# The Water Cycle in Volusia County

Prepared in cooperation with Volusia County

*Earth's water is always in motion. The water cycle, also known as the hydrologic cycle, describes the continuous movement of water on, above, and below the Earth's surface (fig. 1). This fact sheet provides information about how much water moves into and out of Volusia County, and where it is stored. It also illustrates the seasonal variation in water quantity and movement using data from some of the hydrologic data collection sites in or near Volusia County (fig. 2).*

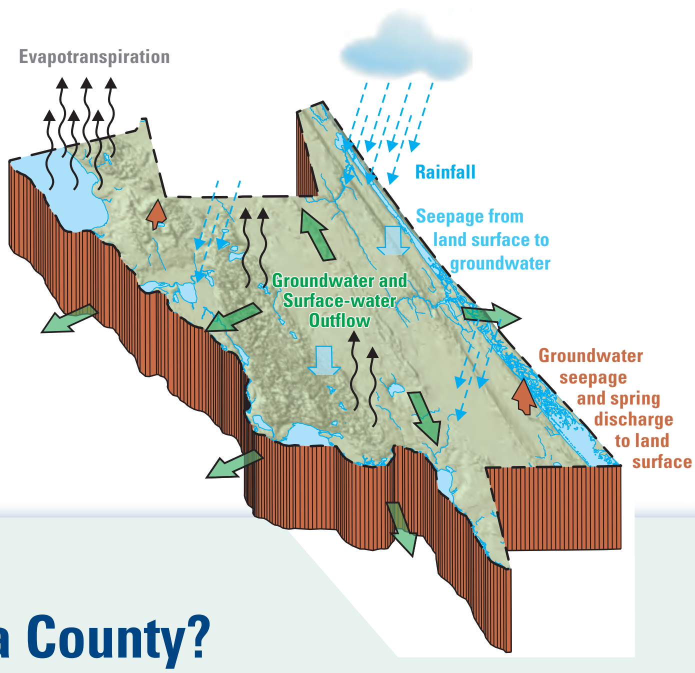



**Figure 1.** Major components of the water cycle.

## Where is the water and how does it move in Volusia County?

### Basic Concepts

Water that comes from the clouds in the form of rain is known as precipitation. Water from the clouds falls to the Earth and runs downhill into streams and lakes as surface runoff. Some of this runoff percolates into the soil and deep into the ground to be stored in the aquifer. Water travels from the aquifer through the springs back up to surface streams or to the ocean. Water transpires from plants and trees and evaporates from the Earth's surface and the ocean, returning to the atmosphere. Together these two processes are called evapotranspiration, or ET. The water vapor from ET condenses to form clouds which produce precipitation that falls back to the earth. This cycle of the never ending movement of water on the Earth is called the water cycle.

Most of the water in Volusia County is stored in three types of places—the atmosphere (where water occurs in water vapor and droplets); surface-water features such as lakes, wetlands, and streams; and in underground reservoirs known as the aquifers. The amounts of water in these three individual places are constantly changing as water moves from one place to another.

Human activity affects the movement of water between the three distinct storage places. For example, some people use water from lakes, streams, or aquifers for irrigating lawns and crops, or in industrial activities such as generation of electricity. Irrigation water is used by grass and other plants during photosynthesis. Some of the water taken up by plants is returned to the atmosphere through the process of transpiration. Irrigation water that is not used by the plants seeps (percolates) into the ground as recharge to the aquifers. Residents of Volusia County also use water pumped from the aquifers for drinking water and for household activities such as cleaning, bathing, and flushing the toilet. Some of this water ends up as wastewater and is treated in septic tanks or, more commonly, is discharged into sewers that transport the wastewater to wastewater treatment plants. Septic-tank drainage seeps back into the ground as does treated wastewater that is put into percolation ponds or sprayed onto the land surface at some wastewater treatment plants. However, in most coastal communities and near the St. Johns River, treated wastewater is discharged directly into rivers or estuaries and flows from the county.

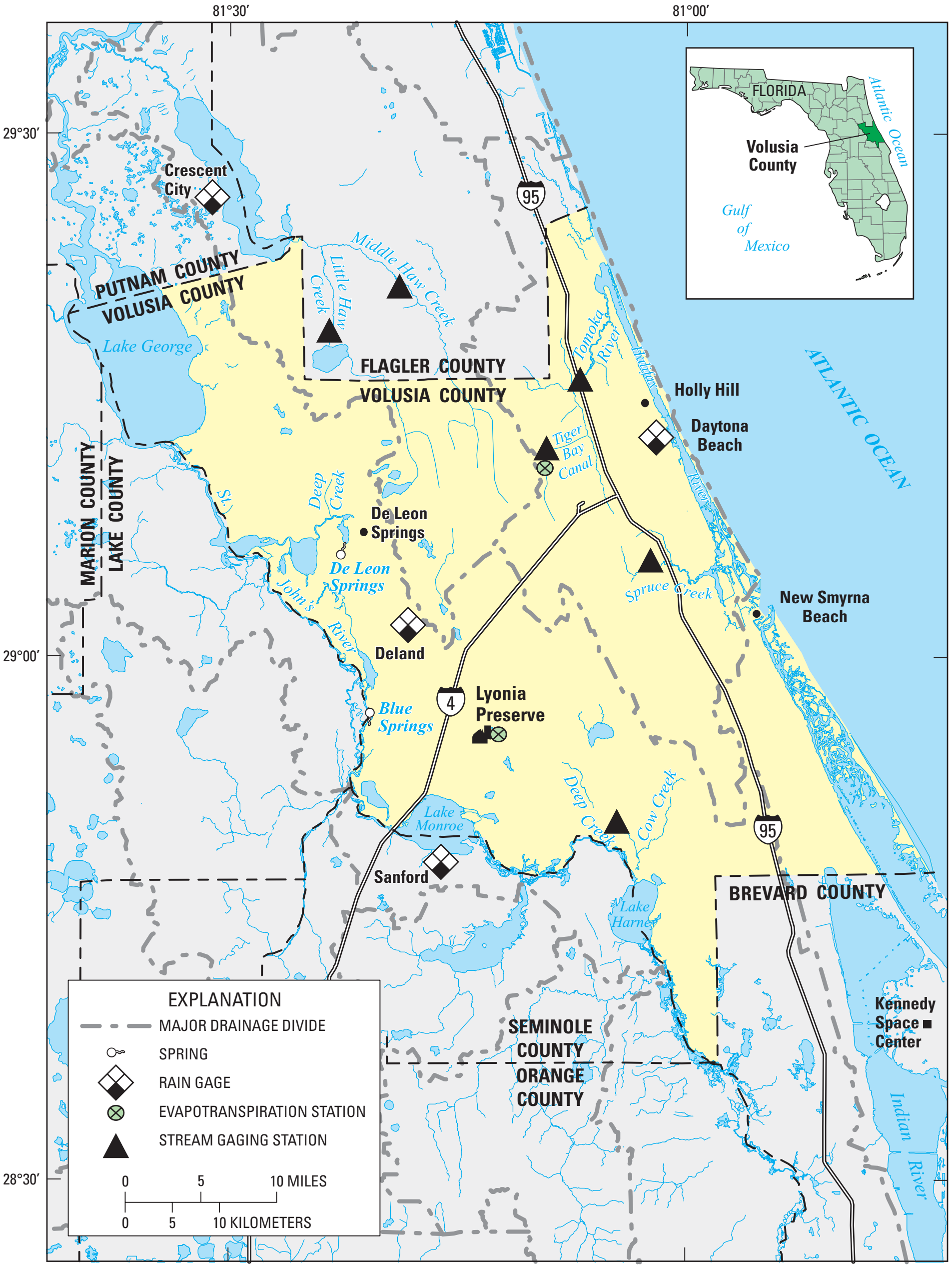



**Figure 2.** Surface drainage features and locations of hydrologic data stations.

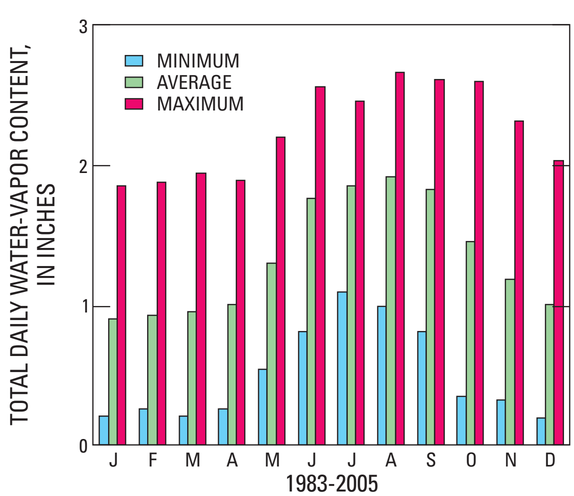



**Figure 3.** Total daily water-vapor content by month, 1983-2005 (data furnished by NOAA, from radiosonde station at Kennedy Space Center).

Water does not only move from one storage place to another. It is also in motion as streamflow on the land surface and as groundwater flow through the aquifers beneath the land surface. This motion is driven by gravity, as the natural behavior of water is to "flow downhill"; that is, from locations with higher water levels to those with lower water levels. Most streams in Volusia County begin within the county and flow into the coastal estuaries, the St. Johns River, or Flagler County (fig. 2). Likewise, the flow of groundwater is mostly from Volusia County to the areas with lower water levels, such as the St. Johns River, the coastal estuaries, the Atlantic Ocean, and parts of surrounding counties. Little groundwater flows into Volusia County. Thus, most of the water in Volusia County, both surface water and groundwater, is of "local" origin, as it ultimately results from the rain that falls directly on the county.

Of course the St. Johns River, on the western edge of Volusia County, drains parts of Volusia County and also a large area to the south of Volusia County. The St. Johns River is not considered in the water budget because flow in this river is along the edge of the county rather than through it.

## Storage of Water in the Atmosphere

There is always some water in the atmosphere. Clouds are, of course, the visible condensation of atmospheric water, but even clear skies contain some water—water in particles that are just too small to be seen.

The total amount of atmospheric water vapor in a vertical column of air (often called the precipitable water, or PW) is measured daily by the National Weather Service with radiosondes (weather balloons). The highest daily water-vapor content measured at the Kennedy Space Center radiosonde station (about 20 miles southeast of Volusia County) between 1983 to 2005 would be equivalent to a water depth of about 2.6 in. (inches) on the Earth's surface (fig. 3). This is less than the amount of rainfall that can be produced from a single thunderstorm in just a few minutes! Thunderstorms often produce amounts of rain that exceed the water-vapor content of the overlying atmosphere. This excess of rainfall over water-vapor content can occur because colliding air currents can

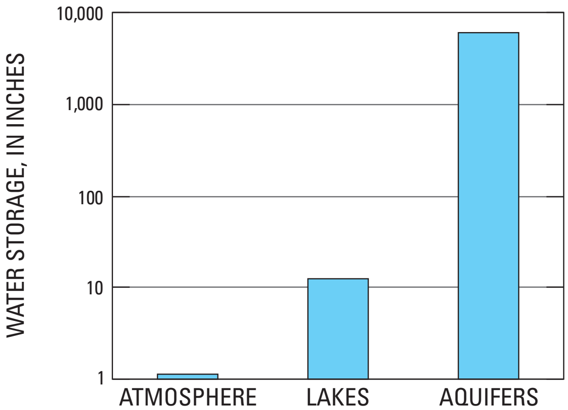
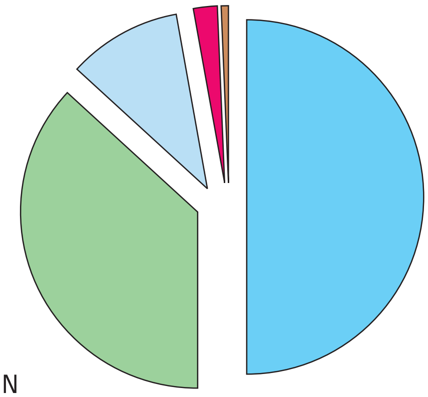



**Figure 4.** Estimated average water storage in Volusia County. (Amount of storage is equivalent to depth of water over the entire surface of Volusia County. Each horizontal line represents 10 times more water than the line below it).

**Figure 5.** Annual water budget for Volusia County (adapted from Rutledge, 1985). All quantities except rainfall are outflow from the county, and are in inches over the entire county.




bring additional water vapor from surrounding areas into the storm.

The average daily atmospheric water-vapor content, based on data for 1983 through 2005, is equivalent to only about 1.3 in. This is a relatively small amount of water as compared to the amounts of water contained in surface-water and groundwater storage. Although the atmosphere may not be a great storehouse of water, it is the superhighway used to move large quantities of water from one location to another.

### Storage of Water on the Land Surface

Lakes are the most important vessels for surface-water storage in Volusia County. There are at least 239 lakes in Volusia County that are 10 acres or more in size (Florida Board of Conservation, 1969). These lakes have a combined area of about 79,300 acres, of which the vast majority is linked to the St. Johns River that forms the western boundary of Volusia County. The total surface area of Volusia County is about 768,000 acres. Therefore, the percentage of the land surface that is covered by lakes is about 10 percent. For the lakes that are not part of the St. Johns River, this coverage is only about 1.3 percent.

The amount of water contained in lakes depends on the depth of the water in the lakes. Lake depths have not been documented for many of Volusia County lakes, so only an estimate of total lake water volume can be made. While most lakes in Florida are shallow and average between 7 and 20 ft (feet) in depth (Fernald and Purdum, 1998), there are a few lakes of sinkhole origin which could be more than 100 ft in depth. For example, the assumption that an average lake water depth is 10 ft suggests that the total amount of water contained in all Volusia County lakes would be about 35 billion cubic feet, which would be equivalent to a water depth of about 12 in. distributed over the entire county.

Other surface-water features were not included in this estimate of surface-water storage on the land surface because the areas or depths of water have not been documented. These include smaller lakes, wetland areas that contain water at least part of the year, and the water that is flowing in streams.

### Storage of Water in the Ground

Underground water is stored in an aquifer, which is a layer of rock, sand, or other earthen material through which water can flow. There are two types of aquifers underlying Volusia County. The surficial aquifer system extends from the land surface to depths of 50 to 100 ft, and is composed mostly of sand, shell, and clay. Underlying the surficial aquifer system is the Floridan aquifer system, which is composed mostly of limestone. The two aquifers are separated in parts of the county by a layer of silt and clay which significantly slows the flow of water from one aquifer to another. The Floridan aquifer system extends to a depth of about 2,000 ft in Volusia County. Underlying the Floridan aquifer are rocks that are impermeable and, therefore, are not aquifers. A more detailed description of the ground-water system for Volusia County has been provided by several investigators, including Knochenmus and Beard (1971), Rutledge (1985), Kimrey (1990), and Williams (2006).

Most of the groundwater in Volusia County is contained within the Floridan aquifer system. Estimates of the amounts of water contained in this aquifer can be made by multiplying the volume (lateral area multiplied by thickness) by the porosity of the rock. Porosity is a measure of the relative volume of empty space within the rock that can be occupied by water. Porosity of the Floridan aquifer system is variable; however, an approximate average porosity can be used to estimate how much water is contained within the system. Scientists used an average of 25 percent porosity in studies of groundwater flow in the upper part of the Floridan aquifer system (Davis, 1996), and thus estimated that the Floridan aquifer system is about 25 percent water. This volume of groundwater is equivalent to an astonishing 500 ft overlying the entire area of Volusia County. Much of this groundwater, especially near the coast and along the St. Johns River, is brackish; that is, it contains salt and is not suitable for drinking.

A comparison of the amounts of water stored in the atmosphere, on the surface, and beneath the ground in Volusia County indicates that groundwater is by far the largest storage place for water (fig. 4). Groundwater probably accounts

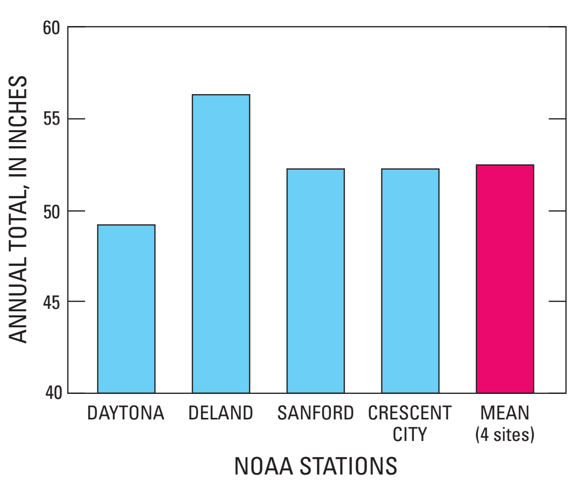



**Figure 6.** Average rainfall at Daytona, DeLand, Sanford, and Crescent City NOAA stations, 1923-2006.

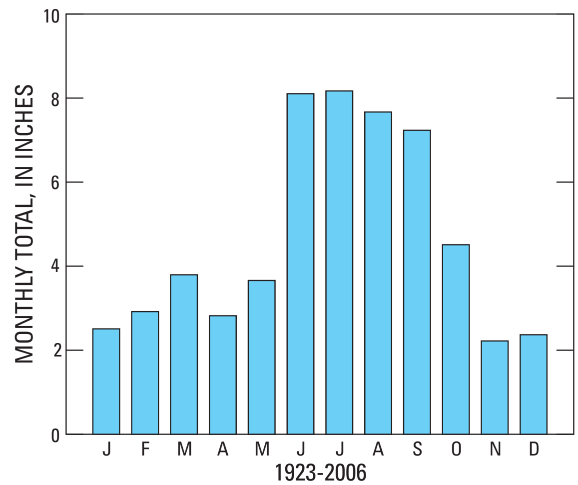



**Figure 7.** Average monthly rainfall at DeLand, Florida, 1923-2006.

for more than 99 percent of the water in Volusia County. By comparison, the amount of water stored in the atmosphere is relatively insignificant. However, as the transporter of virtually all water into the county, the atmosphere becomes a very important feature, even though the atmospheric layer over Volusia County contains very little water at any one time.

# The Water Budget: Moving Water In and Out of Volusia County

In the following discussion, the water budget shown in figure 5 is derived from Rutledge (1985). Although this water budget was developed more than 20 years ago, it still is representative of current conditions (2009). More recent data on rainfall, streamflow, and evapotranspiration are used to illustrate seasonal and location-to-location variability of these components of the water cycle.

## Rainfall

Rainfall provides practically all of the inflow of water to Volusia County (fig. 5). Based on four long-term stations, rainfall is estimated to average about 53 in/yr (inches per year) over the entire county. However, rainfall can vary from place to place. Most of us have witnessed the short-term variability of individual rainfall events. In summer it is not uncommon for a thunderstorm to drench a particular neighborhood, while leaving areas a block or two away dry. On an annual or longer basis, rainfall is less variable from place to place, though differences do occur. For example, the average rainfall for the entire period of record common to all four stations (1923 through 2006) ranged from about 56 in. at DeLand, to about 49 in. at Daytona Beach (fig. 6). The reason for these differences from location to location in or around Volusia County is not clearly understood.

There is a definite seasonal pattern to rainfall in Volusia County. Summers are typically wet, although there can be dry periods of several days or a week or more between storms. Winters are typically dry, and an entire month or more can sometimes pass with no rainfall. This seasonal pattern is evident from the average monthly totals for rainfall at DeLand (fig. 7). Monthly total rainfall is generally between 2 and 4 in. during all months except for June through September, when it is between 7 and a little more than 8 in.

## Evapotranspiration

Evapotranspiration can be estimated by a water-budget analysis, in which ET is the difference between the amount of rainfall and the amount of surface water and groundwater outflow (amount of water flowing away from Volusia County). Evapotranspiration accounts for the largest outflow of water from Volusia County and is estimated to be about 39 in/yr (fig. 5).

Evapotranspiration studies have been conducted at two sites in Volusia County using instrumentation that measures the amount of water vapor moving upward to the atmosphere. These studies also provide a range of the ET that can occur within the county. In 2002, one study at the Lyonia Preserve (fig. 2) determined that ET from a forested upland area was 42 in/yr. In contrast, ET from a wetland near the forested upland area was much higher, and was estimated to be 59 in/yr for the year (Knowles and others, 2005). Another study in a cypress and pine forest near the streamgaging station on Tiger Bay Canal (fig. 2) measured an ET rate of about 38 in/yr in 1998-99 (Sumner, 2001).

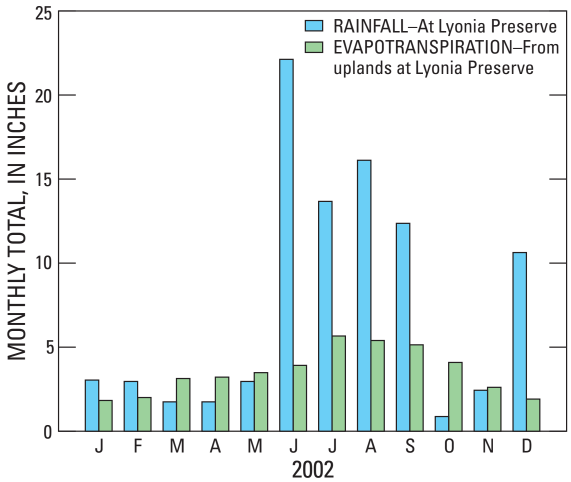



**Figure 8.** Monthly rainfall and evapotranspiration at Lyonia Preserve, 2002 (data from Knowles and others, 2005).

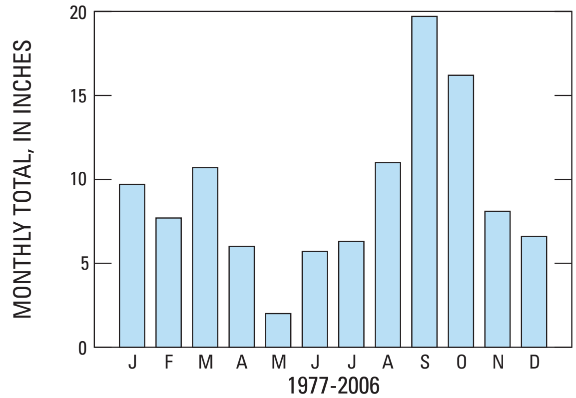



**Figure 9.** Average monthly total streamflow, Tomoka River near Holly Hill, Florida, 1977-2006.

Generally, ET rates are related to water availability at the land surface and within the upper soil layers, and are greatest in lakes and wetland areas, and lowest in the well-drained sandy ridge areas.

Changes in the amount of evapotranspiration on a daily or seasonal basis tend to be smaller than the variation in rainfall. Extended periods of no rainfall can last for several weeks in the winter and spring, but ET occurs nearly every day. Also, unlike rainfall, extremes in daily or monthly ET are relatively not dramatic. For example, at the Lyonia Preserve, monthly rainfall in 2002 ranged from about 0.9 in. to more than 22 in., while ET ranged from about 1.8 to 5.6 in. for the same period (fig. 8).

## Streams transport much more water out of Volusia County than they bring into the county.

### Streamflow

Streams transport much more water out of the county than they bring into the county. Streamflow accounts for the second largest outflow of water from Volusia County, or about 11 in/yr (fig. 5). There are three major streamflow basins in Volusia County (fig. 2). One basin contains Little Haw Creek and Middle Haw Creek and drains north to Flagler County. Another basin includes Deep Creek (north and south tributaries), Cow Creek, and other tributaries, and drains into the St. John River to the west. The other basin drains seaward and contains Tomoka River, Spruce Creek, and Tiger Bay Canal. Streamflows in Volusia County have been measured regularly by the USGS at the streamgaging stations shown in figure 2, with records beginning in 1950 or earlier for some streams.

There is a distinct seasonal pattern to streamflow, with lowest flows occurring at the end of the spring dry period and the highest flows occurring at the end of the summer wet period. Streamflow for the Tomoka River depicts this seasonality, with the 30-year average streamflow ranging from 2.1 in. during May to about 20 in. during September (fig. 9).

### Groundwater

Groundwater movement takes more water out of the county than it brings into the county. However, this groundwater outflow accounts for a relatively small amount of water, compared to the other components of the county water budget, and is estimated to be about 3 in/yr (fig. 5). Most of this groundwater outflow is from springs and flowing wells where groundwater is being discharged from the Floridan aquifer system to surface streams. The two principal springs in Volusia County, Blue Spring and DeLeon Spring, account for about 2.0 in/yr. Rutledge (1985) estimated that two small springs near Lake Monroe discharged an additional 0.1 in/yr, and that flowing wells discharged about 0.2 in/yr. However, most of these flowing wells have since been plugged as a result of the abandoned artesian well plugging project of the St. Johns River Water Management District.

There is also subsurface movement of groundwater through the Floridan aquifer system into and out of the county. This subsurface flow at the county boundaries cannot be directly observed or easily estimated. Estimates by Rutledge (1985) indicate that about 0.8 in. of groundwater flows into the county from adjacent counties, and that about 1.5 in. flows from the county, for a net subsurface outflow of about 0.7 in/yr.

### The Human Role

Does human use of water affect the water budget of Volusia County as a whole? Water is pumped from the Floridan aquifer system for many uses, including drinking-water supply, crop and lawn irrigation, industrial uses, and recreational purposes. In 2005, an average of about 77 Mgal/d (million gallons a day) was withdrawn from Volusia County aquifers (Marella, 2008). This rate of water flow, which is equivalent to filling about 115 Olympic-sized swimming pools each day, could cover the entire Volusia County land surface to a depth of about 1.3 in. in a 1-year period. Thus, human usage of water is relatively small in comparison to the 53 in/yr that the county receives by rainfall.

Some of this water returns to the ground after use as seepage from irrigated lawns and crops, septic tank drainage, or treated wastewater through land application and percolation ponds associated with wastewater treatment plants. Some of the water used for irrigation (about 20 Mgal/d in 2005 according to Marella, 2008) returns to the atmosphere as ET.

Some treated wastewater is discharged to the St. Johns River, the Halifax River, and the Indian River, thus exiting Volusia County. Wastewater treatment plants serving DeLand and the coastal communities of Daytona Beach, New Smyrna Beach, and others discharged about 15 Mgal/d to rivers in 2000 (Marella, 2004.) This is equivalent to about 0.3 in/yr for the Volusia County water budget. Thus, the amount of wastewater that is discharged from the county is small in comparison with the 53 in/yr that the county receives by rainfall.

### References Cited


Davis, H., 1996, Hydrogeologic investigation and simulation of groundwater flow in the Upper Floridan aquifer of north-central Florida and southwestern Georgia and delineation of contributing areas for selected City of Tallahassee, Florida, water-supply wells: U.S. Geological Survey Water-Resources Investigations Report 95-4296, 56 p.

Fernald, E.A., and Purdum, E.D., eds., 1998, Water Resources Atlas of Florida: Institute of Science and Public Affairs, Tallahassee, Florida State University, 312 p.

Florida Board of Conservation, 1969, Florida lakes part III Gazetteer: 145 p.

Kimrey, J.O., 1990, Potential for groundwater development in central Volusia County, Florida: U.S. Geological Survey Water-Resources Investigations Report 90-4010, 31 p.

Knochenmus, D.D., and Beard, M.E., 1971, Evaluation of the quantity and quality of the water resources of Volusia County, Florida: Florida Bureau of Geology Report of Investigations 57, 59 p.

Knowles, L.K., Jr., Phelps, G.G., Kinnaman, S.L., and German, E.R., 2005, Hydrologic response in karstic-ridge wetlands to rainfall and evapotranspiration, central Florida, 2001-2003: U.S. Geological Survey Scientific Investigations Report 2005-5178, 82 p.

Marella, R.L., 2004, Water withdrawals, use, discharge, and trends in Florida, 2000: U.S. Geological Survey Scientific Investigation Report 2004-5151, 50 p.

Marella, R.L., 2008, Water use in Florida, 2005 and trends 1950–2005: U.S. Geological Survey Fact Sheet 2008-3080, 6 p.

National Oceanic and Atmospheric Administration, 2007, Cape Kennedy, Florida: 1950 – 2005 XMR/COF Surface-300 MB Precipitable Water: accessed May 28, 2008 at *http://www.crh.noaa.gov/unr/include/pw.php?sid=xmr*

Rutledge, A.T., 1985, Ground-water hydrology of Volusia County, Florida, with emphasis on occurrence and movement of brackish water: U.S. Geological Survey Water-Resources Investigations Report 84-4309, 29 p.

Sumner, D.M., 2001, Evapotranspiration from a cypress and pine forest subjected to natural fires in Volusia County, Florida, 1998-99: U.S. Geological Survey Water-Resources Investigations Report 01-4245, 56 p.

Williams, Stanley, 2006, Simulation of the effects of groundwater withdrawals from the Floridan aquifer system in Volusia County and vicinity: St. Johns River Water Management District Technical Publication SJ2006-4, 218 p.


# Where will Volusia County get additional water?


**U.S. Department of the Interior**
KEN SALAZAR, Secretary

**U.S. Geological Survey**
Suzette M. Kimball, Acting Director



*By* Edward R. German

For more information contact:
U.S. Geological Survey
Central Florida Research Park
12703 Research Parkway
Orlando, Florida 32826
(407) 803-5531