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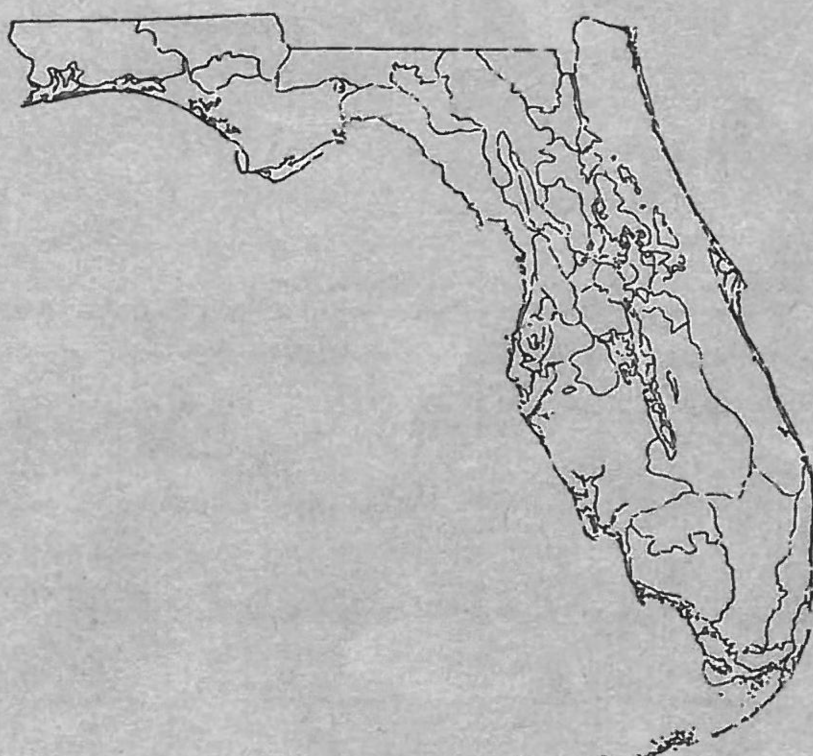
LAKE REGIONS OF FLORIDA



LAKE REGIONS OF FLORIDA

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ABSTRACT

Water resources can be managed more effectively if they are organized by regions that reflect differences in their quality, quantity, hydrology, and their sensitivity or resilience to ecological disturbances. The management of lake resources requires a spatial framework that distinguishes regions within which there is homogeneity in the types and quality of lakes and their association with landscape characteristics, or where there is a particular mosaic of lake types and quality. In the early 1980's, Canfield and others documented regional differences in Florida lake water chemistry and related these to geology and physiography. Building on this work, we have defined forty-seven lake regions of Florida by mapping and analyzing water quality data sets in conjunction with information on soils, physiography, geology, vegetation, climate, and land use/land cover, as well as relying on the expert judgement of local limnologists and resource managers. This spatial framework has also been used to help illustrate the regional differences in parameters such as total phosphorus and acid-neutralizing capacity. A large-format color poster of the lake region maps with photographs and regional descriptions has also been produced. The Florida lake regions and associated maps and graphs of lake chemistry are intended to provide an effective framework for assessing lake characteristics, calibrating predictive models, guiding lake management, and framing expectations by lake users and lakeshore residents.

To obtain a large color map of the Florida lake regions or an ARC/INFO export file of the region boundaries, contact the first author. To obtain the associated color poster publication of Florida lake regions contact Michael Scheinkman, FL DEP, 2600 Blair Stone Rd, Tallahassee, FL 32399, (904) 921-9918.

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PROJECT BACKGROUND

INTRODUCTION

The lakes of Florida provide important ecological habitats for a diverse flora and fauna, and comprise a valuable resource for human activities. With over 7,700 lakes in Florida, the assessment and management of this resource is complicated by its physical, chemical, and biological diversity. Differences in physiography, geology, soils, hydrology, vegetation, and climate affect lake characteristics, and these can occur in regional patterns. Lake management strategies regarding protective water quality standards or restoration goals cannot be carried out effectively on a lake-by-lake basis only, but must consider regional differences in limnological capabilities and potentials.

Regional frameworks are useful for structuring the research, assessment, monitoring, and management of environmental resources. These frameworks are helpful for comparing regional land and water patterns; locating monitoring, refererence or special study sites; extrapolating site-specific information; predicting effects of management practices; and establishing reasonable and realistic regional standards and expectations. A variety of spatial frameworks can be useful for lake assessment and management, ranging from general purpose regional frameworks to specific-purpose single-characteristic maps (Figure 1; Omernik 1994). A national-scale ecoregion framework (Omernik 1987) has proven useful to lake managers in Minnesota for developing realistic regional goals, for protective as well as restorative purposes, relative to summer nutrient concentrations, nuisance algal conditions, and Secchi transparency ranges (Heiskary 1994; Heiskary and Wilson 1989; Wilson and Walker 1989). Lake user expectations and sensitivities to eutrophication conditions can differ greatly between ecoregions (Heiskary 1989; Smeltzer and Heiskary 1990). Ecoregions have been used in Ohio to estimate attainable reservoir phosphorus concentrations and help prioritize reservoir restoration efforts (Fulmer and Cooke 1990). A recent past president of the North American Lake Management Society suggested that a regional approach is needed in the development of lake quality standards with respect to eutrophication:

> "Standards should be specific to regions, subregions, and if warranted, even individual lakes. Because bedrock character and soil type, some areas are naturally richer in nutrients than others. Therefore, standards should be based on attainable quality for that region, or subunit. That approach is consistent with the ecoregion concept and would assist the difficult task of allocating the always limited funds for remediation." (Welch 1993).

As part of the Florida Department of Environmental Protection's Lake Bioassessment / Regionalization Initiative, we have examined regional patterns of lake characteristics in Florida to develop a spatial framework for lake assessment and management. In an earlier project with the FL DEP, level IV ecological regions of Florida were defined to help in the assessment of environmental resources (Griffith et al. 1994). The level IV ecoregion

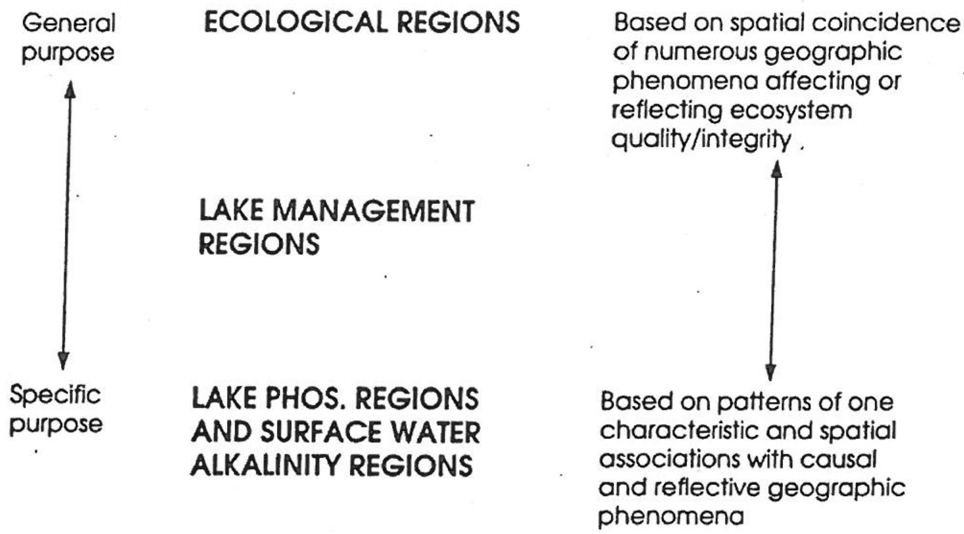

Figure 1. Regional frameworks for lake assessment and management (Omernik 1994).

framework of Florida has been used to select regional stream reference sites, and to assess that data to help develop biological criteria for streams (Barbour et al. 1996). Ecoregion maps are general purpose maps, and for lake assessment and management, more specific maps are often needed (See Figure 1). For the DEP's lake bioassessment work using the paired lake concept (Frydenborg and Lurding 1994; FL DEP 1994), the ecoregion framework appeared too general.

Physiographic maps are also used to classify land and water resources, and have been used to assess Florida lake chemistry (Canfield 1981), but there are several reasons why a physiographic map alone may not work as well as a lake region framework. First, the physiographer obviously has a different purpose and focus than that of lake management. Second, there are several different physiographic frameworks available for Florida, such as Fenneman (1938), Cooke (1939; 1945), White (1958; 1970) and Brooks (1981b; 1982), and each source provides a different interpretation. And third, a particular physiographic division may be too general or too detailed for lake management purposes. Brooks' (1981b) physiographic framework, for example, provides 3 Sections, 10 Districts, and 180 Subdistricts. We have tried to utilize the most useful elements of all of these sources as they appeared to best explain lake differences in Florida.

Hydrologic unit or watershed frameworks are also commonly used for surface water assessments. The DEP has adopted a hybrid watershed/region framework to help implement an ecosystem management strategy to protect the functions of entire ecological systems (Barnett et al. 1995). Florida's unique topographic and hydrological characteristics, however, reduces the significance of basins or watersheds for explaining water quality patterns and, as shown elsewhere, surface water characteristics or ecological characteristics do not coincide with hydrologic units (Omernik and Griffith 1991; Omernik and Bailey 1997). Our intent in this project was to build on the ecological subregion framework, the regional lake assessment of Canfield (1981), and other sources of ecological and limnological information to define regions of similarity in the physical, chemical, and biological characteristics of Florida lakes and their associations with landscape features.

OVERVIEW AND CLASSIFICATIONS OF FLORIDA LAKES

Florida has an amazing abundance and diversity of lakes, reflecting the state's differences in surface features, geology, and hydrology. The more than 7,700 lakes of Florida have an uneven spatial distribution (Figure 2), with more than half occuring in the central upland portion of the peninsula. Approximately 35 percent of the lakes are located in the four central Florida counties of Lake, Orange, Polk, and Osceola (Palmer 1984).

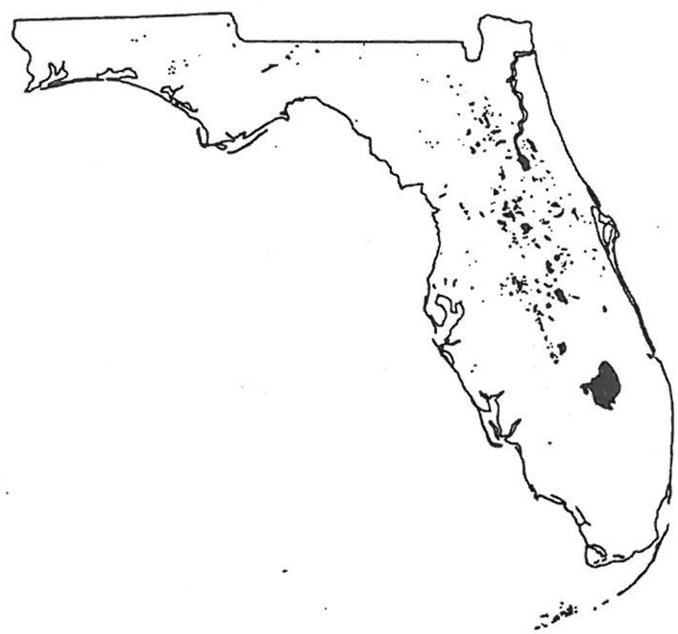

Figure 2. Distribution of Florida lakes (after Brenner et al. 1990).

Although the spatial location of lakes helps explain some of their characteristics, gaining an understanding of their features is complicated by temporal considerations. One could generalize that Florida's subtropical climate has essentially two seasons, a warmer wet one and a cooler dry one, and lake physical, chemical and biological conditions can differ within the year. In addition, longer term climatic fluctuations can make lakes appear or disappear, or alter their chemistry. With relatively flat surrounding topography, some Florida lakes historically had wide fluctuations in surface area. Littoral zone habitats expanded during wet periods, creating productive fish and wildlife areas; and in dry periods, declined, dried out, decomposed, and consolidated, rejuvenating the system (Estevez et al. 1984). As the human population has encroached on these areas with urbanization, agricultural activities, and lake stabilization, these natural processes have been confined and reduced. Other lakes in the state have remarkably stable water levels, such as Kingsley (Deevey 1988).

Average physical configurations of lakes in Florida are varied. There are thousands of lakes with small lake areas, and five lakes, Okeechobee, George, Kissimmee, Apopka, and Istokpoga, have surface areas greater than 40 mi^2 (Heath and Conover 1981). Lake Okeechobee (681 mi^2) is the largest natural freshwater lake in the conterminous U.S. that is entirely within one state. The smallest lakes are primarily the seepage lakes located on the sandy upland ridges, and the largest lakes are drainage types most often found in lowland areas. Florida lakes in general are relatively shallow, and most of the large lakes are very shallow. Lake Okechobee has a maximum depth of about 14 feet and Lake Apopka about 11 feet. Some sinkhole lakes are more than 100 feet deep (Heath and Conover 1981). More detailed overviews of Florida lakes and their characteristics can be found in Brenner et al. (1990), Pollman and Canfield (1991), and Fernald and Patton (1984).

Classifications of Florida's water body types can be found in several references. The lake-related sections of some of these classifications are shown in Table 1. Lake types are usually classified using chemical or physical criteria. In the Water Resources Atlas of Florida, Estevez et al. (1984, p. 96) classifies lakes simply as acid clear, acid colored, or alkaline clear. This is similar to the cluster analysis of 55 lakes by Shannon and Brezonik (1972) showing acid colored, alkaline colored, alkaline clear, and softwater clear lakes. Also in the Atlas, Palmer (1984, p.62) discusses the lake types as impoundments, solution lakes (two basic types: those that are circular at the surface with conical cross sections, and lakes that are elongated and branching formed in valley floor sinkholes), lakes in relict sea bottom depressions, and lakes formed by erosion and sedimentation processes in rivers. He also shows the percentage of total lakes classified by stream connection, ie., no inlets and outlets, inlets and outlets, outlets only, and inlets only. The Florida Museum of Natural History (Burgess and Walsh 1991) used this common straightforward hydrologic classification, but at least 70% of Florida's 7800+ lakes are of the "landlocked" type (no inlet or outlet). Berner and Pescador (1988) used bottom type, sand or silt, for their lakes and several criteria for ponds, but did not make a clear distinction between a lake and a pond. Huber et al. (1983) undertook a trophic state index classification of Florida's lakes in response to the requirements of the EPA's Clean Lakes Program. Lakes were first classified as nitrogen limited, phosphorus limited, or nutrient balanced. 573 lakes were classified by an average trophic state index (TSI) as well as by several subindices. Hydrologic lake types (inflow, outflow, inflow-outflow, seepage, unspecified) were found to not be a major factor influencing TSI values.

Table 1. Lake types from Florida aquatic classifications.

Berner and Pescador (1988)	FL Natural Areas Inventory (1990)	Burgess and Walsh (1991)	Frydenborg (1991)
Ponds	Clastic Upland Lake	Streams flowing into lake	Karst solution lake
Sinkhole ponds	Coastal Dune Lake	Streams flowing out of lake	Relict estuary lake
Fluctuating ponds	Coastal Rockland Lake	Streams flowing in and out of lake	Stream-capture lake
Temporary woods ponds	Flatwoods/Prairie/Marsh Lake	Landlocked lake	Perched aquifer lake
Sporadic ponds	River Floodplain Lake and Swamp Lake	Riverine lake (St. Johns River)	Others
Jerome sink	Sandhill Upland Lake	Impounded lake	Marsh
Lakes	Sinkhole Lake		Swamp
Sand-bottomed lakes			Temporary pond
Silt-bottomed lakes			Coastal dune pond
Disappearing lakes			

Myers and Edmiston's (1983) Florida lake classification project grouped lakes into "poor" or "fair to good" classes using trophic state index. They then prioritized lakes for restoration using a quantitative scheme based on the trophic state, recreational use, public interest, impaired use, nutrient loading, and the importance as a public water body. They listed the top 50 lakes in Florida in need of restoration. Most all occurred in central Florida and were affected by cultural eutrophication. Myers and Edmiston also formulated a ranking scheme for the top 50 lakes in Florida most deserving protection and preservation (i.e., those with good quality, public interest, recreation use, importance as water body), and these were located throughout the state.

It is obvious that many different classifications of lakes have been made for Florida and for different reasons. The spatial extent of the lake classes of these different classifications is rarely defined.

FLORIDA LAKE REGIONALIZATION

METHODS AND MATERIALS

The regionalization process included compiling and reviewing relevant materials, maps, and data; outlining the regional characteristics; drafting the lake region boundaries, creating digital boundary coverages and producing cartographic products; and revising as needed after additional data collection and review by state managers and scientists. In our regionalization process we employed primarily qualitative methods. That is, expert judgement was applied throughout the selection, analysis, and classification of data to form the regions, basing judgments on the quantity and quality of reference data and on interpretation of the relationships between the data and other environmental factors. More detailed descriptions of the methods, materials, rationale, and philosophy for our regionalization process can be found in Omernik (1987; 1995), Gallant et al. (1989), and Omernik and Gallant (1990). Maps of environmental characteristics and other documents were collected from the state of Florida, ERL-C, and several university libraries. The most important of these documents are listed in the References section. The most useful map types for our lake region delineation were physiography or land-surface form, soils, geology, natural vegetation, and land cover. Physiographic and land surface-form information were gathered from many sources including Brooks (1981b; 1982), White (1970), Puri and Vernon (1964), and Fenneman (1938). Geology maps included the 1:250,000-scale Environmental Geology Series from the Florida Bureau of Geology, state scale maps (Brooks 1981a; Vernon and Puri 1964), regional scale quaternary geologic maps (Scott et al. 1986; Copeland et al. 1988), and national scale maps (King and Biekman 1974). Soils information was obtained from the Florida Agricultural Experiment Stations and U.S. Department of Agriculture's (USDA) Soil Conservation Service (SCS) (1962), Caldwell and Johnson (1982), the 1:250,000-scale SCS (now NRCS) State Soil Geographic Data Base (STATSGO) soil maps, and the USDA's county-level soil survey publications. Some historical county soil maps (USDA 1914, 1927, 1928, 1954) also proved useful. Climate information was collected from Bradley (1974), Fernald (1981), and Jordan (1984). The vegetation and forest cover maps that we used included Davis (1943, 1967), those in the state atlas (Fernald 1981), and a recent vegetation classification of Landsat Thematic Mapper imagery (1985-1989) developed by the Florida Game and Fresh Water Fish Commission. Land use and land cover were interpreted from a hardcopy USGS Landsat Multispectral Scanner imagery (1979-1985; scale 1:500,000) as well as from 1:250,000-scale USGS land use/land cover maps from the 1970's.

Lake chemical and physical data were gathered from several sources. Our primary lake data came from mean values from 1133 lakes, sampled between 1979 and 1996. Most of the data (82%) were from lakes sampled between 1990 and 1996. The data came from the University of Florida Department of Fisheries and Aquatic Sciences (54%), the Lakewatch program (34%), the U.S. EPA's Eastern Lake Survey (8%) (Kanciruk et al. 1986), and from the U.S. Forest Service (4%). A selected set of parameters for the 1133 lakes of the primary data set can be found in Appendix 2. Water quality and limnological data collected from the Florida Department of Environmental Protection, the Florida water management districts, Huber et al. (1983), the U.S. EPA (Omernik et al. 1988a; Griffith and Omernik 1990), the Gazeteer of Florida Lakes (Shafer et al. 1986), and other sources were also assessed for the delineation of the lake region boundaries, but were not included in our primary data set due to differences in detection limits, sampling methods, duplication of lakes, or other quality control and comparison efforts.

We used USGS 1:250,000-scale topographic maps as the base for delineating the lake region boundaries. Although some maps in this series are old, it does provide quality in terms of the relative consistency and comparability of the series across Florida, in the accuracy of the topographic information portrayed, and in the locational control. It is also a very convenient scale. Fifteen of these maps give complete coverage of the state. Larger-scale (1:100,000) topographic maps were also examined for more detail on hydrology and other physical and cultural features. Lake data were plotted at several scales, but primarily at 1:250,000-scale for overlay on topographic maps.

RESULTS AND REGIONAL DESCRIPTIONS

We have attempted to synthesize the above material to define a reasonable number of lake regions that appear to have some meaningful differences between them. In our first draft, we defined 41 lake regions of Florida. The current version contains 47 lake regions (Figure A1, Appendix A). These regions were developed primarily by evaluating patterns of features that influence lake characteristics. The numbering system for each lake region consists of two numbers: the first number (65, 75, or 76) relates to the numbering scheme of U.S. ecoregions (Omernik 1987), and the second number refers to the Florida lake regions within an ecoregion.

65-01 Western Highlands

The Western Highlands lake region is characterized by rolling hills, 100-300 feet in elevation, of mixed hardwood and pine forest, with some cropland and pasture. The lake region includes the Blackwater Hills, Escambia Terraced Lands, Milton-Crestview Ridge, and Eglin Ridge (Brooks 1982). The hilly areas are composed of the sands, gravels, and clays of the Citronelle Formation, and the sands and clays of the older Shoal River formation (Brooks 1981a). The Citronelle Formation generally contains more coarse sands and gravels than the clayey sands of the Hawthorn and Miccosukee formations that are found in Panhandle uplands east of the Appalachicola River, such as the Tifton/Tallahassee Uplands (Scott et al. 1980). Soils are well-drained, acidic sands and loamy sands, such as the Dothan-Orangeburg soils in the northern clayhill uplands and the excessively drained Lakeland-Troup soils of sandhill areas such as Eglin Ridge. The region receives some of the highest mean annual precipitation totals of the state, generally 60-75 inches, and, with the rest of the northern part of the Panhandle, the coolest mean minimum and mean maximum temperatures (Bradley 1972; Fernald 1981).

The region has very few natural lakes, primarily just a few ponds and small reservoirs. Local farmers or landowners have made many small ponds, often in a series, for cattle or recreation by damming up small drainages, and the clay content of the sediments in some parts of the region prevents much downward seepage (Schmidt 1978). The largest lakes include Lake Stone in Escambia County, Bear Lake in Santa Rosa County, and lakes Hurricane, Karick, and Silver in Okaloosa County. Similar to the streams of the region that feed these small reservoirs, these would generally be acidic, softwater, low to moderate nutrient lakes, if lake management inputs were low. In Canfield's (1981) study, Western Highland lakes were classified as oligo-mesotrophic, with median phosphorus values generally in the 10-20 µg/l range. However, most lakes in this region, including Karick, Hurricane, and Bear lakes, have been artificially limed and fertilized in an attempt to increase fish production. Bear Lake, for example, in 1980 had a pH of 4.5, alkalinity 2 mg/L, and phosphorus of 15 µg/L. In 1995 the pH was 7.9, alkalinity 20 mg/L, and phosphorus 91 µg/L. Median lake phosphorus values for the region are now generally in the 70-80 µg/l range.

The region also contains some oxbow lakes and other lowland lakes of the river floodplains. Little data exist for these lakes, but they are likely to be darker, more acidic, with moderate nutrients compared to the managed fish ponds and small reservoirs. The characteristics may vary greatly depending on river flow.

65-01 Western Highlands Lake Values

Mean Value	pH (lab) n=4	Total Alkalinity (mg/l) n=4	Conductivity (µS/cm@25°C) n=4	Total phosphorus (µg/l) n=4	Total Nitrogen (µg/l) n=4	Chlorophyll_a (µg/l) n=4	Color (pcu) n=4	Secchi (m) n=4
minimum	7.0	9.6	33	70	417	15	14	1.0
25th %	7.3	12.2	39	76	532	19	15	1.3
median	**7.6**	**16.5**	**46**	**85**	**603**	**24**	**15**	**1.5**
75th %	8.0	20.3	50	102	642	27	16	1.6
maximum	8.2	21.0	51	135	657	28	19	1.7

65-02 Dougherty/Marianna Plains

Stream erosion and solution of Eocene, Oligocene and Miocene limestones has lowered the surface to form this broad lowland (Puri and Vernon 1964; Cooke 1945). This region is characterized by low rolling hills, generally more flat than the regions to the east and west, with agriculture as a dominant land use. There are few streams in the eastern portion of the region and more stream dissection and hills to the west. The Floridan aquifer is at or near the surface in much of the region (Conover et al. 1984; Miller 1990). The northwestern boundary of our region extends further west than the Dougherty Karst District boundary of Brooks (1981b) to include Lake Jackson and the apparant karst-like characteristics of northern Walton County. In this part of northern Walton County, the Floridan aquifer is still only thinly confined (Miller 1990). The lake region is different from the Dougherty/Marianna Plains ecological subregion of Griffith et al (1994) in that the New Hope Ridge/Greenhead Slope area has been separated as a distinct lake region (65-03).

Once called the Lime Sink region (Harper 1914), the solution activity on the limestone bedrock has formed numerous sinks, caverns, springs, and other karst features. Many of the shallow depressions or sinks contain ponds or small lakes surrounded by cypress trees and other hydrophytic vegetation (Hubbel et al. 1956). Bays, dome swamps, or gum ponds are names often used for these wetland areas. Some sinks contain water all year, while many of the others are dry except in rainy periods. Other sinks appear only as areas of darker more moist soils than the surrounding higher land (Head and Marcus 1984). The region contains typically red sandy soils with clay loam subsoils developed on the limestones or on weathered clastic sediments (Fernald 1981; Brooks 1982). The limestone is exposed in some areas, but in other areas, sands and clayey sands reach thicknesses of over 200 feet (Scott et al. 1980). Elevations are generally 100 to 200 feet, but range from 50 feet in the southern ends of the major river floodplains to 345 feet in northwest Walton County, Florida's high point.

The chemical characteristics of lakes in this region can be variable depending upon a lake's contact with bedrock geology or its isolation from the bedrock by surficial deposits of impermeable clays and sands (Canfield 1981). Most of the lakes can be characterized as acidic, slightly acidic or neutral, softwater lakes. They are relatively clear, with low nutrients, and low chlorophyll-*a*. Merrits Mill Pond, which is spring-fed, is somewhat anomalous, with high pH and hard water, and high nitrogen. Blue Lake chemistry also appears affected by limestone near the surface. Cassidy and DeFuniak lakes are somewhat different from the rest of the region's lakes, but the reasons are not readily apparent. Cassidy Lake may be different due to its greater depth. DeFuniak is surrounded by urbanization, but remains clear and unproductive with low color and low nutrients. The Marianna Lowland lakes in Canfield's (1981) study were classified as oligo-mesotrophic or mesotrophic.

65-02 Dougherty/Marianna Plains Lake Values

Mean Value	pH (lab) n=17	Total Alkalinity (mg/l) n=17	Conductivity (µS/cm@25°C) n=17	Total phosphorus (µg/l) n=17	Total Nitrogen (µg/l) n=18	Chlorophyll_a (µg/l) n=18	Color (pcu) n=17	Secchi (m) n=14
minimum	4.7	0.0	11	3	100	1	2	0.5
25th %	5.5	0.8	17	8	317	3	9	1.5
median	**6.3**	**1.8**	**20**	**13**	**438**	**5**	**12**	**2.3**
75th %	6.4	5.4	28	16	499	9	20	2.7
maximum	8.2	96.0	191	44	1497	12	45	4.5

<u>65-03 New Hope Ridge/Greenhead Slope</u>

Also known as the Compass Lake Highlands and Crystal Lake Karst (Brooks 1982), this region contains a relatively high density of solution lakes for the Florida Panhandle. The New Hope Ridge section, with its northern boundary along the Holmes Valley scarp, consists of high sand hills developed over Miocene sands, clays, and gravels (Puri and Vernon 1964; Brooks 1981a, 1982). Elevations are generally 100-300 feet. The relief and elevations decrease on the Greenhead Slope to the south, where karst features and numerous lakes have developed on the Plio-Pleistocene clastic deposits that overlie Miocene and earlier limestone. Similar to other well-drained upland sand ridge areas in Florida, the region is a high recharge area for the Floridan aquifer (Conover et al. 1984).

Soils for the lake region are primarily Entisols, such as those in the Lakeland-Troup-Blanton association.

Lakes of the New Hope Ridge/Greenhead Slope region were chemically characterized as acidic, softwater lakes of extremely low mineral content (Canfield 1981; Canfield et al. 1983). Along with the lakes in the Trail Ridge region, these may be some of the most acid-sensitive lakes of the state, and, as precipitation/evaporation ratios are high and inseepage fluxes of acid neutralizing capacity is small, the ionic chemical composition is largely determined by atmospheric inputs (Canfield 1983b; Pollman and Canfield 1991). The composition of the biotic communities of Florida's acid lakes appear to depend more on the phosphorus and nitrogen status than on pH levels (Canfield 1983b; Pollman and Canfield 1991). Lakes in the New Hope Ridge/Greenhead Slope region are clear, low in nitrogen and phosphorus, low in chlorophyll-*a*, and are among the most oligotrophic lakes in the United States (Canfield 1981). Some of the lakes connected to stream drainages, such as Black Double Lake and Lighter Log Lake in Washington County, are more colored. Round Lake in Jackson County has anomalous chemistry with higher pH, conductivity, and alkalinity values. It is not known if this is related to limestone or groundwater contact, greater depth, or if highway runoff is affecting this lake.

65-03 New Hope Ridge/Greenhead Slope Lake Values

Mean Value	pH (lab) n=28	Total Alkalinity (mg/l) n=28	Conductivity (µS/cm@25°C) n=28	Total phosphorus (µg/l) n=28	Total Nitrogen (µg/l) n=21	Chlorophyll_a (µg/l) n=21	Color (pcu) n=28	Secchi (m) n=22
minimum	4.5	0.0	11	0.7	23	0.5	0	0.9
25th %	4.9	0.0	15	2	87	1	3	3.2
median	**5.2**	**0.0**	**17**	**3**	**153**	**2**	**5**	**3.6**
75th %	5.7	0.7	19	4	213	2	8	5.0
maximum	7.1	6.7	36	8	233	3	29	6.9

65-04 Tifton/Tallahassee Uplands

The characteristics of this region change distinctly from west to east, and it contains a heterogeneous mosaic of mixed forest, pasture, and agricultural land throughout it. The upland region is composed primarily of sands, clays, and clayey sands of the Hawthorn and Miccosukee formations. Mixed hardwoods and pine are found on the clayhill upland soils, while longleaf pine/xerophytic oak types occur on the sandy, well-drained areas. The western part of the region, the Tifton Upland, includes the Appalachicola Bluffs and Ravines and the Quincy Hills, and is classified as Hawthorn and Citronelle formations by Brooks (1981a). Dissection has left many shallow to moderately deep valleys, while flat to rolling land tends to be located on the uplands. Elevations can exceed 300 feet. This western part has few if any natural lakes, but many small ponds and reservoirs created on stream channels. The southwest part of the region consists of thick sand delta deposits (Brooks 1982) and contains one small lake, Lake Mystic three miles south of Bristol in Liberty County, and a large reservoir. Lake Talquin, on the Ochlockonee River, is the second oldest large reservoir in Florida, built originally for power generation in 1929

(Heath and Conover 1981). To the east of the Ochlockonee River, entering Leon County, karst features are more evident with many solution basins and swampy depressions. Two of the larger lakes in the region, Lakes Iamonia and Miccosukee were classified by Wolfe et al. (1988) as swamp lakes. Lake Iamonia drains periodically (e.g., 1910, 1917, 1934, and 1981) when its karst drainage system becomes unplugged (Lane 1986). Lake Jackson has drained about every 25 years since 1881 when its underground karst drainage system becomes unplugged; the most recent drainage was in 1982 (Lane 1986). With diminishing relief, the lake region narrows between Monticello and Greenville, and extends east to near Madison where it merges with the Northern Peninsula Karst Plains (65-06).

Lakes in this region tend to be slightly acidic to neutral, colored softwater lakes with moderate nutrient values. Some lakes, such as Razor and Simpson in Jefferson County and Blairstone in Leon County, have quite high pH and conductivity values because groundwater is pumped in to counteract draining.

65-04 Tifton/Tallahassee Uplands Lake Values

Mean Value	pH (lab) n=25	Total Alkalinity (mg/l) n=25	Conductivity (µS/cm@25°C) n=25	Total phosphorus (µg/l) n=37	Total Nitrogen (µg/l) n=36	Chlorophyll_a (µg/l) n=36	Color (pcu) n=25	Secchi (m) n=27
minimum	5.4	0.4	11	3	227	1	6	0.2
25th %	6.0	2.8	23	15	396	4	8	0.9
median	**6.5**	**5.1**	**31**	**26**	**538**	**12**	**18**	**1.3**
75th %	7.3	16	57	47	697	25	40	2.1
maximum	9.9	69	198	297	3323	216	157	5.8

65-05 Norfleet/Spring Hill Ridge

This lake region contains small, upland, clear, acid type lakes that differ from the darker, swampy, more nutrient-rich lakes of the Tifton/Tallahassee Uplands (65-04) and Gulf Coast Lowlands (75-01) regions. It is somewhat of an anomalous area of xeric sand hills that extend into the Gulf Coast Lowlands. Elevations are generally 60-120 feet, and the natural vegetation consists of longleaf pine and xerophytic oaks (Davis 1967). Acid-tolerant aquatic plants are found here, as most of the lakes have pH levels less than 5.5. Some lakes and ponds show some color associated with rain events, especially Moore Lake and Loften Ponds.

65-05 Norfleet/Spring Hill Ridge Lake Values

Mean Value	pH (lab) n=6	Total Alkalinity (mg/l) n=6	Conductivity (µS/cm@25°C) n=6	Total phosphorus (µg/l) n=7	Total Nitrogen (µg/l) n=7	Chlorophyll_a (µg/l) n=7	Color (pcu) n=6	Secchi (m) n=3
minimum	4.6	0.0	14	5	197	2	4	2.5
25th %	4.9	0.0	16	5	237	2	9	-
median	**5.1**	**0.1**	**17**	**5**	**300**	**3**	**11**	**2.5**
75th %	5.5	0.8	19	6	330	3	17	-
maximum	5.8	2.2	24	11	633	4	20	5.3

65-06 Northern Peninsula Karst Plains

This region, also known as the Suwannee Limestone Plains, is generally a well-drained flat to rolling karst upland with elevations of 50-180 feet, but it contains a diversity of physiographic subdistricts and geologic formations. Natural vegetation consisted of longleaf pine/turkey oak, or hardwood forests on the richer soils (Davis 1967) soils, but agriculture is now extensive in much of the region. Most areas are underlain by the geologically diverse Miocene-age Hawthorn Group or by undifferentiated Quaternary-age sediments. Brooks (1981a) mapped much of the region as the Pliocene Bone Valley formation. Nutrient levels vary, but many lakes tend to have high phosphorus concentrations.

In the north, the Madison Hills and Jennings Hills are somewhat hilly uplands of rich soils with hardwood forests and agriculture. There are a few lakes, mostly small in size; the largest are Grassy and Langford ponds in Madison County and lakes Octahatchee and Alcyone in Hamilton County. Grassy Pond, as shown in the county soil survey, is located in more poorly drained soils, the Plummer-Surrency association compared to the sandy upland soils (Alaga-Blanton-Troup) of Langford Pond.

Many of the lakes in the lake region are located in an area between Live Oak and Lake City in eastern Suwannee and western Columbia counties. The Lake City Karst subdistrict is a karst area with several lake basins and xeric hills with elevations 90-180 feet. Lakes in this subdistrict include Orange Pond, Johns Pond, Hancock Lake, lakes Wilson and Lona (appear intermittent on 1;100,000-scale topographic maps), Lake Jeffery, and several lakes in the Lake City urban area including Lake Hamburg, Alligator Lake, and Watertown Lake. Both Alligator and Watertown lakes are hard-water lakes (Canfield 1981), although Alligator has received municipal sewage and stormwater runoff and parts of it have been diked and drained for agriculture (Hand and Paulic 1992). Groundwater connections as well as anthropogenic inputs could be elevating the conductivity and phosphorus of some lakes around Lake City. The area occurs over Miocene deposits with phosphatic sand and clayey sand (Brooks 1981a,b; 1982). The Wellborn Uplands (Live Oak Hills, Rocky Creek Terrace, and Wellborn Hills) are primarily clastic capped hills of moderate relief. Some areas have thick deposits of fine to medium sands and silts, especially the Wellborn Hills between Wellborn and Live Oak (Knapp 1978b; Brooks 1982).

The McAlpin Plain, Haile Limestone Plain, and Williston Plain, karst plains generally 50-150 feet in elevation, are part of Brooks' (1981b; 1982) Northern Peninsula Plains. Lakes are not abundant in these areas but the many solution basins may fill seasonally.

In summary, the mosaic of lake types in this region has a wide-ranging distribution of chemical and physical characteristics, as can be seen in the ranges between the 25th and 75th percentiles in the table below. Lakes tend to be slightly acidic, with low to moderate alkalinity, and some color. Nutrient levels are variable, with some lakes definitely having high levels. The region's median phosphorus is one of the highest in northern Florida.

65-06 Northern Peninsula Karst Plains Lake Values

Mean Value	pH (lab) n=21	Total Alkalinity (mg/l) n=19	Conductivity (µS/cm@25°C) n=21	Total phosphorus (µg/l) n=28	Total Nitrogen (µg/l) n=26	Chlorophyll_a (µg/l) n=25	Color (pcu) n=21	Secchi (m) n=22
minimum	4.6	0.0	22	11	282	1	12	0.3
25th %	5.8	2.3	39	23	605	6	19	0.7
median	**6.5**	**6.8**	**52**	**74**	**867**	**12**	**42**	**1.2**
75th %	7.3	33.5	131	153	1011	37	73	1.5
maximum	9.2	80.7	169	346	3083	300	333	2.8

75-01 Gulf Coast Lowlands

This is a disjunct region of three sections: Escambia County to Wakulla County in the west, parts of Taylor, Madison and Lafayette counties in the center, and a narrow strips of central Gilchrist and Levy counties. In the western Panhandle, xeric coastal strand and pine scrub vegetation are found on the relic lagoon, dune, and barrier island features. Inland, pine flatwoods mixed with some hardwood forest and swamp vegetation are typical on the clastic non-karst terraces and deltas of the Appalachicola area and the other flats and swamps areas.

Several types of lakes occur in this region including coastal dune lakes, flatwood lakes, "edge lakes", river floodplain or oxbow lakes, and reservoirs. Most of the lakes tend to be darkwater, acidic, softwater lakes with low to moderate nutrients. Coastal dune lakes are generally within two miles of the coast. These lakes can be eliptical or irregular in shape, with or without surface inlets and outlets. Water is generally derived from lateral ground water seepage through the well-drained coastal sands. They are slightly acidic, low nutrient, darkwater systems that can freshen or turn salty depending on rainfall and subsurface or overwash saltwater input, or salt spray. As one would expect, these dune lakes have higher sulfate, sodium, and chloride levels than inland lakes. Examples of coastal dune lakes are Morris, Campbell, Western, and Camp Creek lakes in Walton County, Powell Lake in Bay County, and Duck Lake and Corn Landing Lake in Franklin County. Coastal lakes, such as Corn Landing Lake, that are higher in elevation would have longer periods of freshwater. Some lakes such as Western Lake in Walton County contain freshwater fish, with saltwater fish in the more saline bottom layers. Dune lakes are important breeding areas for insects that form the base of many food chains, and are important for birds and mammals inhabiting surrounding xeric and coastal ecosystems (Wolfe et al. 1988; Florida Natural Areas Inventory 1990).

Flatwood lakes receive the majority of their water from direct rainfall and runoff from surrounding poorly drained soils. These are generally acid, softwater lakes that are oligotrophic to oligomesotrophic.

"Edge lakes" or sag ponds are found at the foot of relict marine terrace scarps or where soluble limestone that is near the surface abuts an upland of thick insoluble sands. As Wolfe (1989) explained it, "The slope of the water table steepens behind the face of the scarp with the increased gradient of water flow, bringing the water table closer to the ground surface immediately below the scarp. The increased water flow tends to dissolve the buried surface of the limestone, creating sag ponds along the tow of the scarp." An example is Chunky Pond near the western edge of the Northern Brooksville Ridge (75-05). In the Wacasassa Flats area of northern Gilchrist County, Sevenmile and Bagget lakes appear to have some limestone influence, showing high pH, alkalinity, and conductivity values (Suwannee River Water Management District data). These lakes are darker in color, however, than the limestone influenced lakes of the nearby Big Bend Karst (75-06).

Two large reservoirs are located in the Gulf Coast Lowlands region. Dead Lake on the Chipola River in Gulf and Calhoun counties was originally a natural impoundment created by the alluvial sediments and old levees of the Appalachicola River. A dam was constructed in the 1960's to enlarge and stabilize the impoundment, but was removed in 1988 (Florida Resources and Environmental Analysis Center 1989). Dead Lake could be classified as a riverine swamp lake. Its pH is generally between 6.0 and 7.0 and the lake receives some limestone groundwater inputs. Deer Point Lake on Econfina Creek, is impounded above North Bay, and is the major potable water supply for Panama City and Bay County (Florida Resources and Environmental Analysis Center 1989).

75-01 Gulf Coast Lowlands Lake Values

Mean Value	pH (lab) n=26	Total Alkalinity (mg/l) n=26	Conductivity (µS/cm@25°C) n=26	Total phosphorus (µg/l) n=32	Total Nitrogen (µg/l) n=32	Chlorophyll_a (µg/l) n=32	Color (pcu) n=26	Secchi (m) n=28
minimum	3.9	0.0	19	5	184	1	28	0.1
25th %	4.9	0.0	30	8	482	3	65	0.6
median	**5.3**	**0.5**	**44**	**15**	**648**	**4**	**117**	**0.9**
75th %	6.5	10.5	75	22	863	9	204	1.3
maximum	10.3	34.0	5636	340	2500	65	521	2.9

75-02 Okefenokee Plains

This lake region has the same boundaries as the Okefenokee Swamps and Plains ecological subregion (Griffith et al. 1994). It is characterized by flat plains and terraces with pine flatwoods and swamp forests over peat, muck, clayey sand and some phosphatic deposits. The region separates some distinct lake types from those in lake region 65-06 that were previously lumped together as the Northern Highlands (Canfield 1981). There are only a few lakes in the region, and these are primarily in the southern part. Ocean Pond is located on the Lake City Ridge, and Palestine Lake, Swift Creek Pond, and Lake Fisher are on an upland plain that Brooks (1982) calls the High Flatwoods. These are highly acidic softwater lakes, mostly low clarity and darkly colored, but the color is variable depending on rainfall. The region's median pH value of 4.7 is the lowest of all the Florida lake regions. Although Ocean Pond is one of Florida's most acidic lakes, it supports a sustained sport fishery for largemouth bass, black crappie, bluegill, and other centrarchids (Canfield 1983b). Phosphorus values for the lakes are generally in the 10-20 µg/l range (20-25 µg/l range in Canfield's 1981 study), but Swift Creek Pond has higher phosphorus values than the other lakes, and there may be other phosphatic areas. Palestine Lake and

Swift Creek Pond appear to have more swampy soils surrounding them (Plummer-Pamlico-Dorovan association) than does Ocean Pond.

75-02 Okefenokee Plains Lake Values

Mean Value	pH (lab) n=4	Total Alkalinity (mg/l) n=4	Conductivity (µS/cm@25°C) n=4	Total phosphorus (µg/l) n=4	Total Nitrogen (µg/l) n=4	Chlorophyll_a (µg/l) n=4	Color (pcu) n=4	Secchi (m) n=3
minimum	4.4	0.0	40	11	383	1	77	0.3
25th %	4.6	0.0	43	12	411	4	109	-
median	**4.7**	**0.0**	**50**	**14**	**731**	**6**	**231**	**0.8**
75th %	4.8	0.0	59	27	1086	9	368	-
maximum	5.0	0.0	70	61	1220	16	445	1.2

75-03 Upper Santa Fe Flatwoods

This region includes portions of the High Flatwoods in the Sea Island District, and the Perched Lakes and Prairies physiographic subdistrict from the Central Lakes District of Brooks (1981b; 1982). It is predominantly an area of pine flatwoods with some swamp forests (Davis 1967), and elevations are generally 120-180 feet. Lakes in this region include Butler, Sampson, Crosby, Rowell, Hampton Lake, Alto, Hickory Pond, Santa Fe, and Little Santa Fe. Punchbowl Lake sampled by the Lakewatch Program is on or near the boundary with the adjacent Trail Ridge lake region. Almost all of the lakes in the region occur on thin Plio-Pleistocene undifferentiated sediments that overlie deeply weathered clayey sand, granular sand, and kaolinitic clay of the Miocene Hawthorn Group.

In general the lakes are slightly acid, colored, with low to moderate nutrients. The pH and alkalinity levels are higher than the Okefenokee Plains (75-02) to the north, and phosphorus levels of the lakes are relatively low, averaging in the 10-15 µg/l range. Lake Rowell phosphorus levels are two to three times higher than the regional average, receiving wastewater treatment plant discharges from the city of Starke via Alligator Creek (Hand and Paulic 1992). Lake Sampson's chemistry may also be affected by these discharges. Santa Fe Lake receives stormwater runoff from the city of Melrose.

75-03 Upper Santa Fe Flatwoods Lake Values

Mean Value	pH (lab) n=9	Total Alkalinity (mg/l) n=9	Conductivity (µS/cm@25°C) n=9	Total phosphorus (µg/l) n=11	Total Nitrogen (µg/l) n=11	Chlorophyll_a (µg/l) n=11	Color (pcu) n=9	Secchi (m) n=11
minimum	5.0	0.0	52	8	422	3	17	1.0
25th %	5.4	0.3	66	10	515	5	33	1.2
median	**5.9**	**1.0**	**68**	**13**	**557**	**6**	**55**	**1.6**
75th %	6.2	1.8	69	14	647	10	72	1.7
maximum	7.2	23.3	234	37	753	15	79	1.8

75-04 Trail Ridge

Our Trail Ridge lake region consists of the Trail Ridge and Interlachen Sand Hills physiographic subdistricts, and extends into the St. Johns Offset (Brooks 1981b;1982). The lake region has different characteristics from north to south. In the north, the narrow depositional ridge has poor drainage and flatwood forest vegetation. It broadens to the south becoming a karstic landscape with numerous solution depressions and lakes, with longleaf pine-xerophytic oak vegetation. The sands that overlie the Hawthorn Group in western Putnam County are slightly clayey, silty, poorly sorted quartz sands (Readle 1987). The region is dominated by well-drained, nutrient-poor upland soils such as Candler, Apopka, Astatula, and Tavares (Readle 1987; Caldwell and Johnson 1982).

Lakes in the Trail Ridge region are mostly small, acid, clear lakes, with some slightly colored lakes, and are characterized as oligotrophic or oligo-mesotrophic. To the south, conductance and macrophytes in the lakes tend to increase. Average lake phosphorus values were mostly less than 10 µg/l, with several lakes in the 10-15 µg/l range.

With soils that generally have low cation exchange capacity and base saturation, there is concern about increased acidification of Trail Ridge lakes. Although the evidence is not clear for many lakes, there is some evidence that atmospheric deposition is contributing to progressive acidification of lakes in this region (Hendry and Brezonik 1984; Pollman and Canfield 1991).

Kingsley Lake is one of the largest lakes in the region and is also one of the deeper lakes in Florida at around 85 feet (Heath and Conover 1981). It is different chemically from most Trail Ridge lakes, with higher pH, alkalinity, and a different cation/anion mix that reflects groundwater inputs rather than atmospheric controls on chemistry (Canfield 1981). Kingsley Lake water levels were shown to be remarkably stable over time from 1945-1985 (Deevey 1988). Kingsley Lake and Lake Geneva, another lake of elevated alkalinity and pH, also have the most shoreline development in the region.

75-04 Trail Ridge Lake Values

Mean Value	pH (lab) n=50	Total Alkalinity (mg/l) n=50	Conductivity (µS/cm@25°C) n=50	Total phosphorus (µg/l) n=72	Total Nitrogen (µg/l) n=62	Chlorophyll_a (µg/l) n=62	Color (pcu) n=50	Secchi (m) n=64
minimum	4.3	0.0	25	2	57	0.5	0	0.7
25th %	4.9	0.0	41	5	137	2	5	1.8
median	**5.6**	**0.3**	**48**	**9**	**243**	**3**	**9**	**2.2**
75th %	6.2	1.6	64	12	391	5	11	3.3
maximum	8.0	33	99	40	1161	24	65	7.6

75-05 Northern Brooksville Ridge

This region, also known as the Newberry Sand Hills (Brooks 1981b), extends from the southeast corner of Gilchrist County, through Levy County and into western Marion County. Similar to the Southern Brooksville Ridge (75-13), the region's land surface is very irregular. Elevations vary over short distances from about 70-170 feet. It is an area of internal drainage and xeric sand hills, with natural vegetation of longleaf pine and