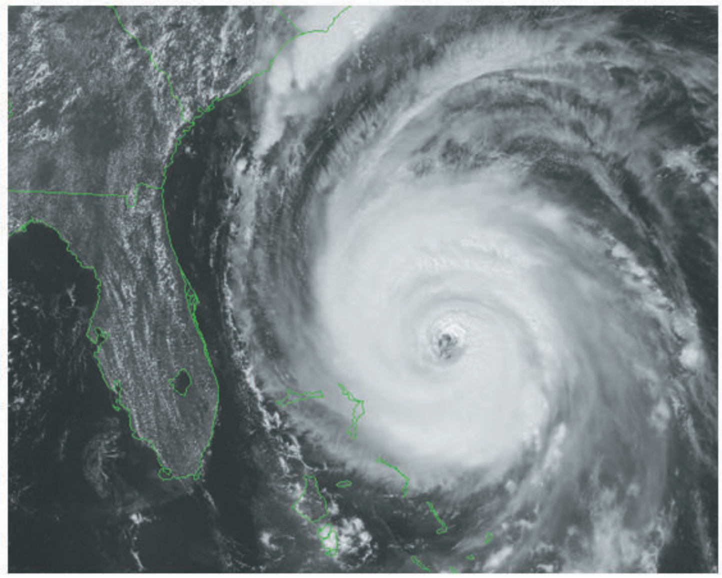
Science Plan U.S. Geological Survey Florida District

U.S. Geological Survey Open-File Report 01-180



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Front Cover:

Photographs representing the five key science issues of the U.S. Geological Survey, Florida District:

Issue 1	Watershed Systems and Processes	Cypress Trees
Issue 2	Water Resources Assessment and Availability	Public Supply Water Intake Facility
Issue 3	Hydrologic Hazards	Hurricane Satellite Image
Issue 4	Occurrence, Transport, and Fate of Contaminants	Pesticide Application
Issue 5	Preservation and Restoration of Ecosystems, with Emphasis on the Everglades	Wood Stork

Text:

Photographs included in this report were taken by employees of the U.S. Geological Survey during various scientific investigations and studies. Some satellite images are from the National Oceanic and Atmospheric Administration (NOAA).

Back Cover:

Photographs representing the science disciplines of the U.S. Geological Survey, Florida District:

Ecosystem Restoration Studies	Multidisciplinary
Coastal Processes, Systematic Mapping, and Remote Sensing	Geology
Ground Water, Surface Water, Water Quality, and Water Use	Hydrology
Manatees, Coral Reefs, Amphibians and Reptiles, Aquatic Fauna, and Nonindigenous Species	Biology
Maps, Satellite Imagery, GIS Products, and Land Surface Elevations	Mapping

Science Plan
U.S. Geological Survey
Florida District

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U.S. GEOLOGICAL SURVEY

Open-File Report 01-180

Tallahassee, Florida

2001

U. S. DEPARTMENT OF THE INTERIOR

GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY

Charles G. Groat, Director

The contents of this report will be periodically revised and updated. The most recent version of this report will be available on the Internet at http://fl.water.usgs.gov

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Conversion Factors and Datums

Multiply	By	To obtain
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	4,047	square meter
acre	0.4047	hectare
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
inch per month (in/mo)	2.54	centimeter per month
inch per year (in/yr)	2.54	centimeter per year

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows: °C=(°F-32)/1.8.

Sea level: In this report, sea level refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD of 1927).

Science Plan
U.S. Geological Survey
Florida District

INTRODUCTION

This Science Plan has been prepared by the Florida District of the U.S. Geological Survey (USGS) as a tool to provide direction for the scientific work to be accomplished in the District during the next 5-10 years. A Science Plan can serve as a guide to determine the optimum use of the limited financial resources of the USGS in Florida to address water resource issues. The Florida District has four primary operational centers geographically distributed across the State, in Tallahassee, Orlando, Tampa, and Miami, with a laboratory in Ocala and field offices in Jacksonville and Fort Myers. Other USGS discipline offices in Florida are located in Gainesville (biology), St. Petersburg (geology), and Miami (restoration ecology) (fig.1). Although some differences exist in programs among the four water-resource offices because of differing physiographic settings and information needs, many common elements are present and these common elements are the focus of this District Science Plan. Science Plan development was based on other planning documents including individual Science Plans prepared by personnel in each of the four primary Florida water resource offices, and strategic planning documents of the Southeastern Region, Water Resources Discipline (WRD), and the USGS.

A broad cross-section of District staff, representing all primary offices, a number of different scientific disciplines, and different programs of the District (data collection, investigations, and research) collaborated on the development of this Science Plan. As part of the development process, input was solicited from staff in every office and considered for inclusion in the plan. The Science Plan will be evaluated on an ongoing basis to ensure its continued relevancy to recognized water resources needs in Florida, and to guide future program development and collaboration with our existing and potential partners and customers, both within and outside the USGS.

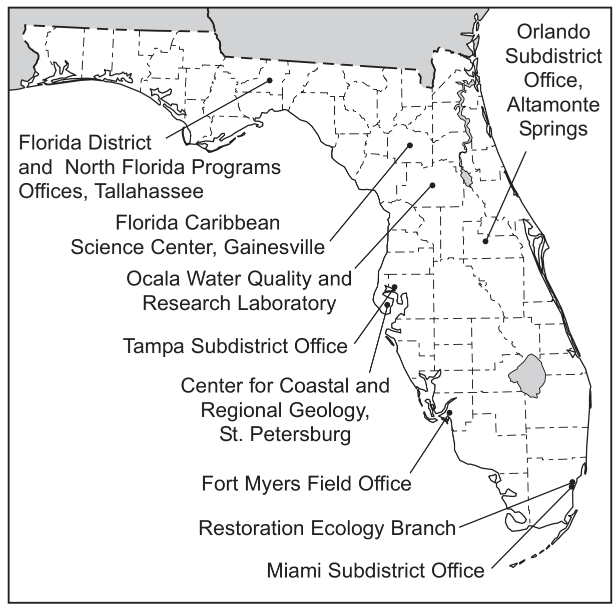


Figure 1. Location of U.S. Geological Survey offices in Florida.

Physical Setting

Florida has unique hydrologic features that distinguish it from other southeastern states. The Florida peninsula has very little topographic relief (the highest elevation is no more than 350 feet above sea level), has a lack of surface storage (contributing to flooding and drought problems in many areas), has hundreds of miles of coastline, and is underlain by one of the most productive aquifer systems in the United States, the Floridan aquifer system. The karst geology of the peninsula is the reason for the well-developed aquifer system, the many internally drained surface-water basins, the numerous depression features (sink-holes being the most notable), and other karst-related features. The natural resources of the state that attract new residents and tourists alike include numerous streams, lakes, springs, wetlands, estuaries, and the extensive coastline along the Atlantic Ocean and the Gulf of Mexico.

Figure 2. Satellite image of central and south Florida illustrating the distribution of lakes in the ridge area and Lake Okeechobee.

The climate of Florida varies slightly from the northern panhandle area to southern Florida, but in general is characterized by a relatively high mean annual temperature and rainfall, and is humid and subtropical. Average annual rainfall in Florida can range from about 40 inches in the western Keys to more than 60 inches in the panhandle. Severe weather generally comes in the form of intensive thunderstorm activity in the summer months, tornadoes, tropical storms, and hurricanes. In recent years, weather extremes appear to be intensifying, from drought-like conditions during spring months to more active hurricane seasons.

Water resources are one of Florida's most valued assets. The State has more than 1,700 streams and rivers, 7,800 freshwater lakes, including Lake Okeechobee (one of the largest lakes in the United States after the Great Lakes), and is underlain virtually everywhere by aquifers capable of yielding significant quantities of freshwater to wells (fig. 2). The State has about 320 springs, whose combined discharge is estimated at over 8 billion gallons per day, and has 27 of the 78 first-magnitude springs (discharge greater than 100 cubic feet per second) in the United States (figs. 3 and 4).

Although Florida's water resources are extensive, they are finite, and growth in population, tourism, industry, and agriculture is placing an increasing demand on them. Satisfying the demands of all water users is perhaps Florida's greatest resource challenge.

Figure 3. A spring run in northern Florida.

Figure 4. An underwater view of spring biota.

North Florida has some of the largest rivers in the State as well as a number of important streams, lakes, springs, and estuaries. In terms of annual discharge, the area has three of the five largest rivers in the State: the Apalachicola, Choctawatchee, and Escambia. Many of the rivers in northwest Florida originate in Alabama and Georgia, and interstate water management relating to these rivers is an increasingly important issue.

Ground water is the primary source of water supply for northwest Florida. The four major ground water systems in northwest Florida include the surficial aquifer system (which includes the sand and gravel aquifer), the intermediate aquifer system, the Floridan aquifer system, and the Sub-Floridan system. Wellhead protection is particularly important in the westernmost parts of northwest Florida, where much of the population relies on the sand and gravel aquifer for water supply. This aquifer is close to the surface and is susceptible to contamination from surface activities. In the big bend area of the State (Suwannee River basin), most of the Floridan aquifer system is unconfined and also vulnerable to contamination from the surface (fig 5).

In central Florida, the St. Johns River is the dominant surface-water feature (fig. 6). The river was selected as one of the first of the American Heritage Rivers, because of its unique character and value to the residents of Florida. Other than the several tributaries to the St. Johns River, major river systems in central Florida include the Kissimmee River (the subject of current restoration efforts), and the Withlacoochee, Hillsborough, Manatee, and Peace Rivers. The central Florida landscape is noted for its many seepage lakes and springs. However, increasing urbanization has resulted in concerns over declining lake levels and spring discharge. Central and west-central Florida are underlain by the surficial aquifer system, the intermediate confining unit, and the Floridan aquifer system (including the Upper and Lower Floridan aquifers). The primary source of drinking water for central and west-central Florida is the Floridan aquifer system. Contamination of ground water is of great concern in central Florida because of the proximity of the surficial aquifer to land surface, land uses in the area (including phosphate mining), the lack of a confining layer in many areas, and the presence of breaches through the confining layer that provide direct conduits to underlying aquifers.

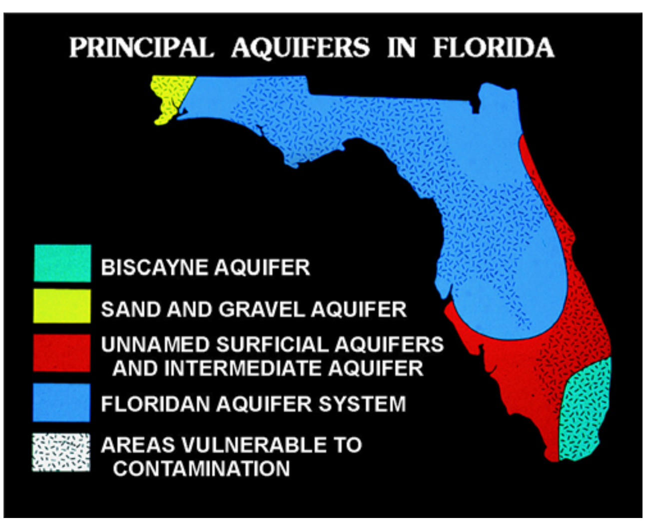


Figure 5. Map showing principal aquifers in Florida and areas where aquifers are vulnerable to contamination.

Water supply in west-central Florida is a critical issue, requiring the consideration of development of a variety of alternative sources including brackish water and submarine springs in the Gulf of Mexico. Northeast Florida is particularly vulnerable to saltwater intrusion because of a large population and consequent demands on ground-water resources. Water managers in northeast Florida and in west-central Florida are actively monitoring public supplies for increasing chloride content, and are developing alternative plans for water supplies for the future.

The southern part of the Florida peninsula contains a unique ecological landscape. One of the major hydrologic features of south Florida is Lake Okeechobee, which is the second largest freshwater body wholly contained within the continental United States. The entire natural system in south Florida lies on top of a limestone platform containing a complex

Figure 6. St. Johns River at Jacksonville, Florida, showing the Main Street Bridge.

sequence of aquifers (the Biscayne and Floridan aquifer systems). The Everglades is an irreplaceable wilderness that is bounded to the east by a highly developed urban corridor and to the west by a rapidly growing urban area. Along the periphery of the Florida peninsula in south Florida are beautiful beaches, highly productive bays, estuaries, mangrove forests, and extensive coral reefs. The hydrology of south Florida is unique in the State because of its highly manipulated character. About half of the original Everglades has been lost to urban, suburban, and agricultural uses through "reclamation" of the land using a complex series of drainage canals, levees, control structures, and pumps that have been constructed since the 1940's. The result is a hydrologic system that is directly controlled and managed to distribute freshwater in support of urban and agricultural activities. Reduced water availability to the Everglades and disruption of normal high and low water conditions have excessively stressed natural ecosystems with resulting large-scale reductions of terrestrial and aquatic wildlife communities. Additionally, nutrient-laden water from agricultural areas flowing through the greater Everglades has inexorably shifted the dominant vegetation from sawgrass to cattails in many areas with resulting disappearance of many species of natural fauna.

Driving Forces

Florida's unique character, warm climate, abundant natural resources, and economic opportunities continue to attract many new residents, which increasingly stresses hydrologic systems (fig. 7). With development in the State comes increased demand for water and increased potential for degradation of natural systems. Fundamental to the wise stewardship of water resources in Florida is an understanding of watershed systems and processes. The definition of a watershed has been broadened to include not only the surface water drainage basin but the ground-water basin as well. The understanding of processes and interactions between ground water and surface water on a watershed-based scale forms the

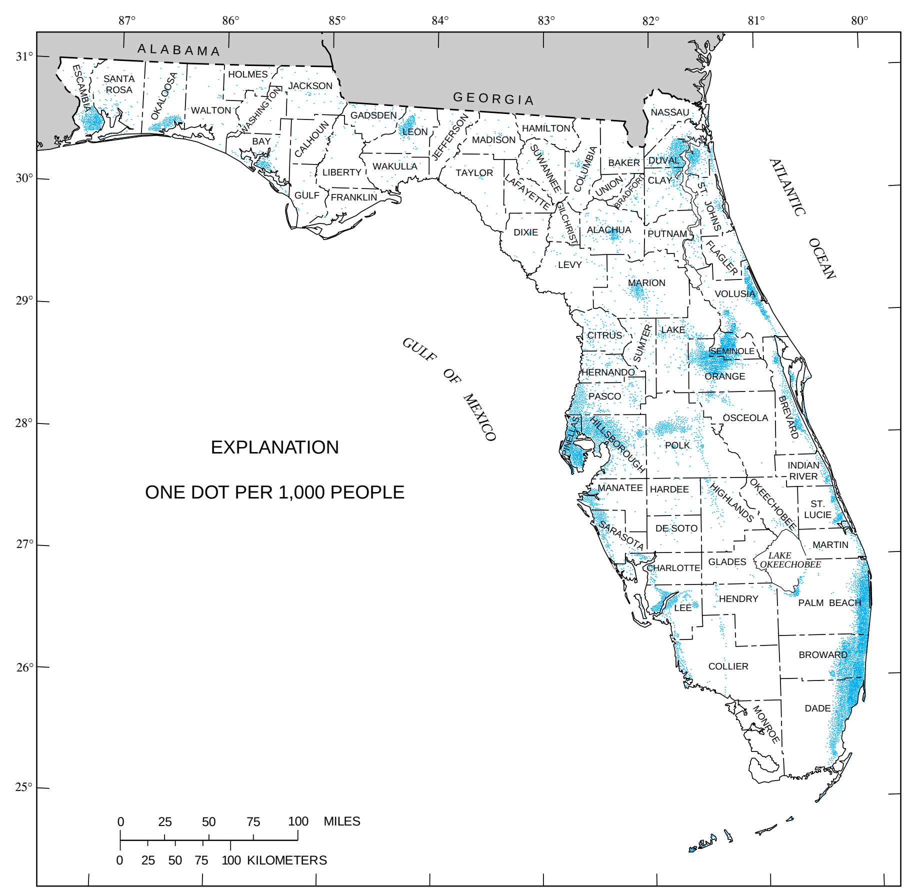


Figure 7. Population distribution in Florida. (From Marella, 1998, Water use and trends and demand projections in the Northwest Florida Water Management District: U.S. Geological Survey Open-File Report 98-269, 35 p.)

framework for answering complex questions and for allocation and protection of resources. To evaluate the entire watershed, cross-disciplinary integrated science is required to effectively evaluate physical, chemical, and biological processes.

Florida has experienced dramatic population growth since the middle of this century. It is the fourth most populated State in the United States and is expected to grow at a rate of three percent annually, with most of the growth concentrated in coastal areas where less freshwater is available. In 1950, the State's population of 2.77 million used about 2.9 billion gallons per day and by 1995, the State's 14 million people used 7.2 billion gallons of freshwater daily. In addition to the resident population in Florida, an estimated 41 million people visited the State in 1995. In 1995, Florida ranked fifth nationally in terms of total water use, eighth in water used for public supplies, and second to California in use of ground water for public supplies. Irrigation in Florida has expanded at such a rate that in 1995 Florida agricultural production ranked among the top ten states in the Nation, 13th in total water used for irrigation, and 10th in ground water used for irrigation (fig. 8).

Historically, ground water has supplied most of Florida's water needs, but increased demands have stressed this resource to its limit in many areas. As water needs increase, alternative sources of water and ways to store water are sought. Some alternative sources include surface water and desalination of brackish water. More recently, storage in and recovery of freshwater from aquifers has been successfully used in local areas of Florida and elsewhere, and is under further investigation as a viable alternative to above-ground surface water storage. This process is known as aquifer storage and recovery (ASR) (fig. 9). Florida also has large agricultural and industrial users of water resources competing for the finite water resources of Florida. The development and allocation of water resources is anticipated to continue to be of major concern in the immediate and long-term planning for the State.

Figure 8. Agricultural water use.

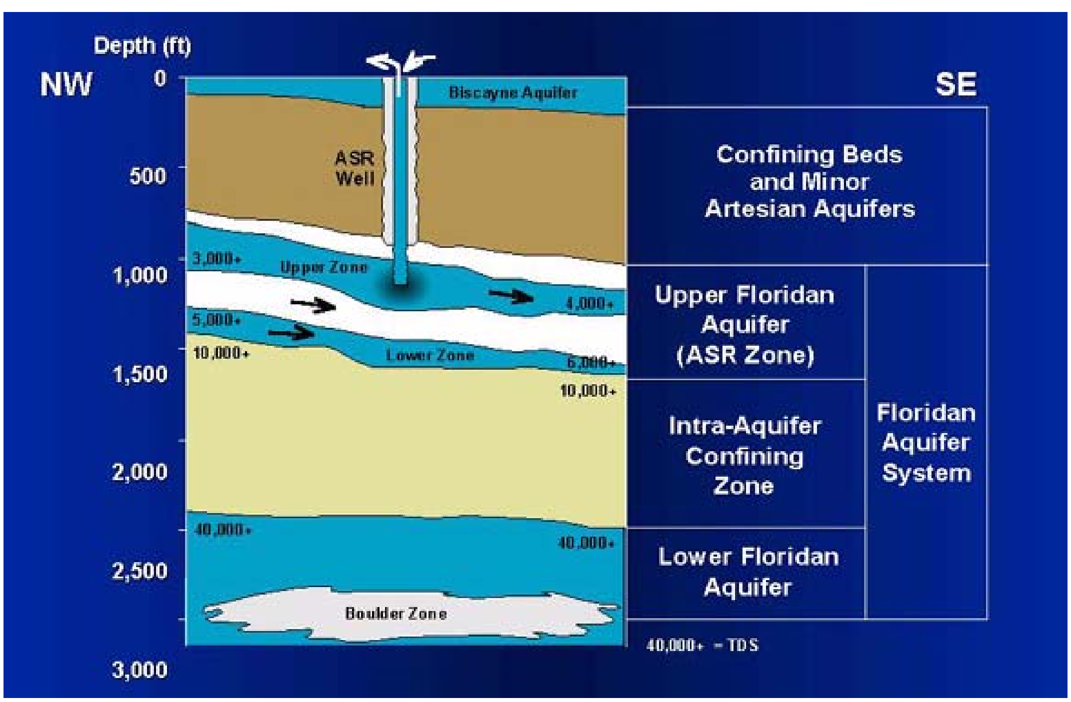


Figure 9. Conceptual hydrogeologic cross-section illustrating aquifer storage and recovery (ASR) in south Florida.

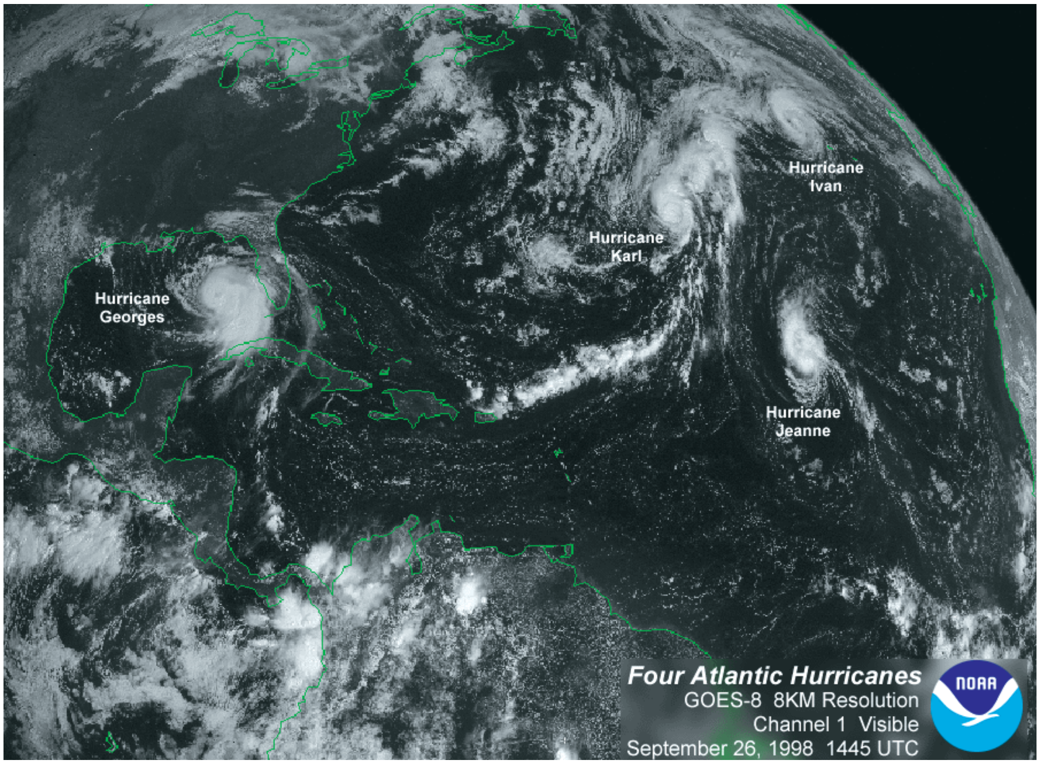


Figure 10. Satellite image of the Atlantic Ocean and the eastern coastline of the United States during a particularly active period of hurricane activity in 1998.

Florida's natural resources and climate that attract new residents and visitors also contribute to its susceptibility to hydrologic hazards, including floods, droughts, hurricanes, thunderstorms, hailstorms, and lightning strikes (fig. 10). The USGS provides hydrologic data and studies that can improve the understanding of effects resulting from some of the hydrologic hazards common to the state. Activities associated with the hazards mission of the USGS include long-term monitoring and forecasting, real-time monitoring, and evaluation of effects after flooding events to provide valuable data that can be used to mitigate the impact of future events and aid in preparation of risk assessments.

The karstic terrain of the State makes the ground-water resources particularly vulnerable to contamination from surface activities. Changing land use, as a result of development, changes the characteristics of the quality of water recharging the aquifer or entering surface-water systems. Contaminants from industrial, commercial, agricultural, and residential land uses have the potential to enter surface and ground waters. Some constituents, such as nutrients, pesticides, and selected organic compounds, have been studied; others, including pharmaceuticals and endocrine disruptors, are beginning to receive increased attention as contaminants of concern to human and environmental health (even at very low concentrations). The potential for the presence of these contaminants in ground water and surface water represent a new area of data collection and investigation for the USGS in Florida.

Rather than evaluating point and nonpoint contaminant sources separately, the concept of integrated or total loading to receiving water bodies from both sources is being used in the State to realistically evaluate contaminant impacts and serve as a basis for regulation of these sources. Total Maximum Daily Loads (TMDLs) are being determined based on water-quality data and discharge data for rivers and streams and lakes in the State. These water bodies have been prioritized according to the degree of degradation of water quality, based on existing data.

The Florida of 150 years ago was a vastly different place from what it is today because of entrepreneurs who saw opportunity in the state and modified the landscape to accommodate their visions

Figure 11. Aerial photograph showing the meandering course of a natural stream channel of the Kissimmee River.

Figure 12. Aerial photograph showing a drainage canal in south Florida.

of the future. Through the 20th century large tracts of land were "reclaimed" through industrious civil engineering projects that created vastly different ecosystems than what was originally in place. The primary tool for overhauling the landscape was the digging of canals to connect lakes for navigation and to convert wetlands to land suitable for agriculture or other uses. Late in the 20th century, the value of the natural systems was recognized and plans were made to restore as many areas as possible to their natural conditions. The effort to restore ecosystem functions has now become a defined societal goal that has broad public support. The Everglades, the Kissimmee River Basin, and Lake Apopka are examples of current efforts in the State (figs. 11 and 12). Preservation and restoration of ecological systems are important driving forces because of the close connection between ecological functions, hydrologic system characteristics, and human health.

U.S. Geological Survey Role and Capabilities

To provide the Nation with reliable, impartial information to describe and understand the Earth, the USGS mission supports water-related, geologic, biologic, land use, and mapping studies that contribute to the safety, health, and well-being of Florida's citizens. The work conducted to meet the goals of the science issues identified in this Science Plan is divided into three general categories: basic data collection, hydrologic investigations, and research. The USGS in Florida has the capability to conduct multidisciplinary work to address these science issues because of the availability of expertise in geologic, biologic, and water resources. In addition to the available personnel in the State, expertise is available nationally and can be called upon as needed for interdisciplinary investigations, training of local personnel, and development of new approaches and technology to address the complex science issues of the State.

The USGS is the Department of the Interior's science agency; it is a multidisciplinary, non-regulatory, and non-advocacy agency, and it has an established, long-term presence throughout Florida. The Florida District has programs underway that include surface- and ground-water monitoring networks, investigative and research studies with local agencies, and parts of nationwide initiatives such as Place-Based Studies and National Water Quality Assessment (NAWQA) programs. In addition, the presence of large areas of public land administered by the National Park Service (NPS), Fish and Wildlife Service (FWS), State agencies, and Florida Water Management Districts offers opportunities for cooperative work between the Florida District and these agencies. Opportunities also exist to cooperate with Tribes and other agencies such as the Environmental Protection Agency (EPA), National Oceanographic and Atmospheric Administration (NOAA), U.S. Army Corps of Engineers (USACE), Florida Department of Environmental Protection (FDEP), Florida Department of Agriculture and Consumer Services (FDACS), other State agencies, and universities that are conducting research on or near public lands. Through the Federal-State Cooperative Water Program, the Florida District plays an active role in water-related geologic, biologic, land use and mapping issues in many parts of the State by providing reliable, timely and impartial information needed to understand and wisely manage water resources (fig. 13).

The need to understand systems and processes on a watershed scale is most closely linked to the USGS mission goal "to provide science for a changing world in response to present and anticipated needs to expand our understanding of environmental and natural resource issues on regional, national, and global scales and enhance predictive/forecast modeling capabilities." The multidisciplinary approach to watershed science that is necessary to evaluate natural systems introduces opportunities for collaborative efforts within the USGS and with partners in the State.

The USGS is uniquely qualified to evaluate the effects of development, both past and present, on ecosystems, because of the breadth of experience available from all the programs of the USGS. The ongoing ecosystem restoration work in the Florida Everglades (a "Place-Based Study") has involved individuals from all the USGS programs (water, geology, biology, and mapping) and is a model for future collaborative studies. Other natural systems, where restoration is planned or is already underway (such as the Kissimmee River), offer additional opportunities for collaborative work.

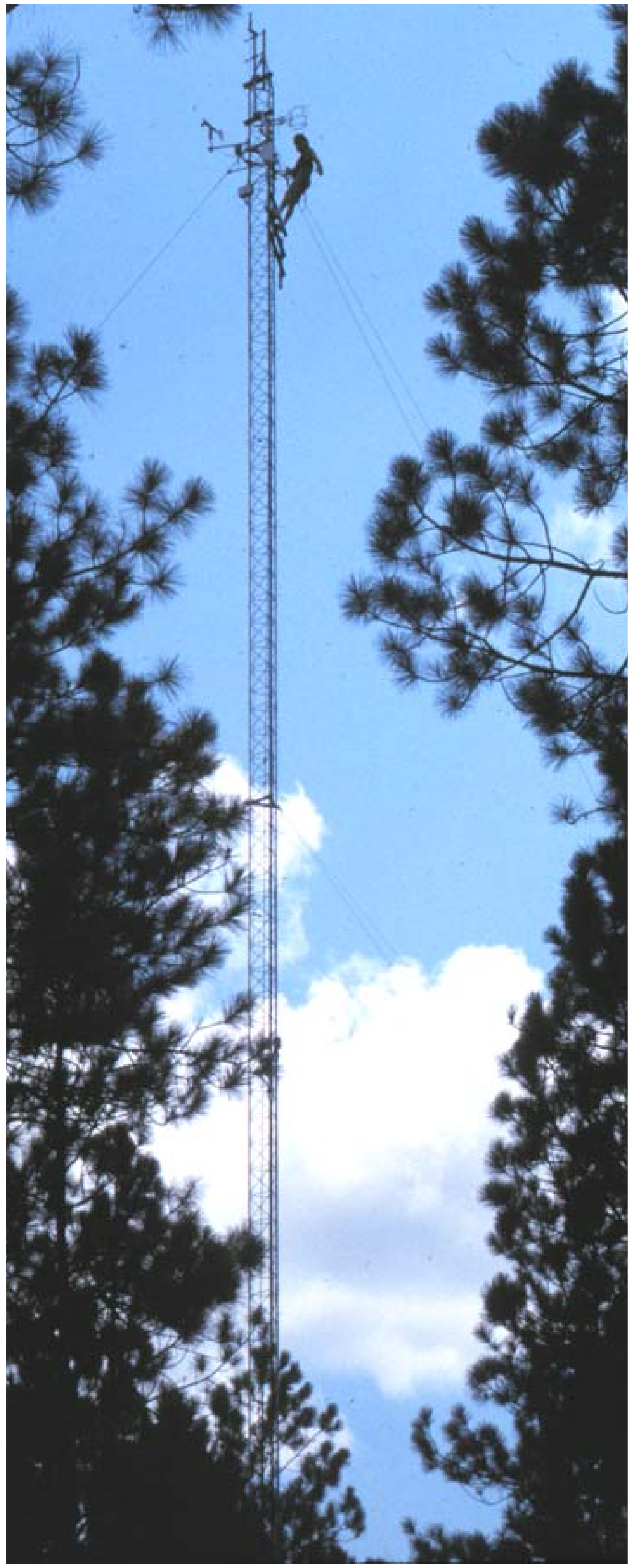
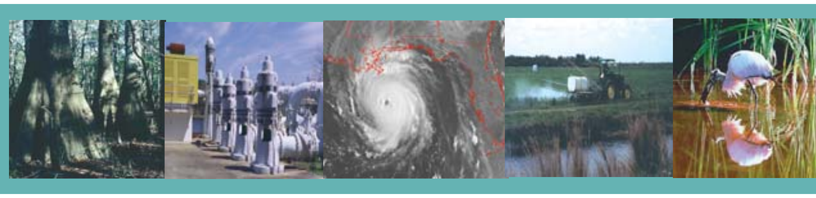


Figure 13. U.S. Geological Survey employee servicing equipment on a tower in Volusia County, Florida, used to measure evapotranspiration (ET) from an area of pine forest.

Acknowledgments

The Florida Science Plan Team extends appreciation to Teresa Embry, Ron Spencer, and Jim Tomberlin of the Florida Scientific Reports Production Unit for their work on this report and visual presentation.

KEY SCIENCE ISSUES



Issue 1: Watershed Systems and Processes

Background

Florida's landscape has been subdivided into 53 hydrologic units that correspond to distinct surface-water drainage basins or "watersheds" (fig. 14). The term "watershed" specifically refers to an area that gathers water originating as precipitation and contributes it to a particular stream channel, lake, or other body of water. However, interactions between ground water and surface water typically result in a single dynamic flow system in many watersheds in Florida. Ground water and surface water are hydraulically connected through numerous karst features (such as sinkholes, conduit systems in the underlying limestone, and springs) that facilitate the exchange of water between the surface and subsurface, particularly where the Upper Floridan aquifer is semiconfined or unconfined. As a result, ground-water basin boundaries may not coincide with boundaries for surface-water basins, which means that there can be substantial flow of ground water across surface-water basin divides. Also, ground-water basin boundaries are not static; they can change with varying hydrologic conditions. Unique problems can arise in protecting both ground-water and surface-water quality in karst areas because of the direct and rapid transport of recharge through conduits to the subsurface and through resurgence by springs. In some watersheds, recharge from unknown drainage pathways to areas of discharge may contribute to contamination of water supplies.

Federal and State agencies have moved to a watershed approach for managing and protecting the quality of ground water and surface water and preserving the health of ecosystems. The holistic watershed approach now includes many different components (biota, ecosystem, air and water quality, land and water use) within the boundaries of a surface-water drainage area and focuses on interactions among these components. Watersheds provide a convenient natural accounting unit for calculating water budgets, chemical loading to surface water and ground water, and assessing ecological health that is not constrained by political boundaries. However, to adequately address ecosystem protection and other water-resources issues, several components of the hydrologic cycle need better quantification. For example, higher resolution of the spatial distribution of rainfall is needed because many watershed models are driven by rainfall data that presently introduce considerable uncertainty in simulation efforts. Better estimates of evapotranspiration are needed for improving the accuracy of water budgets and for quantifying recharge used in ground-water flow models. Better time resolution of loading of nutrients and other contaminants is necessary to determine the TMDLs for streams receiving contaminants from nonpoint sources. Basic hydrologic and water-quality data also are needed to provide baseline information for increased understanding of watershed processes, for evaluating causes of problems, for assessing the status of watershed resources, and for detecting and predicting trends. Various simulation models linking watershed components are needed to provide more effective decision-making support systems.

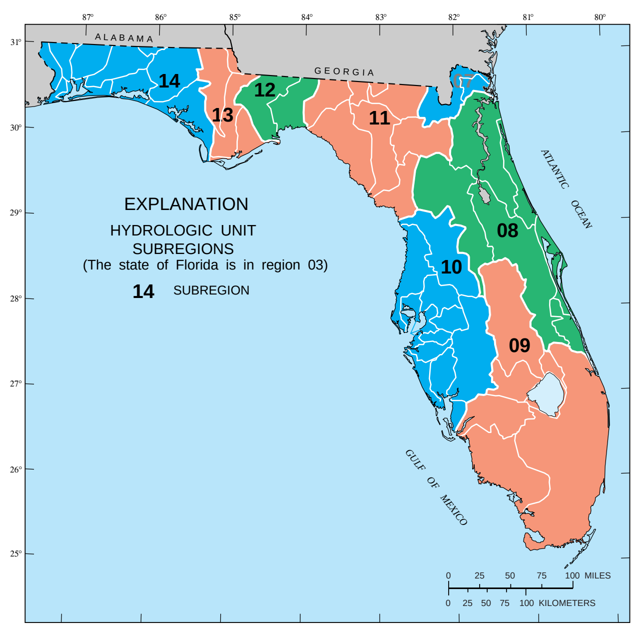


Figure 14. Map of major watersheds in Florida as delineated by hydrologic unit subregions.

Program Objectives

The USGS is in a position to take a leading role in watershed systems studies in Florida, with the ability to quantify hydrochemical interactions between the surface and subsurface, describe the hydrogeologic framework and ecosystem functions, and identify the myriad of processes that affect the movement of water within and through a watershed. To intensify and hone our efforts in watershed system studies, we should concentrate on the following activities:

- Improve methods for quantifying watershed water-budget components, such as rainfall, recharge, and evapotranspiration.
- Optimize the design of surface-water, ground-water, and water-quality monitoring networks to address key watershed issues.
- Link hydrologic, ecologic, land-use, and water-quality databases for watersheds using GIS techniques.
- Enhance existing watershed models and develop watershed models (where needed) to address interactions between ground water and surface water and contaminant loading (TMDLs).
- Collect and evaluate data on ground-water and surface-water resources to minimize the effects of state line issues on watershed assessment.

Current Program

Various components of watersheds are being investigated in numerous USGS projects across Florida. These studies include routine monitoring of the quantity and quality of surface water, ground water, and atmospheric deposition; simulation of the hydrologic flow system; and quantifying rainfall, evapotranspiration, recharge processes, and nutrient cycling. Surface-water data from flow-monitoring stations provide discharge information that is critical for understanding watershed systems. The data is used in calculating loading of contaminants, operating reservoirs, forecasting, determining status and trends in streamflow, calibrating watershed models, and planning for the disposal of wastes. Long-term data on ground-water levels provide information for evaluating effects of development, calibrating ground-water flow models, predicting future supplies, evaluating the response of hydrologic systems to induced stresses, and defining potential problems early enough to allow for proper planning and management. Examples of some current studies are listed below:

- The USGS; in cooperation with State, county, and other local government agencies; maintains an extensive network of surface-water and ground-water stations. In water year 1999, the USGS operated 354 continuous-record streamflow gaging stations distributed throughout the State in most of the 53 hydrologic units (fig. 15). Continuous ground-water levels were measured at 408 sites during water year 1999.

Figure 15. U.S. Geological Survey employee making a discharge measurement in a stream with tannic water.

- The USGS National Water Quality Assessment (NAWQA) Program is studying watershed processes that affect ecological systems and the quality of ground water and surface water in two study units (fig. 16). The Georgia-Florida Coastal Plain Study Unit, which began in 1991, has been studying the occurrence of nutrients, and pesticides in watersheds with predominantly urban and agricultural land uses, as well as interactions between ground water and surface water in the Suwannee River basin. The Southern Florida Study Unit, which began in 1994, has been focusing on the degradation of water resources in south Florida due to human activities. Some particularly severe impacts to surface and ground waters being investigated include nutrient enrichment, widespread occurrence of pesticides, mercury contamination, and reduction in abundance and diversity of native aquatic biota. The Southern Florida study also is estimating nutrient loading from point and nonpoint sources for nine watersheds as well as for canal and river outflows to estimate nutrient loading to coastal waters.

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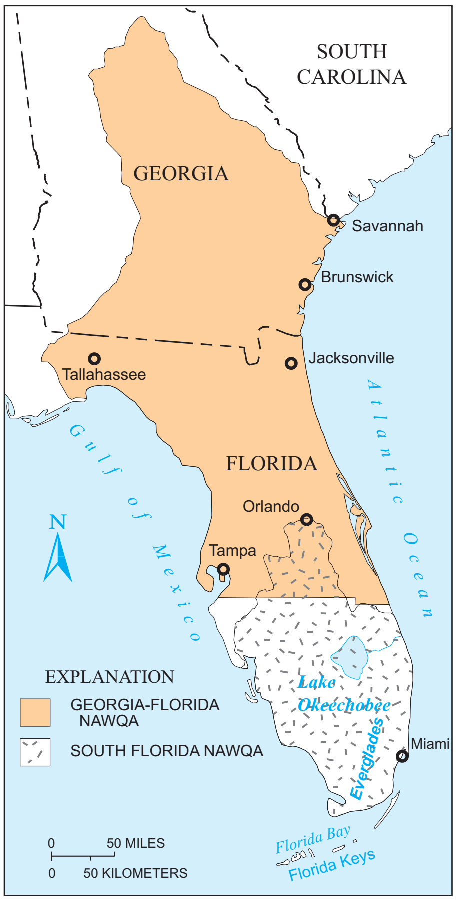


Figure 16. Map showing Georgia-Florida and South Florida National Water Quality Assessment (NAWQA) study units.

- Two large hydrologic budget components of watersheds, evapotranspiration (ET) and rainfall, are being studied in detail. Major efforts using several innovative methods are underway to estimate ET throughout the Everglades ecosystem and in the Tiger Bay wetland in Volusia County (fig. 17). A study is comparing digital information on rainfall amounts using Doppler radar data from the National Weather Service and measured data from rainfall gages throughout a watershed.

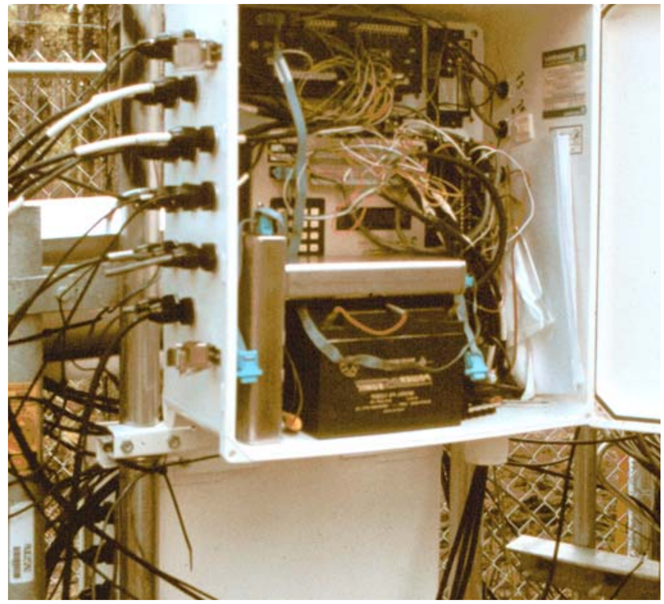


Figure 17. Data collection and storage equipment for an evapotranspiration site. (Sensors are located at the top of the tower to which this shelter is attached.)

- Understanding the relation between ground water and lakes is critical for managing water levels and protecting lake water quality. Several studies in central and west-central Florida are using steady- and transient-state ground-water flow models to evaluate the susceptibility of individual lakes to rapid changes in stage due to excessive pumpage and low rainfall. Another study is using an isotope mass balance approach to quantify ground-water inflow to lakes and to better understand the factors controlling ground-water exchange with lakes.

- Rainfall, aerosols, and dry fallout can contribute substantial quantities of substances of ecological concern that are dispersed in the atmosphere to watersheds throughout the State. Detailed measurements of these substances are essential for effective management of agricultural, forest, and aquatic ecosystems in Florida. Currently, as part of the National Atmospheric Deposition Program (NADP) and National Trends Network (NTN), the chemistry of wetfall is being monitored weekly at seven sites in Florida (Bradford Forest, Chassahowitzka National Wildlife Refuge, Everglades National Park, Quincy, Sumatra, Verna Well Field, and Kennedy Space Center.)

- The salinity of estuarine systems is critical for maintaining ecosystem integrity. The relation between ground-water head and spring flow is being studied in the coastal river basin of west-central Florida to determine the effects of increasing demands for freshwater on flow of three first-magnitude springs and 23 smaller springs in the basin. In south Florida, a variable-density ground-water flow model has been developed to quantify ground-water discharge rates to Biscayne Bay. Also, flow and transport of surface water and ground water are being simulated using the Tides and Inflows in the Mangroves of the Everglades (TIME) model for the Everglades and southwestern portions of Florida. Output from the TIME model will be used by the Across Trophic Level System Simulation (ATLSS) biological model, which simulates population dynamics for selected species.
- Several studies are investigating interactions between watershed components in the Suwannee River basin in Florida. Interactions between ground water and surface water are being simulated in the Lower Suwannee River basin using a coupled ground- and surface-water model. This model also is being used to test various scenarios of water withdrawals from the Suwannee River, the Upper Floridan aquifer, or both. A study of flood-plain habitats also is being conducted in the Lower Suwannee River basin to better understand water needs for maintaining healthy wetland ecosystems.

Issue 2: Water Resources Assessment and Availability

Background

Water availability will continue to be a major hydrologic issue in Florida. Currently the fourth most populated state in the United States, Florida is rapidly growing and pressures of population growth and development have adversely affected Florida's water resources. Ground-water pumpage has caused the lowering of lake and ground-water levels, reduction in streamflows, and saltwater encroachment. The quality of water supplies has been degraded by point and nonpoint sources of pollution and Florida's wetland, riverine, and estuarine habitats have been compromised by the reduction of freshwater flow and introduction of contaminants.

Although Florida has extensive water resources, most people live in coastal areas where less freshwater is available and population continues to increase. The need for additional water supply for coastal Florida presents a significant problem. Ground water that traditionally has been pumped from inland well fields to coastal areas will no longer be sufficient to supply the increasing water demands. To supply the projected water demands, water managers must either develop new, more expensive supplies, or develop alternative sources that in the past were considered to be of marginal quality. Water reuse and aquifer storage and recovery (ASR) practices will become critically important alternative sources of water for Florida in coming years. Surface water will be tapped to meet future water-supply demands. Saltwater desalination, well-field rehydration, and development of Florida's offshore springs are expected to see increased attention in the near future. These practices are viable alternatives to help maximize and maintain existing water resources.

Florida's challenge is to satisfy escalating demands for the finite quantities of water while preserving Florida's environment. In an attempt to preserve Florida's water resources, the State directed the five Water Management Districts in 1996 to establish minimum flows for streams and minimum levels for aquifers and surface water. The purpose is to identify a limit at which further water withdrawals would be significantly harmful to the water resources or ecology of the area. In response to this direction, methodologies are being established by each Water Management District for development of the proposed Minimum Flows and Levels (MFLs). However, no common approach is being taken by the Water Management Districts and the methodologies and data in developing the MFLs have been questioned. Water managers need up-to-date, sound scientific data to make informed decisions on the optimum allocation that would minimize impacts on the natural systems caused by water withdrawals.

Program Objectives

The Florida District remains committed to active participation in the water-resource activities of Florida. Program objectives for the District are to:

- Continue our role as a key participant with the State and other stakeholders in providing basic hydrologic data and information needed to manage the water resources in Florida.

- Optimize data collection networks and data dissemination.

- Develop and apply new and improved modeling and statistical techniques for analyzing complex ground- and surface-water flow systems, stream-aquifer relations, and solute transport.

- Improve our understanding of the processes involved in water resources assessment and availability.

- Expand studies and capabilities in fractured-rock systems.

Current Program

In 1999, the Florida District conducted about 80 hydrologic studies categorized as hydrologic data collection, hydrologic investigations, and applied research. Projects that deal directly with water-resources assessment and availability include, by broad categories:

Data-Collection Activities

- Collection of basic data for surface water, ground water, and quality of water.

- Assistance to the five Water Management Districts, Florida Department of Environmental Protection, and other State agencies in the collection, interpretation, publication and dissemination of water-use data.

- Collection of continuous water-velocity, water-level, and water-salinity data in Florida's rivers, and coastal and estuarine waters for monitoring effects of changes in freshwater flow.

Hydrologic Investigations

- Application of a wide assortment of regional, subregional, and local numerical simulation models to aid in the understanding of hydrologic system behavior for planning, evaluation, and design purposes.

- Investigations to determine the availability and sustainability of regional water resources for population growth management planning (fig. 18).

Figure 18. Public supply water intake in Bay County, Florida.

- Hydrogeologic characterization and mapping of the subsurface to provide sufficient detail to build reliable numerical models for making water-resource management decisions.

- Application of surface and borehole geophysical techniques for evaluating hydrogeologic heterogeneity and structure.

- Mapping of the current position of the saltwater interface and design of networks to monitor movement and the future location of the saltwater interface (fig. 19).

- Assessments of water-quality degradation.

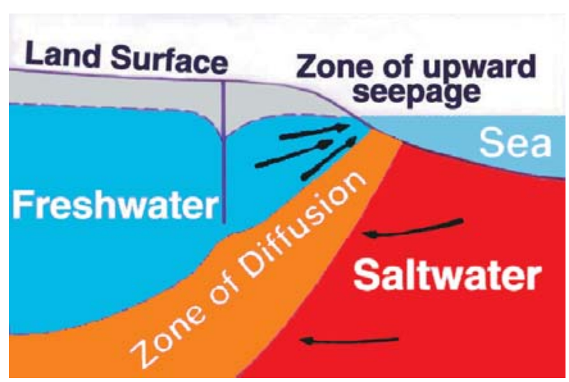
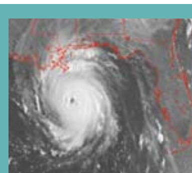


Figure 19. Conceptual diagram of saltwater-freshwater interface in an unconfined coastal aquifer.

Research studies on such topics as

- Evapotranspiration and natural ground-water recharge relations.
- Development of brackish ground-water resources.
- Interactions of lakes and wetlands with ground water.
- Chemical modeling of ground- and surface-water flow.
- Wetland processes.
- Feasibility of aquifer storage and recovery.
- Lake augmentation, raising lake water levels by pumping from ground water.

Issue 3: Hydrologic Hazards



Background

Extreme hydrologic events, such as hurricanes, tropical storms, and droughts, are commonplace in Florida and severely impact the citizens and resources of the State. Hurricanes and extreme tropical storms bring dangerous force winds and heavy rainfall into flood-prone areas and cause elevated sea level near shorelines, leading to loss of property and life. Continued urbanization in the State of Florida, specifically along the coastline, can further alter watershed characteristics and increase the probability of flooding. Drought conditions deplete the State's water resources. Water level fluctuations in the surficial and Floridan aquifer systems, whether through natural fluctuations or triggered by increased water pumping, can result in the formation of sinkholes, which pose a risk to property and life. Long-term hydrologic impacts are caused by global warming. The low topography, specifically in south Florida, and the extensive coastline make Florida extremely vulnerable to the consequences of sea-level rise. A gradual rise of only a few inches can flood thousands of miles of coastline and destroy shoreline property.

Program Objectives

The USGS plans to continue monitoring and documenting the occurrence and magnitude of extreme hydrologic events, and studying the basic processes underlying these events. The information gleaned from these activities will improve the ability to forecast probability of occurrence and likely magnitudes of future events. USGS program objectives in Florida include:

- Providing comprehensive information on the elevation and extent of storm surges in cooperation with Federal Emergency Management Agency (FEMA), U.S. Army Corps of Engineers (USACE), and other local and State emergency agencies.
- Processing and disseminating relevant hydrologic information to customer agencies in a timely manner for emergency management and evaluation of remedial measures needed in the aftermath of a storm or any other hydrologic event (fig. 20). These agencies depend on our data to make decisions that affect life and property; therefore, data collection programs must be responsive to changing expectations and needs for USGS water resources data.

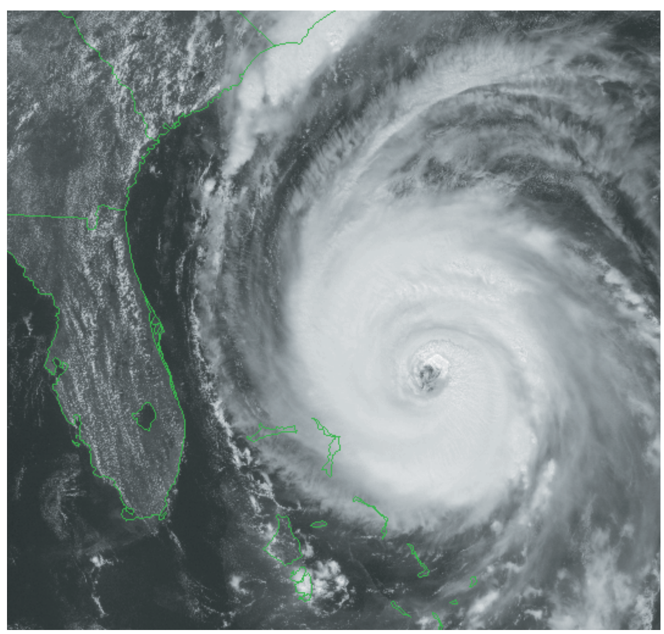


Figure 20. Satellite image showing a major hurricane threatening the southeastern coastline of the United States.

- Improving the coordination and understanding of the roles that various agencies have for the collection and distribution of information related to hydrologic events.

- Identifying hydrologic problems in urban areas and providing the necessary information to assist water managers in selecting appropriate development strategies to remediate current problems and avoid future flooding.

Current Program

Current USGS efforts dealing with the collection and analysis of data related to hydrologic hazards in the State of Florida include the following:

- The USGS, in cooperation with many State and local agencies as well as the USACE and FEMA, measures water levels and flood flows, and surveys storm surges after landfall of extreme tropical storms and hurricanes (fig. 21).

- Flood frequency studies are being conducted for sections of southwest Florida.

- The USGS water resources staff, in cooperation with numerous state, county, and other federal agencies, has established extensive monitoring networks to determine long- and short-term ground-water level fluctuations and changes in surface-water flows throughout the State.

- Satellite telemetry and other technologies have been applied to monitoring networks at key sites around the State to provide real-time information on ground-water level and surface-water discharges to local, state, and other federal agencies engaged in resource management and protection. Most of this information is currently made available on the Internet.

- Ground-water network analyses are part of ongoing efforts in south Florida to maximize the efficiency of the information generated and to avoid redundancy.

Figure 21. Coastal flooding during a hurricane.

- Potentiometric-surface maps are produced to describe annual and seasonal ground-water level fluctuations of specific aquifers.
- Drought-alert networks are currently being established, or expanded, to provide real-time information on the Internet to local, State, and other Federal agencies involved in the management, regulation, and preservation of Florida's water resources.
- Water-quality sampling following storms documents possible increases in pollutant transport within the ground-water and/or surface-water systems.

Issue 4: Occurrence, Transport, and Fate of Contaminants

Background

Because of Florida's karstic terrain, ground water and surface water are linked in an interactive system and contaminants entering one part of the system can, and do, move to other parts of the system. The term contaminant is used to describe any constituent or substance that is undesirable at a given point in time or location. For example, saltwater is not a contaminant in the Gulf of Mexico, but if it moves into an aquifer or river reach that has always been fresh, it becomes a contaminant. Conversely, freshwater may become a contaminant to an estuary when large volumes are discharged for flood-control purposes. Or, clean sediment may be termed a contaminant when it causes unnaturally high levels of turbidity for extended periods of time.

The occurrence of contaminants is directly related to stresses associated with agricultural, industrial, and urban development and population growth (fig. 22). The occurrence, transport, and eventual fate of contaminants are of concern to the human population, but contaminants have an equal or more profound effect on the numerous plant and animal communities found in the State. Contaminants originate from both point sources, such as sewage treatment plant effluent and industrial discharges, and nonpoint sources, such as atmospheric deposition and stormwater runoff. As defined in the preceding paragraph, contamination also may result from natural phenomena such as sediment transport and tidal exchange.

Excessive nutrient loads contribute to eutrophication in receiving waters. In the Everglades, the availability of phosphorus generally limits the degree of eutrophication. However, phosphorous is naturally abundant in areas of central and northern Florida and, unlike much of the rest of the country, the availability of nitrogen generally limits eutrophication in those areas.

Nitrate concentrations higher than 10 micrograms per liter (mg/L) are found in ground water in many areas of the State as a result of fertilizer applications and confined animal feeding operations. Many of Florida's springs discharge high-nitrate ground water into streams and coastal waters. Stormwater runoff from fertilized land areas, discharge from sewage treatment plants, and leachate from septic tank drain fields can also increase nitrogen loads.

Organochlorine pesticides have been detected in fish that are part of the Everglades food chain since the late 1960's. Even though DDT was banned for use in the United States in 1972, DDT or its degradation products were detected in 25 of 27 fish samples from 15 sites in south Florida in 1995. In 1997, agricultural areas around Lake Apopka were reflooded as part of a restoration effort for the lake,

Figure 22. Pesticide application in a vegetable farming area.

but within a year more than 1,000 waterfowl died. Investigators believe that, when the former farming areas were flooded, pesticides in the soils were released into the water column resulting in the bird deaths.

Florida is one of 28 states that has issued health advisories to restrict fish consumption because of high levels of mercury (fig. 23). In south Florida high levels of mercury have been found in various species of fish and in alligators, raccoons, and panthers. The sources of mercury and processes controlling its transport and accumulation are not well understood, but atmospheric deposition patterns may play a significant role. Methylmercury is the more toxic bioaccumulative species. Because of the existing burden of mercury in the environment, recycling of mercury between demethylated and methylated forms can provide a source of methylmercury even if atmospheric deposition ceases. There also is concern that nutrient removal may promote the release of sediment-bound mercury or an increase in the methylation of mercury.

Microbes such as giardia and cryptosporidium have been found in surface water sources in the State. Proposals to develop ASR systems for water supply raise the possibility that these microbes could be introduced into the ground-water system. Ground-water systems also could be affected by disinfection byproducts resulting from the treatment of surface waters prior to storage using ASR systems.

Ground water, surface water, reclaimed water, and desalinated water will be blended in various proportions throughout the year to provide water in west-central Florida. One major proposal calls for storing this blended water in a reclaimed phosphate area, which characteristically has high levels of radiochemicals. Blending various source waters may induce unforeseen chemical, geochemical, and biochemical reactions in the blending, storage, treatment, and/or distribution systems. Recently, a lake in west-central Florida that was being augmented with potable-quality ground water was found to have a build up of radium in the sediments.

The proposed use of reclaimed water to augment potable supplies raises questions regarding the occurrence, transport, and fate of microbes and viruses, as well as pharmaceuticals and various disinfection byproducts. Even if reclaimed water was not being considered for use in potable supplies, the potential impacts of microbes, viruses, pharmaceuticals and disinfection byproducts on the plant and animal communities of receiving waters must be considered. Endocrine disruption and development of antibiotic-resistant strains of bacteria may be linked to the presence of pharmaceutical agents in water bodies.

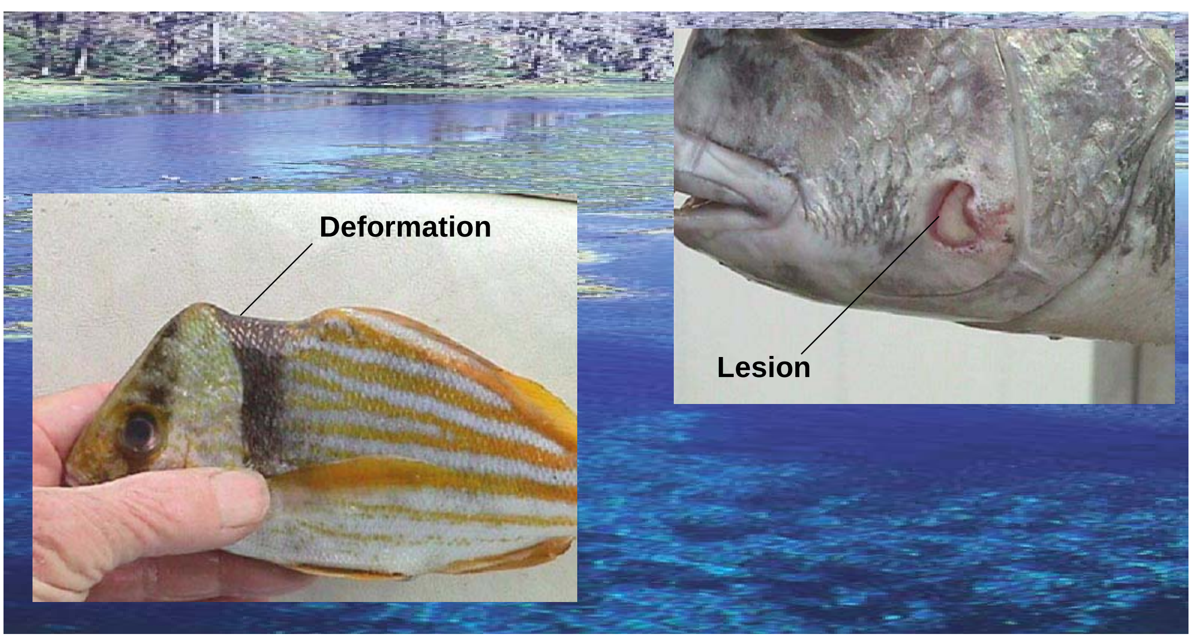


Figure 23. Fish affected by high levels of mercury.

Program Objectives

To address the concerns associated with the occurrence, transport, and fate of contaminants, the USGS program must include a mix of process-oriented research, long-term monitoring, methodological development, and synoptic studies. Specific objectives of this program are to:

- Optimize data collection networks to complement national programs, maximize transferability, and minimize redundancy with other programs and agencies.

Figure 24. Pharmaceutical compounds.

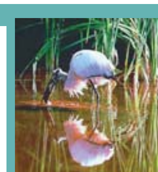
- Investigate radiochemical substances in ground water and surface water.
- Develop and improve field sampling and laboratory detection methods for emerging contaminants such as pharmaceuticals, pesticides, disinfection byproducts, and other organic compounds (fig. 24).
- Develop, test, and apply new methods for evaluating, interpreting, and reporting on water-quality data.
- Develop process-oriented research projects to evaluate hydrogeochemical and biogeochemical reactions associated with occurrence, transport and fate of contaminants in fresh and brackish surface-water and ground-water systems.

Current Program

Several Florida programs focus on the collection and analysis of data that can be used to evaluate the occurrence, transport, and eventual fate of contaminants in surface-water and ground-water systems. These include:

- Assessment of water and sediment quality in the Georgia-Florida Coastal Plain and in South Florida, including the Everglades, as part of USGS NAWQA studies.
- Research centered on the biological and chemical processes that affect and control the cycling of nutrients, mercury, and other contaminants as part of south Florida ecosystem restoration studies.
- Use of isotope tracers to determine the sources and chronology of contamination in lakes, streams, and springs.
- Use of acoustic and optic techniques to measure suspension of sediments in streams and estuaries.
- Long-term continuous salinity monitoring and monthly water-quality sampling in the tidal Peace River to determine the consequences of increased freshwater withdrawals and changes in the salinity regime over the next 20 years.
- Monitoring and evaluation of the effects of excess freshwater discharges into estuaries on both the Atlantic and Gulf coasts.
- Evaluation of the effects of septic tank removal on water quality in areas of the St. Johns River basin.

Issue 5: Preservation and Restoration of Ecosystems, with Emphasis on the Everglades



Background

Florida encompasses a diverse group of natural ecosystems including unique ones, such as large freshwater springs in the central and northern regions, the Everglades and Big Cypress Swamp in the south (fig. 25), and coral reefs along the southeastern coast.

Figure 25. Northern Big Cypress Swamp.

All of Florida's ecosystems are threatened by human growth and development. Bottomland hardwood and pine forests in the north have been cut and replanted or developed as farms or residential lands. Pine flatwoods, prairies, and upland scrub throughout the peninsula have been converted to citrus groves, pastures, or urban land. Massive drainage projects, particularly in the south, have significantly impacted wetlands, rivers, lakes, and estuaries; many of the State's wetlands have been lost. Along the coast, intensive urban development has replaced natural ecosystems and has degraded beaches, marshes, mangrove forests, estuaries, and bays (fig. 26). Ecosystems that are protected in parks, refuges, preserves, and other public lands have been impacted by development beyond their boundaries. Intense competition for water and land, input of nutrients and contaminants, suppression of natural fires, introduction of exotic species, and potential climate change are all threats. Even the largest protected areas, such as the Everglades, are degraded and face continuing environmental assaults.

About half the Everglades has been lost to drainage and development since the early 1900's, yet it remains the largest subtropical wetland wilderness in the United States. Most of the remaining Everglades is included in Everglades National Park (ENP), Water Conservation Areas, and Loxahatchee National Wildlife Refuge, where, though protected from physical destruction, it is degraded by nutrient enrichment, contaminants, exotic species, and altered freshwater inflows. The Everglades requires seasonal inflows of uncontaminated freshwater to maintain its ecological integrity, yet freshwater is limited and there is intense competition for this resource between the remaining natural ecosystem, agriculture, and the rapidly growing urban system.

A consensus has recently emerged among Tribes, Federal and State agencies, as well as environmental groups, that the south Florida ecosystem, and the Everglades in particular, should be protected and restored to the extent possible to its predevelopment condition. A first and primary step in this undertaking would be the restoration of predevelopment hydrologic conditions to the remaining natural system. Plans are being made, under the USACE Comprehensive Everglades Restoration Plan (CERP), to change the man-made water-conveyance system to restore the natural hydrologic cycle of the predevelopment Everglades; scientists expect this will lead to overall ecosystem restoration.

Figure 26. Marshlands in south Florida.

Program Objectives

Ecological restoration is a primary activity and concern in Florida today. Billions of dollars will be spent to protect and restore Florida's remaining natural ecosystems. The USGS should remain committed to active participation in this endeavor by:

- Increasing the role of USGS in providing the science needed for restoration.
- Working cooperatively with others to develop multidisciplinary investigations in support of ecosystem protection and restoration.
- Supporting development of models that link and integrate hydrologic and ecological processes.
- Continuing active participation and leadership in scientific committees and symposia that relate to ecosystem restoration.

Current Program

Two major USGS Federal programs that address issues of preservation and restoration are underway in Florida. These programs are the:

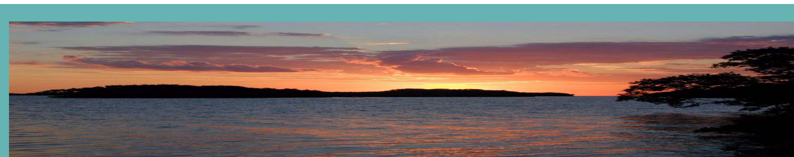
- Place-Based Studies Program.
- National Water-Quality Assessment Program.

The Place-Based Studies Program was established to provide sound science for resource managers in critical ecosystems throughout the country. The program, which began in south Florida in 1995, provides relevant information, high-quality data, and models to support decisions for ecosystem restoration and management. The program applies multi- and inter-disciplinary approaches including topographic mapping; hydrologic and geochemical evaluations; paleoecological studies to reconstruct the predevelopment environment; and hydrologic, chemical, and biological modeling to address regional environmental issues such as mercury contamination, nutrient enrichment, estuarine health, past and present water distribution and flow, and the dynamics of animal populations.

The National Water-Quality Assessment Program (NAWQA) was established to provide a consistent description of current water-quality conditions of the Nation's water resources; to define long-term trends (or lack of trends) in water quality; and to identify, describe, and explain the major factors that affect water-quality conditions and trends. NAWQA began in north Florida in 1991 and in south Florida in 1994, and covers most of the peninsula. Information generated by NAWQA is needed for aquatic ecosystem management and restoration. The USGS, in cooperation with Tribes as well as State, county, and other local government agencies, also carries out studies that contribute to ecosystem management and restoration, including:

- A study in the Suwannee River basin to evaluate effects of ground-water withdrawal and minimum river flows on the ecosystem, including downstream salinity, water quality, ground-water/surface-water interactions, and wetland habitats.
- A study of the relation between sources of nitrate in spring waters and changes in land-use patterns in the Suwannee River and other basins.
- Studies of lakes and wetlands in central Florida, including the effects of water level augmentation to restore the health of impacted wetlands by maintaining water levels that prevent harm to these ecosystems.
- A study of the source-water-quality characteristics of surface and ground waters near Lake Okeechobee is planned for use in ASR, a major component of the USACE CERP for Everglades restoration.
- Monitoring of streamflow and water quality in basins north of Lake Okeechobee is planned as part of the Lake Okeechobee Watershed Project, another component in the CERP.
- Studies of the effects of freshwater runoff on estuaries, including the Suwannee and St. Lucie Rivers.

PROGRAM OPPORTUNITIES AND PLAN OF ACTION



The USGS, Florida District, is well suited to carry out the necessary data collection, investigations and research needed to address the issues previously discussed. The Florida District can improve the understanding of processes that lead to or result from meteorological and hydrological events affecting the safety, health, and well-being of citizens of Florida. Together with water managers in the State, the Florida District has identified several areas of investigation that serve as future program opportunities. The opportunities emphasize multidisciplinary approaches that in many cases will yield results applicable to a number of the issues previously identified. The issues to which these opportunities will contribute most are shown in parentheses after each item.

Expanding and Improving Monitoring Networks

Although the USGS currently administers an extensive hydrologic monitoring network in Florida, opportunities exist for expanding and improving this network to add parameters which have not been previously measured, improve accuracy and precision for parameters currently measured, and achieve lower detection limits for some parameters. An essential element of this work will be the development of new instrument technology, equipment testing, equipment calibration and maintenance, and real-time telecommunications. Specific areas of opportunity include the following:

- Additional work is needed to adequately measure streamflow, suspended sediments, water quality, discharge in tidal areas, and ET. In particular, techniques to estimate flows at ungaged surface-water sites are needed. (Issues 1, 2, 3, 4, 5)

- The statewide ground-water network which provides statistical information on a regional basis should be reevaluated to ensure that it's design is optimum for providing the kind of information that will be required now and in the future. (Issues 1, 2, 3, 4, 5)

- The real-time data network for both ground-water and surface-water needs to be expanded with efforts directed towards the inclusion (on the Internet) of all data collected at sites with real-time capabilities. (Issues 1, 2, 3, 5)

- Saltwater encroachment in Florida's aquifers is a continuing problem and many opportunities will exist during the next decade for saltwater monitoring and development of numerical models to simulate movement of the saltwater interface in sensitive coastal areas. (Issues 1, 2, 3, 4, 5)

- Use of satellite imagery technology needs to be intensified to address the impact of urban sprawl and climate change on water resources and ecosystems (fig. 27). (Issues 1, 2, 3, 4, 5)

Figure 27. Satellite view of Florida.

- Additional data collection and analyses are needed to better understand the effects of scalping (diverting and storing high flows) surface water on rivers, wetlands, and estuaries. (Issues 1, 2, 5)

- The frequency of measuring water levels needs to be increased for wells tapping the surficial and Floridan aquifer systems in the Kissimmee River Basin to adequately monitor changes resulting from restoration efforts. (Issues 1, 2, 5)

Plan of Action:

- **Enhance delivery of data and information.**

- **Expand the current real-time hydrologic data network that includes ground-water, surface-water, and water-quality data that is accessible through the Internet.**

- **Expand monitoring techniques for studying sediment transport and resuspension.**

- **Develop a coastal network for monitoring surface-water and ground-water flows and loading of contaminants to estuaries.**

- **Increase the frequency of measuring ground-water levels in wells in the Kissimmee River Basin in collaboration with the South Florida Water Management District.**

- **Expand data collection and data-base development in support of ground-water flow and solute-transport models of the Floridan aquifer system.**

Watershed-Based Programs

Opportunities for watershed-based programs exist throughout the State at the regional, sub-regional, and local scale. A better understanding of watershed processes will help guide watershed restoration efforts as well as aid in developing strategies for effective management and protection of watersheds. The following activities represent program opportunities that are particularly well suited for USGS:

- Watershed and water-quality models can be used to address contaminant transport issues, particularly with respect to determining how much contamination from nonpoint sources in a watershed can be contributed to a stream without exceeding its total maximum daily load (TMDL). (Issues 1, 2, 4, 5)

- Hydrochemical methods can be used to quantify the transport and fate of nutrients and effects on aquatic ecosystems in springwater basins in collaboration with Florida's Water Management Districts and USGS biological resource programs (fig. 28). (Issues 1, 4, 5)

- Data from a statewide ET network can be used to provide ground-truthing information in conjunction with satellite-based regional estimates of ET. Possible collaborators include NASA and the Florida Department of Agriculture and Consumer Services. Also, ET studies can be integrated with vadose-zone hydraulics to provide a better understanding of recharge rates to aquifers in various land-use and climatic settings. (Issues 1, 2, 5)

- Hydrochemical and geophysical methods can be used to assess the importance of submarine ground-water discharge in coastal areas. This information is critical in maintaining ecosystem diversity and health of estuaries. Opportunities exist for collaboration with the Florida Fish and Wildlife Conservation Commission, NOAA, and USGS geologic and biologic programs to study coastal ecosystems with respect to tributary watersheds that impact these sensitive systems. (Issues 1, 2, 4, 5)

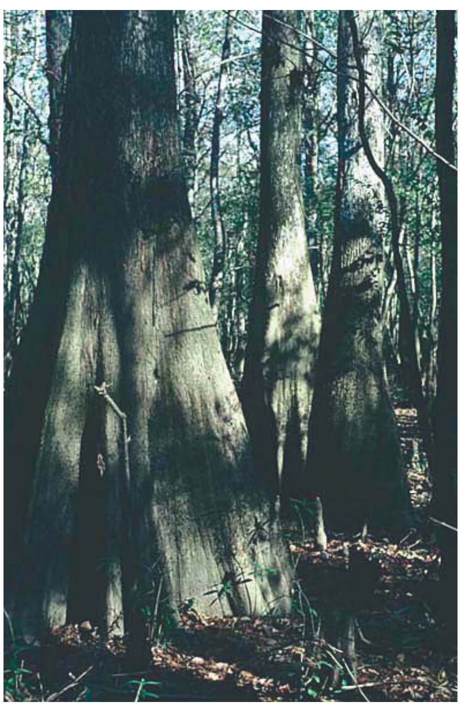


Figure 28. Cypress trees in Apalachicola River flood plain.

- Advanced modeling techniques can be used to simulate effects of ground-water withdrawals on water levels in karstic lakes, and effects of pumpage on springflow in central and northern Florida. (Issues 1, 2, 3, 5)

- Cooperation between the USGS and NOAA can be increased to use rainfall data from an extensive network of USGS stations throughout the State for ground-truthing Doppler radar information. (Issues 1, 2, 3, 4, 5)

- The design and suitability of current ground-water, surface-water, and atmospheric deposition networks for watershed-based analyses can be evaluated using stochastic and deterministic methods. (Issues 1, 2, 3, 4, 5)

- The USGS should serve as liaison for watershed issues that are shared among Florida, Alabama, and Georgia. (Issue 1, 2, 5)

Plan of Action:

- **Work with FDEP and Water Management Districts to conduct nonpoint source studies as part of the Clean Water Act (Section 319).**

- **Develop new skills in watershed modeling.**

- **Initiate studies to enhance existing models and develop new water-quality models on which to base TMDLs.**

- **In cooperation with other Federal and State agencies, develop a statewide ET network which would encompass a variety of soil and vegetation types for both natural and developed conditions. Also, conduct site-specific studies to develop a better understanding of ET processes, and use remote sensing in conjunction with ground truthing to develop a connection between satellite data and ET patterns.**

- **Initiate a cooperative program with NOAA to develop a rainfall network for ground-truthing Doppler radar information.**

- **Serve as liaison for the collection and analysis of ground-water and surface-water data for watersheds that span Florida, Georgia, and Alabama.**

- **Work more closely with State agencies in developing new hydrologic models.**

Ecosystem Programs

Opportunities for programs to monitor and study ecosystem health exist throughout the State and will increase as growth and development accelerate. Wetland and aquatic ecosystems, though reduced and degraded, are still widespread in Florida, whereas upland ecosystems have been largely eliminated or reduced to relict areas. The remaining wetland and aquatic ecosystems are vulnerable because of their need for uncontaminated freshwater--a resource that is becoming increasingly sought after to sustain continued urban growth in the State. These opportunities will be greatest in central and south Florida, where restoration is underway in the Kissimmee River Basin and the Everglades, where an $8 billion dollar restoration program is being planned. This CERP program will involve large structural and operational changes in the Central and Southern Florida (C&SF) project. These changes will require a substantial increase in available scientific data and understanding. Opportunities exist for the USGS to carry out data collection and investigations to provide this understanding. The opportunities include:

- Hydrologic characterization of the predevelopment (natural) system and determination of key characteristics that supported the rich diversity and abundance of wildlife in the past (fig. 29). (Issue 1, 2, 5)
- Assessment of the hydrologic and ecological results of Everglades restoration modifications through pre- and post-modification monitoring (Issue 1, 2, 5)
- Evaluation of historic water-quality trends in National and State Parks and surrounding lands. (Issue 5)
- Monitoring water flows and water quality at key locations relevant to Everglades restoration. (Issue 5)
- Developing hydrologic models, including flow, water quality, and transport models. (Issues 1, 2, 3, 4, 5)
- Linking hydrologic models with biological models, such as the ATLSS model. (Issues 1, 2, 5)

Plan of Action:

- **Develop a cooperative project with other Federal and State partners to evaluate long-term trends by analyzing historic water-quality data from National and State Parks and surrounding lands.**
- **Submit a proposal to the National Park Service's Critical Ecosystem Studies Initiative, the USGS's Place-Based Studies Program, and/or other potential partners, to link hydrologic and biological models.**
- **Implement the proposed program for evaluating the feasibility of ASR. This includes investigating improved methods to determine injection and storage capacities and better defining the geochemical character of source, resident, and recovered water for the CERP program.**

Figure 29. Alligator in Big Cypress Swamp.

Hydrogeologic Framework and Modeling

Opportunities exist to improve our knowledge of the basic geologic, hydrologic and hydrogeologic framework throughout Florida (fig. 30). Although the USGS and other agencies have conducted investigations over several decades, new water management challenges require reassessment of this work and application of newer and more advanced techniques to improve our understanding of hydrogeologic frameworks and processes. Specific areas of opportunity include:

- Enhancing our knowledge of subsurface conditions, particularly field determinations of aquifer and confining unit characteristics, to effectively evaluate the regional potential of ASR. (Issues 1, 2, 4, 5)

- Improving our understanding of ground water/surface water interactions and, in particular, the effects of ground-water withdrawals on streamflows, wetlands, lakes, and spring flow is needed to assist in water-resources assessments. (Issues 1, 2, 4, 5)

- Evaluating the potential for chemical reactions in aquifers as a result of storage and mixing of ground water, surface water, brackish, or reclaimed water in surface or underground reservoirs. (Issues 1, 2, 5)

Plan of Action:

- **Develop projects to better define the directions and gradients of ground-water flow, the hydraulic properties of the aquifer systems, and the nature of cavernous flow to Florida springs.**

- **Acquire new hydrogeologic data through drilling and geophysical data collection in support of future ASR projects.**

- **Develop proposals to study hydrogeochemical interactions associated with proposed ASR sites throughout Florida.**

- **Work more closely with the South Florida Water Management District in developing a regional density-dependent model of the Floridan aquifer system in south Florida.**

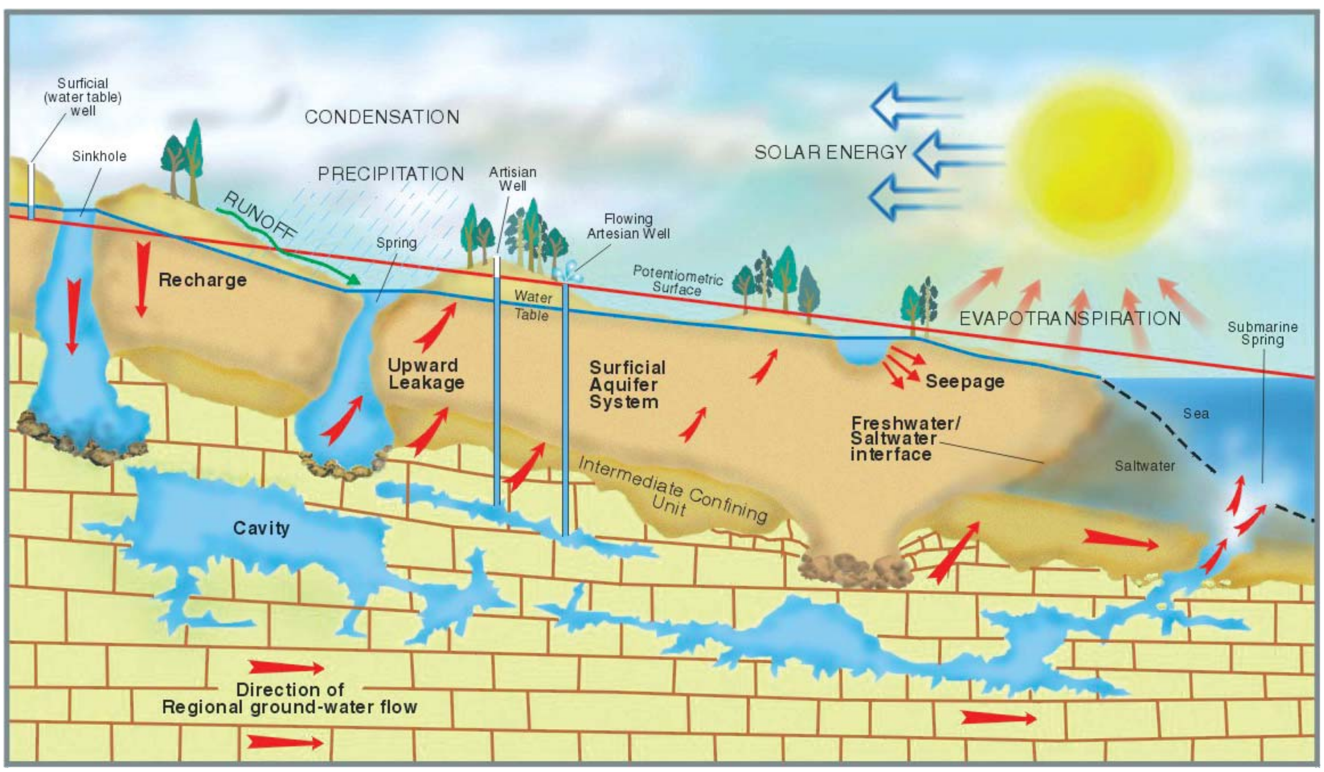


Figure 30. Conceptual illustration of a generalized cross-section through the Florida peninsula, showing karstic features and the hydrologic cycle.

Occurrence, Transport, and Fate of Contaminants

The widespread and increasing use of chemicals in agriculture and industry and the potential for harm which these pose both to human health and the natural environment offers additional opportunities for increasing our knowledge of their distribution and interactions in the environment. There are multiple areas in which the Florida District could develop programs dealing with the occurrence, transport, and fate of contaminants, as outlined below:

- Include the use of DNA ribotyping to identify sources of bacterial contamination. (Issues 1, 2, 4, 5)
- Develop an *in situ* monitoring program to evaluate the transport and fate of brine concentrate in estuarine and coastal waters. (Issues 1, 2, 4, 5)
- Develop a better understanding of the transport and fate of nutrients in reclaimed water in the subsurface at different scales. (Issues 1, 2, 4, 5)
- Identify sources of increased concentrations of nitrate in ground water and spring flow. (Issues 1, 2, 4, 5)
- Understand the movement of sediment and transport of associated metals and chemicals in Florida streams. (Issues 1, 2, 4, 5)
- Study the occurrence, transport, and fate of contaminants associated with confined animal feedlot operations. (Issues 1, 4, 5)
- Evaluate best management practices, including the use of wetlands, for the treatment of runoff. (Issues 1, 4, 5)
- Study the processes affecting the fate and transport of pharmaceuticals and other related chemicals in the environment (fig. 31). (Issues 1, 2, 4, 5)
- Evaluate the ecological impact of desalination facilities in coastal environments. (Issues 1, 2, 4, 5)
- Study the occurrence and fate of contaminants in drinking water, including organic compounds, disinfection by-products, radionuclides, and trace elements. (Issues 2, 4)
- Study the occurrence and fate of contaminants in natural ecosystems, including organic compounds, radionuclides, and trace elements. (Issues 1, 2, 4, 5)

Plan of Action:

- **Develop a project to investigate variations in the chemical characteristics of blended waters and work with State and Federal agencies to begin developing strategies and priorities for sampling and detecting compounds associated with reclaimed water.**
- **Develop a program for the study of the subsurface transport and fate of nutrients in reclaimed water, and how reclaimed water application rates and schedules can be modified to enhance the natural attenuation or removal of nitrogen and phosphorus.**
- **Promote projects that evaluate the fate of contaminants and transport of constituents and develop methods to identify common sources of contaminants in drinking water and natural systems.**
- **Use the results of recent reconnaissance sampling for emergent contaminants (pharmaceuticals, pesticides, endocrine disruptor compounds) to develop additional projects.**

Figure 31. Aerial application of pesticides in an agricultural area.

Hydrologic Hazards

The Florida District can improve the understanding of processes that lead to or result from extreme meteorological and hydrological events affecting the safety, health, and well-being of Florida citizens. Specific opportunities include:

- Completing statewide flood frequency studies to assist in emergency management operations. Rapid changes in the Florida landscape require periodic updating of these studies to reflect current conditions. (fig. 32) (Issue 3)

- Developing studies addressing the joint probability for storm surge and floods, a problem that can result from completely different meteorological events and yet pose similar threats to life and property (fig. 33). (Issue 3)

- Developing techniques for monitoring sinkhole-prone areas for early detection of sinkhole formation and collapse. (Issue 3)

- Improving techniques for monitoring and evaluating scour resulting from the passage of hurricanes and tropical storms. Scour along coastal bridges is an example of work that can be done in cooperation with the Florida Department of Transportation. Coastal erosion can be studies by the USGS (geologic and water resources staff) in cooperation with the USACE. (Issue 3)

Figure 32. Aerial photograph of a large sinkhole which formed in Winter Park, Florida, May 1981.

Plan of Action:

- **Install a network of Crest-Stage Indicators (CSI) along coastal streams to simplify storm surge surveys. After extreme storm events, the cork lines on the CSI's will serve as estimates of surge elevation.**

- **Prepare a proposal for a statewide flood frequency study, in cooperation with State partners, to update existing information.**

- **Work with USGS geologic staff and the Florida Geological Survey in the documentation of new sinkholes and development of a GIS coverage of sinkholes in Florida.**

- **Prepare a proposal to do stochastic modeling of the joint frequency distribution of storm surges and riverine flooding (Statewide).**

- **Prepare proposals to evaluate post-hydrologic event effects (ecological, hydrologic, ground-water, water quality) so that the USGS can be ready to take action in a timely fashion.**

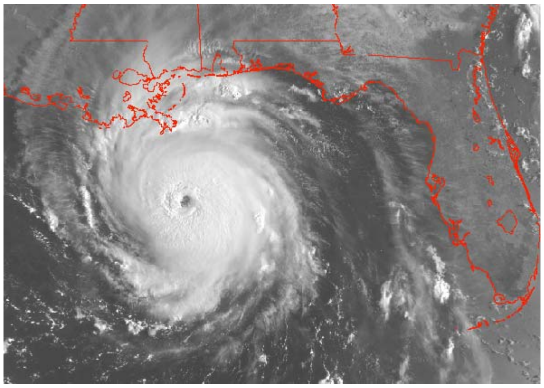


Figure 33. Satellite image of a hurricane in the Gulf of Mexico.

New Instrumentation, Equipment, Technology, and Methodology

Opportunities exist for the USGS to develop new methods and adapt existing and emerging technologies to support the collection of hydrologic information (fig. 34). The USGS is uniquely qualified to test new equipment, evaluate its application and reliability, and find applications for existing technologies (fig. 35). The USGS also evaluates models and analytical methods for applicability to unique, complex, hydrologic applications. Specific opportunities include:

- Development of analytical methods to study and collect information on newly recognized, emerging contaminants such as microbes, pharmaceuticals, pathogens, and endocrine disruptor compounds. (Issue 4)
- Evaluation of new instrumentation for specific applications in Florida, such as determining flow in low-gradient streams and transport and fate of contaminants in blackwater streams. (Issue 1, 2, 4)
- Development of new algorithms and modification/adaptation of models to the unique features of Florida, which address the hydrologic character of various areas of the State. (Issue 1, 2, 3)

Plan of Action:

- **Expand the capability of the Ocala Water Quality and Research Laboratory (OWQRL) to analyze pharmaceuticals, pathogens, and pesticides and their degradation products.**
- **Seek additional opportunities to continue testing the use of acoustic technology for the monitoring of suspended solids.**
- **Identify and test available instruments for application in hydrologic investigations. Select sites throughout the State for testing and verification of instruments.**
- **Expand application of remote data acquisition using non-contact sensors (such as radar for sensing water level).**

Figure 34. U.S. Geological Survey employees measuring discharge at a Florida Bay tributary station.

Figure 35. Sensors used for estimation of evapotranspiration using the Bowen-ratio technique in Everglades National Park.

Information Transfer

In keeping with the mission of the USGS to provide reliable, impartial, and timely information needed to wisely manage the Nation's natural resources in the public interest, the Florida District can transfer this information to where it is most needed. Specific ways in which information transfer can be accomplished include:

- Participating in national reconnaissance and research data collection efforts. Provide results from those programs to cooperators interested in comparative information (fig. 36). (Issues 1, 2, 3, 4, 5)
- Enhancing Internet capabilities to release data and interpretive reports in a user-friendly, timely manner. (Issue 1, 2, 3, 4, 5)
- Encouraging the use of historical data in evaluating long-term trends in water quality and quantity, and in water resources management. (Issues 1, 2, 3, 4, 5)
- Providing scientific information and expertise on hydrology, geochemistry, and ecology to local and regional watershed groups. (Issues 1, 2, 3, 4, 5)
- Providing a forum through which cooperators can standardize and improve water-quality data collection across the State. (Issues 1, 2, 3, 4, 5)
- Emphasizing the multidisciplinary capabilities of the USGS to address environmental issues in Florida. (Issues 1, 2, 3, 4, 5)
- Providing water-quality sampling methods, training, and quality-assurance/quality-control support to cooperating agencies. (Issues 1, 2, 3, 4, 5)

Plan of Action:

- **Continue to participate in national reconnaissance and research data collection.**
- **Pursue opportunities to collaborate with and support other Federal agencies and other USGS programs in Florida. Initiate and support periodic symposia and workshops for the exchange of ideas and information among USGS programs in Florida (biological, geological, mapping, hydrologic).**
- **Improve the transfer of hydrologic information to the Internet by prioritizing funding to support this effort.**
- **Identify and set aside funding for outreach activities that will provide transfer of technical information to local and regional watershed groups.**
- **Expand programs by the OWQRL to training cooperator agencies about water-quality sampling methods (such as ppb sampling protocols, and flow composite sampling of streams) and quality assurance/quality control of field sampling parameters (such as providing pH and specific conductance quality-control samples to cooperators).**

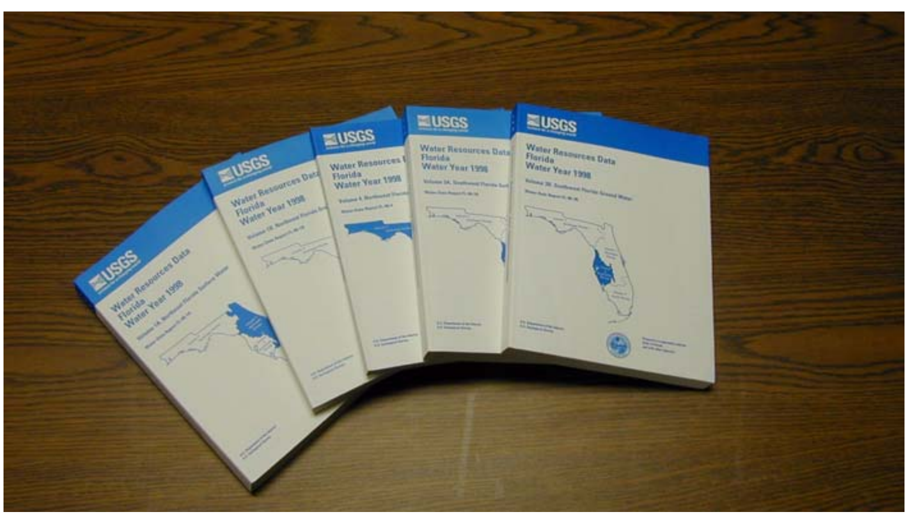


Figure 36. Annual Florida water data reports published by the U.S. Geological Survey.

The USGS in Florida

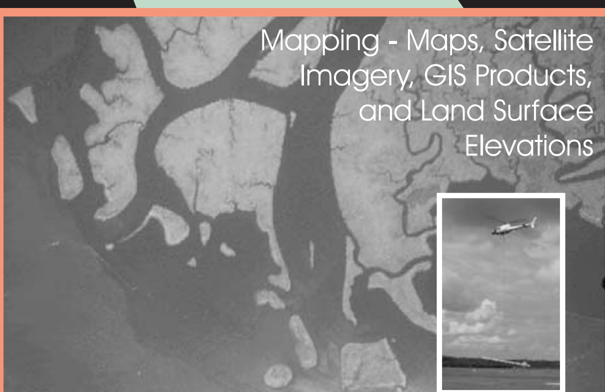



Multidisciplinary Ecosystem Restoration Studies

Geology - Coastal Processes, Systematic Mapping, and Remote Sensing

Hydrology - Ground Water, Surface Water, Water Quality, and Water Use

Biology - Manatees, Coral Reefs, Amphibians and Reptiles, Aquatic Fauna, and Nonindigenous Species



Mapping - Maps, Satellite Imagery, GIS Products, and Land Surface Elevations

USGS
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Florida Science Plan Team -- Science Plan, U.S. Geological Survey, Florida District
U.S. Geological Survey Open-File Report 01-180