Florida WATERS

A Water Resources Manual from Florida's Water Management Districts

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Chapter 1

The Human Framework

We see things not as they are, but as we are.

— Henry Major Tomlinson, Out of Soundings, 1931

KEY IDEAS

- Water has played a critical role in the settlement of Florida since the first humans arrived around 14,000 years ago.
- Water resources exist within legal, social, economic and political contexts.
- Early in Florida's development as a state, the main themes of water management were drainage, flood control and navigation.
- Today, Floridians are actively seeking ways to preserve, protect and restore water resources.
- Modern water management in Florida is governed by the Water Resources Act of 1972, one of the most innovative laws of its kind in the nation.

VOCABULARY

Drainage
Ecosystem restoration
Flood control
Hammocks
Land acquisition
Limestone
Minimum flows and levels
Navigation
Prior appropriation
Reasonable and beneficial use
Riparian
Savanna
Water allocation
Water supply

In Florida for at least 14,000 years, human settlement has been shaped by water. Although its official nickname is "The Sunshine State," Florida could very well be called "The Water State." Florida is surrounded on three sides by water. Its landmass is underlain by water-filled **limestone**: highly porous rock formed over millennia from shells and bones of sea animals. The Florida Keys, a gentle arc of islands extending 93 kilometers (150 miles) south of the peninsula to Key West, are coral rock covered in most places with a thin layer of sand. Florida's abundance of sinkholes, springs, rivers and lakes is partly the result of the rising and falling of sea level. The sea is also largely responsible for the state's many bays, inlets and islands. On average, more rain falls in Florida (135 centimeters or 53 inches) per year than in any other state in the nation besides Louisiana, which receives an average of 140 centimeters (55 inches) (Henry et al. 1994). In Florida, rain does not always fall when and where it is needed, and sometimes too much rain falls too quickly.

Water management in Florida today has evolved from lessons learned through experience, as well as from changing philosophies about natural resources and the environment. Early in the state's history, Floridians were most concerned about **drainage**, **flood control** and **navigation**. Natural resources were to be used, controlled and modified. Wetlands were drained for farms, groves and houses. Canals were cut to facilitate drainage and to improve navigation. Floodwaters were held back with engineering works. Wastes were discharged without treatment into rivers, lakes and coastal waters. Florida was thought to have too much water. Now, the value and the finite nature of Florida's water resources are clear. Water managers today are concerned with water quality protection, **water supply** planning and water resources development, and preservation and protection of the natural environment. Conserving, protecting and restoring natural systems, while ensuring an adequate supply of water, remains one of Florida's greatest challenges.

The First Floridians

About 14,000 years ago, people first entered the Florida peninsula. Known as "Paleoindians," these original Floridians survived by hunting mastodons, camels, mammoths, bison and horses. At the time, much of the world's water was frozen in glaciers, sea level was much lower than it is today, and Florida was a dry, large, grassy prairie. Many present-day rivers, springs and lakes had yet to be formed; even groundwater levels were far lower than they are today. Sources of fresh water were limited, and finding them was critical to the survival of the Paleoindians and the animals they hunted for food. The Paleoindians lived and hunted near springs and lakes. Many of these sites are now under water. Archeologists have found bone and stone weapons and tools in many springs and rivers, and even offshore in the Gulf of Mexico.

About 9000 B.C., glaciers melted, sea level rose and Florida's climate became wetter. As forests replaced grasslands, big game animals disappeared. A larger number of rivers and lakes afforded many more suitable places for people to live. By 3000 B.C., when Florida's climate became similar to today's climate, people occupied almost every part of the present state. Numerous settlements developed in coastal regions in southwest, northwest and northeast Florida, as well as along the St. Johns River (Milanich 1995). People took full advantage of the plentiful supply of fish and shellfish. Along the coasts and the banks of rivers and bays, huge mounds of shells from millions of prehistoric meals began to accumulate.

When Spanish explorers arrived in Florida in the 1500s, an estimated 350,000 Native Americans were living throughout the present-day state (Milanich 1995). The Apalachee and Timucuan in the north were farmers and grew corn, beans and squash. Their large villages were often located near the region's many lakes and rivers. Although they grew food, the Apalachee and Timucuan still obtained part of their diet from hunting, fishing and gathering of wild plants. The Native Americans living in the southern part of the peninsula continued to live exclusively off the natural bounty of the land and the sea.

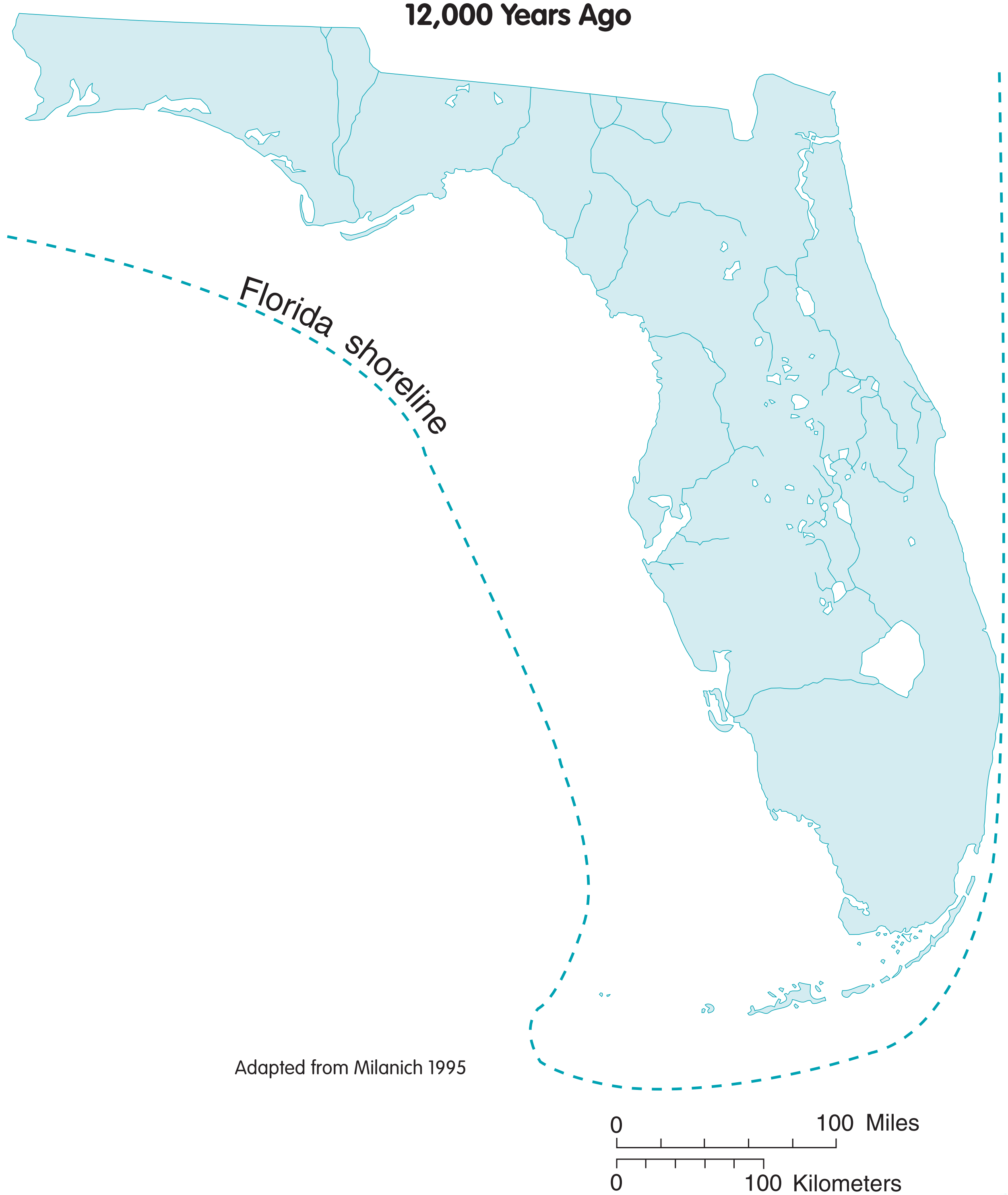
The Belle Glade people lived on the vast **savanna** around Lake Okeechobee. They built villages on mounds and earthen embankments, and connected them by canoe highways.

Along the southwest coast, a remarkable people called the Calusa lived by fishing, gathering shellfish, collecting plants and hunting. The Seminole Indians later immortalized the Calusa by naming the major river in the region the Caloosahatchee, "river of the Calusa." A single chief ruled the Calusa's vast domain. They lived in large villages and developed elaborate political, social and trade networks, as well as highly sophisticated art. They traveled into the gulf in canoes lashed together to form catamarans. This level of cultural development is usually only obtained with agriculture. Only by growing crops do people usually have enough food to support villages and to allow some individuals to specialize in pursuits other than obtaining food. However, the Calusa's natural environment was so rich that they were able to grow and thrive without crops.

By the early 1700s, virtually all the members of Florida's original Native American groups were gone, many having succumbed to European diseases for which they had no resistance. Remnants of other southeastern Indian groups, later known as the Seminoles, began to move into the now abandoned fertile farmlands around the lakes and rivers in northern Florida. The only permanent settlements of any consequence were St. Augustine, Pensacola and Key West.

Paleoindian Period

12,000 Years Ago



Adapted from Milanich 1995

Seminole Indian Village, Royal Palm Hammock, 1920s

Source: Florida State Archives

THE SEMINOLES

ADAPTATION TO A WATERY WILDERNESS

The Seminole Indians — with their dugout canoes, chickees, and loose, colorful patchwork clothing — have long been associated with south Florida. But the Seminoles did not originate in south Florida or any place else in the state. Their ancestors were members of populous tribes and chiefdoms from other parts of the southeastern United States. These groups — the Oconee, Yuchi, Alabama, Yamasee, Hitchiti, Koasati and dozens of others — were called "Creeks" by English settlers.

The Creeks were farmers and hunters. Corn was their principal crop, and each year the Creeks celebrated its ripening with the Green Corn Dance. Some Creeks lived in towns of 5,000 to 15,000 people. These towns were built around a plaza, which included a square ground (a square flat cleared area). In the center of the square ground was the ceremonial fire with four logs pointing in cardinal directions. At one end was a circular council house where men discussed political affairs. Family compounds consisted of a cooking house, a winter house and a storage house. Other Creeks lived outside of towns along the banks of rivers and streams in family camps (Weisman 1999).

Creeks in towns and in the countryside were linked together by clans. All Creeks belonged to clans, family groups named after animals or natural events. Some Creek clans were the Bear, Deer, Wildcat, Tiger (Panther), Wolf, Alligator, Wind and Turkey. Both male and female children belonged to the clan of their mother and remained a part of this clan for their entire lives. Clans lived together in camps or in the same part of town. When you visited a new town or a new part of Creek country, other members of your clan welcomed you.

By the 18th century, Creek clothing was a blend of European and traditional Indian styles. The men wore cloth turbans, belts, beads, and leggings and jackets of deerskin. Women wore long dresses of manufactured cloth.

The Creeks traveled long distances on the Southeast's numerous rivers and streams in dugout canoes. They were skilled hunters, and the men spent much of their time hunting deer and other animals. Creeks traded the pelts of the animals they hunted for European traders' guns and other manufactured items.

By the early 1700s, small bands of Creeks began migrating into northern Florida, at first to hunt and later to farm lands once occupied by the Timucuan and Apalachee Indians. These groups were now gone, their members having died in conflicts with Europeans or from European diseases for which they had no resistance.

The name "Seminole" was first recorded in field notes accompanying a 1765 map of Florida. Most scholars believe it was derived from the Spanish "cimarrone," meaning "wild" or "runaway." By 1800, many of the Seminoles were prospering, raising cattle and growing crops. Some lived in two-story houses and owned slaves. These newcomers to Florida had built towns from the Apalachicola River to the St. Johns River and from south Georgia to the Caloosahatchee River.

As the American colonists settled more and more of the South, more Indians fled to Florida. Soon, however, Florida lands also became desirable to the colonists. The Treaty of Payne's Landing, signed in 1832, required the Indians to give up their Florida lands and move to Indian Territory in the West. The Seminoles refused and a 7-year war ensued, fought between the Seminoles and the United States in the swamps and hammocks of central Florida. At the end of the war, several hundred Seminoles were forcibly shipped to Indian Territory, while others escaped into the watery wilderness of Big Cypress Swamp and the Everglades.

It was on the **hammocks**, small tree islands in the midst of marsh and swampland, that the Seminoles made their home. Never a maritime or aquatic culture, like the Calusa Indians who had lived before them in southern Florida, the Seminoles adapted their traditional ways of making a living — farming, raising livestock and hunting — to their new wetter and warmer home.

They settled in clan camps rather than in towns. Although no longer united around towns, clan camps came together each year for the traditional Green Corn Dance. They cleared trees from the center of the hammocks and grew corn, squash, melons and peas on the rich soil. They ran their cattle on lands that were dry enough. Their reliance on wild plants and animals increased. They ate the new shoots of cabbage palm and prepared flour (known as coontie) from the root of the tropical tuber zamia. They continued to hunt deer and hunted the then-abundant manatee, which they called "giant beaver."

They abandoned their traditional four-walled board cabin for chickees, distinctive open-air structures built of cypress poles with palmetto-thatched roofs. The local environment provided all the materials they needed for construction. They traveled between settlements in dugout canoes, and they exchanged their deerskin garments for fewer, more loosely fitting cotton clothes.

After the Civil War, the Seminoles, like their Creek ancestors, began to hunt commercially. They provided traders with skins of otters, deer, raccoons and alligators, as well as with feathers from the thousands of tropical birds found in the Everglades (Kersey 1975). Women in cities in America and Europe fueled the market for plumes with their insatiable desire for exotic feathers used to decorate their hats.

By early in the twentieth century, the Seminoles' world changed again. Plume hunting was outlawed in an effort to save the remaining birds. Illegal trade continued and ended only when women's fashions changed (Weisman 1999). The physical environment was also rapidly changing. Roads were being built, land was being drained for agriculture, and new communities were springing up overnight. In order to survive, the Seminoles had to adapt. This time they adapted by responding to the growing tourist market (West 1998). They entertained tourists with alligator wrestling and later with airboat rides. Women used hand-cranked sewing machines to more quickly sew the colorful cotton patchwork for which the Seminoles are famous. Seminole dolls and patchwork clothing became popular tourist items.

By the 1960s the Seminoles had separated into two political groups: the Seminole Tribe of Florida and the Miccosukee Tribe. A group of about 100 individuals continued to live in the Everglades and chose not to enroll in either tribe.

Today, tourism is still an important aspect of the Seminole culture and economy. Both the Seminole Tribe and the Miccosukee Tribe operate high-stakes bingo palaces. On its Big Cypress reservation, the Seminole Tribe attracts tourists with its Ah-Tha-Thi-Ki ("to learn") Museum, Big Cypress Hunting Adventures, and Billie Swamp Safari. The Seminoles also run multi-million dollar cattle and citrus operations and maintain a fleet of aircraft. But they still pass their legends on from generation to generation and they still belong to clans (Bear, Panther, Wind, Otter, Snake, Bird, Deer and Big Town). They continue to gather each spring in a secret location far from the hustle and bustle of the modern world to reaffirm their identity and survival through the Green Corn Dance.

Drainage, Flood Control and Navigation

When Florida became a state in 1845, most of its 70,000 inhabitants lived in the north. The state had few assets other than land, much of which was unsuitable for development without drainage and flood control. Water remained the main avenue of travel, and Floridians clamored for canals and river improvements. As early as 1824, the legislative council of the territory had proposed a ship canal across north Florida to spare ships the long and dangerous journey around the peninsula.

At statehood, Congress granted the state 500,000 acres (202,400 hectares) of federal land outright for "internal improvements." Five years later, the state received an additional 20 million acres (8 million hectares) through an act that transferred all "land unfit for cultivation due to its swampy and overflowed condition." In 1881, the state sold 4 million acres (1.6 million hectares) at 25 cents per acre to Philadelphia businessman Hamilton Disston. The following year, Disston began to dig canals in the upper Kissimmee River basin and the Caloosahatchee-Lake Okeechobee region. These waterways were to drain the land in the interior of the state and to provide corridors to transport crops and commercial products.

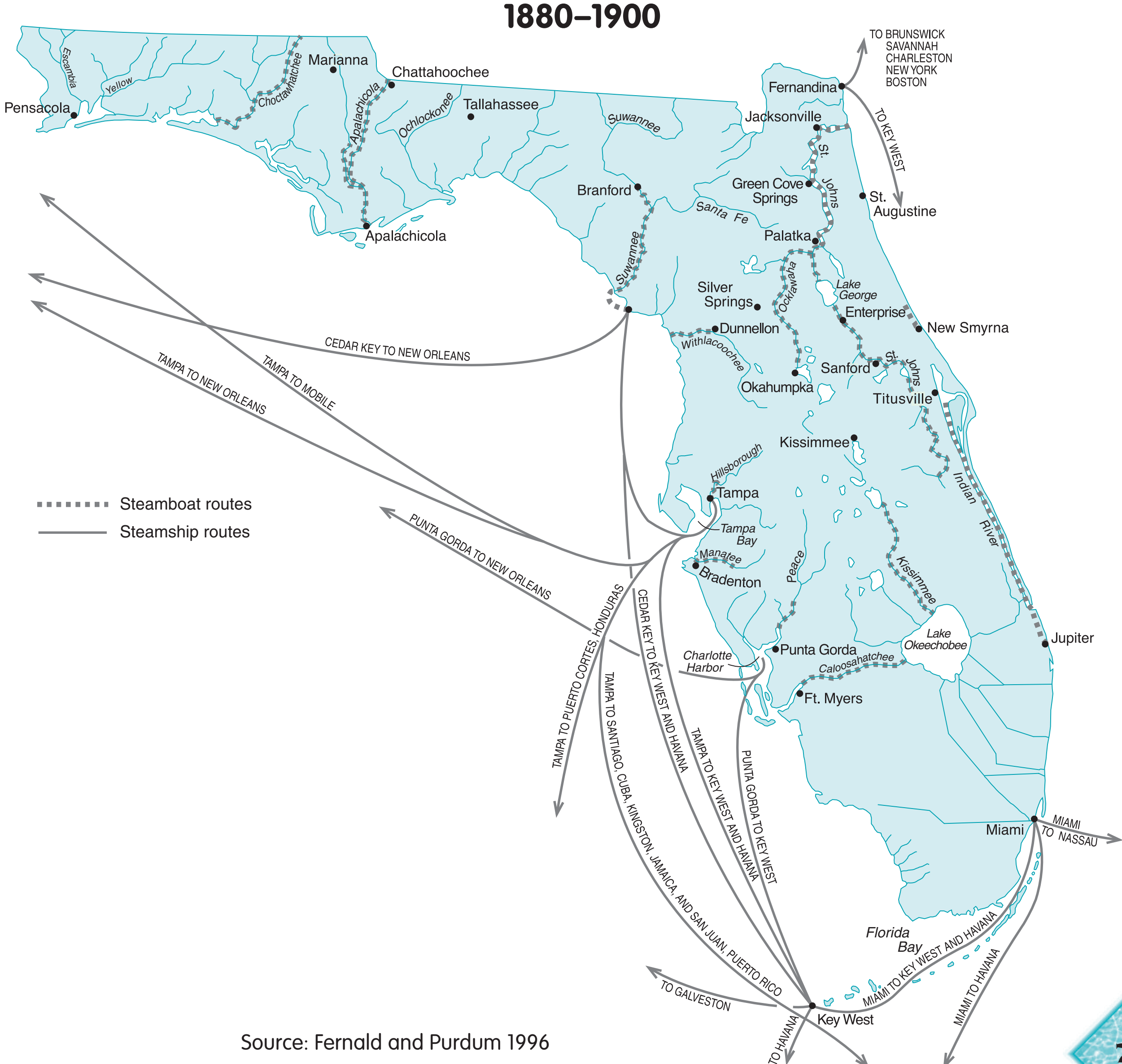
As the 1800s drew to a close, Florida remained largely dependent on water transport. Phosphate had been discovered in the Peace River valley, and boats equipped with steam dredges were used to mine the sand bars. Steamboats carried passengers and freight to coastal ports and to hundreds of riverside docks. Florida's leading product, lumber, was transported by water to markets in Europe and the northeastern United States. Construction of railroads in the late 1800s opened virgin forests to the growing lumber and naval stores (turpentine and rosin) industries. Before railroads, water transportation limited lumbering to the banks along major rivers and streams. During times when rivers were low, logs could not be transported to markets and water-powered saw mills had to be shut down.

Meanwhile, Florida's mineral springs, spas, rest homes and warm climate began to attract northern visitors seeking relief from rheumatism and from asthma and other lung ailments. Steamboat tours along the major rivers of north and central Florida became very popular, especially with hunters. In fact, by the late 1800s, game animals along the middle St. Johns River had become scarce.

As the twentieth century dawned, south Florida was still largely in its natural state. In 1904, Napoleon Bonaparte Broward was elected governor by promising to drain the Everglades. Established in 1913, the Everglades District became the first of several districts that carried out drainage projects in south Florida.

Drainage projects around Lake Okeechobee encouraged settlement and development of agriculture, but the region was still vulnerable to the catastrophic effects of extremely strong hurricanes that swept across south Florida in the 1920s. During the 1926 hurricane, the dike along the southern perimeter of the lake broke, killing more than 400 people in the Moore

Navigation
1880–1900



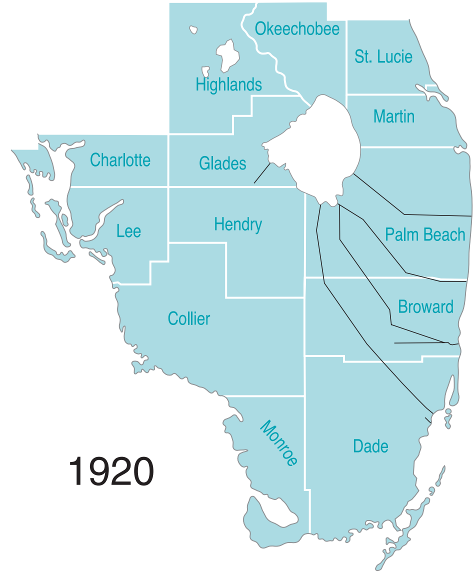
Source: Fernald and Purdum 1996

Growth of Water Control System South Florida

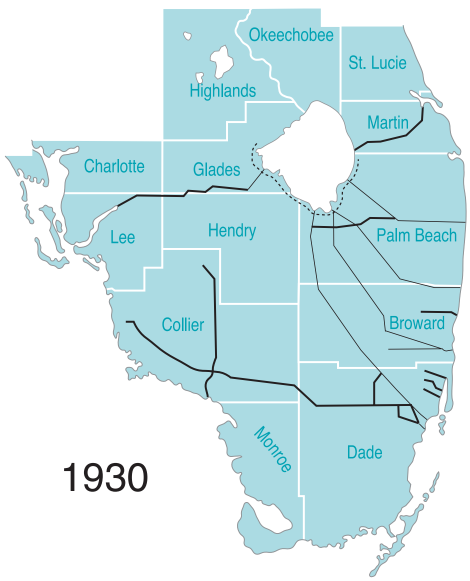
Major canal existing at given date

New canal since last date

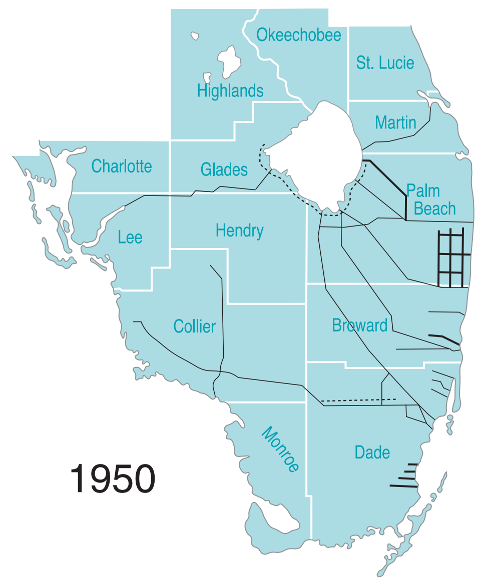
Major levee



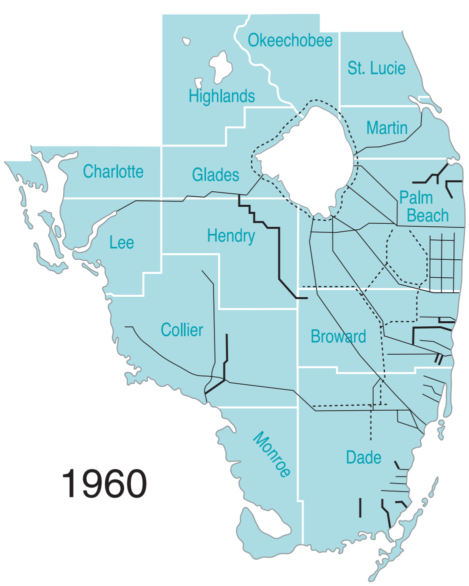
1920



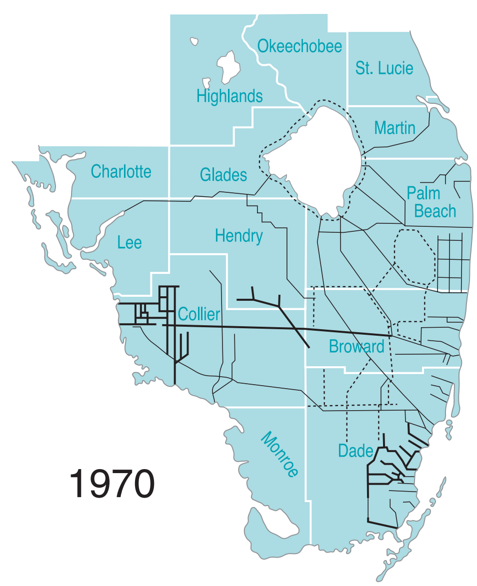
1930



1950



1960



1970

Source: Fernald and Purdum 1996

Haven area. During the 1928 hurricane, wind-blown water overflowed the lake, drowning more than 2,000 people. As a consequence, the Okeechobee Flood Control District was established in 1929. The U.S. Army Corps of Engineers began a major program of flood control in Florida, including construction of the 53-kilometer-long (85-mile-long) Herbert Hoover Dike flanking Lake Okeechobee.

In 1947, two more hurricanes and floods hit south Florida. Again, the existing network of canals and levees failed to protect farms and newly populous coastal communities. In response, Congress passed the Flood Control Act of 1948, calling for a huge multistage flood control project designed and constructed by the U.S. Army Corps of Engineers. The Central and Southern Florida Flood Control District was created by the Florida Legislature in 1949 to operate and maintain the massive project.

Streams and lakes were also modified in other parts of Florida. In the late 1800s and early 1900s, land was drained in the Ocklawaha and Peace river basins for farms, and canals were dug to create navigation routes for shipping vegetables, citrus, timber and other products. Coastal navigation waterways were also under construction, and the Intracoastal Waterway from Jacksonville to Miami was completed in 1912. The waterway provided a safer means of travel along the often hazardous east coast, and it linked river channels and the Okeechobee Waterway to Florida's deep-water coastal ports.

Construction of major water control works continued into the 1960s. In 1961, Congress authorized the Four River Basins, Florida Project for flood control in the Tampa Bay area. Construction of the Kissimmee Canal began in 1962. Work on the Cross Florida Barge Canal, first begun in 1935, resumed in the 1960s with the installation of major locks and dams on the Withlacoochee and Ocklawaha rivers. Opposition to this canal grew steadily during the late 1960s until President Nixon halted construction in 1971. Controversy about the Rodman Dam and Reservoir portion of the Cross Florida Barge Canal project persists to this day. Various environmental groups have called for removal of the dam and the restoration of the Ocklawaha River. Portions of the Kissimmee River, channelized barely 30 years ago, are now being restored.

1972
YEAR OF THE ENVIRONMENT

- Florida Water Resources Act creates regional water management districts and establishes a permit system for allocating water use.
- Land Conservation Act authorizes the sale of state bonds to purchase environmentally endangered lands.
- Environmental Land and Water Management Act creates Development of Regional Impact and Area of Critical State Concern programs.
- The Comprehensive Planning Act requires development of a state comprehensive plan.
- First public hearing on the restoration of the Kissimmee River.
- Federal Clean Water Act sets "swimmable and fishable" as goal for all U.S. waters.
- Florida citizens approve a constitutional amendment authorizing $240 million in state bonds for the Department of Natural Resources to purchase environmentally endangered lands.

Modern Water Management

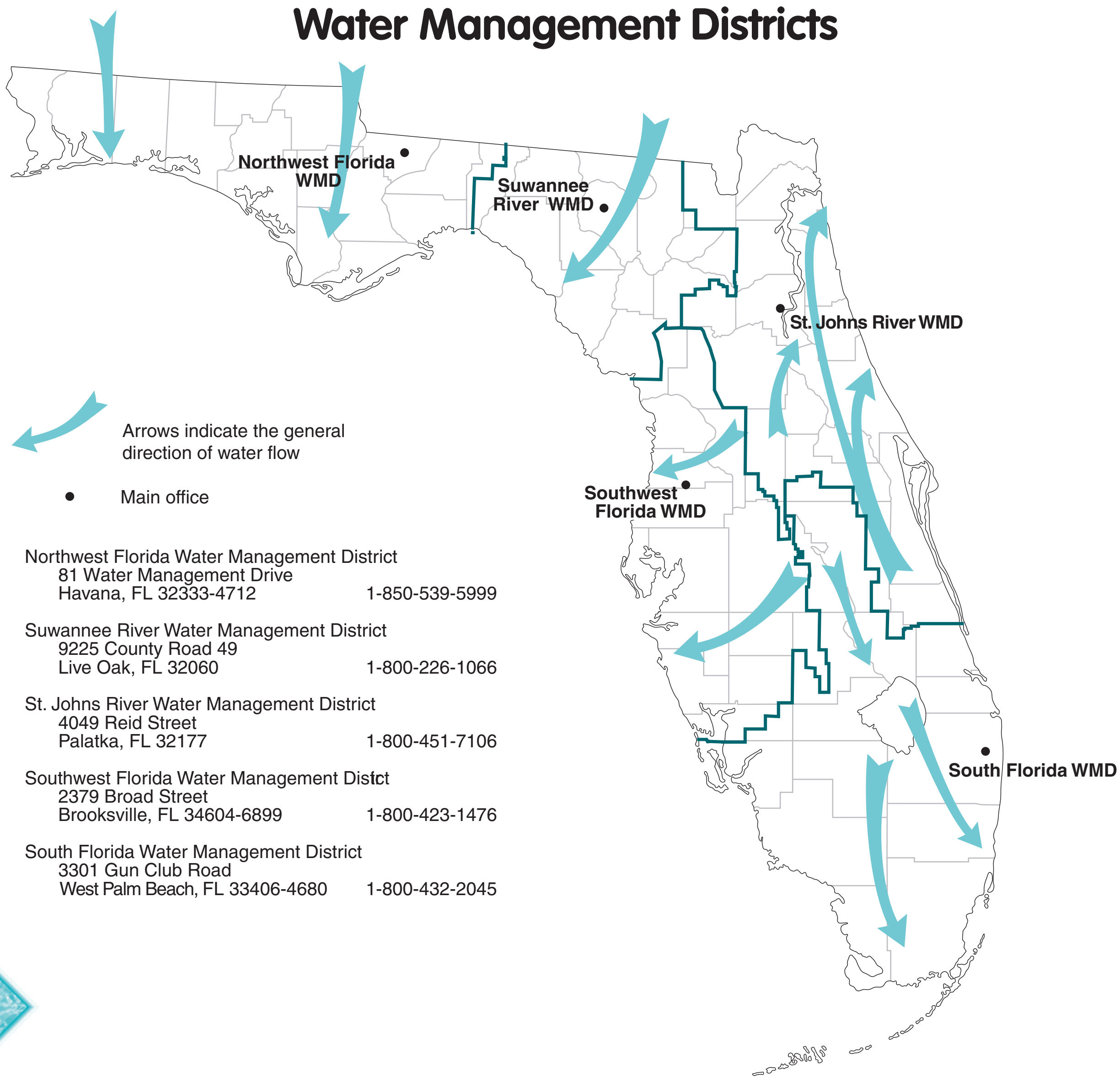
1970s

Attitudes toward water and the environment began to change as the consequences of uncontrolled growth and damage to the natural environment became more and more evident. During 1970–71, Florida experienced its worst drought to date, spurring state leaders to action. Four major pieces of legislation were enacted by the 1972 Legislature: the Environmental Land and Water Management Act, the Comprehensive Planning Act, the Land Conservation Act, and the Water Resources Act. These laws are based on the philosophy that land use, growth policy and water management cannot be separated, a theme that continues to this day.

Florida's institution of water management is unique — regional agencies, established by the Legislature and recognized in the state constitution, based on hydrologic boundaries and funded by a tax usually reserved for local government.

The 1972 Water Resources Act established five water management districts with broad authority and responsibilities. Responsibilities encompass the four broad categories of water supply (including conservation and allocation), water quality, flood protection and natural systems management.

Water Management Districts



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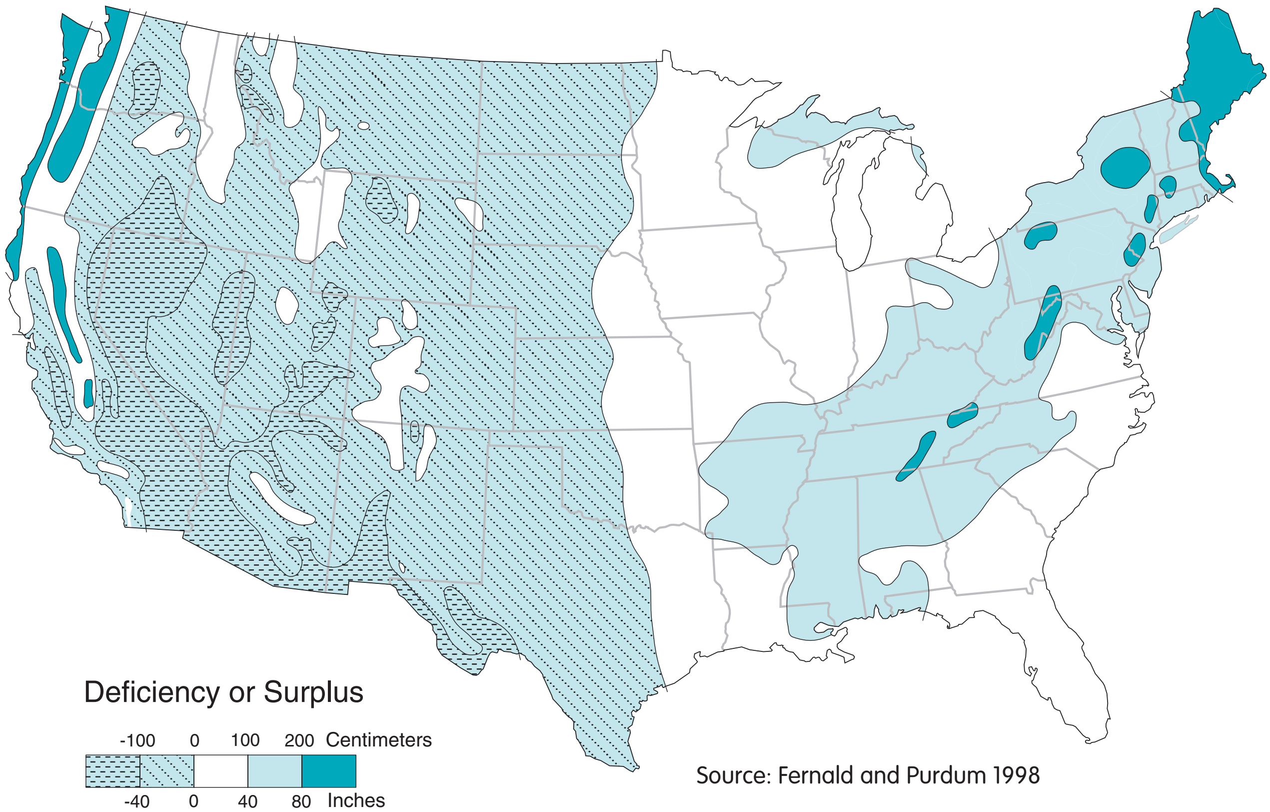
Brooksville, FL 34604-6899 1-800-423-1476

South Florida Water Management District
3301 Gun Club Road
West Palm Beach, FL 33406-4680 1-800-432-2045

Water Deficiency and Surplus



WATER LAW

Study this map. What differences do you notice between the eastern and western United States?

Significantly less water is available in the western United States than in the eastern United States. This fact has resulted in two very different systems of law governing the use of water.

Western Water Law

In the West, water is often scarce. Cities and farms may be long distances from sources of water. Western water law, also called the **prior appropriation** doctrine, is based upon the premise that water is a property right derived from a historic claim to water — "first in time, first in right." The first person or entity, such as an agricultural business, a mining company or a city, to withdraw the water from a stream or an aquifer had rights to continue to do so. These rights would be upheld in court. This system originated during the Gold Rush. Mining required diversion of water, and miners wanted certainty that they would have enough water to continue their operations. Later the doctrine of prior appropriation was modified to include the requirement that the water must be used for beneficial purposes.

Water rights in the West are separate from land rights. A water right is a very valuable commodity that can be bought and sold and passed from one generation to the next.

<u>Advantages</u>: Certainty. Users know they will continue to have water indefinitely.

<u>Disadvantages</u>: May lead to waste by discouraging conservation since reduction in water use may lead to reduction in water rights. Relatively uneconomic or socially unimportant water uses may be continued,

although some people think that free market forces will transfer water rights to the most economical uses. Water needs of natural systems may not be met because all of the water in a stream may have been appropriated for human uses.

Eastern Water Law

Water is considerably more abundant in the eastern United States than it is in the western United States. Eastern water law, also called the **riparian** system, is based on the premise that the riparian, the landowner along the shore, had the right to use the water for boating, fishing, swimming or viewing. Riparians also have a right to take as much water as they want to use on their land as long as they do not interfere with the reasonable use of water by other riparians. Landowners have a similar right to withdraw ground water for use on overlying land.

Advantages: Generally more protective of the water resources than Western law.

Disadvantages: Restricted commercial and other uses of water on nonriparian lands. Ongoing riparians constantly had to adjust to new riparians. Courts had to resolve disputes on a case-by-case basis.

Florida Water Law

Florida water law, found in Chapter 373 of the *Florida Statutes* (available on the Web at www.leg.state.fl.us), is considered by many to combine the best aspects of Western (prior appropriation) and Eastern (riparian) law. In Florida, water is a resource of the state. It is not owned by anyone.

Consumptive use permits: Water is allocated by a permit system administered by the five water management districts. The allocation system is designed to (1) prevent waste, (2) provide certainty to existing users, (3) provide equal rights irrespective of economic power, (4) protect natural resources and (5) provide for future users by requiring water managers to address comprehensive planning and resource development. Permits to use water are issued by the water management districts and may be issued for up to 50 years. The quantity of water available for use under a permit may be reduced during droughts.

To obtain a permit, the applicant must establish three things: the use is **reasonable and beneficial**, the use will not interfere with any presently existing legal use of the water, and the use is consistent with the public interest. If there is not enough water for all proposed uses, the water management districts are to make decisions based on which use best serves the public interest. If all the competing applicants equally serve the public interest, preference is given to the existing permit holder.

Unlike the Western system of prior appropriation, Florida law discourages the long-distance transfer of water across hydrologic boundaries. A transfer must not diminish the availability of water for present and future needs of the sending area, and the receiving area must have exhausted all reasonable local sources and options. In addition, the transfer of water across county boundaries is discouraged.

Minimum flows and levels: Florida water law requires the water management districts to establish minimum flows for all rivers, streams and canals. This means the districts must identify an amount of water flow below which further withdrawals would cause significant harm to the water resource or to the ecology of the area. The law also requires the water management districts to establish minimum levels for ground water and surface waters (rivers, streams, canals, lakes and wetlands) below which further withdrawals would cause harm to the water resource. Surface waters less than 25 acres (10 hectares) generally are exempt from this requirement.

Determining minimum flows and levels requires complex scientific and technical analyses. The water management districts are now making progress in establishing minimum flows and levels, which will play a much greater role in water resources planning and permitting in the future.

Advantages: Consumptive use permits help ensure that the use of water in Florida is reasonable and beneficial. Some degree of certainty is given by permits that give the right to withdraw a certain amount of water for a given time period. The minimum flow provision and the restrictions on the long-distance transport of water help protect the water resources and the environment.

Disadvantages: Terms such as "public interest," "reasonable and beneficial" and "significant harm" are open to interpretation and may result in conflicts that have to be resolved through the courts.

The districts are drawn on watershed boundaries. These are natural drainage basins, not political boundaries. Water management districts are overseen at the state level by the Department of Environmental Protection. They are governed by a board appointed by the Governor and approved by the Senate. They are funded to do the job of water management by a tax granted to them by the people of Florida in 1976. However, the budgets of the districts are closely monitored by the Governor's Office and by the Legislature.

1980s

In the late 1970s and early 1980s, protection of Florida's ground water, the primary source of drinking water in the state, became a major issue. The 1983 Task Force on Water Issues reported that the threat of contamination of ground water and related surface waters from hazardous wastes, sewage, industrial wastes and pesticides had become a major problem. The Legislature passed the Water Quality Assurance Act, granting the Department of Environmental Regulation more authority to protect ground water and to clean up contaminated resources.

In 1985, the Florida Legislature passed the Surface Water Improvement and Management Act (SWIM), the first statewide program for protecting or restoring waters of regional or statewide significance. The initial legislation named the first six water bodies to be restored and protected under SWIM: Lake Apopka, Tampa Bay, Lake Okeechobee, Biscayne Bay, the Indian River Lagoon and lower St. Johns River.

1990s

Throughout the 1990s, Florida continued to protect environmentally sensitive lands, critical water resources and vital habitats through **land acquisition** efforts. With programs such as Preservation 2000 and Save Our Rivers, Florida has carried out the largest land acquisition effort in the nation. In the last quarter of the twentieth century, Florida purchased 2.1 million acres (850,000 hectares) of conservation and resource-based recreation land. In combination with land protected by local and federal programs or under private conservation management, these purchases protect and preserve 7.6 million acres (3.1 million hectares) of land (about 22 percent of the land in Florida).

In the 1990s, major **ecosystem restoration** projects and land acquisition programs were undertaken throughout the state. The Everglades Forever Act, passed by the Legislature in 1994, outlines a comprehensive program for restoring water quality and improving the amount, timing and distribution of water flows for the entire south Florida ecosystem (Kissimmee River-Lake Okeechobee-Everglades-Florida Bay). In the St. Johns River Water Management District, restoration projects began in the Lower St. Johns River Basin,

WATER KNOWS NO POLITICAL BOUNDARIES

The Apalachicola-Chattahoochee-Flint River Basin (ACF) is located within three states — Georgia, Alabama and Florida. The headwaters are in Georgia above Lake Lanier near Atlanta. The basin terminates in northwest Florida where the Apalachicola River flows into Apalachicola Bay on the Gulf of Mexico. In 1990, Florida joined with Alabama in a federal lawsuit over the Army Corps of Engineers' and Georgia's plan to reallocate water in Lake Lanier for the Atlanta urban area's water supply. In 1997, after years of negotiations, the three states entered into the ACF River Basin Compact, ratified by the three state legislatures and Congress. The Compact directed the three states to develop a water allocation formula to apportion the water in this river system.

The Suwannee River Basin begins in Georgia in the Okefenokee Swamp and ends in the Gulf of Mexico. Two of the Suwannee's major tributaries, the Withlacoochee (distinct from the southern Withlacoochee) and the Alapaha, also originate in Georgia. In the 1990s, the Suwannee River Water Management District and the Florida Department of Environmental Protection and their counterpart agencies in Georgia formed the Suwannee Basin Interagency Alliance. This group is working to develop a basinwide management planning and river protection program that, for the first time, will address the entire watershed.

Lake Apopka, the Indian River Lagoon, and the upper Ocklawaha River Basin. In the Northwest Florida Water Management District, restoration began in portions of Tates Hell Swamp, formerly ditched and drained for pine plantations. In the Suwannee River Water Management District, large parcels within the 100-year floodplain of the Suwannee River are being acquired, protected, and restored where necessary. In the Southwest Florida Water Management District, over 30 ecosystem restoration projects are under various stages of development for the Tampa Bay estuarine ecosystem.

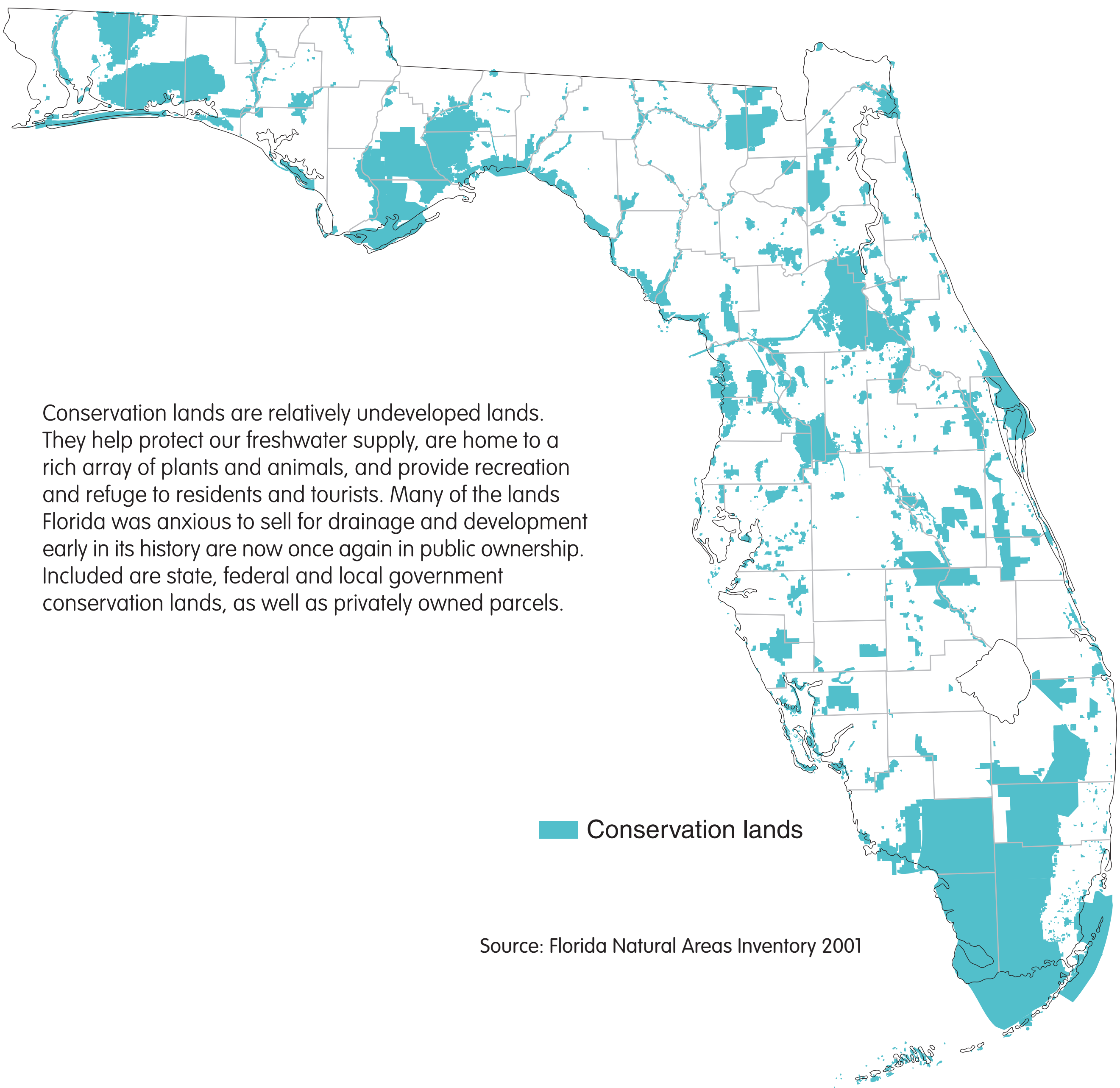
In 1999, the Florida Legislature passed the Florida Forever Act, the successor to Preservation 2000. The act provides $300 million per year for 10 years for land acquisition, water resources protection, ecosystem restoration, and urban parks and open space. Half of the water management districts' allocation (35 percent) may be used for water resources development, including restoring aquifer recharge, capturing and storing of excess flows of surface water, surface water reservoirs, and implementing aquifer storage and recovery.

Conclusion

The basic water management framework established by the 1972 Water Resources Act has remained intact. The Department of Environmental Protection and the water management districts jointly implement a broad range of programs related to water supply, flood protection, water quality and natural systems protection.

Water supply and **water allocation** have emerged as paramount issues for the next century. In some areas of the state, demands for water are beginning to exceed the capacity of aquifers and surface waters to meet these demands. Competition for water is increasing. The effects of withdrawing more ground water than rainfall can replenish are evidenced by saltwater intrusion, diminished spring flow, dried-out marshes and disappearing lakes. In some areas, new, easily developed, clean sources of water no longer exist. Alternative sources can be developed, but at higher costs than traditional sources. Although Florida is in many ways "The Water State," its supplies are not boundless.

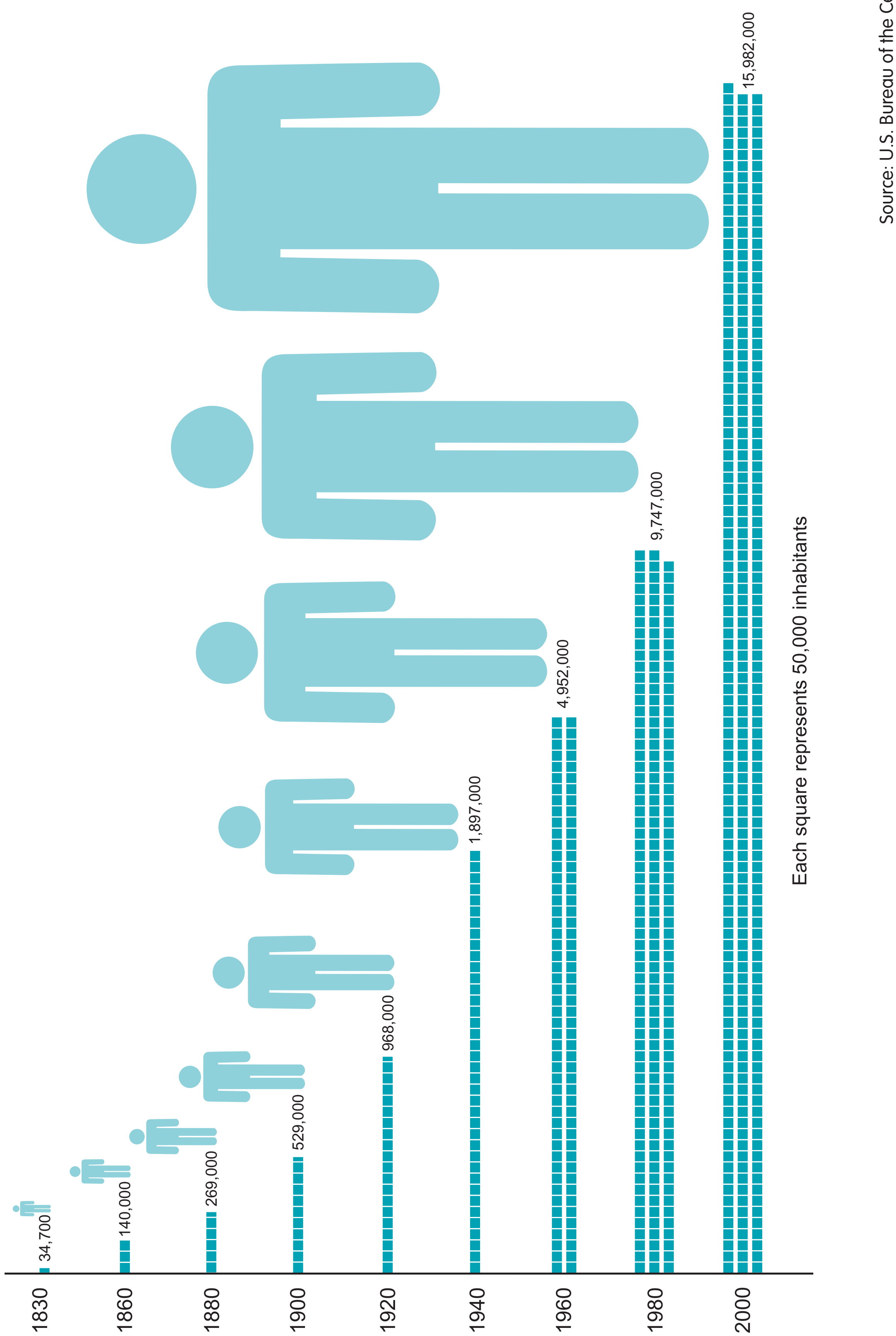
Conservation Lands
2001



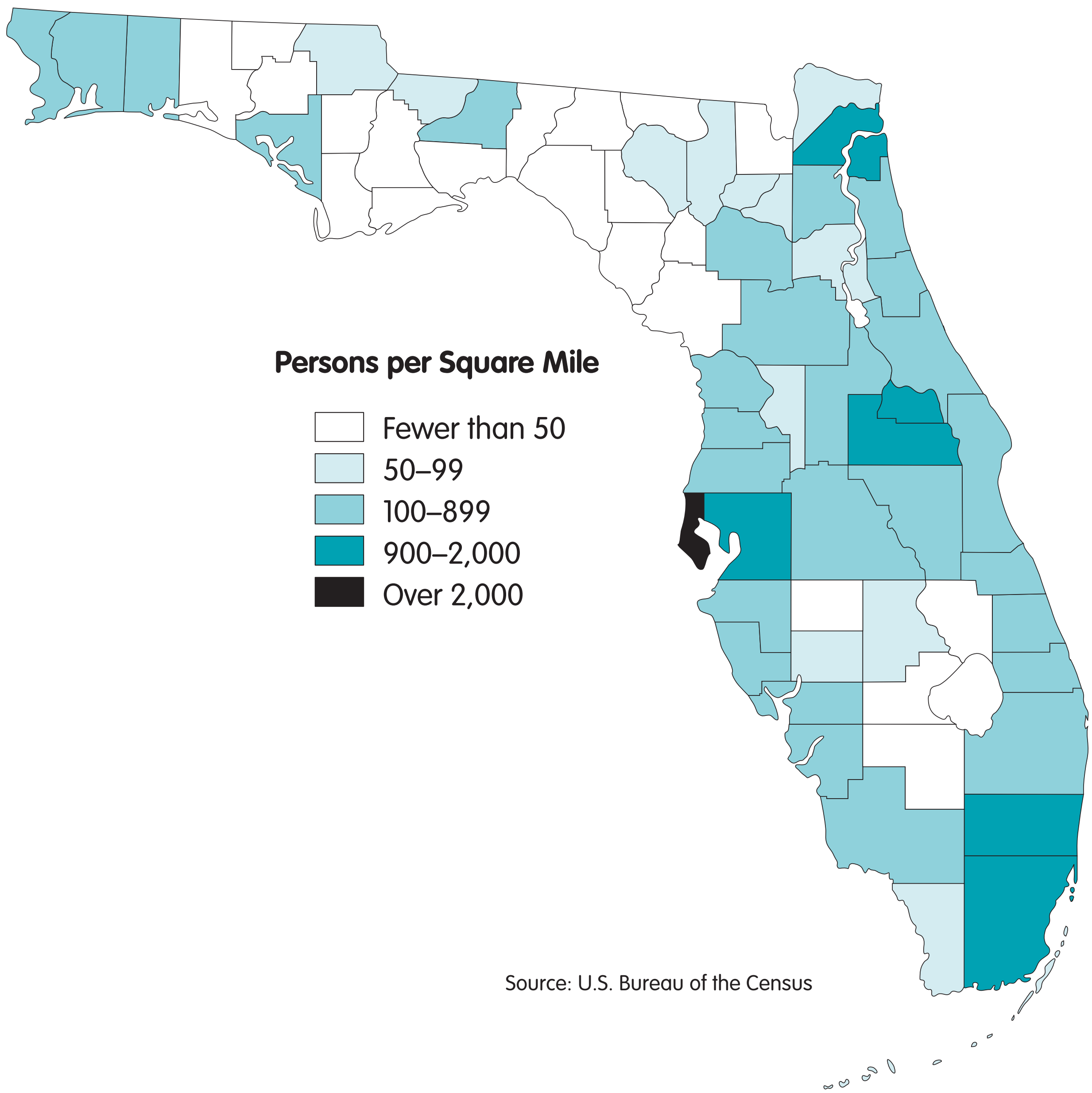
Conservation lands are relatively undeveloped lands. They help protect our freshwater supply, are home to a rich array of plants and animals, and provide recreation and refuge to residents and tourists. Many of the lands Florida was anxious to sell for drainage and development early in its history are now once again in public ownership. Included are state, federal and local government conservation lands, as well as privately owned parcels.

Source: Florida Natural Areas Inventory 2001

Florida's Population Growth



Population Density
2000



The Human Framework Time Line

12,000 BC — 1500 — 1770 — 1820 — 1830

12,000 B.C.
First Floridians enter the Florida peninsula.

1500
Beginning of Spanish exploration of Florida.

350,000 Native Americans living throughout the present-day state.

1774
The Suwannee River is "The cleanest and purest of any river. . . almost as transparent as the air we breathe."
— Naturalist William Bartram

1821
Spain cedes East and West Florida to the United States

1827
"In appearance it [northern Florida] is entirely unlike any part of the United States. The lakes abound in fish, trout, brim, perch and soft-shelled turtle; and in the winter with wild fowl."
— Judge Henry M. Brackenridge

Source: Florida State Archives

Timucuan Indians depositing grain in public granary

1835
Steamboats begin arriving in Florida.

1845
Florida statehood. Federal government grants 500,000 acres of land to the state for "internal improvements."

1848
Secretary of the Treasury Buckingham Smith declares the Everglades can be reclaimed by digging canals. Stephen R. Mallory, collector of customs at Key West, warns "it will be found wholly out of the question to drain all the Everglades."

1850
U.S. Congress conveys all swamp and overflowed lands to the state.

1851
Board of Internal Improvement established to transfer wetlands to private companies for drainage. Dr. John Gorrie of Apalachicola patents a process for making ice; he used the process to cool the rooms of his patients.

1840 1850 1860

Source: Florida State Archives

Dr. John Gorrie

John Muir ca. 1870

Source: Florida State Archives

1867
Florida is "so watery and vine tied that pathless wanderings are not easily possible in any direction."
— John Muir

1875
The Ocklawaha River is "the sweetest waterlane in the world" and Silver Springs Run is a "journey over transparency."
— Sidney Lanier, Florida: *Its Scenery, Climate, and History*

1865 1870 1875

1866
Governor Davis Walker grants William Gleason over 6 million acres based on his proposal to drain swamplands east and south of the Everglades.

1868
State's first water pollution law establishes a penalty for defiling or corrupting springs and water supplies.

1870
Jacksonville becomes a major port for lumber production and export.

Source: Florida State Archives

Lumber wharf, Jacksonville, 1870s

Source: Florida State Archives

Water hyacinths, Lake Monroe, between 1903 and 1906

1879
Santa Fe Canal Company constructs two canals from Waldo to Melrose via Lake Alto and Lake Santa Fe.

1881
State of Florida sells 4 million acres of land near Lake Okeechobee and in the Kissimmee River basin to Hamilton Disston of Philadelphia for 25 cents per acre.

1884
Mrs. W. F. Fuller plants water hyacinths along the shore of her home on the St. Johns River.

1875 1880 1885

1882
Disston links Lake Okeechobee outlet to the Gulf coast via the Caloosahatchee River. ". . . by their insane shooting at everything, the tourists were driving all birds, alligators, and animals from this portion of the [Ocklawaha] river."
— George Barbour, *Florida for Tourists, Invalids, and Settlers*

Source: Florida State Archives

Steamboat on the Ocklawaha River, 1877

Source: Florida State Archives

Frost damage to citrus crop

1886
Freeze and hurricane destroy north-central Florida's citrus industry.

1894–95
Great Freeze ends commercial agriculture industry in north Florida.

1885 **1890** **1895**

1889
Phosphate is discovered near Dunnellon.

Source: Florida State Archives

Early phosphate mine

1900
"The existing practices of lumbermen in cutting timber land so close . . . [left] no young trees unscathed to form new forests, and when the pine disappears, it is replaced by utterly worthless scrub."
— *Pensacola Daily News, March 27*

1900
"[I]n our very midst, we have a tract of land one hundred and thirty miles long and seventy miles wide that is as much unknown to the white man as the heart of Africa."
— Hugh L. Willoughby, *Across the Everglades*

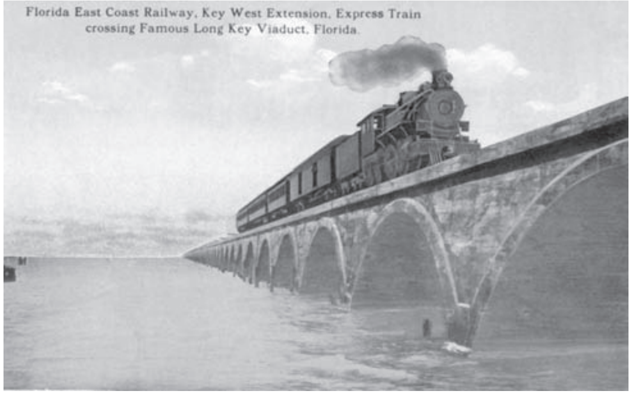
1895 1900 1905

Source: Florida State Archives

Reclaiming the great Everglades, 1912

1904
Napoleon Broward elected governor on a promise to drain the Everglades for gardens and farms.

Source: Florida State Archives



Florida East Coast Railway, Key West Extension, crossing Long Key Viaduct

1912
The Flagler Railroad to Key West is completed.

Intracoastal Waterway from Jacksonville to Miami is completed.

1906
John Gifford introduces melaleuca as the ideal plant for drying the Everglades.

1905 **1910** **1915**

1907
Everglades Drainage District established.

1913
"Drainage of the Florida Everglades is entirely practicable and can be accomplished at a cost which the value of the reclaimed land will justify, the cost being very small."
— Florida Everglades Engineering Commission

Source: Florida State Archives

Former Governor Jennings and family with press tour of Everglades Drainage Project, 1907

Source: Florida State Archives

Tamiami Trail blazers

1916
Construction of the Tamiami Trail begins.

1920s
South Florida real estate boom; Carl Fisher transforms wet, mangrove-fringed island to resort of Miami Beach; saltwater intrusion in St. Petersburg's municipal well fields.

Source: Florida State Archives

Bathing beauties at the beach

1931
Gulf Intracoastal Waterway extended from Pensacola to Carrabelle.

1926
Hurricane kills 400 in Lake Okeechobee area.

1929
Okeechobee Drainage District formed. In *From Eden to Sahara: Florida's Tragedy*, John Kunkel Small predicts that, once drained, Florida will become a desert.

1935
Construction begins on the Cross Florida Barge Canal; "Labor Day Hurricane" hits the Keys, killing 400.

1925 1930 1935

1928
Hurricane kills 2,000 south of Lake Okeechobee when earthen dike fails to contain Lake Okeechobee: "The monstropolous beast had left his bed. The two hundred miles an hour wind had loosed his chains. He seized hold of his dikes and ran forward until he met the quarters; uprooted them like grass and rushed on after his supposed-to-be-conquerors, rolling the dikes, rolling the houses, rolling the people in the houses along with other timbers. The sea was walking the earth with a heavy heel."
— Zora Neale Hurston,
Their Eyes Were Watching God

Source: Florida State Archives

Funeral service for hurricane victims, 1928

Source: Florida State Archives

Drought, Everglades

1931–45
Florida experiences drought, saltwater contamination in wells along the coast, and fires in dry muck soils in the former Everglades.

1937
Work suspended on the Cross Florida Barge Canal.

1935 1940 1945

1937
U.S. Army Corps of Engineers completes 85-mile-long Herbert Hoover Dike flanking three-quarters of Lake Okeechobee.

1941–45
In World War II, Florida became a training ground for tens of thousands of soldiers. Many later returned as tourists or to become residents.

Source: Florida State Archives

Source: Florida State Archives

President Harry Truman with John Pennekamp at dedication of Everglades National Park, 1947

1947
Two hurricanes flood Miami. First algal blooms reported in Lake Apopka. Everglades National Park opens — "There are no other Everglades in the world."
— Marjory Stoneman Douglas, *The Everglades: River of Grass*

1949
Florida Legislature creates the Central and Southern Florida Flood Control District to act as local sponsor for the federally authorized project.

1945 1950 1955

1948
Congress authorizes the Central and Southern Florida Flood Control Project; U.S. Army Corps of Engineers proposes three water conservation areas.

1955
State Board of Health declares Peace River "is now suffering severely from excessive organic and chemical pollution."

Source: Florida State Archives

Kissimmee River, Canal 38

1955

1957
Jim Woodruff Lock and Dam on the Apalachicola River becomes fully operational.

1959
Suwannee River Authority and Peace River Valley Water Conservation and Drainage District created.

1960

1960
Hurricane Donna floods Tampa Bay Area.

1961
Congress authorizes the Four River Basins, Florida Project for flood control in Tampa area; the Southwest Florida Water Management District is created; south Florida receives only 30 inches of rain.

1962
Construction of the Kissimmee Canal begins.

1964
U.S. Army Corps of Engineers recommends construction of a $12.5 million hurricane levee across Hillsborough Bay at Tampa.
"God was good to this country . . . But in His wisdom the Creator left something for men to do for themselves."
— President Lyndon B. Johnson, Groundbreaking for the Florida Cross State Barge Canal

1965

1965
Congress enacts the Federal Water Quality Act.

1965

1966
Central and Southern Florida Flood Control District pumps excess water from farmlands into water conservation areas, drowning hundreds of deer.

1966–67
Fifteen new sinkholes appear in central Florida, indicating a serious drop in the water table.

1969
United States Geological Survey map shows area in southwestern Polk County as a "caution area" for further water withdrawals.

1970

1970
Four River Basins, Florida project is halted for restudy; first Earth Day.

1970s
Escambia Bay experiences repeated massive fish kills.

1970–71
State experiences worst drought to date.

1971
Congress orders U.S. Army Corps of Engineers to deliver more water to Everglades National Park; construction of the Florida Cross State Barge Canal halted; canalization of the Kissimmee completed.

1972
Year of the Environment
(see page 9)

1973
Record flood occurs in the upper reaches of the Suwannee River basin.

Source: Suwannee River Water Management District

Suwannee River at Dowling Park, April 1973 flood

1974
Big Cypress National Preserve, located in Ochopee, Florida, next to the Everglades National Park, was established.

1975

1976
Summary Report on the Special Project to Prevent Eutrophication of Lake Okeechobee finds “water delivered to Lake Okeechobee from the Kissimmee River by Canal-38 contributes significantly to the eutrophication of the Lake.”

1977
Upper St. Johns River Basin Restoration Project begins.

1979
Conservation and Recreation Lands (CARL) Trust Fund established.

1980
Florida Hazardous Waste Management Act enacted. Floridan aquifer levels in Ft. Walton Beach area had declined as much as 100 feet below sea level.

1981
Florida Legislature creates Water Management Lands Trust Fund, provides funding for Save Our Rivers land-buying program.

1982–83
Over 400 drinking water wells in northeastern Jackson County found to be contaminated by the pesticide ethylene dibromide.

1983
Florida Water Quality Assurance Act establishes statewide groundwater monitoring network; Governor Bob Graham announces the Save Our Everglades program.

1984
The Warren S. Henderson Wetlands Protection Act is enacted.

1985
Elevated levels of nitrogen detected in the upper reaches of the Suwannee River.

1975 1980 1985

1986
Florida Legislature establishes the nation's first program to clean up contamination from leaking underground petroleum storage tanks.

1987
Florida Surface Water Improvement and Management (SWIM) Act enacted.

1988
St. Johns River Water Management District begins restoration of Lake Apopka.

1989
Southwest Florida Water Management District declares northern Tampa Bay, eastern Tampa Bay, and Highlands Ridge as water use caution areas.

1990
Preservation 2000 provides $300 million per year over 10 years to purchase ecologically valuable lands.

1992
Hurricane Andrew strikes southern Dade County, causing $16 billion in damages; Congress directs the U.S. Army Corps of Engineers to undertake restoration of the Kissimmee River; Southwest Florida Water Management District combines its three water use caution areas to establish the Southern Water Use Caution Area.

1993
The State Department of Natural Resources and Department of Environmental Regulation are merged into the Department of Environmental Protection. The Department of Community Affairs estimates 1.3 million Floridians live in areas subject to flooding.

1994
Everglades Forever Act outlines major elements of Everglades restoration; Tropical Storms Alberto and Beryl and Hurricane Opal flood Panhandle.

1995
Florida Water Plan adopted by the Department of Environmental Protection declares "water must be managed to meet the water needs of the people while maintaining, protecting, and improving the state's natural systems."

1985 1990 1995

Source:
South Florida Water Management District

Hurricane Andrew, 1992

Photo credit:
St. Johns River Water Management District

Upper St. Johns River Basin, 1995

1996
Water management districts required to submit priority lists and schedules for establishment of minimum flows and levels.

1999
Florida Forever Act provides $300 million dollars per year for 10 years for land acquisition, water resources protection and supply, ecosystem restoration, and urban parks and open space.

1995 **2000** **2005**

1997
Florida Legislature defines regional water supply planning responsibilities of the five water management districts, local governments, and utilities; Legislature approves an agreement with Alabama and Georgia establishing the basis for an interstate compact on the Apalachicola/Chattahoochee/Flint River system; 38 percent of flow from Florida's domestic wastewater treatment plants is reused.

Photo credit: Diane Sterling

Pitcher plants, Apalachicola National Forest

Chapter 2

Water: It's Magic

"If there is magic on this planet, it is in water."

— Loren Eisley, Naturalist and Philosopher

"One question I ask of you:
Where flows the water?
Deep in the ground in the gushing spring,
A water of magic power — The water of life!
Life! O give us this life!"

— Native Hawaiian poem

KEY IDEAS

- Water is critical for all life on Earth.
- Water has many amazing chemical and physical properties.
- Most of the water on Earth is salt water.
- Only 3 percent of the Earth's water is fresh water and less than 1 percent of the fresh water is available for use. Most fresh water is frozen in glaciers and polar ice caps.
- Water is continuously circulating between the sky, land and sea.
- No significant amount of water enters or leaves the global water cycle.
- Water does enter and leave Florida's water cycle.
- Rainfall in Florida varies with season and location.
- Florida is susceptible to extreme weather events including tornadoes, hurricanes, floods, thunderstorms and droughts.
- Florida's climate is influenced by global patterns.

VOCABULARY

Atom
Capillarity
Condensation
Drought
El Niño
Evaporation
Evapotranspiration
Flood
Gas
Global warming
Ground water
Humid subtropical
Hurricane
Hydrologic divide
La Niña
Liquid
Molecule
Precipitation
Saltwater intrusion
Solid
Solvent
Stormwater runoff
Surface tension
Surface water
Tornado
Transpiration
Tropical savanna
Water budget
Water cycle

The wonders and life-giving powers of water have awed and intrigued people throughout the world. To many, water came first in the unfolding of creation. Only after water did land appear, then plants and animals, and then humans. The Winnebago Indians of Wisconsin speak of the Earthmaker. Sitting alone in empty space, the Earthmaker began to cry, and as his tears fell, the waters of the Earth formed. For the Maori of New Zealand and the Crow Indians of the North American plains, in the beginning there was no land on Earth, only water. The Book of Genesis describes Earth before creation as dark, with water covering all the land. Scientists believe life on Earth began in water, where it remained for 3 billion years. About 450 million years ago, plants began to grow out of water, but only on wet ground (Hooper and Coady 1998). Today, water covers 75 percent of the Earth.

Water is essential for all life processes. Plants and animals are between 50 and 97 percent water. The human body is 70 percent water. Protoplasm, the basic material of all living cells, is a solution of fats, carbohydrates, proteins, salts and other chemicals in water. Sap in plants and blood in animals are largely water. Humans can live almost 30 days without food, but only about three to four days without water.

Water's cleansing, healing and renewing powers are unmatched by any other resource on Earth. Religions baptize their initiates in water, and the aged and infirm continue to flock to springs thought to have special healing powers. Water is

IN THE BEGINNING

The world was covered with water, and Old Man and all the animals floated about on a raft. Old Man sent a beaver to bring up some mud, but the water was too deep. Old Man next sent a loon but the water was still too deep. At last he dispatched a muskrat. After a long time, the muskrat surfaced with a clump of mud in its paws. Old Man made the land and all the people from the mud retrieved by the muskrat.

— Plains Indians

The Sun-father and the Moon-mother ordered their children to leave the heavens and to live on the Earth. But Earth was completely flooded with water, and the children were afraid. The elk, the bravest of all animals, went with them. The elk dove into the water and called for the wind to dry the land. Joyous, the elk rolled on the new land, and plants sprang up from the loose hair he left behind.

— Osage Indians

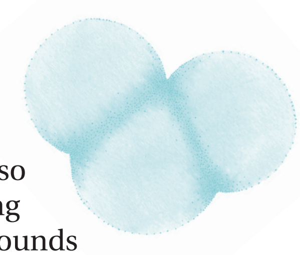
Source: Feder 1997

fun as well as awe-inspiring and is the single most sought-after recreational resource on Earth.

Water and the lack of water can also bring death and destruction. People have always feared the devastating effects of floods, droughts and storms. Modern technology has helped us predict these events and prepare for them, but their occurrence is still largely beyond our control.

Water's Structure

Water has some remarkable chemical and physical properties. The water **molecule** is simple: two hydrogen **atoms** bound to one oxygen atom. An extremely strong bond called a covalent bond connects these atoms. The two hydrogen atoms are always at an angle of exactly 104.5 degrees from each other, making all diagrams of water molecules "look like the ears on a round head of a panda" (Watson 1988).



Because the fit between the atoms is so perfect, water is among the most stable compounds in nature. The tiniest droplet of water contains more than 300 trillion water molecules.

WATER'S AMAZING PROPERTIES

- Water is the only substance that exists in nature as a **liquid**, a **solid** and a **gas**.
- Water circulates continuously between land, sky and sea.
- Pure water is odorless, transparent and, for many people, tasteless. Taste is often from minerals or other items dissolved in the water.
- Unlike most liquids, water expands rather than shrinks when cooled.

Thus, water is lighter in its solid state than it is in its liquid state. This is why ice floats. Imagine how different the world would be if ice sank. In colder climates, rivers, lakes and ponds would be frozen solid, and fish and other aquatic life would be unable to survive the winter.

- Water holds heat much better than air does. Air temperature may change rapidly, but water temperature changes slowly. On a cool summer night, seawater is still warm enough for a swim.

- Water is the universal **solvent**. This means that more substances will dissolve in water than in other liquids. This property makes water very useful for washing clothes, dishes and human skin. It also means water becomes contaminated or polluted very easily.

- Water shapes the surface of the Earth. In combination with gravity, wind and expansion and contraction caused by freezing and thawing, water can dissolve rocks, wear down mountains and hills, and sculpt drainage basins.

- Water has **surface tension**. Surface tension occurs when two substances that do not mix freely, such as air and water, come into contact. The water molecules draw closer together and cling or adhere to each other like little magnets, causing the surface to shrink (Wick 1997). Because of surface tension, insects can skate across the surface of a pond, which seems to have a skin. Surface tension also holds molecules together in drops.

- Water has **capillarity**. Capillaries are long, slender, tubelike structures. Water rises in capillaries because of the attraction of water molecules to each other and to the molecules on the side of the solid capillary. For example, if you rest a straw in a glass of liquid, the liquid rises in the straw above the level of liquid in the glass. This is because of capillarity, which results from the attraction of the water molecules to each other and to the molecules in the straw. Because of capillarity, plants are able to draw water from the ground up through their roots and stems.

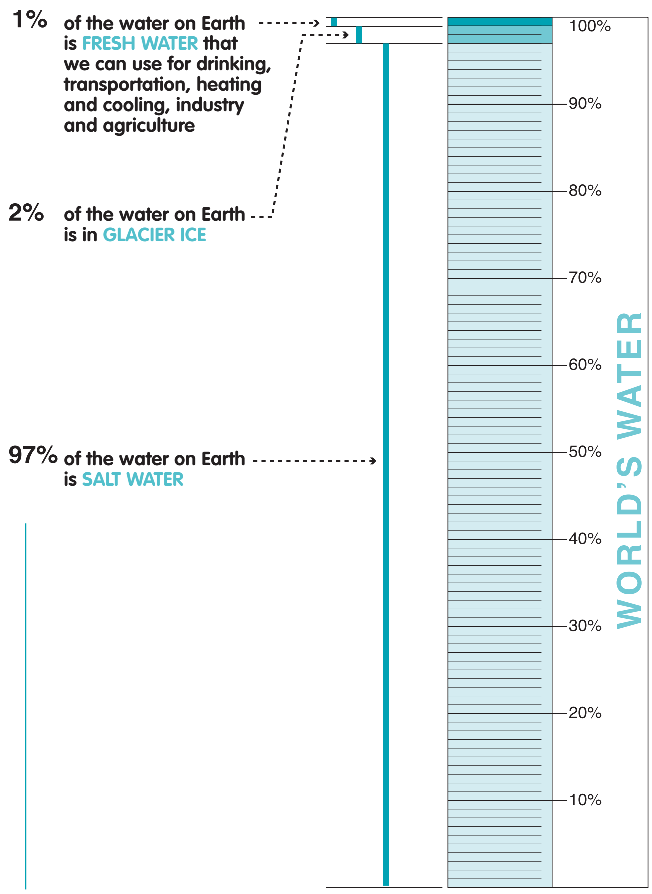
Global Water Cycle

Until the late 1980s, scientists assumed the amount of water on Earth was fixed and finite. Now some scientists believe that Earth's water supply may be constantly growing as a result of huge "snowballs" that enter the Earth's gravitational field from outer parts of the solar system. These snowballs, about the size of small houses, are thought to melt and evaporate when they approach the Earth (Frank 1990, cited in Pielou 1998). In any event, this possible addition is relatively insignificant in relation to the vast amount of water constantly on Earth.

Water on Earth today has been here for millions and perhaps billions of years. Scientists believe water originated early in the Earth's history from hydrogen and oxygen in the gas cloud from which our universe formed.

In 1998 in Monahans, Texas, five boys were playing basketball when they heard what sounded like a sonic boom. In a nearby vacant lot, they saw a black rock the size of a grapefruit. One of the boys picked up the still-warm rock and

World's Water



handed it to his father, who correctly identified it as a meteorite. Inside was a minute amount of liquid water, the first ever found in a meteorite. Scientists believe this water dates from very early in the solar system and may be 4.5 billion years old. This finding supports the theory that water is indeed very ancient. It also suggests that perhaps there were other places in the solar system where life may have developed.

Nearly all of the water on Earth is salt water. Less than 3 percent is fresh water and most of this is locked up in glaciers and polar ice caps. Less than 1 percent of the world's water is fresh water available for human and nature's use.

The water on Earth is continuously circulating between the air or atmosphere, the land and the sea. The ways in which water moves around, above, on and within the Earth is the hydrologic or **water cycle**.

The sun is the energy source for the water cycle, causing water to evaporate from lakes, rivers and oceans, as well as from land surfaces and vegetation. When water evaporates, it changes to a gas (water vapor) and rises in the air. When the water vapor rises and meets cold air, it condenses, forming water droplets, or what we see as clouds or fog. This process is called **condensation**. Water droplets combine into water drops and return to the Earth as **precipitation** in the form of rain, sleet, hail or snow.

Exactly how clouds produce rain has eluded meteorologists until recently. In 1999, Dutch scientists using a supercomputer to model cloud behavior announced that rain is produced when whirling masses of water, a few centimeters in diameter, force water droplets outward by centrifugal force. These droplets then collide and grow. To fall to the ground as precipitation, they need to reach a diameter greater than 20 micrometers (Environmental News Network online, November 16, 1999).

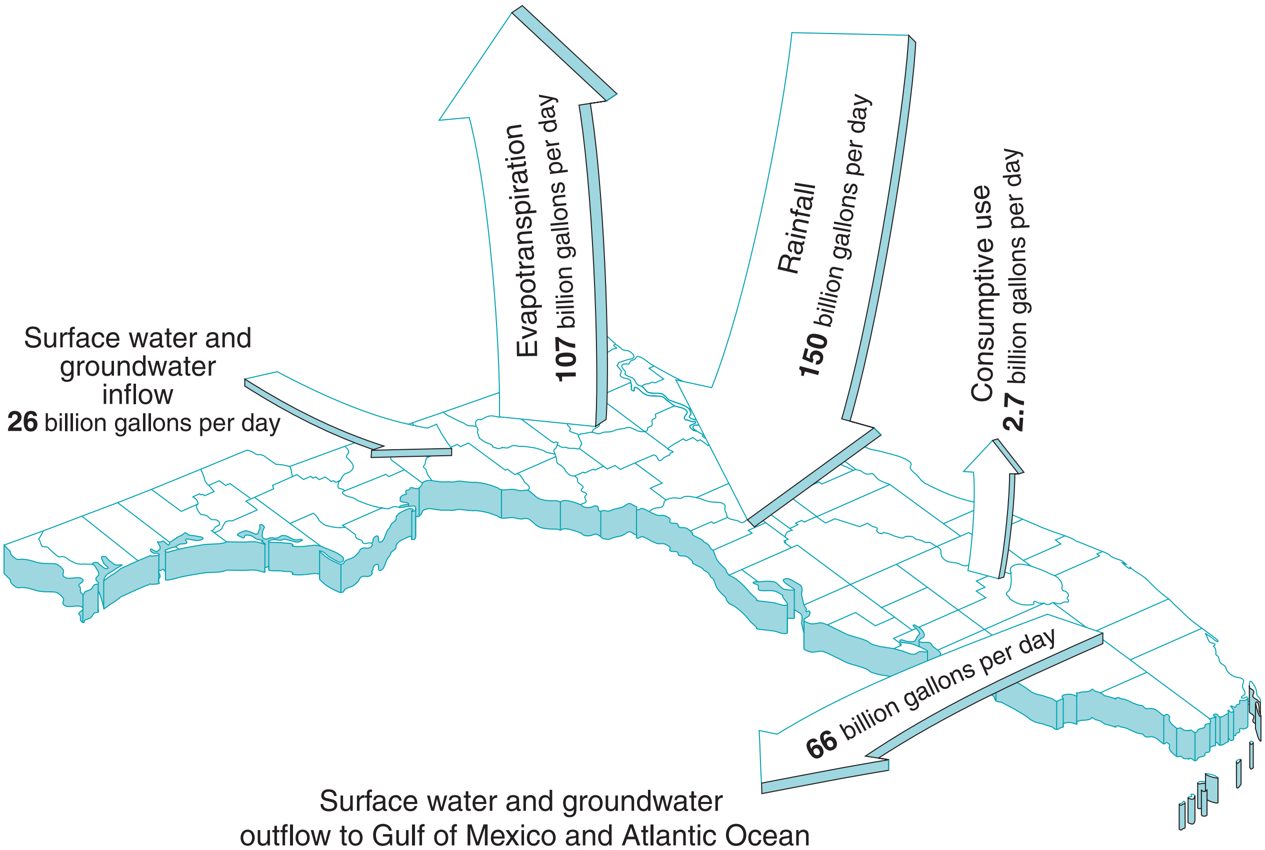
Some rain is absorbed by vegetation or evaporates before it reaches the ground. Some evaporates after it reaches the surface. Some soaks into the ground and is taken up by the roots of plants and then released back into the air through the leaves of the plants in a process called **transpiration**. The combination of **evaporation** and transpiration is referred to as **evapotranspiration**. Some rain soaks beneath the water table into underground units of water-bearing rock called aquifers. The remainder becomes surface or **stormwater runoff** that flows over the ground to wetlands, lakes, ponds, rivers and oceans.

A water molecule's trip from the atmosphere and back may be very long or very short. It may stay in the atmosphere for only a few days or it may remain deeply buried in cavities in the earth or frozen in polar ice caps for thousands of years.

Water Cycle in Florida

No significant amount of water enters or leaves the global water cycle. The water cycle in Florida, however, is an open system. Florida's water cycle includes the flow of **surface water** and **ground water** from Georgia and Alabama into northern and northwestern Florida, as well as outflows to the Atlantic Ocean and the Gulf of Mexico. Hydrologist Garald Parker was the first to discover that neither surface water nor ground water crosses a line snaking across the peninsula from Cedar Key on the Gulf to New Smyrna Beach on the Atlantic (Betz 1984). This line is known as the **hydrologic divide**. South of the hydrologic divide, Florida is an island as far as fresh water is concerned: it totally depends on rainfall for its fresh water, including ground water stored in aquifers. North of the hydrologic divide, Florida receives water from outside the state.

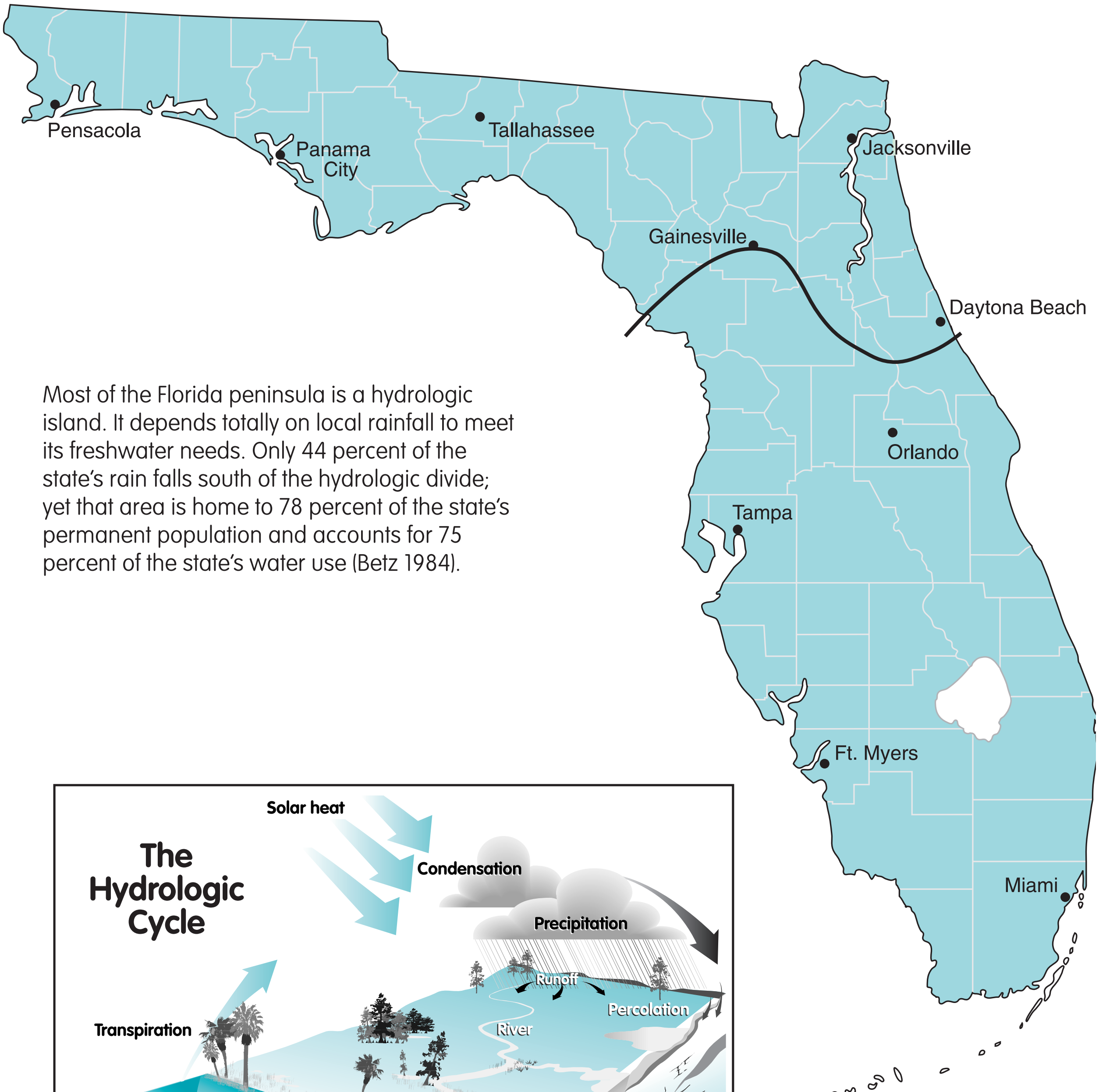
Florida's Water Cycle



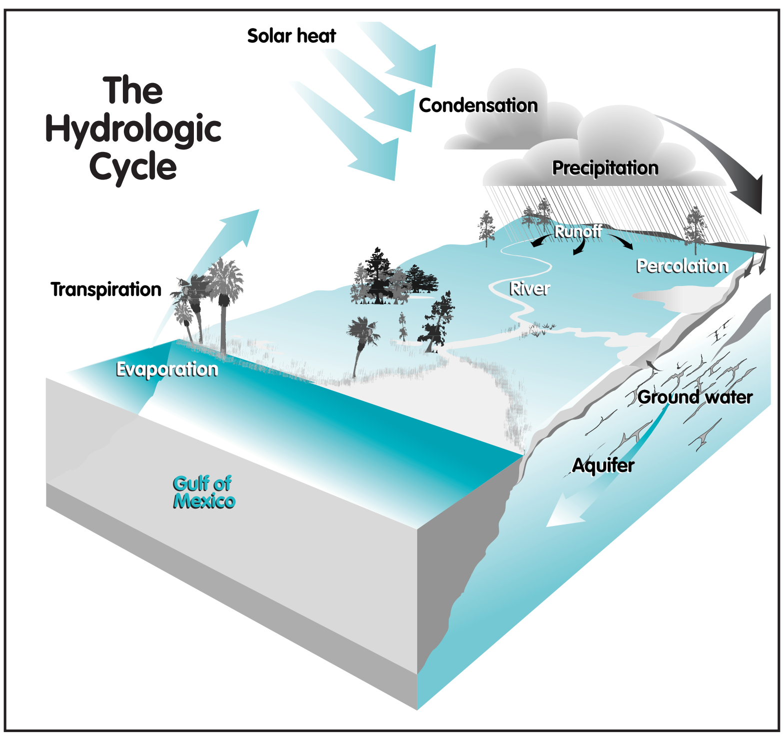
Source: Fernald and Purdum 1998

An average of 150 billion gallons of rain falls each day in Florida. Another 26 billion gallons flows into the state, mostly from rivers originating in Georgia and Alabama. Nearly 70 percent of the rain (107 billion gallons) returns to the atmosphere through evaporation and plant transpiration (evapotranspiration). The remainder flows to rivers or streams or seeps into the ground and recharges aquifers. Each day in Florida, 2.7 billion gallons are incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate environment (consumptive use).

Hydrologic Divide



Most of the Florida peninsula is a hydrologic island. It depends totally on local rainfall to meet its freshwater needs. Only 44 percent of the state's rain falls south of the hydrologic divide; yet that area is home to 78 percent of the state's permanent population and accounts for 75 percent of the state's water use (Betz 1984).



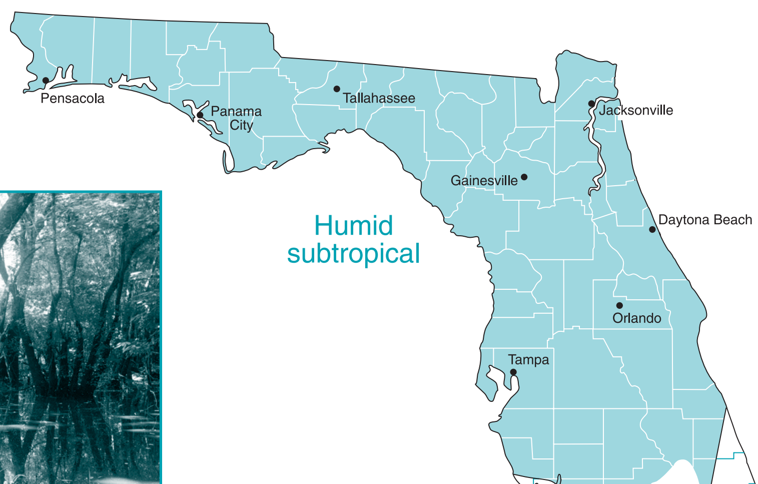
Weather and Climate

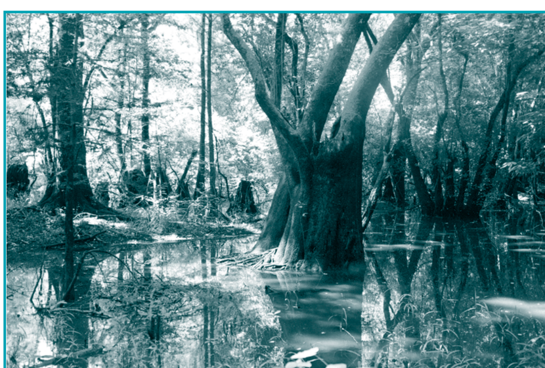
Florida has two types of climate: **humid subtropical** in the northern two-thirds of the state and **tropical savanna** in the southern third and the Keys. A humid subtropical climate is cooler than a tropical savanna climate, especially in the winter months, and lacks distinct wet and dry seasons. A tropical savanna climate is warm year-round and has distinct rainy and dry seasons. The rainy season in south Florida is in the summer and early fall, when thunderstorms occur nearly every afternoon. The dry season is in the winter. In the United States, only portions of Hawaii share this climate type. A tropical savanna climate is also found in nearly half of Africa, parts of the Caribbean Islands, central and southern Brazil and southeast Asia (Henry, Portier and Coyne 1994).

An average of 135 centimeters (53 inches) of rain falls each year in Florida. Some areas, however, receive considerably more, while some areas receive considerably less than this amount. Wewahitchka in the Panhandle receives an average of 175 centimeters (69 inches) and Key West receives only 102 centimeters (40 inches). Rainfall throughout the state varies considerably from season to season and from year to year, as well as from place to place.

The variability of rainfall in Florida cannot be overemphasized: it is quite possible for it to rain on one side of the street and not the other! Stations within the same city often record large differences in the amount of rainfall. For instance, in the greater Miami area, Miami Beach receives an average of 114 centimeters (45 inches) annually, and the Miami airport receives an average of 143 centimeters (56 inches) annually. Many counties have distinct rainfall zones based on Florida's subtle geographic features, vegetation and water bodies.

Climate Types



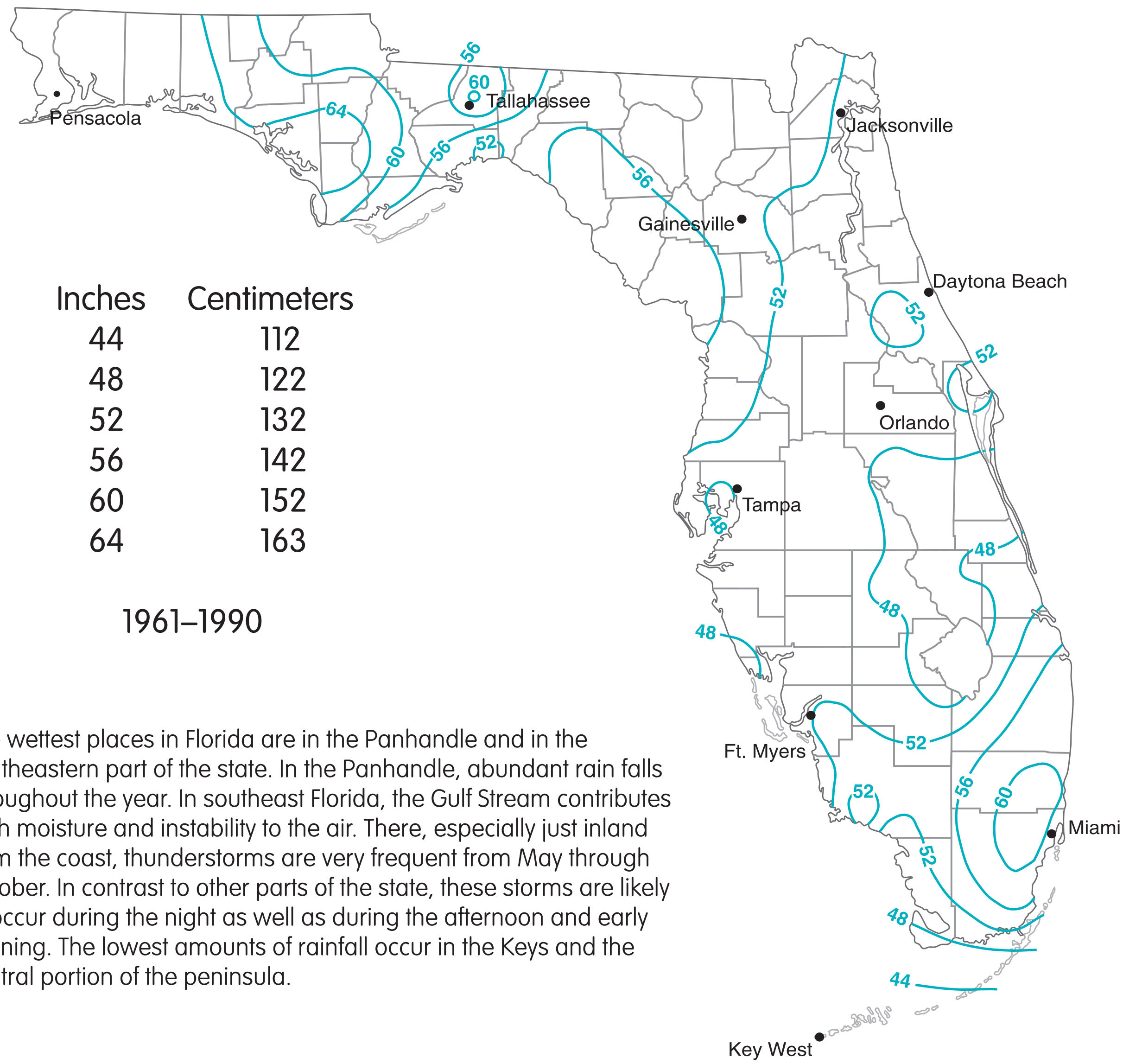


Source: Diane Sterling

Source: Florida Department of Commerce

Source: Henry 1998

Average Annual Rainfall



Inches	Centimeters
44	112
48	122
52	132
56	142
60	152
64	163

1961–1990

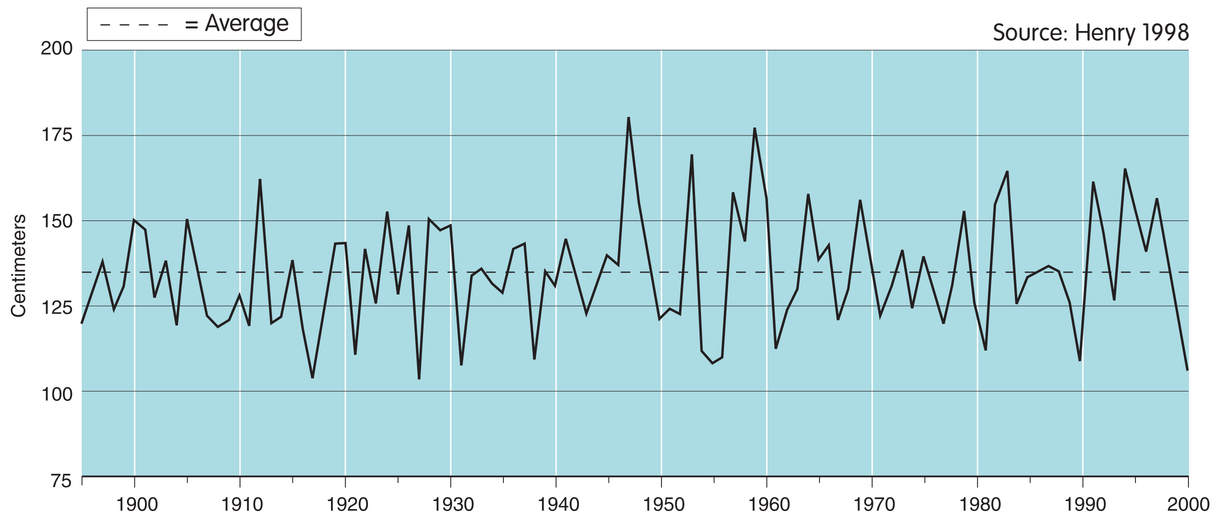
The wettest places in Florida are in the Panhandle and in the southeastern part of the state. In the Panhandle, abundant rain falls throughout the year. In southeast Florida, the Gulf Stream contributes both moisture and instability to the air. There, especially just inland from the coast, thunderstorms are very frequent from May through October. In contrast to other parts of the state, these storms are likely to occur during the night as well as during the afternoon and early evening. The lowest amounts of rainfall occur in the Keys and the central portion of the peninsula.

Source: Henry 1998

FLOODS AND DROUGHTS

Floods and droughts have always been a natural part of Florida's weather pattern. Many natural systems are adapted to and dependent on these events. Floodwaters bring needed nutrients to river floodplains, bays and estuaries. Fires from lightning (more common during droughts) help maintain certain natural communities, such as pine flatwoods, prairies and scrub. Without regular, naturally occurring fires, these communities will succeed to hardwood forests or will burn catastrophically, as occurred in portions of northern and central Florida in the summer of 1998 because of accumulation of pine needles and other fuel. The problems associated with floods and droughts cause more severe impacts because population growth in Florida has been permitted in places that naturally flood or because too much growth has been permitted in places without enough water. Because parts of Florida have large numbers of people, large water demands for agriculture and industry and relatively small capacity to store water, extended periods of low rainfall usually result in water shortages.

Statewide Annual Rainfall



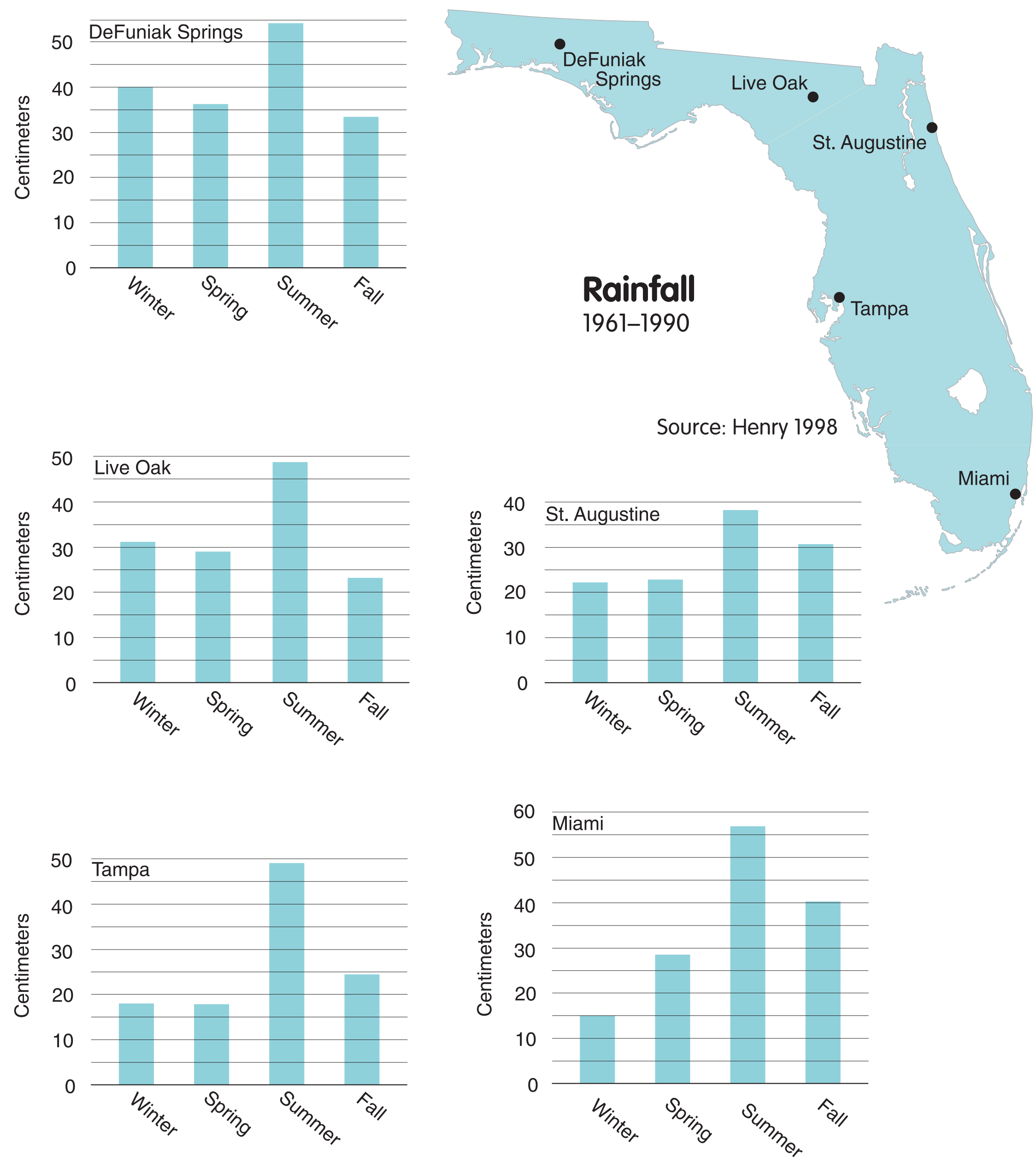
Florida's average rainfall varies greatly from year to year. However, averages in a state as large and as diverse as Florida may be misleading. In a year with "average" rainfall, one part of the state may have been very dry and another part may have been very wet!

In the Sunshine State, when it rains, it usually pours, and floods may result. Floods generally occur in winter and early spring in northern Florida from heavy rain accompanying cold fronts. In summer and fall, all of Florida is susceptible to flooding from thunderstorms and **hurricanes**. Human activities can create environments prone to flooding. Practices that remove soil and vegetation can increase an area's vulnerability to flooding. In northern Florida, flooding usually occurs along rivers. In southern Florida, flooding may occur in any low-lying area. Dikes, canals and other stormwater systems have been built in south and southwest Florida to help prevent flooding in developed areas.

Although Florida is one of the wettest states in the nation, it is still sometimes affected by **droughts** (extended periods of low rainfall). Moderate droughts occur frequently, and severe droughts occur in some part of the state about every six years. In the 1980s, a series of droughts occurred in the state. In 1988–89, rainfall in Key West was less than one-fifth the normal amount and in southwest Florida, groundwater levels were at a record low, causing many sinkholes to form. In June and July of 1998, extremely dry conditions in northern and central Florida resulted in more than 2,300 wildfires that consumed 200,000 hectares (500,000 acres), destroyed 368 houses and forced the evacuation of 130,000 people.

Rainfall deficits have continued since 1998 until the present (May 2001) throughout the state. These deficits would statistically be expected to occur only once every 100 to 200 years. The flow of the Apalachicola River and the depth of Lake Okeechobee have dropped to all-time lows. The St. Johns River Water Management District has experienced vast fluctuations in rainfall levels from one end of the district to the other. Calendar year 2000 was the driest on record (since 1915) in the Southwest Florida Water Management District. In some parts of the Southwest Florida Water Management District, drought conditions have increased the potential for sinkhole development, water quality problems and drying up of private wells.

During droughts, when the level of fresh water in the ground is lowered, salt water may move into freshwater portions of aquifers in a process known as **saltwater intrusion**. Because droughts reduce recharge, they can have a major



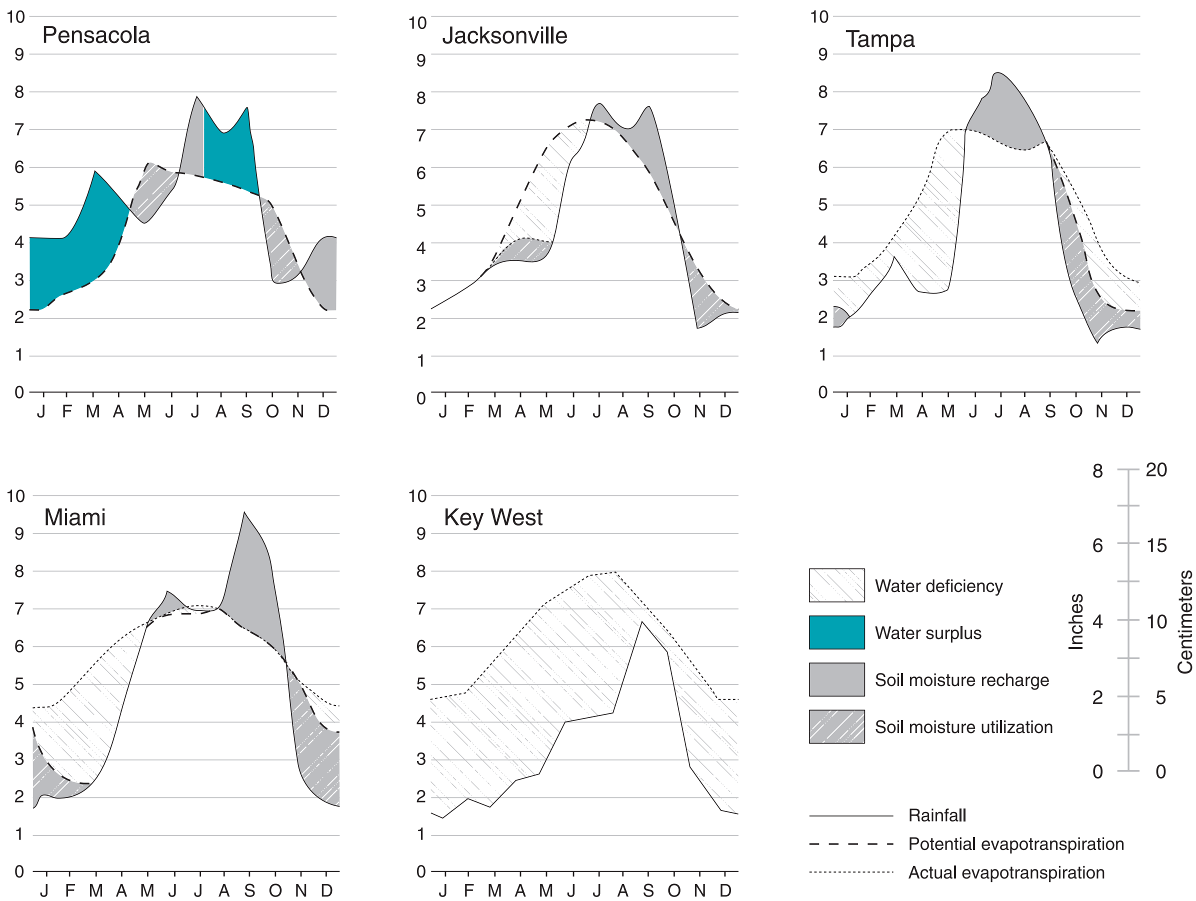
Throughout Florida, summer is the wettest season as a result of nearly daily thunderstorms. Hurricanes may also bring large amounts of rain. Winter and spring are the driest seasons in south Florida. Preceding cold fronts, significant amounts of rain usually fall in the Panhandle and north-central Florida during the winter.

impact on our underground water supply. Since salt water is heavier than fresh water, it occupies the lower portions of the aquifer. If the freshwater level is lowered by pumping and not replaced by recharge, salt water can flow in or rise up and contaminate underground freshwater supplies.

STORMS

Florida's peninsular shape, converging sea breezes, position relative to the Atlantic high pressure system, and tropical and subtropical location make it an ideal spawning ground for thunderstorms. Peninsular Florida is the thunderstorm capital of North America. "Tampa" may come from

Monthly Water Budgets



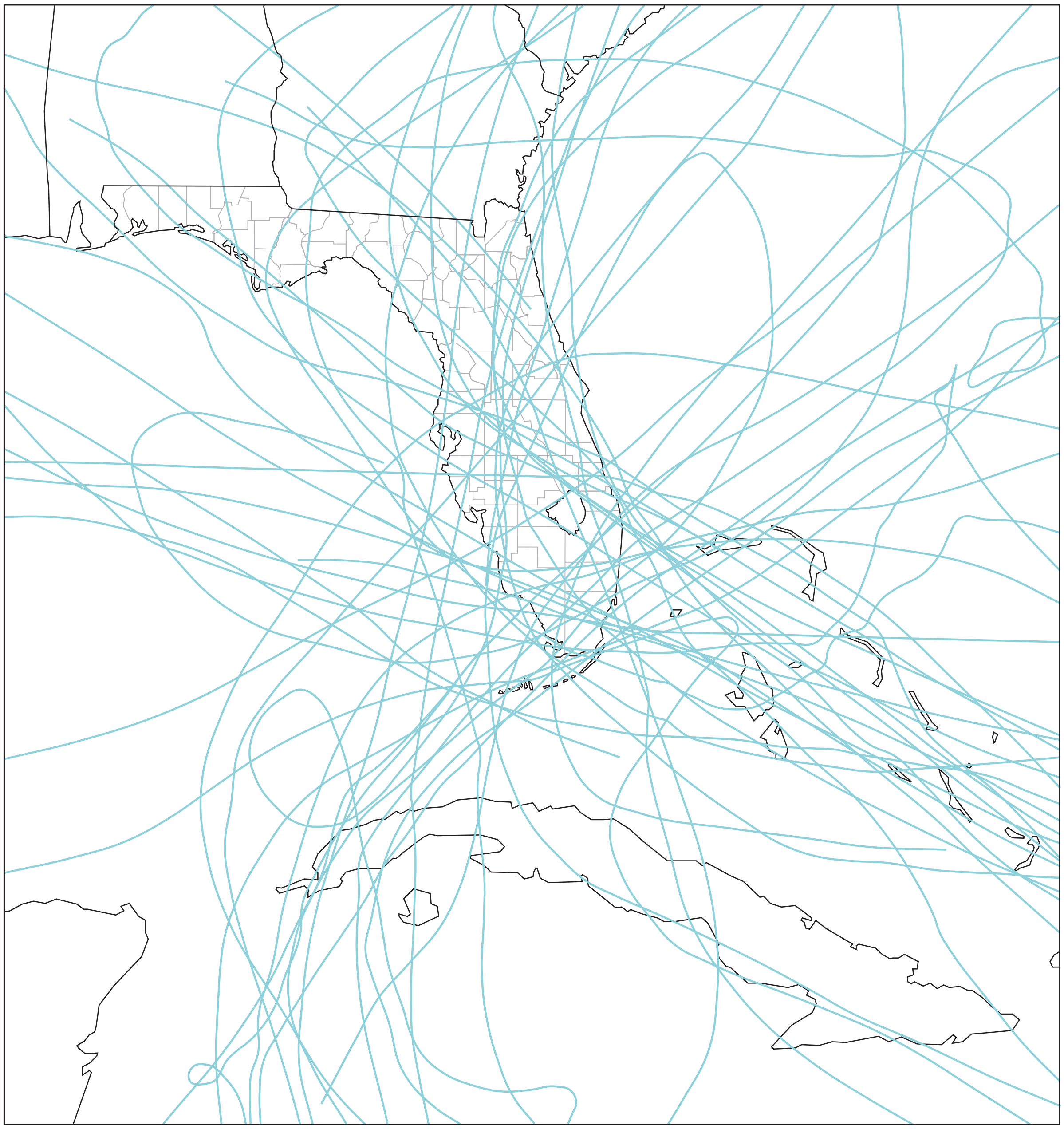
Source: Henry 1998

Hydrologists calculate **water budgets**, formulas used by hydrologists to determine water surpluses and deficits in an area, to help determine where and when these surpluses and deficits are most likely to occur. This knowledge is essential for planning and management. Floods may occur during times of surpluses, and water shortages may occur during times of deficits, particularly in high population areas. Irrigation of crops is usually necessary during periods of water deficits. In Florida, a water deficiency exists throughout the year in Key West. To meet its freshwater needs, Key West depends on either water pumped from the mainland or desalination. In the peninsula, deficits are common in winter and spring. Water deficits rarely occur in the Panhandle, but floods may occur during times of surpluses, particularly during the winter.

an Indian word meaning "stick of fire" (Henry, Portier and Coyne 1994) and is often referred to as the lightning capital of the United States. The Gulf coast from Tampa to Ft. Myers is one end of a lightning belt that stretches across the state to Daytona Beach and Cape Kennedy. Over 200 hours of thunderstorms occur each year in southwestern Florida.

Florida is also susceptible to hurricanes and **tornadoes**. Nearly 40 percent of all hurricanes that have made landfall in the United States have hit Florida. The most common points of landfall are in the Panhandle and along the southern portion of the peninsula. Hurricanes typically bring from 12 to 30 centimeters (5 to 12 inches) of rain, but have brought as much as

Hurricane Tracks 1886–1996

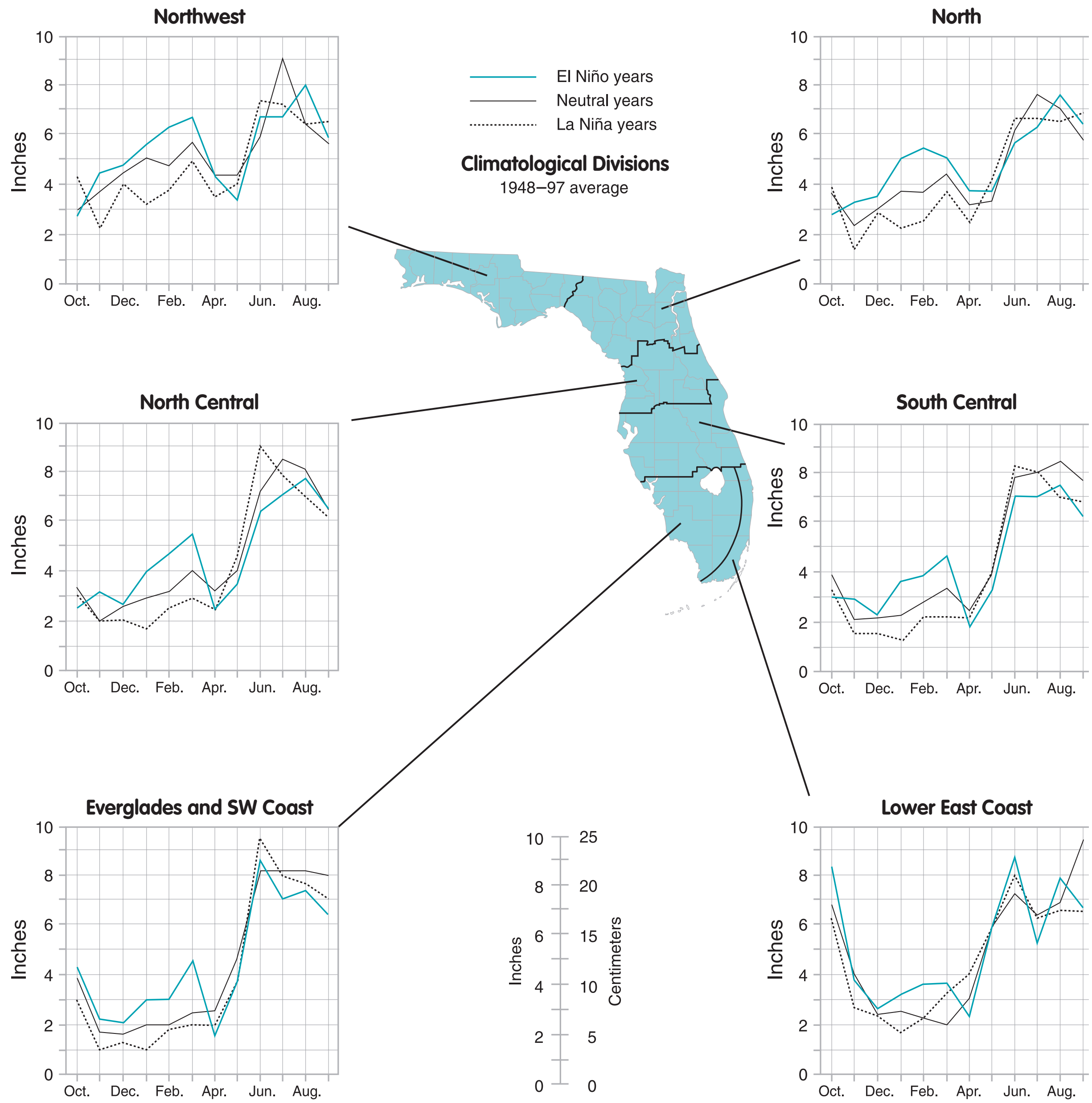


Source: Henry 1998

98 centimeters (38.7 inches) or as little as 1 centimeter (0.5 inches) (Henry 1998). South Florida was spared severe hurricanes from 1965 until 1992, when Andrew crossed southern Dade County, causing 26 deaths and over $3 billion in damages.

Florida also suffers from tornado damage, averaging 45 tornadoes each year. In Florida, tornadoes develop under four conditions: along the squall line ahead of an advancing cold front, along the squall line where masses of warm air converge, in isolated local summer thunderstorms, and within feeder bands associated with hurricanes (Winsberg 1990). Numerous water spouts that are in essence "mini-tornadoes" also occur.

Effects of El Niño



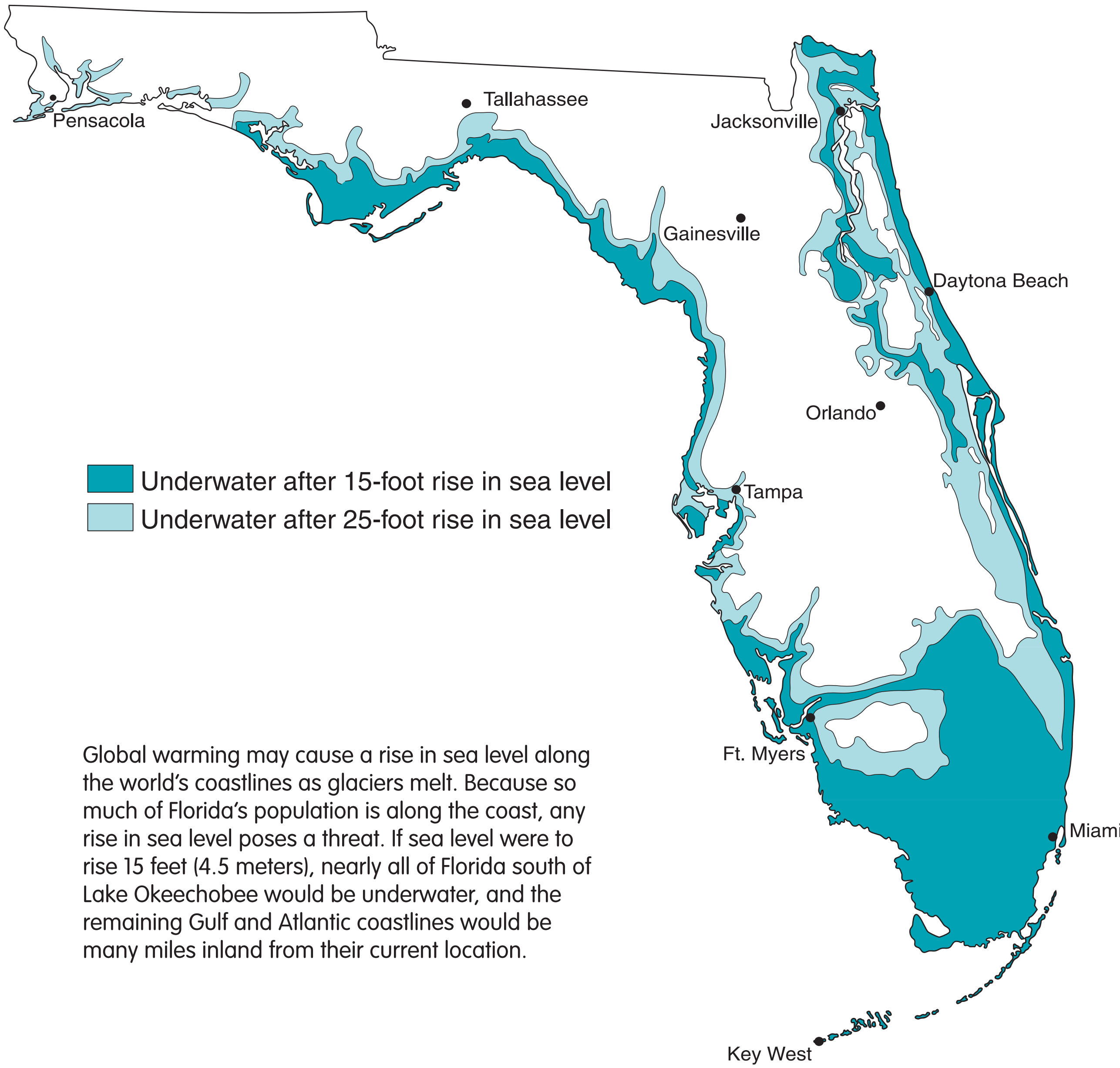
Source: Florida Consortium 1999

The Global Picture

EL NIÑO AND LA NIÑA

Florida's climate is strongly influenced by the temperatures of the Atlantic and Pacific oceans (Henry 1998). When the temperature of the Atlantic near the equator is higher than normal, less rain falls on Florida. This is a result of changing wind patterns that bring less moisture over Florida from the Gulf of Mexico.

Even more of an influence on Florida's weather are El Niño and La Niña, phenomena that occur in the Pacific Ocean off the coast of Peru. **El Niño** is an unseasonably warm ocean current that generally occurs every 3 to 7 years and lasts an average of about a year to 15 months.



Global warming may cause a rise in sea level along the world's coastlines as glaciers melt. Because so much of Florida's population is along the coast, any rise in sea level poses a threat. If sea level were to rise 15 feet (4.5 meters), nearly all of Florida south of Lake Okeechobee would be underwater, and the remaining Gulf and Atlantic coastlines would be many miles inland from their current location.

Source: Lane 1994

Peruvian fishermen first identified the event and named it El Niño after the Christ Child because it appeared off their coast around Christmas. Scientists do not fully understand this phenomenon. It begins when Pacific trade winds become weak and the top layer of the eastern Pacific gets warmer and warmer. The mass of clouds created by the warm water is carried eastward by the subtropical jet stream. **La Niña** (also sometimes called El Viejo) is the opposite of El Niño. La Niña occurs when stronger than normal trade winds stir up cooler water from the ocean depths.

El Niño years bring greater than normal amounts of rainfall to Florida in the winter than La Niña or neutral years, as well as more intense and frequent storms from the Gulf of Mexico. La Niña years bring less winter rainfall. Hurricanes, which originate in the Atlantic, are less frequent during El Niño years than during La Niña or neutral years.

By monitoring the Pacific Ocean west of Peru, scientists can now forecast El Niño and La Niña

(Florida Consortium 1999). This knowledge is critical to agriculture, forestry and emergency management. Winter vegetables and fruits are a big industry in Florida. Growers now know whether they are likely to face a wet or a dry growing season. Strawberry growers, for example, have learned to plant drought-tolerant varieties during La Niña years (Florida Consortium 1999). Dry La Niña winters may mean greater risk of forest fires in the normally dry spring. During El Niño years, although winters are wetter than normal, springs tend to be drier than normal in many parts of the state. These conditions may result in fires in early summer, as occurred in June 1998. Knowledge of La Niña helps emergency managers plan in advance for a hurricane season that will probably be more active than normal.

GLOBAL WARMING

In January 2001, over 700 scientists from more than 100 countries met in Shanghai, China, to discuss world climate change. They reviewed the data and agreed that the average global surface temperature has risen by 0.6 degrees centigrade over the twentieth century, and the sea level has risen between 0.1 and 0.2 meters. They predict temperatures will rise between 1.0 and 3.5 degrees centigrade over the coming century, causing more frequent floods and droughts, rising oceans and expansion of temperate climates northward. The group concluded that most of the warming observed over the last 50 years is attributable to human activities, specifically burning of fossil fuels such as coal and oil.

Although global warming is not accepted by the entire scientific community, some scientists predict that **global warming** will impact several aspects of Florida's climate (Henry 1998). While global rainfall levels are expected to increase, rainfall in Florida is expected to decrease as temperatures rise. According to some researchers, reduced rainfall and fewer winter storms reaching Florida would result from a predicted northward shift of the jet stream. Another study, however, indicated that summer rainfall would increase, particularly in the Panhandle. Droughts may also be more severe if temperatures rise, because rainfall would likely be more variable. Will the frequency and intensity of hurricanes reaching Florida increase with global warming? Early studies indicated that Florida might experience more frequent and more intense hurricanes in a warmer world, but more recent studies indicate that the threat from hurricanes will not likely increase significantly in the near future (Henry 1998).

Conclusion

Water is basic to all life on Earth. "Living things depend on water but water does not depend on living things. It has a life of its own" (Pielou 1998:x). The hydrologic cycle continues regardless of the activities of the millions of life forms it nourishes. Rain falls or fails to fall, rivers flow to the sea, snow falls and lakes freeze, hurricanes form over the warm seas, water seeps through the soil to replenish aquifers.

Today, humans have spread throughout the globe and have the power to influence the waters of the world on a scale unprecedented in our history. Burning of fossil fuels is contributing to global warming, which is predicted to bring more rain to some parts of the world and less to others. In many places, aquifers, rivers and lakes are being depleted and polluted. The water now on Earth is essentially all the water we will ever have. Yes, water is magic. It is up to us to respect and protect it.

Chapter 3

Florida's Water Resources

"Florida is blessed with water. Water makes the difference between desert and flourishing green plants, as much of the land around the earth at the same latitude is desert."
— Peggy Lantz, The Florida Water Story

KEY IDEAS

- Most of Florida's water is ground water.
- No rocks. No water.
- Ground water is replenished by rainfall.
- Surface water in the form of rivers, lakes, bays and wetlands is abundant.
- Much of Florida has a karst terrain with sinkholes, underground caverns and an active interchange between surface water and ground water.
- Pollution on the land's surface may end up in drinking water.
- Wetlands perform many valuable functions and are protected by law from development.
- Estuaries are nursery areas for many sport and commercial fish and shellfish.

VOCABULARY

Alluvial river
Aquaculture
Aquifer
Blackwater river
Brackish
Discharge
Drainage basin
Estuary
Fill
First-magnitude springs
Karst
Recharge
Runoff
Sheetflow
Sinkhole
Spring
Spring-fed river
Streamflow
Tributary
Watershed
Wetland

Florida is, indeed, blessed with water. Yet you cannot see most of Florida's fresh water: it seeps beneath the ground through sand and gravel and flows through cracks and channels in underlying limestone. The amount of ground water under Florida's forests, pastures, cities, marshes, roads, schools and suburbs is mind-boggling: more than a quadrillion gallons. This is equivalent to about one-fifth of the water in all five of the Great Lakes, 100 times as much water as in Lake Meade on the Colorado River, and 30,000 times the daily flow to the sea of Florida's 13 major rivers (Conover 1973). In fact, Florida has more available ground water in aquifers than any other state.

Florida also has abundant surface water in springs, rivers, lakes, bays and wetlands. Of the 84 **first-magnitude springs** (those that discharge water at a rate of 100 cubic feet per second or more) in the United States, 33 are in Florida — more than in any other state. Within Florida's boundaries are approximately 16,000 kilometers (10,000 miles) of rivers and streams and 7,800 lakes (Kautz et al. 1998). Although more than half of Florida's original wetlands have been drained or developed (Noss and Peters 1995), the state still has vast and diverse wetlands. The Florida Everglades and Big Cypress Swamp cover much of southern Florida, and some Florida wetland communities, such as mangrove swamps and hydric (wet) hammocks, rarely occur in other states.

In Florida, ground water and surface water are connected, often in complicated and changing ways that are invisible at the land's surface. Lakes may disappear into sinkholes, springs may bubble up through new breaks in underlying rocks, and water may flow one way at the land's surface and quite a different way underground. This is because much of Florida has what geologists term a **karst** landscape.

Karst landscapes are underlain by limestone (mostly calcium carbonate), a soluble rock composed of shell fragments, limey mud and sand. Limestone is easily dissolved by water charged with carbon dioxide (CO_2). As rain falls, it mixes with CO_2 in the air. As it soaks through the ground's surface, the water gathers more CO_2 from decaying plants. Water charged with CO_2 forms a weak acid (carbonic acid) that reacts with limestone to dissolve it.

In many parts of the world, land slopes gradually to the sea. "One can always walk downhill, arriving eventually at a stream that can be followed to a river, which can be followed to the ocean. A characteristic feature of karst landscapes is that the land usually slopes down into closed depressions from which the only exit is underground" (White 1988:19–20).

The name *karst* derives from the Slovenian *kars,* meaning rock, and was first used by the Germans to describe a high plateau in Slovenia with numerous caves and disappearing streams. Karst is now used to describe similar areas around the world. Well-developed karst features may also be found in south-central Kentucky, the Yucatan peninsula, parts of Cuba and Puerto Rico, southern China and western Malaysia, as well as in Florida. Rivers and streams are few and even absent in most karst areas of the world. Because Florida has high water tables and flat terrain, karst areas in Florida have more rivers and streams than karst areas elsewhere.

Photo credit: Joann Mossa

Limestone banks, Suwannee River

Watersheds

Today, rather than looking at land and water resources as separate, unrelated parts, water managers consider the connections within a watershed or **drainage basin**. Every part of the Earth's land surface is within a watershed. Divides (ridges, peaks or areas of high ground) separate watersheds. Because water flows downhill, rain falling on these divides may flow in opposite directions, becoming part of different watersheds. For example, from the Great Divide in North America the continent's river systems flow in opposite directions.

A **watershed** is the land area that contributes runoff, or surface water flow, to a water body. The water resources within a watershed are affected primarily by what happens on the land within that watershed. Anything on the land within the watershed, however far from the water body, can eventually reach and impact that water resource. Some examples of contaminants that may be picked up by water in the watershed are soil particles (suspended materials) and chemicals (dissolved materials), such as nutrients, pesticides, oils and gasoline residues.

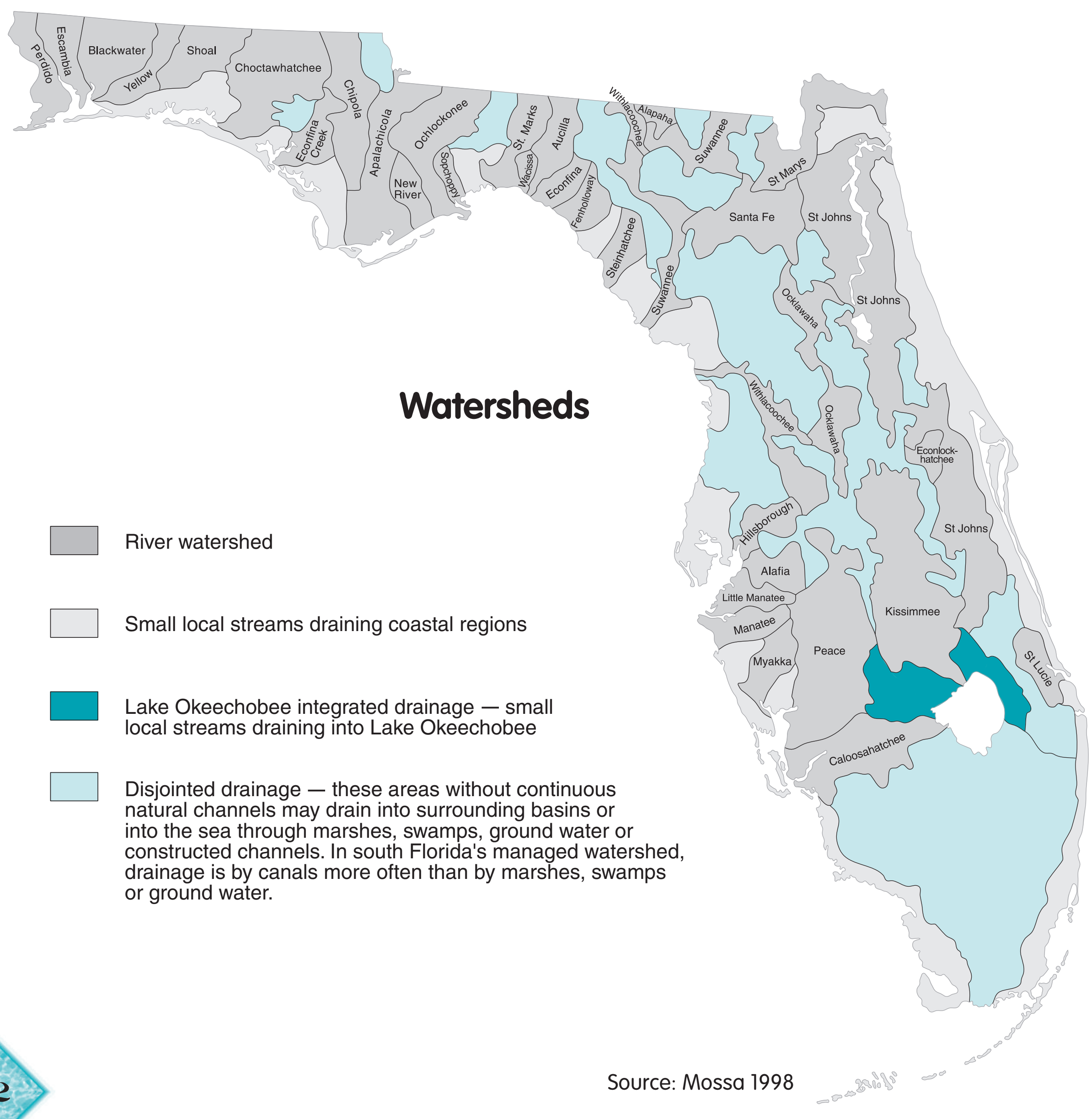
The shape of the land defines a watershed. Water flows both above and below the ground from points of higher elevation to points of lower elevation through the force of gravity. Rainfall that is not absorbed by the soil but flows to a larger body of water is known as **runoff**; runoff collects in channels such as streams, rivers and canals. The small channels, in turn, flow to larger channels and eventually flow to the sea. These channels or streams are also known as **tributaries**. The slope of the land, as well as

Surface Water Drainage

Source: Mossa 1998

the amount and type of vegetation and soil and the type of land use, determine the rate and amount of runoff that enters a water body. More water soaks through sandy soils than through clay soils; gentle slopes allow more time for rain to soak into the ground or to evaporate than do steep slopes; and natural areas generally allow more water to enter the ground than areas that are covered with houses or pavement. Vegetation also absorbs water and slows its movement.

Florida's karst terrain and flat topography sometimes make determining watershed boundaries difficult. In some places the drainage pattern is best described as "disjointed" because streams and rivers do not form continuous channels on the land surface (Mossa 1998) — they may disappear underground in sinks or depressions. Large rivers may form from springs issuing from the aquifer, and surface water watersheds may be quite different from groundwater watersheds. Some portions of Florida are poorly drained (Mossa 1998). There are few or no streams or channels in these areas, and water flows across the surface through extensive swamps or marshes. This is known as **sheetflow**.



Source: Mossa 1998

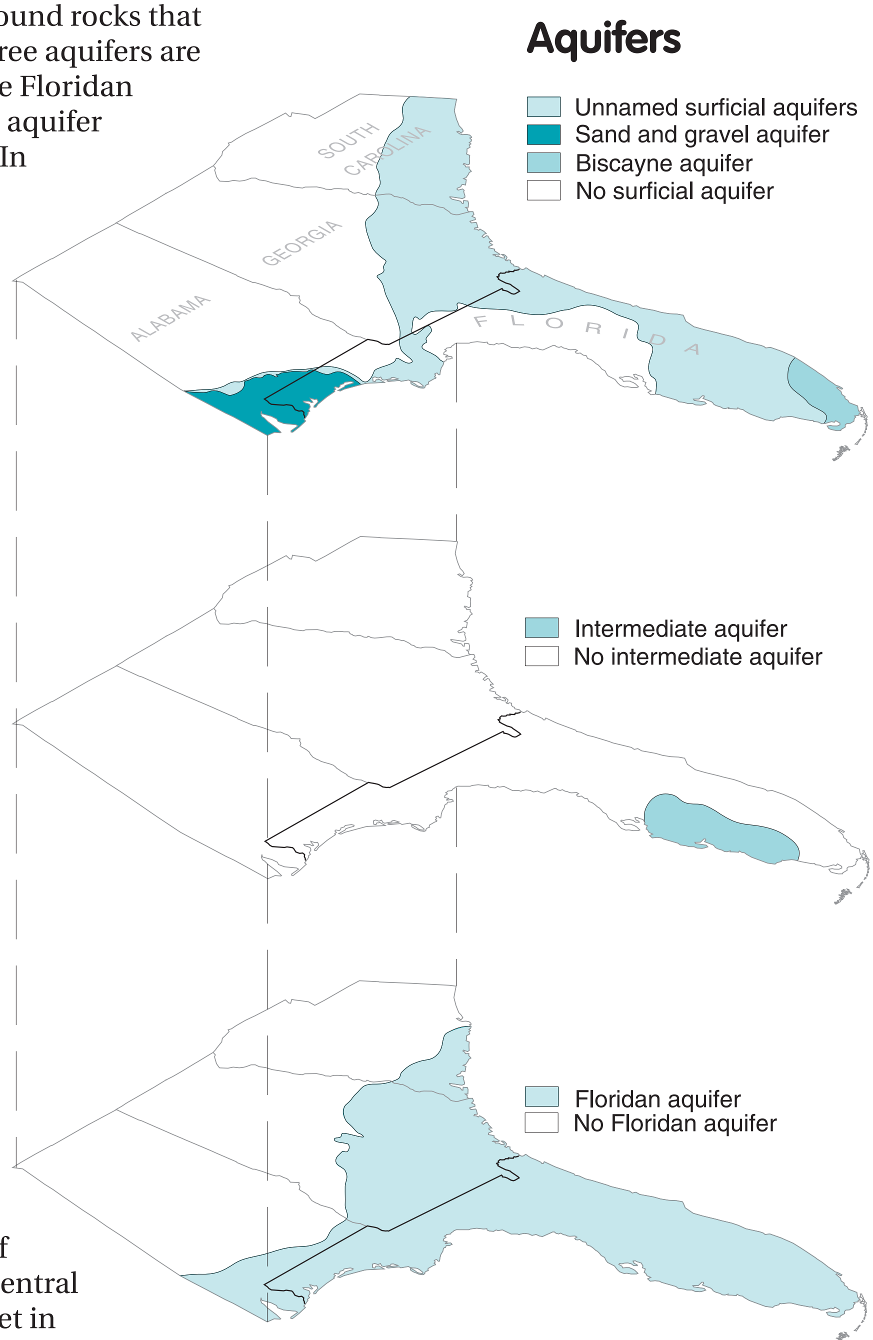
In much of south Florida, the natural landscape has been altered with huge public works projects, making the region a managed watershed. Canals, pumping stations and water-control structures, such as dikes and weirs, have altered the watershed. The historic swamps, marshes and associated sheetflow are greatly altered or are replaced by urban development and agriculture and drained by canals. Public and private entities are responsible for water movement, especially the discharge of floodwater.

Ground Water

AQUIFERS

Aquifers are underground rocks that hold water. In Florida, three aquifers are used for water supply: the Floridan aquifer, the intermediate aquifer and the surficial aquifer. In northwest Florida, the surficial aquifer is called the sand and gravel aquifer, and in southeast Florida it is called the Biscayne aquifer.

The Floridan aquifer has been called Florida's rain barrel (Parker 1951) and is one of the most productive aquifers in the world. Each day Floridians use about 2.5 billion gallons of water from the Floridan aquifer. It underlies 250,000 square kilometers (100,000 square miles) in southern Alabama, southeastern Georgia, southern South Carolina and all of Florida. Over most of Florida, the Floridan aquifer is covered by sand, clay or limestone that ranges in thickness from a few feet in parts of west-central and north-central Florida to hundreds of feet in southeastern Georgia, northeastern Florida, southeastern Florida and the



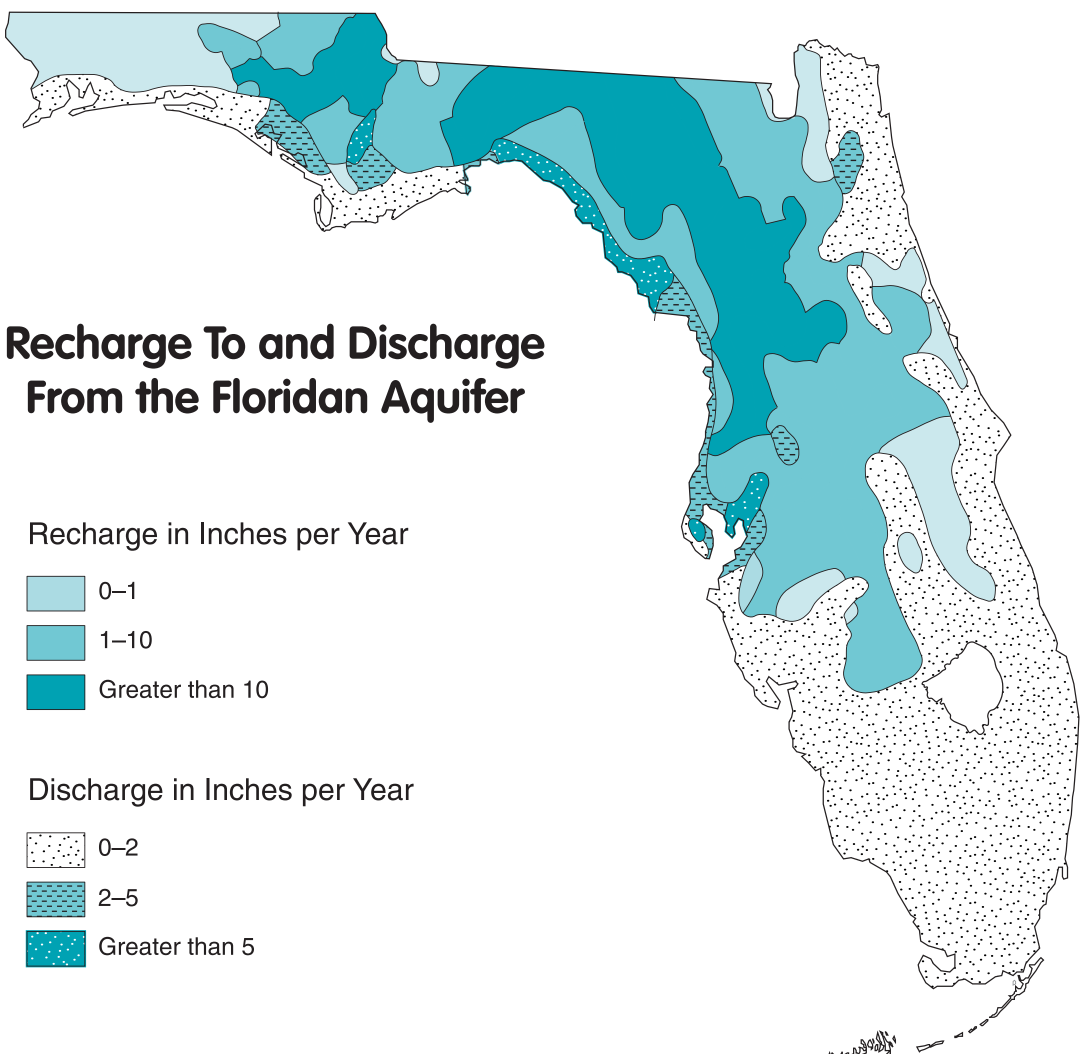
Source: Berndt 1998

westernmost Panhandle. Within the aquifer, water may travel quickly or very slowly. In parts of the aquifer with caves and large conduits, water may travel several miles in only a few hours. Where water-filled spaces are small and underground routes convoluted, it may take days, weeks or even years for water to travel the same distance.

In the past several decades, increased pumping of ground water has lowered water levels in the Floridan aquifer in several places in Florida and Georgia, including the Panhandle, northeastern and southwestern Florida, and southeastern and coastal Georgia (Berndt et al. 1998).

Water is replaced in the Floridan aquifer by rainfall that soaks into the ground. This is referred to as **recharge**. Recharge does not occur everywhere. In some places (mostly along the coasts and south of Lake Okeechobee) water flows out of, rather than into, the aquifer. This is referred to as **discharge**. In other areas, thick clay covers the aquifer and slows or stops the downward flow of water. Areas of high recharge only occur in about 15 percent of the state and include the well-drained sand ridges of central and west-central Florida. Sand is porous, which means water can easily flow through it. Limiting intensive development in high

Recharge To and Discharge From the Floridan Aquifer



Source: Berndt 1998

recharge areas is critical for maintaining water supplies: water cannot soak through pavement.

In some parts of Florida, the Floridan aquifer is not a suitable or drinkable source of fresh water. In some places, it is too far below the surface; in other places, the water is salty. The surficial sand and gravel aquifer is the major source of fresh water in Escambia and Okaloosa counties in northwest Florida, and the surficial Biscayne aquifer is the major source of fresh water in Dade and Broward counties in southeast Florida. Between the surficial aquifers and the Floridan aquifer in some parts of the state is the intermediate aquifer. This aquifer is an important source of fresh water in Sarasota, Charlotte and Glades counties. The remainder of the state uses the Floridan aquifer as its main source of drinking water.

SINKHOLES

Sinkholes are dramatic testimony to the fragile nature of the limestone underlying the state. A **sinkhole** is a depression in the land surface caused when rainwater dissolves limestone near the ground surface or when the roofs of underground channels and caverns collapse. Under natural conditions, solution sinkholes form slowly and expand by the gradual erosion of subsurface limestone caused by rainwater. Dredging, constructing reservoirs, diverting surface water and pumping large amounts of ground water may result in the abrupt formation of collapse-type sinkholes (Berndt et al. 1998). Loss of water from underground cavities, compounded by drought, may cause the overlying rock and earth to collapse. Weight on the top of the caverns caused by heavy rains or construction may also result in collapse.

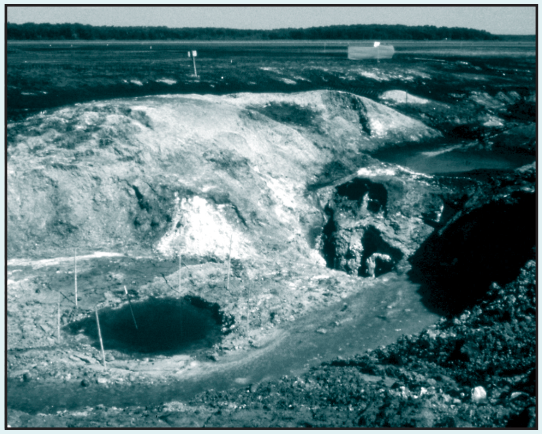
SINKHOLE PHENOMENON

In early March 1998, as a drilling company was drilling an irrigation well for a future golf course in western Pasco County, a massive sinkhole opened up and threatened to swallow the entire drilling rig. Although the driver got the rig out in time, a crane had to retrieve a truck from the 150-foot-wide, 15-foot-deep sinkhole. Shortly after this event, nearly 700 sinkholes, most only a few feet wide, appeared in the surrounding area.

While sinkholes are common in the area, “this event was unique,” according to Mark Stewart, chairman of the Geology Department at the University of South Florida. “I know of no other recent event in Florida that opened so many sinkholes in one small area.”

According to Tony Gilboy, hydrogeologist for the Southwest Florida Water Management District, the phenomenon began when the contractor drilled a hole into the Floridan aquifer for an irrigation well. As he cleaned out the hole using compressed air, a common development practice, a large underground cavity collapsed, resulting in the large sinkhole near the drill rig. The force of several tons of dirt falling into the cavity caused a massive pressure wave through the aquifer, producing the nearly 700 smaller sinkholes on the surrounding property. Heavy rains, which the area had been experiencing, may also have contributed by putting pressure on the underground cavities, causing them to collapse.

DISAPPEARING WATERS



Lake Jackson Photo credit: Tom Scott

The Indians called Lake Jackson in Leon County *Okeeheepkee*, meaning "disappearing waters." Between September 13 and 16, 1999, that is precisely what the lake did as approximately 30 million gallons of water drained out of the southern portion of the lake through Porter Hole Sink into the vast underlying Floridan aquifer, like bathwater out of a tub. In a few short days about half of the popular 4,000-acre lake had gone dry. Water depth in the lake had been steadily dropping during the long dry summer from a norm of 8 feet to only 2–3 feet. Water levels in the aquifer also dropped. At this point, either a plug blocking the sinkhole washed out, taking the lake with it, or once the lake level dropped below a certain level, the remainder drained into the partially opened sinkhole. With the water gone, all that was visible at the land surface was a canyon cut by the water and a hole 26 feet deep and 8 feet wide in the Torreya Formation underlying the lake. As the local confining unit for the Floridan aquifer, the Torreya Formation is a combination of clays, sands and some carbonates with relatively low permeability. Exploring the hole, Florida Geological Survey geologist Dr. Tom Scott found a passage to the northwest about 20 feet into the Floridan aquifer. Several months later two passages were visible, the one to the northwest that had expanded to 30 feet and one to the east running about 30 feet. In the spring of 2000, the remainder of the lake, the northern portion, drained through Lime Sink.

Although some homeowners may not be happy with the loss of their lakefront property, and fishermen will have to go elsewhere, natural drainage can be healthy for a lake. Pollutants and sediments from runoff and nutrients from fertilizer and dead vegetation build up in the water and on the lake bottom. When the lake is dry, the sediment is hardened and compacted by air and sunlight. Exposure to the air also oxidizes some of the nutrients. The Northwest Florida Water Management District, Leon County, the Florida Department of Environmental Protection and the Florida Fish and Wildlife Conservation Commission opted to help nature along by removing some of the nutrient-rich sediments from the dry lake bed. When the lake refills, its water quality and its ecology will be improved.

Lake Jackson is a closed basin — no water enters or leaves the lake through streams or rivers. Nor does ground water enter the lake through major springs. The lake is totally dependent on rainfall. A return to normal rainfall amounts should cause the lake to refill by replenishing the aquifer and possibly plugging the sinkhole with the sediments that run off the dry lake bottom.

Lake Jackson has gone dry several other times during the twentieth century — in 1907, 1909, 1932, 1935, 1936, 1957 and 1982. According to geologist Scott, when the Spanish arrived in the 1500s they chronicled a prairie, not a lake. In 1716, Spaniard Diego de Peña also found a vast prairie where he reported seeing over 300 buffalo and a few cows. In 1959, another sinkhole in the lake bottom, Lime Sink, was plugged with cement and various objects as people tried to help nature along. After draining, the lake can stay dry for years, but in 1982 the lake refilled in only three months.

SPRINGS

Springs are a "window" into the aquifer from which they flow. Cool in the summer and warm in the winter, they are among the most sought-after of all the state's natural and scenic resources. Most of Florida's springs are found in the northern half of the state and flow from the Floridan aquifer. As rainwater enters and recharges the aquifer, pressure is exerted on the water already in the aquifer. This pressure causes the water to move through cracks and tunnels in the aquifer. Sometimes this water flows out naturally to the land surface at places called **springs**. When the openings are large, spring flow may become the source of rivers. The Ichetucknee is an example of a river created by a spring. Springs also make substantial contributions to the flow of other rivers. Manatee, Fanning, Troy and Blue springs contribute nearly 368 million gallons each day to the Suwannee River.

For thousands of years, Native Americans settled near springs and fished in spring-fed streams. Spanish explorer Ponce de Leon came to Florida seeking a Fountain of Youth, as well as gold and other treasures. Travelling in Florida in 1774, botanist William Bartram described water issuing from one of the springs along the St. Johns River as "perfectly diaphanous," with fish appearing "as plain as lying on a table before your eyes, although many feet deep in water" (Van Doren 1955:135). Today, springs are popular with both tourists and residents. Many of Florida's largest springs have been incorporated into state parks, including Manatee, Homosassa, Silver, Wakulla and Ichetucknee. Wakulla and Silver springs have been popular locations for movies. Majorie Kinnan Rawlings' *The Yearling,* as well as more than 100 episodes of the popular TV series *Sea Hunt,* were filmed at Silver Springs. The *Creature from the Black Lagoon* and some of the Tarzan movies were shot at Wakulla Springs.

Rain falling onto nearby recharge areas and entering the aquifer is the source of most of Florida's ground water, including water that flows from springs. Contrary to popular belief, underground rivers do not carry water into Florida from other states (Spechler and Schiffer 1995). Caverns in the aquifer are sometimes large and interconnected and may transmit water underground for several miles, but there are no underground rivers. The 320 known springs in the state discharge nearly 8 billion gallons of water each day, more than all the fresh water used in the state each day (Spechler and Schiffer 1995).

Large withdrawals of water from wells near a spring can cause the flow of the spring to stop. Silt or sediments building up in the spring can also cause loss of flow. The only large spring in Florida known to have ceased flowing is Kissengen Spring, about 4 miles southeast of Bartow (Berndt et al. 1998). The spring stopped flowing in 1950 (Rosenau et al. 1976).

Surface Water

RIVERS

Florida's largest rivers are in the northern part of the state. Portions of the watersheds of many of these rivers are in Georgia and Alabama. Even the largest rivers in Florida — the Apalachicola, the Suwannee and the St. Johns — have only a fraction of the flow of the continent's and the world's largest rivers.

In the Panhandle, rivers flow south to the gulf; along the west coast, rivers flow west to the gulf. In the central portion of the peninsula, streamflow is south. In the lower southeastern portions of the peninsula, rivers flow east to the Atlantic. In the northeastern and east-central portions of the peninsula, the St. Johns River flows north to the Atlantic and other rivers flow east to the Atlantic. The only major river that does not flow to the gulf or to the Atlantic is the Kissimmee River, which flows south and discharges to Lake Okeechobee (Nordlie 1990).

WHAT IS STREAMFLOW?

Streamflow, also known as discharge, is the volume of water passing a point in a certain amount of time. The slope of the watershed surrounding the stream or river, the permeability and water storage capacity of the surrounding soils, and the rainfall pattern all affect streamflow. Current or velocity measures the distance traveled by the water during a certain length of time. Velocity depends on the depth of the stream or river, the slope and friction due to the texture of the bottom and the shape of the river or stream channel. Velocity is highest just under the water's surface because the friction between water and air is slight. Faster currents are found at the outside of a bend. The stream's force erodes the outer edges. Slower water is found on the inside of a turn and is often where soils will be deposited, forming sandbars.

Bottom type is closely related to the velocity of streamflow. Fast water has more energy and scours or carries away all but the largest particles of soil, sand or rock. So the bottoms of fast-flowing rivers and streams are rock, rubble and gravel. These are generally found in the upper stretches of a river system. Slower water allows fine particles (sand, silt and clay) to be deposited, resulting in sandy or mucky bottoms.

In the United States, river discharge is most commonly measured in cubic feet per second. In her book *Fresh Water*, British Columbian naturalist E. C. Pielou outlines a method for measuring flow in a small stream. (Be sure to select a stream that is safe to wade.)

<u>Materials</u>: rope marked at equal intervals, measuring stick, stop watch, oranges

1. Select a straight area in a stream and stretch a rope across it. The rope should have marks at equal intervals. Four or five intervals should be sufficient. Secure the rope across the stream. One way to do so is to tie it around trees.

2. Wade in and measure the depth of the water below each of the interval marks. Calculate the area of the cross section by averaging the depth and multiplying by the width of the stream. OR, measure depth in three places across the stream in a straight line, then divide the total by four to get the average depth of the stream. The reason you take three depth measurements and divide by four is to take into account the shallow areas of the stream.

3. Select a length of stream to measure the velocity and mark each end with an object such as a rock. A distance two or three times the width of the stream is usually enough.

4. Measure the velocity by putting a float in the stream and using a stopwatch to measure the amount of time it takes for the float to travel from the upstream marker to the downstream marker. An orange or an orange peel may be used as a float. Repeat until you have recorded velocities below each marked interval on the rope. Average the velocities and multiply by 0.85 (this number corrects for the fact that velocity has only been measured at the surface).

5. Calculate streamflow by multiplying the corrected average velocity by the area of the cross section.

Professional hydrologists use special instruments called current meters to measure streamflow.

Florida's rivers may be classified as predominantly alluvial, blackwater or spring-fed. **Alluvial rivers**, such as the great Mississippi, have large, well-defined drainage basins, carry high sediment loads and have large forested floodplains. These rivers typically flood each year (usually in the winter in Florida), depositing a rich load of sediment. All of Florida's alluvial rivers are in the Panhandle. The Apalachicola, Choctawhatchee, Escambia and Ochlockonee are examples.

Blackwater rivers have dark, stained waters from decomposing plant materials. Typically they drain pine flatwoods and cypress swamps. Many of Florida's rivers are blackwater types, including New River in northwest Florida, which drains Tates Hell Swamp, and the Withlacoochee, Hillsborough and Peace rivers in central Florida, which begin in the Green Swamp (Clewell 1991).

Spring-fed rivers are most common in the karst regions of north-central Florida where limestone is close to the ground surface. Spring water is cool year-round, and clear. The Wakulla, Silver, Weekiwachee, Rainbow and Crystal rivers are spring runs issuing from five of Florida's 33 first-magnitude springs. The Chipola, St. Marks, Aucilla, Santa Fe, Ocklawaha and Homosassa are also spring-fed rivers (Clewell 1991).

Many Florida rivers are a mixture of these types. For example, the Suwannee begins as a blackwater river draining the Okefenokee Swamp. As it travels south, it becomes a spring-fed river, as many springs contribute to its flow. As it approaches the gulf, it has a low-forested floodplain characteristic of alluvial rivers (Kautz et al. 1998).

LAKES

Florida has thousands of lakes, large and small. By far the largest (1,890 square kilometers or 730 square miles) is Lake Okeechobee, which extends into Glades, Hendry, Martin, Okeechobee and Palm Beach counties. Lake Okeechobee, the second largest lake wholly within the United States, has an average depth of 2.6 meters (8.6 feet) (VanArman et al. 1998). Most of Florida's other lakes are also shallow (between 2 and 9 meters, or 6.5 and 29.5 feet, deep), although a few sinkhole lakes are hundreds of feet deep (Heath and Conover 1981). Over one-third of the lakes in Florida are found in four central Florida counties (Osceola, Orange, Lake and Polk).

Most of Florida's lakes were formed in the same manner as sinkholes. Ground water dissolved limestone, forming underground cavities; the roof of these cavities collapsed, forming a depression, which then filled with ground water and rainwater. Other lakes were once depressions in the sea bottom, and still others were carved out by rivers.

According to Thomas Scott, many theories exist for the origin of Lake Okeechobee, including meteorite impact, compaction of underlying rock deposits and faulting along the northern part of an ancient lagoon (pers. com). Dr. Scott, a geologist with the Florida Geological Survey, thinks the lake developed from a large lagoon that existed at the northern end of the Everglades.

In addition to natural lakes, Florida abounds in constructed lakes and ponds created by digging into the shallow water table for **fill** (sand and rock), for irrigation, mining or **aquaculture** (commercially growing fish or other water species). Lakes and ponds are also designed and created to manage stormwater runoff from developed areas or to serve as reservoirs.

WETLANDS

Wetlands is a general term for portions of land periodically covered by fresh water or salt water. Over the past 400 years numerous words have been used to describe these areas including *swamp*, *tidal swamp*, *coastal swamp*, *marsh*, *tidal marsh*, *salt marsh*, *salt meadow*, *bog*, *fen*, *morass*, *overflowed land* and *quagmire* (Moss 1980). Terminology has changed as people's perceptions of the value of these lands have changed. The term *wetlands* began to appear in the 1950s, along with a concern for the preservation of these lands as wildlife habitat (Moss 1980). In 1953, the U.S. Fish and Wildlife Service defined wetlands as "lowlands covered with shallow and sometimes temporary or intermittent waters….and holding water long enough to grow moist-soil plants" (quoted in Moss 1980:200). The wetlands definition found in Florida law today (Chapter 373.019, *FS*) is based on vegetation and soil, as well as on the hydrologic conditions. Topography is no longer considered part of the definition. Some wetlands actually have higher elevation than surrounding land.

Wetlands are often classified as swamps or marshes, depending on

FLORIDA'S LEGAL DEFINITION OF WETLANDS

In Florida, when a proposed land use potentially affects a wetland, a permit is required. The permitting criteria first attempt to ensure that the wetland will be preserved. When some impact to the wetland is unavoidable, the permit conditions may require restoration or mitigation at another site. Wetland mitigation usually means that more wetlands than those impacted will be preserved, protected or restored either at the impacted site or at another site.

In order to protect wetlands and their valuable functions, it is necessary to understand exactly what they are. As defined in subsection 373.019 (22), *F.S.*, wetlands are those areas

> inundated or saturated by surface water or ground water at a frequency and a duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soils. Soils present in wetlands generally are classified as hydric or alluvial, or possess characteristics that are associated with reducing soil conditions. The prevalent vegetation in wetlands generally consists of facultative or obligate hydrophytic macrophytes that are typically adapted to areas having soil conditions described above. These species, due to morphological, physiological, or reproductive adaptations, have the ability to grow, reproduce, or persist in aquatic environments or anaerobic soil conditions. Florida wetlands generally include swamps, marshes, bayheads, bogs, cypress domes and strands, sloughs, wet prairies, riverine swamps and marshes, hydric seepage slopes, tidal marshes, mangrove swamps and other similar areas. Florida wetlands generally do not include longleaf or slash pine flatwoods with an understory dominated by saw palmetto.

Even with such a long and specific definition, identifying wetlands and determining their boundaries is not easy. Wetland determination is based on three factors — hydrology, soil and plants. Identification and delineation are based on

Source: Southwest Florida Water Management District

Wetland boundaries appear clearly demarcated by vegetation in this picture. When this is not the case, scientists rely on hydrologic indicators and soil analysis.

applied science and require field tests. Throughout Florida, all government agencies now use the same method to identify wetlands. The methods are Florida-specific rather than national or global. The complete methodology is set forth in the *Florida Administrative Code*, Chapter 17-340. Simply stated, wetlands must have at least two out of the following three conditions:

The hydrology — Wetlands are affected by the frequency and duration of water upon the land. There are thirteen hydrologic indicators of wetlands, such as water marks, algal mats and aquatic plants and animals.

The soil — Wetland soils are saturated or ponded long enough to develop anaerobic, or low oxygen, conditions in the upper part of the soil. There are twelve hydric (wet) soil indicators, such as a sulfur odor, dark color and muck or peat.

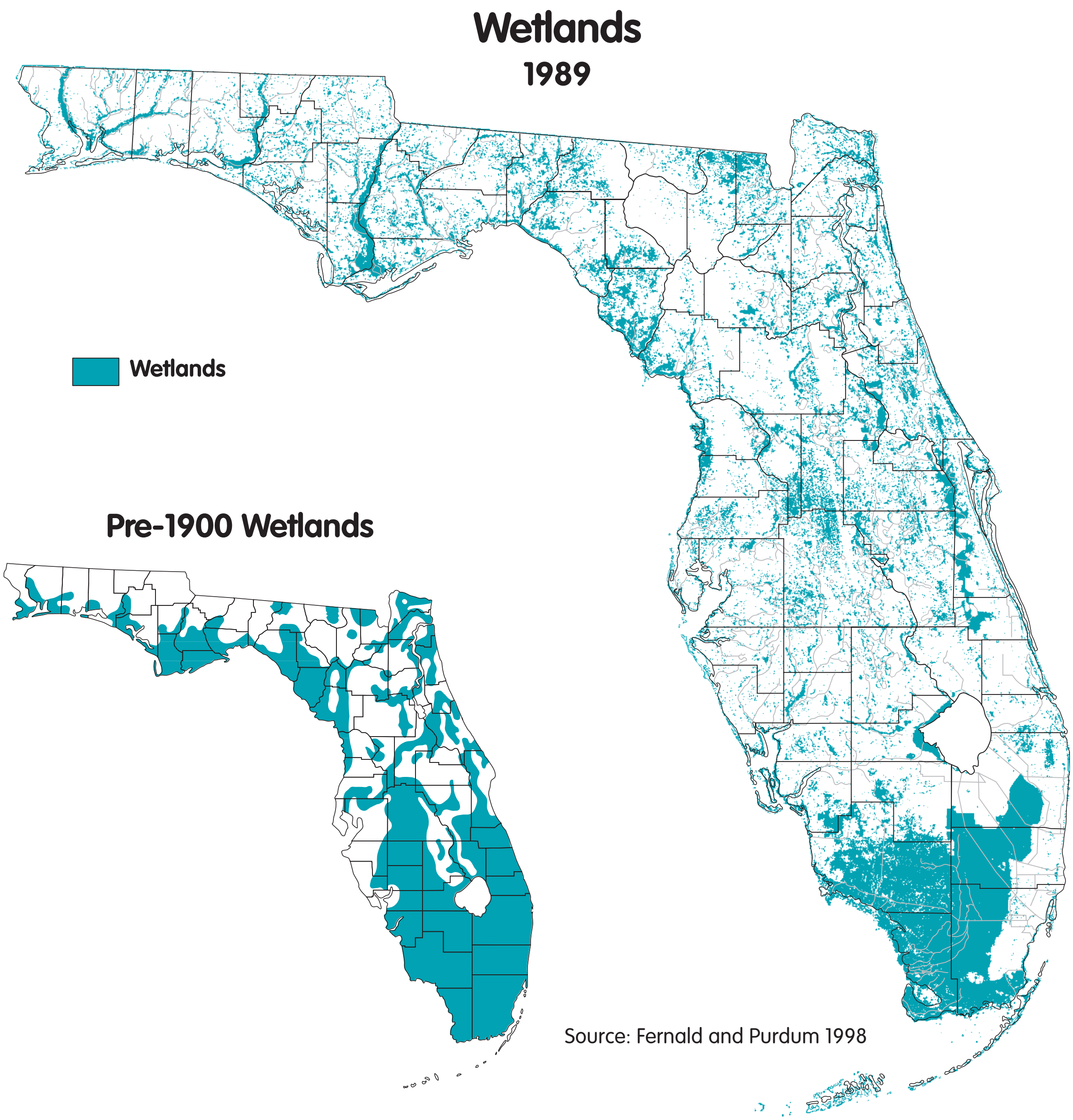
The plants — Wetlands have more plants that grow, reproduce or persist in saturated or wet conditions than uplands. These are called obligate or facultative-wet plants. Common examples are cypress trees, willow, bull rush and cattails.

You should contact your water management district before doing work in, on or around a wetland.

whether the vegetation is dominated by trees (swamps) or by grasses (marshes). Cypress ponds, strands, prairies, river swamps, floodplains, freshwater marshes, wet prairies, salt marshes and mangrove swamps are all wetlands.

Wetlands perform many valuable functions. They provide vital habitats for fish and wildlife. They improve water quality by trapping nutrients such as nitrogen and phosphorus, toxic substances and disease-causing microorganisms. They slow and intercept runoff, protect shorelines and banks from erosion, and protect upland areas from floods.

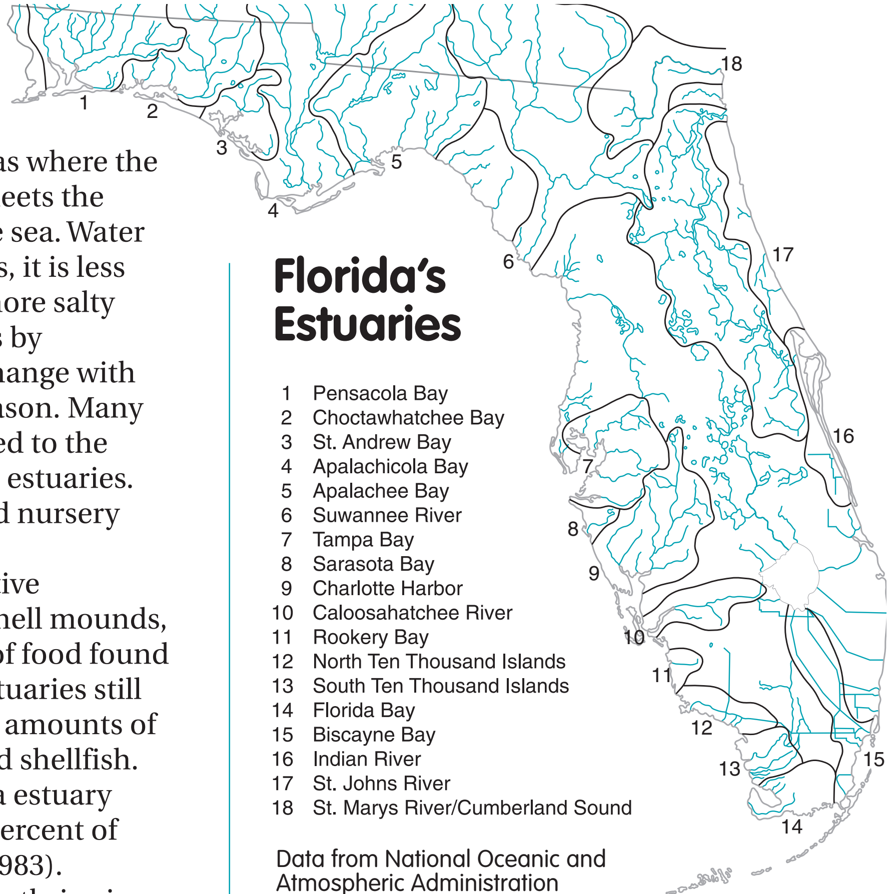
Wetlands once covered half of Florida. Over one-half of these wetlands have been drained for agriculture, flood control and residential development. Extensive areas of remaining wetlands include the Everglades and Big Cypress Swamp in southern Florida, Green Swamp in central Florida, Okefenokee Swamp near the Florida-Georgia border, and Tates Hell Swamp in northwest Florida.



ESTUARIES

The word ***estuary*** is derived from the Latin *aestuarium*, meaning boiling tide. Estuaries are coastal areas where the freshwater current of rivers meets the incoming saltwater tide of the sea. Water in estuaries is **brackish**; that is, it is less salty than the seawater and more salty than the river water. Estuaries by definition are unstable and change with the tide as well as with the season. Many plants and animals are adapted to the changing conditions found in estuaries. Estuaries are the breeding and nursery areas for most sea life.

Along Florida's coasts, Native Americans left behind huge shell mounds, testament to the abundance of food found in estuaries. Today, Florida estuaries still produce many kinds and vast amounts of sport and commercial fish and shellfish. For example, the Apalachicola estuary provides between 80 and 90 percent of Florida's oysters (Livingston 1983).



Florida's estuaries vary greatly in size and shape. Some estuaries such as tidal creeks and spring-fed streams entering the Gulf of Mexico are only a few acres in area, whereas the mangrove forests and brackish portions of the Florida Everglades are 1,000 square miles. On the gulf coast many of the estuaries end in bays. On the Atlantic coast many of the estuaries are long and narrow and bordered by barrier islands.

The health of an estuary depends on frequent but gradual changes in the amount of fresh water and nutrients it receives. This in turn depends on the health of wetlands. Forested river swamps and freshwater marshes produce nutrients to feed plants and animals in estuaries; they slow floodwaters so that estuaries do not receive too much fresh water too quickly; and they help keep soil from eroding and clogging estuaries with sediment.

Conclusion

The health of all of Florida's vast water resources depends on us. Choices we make in one place or regarding one type of water resource may have unforeseen and undesirable consequences elsewhere. Nutrients and pesticides applied to land many kilometers away from a pristine river may seep into the aquifer and end up in the river through spring discharge. Clear-cutting forested floodplains may harm fish and shellfish by decreasing nutrients and increasing sediment. Excessive pumping of ground water may result in saltwater intrusion or drying of wetlands.

Yes, Florida is blessed with water. It's up to us to use it wisely.

Chapter 4

Water and Life: Natural Systems

"Florida is a complex living creature,
and subtlety is its most endearing quality."
— Clay Henderson, President, Florida Audubon Society

KEY IDEAS

- Water is the link connecting all of Florida's natural communities.
- Water is the major defining feature of Florida's natural communities.
- Hydrology and soils determine the kinds of plants that grow.
- Plants in turn attract and support various kinds of animals.
- Healthy uplands are critical for maintaining healthy aquatic ecosystems.
- Florida is a global hot spot of biodiversity and has many rare communities, as well as more endangered plants and animals than any other state except Hawaii and California.
- Human disruption of natural processes affects natural communities.

VOCABULARY

Coral reefs	Marsh
Dry prairies	Microbes
Ecosystem	Natural community
Endemic	Pine flatwoods
Entisols	Pleistocene
Hardwood hammock	Prescribed burns
Histosols	Scrub
Hydrogenase	Seagrass beds
Hydrology	Slough
Hydroperiod	Steepheads
Insectivorous plants	Strand
Limnologist	Swamp
Mangroves	Symbiotic
	Uplands

Water and its antithesis, fire, account for much of the subtlety we see in Florida's natural communities. The Florida Natural Areas Inventory, a project of The Nature Conservancy and the Florida Department of Environmental Protection, recognizes 81 distinct natural communities in Florida. No state east of the Mississippi can rival Florida in its abundance and diversity of plants and animals. Florida also has more endangered and threatened plants and animals than any other state except California and Hawaii (U.S. Fish and Wildlife Service 2000).

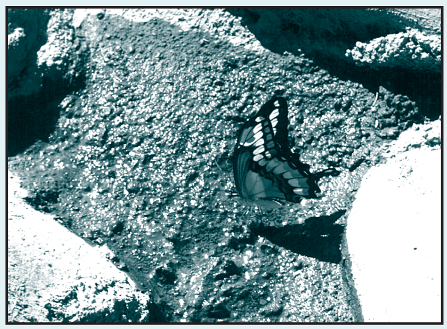
The state was colonized over many thousands of years by species from continental areas to the north and tropical Caribbean areas to the south. Some species, such as the American beech and the white oak, reach the southern limits of their ranges in the Florida Panhandle. Others, such as gumbo limbo and Bahama lysiloma, reach the northern limits of their ranges in southern Florida. Semi-isolation by ocean on three sides has contributed to a high percentage (8 percent) of **endemics** in Florida (plant, fish, amphibian, reptile, bird and mammal species native to nowhere else in the world) (Governor's Office 1999).

Ancient Origins

During the **Pleistocene** Epoch (from about 1.8 million to 10,000 years ago), massive ice sheets formed over the northern latitudes in at least four separate events, and sea levels around the world fell by as much as 400 feet. During the warmer interglacial periods, sea levels rose as high as 150 feet above their current level, leaving only the highest land areas of Florida, such as the central highlands, exposed as islands. The Appalachian Mountains eroded and marine currents carried a steady supply of sand south to portions of Florida, then below sea level. A blanket of sand was deposited over the underlying limestone, infilling the irregular rock surface and forming a relatively featureless sea bottom. As sea level fell, these flat, shallow sea bottoms eventually emerged from the sea to become today's pineland ecosystems. Sand dunes and sand ridges formed along the coastlines as sea level varied. Many of these once-coastal regions are the sites of today's scrub and sandhill ecosystems.

IN DEFENSE OF MUD

A spoonful of soil contains more microorganisms than the number of people on Earth.



Species diversity in soil: 30,000 species of bacteria, 1.5 million species of fungi, 60,000 species of algae and 100,000 species of protozoa.

Over 30 years ago, Edward S. Deevey, Jr., delivered a statement to the National Water Commission entitled "In Defense of Mud." Deevey, a distinguished **limnologist** (one who studies inland waters) argued that mud, as the habitat of essential microorganisms, is as important as water to the health of this planet. Mud is not all the same, and different kinds of microorganisms require different kinds of muddy water. By conserving different kinds of mud, we conserve different, yet essential microorganisms, as well as different types of water resources. Lakes, swamps, marshes and estuaries all have different kinds of mud and associated microorganisms.

Deevey is concerned with a common yet "dangerous misapprehension: the idea that balanced living systems consist of animals plus plants. As long as the sun shines and the plants are green, it seems to follow that animals and people have nothing to worry about. The truth, of course, is that no living system is ever balanced without microbes" (1970:7).

Microorganisms that live only in mud produce **hydrogenase**, a catalyst for recycling natural materials. Hydrogenase breaks down nitrogen and sulfur in dead matter to forms that can be used by plants to grow new tissue. These microorganisms also help reduce pollution by breaking down harmful compounds and contributing oxygen to the atmosphere. Hydrogenase-producing microorganisms are found in the mud of lakes, swamps, marshes and estuaries.

Deevey concludes that the most valuable inhabitants of wetlands are sulfate-reducing bacteria. Destruction of wetlands has reduced these bacteria and their habitat by half, but the amount of airborne sulfur they need to process has more than doubled as a result of industrial pollution. "To the last generation of conservationists, the haunts of coot and heron seemed to need no reasoned defense from anybody. Henceforth, I believe, the 'new conservation' can take a more worldly stand. Its basis is that hydrogenase, like water and oxygen, is no longer a 'free good,' but a commodity more precious than we know" (1970:8).

The next time you watch a sunset over the endless expanse of saw grass in the Everglades, fish on a lake or hear an osprey call as you paddle a canoe down a river, think of the mud beneath the water. Without it, there would be no saw grass or fish or birds.

Before the Pleistocene, naturally acidic rain and ground water flowed through and dissolved the limestone rock of the Florida land form, forming a web of underground caverns and conduits. During low sea level periods in Pleistocene times, these conduits often collapsed, creating many of the sinkholes, springs and lakes that punctuate the modern Florida landscape. In the central portion of the peninsula, dissolution and collapse of the underlying limestone created lakes and large valleys, such as Lake Apopka in the Central Valley.

Ecosystems

Water is the thread connecting all ecosystems on Earth, as well as the sculptor of ancient and modern land forms. In Florida, water flows from upland ecosystems through rivers, swamps and freshwater marshes, and eventually to salt marshes, mangroves, seagrass beds and coral reefs along the coast.

An **ecosystem** is a community of **microbes**, plants and animals, including humans, interacting with one another and with the physical environment where they live. The term ***natural community*** is frequently used interchangeably with the term ecosystem, although ecosystems may encompass more than one natural community. The physical environment includes soils, water and nutrients, as well as human-made structures and alterations. In a healthy ecosystem, living and nonliving components provide a framework through which solar energy is transferred and within which nutrients such as nitrogen and phosphorus circulate. English botanist Sir Arthur Tansley coined the word *ecosystem* in 1935 from the Greek root *oikos,* meaning house. Ecosystems are place and life functioning together.

An ecosystem can be as small as a community of bacteria, insects and microscopic plants living in rainwater collected in the crook of a tree, or larger than the Kissimmee River-Lake Okeechobee-Everglades-Florida Bay ecosystem. The Earth itself is one huge ecosystem. The size of an ecosystem, and often its boundaries, are arbitrary and depend on the needs and interests of the investigator. Sometimes the observer can clearly see boundaries between ecosystems. In other instances, ecosystems blend gradually one into another. In Florida, changes in moisture, soil fertility, fire frequency and human alteration often occur over very short distances and result in clear and striking changes in the landscape: a scrub community adjoins a cypress pond, a tropical hammock stands out from surrounding pineland (Myers and Ewel 1990).

Scientists do not agree on any one way to classify ecosystems. Most ecosystem classifications are based on vegetation, the physical landscape and environmental factors. In Florida, one key defining factor is water. **Hydrology**, combined with type of soil, determines the kinds of plants that grow. Plants in turn attract and support various kinds of animals. Although animals are critical components of ecosystems, many animals use more than one ecosystem, especially during different times of their life cycles. Thus it is far easier to define ecosystems by plant than by animal life.

In Florida, ecosystems may be divided into **uplands** (pinelands, scrub, dry prairies and hardwood hammocks), swamps (river swamps, cypress swamps), marshes (freshwater marshes, salt marshes), lakes, rivers and coastal systems (seagrass beds, mangroves and coral reefs). Healthy uplands are critical for maintaining healthy aquatic ecosystems. The type and condition of uplands influence the amount and the quality of water reaching lakes, streams and estuaries. Plants in uplands slow runoff and prevent soil from eroding. Many uplands are also groundwater recharge areas.

Much of Florida is a subtle mosaic of uplands and lowlands. Within an expanse of cypress swamp or marsh, slash pines will grow on the slightly higher and drier ground. In Florida, a few inches difference in elevation is all that separates lowlands from uplands.

Prior to European settlement, pine flatwoods, interspersed with cypress swamps, bay swamps and herbaceous wetlands, were the most extensive vegetation type, covering 35.3 percent of Florida. The second most abundant type was longleaf pine/xeric oak, which covered 20 percent of Florida.

Modern Florida is dominated by pine forests, cropland and rangeland, urban and barren lands and old fields. Pine forests still dominate in the Panhandle and northern third of the peninsula, although these are more likely to be managed timber plantations than natural pinelands (Kautz et al. 1998). Cropland and pastureland dominate in the south-central portion of the peninsula. Urban development is most common in coastal areas, along the I-4 corridor and around Jacksonville. Today in Florida, freshwater marshes and wet prairies are most abundant, dominating the Everglades of south Florida and the upper St. Johns River valley. Upland hardwood forests are also abundant, occurring largely along river bluffs, in coastal areas, and as small, scattered patches in north Florida. Mixed hardwood swamps are most common along the floodplains of Panhandle rivers, in the floodplain of the Wekiva River, and in the extensive wetlands systems of Dixie County. Cypress swamps are most abundant in the Big Cypress Swamp in south Florida, Green Swamp in central Florida and the Pinhook Swamp region of north Florida. Dry prairies are found scattered throughout the south-central portion of the peninsula.

STEEPHEADS: FLORIDA'S MOUNTAINS

Photo credit: ©The Nature Conservancy 1994

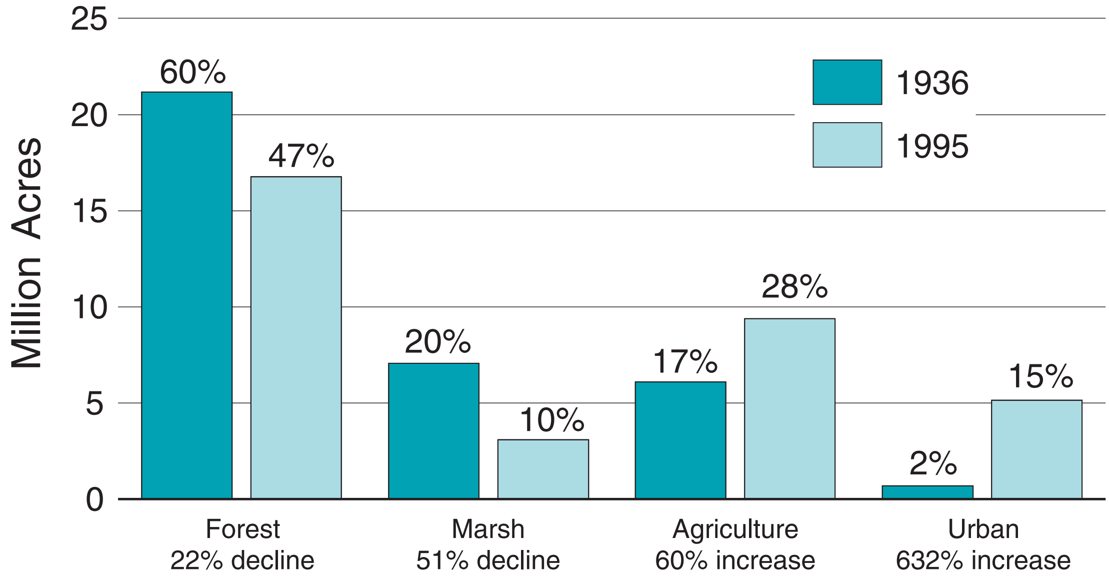
Ashe's magnolia, an endangered plant of steephead forests

Steepheads are a distinct type of slope forest found in northern Florida. A steephead forms when ground water leaks through porous sand onto a sloping surface at the head of a stream. The ground water removes sand from the bottom of the slope, causing the sand above to slump down and to be carried away by the flowing ground water. Heads of steephead streams are low in relation to their mouths: they erode from the bottom up (Means 1981). Other streams develop from gully erosion. Surface runoff from rainfall washes sediments off the ground's surface gradually, eroding land from the top down. Gully-eroded streams depend on rainfall for their flow, whereas steephead streams have a steady flow of constant-temperature spring water. Steephead forests contain many endemics, as well as rare northern plants. The endangered Okaloosa darter is found exclusively in steephead streams.

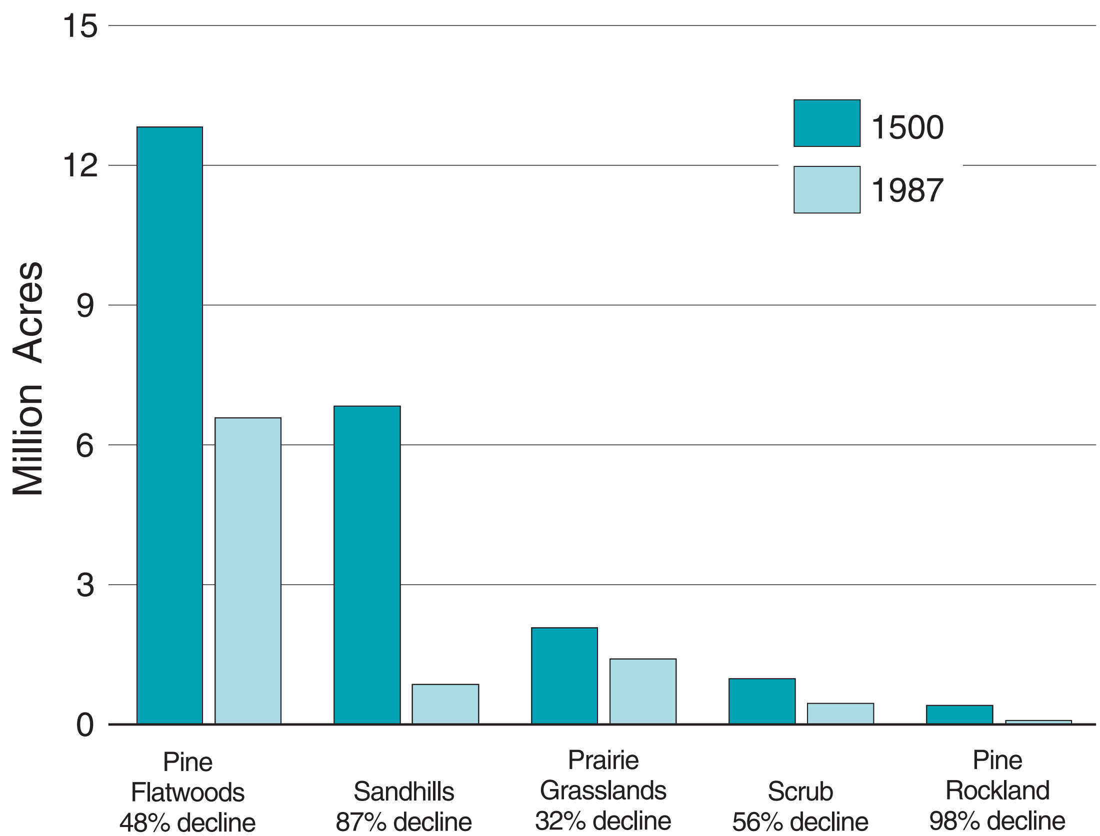
SOILS

Florida's soils are generally sandy and low in fertility. Well-drained loamy soils occur only in the western highlands, which extend approximately 30 miles south of the Alabama and Georgia borders. Deep and excessively drained sands, **Entisols**, often referred to as sandhills, occur in the western highlands of the Panhandle and on the central ridge from the vicinity of the Suwannee River in north-central Florida south to

Change in Florida Land Cover



Declines in Florida Natural Communities



Source: Kautz et al. 1998

south-central Florida. These areas are important for groundwater recharge. Poorly drained sandy soils are the most common soils in the state, occurring in pine flatwoods. Poorly drained organic soils underlain by limestone or marl (**Histosols**) occur on flat lands primarily in the Everglades and in the upper Ocklawaha River.

ECOSYSTEM PROCESSES: WATER AND FIRE

Floods, fires from lightning and droughts are common in Florida and often occur in quick succession. Plants, animals and natural communities have evolved a variety of adaptations to deal with these stresses and changes. Pond cypress, for example, survive better than bald cypress in nutrient-poor, still waters. Longleaf pine's ability to withstand fire, even in its "grass" seedling stage, is well known. Fire also produces minerals necessary for longleaf pine germination (Abrahamson and Hartnett 1990).

Hydroperiod, the duration of standing water, plays a strong role in determining the location of the various wetland communities. Forested wetlands along floodplains of major rivers are typically inundated for one to six months each year. In hammocks where limestone is near the surface, the ground is frequently damp from groundwater seepage. Freshwater marshes typically have shallow standing water (less than 12 inches deep) from 7 to 12 months each year (Kautz et al. 1998).

In southern Florida, water levels varied greatly between wet and dry seasons and from year to year. Naturalist and adventurer A. W. Dimock describes a canoe trip he took in 1908: "We began the trip in canoes, but ended in an oxcart. We paddled and wallowed through two hundred miles of flower-clad lakes and boggy, moccasin-infested trails, zigzagging from border to border of the Florida Everglades and were hauled for 5 days on pine-covered strands of sand….Last year we crossed the 'Glades from west to east, in a power boat, over the deepest water known for a decade. This year, from Cape Sable to Lake Okeechobee, we could seldom find water to float a canoe" (Tebeau 1966:15).

Naturally occurring wildfires, as well as water, have played a defining role in shaping Florida's natural communities. Florida has one of the highest frequencies of lightning strikes of any region in the United States and more thunderstorm days than anywhere in the country (Abrahamson and Hartnett 1990). As a result of thousands of years of frequent lightning-set wildfires, many natural communities in Florida have come to depend on fire. Pinelands, prairies, scrubs and marshes all require regularly occurring fire. Without fire, hardwoods will invade a site and, over time, a hardwood forest will replace the original vegetation.

Today, roads, fire lanes and the need to protect lives and property have limited naturally occurring wildfires. Many fire-maintained communities are no longer able to sustain themselves without help. Forests must now be burned under **prescribed** conditions in order to reduce fuel and to eliminate hardwoods.

Natural Communities

Pine flatwoods: The most common plant community in Florida, **pine flatwoods** have acidic sandy soil with some peat and often a clay layer one to three feet below the surface. They are usually moist during the rainy season and sometimes even flood. Fire is required to prevent their transformation to hardwood forests. Vegetation density varies from nearly closed to open and

THE KISSIMMEE PRAIRIE

Dry prairies are very rare communities. Their diversity distinguishes them from vast grasslands, also called prairies, such as the Great Plains of North America and the steppes of Asia. Dry prairies are becoming even scarcer because they are highly desirable for farming and development.

Dry prairies are nearly level, treeless expanses of saw palmetto, drought-tolerant grasses and small shrubs interspersed with oak and cabbage-palm hammocks, marshes and ponds. The term "dry prairie" is somewhat of a misnomer, as these areas may have water at or above ground surface for a month or more during the summer wet season. They are only dry when compared to other treeless communities of central Florida — wet prairies and marshes.

The Kissimmee Prairie, most of which is protected in public ownership, is a prime example of the dry prairie. The Kissimmee River State Preserve, north of Lake Okeechobee in south-central Florida, offers great opportunities for wildlife observation, particularly in the winter months during bird migration periods when visitors can usually see several distinctive and rare birds, including the crested caracara, the burrowing owl, the sandhill crane, the Florida grasshopper sparrow and the snail kite.

The Kissimmee Prairie was Florida's early cattle country. "Cow-hunters" once drove cattle across the open range of the Kissimmee Prairie to the west coast of Florida for export to Cuba. In Florida, cattlemen were not called cowboys, for the work was too rugged for mere "boys." Here, the cow-hunter used the powerful and very loud cow whip to drive cattle, hunt and communicate across the vast land. According to oral history, "Florida Cracker" referred originally to those who used these whips.

almost savanna-like (Alden et al. 1998). Thickets of saw palmetto are frequently present. Pine flatwoods are home to the endangered red-cockaded woodpecker and the threatened eastern indigo snake.

Scrub: Florida **scrub** is a series of desert-like islands in a sea of marshes, swamps and pine flatwoods (Ripple 1997). Thousands of years ago, arid scrub land stretched from the western United States through the southern United States east to the Atlantic Ocean. The climate changed, and all that now remains of scrub in the southern United States are a few patches on ancient sand dunes in Florida. Although scrub receives as much rain as nearby areas, rain passes rapidly through the thick layer of well-drained sand to the underlying aquifer. Like desert plants, scrub plants have evolved ways of efficiently gathering and retaining moisture. Plants and animals are also able to survive relatively infrequent yet intense fires. The most common scrub plants are sand pine, rosemary and several species of dwarfed, gnarled evergreen scrub oak.

Dry prairies: Open grasslands with scattered saw palmettos and oak/cabbage-palm hammocks once stretched north and west of Lake Okeechobee and along the Kissimmee River. Most of Florida's **dry prairies** have been converted to ranch land. Remaining dry prairies are important habitat for the threatened crested caracara and the burrowing owl. Dry prairies occasionally flood for short periods during the rainy season. Fires every one to four years maintain their grassy landscapes dominated by wiregrass and broomsedge.

Hardwood hammocks: Florida has no vast forests of hardwoods. Instead, it has small (usually less than 20 hectares, or 49 acres) islands of hardwoods found on ground that's slightly higher than the surrounding landscape. **Hardwood hammocks** have rich organic soil, acidic sandy loam with dissolved limestone or clay over limestone. Hammocks rarely flood or burn. Vegetation is thick and more than 150 species of trees and plants, including beautiful and rare orchids and bromeliads, are found here. In south Florida, hardwood hammocks provide critical habitat for the endangered Florida panther.

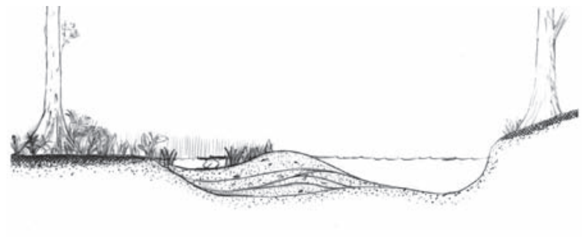
Swamps: Florida has a remarkable diversity of **swamps**. Hardwood swamps occur along rivers in north Florida and in **strands** along sloughs in south Florida. **Sloughs** are broad shallow channels of flowing water corresponding to linear depressions in underlying limestone. The most common type of swamp in Florida is the cypress swamp, which occurs in all parts of Florida except the Keys. Cypress belong to the same family as redwoods and sequoias. Two types are recognized: the bald cypress and the pond cypress. Bald cypress is most easily distinguished at maturity from pond cypress by its feather-like leaves (Nelson 1994). Because cypress seeds cannot germinate underwater, they require land that is dry for part of the year. They are typically wet 200–300 days out of the year. Cypress swamps are favored nesting spots for the endangered wood stork.

Marshes: Florida has expansive freshwater **marshes**, salt marshes and even bogs. The largest freshwater marsh in the state is the Everglades, where saw grass stretches as far as the eye can see, interrupted only by an occasional tropical hardwood hammock or cypress head. Saw grass is a sedge, not a true grass, and its sharp teeth can tear clothes and cut skin. Soils in freshwater marshes are wet about 250 days each year. Natural ground fires are ignited by lightning in the dry season and prevent bushes and trees from growing. Freshwater marshes support flocks of wading birds, as well as alligators and fish.

Vast salt marshes can still be seen along much of Florida's coast, even in areas where coastal development has been intense. Salt marshes have characteristics of both terrestrial and marine ecosystems and support many visiting, as well as resident, animals. Vegetation must tolerate at least periodic inundation by salt water keyed to tides and is commonly dominated by smooth cordgrass and black needlerush. Several hundred species of benthic microalgae and phytoplankton are found in salt marshes. Salt marshes are nursery grounds for many fish and shellfish of commercial and recreational importance and are the exclusive home of three birds — clapper rails, long-billed marsh wrens and seaside sparrows (Montague and Weigert 1990).

The coastal lowlands of Mississippi, Alabama and Florida were once a nearly continuous bog and habitat for one of North America's most unusual assemblages of plants and animals, including **insectivorous plants**. The leaves of one of these — the pitcher plant — are so distinctive that these wetlands are often called pitcher plant bogs (see picture, page 33). Over 90 percent of the bogs have been lost to development. Bogs develop on acidic water-saturated, nutrient-poor, sandy soil that rarely floods. The soil lies on top of an impermeable layer of rock or clay that prevents water from draining. Pine Barrens tree frogs, ribbon snakes and cottonmouths are common in bogs. Endemic plants include violet flowered butterwort, tropical waxweed, Harper's beauty and white birds-in-a-nest.

Lakes: Most of Florida's 7,800 lakes were formed by dissolution of underlying limestone, collapse of the overlying land surface and flow of ground water into the resulting cavity. Most Florida lakes are small, shallow and in the peninsula's central sandy ridge. These sandhill lakes are naturally very clear, are nutrient-poor and usually have closed basins (that is, no streams flow either in or out). These lakes are typically surrounded by emergent vegetation and frequently support submersed grasses, such as maidencane. Many Florida lakes are polluted by the discharge of nutrients, other pollutants and siltation from human development. Increase in lake nutrients has contributed to the explosion of invasive exotic plants such as water hyacinth and hydrilla. Twenty-one established exotic fish species also compete with native fish (Kautz et al. 1998).



Rivers: Florida has three main types of rivers: alluvial rivers, spring-fed rivers and blackwater rivers. Floodplains along alluvial rivers contain a wide variety of hardwoods, shrubs and woody plants. The rivers themselves contain 100 to 152 species of fish. The Apalachicola River system encompasses more rare and endangered species of plants and animals than any other river system in Florida. In spring-fed rivers, submerged vegetation is abundant because of water clarity. Spring-fed rivers also support abundant populations of mussels and snails, which in turn support mussel- and snail-eating turtles and fish. One small spring along the Ichetucknee River is the only place in the world where the sand grain snail is found. The federally endangered Gulf sturgeon travels from a coastal estuary up the spring-fed Suwannee River to spawn. Blackwater rivers drain pinelands and swamps. Submerged vegetation is limited because the water is dark and acidic from the tannin and humic acids produced in the pinelands and swamps. Blackwater rivers have lower fish and invertebrate species diversity than spring-fed or alluvial rivers, due in part to the high acidity of the water. The three-lined salamander, the southern dusky salamander and the mud salamander are commonly found in blackwater rivers.

Dunes and Maritime Forests: Grasses such as sea oats grow on dunes closest to the water's edge, and a variety of forest vegetation (maritime forests) grows on the more stable dunes inland from the coastline. Going south from Cape Canaveral on the east coast and from Tampa on the west coast, vegetation gradually changes from a dominance of temperate species to a dominance of tropical species. At least 22 species of endemic plants are found on dunes and in maritime forests in Florida. Atlantic and gulf beaches themselves are the most important nesting site for loggerhead turtles in the Western Hemisphere, as well as for several species of shore birds, including the endangered snowy plover. Exotic plants such as Australian pine and Brazilian pepper are a serious problem along many of Florida's beaches.

Mangroves: **Mangroves** are limited by temperature to the tropics and subtropics and are established along low wave-energy coastlines in those parts of the state. Mangrove forests grow in zones of red, black and white mangroves with buttonwoods (not a true mangrove) on the upland fringe. Water fluctuations are important to mangrove forest development. Fluctuating water levels, waterlogged sediments and salt water exclude most other plants. Mangroves have specially adapted roots that allow them to grow and propagate in water. Mangroves and buttonwoods also have a variety of means of dealing with fluctuations in salinity. Red mangroves, for example, filter fresh water from seawater at the root surface, whereas black and white mangroves and buttonwoods excrete excess salt via salt glands at the leaf surface (Odum and McIvor 1990). Mangrove forests are valuable habitat for a wide range of invertebrates, fish, amphibians, reptiles, birds and mammals, including the endangered American crocodile, the endangered hawksbill sea turtle, the endangered Atlantic ridley sea turtle, the endangered Florida manatee and the threatened Atlantic salt marsh snake. Mangroves are important nursery areas for sport and commercial fish and shellfish, including spiny lobster, pink shrimp, mullet, tarpon, snook and mangrove snapper. Mangroves are easily destroyed by oil spills and herbicides.

Seagrass beds: Seven species of seagrass are found in Florida's coastal waters. The most common are turtle, shoal and manatee grasses. **Seagrass beds** are excellent habitat for many fishes, crustaceans and shellfish, and are critical nursery areas for young marine animals. Bay scallops, blue crabs and spotted sea trout are examples of species that depend on seagrass beds. Seagrasses are also a major part of the diets of manatees and sea turtles and are substrate for epiphytic (attached) algae, a critical component of the marine food web.

Coral Reefs: **Coral reefs** are among Florida's most spectacular and beautiful natural communities. Found in the shallow waters off southeast Florida and the Florida Keys, coral reefs require transparent, warm and relatively nutrient-poor waters. Only the surface layers of coral reefs are alive. The reef's limestone base is composed of skeletal deposits of dead corals and algae. Microscopic algae live **symbiotically** in the outer parts of the coral polyp. Over 100 species and subspecies of coral and algae are found in Florida's coral reefs, as well as numerous other species of recreational and commercial value, including spiny lobster, grouper, snapper, parrot fish and butterfly fish. Many reef species live in narrow niches and have specialized food requirements and complex life cycles.

Conclusion

People have been part of the ecosystems of Florida for more than 10,000 years. For most of this time, human population was relatively low and human use of natural resources did not cause any significant decrease in the ability of the environment to maintain clean air and water, as well as productive, biologically diverse ecosystems. In the past 200 years, however, human uses have had enormous impacts. Deforestation in the north, wetland drainage in the south, agriculture in the center and urbanization along the coasts and the I-4 corridor have caused massive losses of natural ecosystem diversity and productivity. In Florida, the major challenge of the next century will be to create an environmentally, as well as economically, sustainable way of living (Kautz et al. 1998).

Chapter 5

Water Supply and Water Quality

"Not only is the level of the water in the global well getting low, the water is also polluted, sometimes to the point where it is no longer drinkable."

— Julie Stauffer, The Water Crisis, 1998, p. xi

"Although water is part of a global system, how it is used and managed locally and regionally is what really counts. Unlike oil, wheat and most other important commodities, water is needed in quantities too large to make it practical to transport long distances."

— Sandra Postel, Last Oasis, 1992, p. 23

KEY IDEAS

- Florida's future depends on a continued supply of adequate amounts of clean fresh water for human consumption and for natural systems.
- The amount of water changed by human activity is far greater than the amount of water directly used by humans.
- In some places in Florida, the demand for fresh water is greater than supply.
- Florida's water management districts are committed to finding new ways to meet the demand for water.
- Pollution is anything that causes an imbalance in or harms the natural environment.
- Scientists use a number of tests and measures to determine water quality.
- Pollution takes two main forms: point source pollution and non-point source pollution.

VOCABULARY

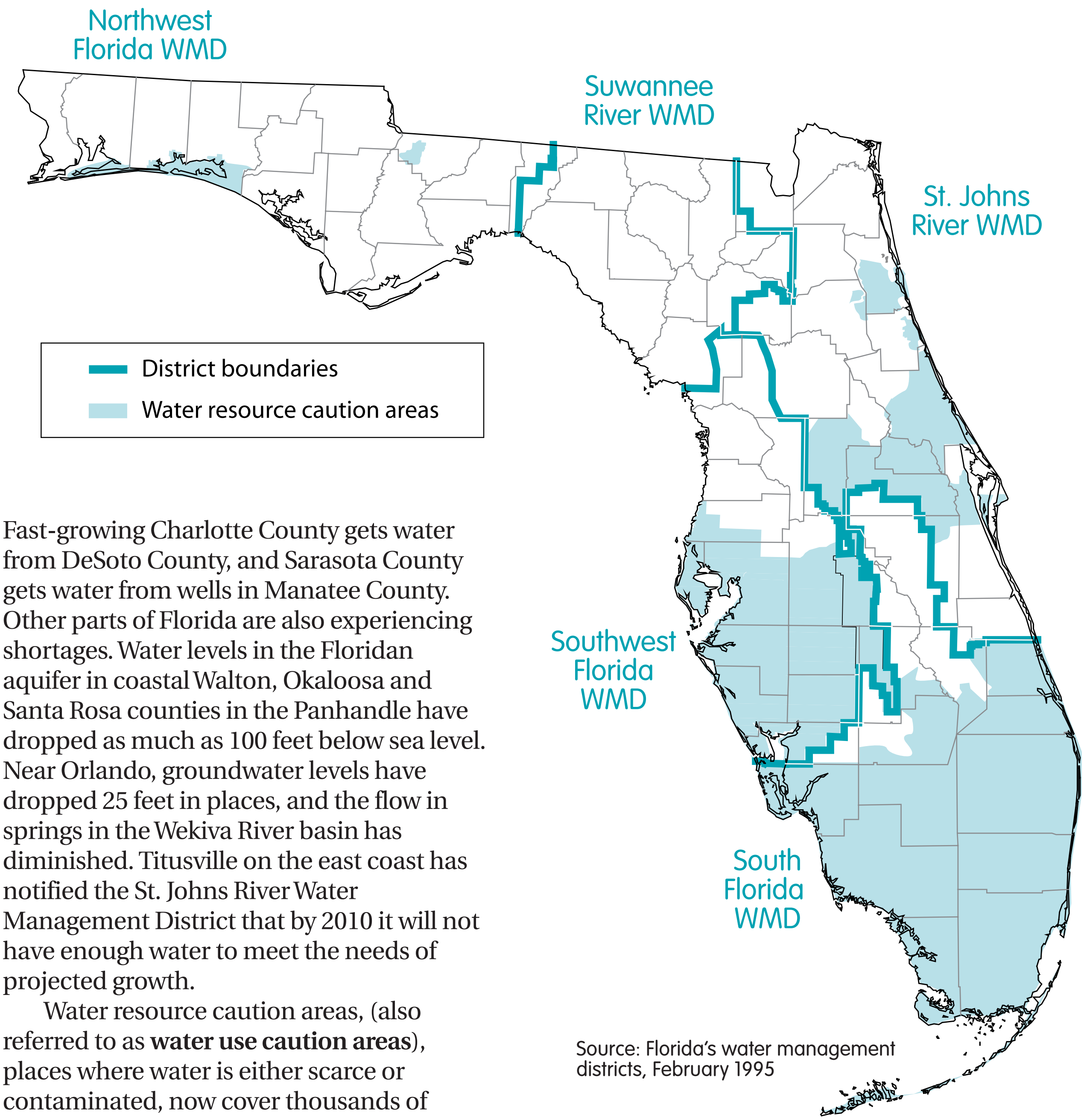
Aquifer storage and recovery
Best management practices
Conductivity
Desalination
Detention pond
Dissolved oxygen
Drip irrigation
Environmental pollution
Filtration
Impervious surface
Irrigation
Non-point source pollution
Nutrients
pH
Point source pollution
Pollution
Public supply
Reclaimed water
Retention pond
Reuse
Turbidity
Wastewater
Water Use Caution Areas
Xeriscaping

Florida's future depends on a continued supply of adequate clean fresh water. Water quality and water quantity are both important: it does little good to have vast amounts of polluted water. Plants, fish and other animals, as well as humans, all require adequate amounts of clean water.

The quantity of water changed by human activity is far greater than the amount of water directly used by humans (Betz 1984). Each time humans withdraw ground water or surface water for a particular purpose, waste is generated. Household use generates **wastewater** from toilets, sinks, showers, bathtubs, dishwashers and washing machines; phosphate mining generates phosphate slime; manufacturing generates chemical waste; irrigation generates runoff containing nutrients from fertilizers, as well as from pesticides and herbicides. Even rain contains impurities generated by burning of fossil fuels, dust and ash. It's not enough to be careful about the amount of water we use. We must also do our best to return it to the environment as pure as possible.

Some places in Florida, such as the Florida Keys and St. Petersburg, never had enough fresh water to support large-scale development. Each day, 16 million gallons of water flow from wells near Homestead, on the mainland of Florida, to the Florida Keys. Water travels through a 130-mile-long pipeline supplying water all the way to Key West. St. Petersburg, "a peninsula on a peninsula" with the highest population density in Florida (3,100 persons per square mile), ran out of water in the 1920s and now relies on well fields in Hillsborough and Pasco counties. In other places, water use is rapidly surpassing inexpensive water supply.

Water Resource Caution Areas (WRCAs) in Florida



Fast-growing Charlotte County gets water from DeSoto County, and Sarasota County gets water from wells in Manatee County. Other parts of Florida are also experiencing shortages. Water levels in the Floridan aquifer in coastal Walton, Okaloosa and Santa Rosa counties in the Panhandle have dropped as much as 100 feet below sea level. Near Orlando, groundwater levels have dropped 25 feet in places, and the flow in springs in the Wekiva River basin has diminished. Titusville on the east coast has notified the St. Johns River Water Management District that by 2010 it will not have enough water to meet the needs of projected growth.

Water resource caution areas, (also referred to as **water use caution areas**), places where water is either scarce or contaminated, now cover thousands of square miles throughout the state. The most extensive water resource caution areas are in southwest Florida in all or parts of Pasco, Pinellas, Hillsborough, Sarasota, Charlotte, DeSoto, Polk and Highlands counties.

Florida's water management districts are committed to finding new ways of meeting the demand for water. Providing high-quality drinking water is expensive, and using that water to meet all water needs is unnecessary. Floridians will increasingly use alternative supplies of water to meet nonpotable demands, instead of seeking new, often far-away and more pristine sources. **Reclaimed water**, for example, can be used to irrigate golf courses and landscaping, as well as in industrial processes and power generation. The use of **desalination**, particularly of brackish ground water, is increasing in Florida's populated areas. Another way to increase water supply is conservation and increased efficiency. Household fixtures, such as toilets and showers, that save water are now available. Landscaping with native, drought-tolerant plants (**Xeriscaping**) also helps conserve water. Agriculture and industry have begun to implement new and more efficient ways of using water. Water management districts have begun to explore the option of storing water in aquifers during times of abundant rainfall and withdrawing it during times when rainfall is scarce, a process known as **aquifer storage and recovery** (see illustration, page 90).

Water Use

DEFINITIONS

Agencies, such as the U.S. Geological Survey (USGS) that keep track of how much water is used for various purposes, distinguish between withdrawal uses, consumptive uses and nonwithdrawal uses. Withdrawal is the act of taking water from a source for storage or use. In many cases, water is withdrawn from its source and returned to its original source within a short period of time. Water withdrawn from a river to cool power plant equipment and then returned to the river is an example. Some of the withdrawn water is consumed; that means the water is no longer available for immediate reuse. Evaporation, plant transpiration and incorporation into a product are all consumptive uses. When water is withdrawn for irrigation, for example, some evaporates, some transpires and some is incorporated into plants. The remainder may return to the surface water or groundwater source from which it originated. Nonwithdrawal uses include use by natural systems, recreation use and use for transportation.

TYPES OF USES

The USGS collects and compiles water withdrawal data in Florida and throughout the United States. USGS distinguishes between saline water and freshwater use and between surface water and groundwater use. Data are collected in the following water use categories: public supply, domestic self-supplied, commercial-industrial self-supplied (including mining), agricultural self-supplied (including livestock), recreational irrigation and power generation (cooling of thermoelectric power plants).

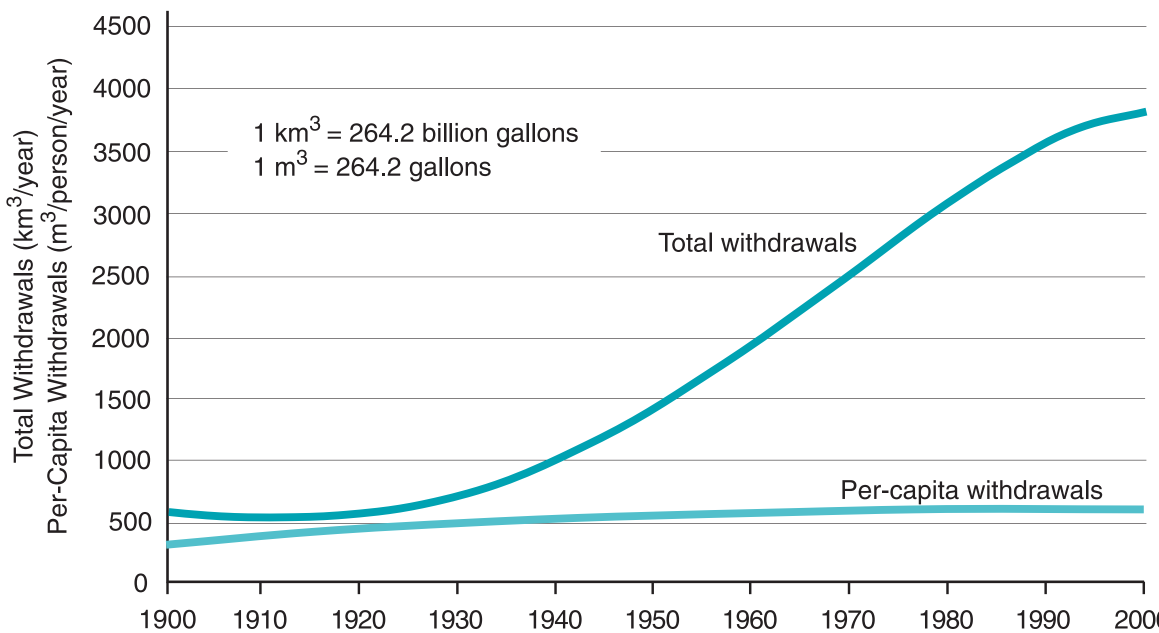
Public supply includes systems that serve more than 400 people or use more than 10,000 gallons of water each day. Public-supply systems provide water to households, businesses and industries. Domestic self-supplied is water withdrawn by the user for household use, usually from individual wells. Agricultural self-supplied includes **irrigation**, the process of supplying water to areas of land to make them suitable for growing crops, sod and landscaping plants, as well as water for livestock.

Recreational irrigation was a new water use category in 1995. It includes withdrawals for the irrigation of land used for recreational purposes. Golf courses are the largest users in this category. Before 1995, recreational irrigation was included under agricultural self-supplied.

HOW MUCH IS A MILLION GALLONS OF WATER?

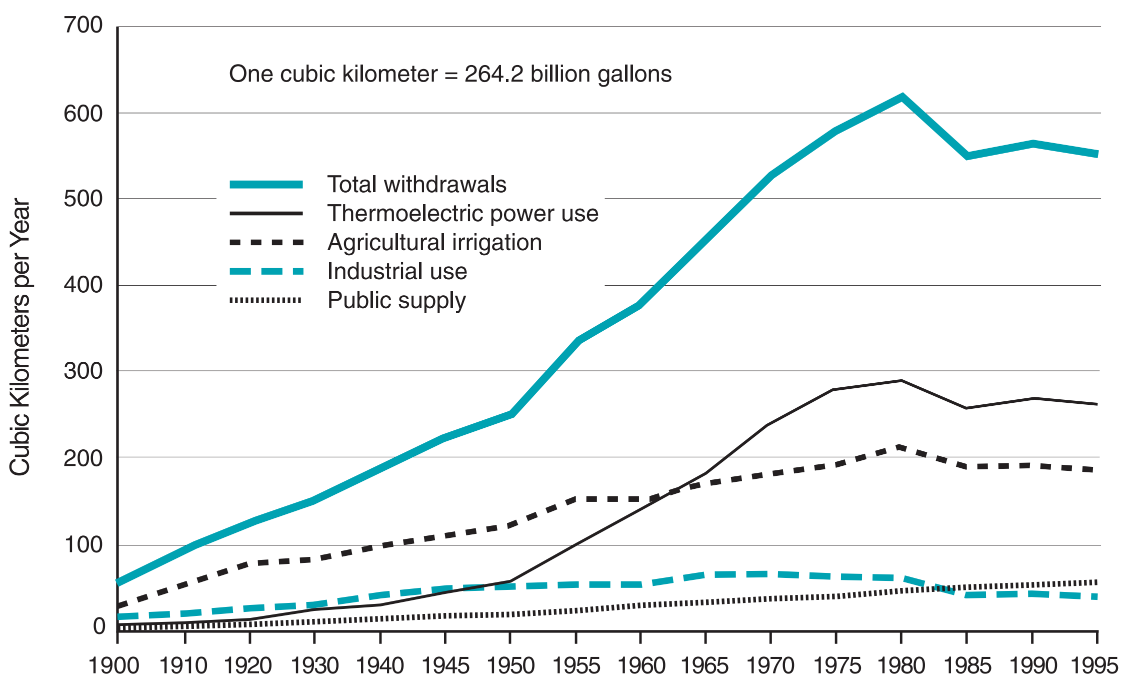
Agencies that keep track of water use usually do so in million of gallons used each day (mgd). Visualizing such a large number is difficult. Think about a bathtub or a swimming pool. A bathtub can hold about 50 gallons of water. You would have to take 20,000 baths before you used a million gallons of water! How big do you think a swimming pool would have to be to hold a million gallons of water? It would have to be 10 feet deep, 50 feet wide and 267 feet long! (USGS 2001)

Total and Per-Capita Global Water Withdrawals



Source: Gleick 1998

Water Withdrawals in the United States



Source: Gleick 1998

WORLDWIDE WATER USE AND TRENDS

Agriculture is the single largest user of water in Florida and in the world. Two-thirds of all the water withdrawn worldwide from surface water and groundwater sources is used for agriculture (Postel 1992). Many of the world's farmers irrigate in the same ways their ancestors did thousands of years ago: by flooding or channeling water across the land. Postel (1992) estimates the overall efficiency of agricultural water use worldwide is only 40 percent, meaning that over half of all water diverted for agriculture never produces food.

Industry also uses vast amounts of water. Even if water is not part of the final product, it is likely to have been used in the industrial process that created the product. For example, paper is manufactured from wood that is washed and soaked in vats of water and chemicals to form pulp. The pulp is rinsed, squeezed dry and then pressed into paper (Prentice Hall 2000). Many industries, such as power plants and steel mills, use high volumes of water to cool down hot machinery.

Worldwide household use is a third leading use of water. Most of us take safe, plentiful water for granted, but in many parts of the world women and children still spend hours every day walking to shallow wells, collecting water in jugs and carrying it home.

Most people in Florida and in other parts of the United States get their water from public-supply systems. When you have hundreds of people living in a square kilometer, it is much more efficient and safer to have the county or city water department deliver water to households than to have each household drill its own well or build its own water tank. Public water systems supply water to schools, businesses and industries, as well as to homes.

In the past century, population growth, industrial development and expansion of irrigated agriculture have resulted in an enormous increase in the amount of water used throughout the world. Throughout the first 75 years of the twentieth century, absolute and per capita demand for water throughout the world

Liters of Water Typically Used to Produce Products in the United States

1 automobile	400,000
900 kg of paper for bags	32,800
1 kg of cotton	8,800
1 kg of aluminum	8,800
1 kg of beef	7,000
1 kg of rice	5,000
1 kg of steel	2,200
1 liter of gasoline	75

Domestic Water Use (liters)

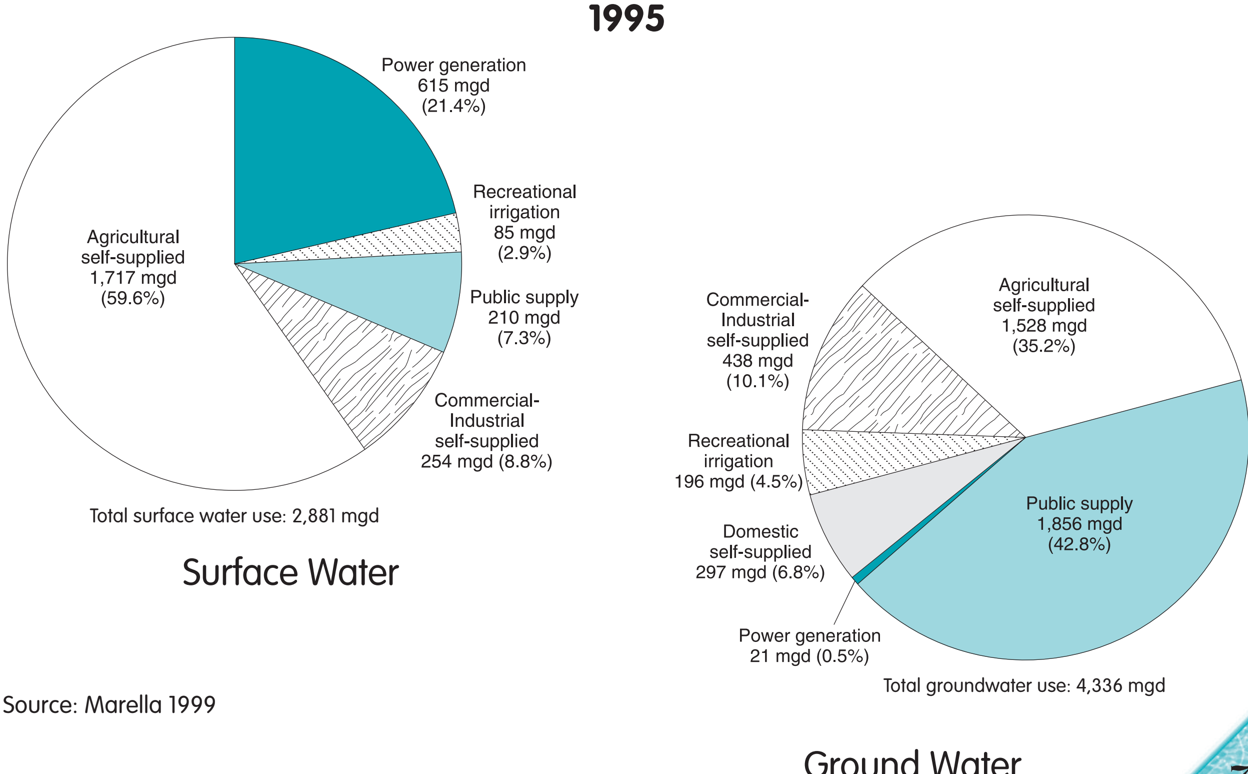
showering 5 minutes	95
brushing teeth	10
washing hands	7.5
flushing standard toilet	23
flushing low-flow toilet	6
washing one load of laundry	151
running dishwasher	19
washing dishes by hand	114

increased. Beginning in the mid-1980s and early 1990s, however, these trends reversed in the United States and water use began to decrease despite continued increases in population and economic wealth. Between 1980 and 1995, water use in the United States declined by nearly 10 percent. The two largest components of United States water use — thermoelectric cooling and agricultural irrigation — declined by about 10 percent. Industrial use dropped even more than thermoelectric cooling and agriculture (40 percent), as industrial water use efficiency improved and as the mix of United States industry changed. Part of the decline in agricultural use is a consequence of the availability of more efficient methods of irrigation. **Drip irrigation** is a process whereby water is applied directly to the roots. It was first developed in Israel and has expanded worldwide.

FLORIDA WATER USE AND TRENDS

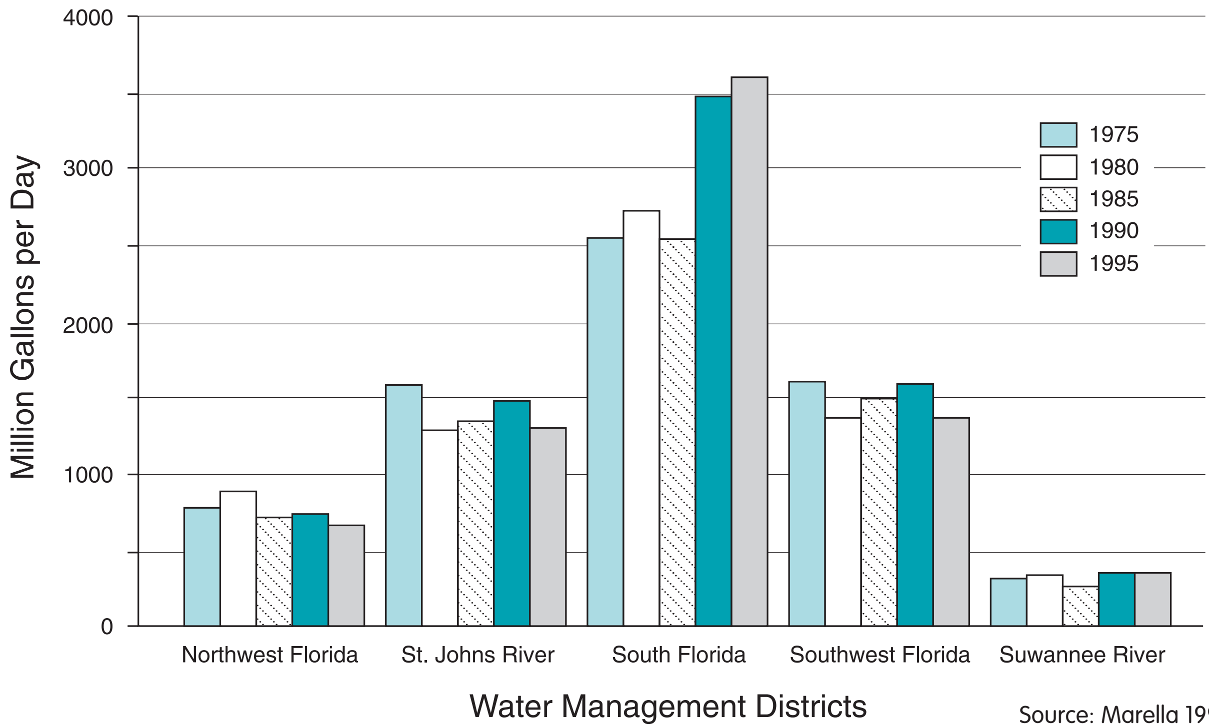
In 1995, ground water accounted for 60 percent of the water withdrawn in Florida. Nearly 93 percent of the state's population relied on ground water for their drinking water needs, far more than any other state in the nation (Solley et al. 1998). The majority of ground water is withdrawn from the Floridan aquifer, although the Biscayne aquifer is the primary source of potable water in south Florida and the sand and gravel aquifer is the main source of potable water in portions of west Florida. Groundwater withdrawals steadily increased between 1950 and 1990, but decreased 7 percent between 1990 and 1995, even though the population increased 9 percent, from 12.94 to 14.15 million. Following trends in the United States as a whole, use of water for agricultural irrigation, industry and thermoelectric cooling has also decreased in Florida, due to more efficient use.

Florida Freshwater Use
1995



Source: Marella 1999

Freshwater Withdrawals



Source: Marella 1999

Statewide per capita residential use of water has decreased from an average of 144 gallons per day in 1980 to 103 gallons per day in 1995. This decrease has resulted from conservation efforts, including the use of more efficient toilets and showers, use of reclaimed water for lawn irrigation, and use of water-saving landscape techniques (Marella 1999). Florida households still use one-half of their water for landscape irrigation.

Florida ranks low (30th in the nation) in withdrawals of fresh surface water. Between 1990 and 1995, withdrawals of surface water increased by less than 1 percent. The primary uses of fresh surface water are for agricultural irrigation and as cooling water for power plants. Major sources of fresh surface water for irrigation are Lake Okeechobeee, Lake Apopka, the Caloosahatchee River and the marshlands associated with the headwaters of the St. Johns River. In some parts of the state, surface water is a significant component of public supply. Hillsborough River and the Tampa Bypass Canal supply Hillsborough County, and Deer Point Lake Reservoir supplies Bay County.

Water Reuse

Florida has become a leader among states in the **reuse** of water. Every day, 60 gallons of wastewater for each person flows out of homes and into sewers. As this wastewater travels miles through the collection system, it is diluted by ground water that infiltrates joints and defects in the sewers. By the time wastewater reaches the treatment facility, its volume has increased to about 100 gallons per person per day. Wastewater is now about 99.9 percent water and 0.1 percent pollutants. After treatment, wastewater can be safely used for many purposes.

State law requires reuse within water resource caution areas. In 1999, the total capacity of all reuse systems in Florida was about 1.04 billion gallons per day, nearly half of the total permitted capacity of all domestic wastewater treatment facilities in the state. A total of 523 million gallons per day of reclaimed water was reused in 1999.

Reclaimed water is being used for landscape irrigation (including golf courses, parks, highway medians, playgrounds and residential properties), agricultural irrigation (including irrigation of edible crops), aesthetic uses (decorative ponds, pools and fountains), groundwater recharge, industrial uses (for cooling, process or wash waters), wetlands creation, restoration and enhancement and fire protection (use in hydrants and sprinklers).

Water Quality

Good quality water in adequate amounts is indispensable for the water we drink, but it is also essential for many other uses. We cannot safely swim or fish in polluted waters nor can Florida's natural systems survive without adequate water of good quality.

The recreational and ecological values of good quality water and other natural resources are frequently acknowledged but are rarely considered in management decisions because we don't buy and sell them as we do other commodities. An article published in 1997 (Costanza et al.) in the journal *Nature* summarizes and synthesizes studies aimed at estimating the value of ecological functions and services. The authors conclude that the economic value of Earth's natural systems averages $33 trillion per year, which is 1.2 times as much economic value created by humans and measured by the combined gross national product of all the countries in the world.

Scientists use a number of tests and measures to help them determine water quality. These include turbidity, nutrient levels, pH, dissolved oxygen, conductivity and temperature.

Turbidity is characterized by a cloudy or muddy appearance caused by suspended solids that decrease the ability of the sunlight to penetrate the water. The most common suspended solids are soil particles and algae. Water may sometimes be naturally turbid because of high amounts of organic debris, erosion, or waves or floods that suspend sediments.

High turbidity reduces underwater plant growth by limiting sunlight penetration and photosynthesis. A decrease in plant growth results in a decrease in the number of organisms that depend on plants for food and shelter. Soil particles also affect the health of fish by clogging and irritating their gills. Turbid waters may suffocate some aquatic plants and animals and impair reproduction and development of eggs and larvae.

Nutrients in the proper amount are necessary for healthy aquatic systems, but in excess, nutrients, primarily nitrogen and phosphorus, can be harmful. Nutrients come from runoff containing fertilizer, waste from leaking septic tanks, decaying lawn debris and animal wastes. When too many nutrients are present, certain plants grow explosively and crowd out other plants, creating a monoculture. Increases in nutrients may result in algal blooms in lakes and rivers. When algae multiplies rapidly, it uses up dissolved oxygen, leaving less available for other forms of aquatic life. Excess nutrients also frequently increase nonnative nuisance plants, such as water hyacinth and hydrilla.

The measure of the amount of hydrogen ions (H+) and hydroxide ions (OH-) in a solution is **pH** (potential of hydrogen). The more acidic a solution, the greater the amount of hydrogen ions. The more basic or alkaline the solution, the greater the amount of hydroxide ions. The pH scale ranges from 0 to 14.

The lower the pH, the more acidic the solution is; the higher the pH, the more basic the solution is. A solution with a pH of 7 is neutral, neither basic nor acidic. Pure water has a pH of 7. Orange juice has a pH of 4 and battery acid has a pH of 0.5. Milk of Magnesia has a pH of 10 and lye has a pH of 14. Most aquatic organisms prefer water with a pH ranging from 6.5 to 8.5. As acidity rises (pH falls), other compounds in contact with the water or the soil may release toxic elements (for example, aluminum and mercury). Stormwater runoff containing leakage from faulty sewer lines or septic tanks, runoff from agricultural areas and acid rain can all decrease pH in lakes, rivers and estuaries, threatening aquatic organisms and releasing potentially harmful elements.

Dissolved oxygen in water is essential for the survival of nearly all aquatic plants and animals. Aquatic organisms, including most fish, generally thrive when dissolved oxygen levels are 5 parts per million (ppm) or greater. Oxygen in the water comes from the air and as a byproduct of photosynthesis. The cooler the water, the more dissolved oxygen it will hold. However, at night when photosynthesis stops, animals continue to use oxygen and the dissolved oxygen content of water drops.

Conductivity refers to how well the water conducts or transmits an electrical current. Pure distilled water does not conduct a current. As the concentration of minerals and salts in the water increases, however, conductivity rises. Conductivity is therefore an indirect measure of the mineral content of water. Sediments from stormwater runoff and intrusion of seawater increase the mineral content of water. Increases in conductivity may indicate water quality problems from increased salinity or increased sediment. Both of these make water less useful to humans and to natural systems.

Temperature affects the growth and life cycles of many aquatic organisms. Nearly all organisms have a temperature range they prefer or even require. Sediments can absorb heat and increase water temperature. Stormwater runoff from heated impervious surfaces and power plant outfalls also increases water temperature. As water temperature increases, the life cycles of aquatic insects may accelerate. The growth of algae generally increases, whereas the growth of other plants such as aquatic grasses may decrease. Other aquatic organisms may become more sensitive and vulnerable to disease and their reproductive cycles may be disrupted with increased temperatures.

CAUSES AND SOURCES OF WATER POLLUTION

Although **pollution** is often defined as contamination by harmful chemicals or waste materials, **environmental pollution** can be *anything* that harms or causes an imbalance in plants and animals in their natural habitat — even though the substance may not be harmful to humans. For example, phosphorus and nitrogen are common elements of most fertilizers. They are not harmful to humans. However, nitrogen runoff can be a pollutant in saltwater bays and estuaries, such as Tampa Bay and the Indian River Lagoon, and phosphorus runoff can be a pollutant in freshwater habitats such as the Everglades and Lake Apopka and other freshwater lakes because it causes an imbalance in the natural system.

Pollution is usually caused by human activities. Pollutants aren't always detectable by smell, sight or taste. Water may look and smell clean and even taste fine, but it may still be contaminated and unsafe for drinking.

Despite successes in cleaning up some water pollution, many modern pollutants are very difficult to remove, and it is obviously better not to pollute in the first place. Heavy metals and synthetic chemicals pose particular hazards to humans and other forms of life.

Heavy metals, such as lead and mercury,

can interfere with production of hormones and with reproduction. Lead can further result in physical and mental developmental problems in children. Other metals, such as copper and zinc, are less dangerous to humans but are toxic to aquatic life (Stauffer 1998).

More than 10 million chemicals are manufactured today. Most are used in agriculture and industry. Some break down quickly, whereas others, like heavy metals, remain in the environment for decades. Fewer than 2 percent of these chemicals have been fully tested with regard to human health risks, and no health information is available for more than 70 percent of them (Stauffer 1998).

Water may be polluted in two general ways: by **point source pollution** and by **non-point source pollution**. With point source pollution, the cause of the problem can be traced to a single source, for example, a pipe discharging waste from a factory. Non-point source pollution is more diffuse and originates from diverse sources over a wider area.

In the past, pollution from industrial and domestic point sources was common. Stronger regulations, new technologies and more advanced treatment of wastes have reduced point source pollution. Today most water quality problems result from non-point source pollution, including stormwater runoff, septic tanks, runoff from croplands, dairies, feedlots and farms, and erosion from construction sites and unpaved roads. Non-point source pollution carries pesticides and fertilizers from lawns and fields, oil and greases from roads and parking lots, sediments from construction sites and clear-cutting of trees, and wastes from improperly functioning septic tanks.

In 1982, the state of Florida implemented a rule to reduce stormwater runoff. Since 1982, all new developments have been required to use **best management practices** (BMPs) to minimize runoff during construction and to treat stormwater after construction. These BMPs include requiring swales, **retention ponds, detention ponds** and detention ponds with **filtration**.

FLORIDA WATER QUALITY AND TRENDS

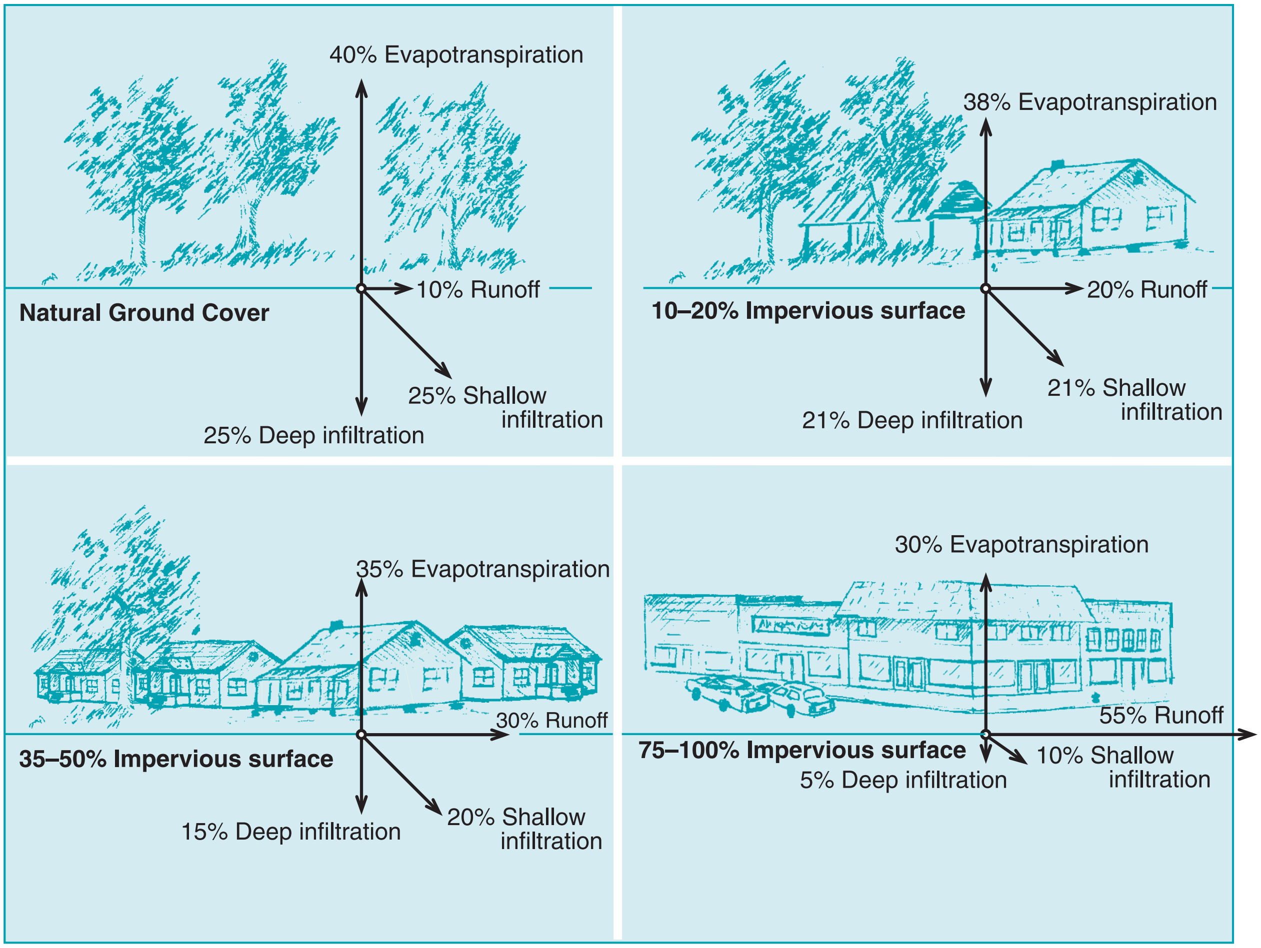
Because Florida is so populous and has grown so rapidly, an important source of pollution, particularly of surface water, is urban storm water. Surface water quality problems occur with the greatest frequency in heavily populated areas — the southeast, in the central region near Orlando, in the St. Johns River basin particularly around Jacksonville, in Pensacola Bay and its tributaries, in the Peace River basin and along the west coast between Tampa and Naples. Water bodies whose watersheds include large urban areas and intensive industry and agriculture have the poorest water quality.

Developed areas have a much higher proportion of **impervious surface** than rural areas. Impervious surfaces are covered with buildings or asphalt, concrete and other materials that prevent water from seeping into the ground. As a consequence, the volume of storm water increases, carrying pollutants with it.

The Florida Department of Environmental Protection monitors water quality in over 600 surface water bodies throughout the state. Between 1986 and 1995, the water quality in 71 percent of these water bodies was unchanged, the water quality of 20 percent improved, and the water quality of 9 percent declined. In general, improvements were related to better control of point source pollution, particularly discharges from wastewater treatment plants. Declines in water quality generally resulted from increases in stormwater runoff.

Florida's ground water, as well as its surface water, is vulnerable to contamination. Large portions of the state are covered with well-drained sandy soils overlying porous limestone. High

The Effect of Covered Surfaces on Runoff

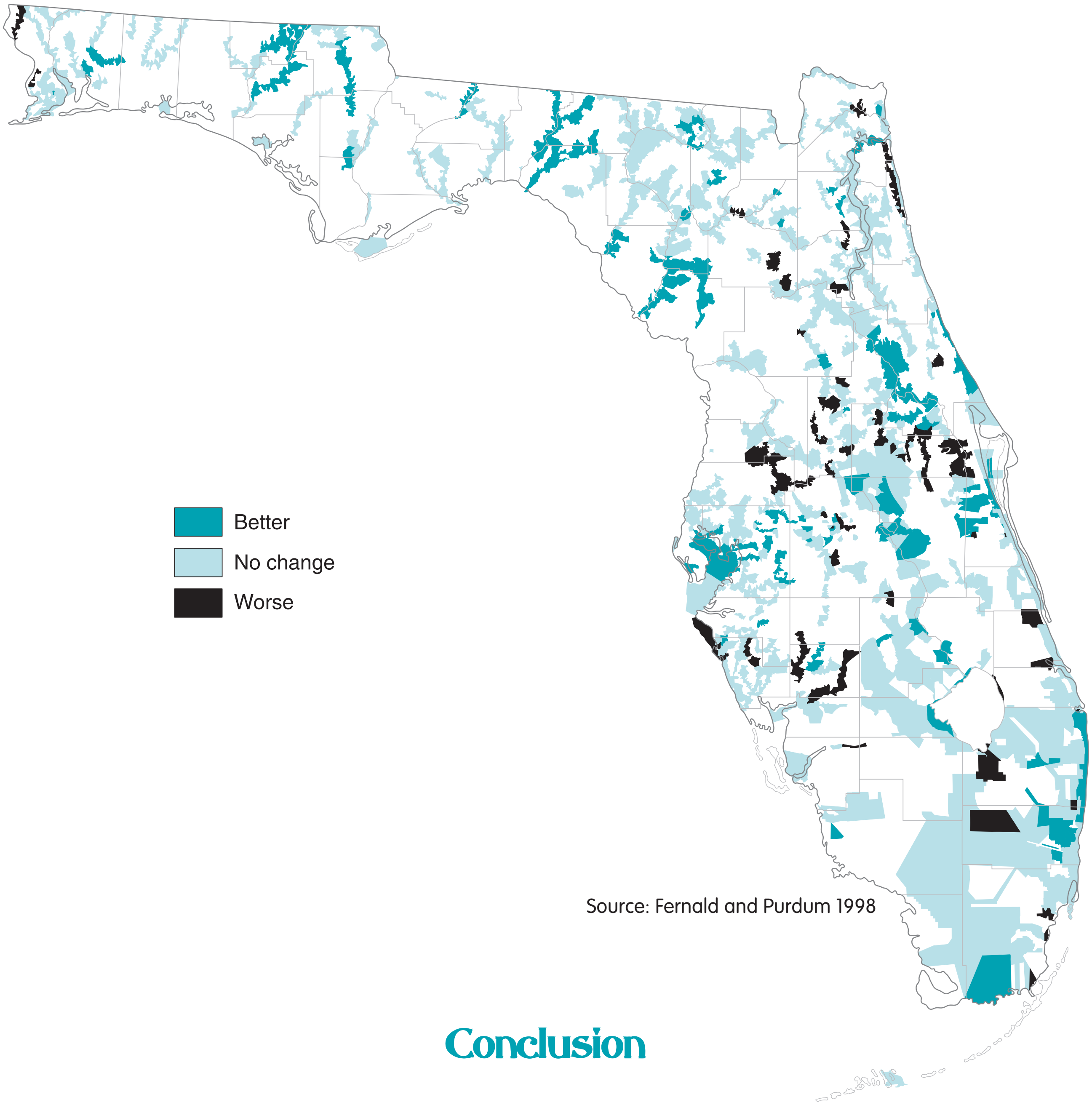


Source: Fernald and Purdum 1998

amounts of rainfall contribute to the potential for contamination of ground water: in many places, anything on the surface is likely to percolate through to the ground water. Connection between ground water and surface water also means that anything found in surface water is likely to find its way into ground water and vice versa.

In the 1980s, hundreds of wells in Florida were found to be contaminated with the soil fumigant ethylene dibromide (EDB). Other wells were found to be contaminated with dry-cleaning solvent and gasoline from leaking underground storage tanks. This resulted in standards for water well construction and water testing within areas of known groundwater contamination. Ground water in Florida has also been found to be contaminated with nitrate from fertilizers or leachate from septic tanks. Nitrate contamination of ground water may cause “blue baby syndrome,” a condition affecting human infants under 6 months of age. High levels of nitrates decrease the amount of oxygen carried in the baby’s blood. The skin around the eyes, mouth and feet appear blue. The syndrome may also cause difficulty breathing, loss of consciousness, convulsions and even death.

Monitored Surface Water Quality Trends
1986–1995



Conclusion

Although the analysis of water quality and water pollution is complex, the need for adequate amounts of clean water is clear. Some major water quality problems of the past, particularly waterborne epidemics, are now well controlled. We must face new challenges resulting from a fast-growing population, industry and intensive agriculture.

As water becomes scarcer, it will undoubtedly become more expensive, not just in Florida but throughout the world.

"In most countries, water is priced at only a fraction of its real cost. The working assumption is that it's an unlimited public resource, and the result is that few consumers have any incentive to use it sparingly. Yet the time is coming when water must be treated as [a] valuable [resource], like oil, not free, like air" (Voyage Publishing 1996).

Chapter 6

Forward to the Past

"The strength of the many is greater than the strength of the individual organization."

— Participant in Indiana Grand Kankalee Marsh Restoration Project (Yaffee et al. 1996)

"You can't look at ecosystem management only in terms of what it can do for native plant and animal species. From the standpoint of sustainability, people have to be strongly involved."

— Participant in Oak Mountain Partnership, Colorado (Yaffee et al. 1996)

KEY IDEAS

- Many of Florida's natural systems have been radically changed and fragmented by human development.
- Water no longer flows unimpeded from uplands to coastal estuaries.
- Florida has responded to the loss, degradation and fragmentation of the natural environment with one of the most aggressive and farsighted land acquisition programs in the nation.
- Land acquisition alone is not enough. These lands must be managed and in many cases effectively restored.
- Throughout Florida, ecosystems are being restored.
- We cannot return to what used to be, but we can restore, protect and better manage what we have.

VOCABULARY

Degradation

Edge habitat

Finger-fill canals

Habitat fragmentation

Invasive exotics

Land restoration

Stormwater treatment areas

Beginning in the 1800s, many of Florida's natural systems were radically changed. Thousands of acres were drained for agriculture. Thousands more were drained for houses for the steady stream of new residents. Rivers were straightened and canals were dug for drainage and flood control and to make travel easier for ships and barges. Rivers were dammed for hydroelectric power and to create lakes for recreation. Forests were cut and trees were tapped for turpentine and rosin. In northern Florida, centuries-old longleaf pine trees were replaced with acre upon acre of fast-growing slash pine. Farther south, ancient cypress were logged and the land left bare.

Today, agricultural enterprises, businesses, houses, cities and roads cover 43 percent of the Florida landscape. Forests and wetlands comprise the other 57 percent. However, humans have left their imprint on nearly all of this remaining land. Most of the forests are now straight rows of young trees, the original trees having been logged. Also, many natural areas have been affected by **invasive exotics** (plants and animals from elsewhere) that "crowd out" native species (Kautz et al. 1998).

A serious consequence of the conversion of the natural Florida landscape to human uses has been the fragmentation of remaining natural habitats. Water no longer flows unimpeded from uplands to coastal estuaries. Wide-ranging species such as the endangered Florida panther and the black bear face hazards as they cross barriers such as roads and levees that isolate and fragment their habitats. **Habitat fragmentation** increases the amount of "**edge**" **habitat**. Although edges are desirable for some game species, such as deer and rabbits, and for some birds, such as song sparrows and cardinals, excessive amounts of edge are undesirable for interior forest dwellers. Edges of forests are also hotter and drier than the forests themselves and may become dominated by common weeds, whereas forest interiors are more diverse and support more rare species (Kautz et al. 1998).

Florida has responded to the loss, **degradation** and fragmentation of the natural environment with one of the most aggressive and farsighted land acquisition programs in the nation. As of March 2001, 8.7 million acres, covering nearly a quarter of the state, were publicly managed conservation lands (Florida Natural Areas Inventory, unpublished data). But public acquisition is not enough: there must be land management and in many instances, **land restoration**. In the past century, conservation efforts focused on acquisition and preservation, basically putting a fence around what's left, according to former U.S. Secretary of the Interior Bruce Babbitt. "We have finally come to recognize that that's not enough. We cannot meet our obligation to the protection of creation by saying 'fence off the back 40,' put somebody in a uniform from the National Park Service here and say we've taken care of our obligation." Today an "ecological revolution," in Babbitt's words, is occurring: it is ecological, not political, boundaries that are critical. You can't preserve or manage or restore public lands in isolation from the landscapes of which they are a part.

Restoration

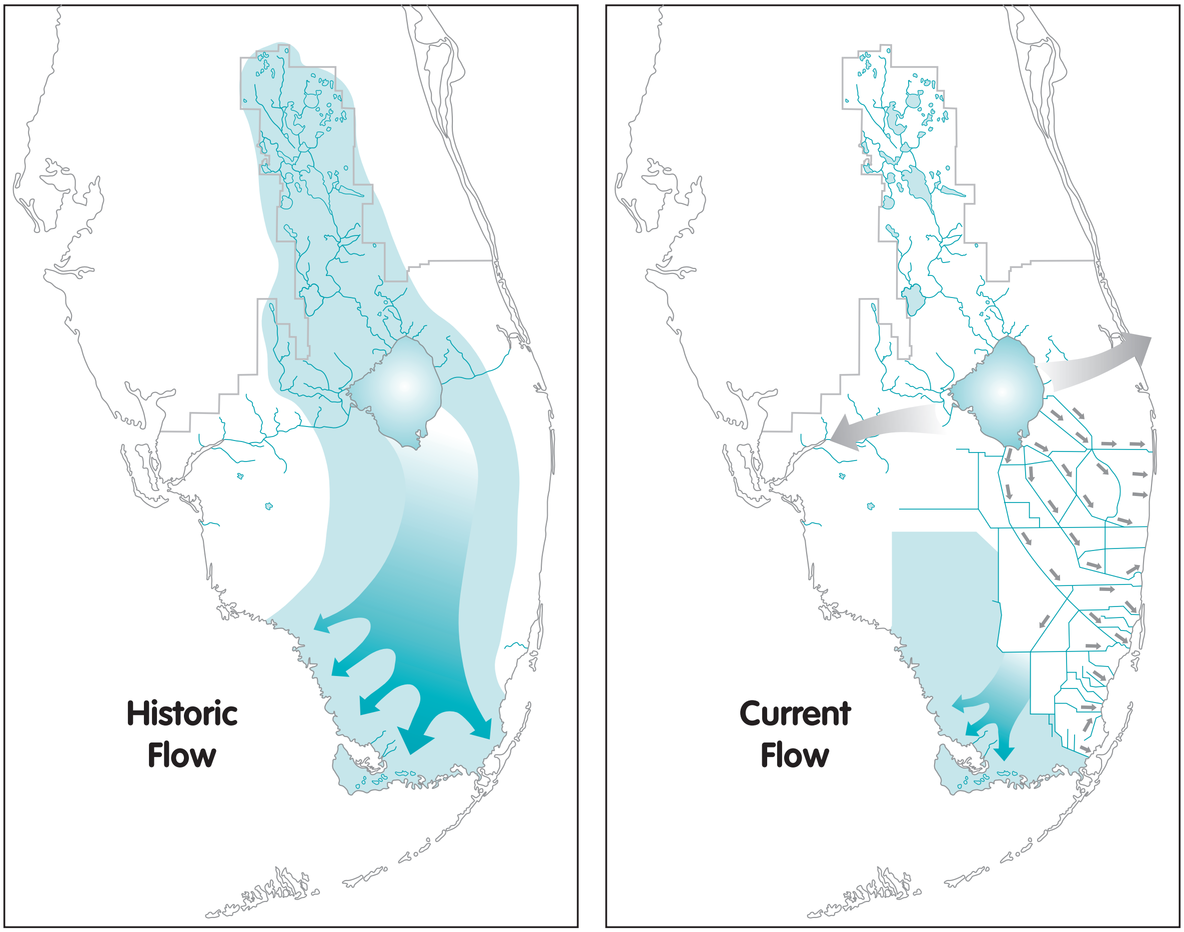
Many things can be taken apart, but some, such as biological systems, are very difficult to put back together again. On the surface, a biological system may look like it's "fixed," but it might not work. Some parts may be missing, some may be forgotten or some may not be put back in the proper relationship to other parts. Complexity and diversity tend to be hallmarks of unaltered systems, and this makes restoration very difficult. Like a broken eggshell, a fragmented and altered ecosystem that is put back together may never be as strong and resilient as the original. In spite of these challenges, throughout Florida, ecosystems are being "put back together."

KISSIMMEE-OKEECHOBEE-EVERGLADES RESTORATION

The U.S. Army Corps of Engineers and the South Florida Water Management District are embarking on the most ambitious ecosystem restoration ever undertaken in the United States. At an estimated cost of $7.8 billion, a 50-year plan provides the road map for reviving what was once an uninterrupted ecosystem from the Kissimmee River valley, through Lake Okeechobee, through the water conservation areas and Everglades National Park, to Florida Bay and the coral reefs. This plan is the culmination of eight years of scientific study and unprecedented cooperation among local, state and federal governments, Indian nations, environmentalists, farmers and urban water utilities.

Many people think of the Everglades as Everglades National Park. They picture a vast expanse of saw grass immortalized by Marjory Stoneman Douglas in her famous book, *The Everglades: River of Grass*. But the Everglades ecosystem is much larger and more diverse. It begins near Orlando, north of the chain of lakes that feeds the Kissimmee River and Lake Okeechobee, and it ends at Florida Bay and the coral reefs.

The natural landscape of the Everglades system was designed to hold water. During wet periods, water overflowed the southern banks of



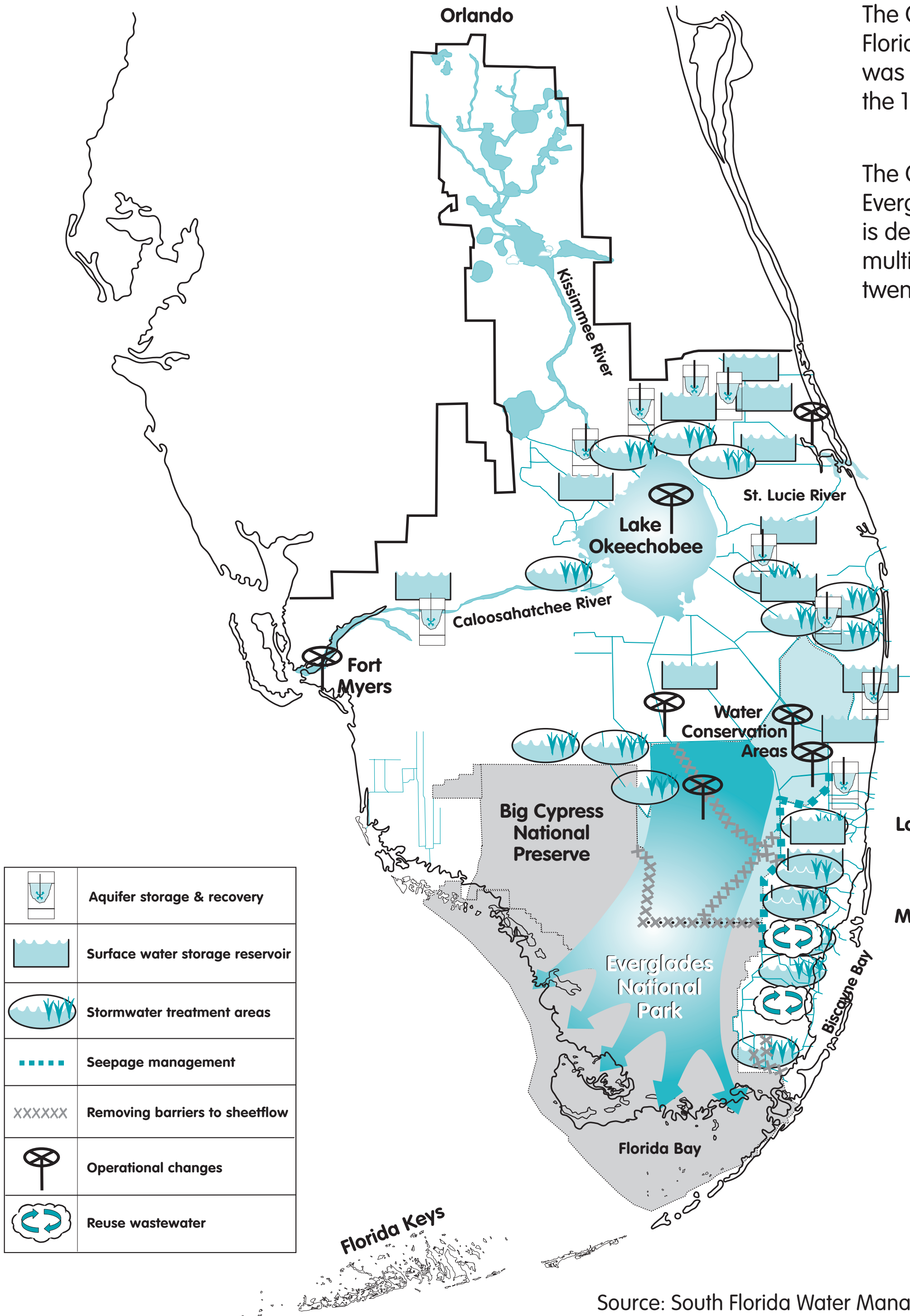
Source: South Florida Water Management District

Lake Okeechobee and continued in a sheetlike fashion across the Everglades. Immediately south of Lake Okeechobee was a custard apple and cypress forest where Seminole Indians hid from federal troops during the Second Seminole War. An eastern coastal ridge and a western inland ridge bound this "river of grass" that slopes imperceptibly from north to south, about one inch per mile. Just south of the lake, in what is now the vast sugar cane and vegetable fields of the Everglades agricultural area, saw grass was the dominant species. The current water conservation areas were once a mixture of sawgrass marsh and tree islands, and were home to huge flocks of birds and other wildlife, including endangered and threatened species such as black bear and the Florida panther. Uplands were pine/palmetto flatwoods and hardwood hammocks. Taylor Slough and Shark River Slough moved water through what is now Everglades National Park to salt marshes and mangrove swamps along Florida Bay and the Gulf of Mexico. During dry times, wildfires were common and were a vital force that helped maintain the balance of natural communities.

The Everglades landscape began to change in 1882 when Hamilton Disston attempted to channelize the Caloosahatchee and the Kissimmee rivers. In 1904, modification of the south Florida environment accelerated when Napoleon Bonaparte Broward was elected governor of Florida on a promise to "drain the Everglades." Between 1905 and 1927, six major canals and channelized rivers were connected to Lake Okeechobee for drainage and navigation. People began to settle and farm newly drained land south and east of Lake Okeechobee.

In 1926, and again in 1928, hundreds of people died when hurricane winds blew water out of Lake Okeechobee and flooded surrounding areas. As a consequence, an 85-mile-long dike was built encircling Lake Okeechobee. In 1947, two more hurricanes flooded south Florida. In response, in 1948, Congress authorized the Central and Southern Florida Flood Control Project, a massive public works project. The project encompassed 18,000 square miles, covered 16 counties and included 1,000 miles of canals, 720 miles of levees, and almost 200 water-control structures. With the completion of the project, the Kissimmee-

Comprehensive Everglades Restoration Plan



The Central and Southern Florida Flood Control Project was designed and built in the 1940s and 1950s.

The Comprehensive Everglades Restoration Plan is designed to meet the multiple needs of the twenty-first century.

Source: South Florida Water Management District

Okeechobee-Everglades ecosystem became a managed watershed. People, not nature, determined where and, to some degree, how much water would flow.

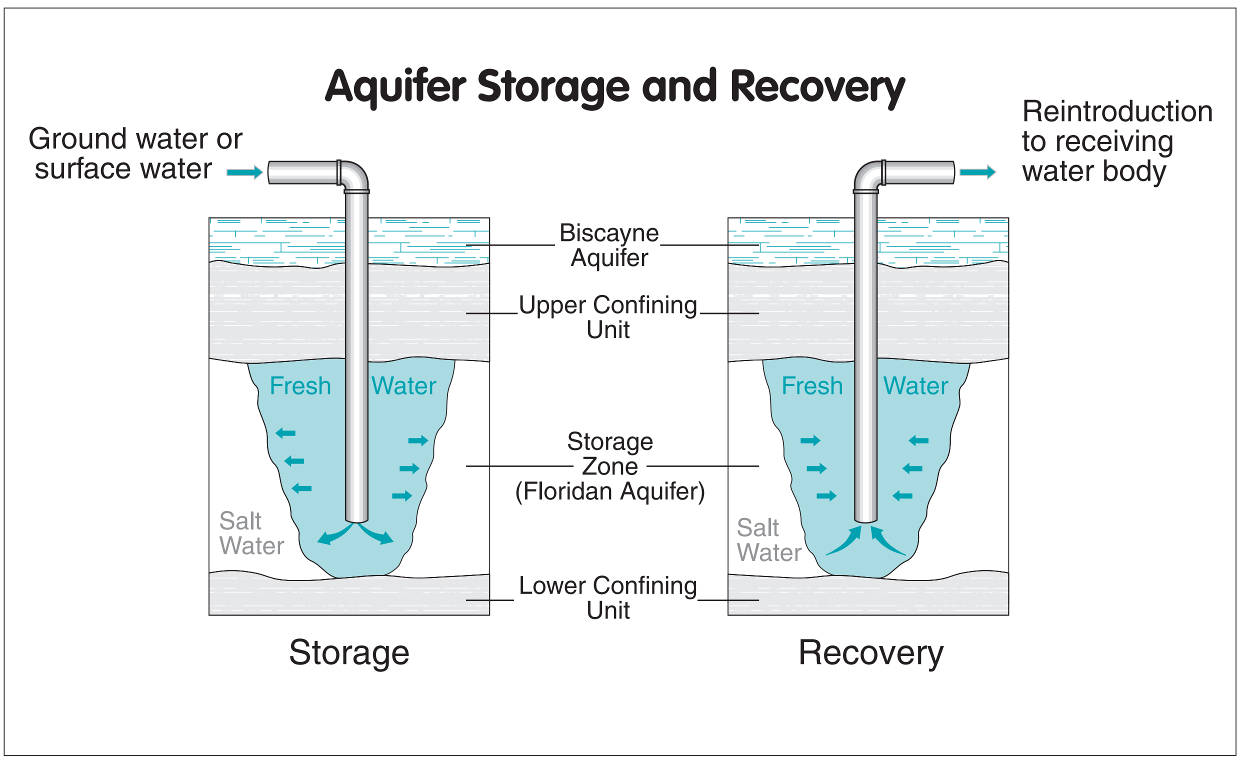
The Central and Southern Florida Flood Control Project opened vast areas for agriculture and urban development, making it possible for more and more people to live in south Florida. It did so at tremendous ecological cost to the Everglades. While the population of *people* in south Florida has risen from 500,000 in the 1950s to more than 6 million today, the number of wading birds in Everglades National Park has declined by 95 percent. Sixty-eight plant and animal species are threatened or endangered and over 1.5 million acres are infested with invasive exotic plants. And, because of seasonal rainfall, subtropical climate extremes and very flat topography, south Florida still occasionally experiences both floods and water shortages.

The Comprehensive Everglades Restoration Plan passed by Congress in 2000 addresses all these concerns. It is a blueprint that aims to:

- Improve the health of over 2.4 million acres of south Florida ecosystem, including Everglades National Park and the Water Conservation Areas.
- Improve the health of Lake Okeechobee.
- Eliminate damaging freshwater releases to estuaries.
- Improve water deliveries to Florida and Biscayne bays.
- Improve water quality.
- Enhance water supply.
- Maintain existing flood protection.

The current Everglades is only about half the size of the Everglades that existed 100 years ago. While the historic Everglades can never be regained, much of what remains can be improved. Restoration addresses four fundamental issues regarding water: quantity, quality, timing and distribution.

Quantity: Each day an average of 1.7 billion gallons of fresh water that once flowed through the ecosystem are discharged to the ocean and gulf. This water is lost for both humans and natural systems. Under the restoration plan, much of this water will be captured in surface and



Source: South Florida Water Management District underground storage areas until it is needed. More than 217,000 acres of new reservoirs and wetlands and 300 underground storage and recovery wells are planned. Most of the water captured will be used for environmental restoration with some reserved for urban and agricultural uses.

Quality: Increased nutrients, especially phosphorus, cause negative changes to the plant communities of the Everglades. Florida's 1994 Everglades Forever Act addresses this water quality issue by mandating the construction of artificial wetlands, called **stormwater treatment areas**, to reduce nutrients and improve water quality before water enters the Everglades. The Comprehensive Plan employs storage and treatment areas that further improve water quality in freshwater releases to the Everglades and Lake Okeechobee and that reduce undesirable freshwater discharges to coastal waters.

Timing: Cycles of flood and drought were vital to the historic functioning of the Everglades ecosystem. Under the restoration plans, the timing of water held and released into the ecosystem will more closely match natural patterns.

Distribution: To improve natural area connectors and to enhance overland flow, more than 240 miles of levees and canals will be removed from the Everglades. Portions of the Tamiami Trail (U.S. Highway 41) will be rebuilt with bridges and culverts, allowing a more natural flow of water across the land into Everglades National Park. In the Big Cypress National Preserve, the levee that separates the preserve from the Everglades will be removed, restoring more-natural overland water flow.

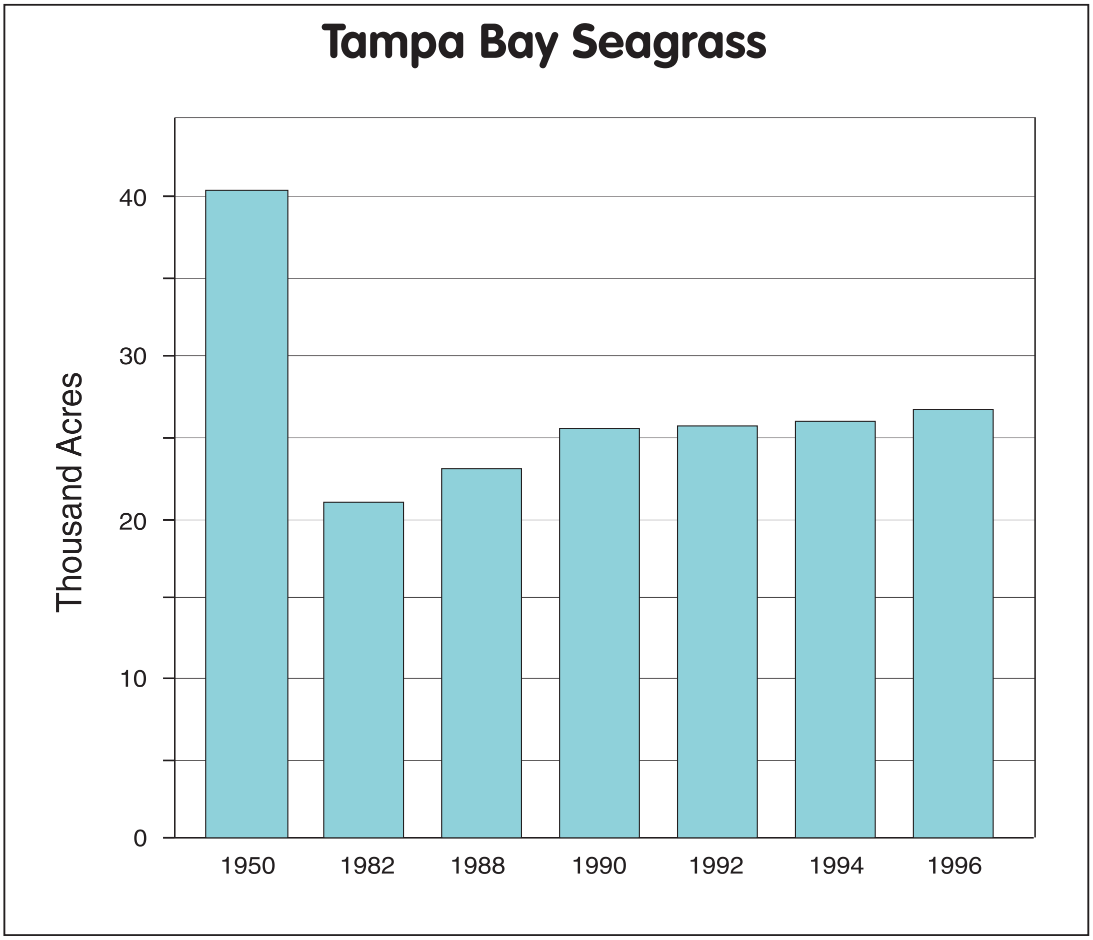
TAMPA BAY

Tampa Bay is Florida's largest open-water estuary, with a surface area of nearly 400 square miles and a watershed of 2,200 square miles. Tampa Bay borders portions of Polk, Pasco, Hillsborough, Pinellas and Manatee counties. Up to 70 percent of saltwater fish, crabs and shrimp spend part of their life cycles in estuaries where there is shelter, abundant food and protection from large predators that swim in the open sea. Tampa Bay is the year-round home to more than 100 dolphins and a winter refuge for the endangered Florida manatees that congregate around the warm-water outfalls of power plants. Economically, the bay yields $5 billion annually from trade, tourism and fishing. Along the bay are three major seaports, and more than 100,000 boats are registered to residents of Pinellas, Hillsborough and Manatee counties. Tampa Bay has been designated an "estuary of national significance" by the National Estuary Program.

Beginning in 1950, population in the bay area began to soar. Industrial and residential development, **finger-fill canals**, farms and causeways altered nearly all of the bay's original shoreline. In 1961, following devastating flooding from Hurricane Donna, the Florida Legislature created the Southwest Florida Water Management District to work with the U.S. Army Corps of Engineers to provide flood control around Tampa Bay. During the resulting Four River Basins, Florida Project, a regional flood detention area, a major canal and several shorter canals were constructed. These facilities were designed to store and (if needed) divert floodwaters around Tampa, but they also altered the timing and quantity of fresh water flowing into the bay — factors that are important to the bay's productivity. Also impacting the bay was the discharge by Tampa of 70 million gallons a day of partially treated wastewater.

Algal blooms and fish kills were common in the bay. Water was so murky that divers couldn't see their own hands. Forty percent of the seagrass beds were lost, and bottom sediments were nearly devoid of life. Populations of fish and birds declined, along with their habitats.

The biggest culprit in the decline of the bay was nutrients, primarily nitrogen, from wastewater discharges and stormwater runoff. In the late 1960s, in response to citizen complaints, a federal investigation recommended substantial reduction in the amount of nutrients entering the bay. The Florida Legislature responded by requiring that wastewater be



Source: Kautz et al. 1998

treated to advanced standards before it was discharged to the bay. In 1979, the city of Tampa, with substantial help from the federal government, upgraded its sewage treatment plant.

The bay responded. Seagrass grew where it had not grown for decades, indicating a healthier, more productive system. Water became clearer and bottom sediments again supported life. In Hillsborough Bay, once the most polluted portion of the Tampa Bay system, soft corals and sea squirts have begun growing. Scallops, which completely disappeared from Tampa Bay during the 1960s due in part to heavily polluted water, have recently returned.

In 1998, local governments, regulatory agencies and the Southwest Florida Water Management District signed the Tampa Bay Estuary Program Interlocal Agreement, a comprehensive long-term plan for preserving and restoring Tampa Bay. Goals of the plan include restoring at least 2,000 acres of coastal habitat and increasing seagrass beds to 40,000 acres. The Southwest Florida Water Management District has acquired 14,100 acres of land within the Tampa Bay/Anclote River watershed and has proposed acquisition of another 1,673 acres. The Southwest Florida Water Management District is in the process of restoring 2,500 acres of coastal habitat. The number of fish species in one restored area, Peanut Lake, increased from 12 to 26, and the number of popular game and commercial species such as mullet, menhaden, snook, redfish and black drum also increased. Restored coastal areas are also being used by many endangered, threatened or protected species of birds.

Wastewater discharges have decreased, but population growth is expected to continue. The challenge will be to control pollution from industries and automobiles and from stormwater runoff from streets, parking lots and lawns.

UPPER ST. JOHNS RIVER BASIN

The St. Johns River arises in the freshwater marshes of St. Lucie and Indian River counties and flows north 440 km (273 miles) to Jacksonville. At Jacksonville, the river turns and continues east 40 km (25 miles) to empty into the Atlantic Ocean at Mayport. The St. Johns River drops only 8 meters (26 feet) in elevation from source to mouth, resulting in many shallow pools — referred to as lakes — along its length. The Upper St. Johns River Basin extends nearly 80 miles from Ft. Drum Creek to the confluence of the Econlockhatchee River, and encompasses over 1 million acres. Remember, because the river flows north, "up is down." That is, the Upper St. Johns River Basin is the southernmost part of the river.

Through the 1800s, there were over 400,000 acres of floodplain marsh in the Upper St. Johns River Basin. Beginning at the turn of the century and accelerating in the 1940s and 1950s, thousands of acres of marsh were diked and drained for agriculture. By the 1970s, nearly two-thirds of the floodplain marsh was lost, resulting in flooding, declines in water quality and decreases in fish and wildlife populations. Remaining wetlands suffered from increased nutrients pumped from untreated agricultural runoff into the marsh.

In 1954, following devastating flooding from hurricanes in the 1940s, Congress authorized construction of engineering works in the Upper St. Johns River Basin as part of the Central and Southern Florida Flood Control Project. Flooding was to be reduced by diverting large amounts of water from the St. Johns Basin to the Indian River Lagoon through a canal. Large upland reservoirs west of the river valley were to detain flood flows. In 1972, the project was halted for a study required by the National Environmental Protection Act of 1969. After the study cited adverse environmental impacts from stormwater discharges to the Indian River Lagoon, as well as increased likelihood of water quality and habitat degradation in the upper basin, the state withdrew its sponsorship of this project, and it was abandoned.

Photo credit: St. Johns River Water Management District

Slough and cypress head in Upper St. Johns River Basin

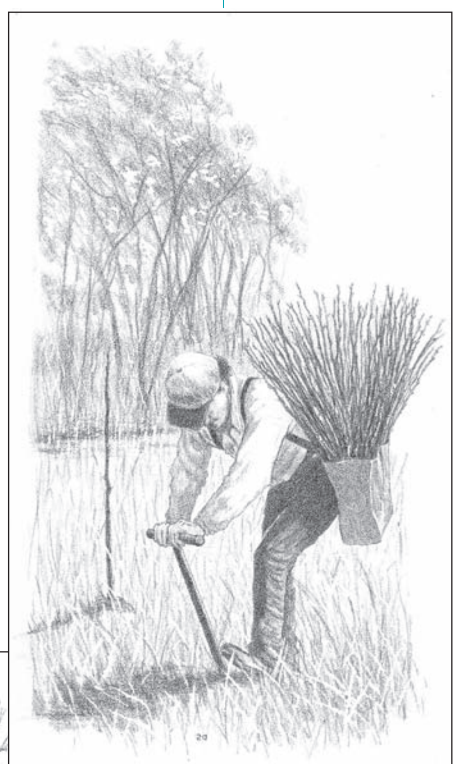
In 1977, the basin became the responsibility of the St. Johns River Water Management District. After extensive study, the District developed a new plan and in 1988 embarked on one of the most ambitious and innovative river restoration projects in the nation. Unlike the original plan that relied exclusively on engineering works, the new plan was semi-structural in design. As part of the plan, water-control structures allow water to sheetflow unimpeded through the river's marshes.

Nearly a century after they were first altered, 125,000 acres of marsh (many of which had been drained and converted to pastureland) in Indian River, Brevard and Osceola counties have been restored. Since restored areas were so large, the District relied on natural processes to restore wetlands. Natural soil moisture and processes of seed dispersal and germination occurred. When the vegetation was well established, the site was hydrologically connected to the adjacent marsh.

These restored marshes have reduced damage from floods, improved water quality, drastically reduced stormwater discharge to the Indian River Lagoon, restored fish and wildlife habitat and increased opportunities for public recreation.

To further improve water quality, 20,000 acres of reservoirs have been created as a buffer between agricultural land and the marshes. These reservoirs collect water from surrounding citrus groves and cattle ranches. Some contaminants settle in the reservoirs, resulting in cleaner water flowing into the marshes and ultimately into the river.

Wildlife now abounds in the restored marshes. The basin supports an estimated 60,000 wading birds. In 1990, the federally endangered Everglades snail kite returned to its historic nesting area in the Upper St. Johns River Basin. It was estimated in 1991 that habitat for more than 25 percent of the entire statewide population of Everglades snail kite is in the Upper St. Johns River Basin due to improved habitat there.



Source: Diane Sterling

LONGLEAF PINE RESTORATION

Longleaf pine forests — also known as sandhills and flatwoods on sandhill sites — originally stretched from Virginia to eastern Texas, covering 6.9 million acres in Florida's upper peninsula and Panhandle regions. These forests are home to hundreds of species, including the federally endangered red-cockaded woodpecker and the declining gopher tortoise. Longleaf pine forests have one of the most diverse plant populations on Earth because of frequent lightning fires, which keep one species from outcompeting the other. Twenty-seven federally listed species and 99 federal candidate species are associated with longleaf pine forests.

Many longleaf pine forests are important groundwater recharge areas. In portions of northwest Florida, water percolates through sandy soil in longleaf pine forests and re-emerges downslope where it forms steephead valleys and ravines.

Destruction of longleaf pine forests began in earnest after the Civil War and has accelerated in the last 50 years. Since

World War II, Florida's longleaf pine forests have been cut at an annual rate of 130,000 acres and largely replaced by single-species plantations of slash pine. These plantations do not support the diversity of the original sandhill and flatwoods communities. Habitat fragmentation and alteration of natural fire regime have left the remaining longleaf pine forests in poor condition.

The Northwest Florida Water Management District is restoring thousands of acres within its 16 counties, including many where longleaf pine once thrived. The District has purchased more than 180,000 acres of environmentally important lands, primarily along river systems and other sensitive water resources areas within the Panhandle. Since 1993, more than 8,000 acres have been restored to their natural state and condition along the Choctawhatchee, Chipola, Apalachicola, Escambia and Yellow rivers and the Holmes and Econfina creek areas. Efforts have focused on reforestation of areas that once contained extensive stands of longleaf pine and wiregrass habitat, although restoration activities also included other pine species such as loblolly, slash and shortleaf, as well as mixed hardwoods. About 4.4 million longleaf pines have been planted on District lands, as well as 563,000 wiregrass plugs, 85,000 loblolly pines, 452,000 slash pines, 28,000 shortleaf pines and 482,000 mixed hardwoods. More than four thousand acres have been restored within the Econfina Creek Water Management Area, along the Econfina Creek corridor. Econfina Creek is an especially sensitive area, since the creek flows into Deer Point Lake Reservoir, which serves as the public water supply source for Panama City and the surrounding area.

SUWANNEE RIVER BASIN

Dredging, draining, and pumping have not occurred on the Suwannee River, so the river has not been altered or impacted by such activities. Water quality has declined due to increasing urban and agricultural development. However, the Suwannee River Water Management District has the opportunity to address the problems before they become excessive. The solutions in the Suwannee watershed are non-engineering and non-structural and involve buying floodplains to filter out nutrients and other contaminants naturally and to provide flood protection. In addition, the water management district seeks to secure the cooperation of local governments, agriculture, industry and residents in preventing pollution.

Conclusion

Florida once had extensive and highly productive ecosystems, many of which were altered and degraded by urban and agricultural development. Much of the activity resulted from a lack of knowledge concerning how ecosystems function, how they are interrelated and the ways in which they help sustain people. There is currently a need to restore the function and integrity of what remains.

We cannot return to what used to be, but we can restore, protect and more effectively manage what we have. Sound science needs to be the foundation, and communication, education and public involvement, the cornerstones.

Links to Project WET Activities

Project WET (Water Education for Teachers) is a nonprofit water education program for educators and young people, grades K–12. The *Project WET Curriculum and Activity Guide* was published in 1995 by The Watercourse and the Western Regional Environmental Education Council and contains more than 90 water education activities. These guides are distributed through water resources workshops that also provide local-, regional-and state-specific information to participants. In Florida, Project WET is sponsored by the St. Johns River, Southwest Florida and South Florida water management districts and the Florida Department of Environmental Protection.

The following activities from the *Project WET Curriculum and Activity Guide* are especially appropriate for the content of each chapter. For Sunshine State Standards correlations for these activities, please visit the Southwest Florida Water Management District's Web site's Information and Education Section at **WaterMatters.org**, or call 1-800-423-1476, ext. 4757, to request a copy.

Chapter 1 — The Human Framework

- The First Floridians
  - *Water Celebration*, page 446, grades 3–8
  - *Water Messages in Stone*, page 455, grades 3–8
- Drainage, Flood Control and Navigation
  - *Dust Bowls and Failed Levees*, page 303, grades 9–12
- Modern Water Management
  - *Humpty Dumpty*, page 316, grades 3–8
  - *Hot Water*, page 389, grades 9–12
  - *Perspectives*, page 397, grades 6–12
- Water Law
  - *Pass the Jug*, page 393, grades 3–12, K–2 option
  - *Water Bill of Rights*, page 403, grades 3–12
  - *Common Water*, page 232, grades 3–8, K–2 option

Chapter 2 — Water: It's Magic!

- Introduction
  - *Wish Book*, page 460, grades 6–12
  - *Water Messages in Stone*, page 454, grades 3–8
  - *Aqua Bodies*, page 63, grades K–5
  - *Aqua Notes*, page 66, grades K–5

Glossary

Alluvial river — a type of river with a large, well-defined drainage basin that carries a high sediment load and has a large forested floodplain

Aquaculture — the cultivation of fish or shellfish

Aquifer — a layer of underground rock or sand that stores water

Aquifer storage and recovery — the process by which fresh surface water or ground water is injected deep into an aquifer and fresh water pumped to the surface at some later time from the same well

Atom — the smallest part of an element that exists in nature

Best management practices — methods designed to minimize harm to the environment

Blackwater river — a type of river that drains pine flatwoods and cypress swamps and that has dark, stained waters from decomposing plant material

Brackish — fresh water that is mixed with salt water

Capillarity — process by which water rises in tubes (capillaries) because of the attraction of water molecules to each other and to the molecules on the sides of the tubes

Condensation — moisture produced when warm water vapor mixes with cooler air in the atmosphere to form clouds or fog

Conductivity — measure of the ability of a substance to conduct an electric charge; indicates presence of minerals or salts

Coral reefs — structure formed over thousands of years by the limestone remains of millions of tiny animals (coral)

Degradation (habitat) — the result of human disturbances and land-use changes commonly associated with urban and agricultural development, as well as with exotic plant invasion, to the extent that habitat size and/or quality becomes negatively impacted

Desalination — any of numerous processes that remove salt from seawater or brackish water

Detention pond — a pond constructed to slow stormwater runoff and to allow the sediment in the runoff to settle to the bottom

Discharge — flowing or issuing out

Dissolved oxygen — oxygen dissolved in water — comes from the air and as a by-product of photosynthesis

Drainage — process of removing water from the land

Drainage basin — land area that contributes runoff to a water body; also known as a watershed

Drip irrigation — most efficient form of irrigation whereby water is delivered through pipes directly to the plants' roots

Drought — a long period of time with little or no rain

Dry prairies — expansive native grass and shrub lands occurring on very flat terrain

Ecosystem — a community of plants and animals and their physical environment

Ecosystem restoration — Re-establishing and maintaining the health, sustainability and biological diversity of natural systems

Edge habitat — the area between natural community types

El Niño — unseasonably warm ocean current that occurs in the Pacific Ocean off the coast of Peru every 3 to 7 years

Endemic — an animal or plant restricted in its distribution to one or a few places

Entisols — soils of slight and recent development, common along rivers and floodplains

Environmental pollution — anything that harms or causes an imbalance in plants and animals in their natural habitat

Estuary — a place where fresh water and salt water mix

Evaporation — process by which water changes from a liquid to a vapor (gas)

Evapotranspiration — the total loss of water to the atmosphere by evaporation from land and water surface and by transpiration from plants

Fill — material taken from the land as a result of drainage

Filtration — to hold and filter runoff through seepage

Finger-fill canals — canals created by dredging wetlands; resulting fill is used to build dry land, usually for houses

First-magnitude spring — one that discharges water at a rate of 100 cubic feet per second or more

Flood — the overflow of water onto an area that is normally dry

Flood control — means used to control floods, may be structural (dams, dikes) or nonstructural (limiting development in floodplains)

Gas — a physical form of a substance as a vapor; generally invisible

Global warming — warming of the Earth's surface thought to result from the burning of fossil fuels

Ground water — water under the ground in aquifers

Habitat fragmentation — isolated patches of habitat remaining after land is cleared

Hammocks — small tree islands in the midst of marsh and swampland

Hardwood hammock — biologically diverse community growing on elevated coastal ridges and islands of ground slightly higher than surrounding wetlands

Histosols — soils that contain large amounts of organic material derived from decayed organisms

Humid subtropical — climate of most of Florida except the southern tip of the peninsula, characterized by cooler temperatures in the winter and lack of distinct wet and dry seasons

Hurricane — a storm with winds of 74 mph or greater

Hydrogenase — catalyst for recycling natural materials produced by microorganisms in mud

Hydrologic divide — area across which water does not flow

Hydrology — study of water's properties, movement and distribution

Hydroperiod — amount of time water is standing on the land's surface

Impervious surface — material such as asphalt and concrete that does not allow water to pass through it

Insectivorous plants — plants that digest insects

Invasive exotics — nonnative species of plants and animals that outcompete native species

Irrigation — the application of water to an area

Karst — type of terrain underlain by limestone and characterized by caves, sinkholes and disappearing streams

La Niña — opposite of El Niño; occurs when stronger than normal Pacific trade winds stir up cooler water from the ocean depths

Land acquisition — purchasing land, as for conservation

Land restoration — returning the land to its former integrity

Limestone — highly porous rock formed over millennia from shells and bones of sea animals

Limnologist — one who studies inland water

Liquid — the physical form of a substance that flows

Mangroves — trees that grow along Florida's southern coasts; most plentiful in salt water where few other trees are able to survive

Marsh — area of shallow water covered with grasses

Microbes — microscopic organisms such as viruses and bacteria

Minimum flows and levels — the limit at which further water withdrawals would cause significant harm to the water resource or ecology of the area

Molecule — group of atoms bonded together

Natural community — interdependent association of plants, animals and microorganisms

Navigation — traveling or transporting goods by water

Non-point source pollution — pollution that does not come from a single point or location

Nutrients — substances that provide sources of energy and growth for plants and animals

pH — a measure of the amount of hydrogen ions (H+) and hydroxide (OH-) in a solution

Pine flatwoods — characterized by low, flat topography; poorly drained and nutrient-poor, acidic, sandy soils; and an open woodland vegetation with a pine overstory.

Pleistocene — geologic epoch beginning about 2 million years ago and ending about 10,000 years ago; also known as the Ice Ages

Point source pollution — contamination that can be traced to a single point or location

Pollution — contamination of water, soil or air by harmful chemicals or waste materials

Precipitation — condensed water vapor that falls to the Earth in the form of rain, snow, sleet or hail

Prescribed burns — controlled fires set by land managers to mimic natural processes

Prior appropriation — doctrine of water use common in the West whereby the first water user had continued rights to withdraw and use the water

Public supply — water delivered to homes, schools, businesses and other users by a utility company

Reasonable and beneficial use — doctrine of water use set forth in Florida law whereby use of water must be both reasonable and beneficial

Recharge — the process of water seeping into the ground and refilling the aquifer

Reclaimed water — water collected and often treated after use

Retention pond — constructed pond where storm water is held

Reuse — use of reclaimed water for various purposes, most commonly for landscape irrigation

Riparian — along the shore of a river or another water body

Runoff — rainfall that is not absorbed by the soil but flows to a larger body of water

Saltwater intrusion — the phenomenon occurring when salt water moves laterally inland from the seacoast or vertically from saltwater zones in the aquifer, mixing with and replacing fresh water

Savanna — a flat grassland of tropical or subtropical regions

Scrub — a type of natural community found on extremely well-drained sands along ancient shorelines and islands; dominated by sand pine or xeric oak

Seagrass beds — expanses of plants that flower and produce fruits and seeds in seawater

Sheetflow — the movement of water, like a sheet, across a surface — moving not in channels, but as a whole mass

Sinkhole — depression in the land surface caused when rainwater dissolves limestone near the ground surface or when the roofs of underground channels and caverns collapse

Slough — shallow channels of slow-moving water

Solid — the physical form of a substance that has three fixed dimensions

Solvent — a liquid that dissolves other substances

Spring — natural flow of water at the Earth's surface caused by pressure of ground water

Spring-fed river — a type of river with cool clear water issuing from springs

Steepheads — a unique natural community found in Florida and created when water seeps from the aquifer eroding land from the ground up

Stormwater runoff — rainwater that runs off land surfaces into the nearest body of water

Stormwater treatment areas — artificial wetlands used to reduce nutrients and improve water quality

Strand — a linear swamp

Streamflow — the amount of water that flows past a given point at a given time; usually measured in cubic feet per second

Surface tension — attraction of water molecules at the surface of a liquid

Surface water — water found on the surface of the Earth (rivers, lakes, streams, ponds, wetlands, oceans and seas)

Swamp — wetland predominantly covered with trees

Symbiotic — characteristic of the relationship between two different kinds of organisms that are interdependent; each gains benefits from the other

Tornado — a violent rotating column of air capable of mass destruction

Transpiration — the process by which plants give off moisture through the surface of their leaves

Tributary — small stream or river that flows into a larger stream or river

Tropical savanna — type of climate found in southern Florida, characterized by distinct wet and dry seasons

Turbidity — the degree of cloudiness of water caused by suspended solids

Uplands — higher parts of the landscape

Wastewater — water that has been used and is no longer clean

Water allocation — the distribution of water among various users

Water budget — formula used by hydrologists to help determine water surpluses and deficits in an area

Water cycle — continuous cycling of water between earth and sky

Water restoration — restoring water bodies to a more natural state

Water supply — amount of water available for human and other uses

Water use caution area — an area that is experiencing, or is anticipated to experience within the next 20 years, critical water resource problems

Watershed — land area that contributes runoff to a water body; also known as a drainage basin

Wetland — area that supports plants adapted to wet soil and often to changes in water level

Xeriscaping — a type of landscaping designed to use water efficiently

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