FLORIDA'S GROUNDWATER RESOURCE: VAST QUANTITY, GOOD QUALITY?

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Introduction

Water is one of Florida's most valuable resources. Each year millions of residents and tourists enjoy the recreational opportunities and esthetics afforded by thousands of miles of ocean and marine waterways along the coasts. Though scenic and plentiful, this water cannot furnish Florida with drinking water, irrigate crops, or supply most industries, because of its salt content. Fresh water supplies come from extensive beds of porous rock beneath the ground called aquifers and from fresh water lakes, streams and reservoirs. Figure 1 summarizes the status of Florida's fresh water sources and uses in 1980. As this figure illustrates, over 50% of the total fresh water used in Florida comes from groundwater, and over 90% of the public rely on groundwater supplies for their drinking water. Thus groundwater is a particularly important resource for this state.

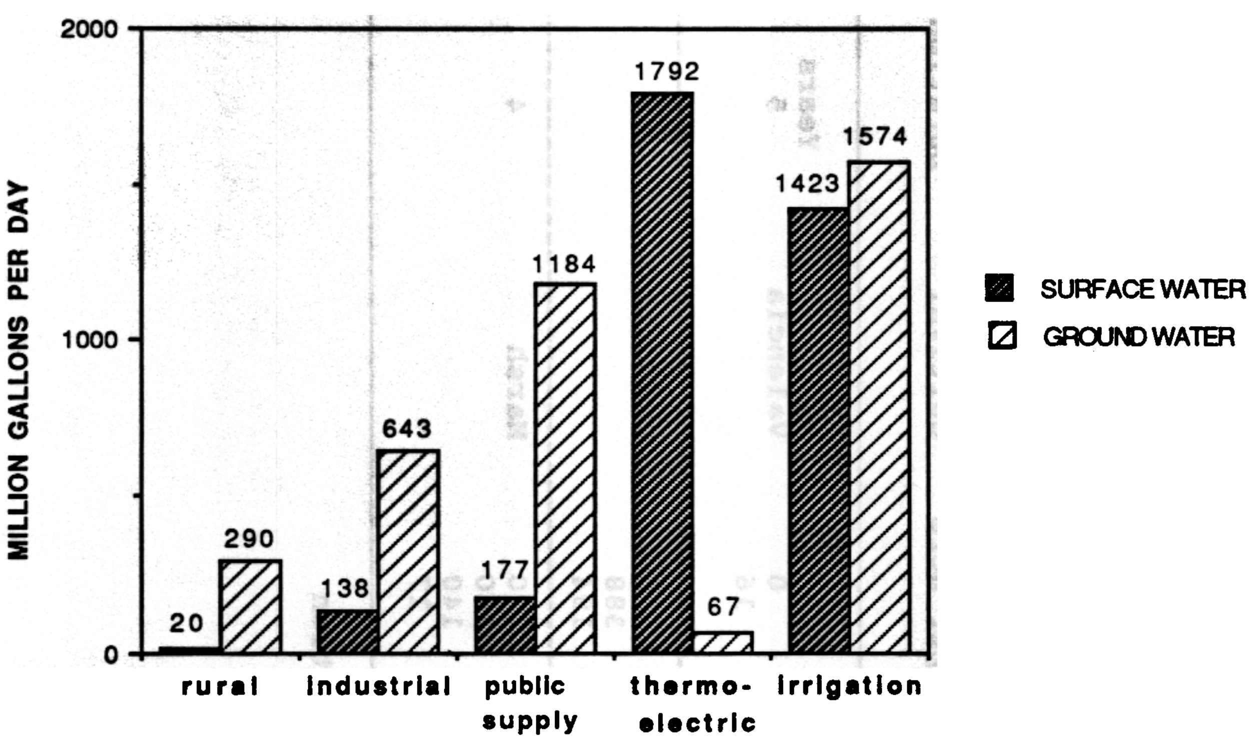


Figure 1. Florida's Water Uses and Sources - 1980

Of all the fresh water withdrawn in Florida, only about one-third is consumed by evaporation, transpiration or production processes. The remaining two-thirds is returned to the environment, either to surface streams or to aquifers Because water comes into contact with a variety of heavy metals, organic chemicals, pesticides and fertilizers during its use, the quality of the water which is returning to the environment has become a widespread concern.

Groundwater and the Hydrologic Cycle

The continuous circulation of water from land and sea to the atmosphere and back again is called the hydrologic cycle. Figure 2 provides a schematic diagram of the hydrologic cycle for a generalized Florida setting. Inflow to the hydrologic system arrives as precipitation, primarily in the form of rainfall in Florida. Outflow takes place as streamflow (or runoff), as evapotranspiration (a combination of evaporation from open bodies of water, evaporation from soil surfaces and transpiration from the soil by plants), and outflow from the groundwater flow system. Precipitation is delivered to streams both on the land surface, as overland flow to tributary channels, and by subsurface flow routes, as interflow and baseflow following infiltration into the soil.

Between the land surface and the groundwater table is the unsaturated, or vadose zone, where both water and air occur in the soil pores. In the flatwoods soils of south Florida the unsaturated zone is typically small. It may occupy the first 10 to 40 inches below the ground surface in the dry season, and may be non-existent in the wet season when the water table is at or above the ground surface. In the sandy soils of the Central Florida Ridge however the vadose zone can extend 100 feet or more. Water in the unsaturated zone is either taken up by plants, evaporated, or drained by gravity into the saturated groundwater.

In the saturated groundwater zone all pores and crevices are saturated with water, and all of the air has been forced out. Water seeping into this zone is called recharge. Groundwater can occur either as an unconfined (phreatic) aquifer, or as a confined (artesian) aquifer as illustrated in Figure 3. In an unconfined aquifer, the water table forms the upper boundary of the aquifer, and the water level in a well will rest at this level. Water infiltrating from the surface has the potential to move rapidly into an unconfined aquifer, thus there is a good chance of contamination from surface activities. In an unconfined aquifer, groundwater moves by gravity from recharge areas to discharge areas. The direction of flow often follows the surface topography moving from areas of high elevation to areas of low elevation.

Confined aquifers are overlain by an impermeable, or semi-permeable layer, and are typically under pressure. Therefore the potentiometric surface, or level to which water will rise in a tightly cased well, is above the top of the aquifer. When this occurs the well is called an artesian

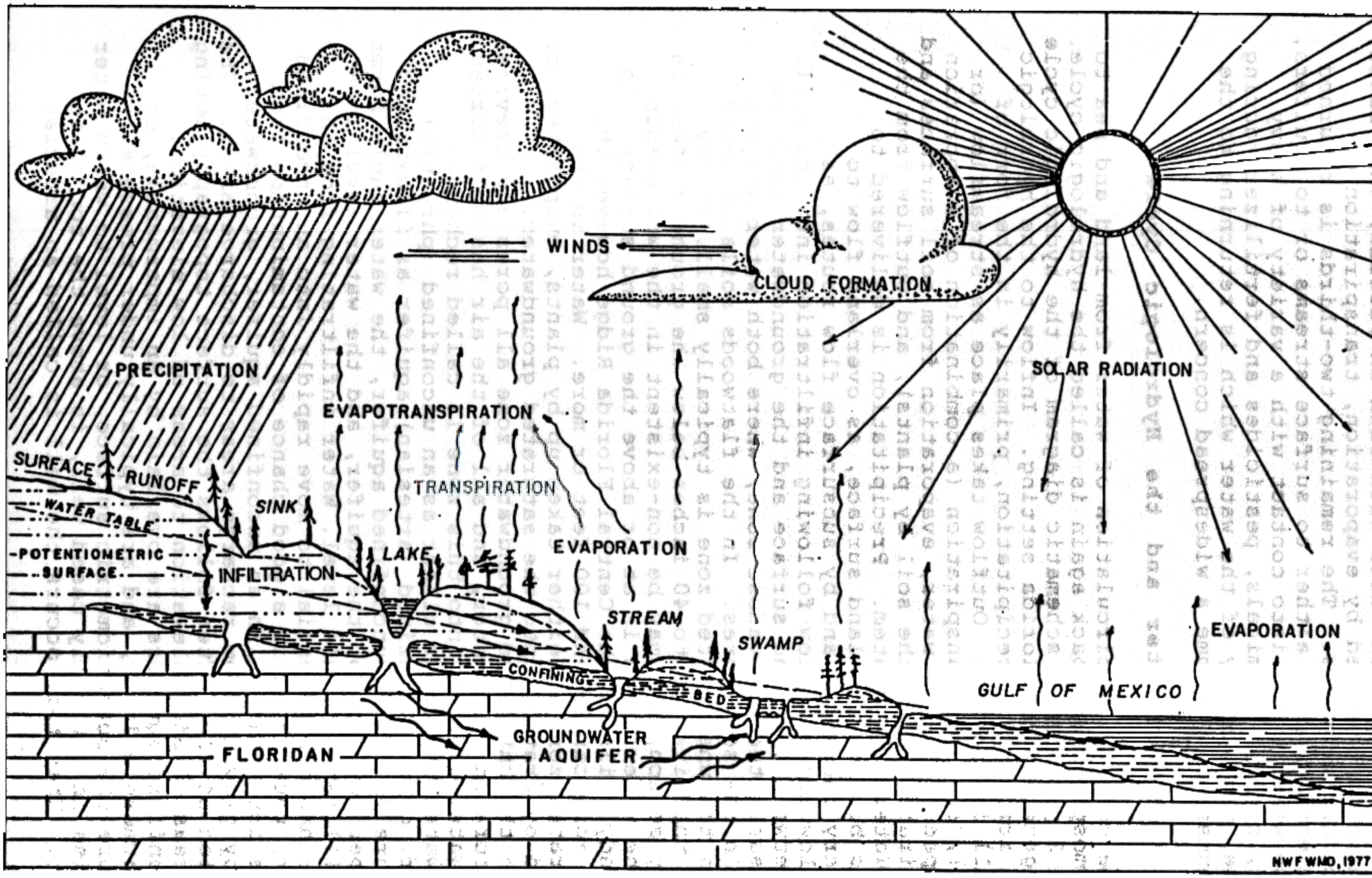
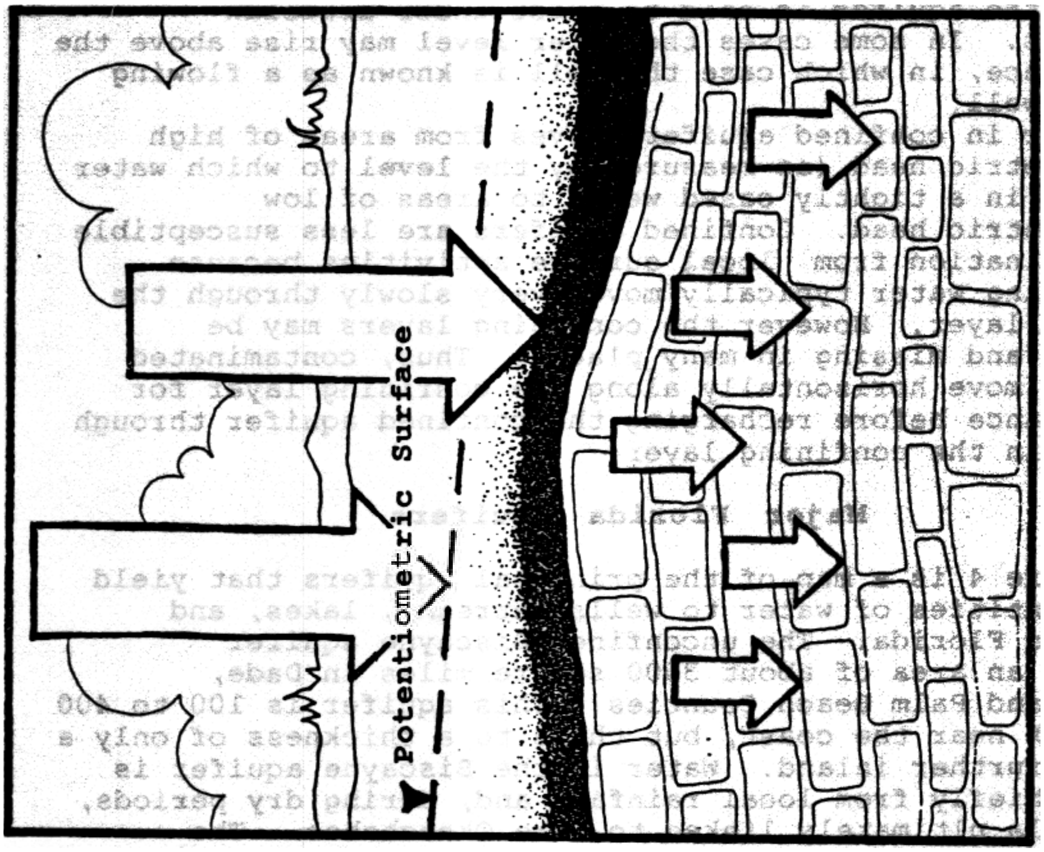
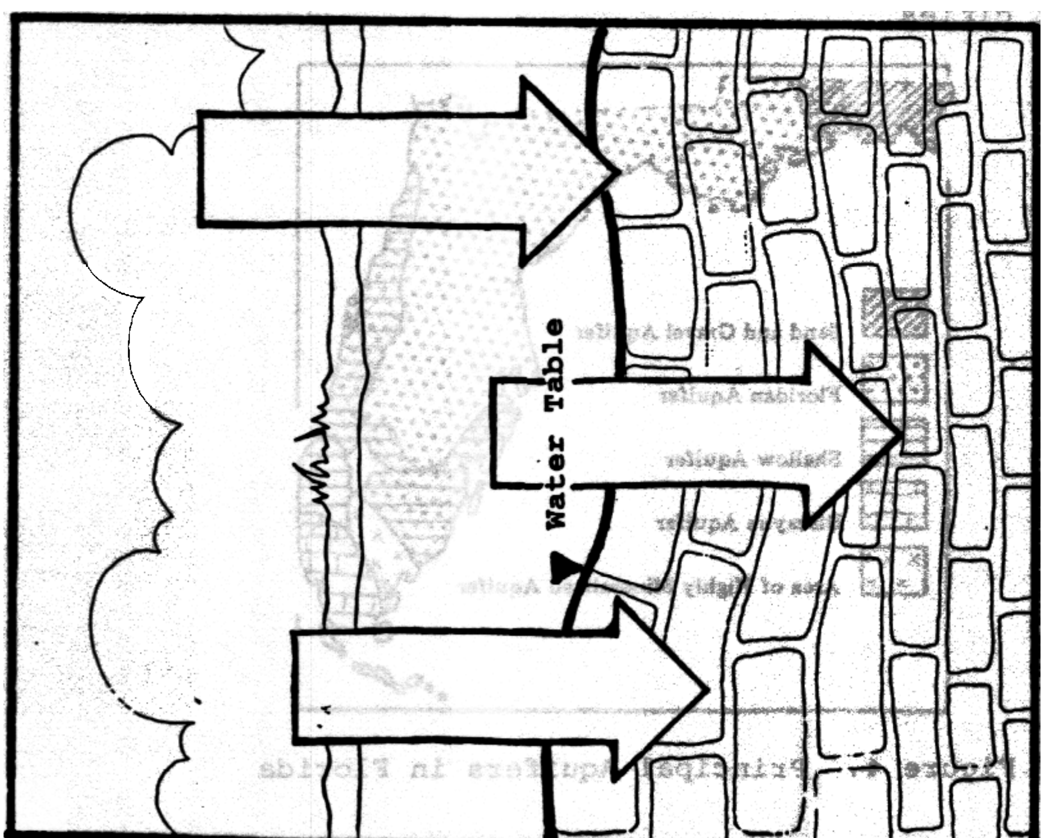


Figure 2. The Hydrologic Cycle


Potentiometric Surface


Water Table

well and the aquifer is said to exist under artesian conditions. In some cases the water level may rise above the land surface, in which case the well is known as a flowing artesian well.

Water in confined aquifers moves from areas of high potentiometric head (as measured by the level to which water will rise in a tightly cased well) to areas of low potentiometric head. Confined aquifers are less susceptible to contamination from local surface activities because infiltrating water typically moves very slowly through the confining layer. However the confining layers may be fractured and missing in many places. Thus, contaminated water may move horizontally along the confining layer for some distance before recharging the confined aquifer through a breach in the confining layer.

Major Florida Aquifers

Figure 4 is a map of the principal aquifers that yield large quantities of water to wells, streams, lakes, and springs in Florida. The unconfined Biscayne aquifer underlies an area of about 3000 square miles in Dade, Broward, and Palm Beach Counties. This aquifer is 100 to 400 feet thick near the coast, but thins to a thickness of only a few feet further inland. Water in the Biscayne aquifer is derived chiefly from local rainfall and, during dry periods, from canals ultimately linked to Lake Okeechobee. The Biscayne is an important source of water supply for the lower east coast cities.

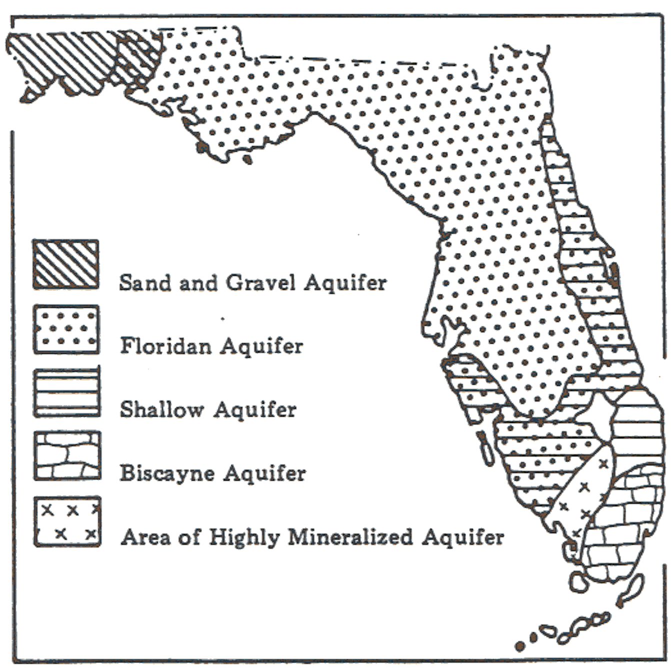


Figure 4. Principal Aquifers in Florida

An unconfined, sand and gravel aquifer is the major source of groundwater in the extreme western part of the Florida panhandle. This aquifer ranges in thickness from 300 to 700 feet and consists primarily of very coarse quartz sand. Water in the sand and gravel aquifer is derived chiefly from local rainfall. Wells in this aquifer furnish most of the groundwater used in Escambia and Santa Rosa Counties and part of Okaloosa County.

A shallow, unconfined aquifer is present over much of the state, but in most areas it is not an important source of groundwater because a better supply is available from other aquifers. However in areas where water requirements are small, this aquifer is tapped by small diameter wells. In south Florida the shallow aquifer is a major source of groundwater in Martin, Palm Beach, Hendry, Lee, Collier, Indian River, St. Lucie, Galdes and Charlotte Counties. The water in this shallow aquifer is derived primarily from local rainfall.

The principal source of groundwater for most of Florida is the Floridan aquifer. Figure 5 shows the areal extent of this formation, which is one of the most prolific aquifers in the United States. In much of Florida the aquifer is confined by low permeability sediments of the Hawthorne formation. The Hawthorne formation is absent however in the north central part of the state along the Ocala Uplift. In this area the aquifer is unconfined, and thus receives recharge from water infiltrating from the surface.

The potentiometric surface of the Floridan aquifer is shown in Figure 6. This surface indicates that the origin of subsurface flow for northern Florida is in Alabama and Georgia; however, the origin of subsurface flow for peninsular Florida is in the Central Uplands of the state. In many areas the potentiometric surface is above the land surface, thus artesian flow occurs in wells or along geologic openings. Figure 7 shows the areas of potential artesian flow from the Floridan aquifer. Not included in this figure are small areas of local artesian flow near springs that derive their flow from the Floridan aquifer.

Sources of Groundwater Contamination

Florida's unique hydrogeologic features of a thin soil layer, high water table, porous limestone, and large amounts of rainfall, coupled with its rapid population growth, result in a groundwater resource extremely vulnerable to contamination. Numerous structures resulting from human activities throughout Florida have the potential to contribute to groundwater contamination. There are tens of thousands of point sources such as surface water impoundments, drainage wells, underground storage tanks, flowing saline artesian wells, hazardous waste sites, power-plants, landfills, and cattle and dairy feedlots. Similarly,

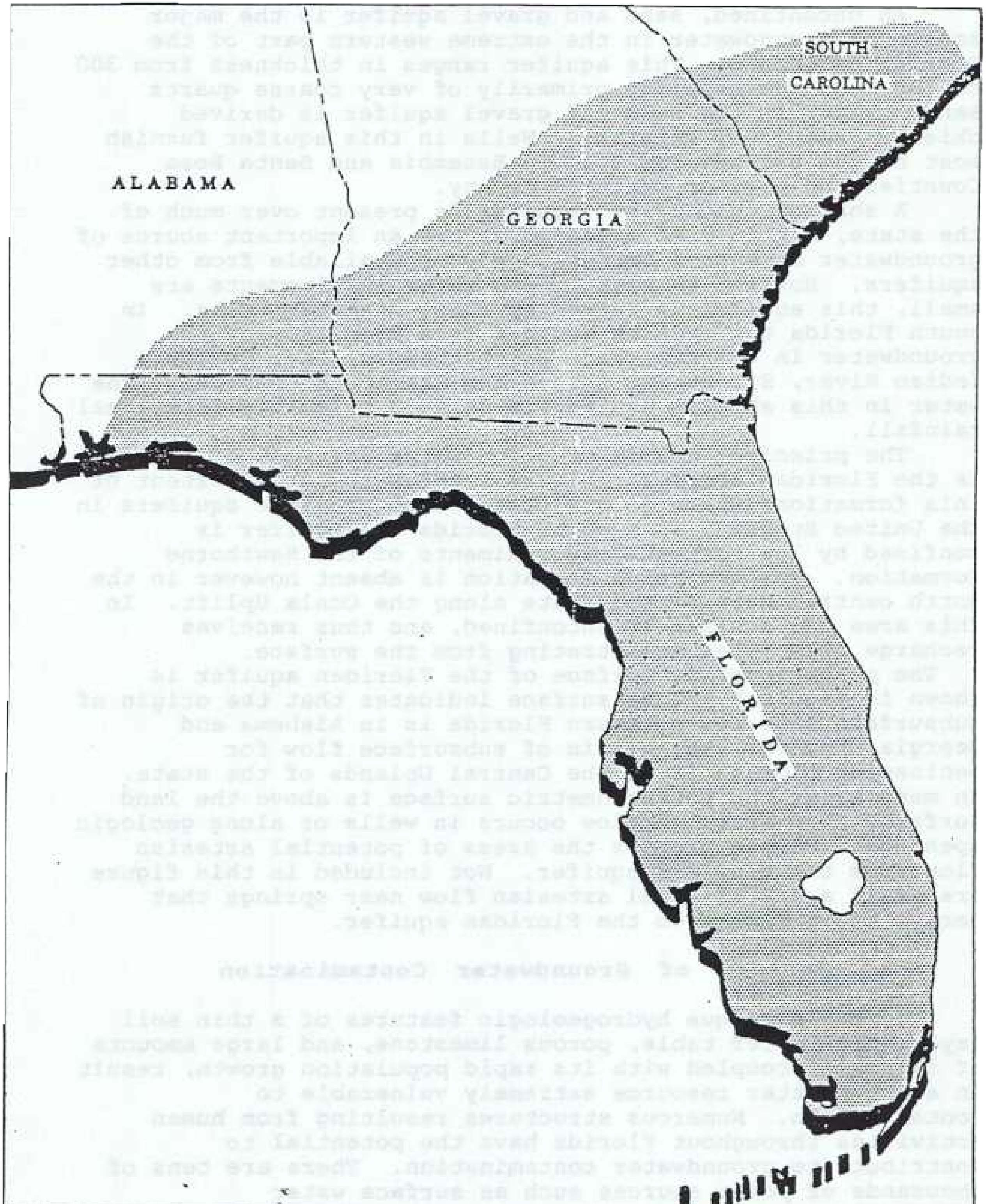


Figure 5. Areal Extent of the Floridan Aquifer

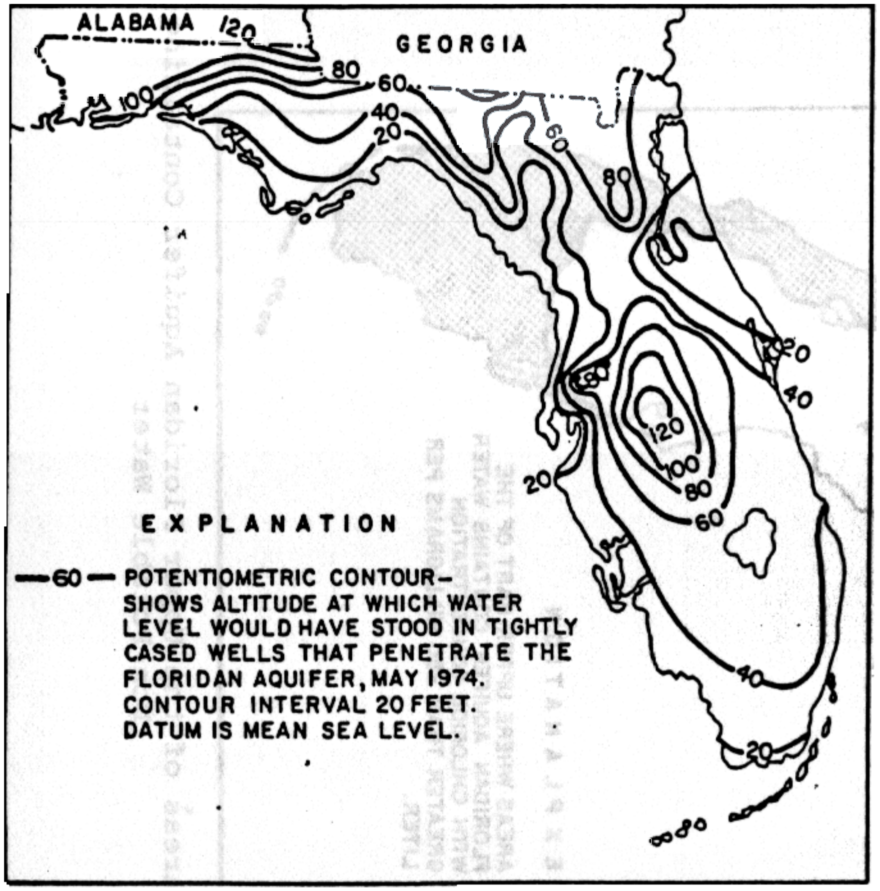


Figure 6. Potentiometric Surface of the Floridan Aquifer

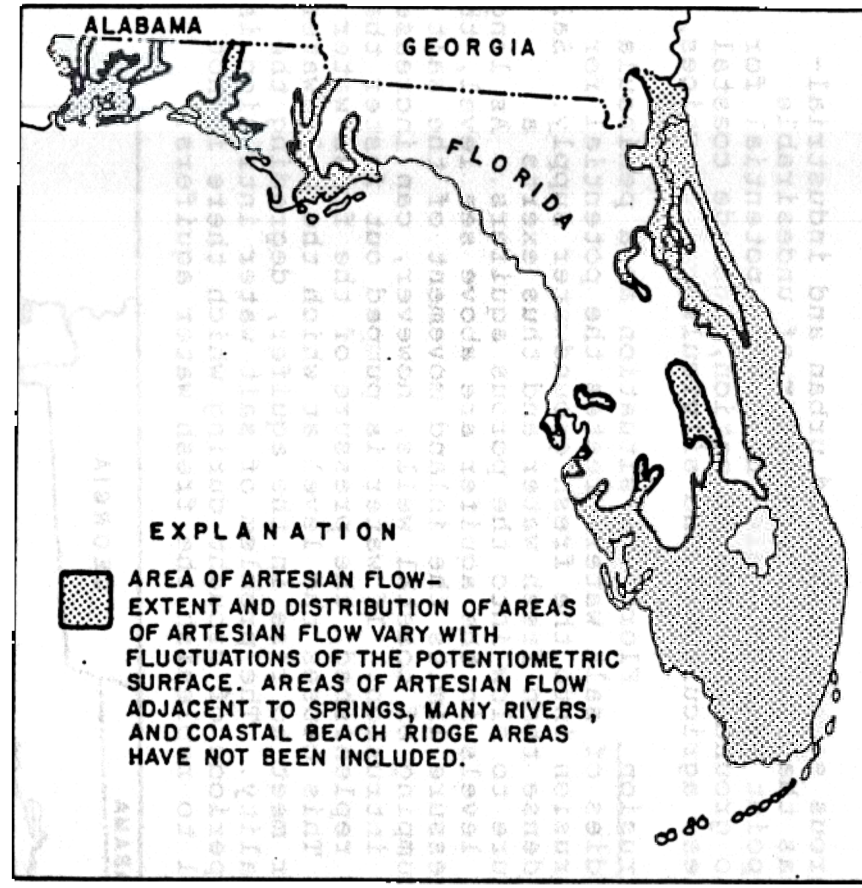


Figure 7. Areas of Potential Artesian Flow in the Floridan Aquifer

there are numerous septic tanks and urban and industrial-commercial areas that may recharge water of undesirable quality. Non-point sources, which have vast potential for contributing to groundwater contamination, include coastal saltwater bodies, agricultural and silvicultural practices, and mining.

Salt Water Intrusion Florida's situation as a peninsula between two bodies of salt water creates the potential for salt water intrusion into the fresh groundwater supply. Salt water is more dense than fresh water and thus exerts a constant pressure to flow into the porous aquifers. As long as fresh water levels in the aquifer are above sea level, the fresh water pressure limits the inland movement of the salt water. Over-pumping of coastal wells, however, can increase the salt water intrusion. If water is pumped out faster than the aquifer is replenished, the pressure of the fresh water is decreased. This causes the level at which the salt water and fresh water meet to rise in the aquifer, degrading the fresh water quality. The problem of salt water intrusion is aggravated by periods of drought during which there is not enough rainfall to replenish the fresh water aquifers.

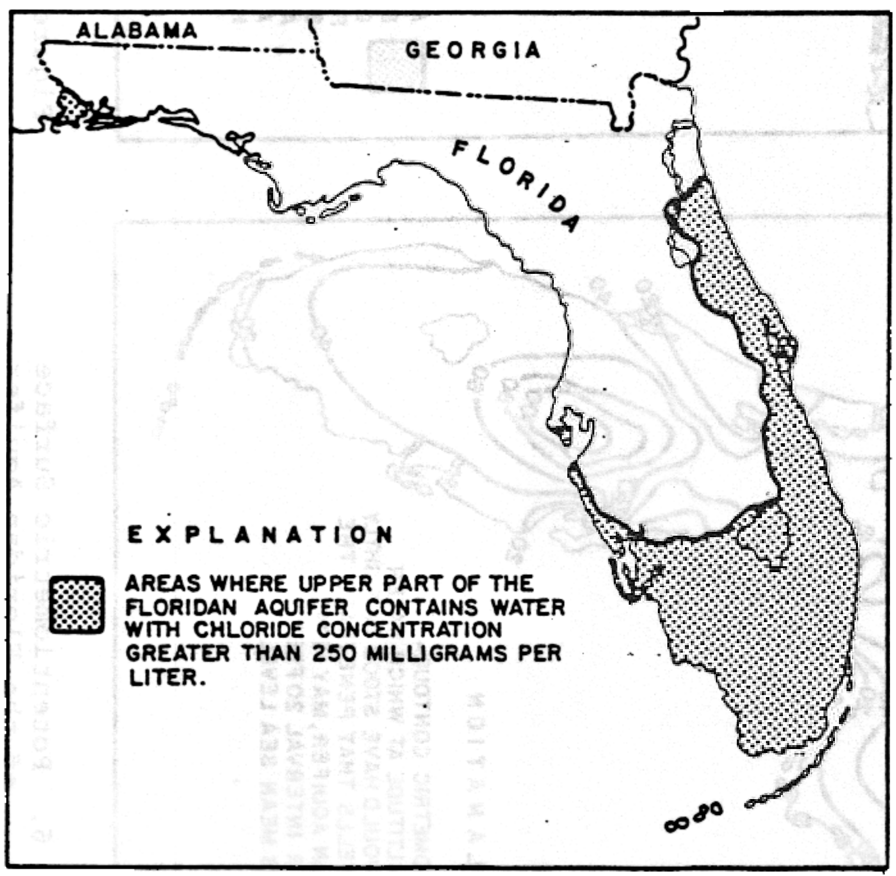


Figure 8. Areas of the Upper Floridan Aquifer Containing Non-Potable Water

All of the aquifers shown in Figure 4 experience problems with salt water intrusion in coastal areas. In south Florida, fresh water levels in coastal canals are managed carefully to control the fresh water level in the Biscayne aquifer and thus minimize salt water intrusion. Figure 8 shows areas of the Floridan aquifer which contain chloride concentrations greater than 250 milligrams per liter, due to salt water intrusion. In south Florida, where the Floridan aquifer is artesian and underlies the Biscayne and shallow aquifers, its saline water may recharge the overlying fresh water aquifers increasing their salt content. This type of recharge may occur naturally by upward seepage through the confining layer or it may be increased by flowing artesian wells.

Hazardous Waste Sites The Florida Department of Environmental Regulation has identified 413 potential hazardous waste sites in Florida. The distribution of these sites over the state is shown in Figure 9. One hundred and eighty-five of these sites have some type of water or soil contamination, and 84 additional sites are suspected of contamination. Groundwater contamination has been confirmed at 156 sites. Enforcement action requiring contamination assessment and remedial action has been initiated at 118 sites. Because of the absence of a significant amount of impermeable material to retard downward movement of contaminants, leakage from many of these sites poses a direct threat to the principal aquifers.

Gasoline Storage Tanks The Florida Department of Environmental Regulation has documented more than 400 instances of groundwater contamination from leaking gasoline pipes or storage tanks. The greatest frequency of gasoline contamination has occurred in Dade, Broward, and Palm Beach Counties, affecting the quality of water in some locations of the Biscayne aquifer. The most environmentally and financially significant incident was the leaking of 10,000 gallons of gasoline which contaminated the public water supply for 2,000 residents in Belleview Florida. Other smaller gasoline leaks have caused local contamination of aquifers in several Florida counties.

Municipal Landfills Florida has about 300 active and 500 inactive landfill sites. Most of the landfills are unlined, increasing the chance that rainwater which percolates through them may dissolve harmful chemicals and ultimately reach the groundwater. Six of Florida's 39 Superfund sites are landfills, and all have contaminated groundwater. Three in southeastern Florida have directly contaminated the Biscayne aquifer.

Organic Compounds Contamination of groundwater by volatile organic compounds (VOC) from industrial discharges have become a concern, particularly in southern Florida. A recent study of public supplies from the Biscayne aquifer in Broward, Dade and Palm Beach Counties reported that four supplies serving 290,000 people contained VOC (primarily

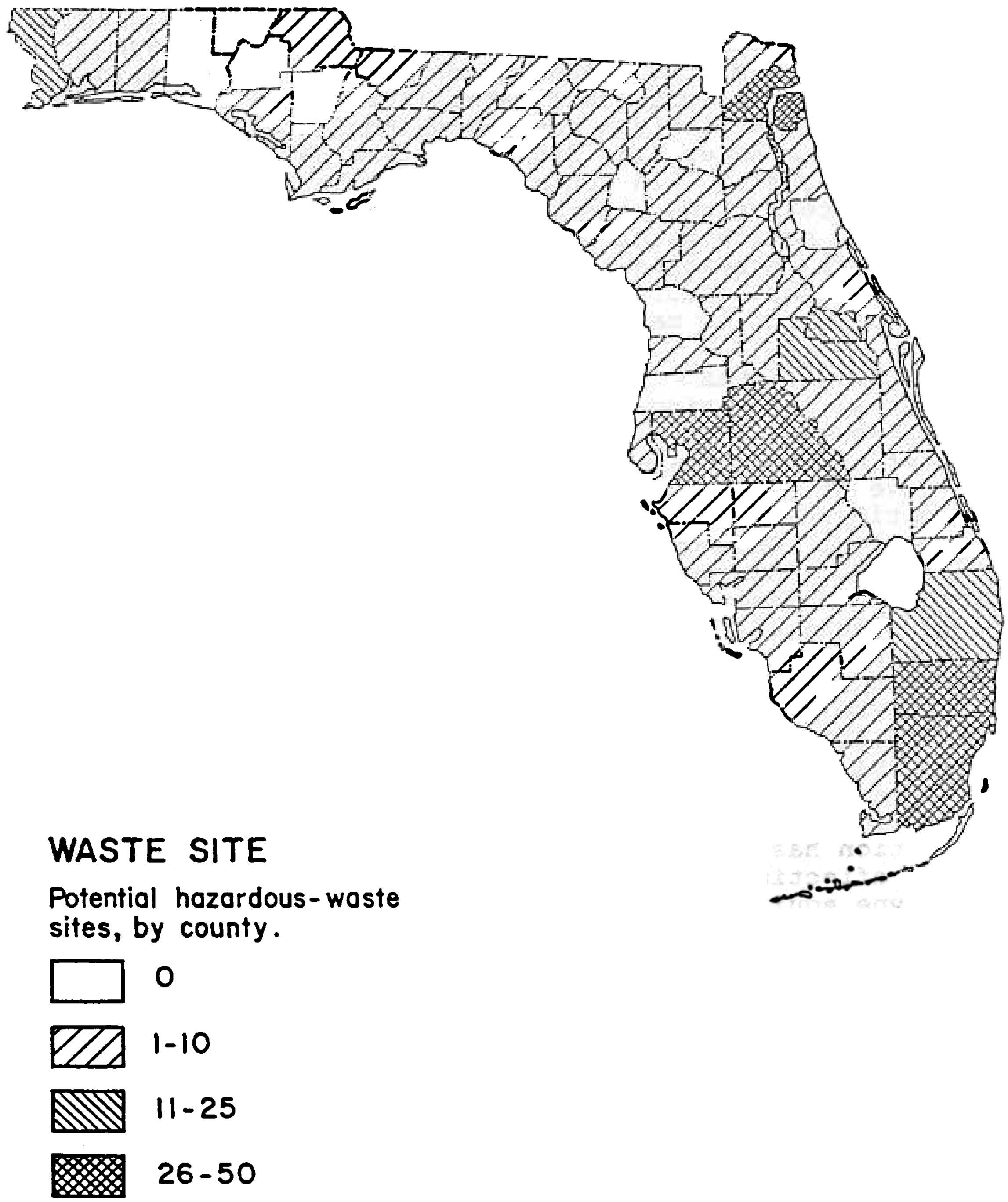


Figure 9. Potential Hazardous Waste Sites in Florida

trichloroethylene and vinyl chloride) concentrations that slightly exceeded Florida drinking water standards. Recent incidents of VOC contamination in groundwater supplies have also occurred in other parts of the state. Several city wells for Pensacola, Gainesville and Tallahassee have been closed temporarily because of VOC contamination.

Agrichemicals Florida is ranked second in agrichemcial application in the nation, but thirty-third in planted acreage. As a result, pesticide and nitrate contamination of groundwater has become a major environmental issue in Florida. Since 1983, water from more than 1,000 public and private supply wells, primarily in the Floridan aquifer system, have been found to contain levels of the soil fumigant ethylene dibromide (EDB) above the state regulation of 0.02 micrograms per liter. The distribution of EDB contamination was extensive, with detections in 22 of the 66 counties tested. Most were in Jackson, Lake, Highlands and Polk Counties.

Aldicarb has also been detected in groundwater at seven agricultural study sites in Hillsborough, Martin, Polk, St. Johns, Seminole and Volusia Counties. Contamination by nitrate from fertilizers and/or wastewater effluent has occurred in some localized portions of the Floridan aquifer, however it has not yet been detected as a widespread problem.

Solutions to the Groundwater Quality Problem

Historically, people have regarded groundwater as pristine, believing that soil cleanses the water as it seeps down into the aquifer. While it is true that the organic matter in soil has some ability to retain or absorb organic compounds such as VOCs, petroleum products and pesticides, it is by no means an infinite sink for these compounds. In addition, the soil has no ability to absorb inorganic anions such as nitrate or chloride. Whether or not the soil filters out viruses and other microbes remains an open question. Therefore, man must actively reclaim and restore soils and aquifers with existing contamination problems, and prevent future groundwater contamination through effective land-use planning and thoughtful management of potential groundwater contamination sources.

Future land-use plans must prevent potential contamination sources from locating over critical recharge areas. Industries, farmers and citizens located above groundwater supplies should minimize their use of hazardous chemicals, and exercise good chemical disposal practices. Site-specific best management practices for both industry and agriculture must be developed which take local soils, geology, aquifer characteristics, and climatic conditions into account. Groundwater monitoring networks should be installed at all potential contamination sources to provide data to fine tune management practices, and to provide early detection of groundwater contamination problems.

References

Carriker, R.R., and A.L. Starr, Florida's Water Resources, 1987, Food and Resource Economics Bulletin FRE 40, Institute of Food and Agricultural Sciences, University of Florida, Gainesville FL, 6p.

Freeze, R.A., and J.A. Cherry, 1979, Ground Water, Prentice-Hall Inc, Engelwood Cliffs, New Jersey, 604p.

Spangler, D.P.,19??, Florida's Water Resources, with Particular Emphasis on Ground Water, Proceedings of the First Annual Symposium on Florida Hydrogeology, 36 p.

U.S. Geological Survey, 1986, Water for Florida Cities, U.S. Geological Survey Water Resources Investigations Report 86-4122, 30 p.

U.S. Geological Survey, 1986, National Water Summary 1986-Ground Water Quality: Florida, 205-213.