation, industrial supply, and public-water supply (Carter and Hopkins, 1986). Water quality in the Oconee River, the northern arm of the Altamaha River, is suitable for most uses (Georgia Department of Natural Resources, 1989). The headwaters of the Ocmulgee River are within the city limits of Atlanta, Ga. An upward trend in total-phosphorus concentration was noted from 1980-89 on the Altamaha, Ocmulgee, and Oconee Rivers (McConnell and Buell, 1993). The median concentrations for nitrate and ammonia in the Altamaha River basin were below USEPA guidelines; however, the USEPA guideline for total-phosphorus concentrations (0.1 mg/L) was exceeded at 6 of the 24 sites (figs. 32 and 33).

Overall, the nitrate and ammonia concentrations in the Ocmulgee River were higher than in the Oconee River. The wastewater discharges in the Ocmulgee River subbasin totaled 95.8 Mgal/d, 4 times the 24.0 Mgal/d in the Oconee River subbasin, and 20 times the 4.7 Mgal/d in the Ohoopee River subbasin (Marella and Fanning, 1995). The highest nutrient concentrations were found on the South River (sites 97 and 101), which receives 33.5 Mgal/d of wastewater discharge from an area with a high population density (fig. 32). Relatively high total-phosphorus concentrations were

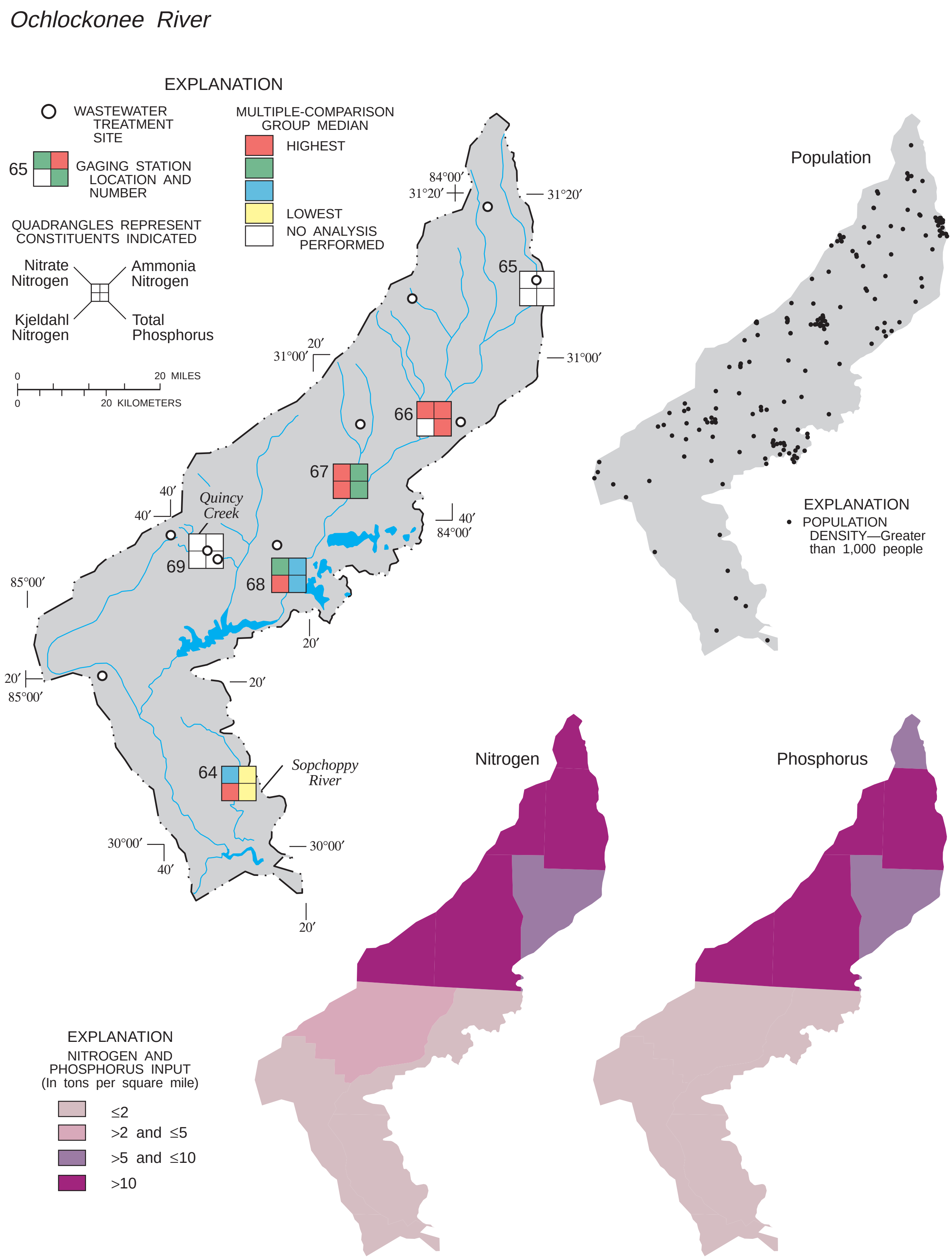

Figure 26. Distribution of population, nitrogen and phosphorus inputs, wastewater discharge locations, and site locations in the Ochlockonee River basin.

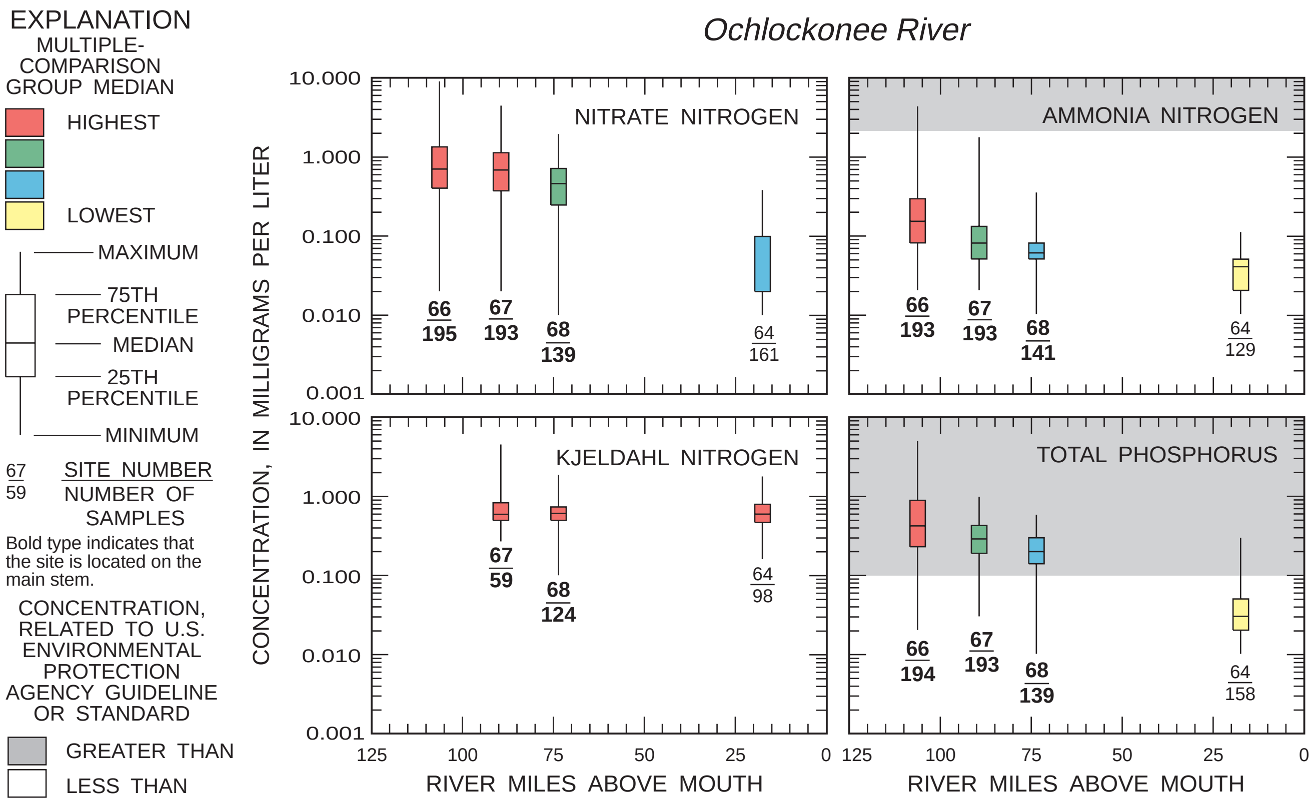

Figure 27. Nutrient concentrations along river miles in the Ochlockonee River basin.

also found at sites 91, 109, and 110, which are also areas receiving higher levels of phosphorus input. Within the Ocmulgee River subbasin, the second largest amount of wastewater discharge (27.6 Mgal/d) occurred in the 21 river miles between sites 108 and 109 causing nutrient concentrations to increase (Marella and Fanning, 1995). Between these two sites is the only area where ammonia concentrations increased in the subbasin. Within the Oconee River subbasin, when comparing wastewater discharges upstream from sites 91, 94, and 80, an increase in ammonia concentrations was found.

The lowest nutrient concentrations occurred on the Ohoopee River (site 84), which enters the Altamaha River below the Ocmulgee and Oconee Rivers. The wastewater discharges in the Ohoopee River subbasin were relatively small and nonpoint source inputs were low. There was no significant difference in mean ranks for nitrate concentrations on the Ocmulgee River below Jackson Lake to its confluence with the Oconee River (sites 106, 108, 109, 110, 111, and 79), a distance of approximately 182 river miles. There was no significant difference in mean ranks for nitrate and total-phosphorus concentrations among the sites on the Altamaha River, downstream from the confluence of the Ocmulgee and Oconee Rivers. Within the entire Altamaha River basin, sediment uptake of total phosphorus appears to be a factor resulting in decreases in total-phosphorus concentrations.

In summary, nutrient concentrations were highest in the Ocmulgee River subbasin and lowest in the Ohoopee River subbasin, which corresponds to the volume of wastewater discharge within these tributaries. The highest nutrient concentrations were found on the South River (sites 97 and 101), an area with 33.5 Mgal/d of wastewater discharge and a high population density. Sediment uptake of total phosphorus appears to be a factor resulting in decreases in total-phosphorus concentrations within the Altamaha River basin.

St. Mary's River

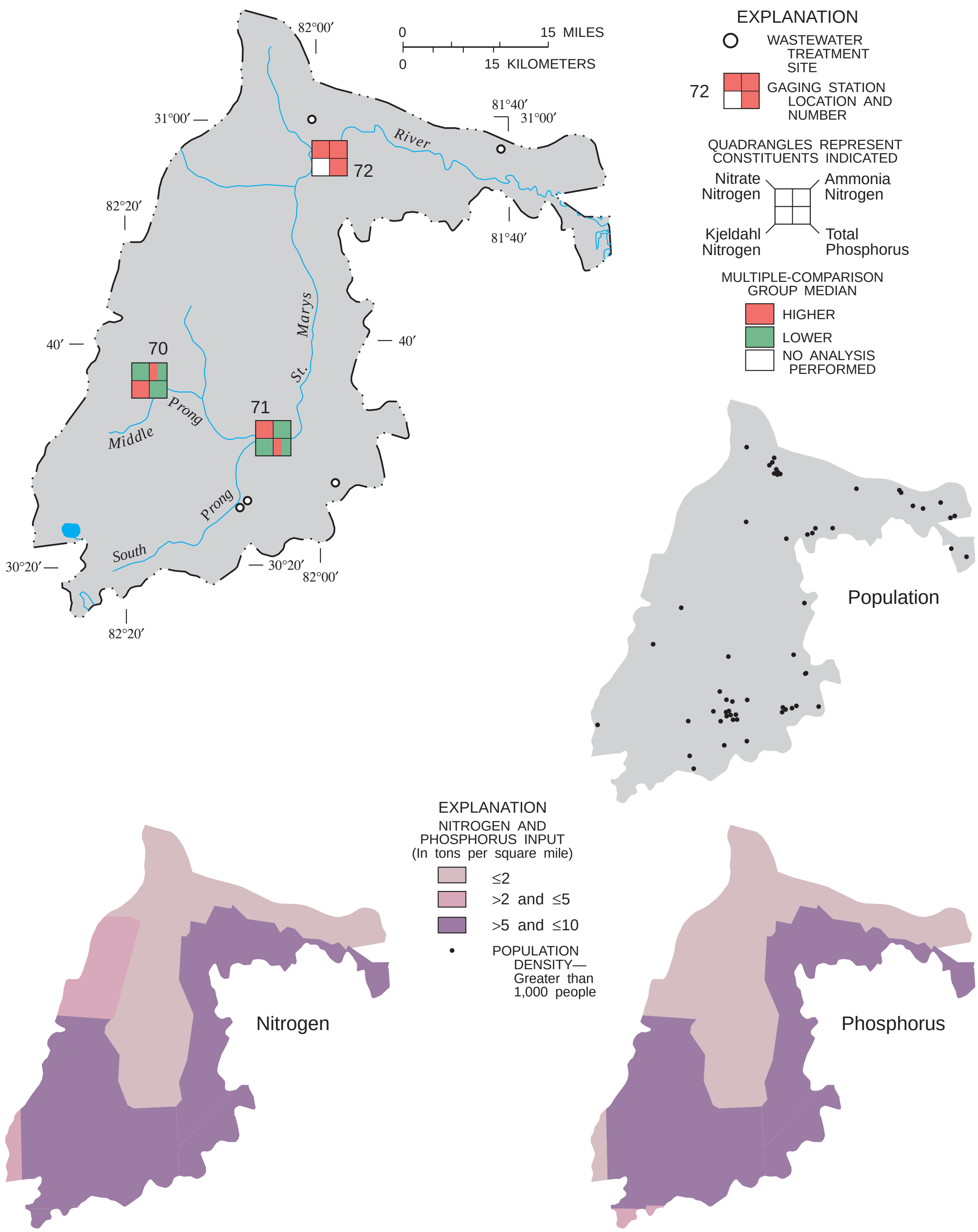

Figure 28. Distribution of population, nitrogen and phosphorus inputs, wastewater discharge locations, and site locations in the St. Marys River basin.

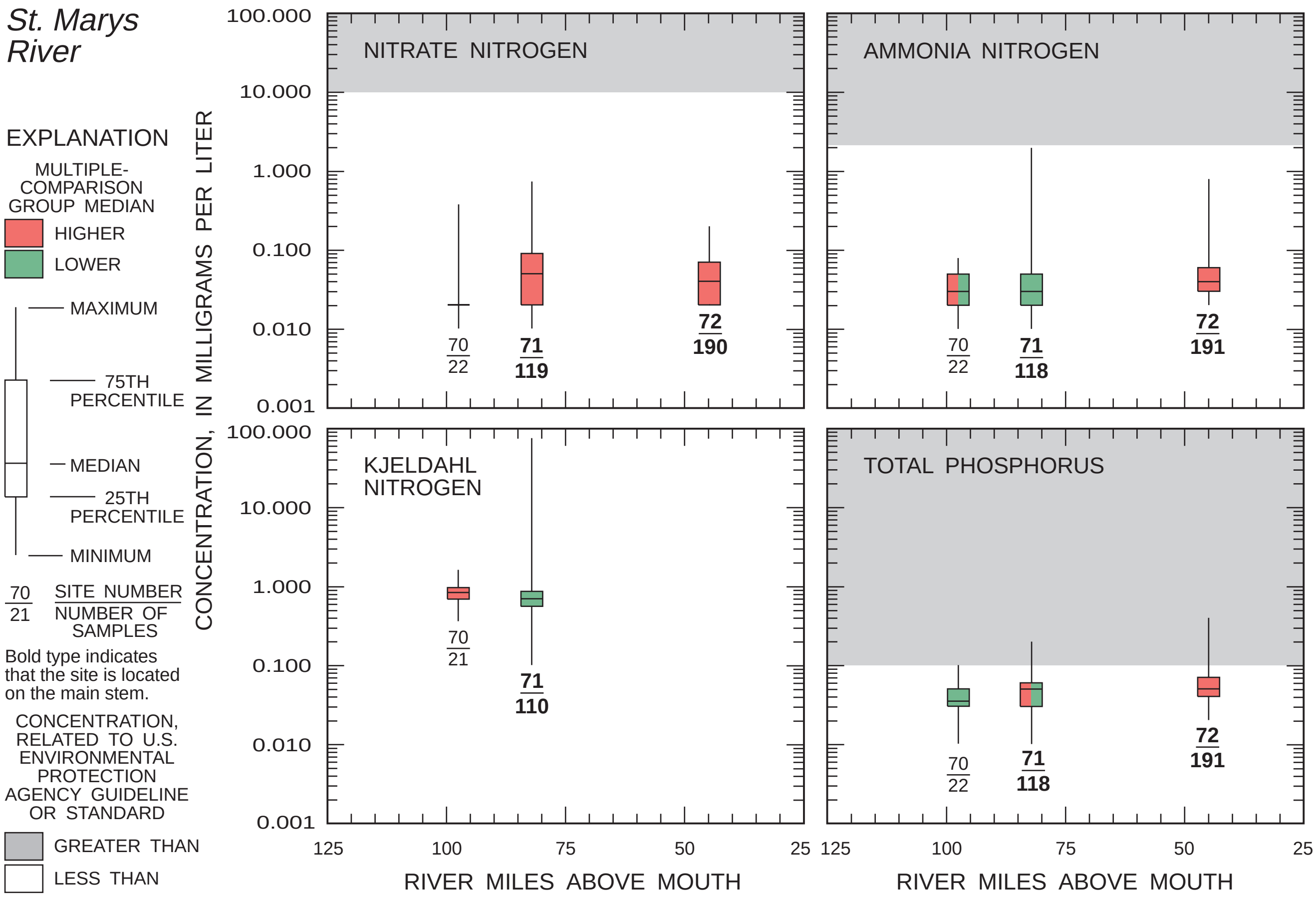

Figure 29. Nutrient concentrations along river miles in the St. Marys River basin.

Ogeechee River Basin

The Ogeechee River, which drains 4,410 mi^2, is affected by tides for approximately 44 mi of its 245 mi length (McConnell and Buell, 1993). The Ogeechee River is usually considered a blackwater river. The land resource provinces included in the river basin are the Southern Coastal Plain and the Coastal Flatwoods (fig. 2). Surface water in the Ogeechee River basin is used primarily for agricultural irrigation. Primary land use within the Ogeechee River basin includes forest, agriculture, and wetland (table 2). Water quality is deemed adequate for most uses (Carter and Hopkins, 1986). No large cities are located directly on the river; however, the Fort Stewart Military Reservation makes up a large part of the lower Canoochee River subbasin. The Canoochee River, also a blackwater river, is the largest tributary of the Ogeechee River.

For the five sites in the Ogeechee River basin, the median concentrations for nitrate and ammonia were below the USEPA standards and guidelines. The median total-phosphorus concentration at site 117 (0.15 mg/L) exceeded the USEPA's recommended upper concentration limit (0.1 mg/L).

Overall, nutrient concentrations are higher in the lower Canoochee River subbasin than in the remainder of the Ogeechee River basin (fig. 34 and 35). Along the Ogeechee River, the median total-phosphorus concentrations increased between sites 113 and 114. Within these 28 river miles there were no reported wastewater discharges, but as indicated by the higher levels of phosphorus input, agricultural practices are common. An increase in nitrate concentrations observed on the Ogeechee River between sites 114 and 115 is probably due to agricultural land use, as indicated by the high levels of nitrogen input. The highest ammonia concen-

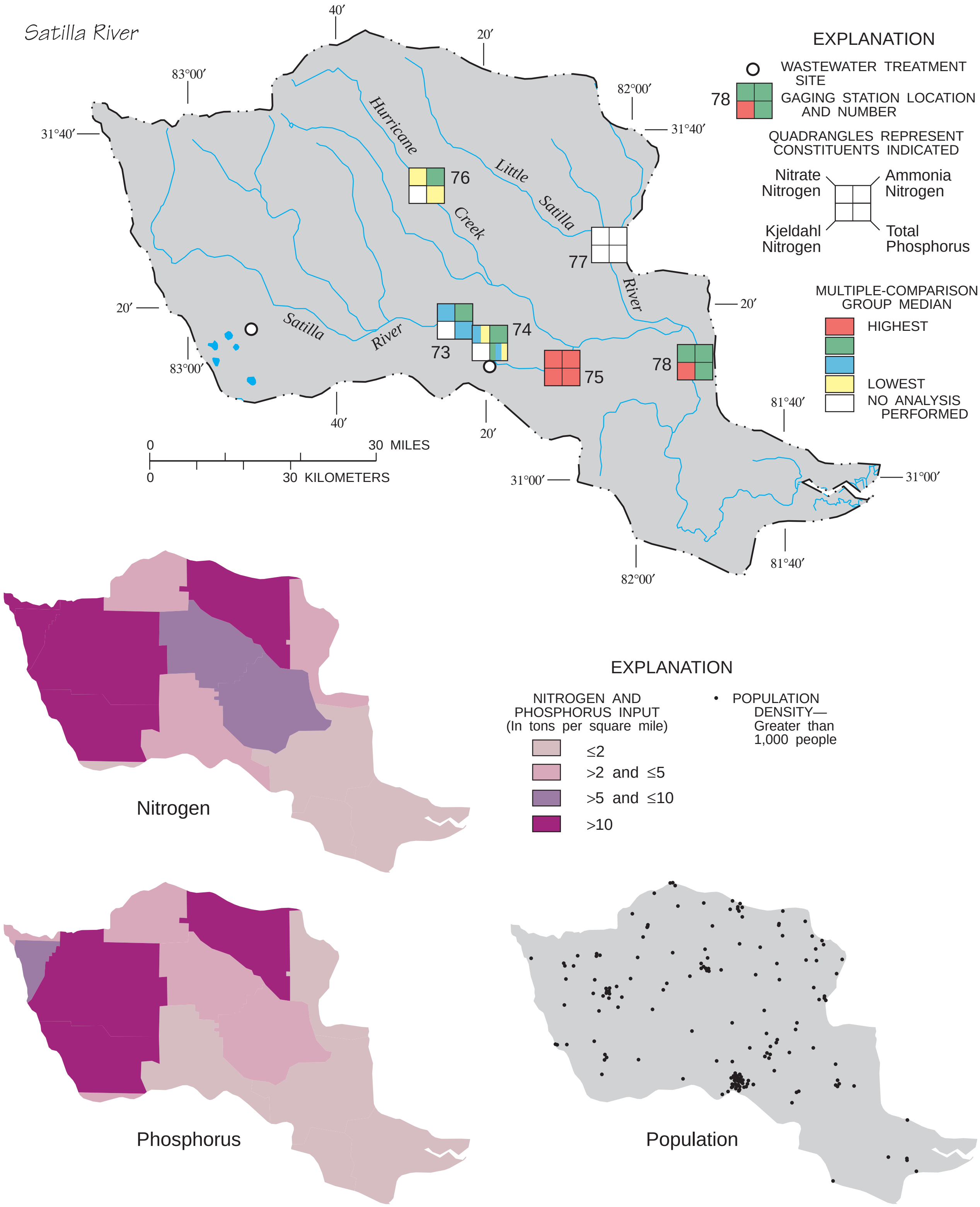

Figure 30. Distribution of population, nitrogen and phosphorus inputs, wastewater discharge locations, and site locations in the Satilla River basin.

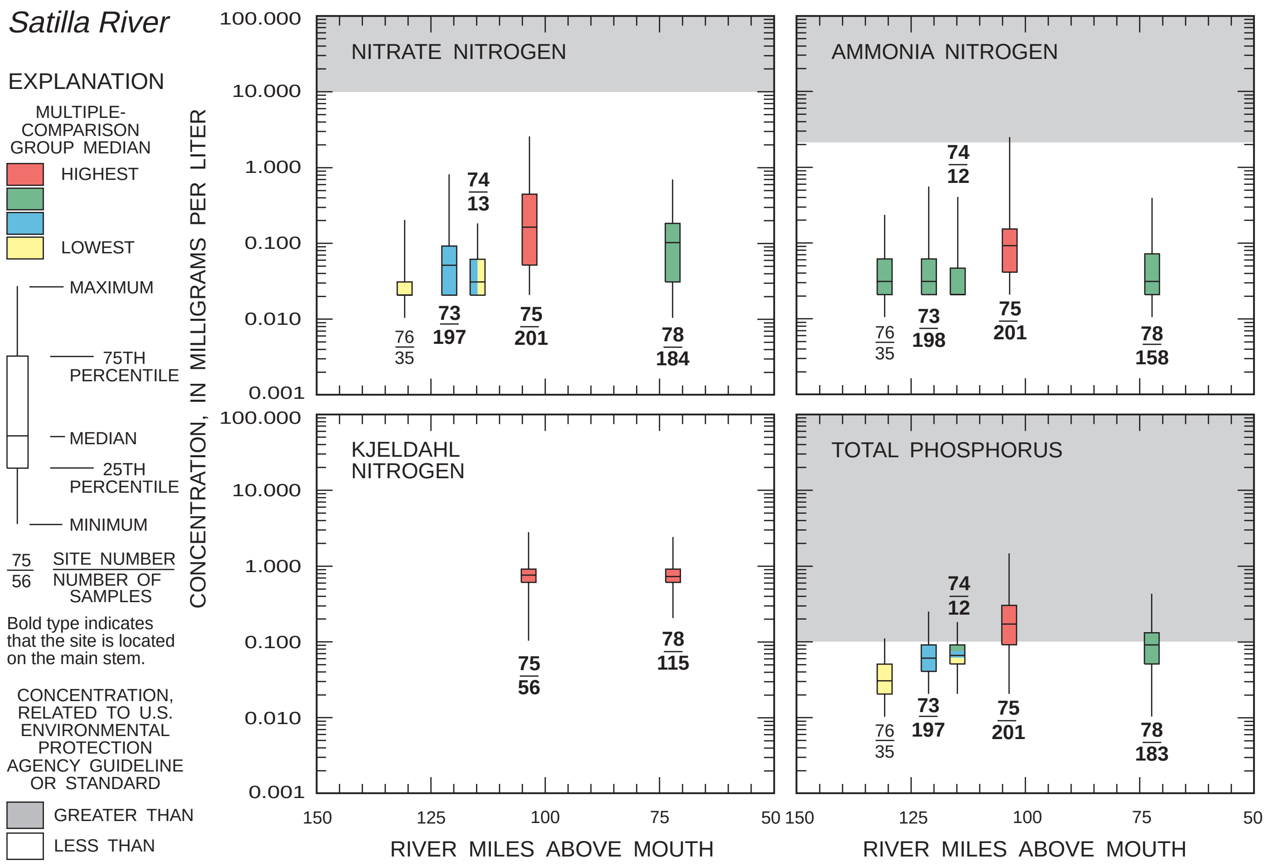

Figure 31. Nutrient concentrations along river miles in the Satilla River basin.

trations in the Ogeechee River basin were found on the Canoochee River at sites 116 and 117 and nitrate and total-phosphorus concentrations increased between these two sites. The amount of wastewater discharge between sites 116 and 117 totals 4.0 Mgal/d, as opposed to the rest of the Ogeechee River basin where discharges total 2.2 Mgal/d (Marella and Fanning, 1995). In addition, high levels of nitrogen and phosphorus input occurs within the Canoochee River sub-basin. The Canoochee River enters the Ogeechee River downstream from any main stem sites; therefore, the influence of this tributary on the main stem cannot be determined.

Low nutrient concentrations, less than 1.0 mg/L, were found along the Ogeechee River. Only two sites in the basin, sites 114 and 115 on the lower Ogeechee River, had sufficient data for analysis of kjeldahl concentrations. The mean ranks of kjeldahl concentrations at these sites were not significantly different. Analysis of ammonia concentrations at sites along the Ogeechee River (113, 114, and 115), spanning 56 river miles, resulted in no significant difference in the mean ranks. Possibly due to sediment uptake, total-phosphorus concentrations between sites 114 and 115 decreased to levels seen upstream at site 113.

In summary, nutrient concentrations are low in the Ogeechee River basin. Nonpoint sources of discharge seem to be the influencing factor in nutrient concentrations in along the Ogeechee River and nonpoint and point-source discharges seem to be influencing factors along the Canoochee River.

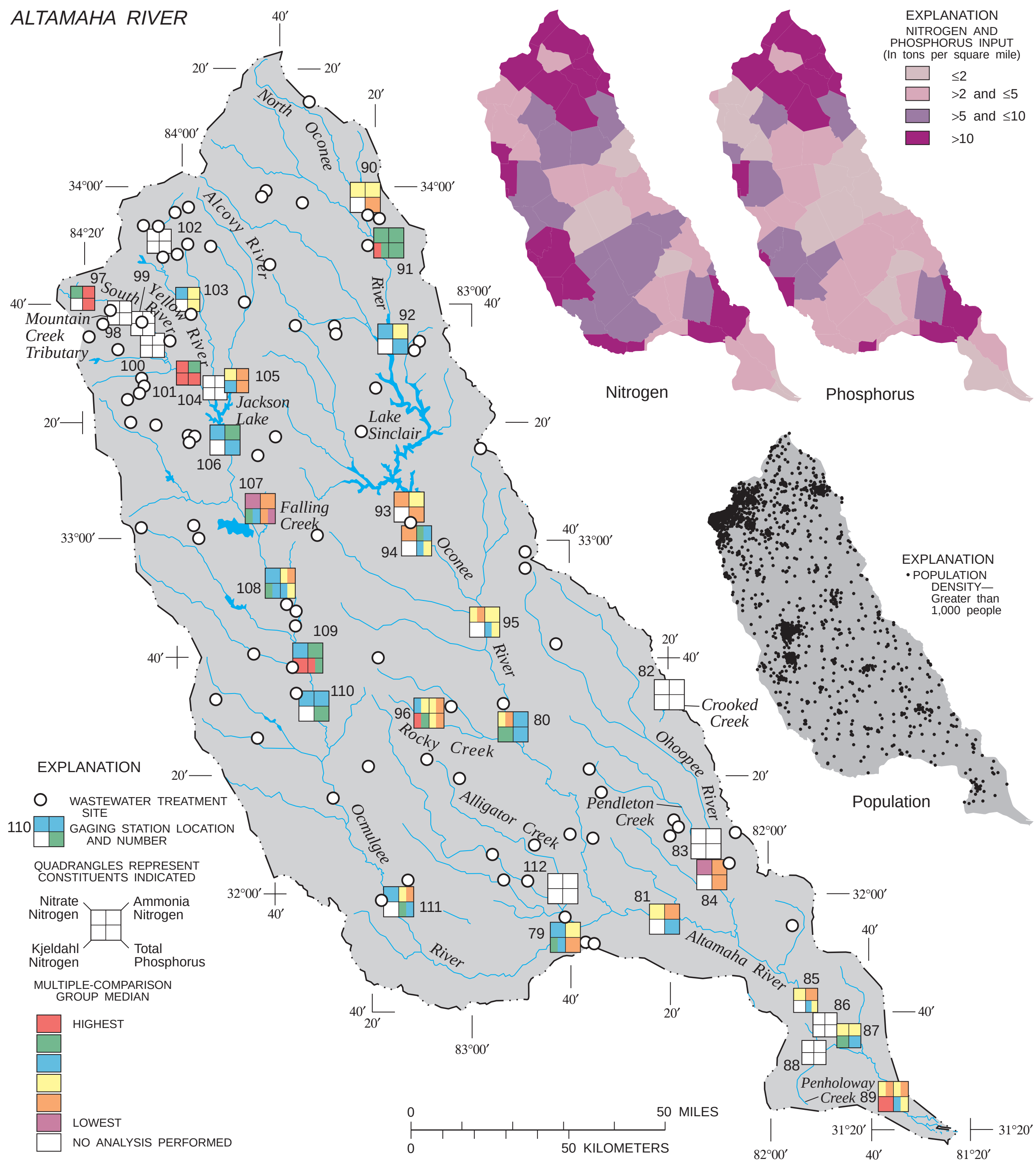

Figure 32. Distribution of population, nitrogen and phosphorus inputs, wastewater discharge locations, and site locations in the Altamaha River basin.

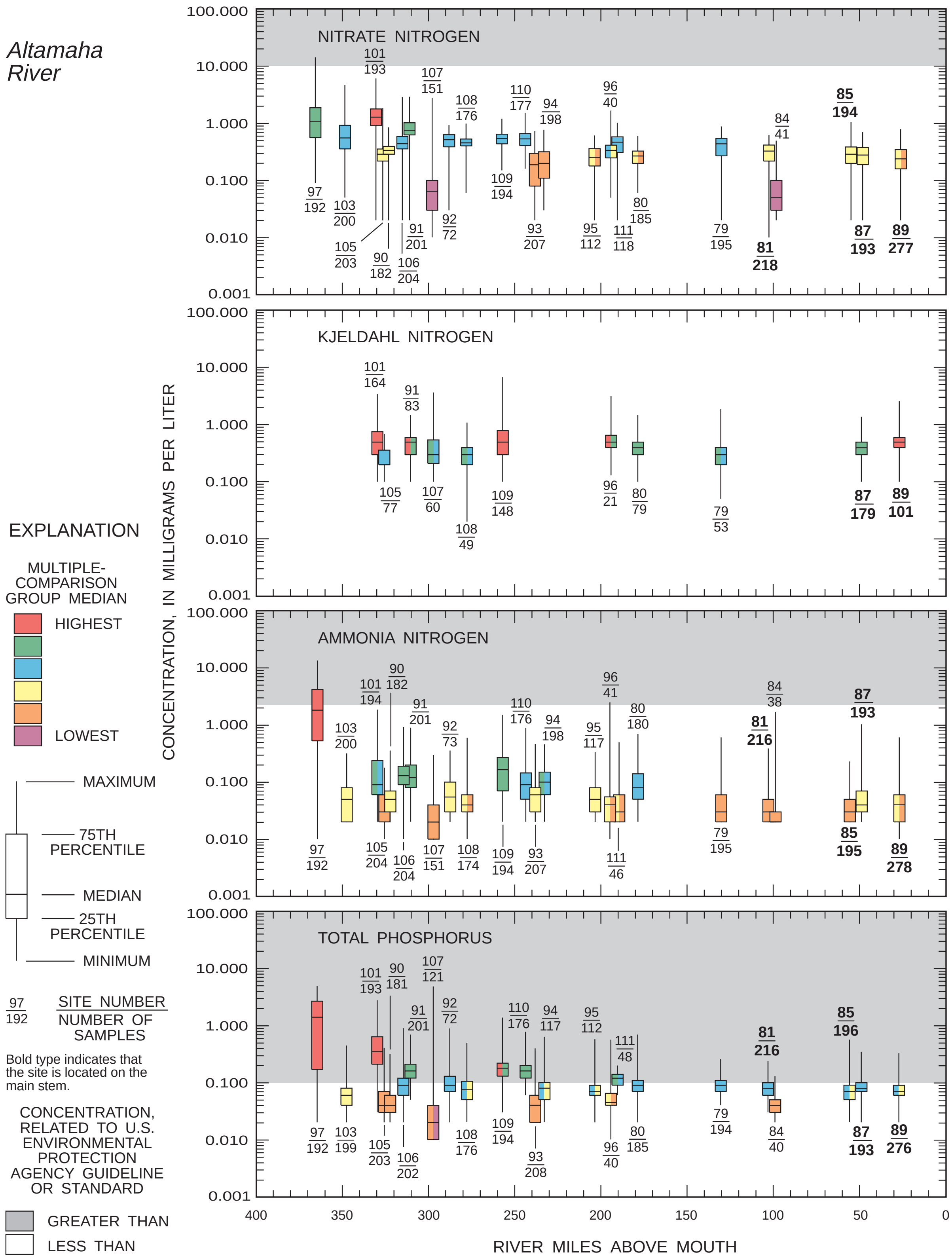

Figure 33. Nutrient concentrations along river miles in the Altamaha River basin.

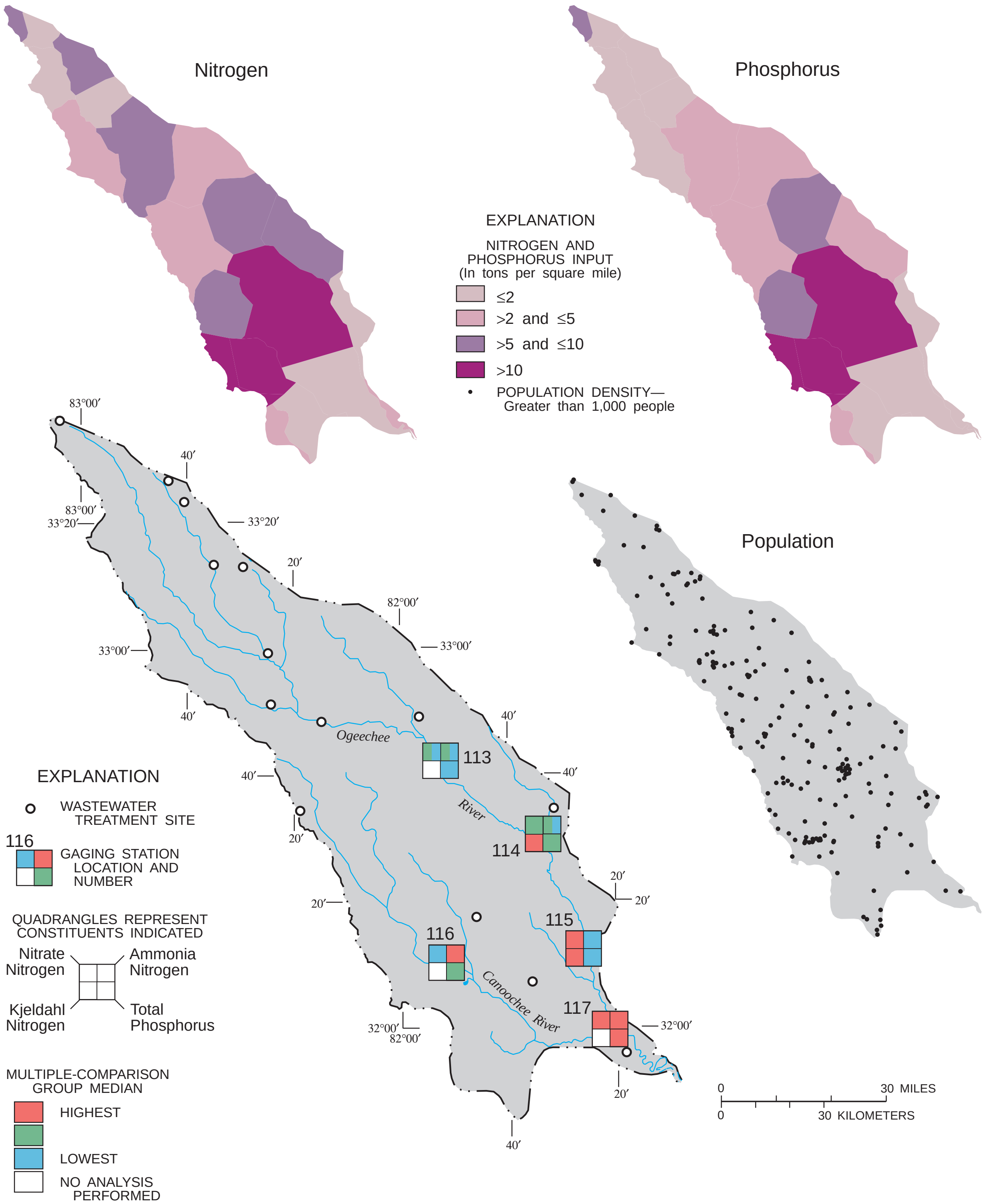

Figure 34. Distribution of population, nitrogen and phosphorus inputs, wastewater discharge locations, and site locations in the Ogeechee River basin.

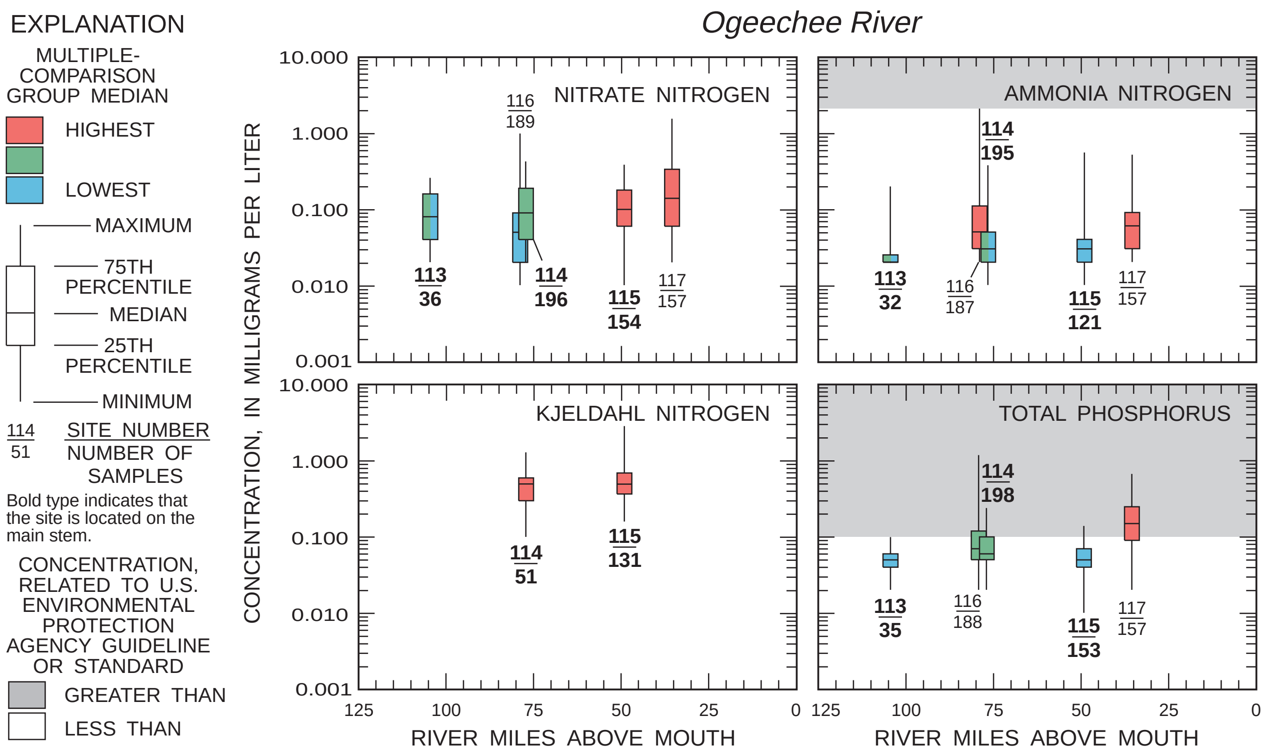

Figure 35. Nutrient concentrations along river miles in the Ogeechee River basin.

LONG-TERM TRENDS

Long-term trends were determined for sites to establish the temporal distribution of nutrients within the study unit. These trends are: (1) seasonal flow-adjusted concentration, (2) seasonal concentration, (3) flow-adjusted concentration, and (4) concentration. A seasonal flow-adjusted concentration trend is one in which the effects of seasonality and changing discharge have been removed from the time series of concentrations. A seasonal concentration trend is one in which only the effects of seasonality have been removed from the time series. A flow-adjusted concentration trend is one in which only the effects of changing discharge have been removed from the time series. A concentration trend is one in which no adjustment is made to the time series of concentrations. A trend was considered to be significant at an alpha level of 0.05.

Decreasing trends may be attributed to upgrades by wastewater treatment plants, use of best management practices in agriculture, changes to a less intensive land use, and lower laboratory reporting limits (which is an artifact of the analysis and not a true trend). Increasing trends may be attributed to increases in general land-use practices, increasing concentrations, or aging wastewater treatment plants. A seasonal trend might exist, for example, as a result of fertilizer application. If no trend exists, it could indicate stable conditions in the basin or it could indicate that several short-term trends exist but the increasing conditions cancel the decreasing conditions over the entire period of record.

Twenty-eight sites within the study unit met the criteria for long-term trend analysis and resulted in 52 nutrient trends. Unfortunately, these sites are not evenly distributed throughout the study unit. From the 28 sites, 19 nitrate trends, 1 kjeldahl trend, 14 ammonia trends, and 18 total-phosphorus trends were determined (fig. 36). Types of trends occurring within the study unit included 2 seasonal flow-adjusted concentration trends, 1 seasonal concentration trend, 28 flow-adjusted trends, and 21 concentration trends. Table 3 summarizes the 28 flow-adjusted concentration and 21 concentration trends.

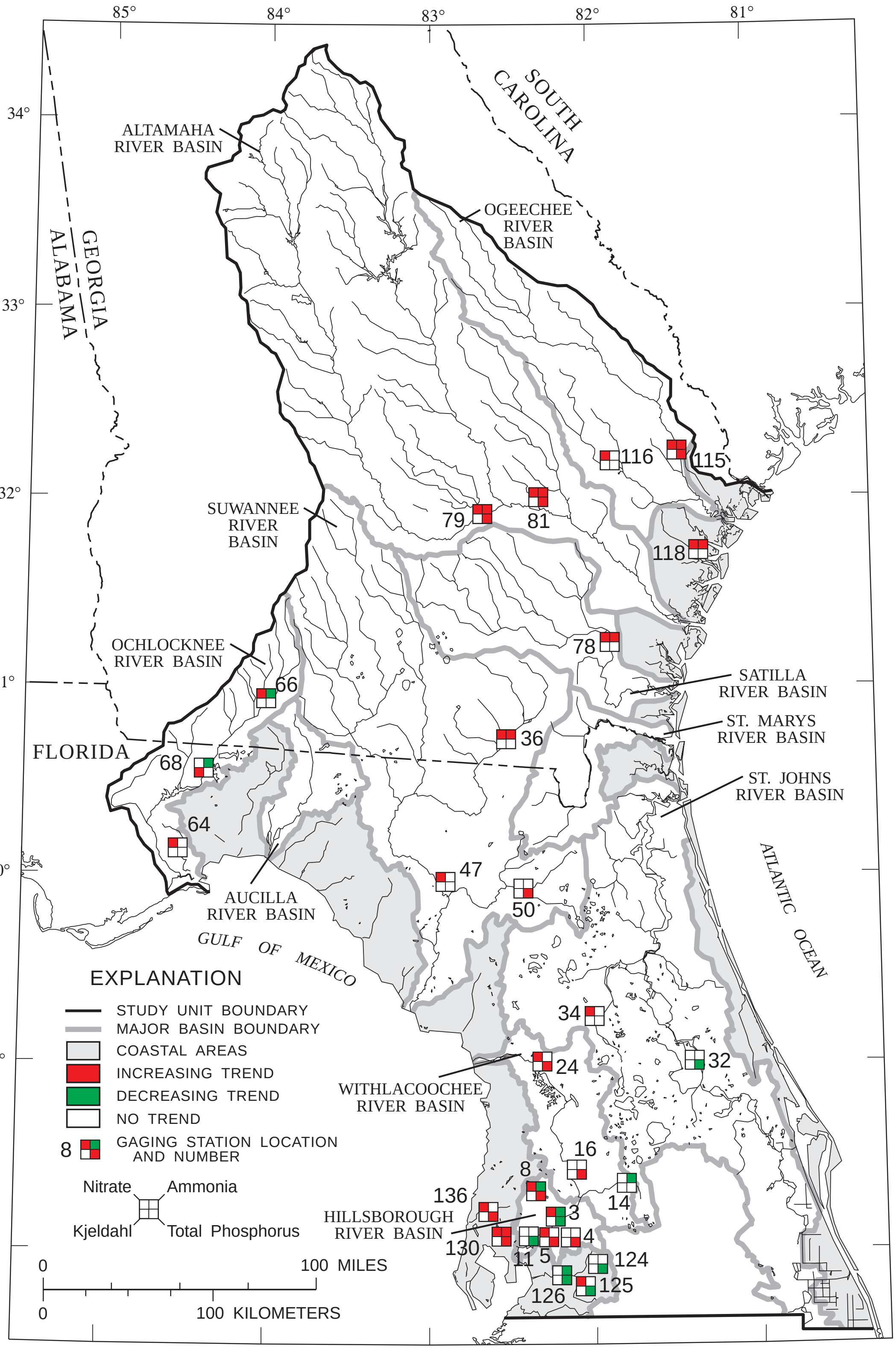

Figure 36. Map showing long-term trends in nutrient concentrations.

Table 3. Summary of nutrient flow-adjusted and concentration trends

[mg/L, milligrams per liter; ft^3/s, cubic feet per second; FA, flow-adjusted concentration; C, concentration; --, not calculated; shading indicates sites where median concentration exceeds USEPA guideline]

Map no.	Stream name	Nutrient	Type of trend	Period of record (water years)	Slope of trend (mg/L)/yr	Slope of trend percent/yr	Median values Concentration (mg/L)	Median values Discharge (ft^3/s)
3	Hillsborough River	nitrate	C	1972-91	+0.03	+2.32	1.1	95
		ammonia	FA	1972-91	-0.03	-7.07	0.0	95
		total phosphorus	FA	1971-91	-0.03	-5.20	0.5	95
4	Pemberton Creek	total phosphorus	C	1972-91	+0.06	+7.05	0.7	10
5	Flint Creek	nitrate	C	1972-91	<0.01	<0.01	0.0	14
		total phosphorus	FA	1972-91	+0.01	+1.53	0.7	14
8	Cypress Creek	nitrate	FA	1974-91	+0.01	--	0.0	7
		ammonia	C	1973-91	<0.01	-3.35	0.0	7
		total phosphorus	FA	1973-91	+0.02	+8.66	0.2	7
11	Hillsborough River	total phosphorus	C	1972-91	-0.01	-3.21	0.4	340
14	Withlacoochee River	ammonia	FA	1973-91	-0.01	-10.04	0.0	7
16	Withlacoochee River	total phosphorus	C	1972-91	<0.01	+3.18	0.0	44
24	Withlacoochee River	nitrate	FA	1971-90	+0.01	+6.20	0.1	609
		total phosphorus	C	1971-91	<0.01	+2.13	0.0	609
32	St. Johns River	total phosphorus	C	1971-91	-0.01	-4.10	0.1	2,365
34	Oklawaha River	nitrate	C	1971-91	+0.02	+3.32	0.5	850
36	Suwannee River	nitrate	C	1971-91	<0.01	<0.01	0.0	326
		ammonia	C	1971-91	<0.01	+3.44	0.0	326
47	Suwannee River	nitrate	FA	1971-91	+0.02	+4.61	0.5	5,125
50	Santa Fe River	total phosphorus	FA	S1973-91	<0.01	+1.46	0.3	167
64	Sopchoppy River	nitrate	C	1972-91	<0.01	+9.93	0.0	82
66	Ochlockonee River	nitrate	FA	1971-91	+0.03	+2.68	0.7	190
		ammonia	FA	1971-91	-0.03	-7.05	0.2	190
68	Ochlockonee River	kjeldahl	FA	1973-91	<0.01	+2.00	0.6	485
		ammonia	FA	1971-91	<0.01	-2.73	0.1	485
78	Satilla River	nitrate	C	1971-91	+0.01	+9.35	0.1	1,000
		ammonia	C	1971-91	<0.01	+6.50	0.0	1,000
79	Ocmulgee River	nitrate	FA	1974-91	+0.01	+2.11	0.4	3,359
		ammonia	C	1971-91	<0.01	+5.96	0.0	3,359
		total phosphorus	FA	1974-91	<0.01	+2.04	0.1	3,359
81	Altamaha River	nitrate	FA	1971-91	+0.01	+1.97	0.3	6,710
		ammonia	C	1971-91	<0.01	+4.61	0.0	6,710
		total phosphorus	FA	1971-91	<0.01	+2.13	0.1	6,710
115	Ogeechee River	nitrate	C	1971-91	+0.01	+7.48	0.1	1,130
		ammonia	C	1971-91	<0.01	+8.01	0.0	1,130
		total phosphorus	FA	1971-91	<0.01	+4.12	0.0	1,130
116	Canoochee River	nitrate	C	1971-91	<0.01	+4.75	0.0	186
118	N. Newport River	nitrate	C	1971-91	<0.01	<0.01	0.0	--
		ammonia	C	1971-91	+0.01	+6.96	0.1	--
124	N. Prong Alafia River	total phosphorus	FA	1972-91	-0.21	-2.46	6.0	66
125	S. Prong Alafia River	nitrate	FA	1972-91	+0.06	+16.28	0.2	48
		total phosphorus	FA	1972-91	-0.22	-8.70	1.9	48
126	Alafia River	ammonia	FA	1972-91	-0.02	-6.64	0.0	161
		total phosphorus	FA	1972-91	-0.24	-4.62	3.9	161
130	Rocky Creek	nitrate	FA	1973-91	+0.07	+16.41	0.3	21
		ammonia	FA	1973-91	+0.01	+6.72	0.1	21
		total phosphorus	FA	1973-91	+0.07	+17.67	0.2	21
136	Anclote River	nitrate	FA	1973-91	+0.01	+8.91	0.0	10
		total phosphorus	FA	1972-91	<0.01	+3.09	0.1	10

All trends in nitrate were increasing—nine flow-adjusted concentration trends and nine concentration trends (table 3). For three of the nine sites (sites 78, 115, and 116) showing a concentration trend, the number of censored values in the data set was greater than 15 percent (see methods section). The spatial distribution of the increasing trends was study-unit wide. Several of the increasing flow-adjusted trends in nitrate occurred in the Tampa area (sites 8, 125, 130, and 136), which has a high population density. Livestock production is common along the Suwannee River (site 47) and crop farming is common along the Ochlockonee River (site 66) which could explain the increasing flow-adjusted nitrate concentration trends at these two sites.

Trend slopes for kjeldahl nitrogen were not calculated for 26 of the 28 sites used in trend analysis because the sites did not meet the established criteria. Of the two remaining sites, site 120 (in a coastal area) showed no kjeldahl concentration trend and site 68 on the Ochlockonee River showed an increasing flow-adjusted kjeldahl concentration trend.

Of the trends in ammonia concentrations, seven were increasing with slopes less than 0.01 (mg/L)/yr and six were decreasing with a range in slope from less than -0.01 to -0.03 (mg/L)/yr (table 3). Six of the seven increasing concentration trends were in the northern part of the study unit. The largest decreasing flow-adjusted ammonia concentration trends occurred at site 3 on the Hillsborough River and site 66 on the Ochlockonee River. Site 68, downstream from site 66, also shows a decreasing trend, which might indicate that the cause of the decreasing trends in ammonia concentrations on the Ochlockonee River may be upstream from site 66.

Of the trends in total-phosphorus concentrations, 11 were increasing and 6 were decreasing. Also, 14 of the 17 trends were in the southern part of the study unit. Two increasing trends were found in the Altamaha River basin: site 81 on the Ocmulgee River and site 79, located 28 river miles downstream on the Altamaha River. Five of the six decreasing flow-adjusted concentration trends occurred in the Tampa area, which may be a result of upgrades in wastewater treatment plants or management of phosphate-mining operations. Some of the decreasing slopes for these sites were relatively large: -0.24 (mg/L)/yr (site 126), -0.22 (mg/L)/yr (site 125), and -0.21 (mg/L)/yr (site 124).

Median total-phosphorus concentrations exceeded the recommended USEPA upper concentration limit (0.1 mg/L) at 10 sites, of which, 9 sites were in the Tampa, Fla., area (table 3; fig. 36). Of those 10 sites, five sites showed decreasing trends (sites 3, 11, 124, 125, and 126) and five sites indicated increasing trends (sites 4, 5, 8, 50, and 130). The highest median total-phosphorus concentrations were found in the Alafia River basin—6.0 mg/L (site 124), 3.9 mg/L (site 126), and 1.9 mg/L (site 125). However, flow-adjusted concentration trends for these three sites were decreasing.

Long-term trends may be masked by fluctuations in seasonal differences in constituent concentrations. However, this variation is accounted for in the ESTREND program, but only the significance and direction of the overall trend for a particular site are reported and not the magnitude of the slope. Only the identification of the most influential seasonal trend is available. Seasonal nutrient trends were detected at three sites within the study unit, all occurring in the Hillsborough River basin—site 3 showed a summer influenced increasing seasonal flow-adjusted nitrate concentration trend; site 8 showed a winter influenced increasing seasonal flow-adjusted ammonia concentration trend; and site 5 showed a summer influenced increasing seasonal total-phosphorus concentration trend.

In summary, for the long-term trends within the study unit, the magnitude of the slopes are considered low; 86 percent of the slopes were less than or equal to 0.03 (mg/L)/yr. A total of 18 long-term trends were found for nitrate, 13 for ammonia, 1 for kjeldahl, 17 for total phosphorus. Three seasonal trends were also found. The spatial distribution of the long-term trends in nitrate concentrations were study-unit wide. Six of the seven increasing ammonia trends were located in the northern part of the study unit. In the southern part of the study unit 13 of the 17 total-phosphorus trends were found. All three seasonal trends were located in the Hillsborough River basin.

SUMMARY AND CONCLUSIONS

The USGS is conducting an assessment of nutrient concentrations in surface waters of the GAFL study unit as part of the NAWQA program. During the early phase of this study, historical data (water years 1971-91) was compiled and analyzed in order to evaluate nutrient concentrations within the 61,545 mi^2 study unit. Evaluation of the nutrient concentrations utilized the characteristics of land resource provinces, land use, and nonpoint and point-source discharges in the study unit. Long-term trends were investigated to determine the temporal distribution of nutrient concentrations.

In order to determine a level of concern for nutrient concentrations the following USEPA standards and guidelines were used as points of reference—the MCL of 10 mg/L for nitrate concentrations in public-drinking water supplies; a value of 2.1 mg/L for ammonia concentrations based on chronic exposure of aquatic organisms; and a value of 0.1 mg/L in flowing water for total phosphorus, based on discouragement of excessive growth of aquatic plants (U.S. Environmental Protection Agency, 1986). There are no guidelines for kjeldahl concentrations. Interestingly, the median total-phosphorus concentration in U.S. rivers (1974-81) was 0.13 mg/L (Smith and others, 1987). The median total-phosphorus concentrations in Florida streams was 0.11 mg/L (Friedemann and Hand, 1989).

Median nutrient concentrations were significantly different among the four land resource provinces in the study unit—Southern Piedmont, Southern Coastal Plain, Coastal Flatwoods, and Central Florida Ridge. In general, the Coastal Flatwoods showed the lowest median nutrient concentrations and the Southern Coastal Plain had the highest median nutrient concentrations. Median concentrations for nitrate and ammonia were below the USEPA standards and guidelines for all four land resource provinces whereas the median concentrations for total phosphorus exceeded the guideline by 0.08 mg/L in the Southern Coastal Plain and by 0.03 mg/L in the Central Florida Ridge. A significant difference among the land resource provinces implies that median nutrient concentrations in surface-water basins located within different land resource provinces are not expected to be the same due to differences in the combination of environmental factors such as soil permeability, runoff rates, and stream-channel slopes. Therefore, land resource provinces should be considered as a contributing factor in explaining differences in water quality when designing surface-water sampling networks that cover large areas.

When land-use percentages were classified into four land-use categories, lower median nitrate concentrations in surface-water basins were associated with the forest/wetland land-use category and higher concentrations of nitrate and ammonia with the urban category. These results were reasonable based on expected high nutrient inputs from urban areas and low inputs from forested and wetland areas. The lack of association between high nutrient concentrations and the agricultural category was not expected since the removal of nutrients in runoff from agricultural production has been documented (Legg and Meisinger, 1982; Taylor and Kilmer, 1980). Median concentrations of nitrate and ammonia for all four land-use categories were below the USEPA standards or guidelines; however, the USEPA guideline for total-phosphorus concentrations was exceeded by 0.25 mg/L in the urban category and by 0.01 mg/L in the agricultural category.

For sites within the ten major river basins, median nutrient concentrations were generally below USEPA guidelines, except for total-phosphorus concentrations where 45 percent of the medians exceeded the guideline. The only exceedance of the ammonia concentration guideline occurred on Swift Creek (3.4 mg/L) in the Suwannee River basin. Median concentrations of nitrate, ammonia, and total phosphorus were below the USEPA guidelines for all sites within the Withlacoochee, Aucilla, and St. Marys River basins. For sites within the remaining basins, the median total-phosphorus concentrations exceeded the USEPA guideline as follows—Hillsborough, 10 of 10 sites; St. Johns, 1 of 3 sites; Suwannee, 11 of the 15 sites; Ochlockonee, 3 of the 4 sites; Satilla, 1 of 5 sites; Altamaha, 6 of 24 sites, and Ogeechee, 1 of 5 sites.

Site nutrient data within each major basin was aggregated for comparisons of median nutrient concentrations among major basins. The Ochlockonee and Hillsborough River basins had the highest median nutrient concentrations and the Aucilla River basin had the lowest median nutrient concentrations. Median concentrations of nitrate and ammonia among all major basins were below the USEPA standards and guidelines. The median total-phosphorus concentration for the following river basins exceeded the USEPA's recommended upper concentration limit of 0.1 mg/L: Hillsborough (0.42 mg/L), Suwannee (0.21 mg/L), and Ochlockonee (0.26 mg/L).

Low nutrient concentrations were found in all ten major river basins when sites were analyzed according to their relative locations in the basin (river miles). Important findings for each major basin are summarized below:

Hillsborough River Basin

Relatively high nutrient concentrations were found in the northeast part of the river basin and higher total-phosphorus concentrations were found on tributaries than on the main stem. Relatively high nutrient concentrations were found on Blackwater Creek.

Withlacoochee River Basin

Median nitrate concentrations were lower in the upper part of the basin, perhaps due to ground water inputs, and higher in the lower part of the basin.

High median kjeldahl concentrations found in the upper part of the basin may be attributed to the Green Swamp. Median ammonia and total-phosphorus concentrations showed little variability throughout the basin.

St. Johns River Basin

Only three sites were used in the St. Johns River basin. Concentrations of kjeldahl and total phosphorus were higher on the St. Johns River than on Oklawaha River and nitrate and ammonia concentrations were higher on the Oklawaha River than on the St. Johns River.

Suwannee River Basin

Natural phosphate deposits, phosphate mining, and wastewater discharges have contributed to the increased nutrient concentrations found within the basin. Swift Creek had higher nutrient concentrations than any other site within the basin.

Aucilla River Basin

There was little variation in nutrient concentrations.

Ochlockonee River Basin

Median concentrations of nitrate, ammonia, and total phosphorus were higher on the Ochlockonee River than on the Sopchoppy River.

St. Marys River Basin

There was little variation in nutrient concentrations.

Satilla River Basin

The highest nutrient concentrations within the basin may be a result of point-source discharge.

Altamaha River Basin

Nutrient concentrations were highest in the Ocmulgee River subbasin and lowest in the Ohoopee River subbasin, which corresponds to the volume of wastewater discharge within these tributaries. The highest nutrient concentrations were found on the South River.

Ogeechee River Basin

Nonpoint sources of discharge seem to be the influencing factor in nitrate and total-phosphorus concentrations along the Ogeechee River and nonpoint and point-source discharges seem to be influencing factors in nitrate, ammonia, and total-phosphorus concentrations along the Canoochee River.

Although nutrient concentrations within the study unit were low, long-term trends were found in all four nutrients at 28 sites throughout the study area. A total of 18 long-term trends were found for nitrate, 13 for ammonia, 1 for kjeldahl, 17 for total phosphorus. In addition, three seasonal trends were found. Of the trends in total-phosphorus concentrations, 11 were increasing and 6 were decreasing. The median total-phosphorus concentrations exceeded the recommended USEPA guideline (0.1 mg/L) at 10 sites, of which, 9 sites were in the Tampa, Fla., area. However, concentration trends for five of these sites were decreasing, which may be a result of upgrades in wastewater treatment plants or management of phosphate-mining operations. The spatial distribution of the nitrate trends was study-unit wide, with increasing slopes ranging from less than 0.01 to 0.07 (mg/L)/yr. Several of the increasing flow-adjusted trends in nitrate occurred in the Tampa area. Of the trends in ammonia concentrations, six were decreasing with slopes ranging from -0.03 to less than -0.01 (mg/L)/yr and seven were increasing with slopes less than 0.01 (mg/L)/yr. Spatially, six of the seven increasing ammonia concentration trends were located in the northeast part of the study unit. Only two of the sites met the established criteria for determining trends in kjeldahl concentrations—one showed no kjeldahl concentration trend and one had an increasing trend.

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Appendix

Explanation of Appendix

Analysis component	Explanation of appendix shading
Map number	Number shown on figures. Shading shows duplicate sites.
Basin Size	Drainage is in square miles. Shading indicates that the site was used in basin size analysis.
Land resource provinces	CFW=Coastal Flatwoods; CFR=Central Florida Ridge; SCP=Southern Coastal Plain; SP=Southern Piedmont. Shading indicates that the site was used in land resource province analysis.
Land-use category	Land-use category derived from algorithm (see methods section). Shading indicates that the site was used in land-use category analysis.
Volume of wastewater discharge	Volume of domestic wastewater discharge (in million gallons per day) found between sites. Total volume for major basin includes areas below most downstream site used in basin, therefore, volumes for individual sites do not always equal the total volume for that basin.
Major basins	Shading indicates that the site was used in major basin analysis.
Rivermiles	Number of rivermiles from mouth of river basin. Shading indicates that the site was used in river miles analysis.
Long-term trends	Shading indicates that the site was used in long-term trend analysis.

Numbers in parentheses, under analysis component header section, are total number of sites used; number in parenthesis following river basin is the hydrologic unit code]

Map no. (144)	Site ID	Stream name	Analysis component						
			Basin size (square miles) (62)	Land resource province (59)	Land use (61)	Volume of wastewater discharge (Mgal/d)	Major basins (94)	Rivermiles (miles)	Long-term trends (28)
Hillsborough River basin (03100205)						18.1			
1	02301990	Hillsborough River	104			0.0		37	
2	02302500	Blackwater Creek	102		mixed	10.5		38	
3	02303000	Hillsborough River	243	CFW		0.4		33	
4	02303200	Pemberton Creek	21	CFW		5.2		34	
5	02303300	Flint Creek	12			0.0		28	
6	02303330	Hillsborough River	392			2.0			
7	02303354	Hillsborough River	445			0.0		20	
8	02303400	Cypress Creek	56		mixed	0.0		41	
9	02303420	Cypress Creek	123			0.0			
10	02303800	Cypress Creek	167			0.0			
11	02304000	Hillsborough River	626			0.0		16	
12	02305780	Curiosity Creek	0.89	CFR	forested	0.0		11	
13	02306006	Kirby Street Drainage	2.6	CFR		0.0		7	
Withlacoochee River basin (03100208)						11.4			
14	02310800	Withlacoochee River	108		mixed	0.0		121	
15	02310947	Withlacoochee River	271			0.0		104	
16	02311500	Withlacoochee River	417			0.0		94	
17	02312180	Little Withlacoochee R	78			0.0			
18	02312200	Little Withlacoochee R	139		agricultural	0.0		74	

Map no. (144)	Site ID	Stream name	Analysis component: Basin size (square miles) (62)	Land resource province (59)	Land use (61)	Volume of wastewater discharge (Mgal/d)	Major basins (94)	Rivermiles (miles)	Long-term trends (28)
19	02312500	Withlacoochee River	800			10.9		68	
20	02312600	Withlacoochee River	980			0.0		55	
21	02312667	Shady Brook	8.7	CFR	agricultural	0.0			
22	02312700	Outlet River	139		agricultural	0.5		53	
23	02312975	Tsala Apopka Outfall	188			0.0		36	
24	02313000	Withlacoochee River	1832			0.0		30	
25	02313100	Rainbow Springs	--			0.0		26	
26	02313180	Blue Run	--			0.0		21	
27	02313230	Withlacoochee River	2020			0.0		10	
28	02313250	Withlacoochee Bypass	2046			0.0		9	
St. Johns River basin (03080101-03)						104.4			
29	02232000	St. Johns River	1234			0.0			
30	02232500	St. Johns River	1789	CFW		4.1			
31	02234000	St. Johns River	2290			14.9			
32	02236000	St. Johns River	3354			13.7			
33	02237700	Apopka-Beauclair Canal	183	CFR	agricultural	0.0		183	
34	02240000	Oklawaha River	1455	CFR	agricultural	0.5		137	
35	02244450	St. Johns River	7603			11.1		78	
Suwannee River basin-- Main stem (03110201-06)						22.1			
36	02314500	Suwannee River	1088	CFW	forested	0.7		193	
37	02314986	Rocky Creek	45	CFW	forested	0.0		176	

Map no. (144)	Site ID	Stream name	Analysis component: Basin size (square miles) (62)	Land resource province (59)	Land use (61)	Volume of wastewater discharge (Mgal/d)	Major basins (94)	Rivermiles (miles)	Long-term trends (28)
38	02315005	Hunter Creek	25	CFW	forested	0.0		170	
39	02315090	Roaring Creek	18		forested	0.0		164	
40	02315500	Suwannee River	2258			0.0		151	
41	02315520	Swift Creek	65			0.5		156	
42	02315532	Rocky Creek	25.4			0.0		145	
43	02316000	Alapaha River	656		agricultural	0.6		216	
44	02316120	Turkey Branch	14	SCP	mixed	0.0			
45	02316218	Stump Creek	14	SCP	agricultural	0.0			
46	02319000	Withlacoochee River	2123			0.0		138	
47	02320500	Suwannee River	7689			6.0		68	
48	02320700	Santa Fe River	94.9			1.0		116	
49	02321000	New River	191			1.1		113	
50	02321500	Santa Fe River	574		forested	0.4		101	
51	02323500	Suwannee River	9448			0.0		30	
Suwannee River basin-- Withlacoochee River (03110203-04)									
52	02317718	New River	11	SCP	mixed	4.3		225	
53	02317749	Withlacoochee River	496		agricultural	1.8			
54	02317757	Withlacoochee River	543	SCP		0.1		178	
55	02317797	Little River	129	SCP	agricultural	0.0			
56	02317800	Little River	145	SCP		0.0		208	
57	02317830	Little River	208			0.0		194	
58	02318500	Withlacoochee River	1362	SCP		5.6			

Map no. (144)	Site ID	Stream name	Analysis component						
			Basin size (square miles) (62)	Land resource province (59)	Land use (61)	Volume of wastewater discharge (Mgal/d)	Major basins (94)	Rivermiles (miles)	Long-term trends (28)
59	02318725	Okapilco Creek	281	SCP	agricultural	0.0		164	
60	02318960	Withlacoochee River	2065	SCP		0.0		143	
46	02319000	Withlacoochee River	2123			0.0		138	
Aucilla River basin (03110103)						4.0			
61	02326500	Aucilla River	747			4.0		27	
62	02326512	Aucilla River	814		mixed	0.0		12	
63	02326526	Wacissa River	--			0.0		16	
Ochlockonee River basin (03120002-03)						8.8			
64	02327100	Sopchoppy River	104	CFW	forested	0.0		17	
65	02327205	Ochlockonee River	98		agricultural	2.7			
66	02327500	Ochlockonee River	554	SCP		0.9		107	
67	02328200	Ochlockonee River	926	SCP		1.0		90	
68	02329000	Ochlockonee River	1140	SCP		0.0		74	
69	02329534	Quincy Creek	17	SCP	mixed	3.1			
St. Marys River basin (03070204)						33.7			
70	02229000	Middle Prong St. Marys	136	CFW		0.0		98	
71	02231000	St. Marys River	870	CFW		0.7		82	
72	02231220	St. Marys River	1326	CFW		0.3		45	
Satilla River basin (03070201-02)						3.9			
73	02226475	Satilla River	1137		mixed	0.2		121	
74	02226500	Satilla River	1200			0.0		115	
75	02226582	Satilla River	1336	CFW		2.8		104	

Map no. (144)	Site ID	Stream name	Analysis component: Basin size (square miles) (62)	Land resource province (59)	Land use (61)	Volume of wastewater discharge (Mgal/d)	Major basins (94)	Rivermiles (miles)	Long-term trends (28)
76	02227000	Hurricane Creek	138	CFW	mixed	0.0		131	
77	02227500	Little Satilla River	664	CFW	mixed	0.0			
78	02228000	Satilla River	2787	CFW		0.7		72	
Altamaha River--Main stem (03070101-07)						6.3			
79	02215500	Ocmulgee River	5238			95.8		130	
80	02223600	Oconee River	4436			24.0		176	
81	02225000	Altamaha River	11557	SCP		2.4		102	
82	02225282	Crooked Creek	2.726	SCP	urban	0.0			
83	02225470	Pendelton Creek	302	SCP	agricultural	0.0			
84	02225500	Ohoopee River	1131	SCP		4.2		98	
85	02225990	Altamaha River	13564			0.0		55	
86	02226000	Altamaha River	13565	CFW		0.0			
87	02226010	Altamaha River	13583	CFW		0.0		48	
88	02226100	Penholoway Creek	183	CFW	forested	0.0			
89	02226160	Altamaha River	14108	CFW		1.6		26	
Altamaha River (03070101-07)--Oconee River basin (03070101-02)						24.0			
90	02217740	North Oconee River	274	SP	mixed	0.8		323	
91	02218000	Oconee River	783	SP		7.5		311	
92	02218500	Oconee River	1076	SP		3.6		288	
93	02223000	Oconee River	2941	SP		2.2		238	
94	02223040	Oconee River	3054			5.3		233	
95	02223250	Oconee River	3836			0.9		203	

Map no. (144)	Site ID	Stream name	Analysis component: Basin size (square miles) (62)	Land resource province (59)	Land use (61)	Volume of wastewater discharge (Mgal/d)	Major basins (94)	Rivermiles (miles)	Long-term trends (28)
80	02223600	Oconee River	4436			3.0		176	
96	02224000	Rocky Creek	62	SCP	agricultural	0.0		194	
Altamaha River (03070101-07)-- Ocmulgee River basin (03070103-05)						95.8			
97	02203800	South River	39		urban	not known		366	
98	02203965	South River	148			0.0			
99	02203970	Mountain Creek tributary	0.19	SP	forested	0.0			
100	02204070	South River	183	SP		0.0			
101	02204520	South River	464	SP		33.5		331	
102	02206500	Yellow River	136		urban	0.0			
103	02207300	Yellow River	243	SP		15.3		349	
104	02208005	Yellow River	443	SP		0.0			
105	02209260	Alcovy River	256	SP	mixed	1.9		327	
106	02210500	Ocmulgee River	1431	SP		1.5		315	
107	02212600	Falling Creek	72	SP	forested	0.0		298	
108	02212950	Ocmulgee River	2239	SP		3.8		278	
109	02213700	Ocmulgee River	2688			27.6		257	
110	02214265	Ocmulgee River	3115			8.4		244	
111	02215260	Ocmulgee River	4460			1.6		190	
79	02215500	Ocmulgee River	5238			0.6		130	
112	02216100	Alligator Creek	242	SCP	mixed	0.0			
Ogeechee River basin (03060201-03)						5.6			
113	02202000	Ogeechee River	1940			1.5		105	

Map no. (144)	Site ID	Stream name	Analysis component						
			Basin size (square miles) (62)	Land resource province (59)	Land use (61)	Volume of wastewater discharge (Mgal/d)	Major basins (94)	Rivermiles (miles)	Long-term trends (28)
114	02202190	Ogeechee River	2382		mixed	0.0		77	
115	02202500	Ogeechee River	2659			0.0		49	
116	02203000	Canoochee River	560	SCP	agricultural	0.1		79	
117	02203519	Canoochee River	1349			4.0		35	
Coastal areas **(03060204, 03080201, 03080203, 03100203-04, 03100206-07, 03110102, 0312001)**						173.0			
118	02203578	N. Newport River	1530	CFW	forested				
119	02248000	Spruce Creek	5.8	CFW					
120	02253000	Main Canal	32	CFW					
121	02300100	Little Manatee River	30	CFW	agricultural				
122	02300500	Little Manatee River	148						
123	02300700	Bullfrog Creek	20	CFW	agricultural				
124	02301000	North Prong Alafia River	184						
125	02301300	South Prong Alafia River	57	CFW					
126	02301500	Alafia River	340						
127	02301766	Tampa Bypass Canal	0.82	CFR	agricultural				
128	02301802	Tampa Bypass Canal	28		mixed				
129	02301840	29th Street Drainage	9.7		urban				
130	02307000	Rocky Creek	43		agricultural				
131	02307359	Brooker Creek	33	CFW	mixed				
132	02307671	Alligator Creek	6.3	CFW	urban				
133	02308931	St. Joe Creek	1.8	CFW	urban				
134	02308935	St. Joe Creek	2.7	CFW	urban				

Map no. (144)	Site ID	Stream name	Analysis component						
			Basin size (square miles) (62)	Land resource province (59)	Land use (61)	Volume of wastewater discharge (Mgal/d)	Major basins (94)	Rivermiles (miles)	Long-term trends (28)
135	02308990	Bonn Creek	2.7	CFW	urban				
136	02310000	Anclote River	69	CFW	agricultural				
137	02310280	Pithlachascotee River	149		agricultural				
138	02310300	Pithlachascotee River	179	CFW					
139	02324000	Steinhatchee River	316	CFW	forested				
140	02326838	Northeast Drainage	9.7	SCP	urban				
141	02326900	St. Marks River	529	SCP	mixed				
142	274141082051300	Grace Creek	1.1	CFW	agricultural				
143	274215082072000	Unnamed tributary	0.36	CFW	agricultural				
144	275647082240601	Palm River	34	CFW	mixed				