GROUND-WATER SOURCES AND 1985 WITHDRAWALS IN FLORIDA

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INTRODUCTION

Florida has abundant ground-water resources. More than 4,000 Mgal/d (million gallons per day) are withdrawn from the five principal aquifers and aquifer systems in the State. Because ground water is abundant, readily available, and generally of quality suitable for most uses, more than 64 percent of the 6,276 Mgal/d of freshwater withdrawn for all purposes in Florida is ground water, compared to 22 percent nationally. Ground water is the source of supply for almost 90 percent of Florida's public water supply and 100 percent of self-supplied rural-domestic needs (see table and fig.1), compared to 40 and 98 percent respectively, nationwide; 55 percent of the water used for irrigation in Florida is ground water, whereas nationally it is 33 percent.

Florida ranks sixth among States in total fresh ground-water withdrawals for all uses, second for public supply, first for industrial uses, first for mining, and ninth for irrigation withdrawals (Solley and others, 1988). Ground water is one of Florida's most valuable natural resources.

GENERAL SETTING

Florida is in the Coastal Plain physiographic province, a region of generally low relief underlain by unconsolidated to poorly consolidated sediments and by indurated carbonate rocks. Nearly everywhere, surficial sands mantle Florida and overlie a thick sequence of bedded limestone and dolomite. Together, the surficial sands, limestone, and dolomite form an enormous ground-water reservoir that, proportionally, provides larger quantities of ground water in Florida than in any other State (McGuinness, 1963, p. 244). Nearly all of Florida's ground water originates from precipitation within the State. Relatively small amounts also are supplied by subsurface inflow from adjacent areas of Alabama and Georgia and by leakage from streams that enter Florida (Vecchioli and Foose, 1984).

Average annual precipitation exceeds 50 inches over most of the State (Hughes and others, 1976). Part of this precipitation percolates to the water table and recharges the ground-water reservoir. Annual recharge rates range from near zero in perennially wet areas that cover about 45 percent of the State, to 10 to 20 inches or more in well-drained upland areas (Stewart, 1980). In much of the State, most of this recharge moves through the surficial aquifers and discharges to nearby streams; only a small fraction, ranging from nearly 0 to 5 inches (Bush, 1982), percolates downward through confining layers to recharge deeper aquifers.

PRINCIPAL AQUIFERS AND AQUIFER SYSTEMS

In Florida, ground water is withdrawn from five principal aquifers and aquifer systems: the Biscayne aquifer, the sand-and-gravel aquifer, unnamed surficial aquifers, an intermediate aquifer system, and the Floridan aquifer system. The large map shows, by counties, the major areas of their use.

The **Biscayne aquifer** is the most intensively developed of all the Florida aquifers. It supplies the densely populated Miami-Palm Beach coastal area with virtually all of its water needs. In 1985, total withdrawal from the Biscayne aquifer was 786 Mgal/d (fig. 2), of which 72 percent was for public supply and 23 percent was for irrigation. The Biscayne aquifer underlies all of Dade and Broward Counties and adjoining parts of Palm Beach and Monroe Counties. It is composed primarily of highly permeable limestone in south and west Dade County but becomes increasingly sandy and less permeable to the north and east. The high permeability is caused largely by extensive carbonate dissolution. Large-diameter public-supply wells in Dade County produce as much as 7,000 gal/min (gallons per minute), with little water-level drawdown. Yields of 500 to 1,000 gal/min are common from wells that are typically 40 to 150 feet deep. Water in the Biscayne aquifer is unconfined and in hydraulic continuity with the many canals that cross the area. Induced recharge from the canals occurs where the water table is depressed below canal stage near well fields. Water levels in the canals are controlled by structures near their mouths to prevent saltwater from flowing inland to the well fields and, there, infiltrating the aquifer.

Because the Biscayne aquifer is very permeable, very vulnerable to contamination, and is the sole source of drinking water for more than 3 million people in southeast Florida, the U.S. Environmental Protection Agency designated it as a "sole-source aquifer" under provisions of the Safe Drinking Water Act of 1974 (Public Law 93-523). Locally, the aquifer has been contaminated by industrial discharges, landfill leachate, and fuel spills. Water from the Biscayne aquifer commonly is very hard.

The **sand-and-gravel aquifer** is the major source of water supply in the western part of the Florida Panhandle. In 1985, withdrawals from the aquifer totaled about 100 Mgal/d of which 45 Mgal/d was withdrawn for public supply and 41 Mgal/d for industrial purposes. The aquifer consists of surficial sediments that exceed 700 feet in thickness in northwestern Escambia County. The aquifer thins to the south and east and pinches out in central Walton County. Water in the sand-and-gravel aquifer is under both unconfined and confined conditions, depending on the presence of discontinuous clay lenses of little permeability that are interbedded with the more permeable sand-and-gravel layers. The deep production zone of the aquifer, which is tapped by most large-capacity wells, generally is semiconfined. Wells capable of producing several hundred gallons per minute are common. Depths of wells tapping the sand-and-gravel aquifer generally range from 100 to 300 feet. Industrial operations in and around Pensacola have caused local contamination of water in the aquifer; a noteworthy example is contamination by phenol and pentachlorophenol from a wood-preserving plant during the past several decades (Mattraw and Franks, 1986). Water from the sand-and-gravel aquifer commonly is soft, has less than 50 mg/L (milligrams per liter) dissolved solids, and locally has iron concentrations that exceed 0.3 mg/L.

Unnamed surficial aquifers are present over much of the remainder of the State but, except for small self-supplied domestic wells, they are little used where more plentiful supplies can be obtained from deeper aquifers that contain potable water. Where the deeper aquifers contain nonpotable water, these surficial aquifers are important sources of supply. Withdrawals from these aquifers in 1985 totaled 361 Mgal/d. The surficial deposits consist of sand and shell with minor limestone beds. These aquifers are used most intensively for public supply in the area southwest of Lake Okeechobee and in scattered towns along the east coast from Palm Beach County northward. Elsewhere, these aquifers are used mainly for self-supplied domestic water supply and private lawn irrigation. The aquifers in many areas have been contaminated locally with saline water from leaky casings and uncontrolled flowing of artesian wells that tap deeper aquifers (Healy, 1978). Hardness and dissolved-solids concentrations from these unnamed surficial aquifers vary widely.

The informally termed **intermediate aquifer system** occurs in southwest Florida and along the eastern part of peninsular Florida between the local surficial aquifer and the underlying Floridan aquifer system. The intermediate aquifer system is composed mainly of limestone and shellbeds interbedded with sand and clay. Water in the intermediate aquifer system is confined. The intermediate aquifer system is an important source of water for public supply and irrigation in southwestern Florida because water in the underlying Floridan aquifer system there is nonpotable. Elsewhere, the intermediate aquifer system generally is used only for self-supplied domestic withdrawals or to supply small communities. In 1985, 298 Mgal/d was withdrawn from the intermediate aquifer system. Well yields differ widely depending on the amount of permeable limestone available; however, yields of 1,000 gal/min or more can be obtained in places. The intermediate aquifer system contains water too saline for human consumption in most of the area south of Lake Okeechobee. Parts of the aquifer system in and around Sarasota County contains water having concentrations of naturally occurring radium 226 and of sulfate that exceed national drinking-water standards (U.S. Environmental Protection Agency, 1982).

The **Floridan aquifer system**, one of the most productive sources of ground water in the United States, extends across the entire State of Florida, southern Georgia, and adjoining small parts of Alabama and South Carolina. The Floridan is the lowermost part of the ground-water reservoir in Florida. It consists of as much as 3,500 feet of limestone and dolomite beds that are interconnected hydraulically to differing degrees. The Floridan is at or near land surface in the western part of the peninsula that extends from Wakulla to Pasco County, in the panhandle area bordering Alabama, and in most of Holmes and Jackson Counties and in a small part of Walton County. Elsewhere, it is confined and buried beneath other aquifers to depths of as much as 1,100 feet below sea level in southern Florida and to 1,500 feet below sea level in the westernmost part of the Florida Panhandle. Water in the Floridan is unconfined in about one-quarter of the State, where the aquifer system is at or near land surface, and is confined elsewhere.

Many public-supply systems tap the Floridan aquifer system including those serving Daytona Beach, Fort Walton Beach, Gainesville, Jacksonville, Lakeland, Ocala, Orlando, and Tallahassee. Some coastal public-supply systems, such as Clearwater and St. Petersburg in Pinellas County, and Cocoa in Brevard County, obtain Floridan aquifer system water imported from adjacent counties because the locally underlying Floridan aquifer system contains saline water. The Floridan also is a major source of water for industrial, irrigation, and rural uses. Though the Floridan is the major source of water in Brevard, Flagler, Indian River, Okeechobee, St. Johns, and St. Lucie Counties, the intermediate aquifer system and surficial aquifers in these counties provide the major source of water for public and domestic supply owing to the the elevated mineral content of water in the Floridan aquifer system there. Total withdrawal from the Floridan aquifer system in Florida in 1985 was 2,503 Mgal/d. This represented 62 percent of total ground-water withdrawal and 40 percent of total water withdrawal. Nearly half the withdrawal from the Floridan, 1,178 Mgal/d, was for irrigation, whereas 28 percent, 693 Mgal/d, was withdrawn for public supply. Yields vary considerably, but yields of several hundred to a thousand gallons per minute commonly are attainable by large-diameter wells, and yields of as much as 20,000 gal/min have been reported (Heath and Conover, 1981, p. 159). Depths of wells also vary widely--from 100 to 1,800 feet. Flowing artesian wells that tap the Floridan are common over much of the lower lying areas of the State. Water in the Floridan aquifer system in the southern third of the peninsula is not suitable for drinking. Elsewhere, the water commonly is hard and in places contains sulfate concentrations in excess of drinking water standards. Contamination by aldicarb and ethylene dibromide from agricultural activities has been noted recently in parts of the State (S.H. King, Florida Department of Health and Rehabilitative Services, written commun., 1983; J.E. McNeal, Florida Department of Environmental Regulation, written commun., 1983). Where the aquifer system is at or near land surface, it is susceptible to contamination by leachate from landfills and other waste-disposal facilities.

In addition to its wide use as a water-supply source, the Floridan aquifer system also is used as a repository for wastewaters. Stormwaters enter the upper part of the aquifer system through hundreds of drainage wells, mostly in central peninsular Florida (Kimrey and Fayard, 1984). Industrial and municipal wastewaters are injected into saline parts of the aquifer system mainly in the Pensacola area, in Pinellas County, and along the southeastern coast from Miami to Indian River County (Vecchioli, 1981).

TRENDS IN GROUND-WATER WITHDRAWALS

Ground-water withdrawals in Florida continue to increase as the population increases. The population increased 26 percent from 1980 to 1985, and the withdrawal of ground water for public supply increased 24 percent in the same period. The relatively small increase in total ground-water withdrawals of 6 percent contrasts with an overall 14 percent decrease in total freshwater withdrawal, resulting from a 36 percent decrease in the withdrawal of surface water in the same period. Moreover, ground-water withdrawals accounted for 48 percent of total withdrawals in 1975 and 64 percent of the total in 1985 (fig. 3). The increased dependency upon ground water is brought about by several factors. In general, ground water is of satisfactory quality for most uses and is readily available in most of Florida, whereas the development of additional surface-water supplies is restricted by the lack of satisfactory impoundment sites and by environmental concerns. Thus, although Florida has about 7,800 freshwater lakes, more than 1,700 surface streams and 27 of the 78 first-magnitude springs (flow greater than 0.6 Mgal/d) in the United States (Heath and Conover, 1981, p. 60, 106, and 131), only a few large water-supply systems obtain all or part of their supply from surface-water sources (Leve and Conover, 1986, p. 14). Further, in many areas where ground water is not potable, such as along the southwestern coast, surface water also is not available with the result that some public-supply systems depend upon saline ground water (about 17 Mgal/d in 1985), about half of which is desalinated before use. The use of ground water for public supply and other purposes reduces competition for the various inherent uses of surface water in Florida's unique environment (Leve and Conover, 1986, p. 6).

In spite of the continued increase in dependence on ground water in Florida, substantial declines of ground-water levels have occurred in only a few local areas. From 1980 to 1985, declines of more than 10 feet in water levels of the Floridan aquifer system occurred in west-central, northeastern, and the western panhandle areas of Florida (Barr, 1987). The greatest long-term observed decline of water levels has been more than 40 feet from 1961 to 1985 in small areas of west-central Florida and in western panhandle Florida (Healy, 1982; Barr, 1987).

Ground water is one of Florida's most valuable resources. It is subject to degradation and pollution by many of man's activities. For instance, as of 1986 more than 400 potentially hazardous waste sites were identified, 270 of which had some type of identified or suspected water or soil contamination. In many areas of Florida, degradation of water has occurred only in surficial deposits and not in the deeper aquifers; however, downward movement of contaminants is a possible threat (Irwin and Bonds, 1988).

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Table 1.--Ground-water facts for Florida

[Mgal/d = million gallons per day; gal/d = gallons per day; Data from Marella, 1988, and Solley and others, 1988]

Population served by ground water, 1985	
Number (thousands)	10,266
Percentage of total population	91
From public water-supply systems:	
Number (thousands)	8,679
Percentage of total population	77
From self-supplied systems:	
Number (thousands)	1,587
Percentage of total population	14
Freshwater withdrawals, 1985	
Surface water and ground water, total (Mgal/d)	[1]6,276
Ground water only (Mgal/d)	[1]4,048
Percentage of total	64
Percentage of total excluding withdrawals for thermoelectric power	72
Category of use	
Public-supply withdrawals:	
Ground water (Mgal/d)	[1]1,492
Percentage of total ground water	37
Percentage of total public supply	89
Per capita (gal/d)	172
Self-supplied domestic withdrawals:	
Ground water (Mgal/d)	259
Percentage of total ground water	6
Percentage of total self-supplied domestic	100
Industrial, commercial, mining, thermoelectric self-supplied withdrawals:	
Ground water (Mgal/d)	651
Percentage of total ground water	16
Percentage of total industrial self-supplied:	
Including withdrawals for thermoelectric power	46
Excluding withdrawals for thermoelectric power	89
Irrigation withdrawals:	
Ground water (Mgal/d)	1,588
Percentage of total ground water	39
Percentage of total irrigation	55
Livestock withdrawals,	
Ground water (Mgal/d)	58
Percentage of total ground water	2
Percentage of livestock withdrawals	88

[1]Includes 17 Mgal/d of saline water, about half of which is desalinated for public supply.

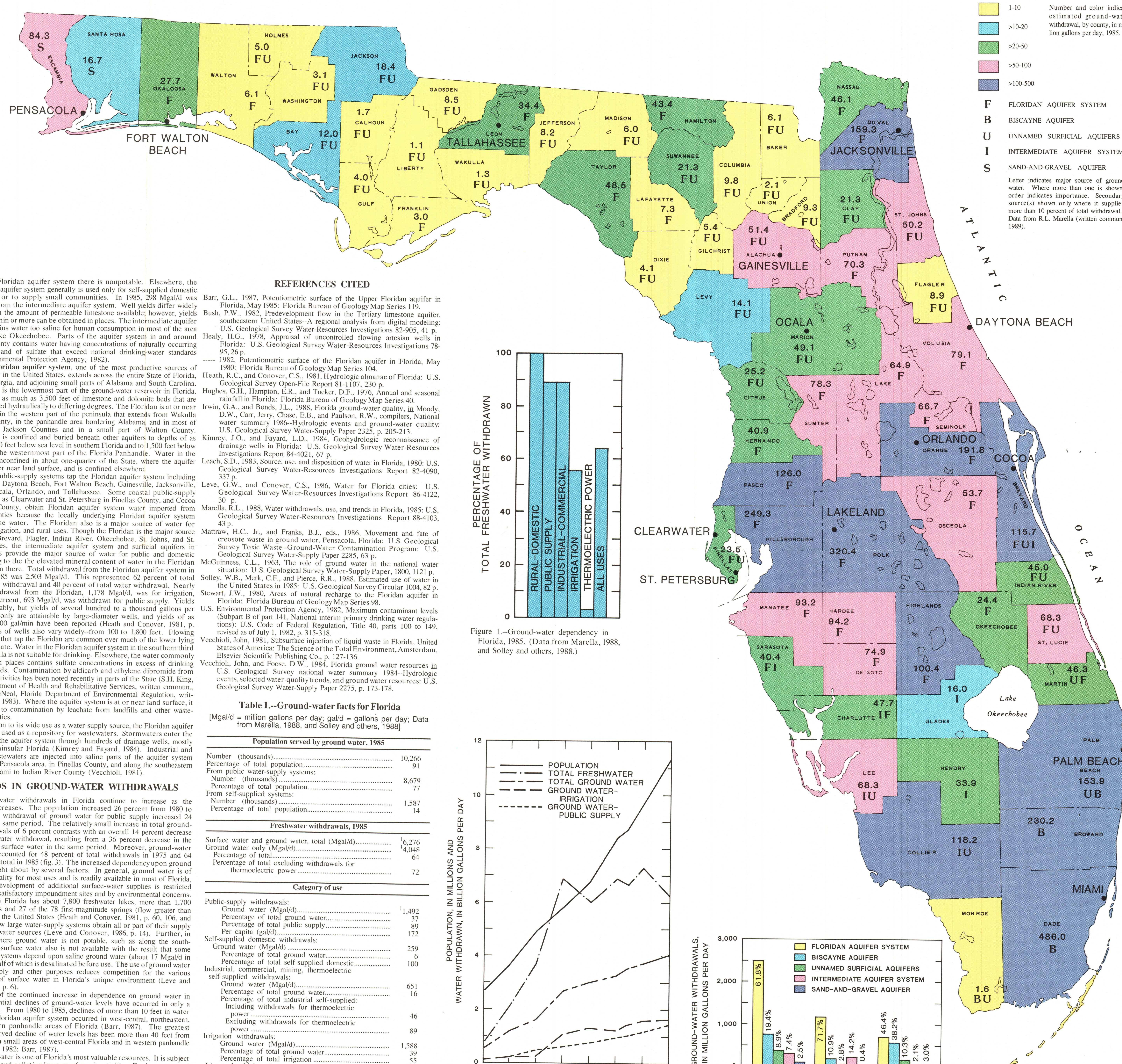

Figure 1.--Ground-water dependency in Florida, 1985. (Data from Marella, 1988, and Solley and others, 1988.)

Figure 3.--Trends in population, freshwater withdrawals, and ground-water withdrawals in Florida, 1950-85. (Modified from Leach, 1983, and Marella, 1988.)

Figure 2.--Ground-water withdrawals by source in Florida, 1985. (Modified from Marella, 1988.) Number shown is the percentage of total withdrawal for the category of use supplied by the aquifer.