chloride concentration. A weak relation between spring discharge and chloride concentration is indicated by the relatively high chloride concentrations that occurred in the 1990s, during a period of relatively low discharge.

Nitrate is another chemical constituent of interest, chiefly because its presence can be an indication of surface contamination. Additionally, increasing nitrate concentrations may adversely affect the aquatic ecosystem in springs and spring runs by promoting algae and undesirable plant growth. Natural sources of nitrate probably do not occur within the surficial and Floridan aquifer systems. Nitrate sources in water that recharges the aquifers may include atmospheric deposition (rainfall and dry fallout), fertilizers, and animal and human wastes. Nitrate concentration levels less than 0.05 mg/L are considered to be natural background levels in ground water in peninsular Florida (Maddox and others, 1992).

Water from Blue Spring has been analyzed for the sum of nitrite plus nitrate, with nitrate accounting for most of this sum. Concentrations since 1975 have ranged from below natural background levels to almost 1 mg/L (fig. 6). Although concentrations of nitrite plus nitrate have shown considerable fluctuation, which probably is related to rainfall, an overall increasing trend in concentrations appears to have occurred since 1975. Prior to 1986, concentrations were as low as 0.01 mg/L and averaged 0.15 mg/L. Since 1998, concentrations have been as low as 0.13 mg/L and have averaged 0.48 mg/L.

Nitrate concentrations that are higher than background levels are not an uncommon occurrence in Florida springs. Data from 125 other Florida springs in 2001-02 indicate that 42 percent of the springs have nitrate concentrations at least 10 times greater than the natural background levels (Scott and others, 2004).

Water in Blue Spring is generally clear, but murky water conditions can occur and adversely affect diving activities. For example, visibility in the spring cave was reduced to less than 10 feet in August 2007 because of a high level of suspended solids. Murky conditions may be caused by a collapse somewhere in the spring's cave system, which results in a cloud of suspended limestone particles. Visibility generally improves over a period of days or weeks as the suspended particles from the collapse settle or are discharged from the cave system.

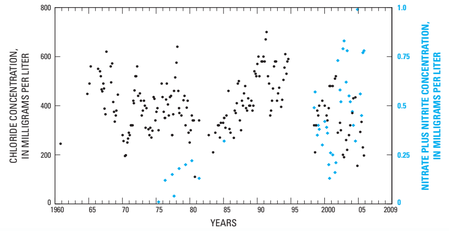

Figure 6. Chloride and nitrate plus nitrite concentration in Blue Spring. (Data from USGS NWIS files, station identifier 02235500; and SJRWMD, Osborn and others, 2006.)

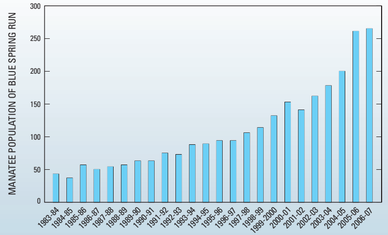

Figure 7. Manatee population of Blue Spring run. (Number refers to number of individual manatees observed in the run during cool months. Data furnished by the Blue Spring State Park.)

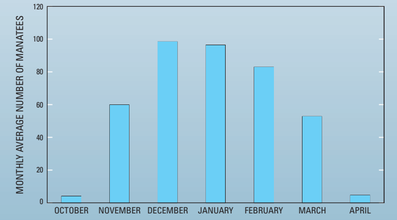

Figure 8. Monthly average manatee population of Blue Spring run. (Number refers to average number of manatees observed in the run from 1983 to 2007. Data furnished by the Blue Spring State Park.)

Manatee Refuge

Blue Spring is well known as a refuge for the West Indian manatee, commonly known as the sea cow. Manatees are gentle, slow-moving mammals related to the dugong, and more distantly, the elephant. They are herbivores and eat a wide variety of aquatic plants. Adult manatees are about 10 feet long and weigh between 1,500 and 2,200 pounds (U.S. Geological Survey, 2007b).

During the warmer months, manatees travel widely through warm, shallow, coastal estuarine waters. They cannot survive for extended periods in water colder than about 63 °F. In the winter, manatees must seek warmer waters, such as Blue Spring run.

Records of the manatee population in Blue Spring run are maintained by personnel of the Blue Spring State Park. These unpublished data, provided from Blue Spring State Park, indicate that the numbers of manatees using the run as a winter refuge are increasing (fig. 7). Since the mid-1980s, the winter population of manatees has increased almost fivefold, from less than 60 to more than 250 individuals in both the 2005-06 and the 2006-07 winter seasons. Manatees usually arrive in small numbers as early as October and leave sometime in April, with the largest population inhabiting the spring run during December and January (fig. 8).

The West Indian manatee is a Federally listed endangered species protected by the Endangered Species Act of 1972, the Marine Mammal Protection Act of 1973, and the Florida Manatee Sanctuary Act making it illegal to harass or disrupt normal manatee behavioral patterns. Major threats to manatee survival in Florida are mostly due to human activities, such as operation of boats and habitat degradation.

Blue Spring is well known as a refuge for manatees. (Photograph courtesy of Blue Spring State Park.)

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Prepared in cooperation with Volusia County

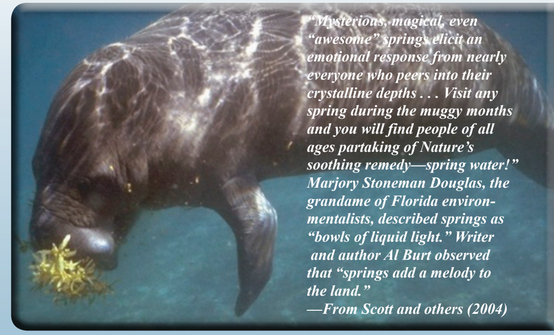
Volusia Blue Spring
—A Hydrological Treasure

Springs are natural openings in the ground through which water beneath the surface discharges into hydrologic features such as lakes, rivers, or the ocean. The beautiful springs and spring rivers are among Florida's most valued natural resources; their gemlike refreshing waters have been a focal point of life from prehistoric times to the present (2008). The steady flow of freshwater at a nearly constant water temperature attracted animals now long absent from Florida's landscape (Scott and others, 2004). Fossil remains and human artifacts, discovered by divers from many spring runs, attest to the importance of springs to the State's earliest inhabitants. Explorers of Florida, from Ponce de Leon to John and William Bartram and others, often mentioned the springs that were scattered across central and northern Florida. As colonists and settlers began to inhabit Florida, springs continued to be the focus of human activity, becoming sites of missions, towns, and steamboat landings.

Recreational opportunities provided by the springs are numerous, and many springs have been preserved as parks. Swimming, snorkeling, diving, and canoeing are among the most common activities.

Because "Blue Spring" is a common name belonging to several springs in Florida, the Florida Department of Environmental Protection adopted the convention of referring to these springs with the county name placed before the name "Blue Spring." In this fact sheet, Blue Spring refers to Volusia Blue Spring (fig. 1).

Blue Spring, one of more than 300 springs in Florida, has been open to the public as a State park since 1972. It is the largest spring on the St. Johns River and is a designated manatee refuge. With an average discharge (or rate of water outflow) of about 158 ft^3/s (cubic feet per second), or 102 million gallons per day, Blue Spring is 1 of 27 springs in Florida classified as a first-magnitude spring, out of a possible 8 levels of magnitude (Spechler and Schiffer, 1995). First-magnitude springs are the largest springs and are defined as those that discharge at least 100 ft^3/s. Blue Spring ranks 17th in rate of discharge compared with the other Florida springs. The average discharge for an entire day (24 hours) is equivalent to a pool of water the size of a football field (360 x 160 feet) and about 240 feet deep.



"Mysterious, magical, even "awesome" springs elicit an emotional response from nearly everyone who peers into their crystalline depths . . . Visit any spring during the muggy months and you will find people of all ages partaking of Nature's soothing remedy—spring water!" Marjory Stoneman Douglas, the grandame of Florida environmentalists, described springs as "bowls of liquid light." Writer and author Al Burt observed that "springs add a melody to the land."
—From Scott and others (2004)

A West Indian manatee, commonly known as a sea cow, feeding. (Photograph courtesy of the USGS Sirenia Project.)

U.S. Department of the Interior
U.S. Geological Survey

Printed on recycled paper

Fact Sheet 2008-3035
August 2008

The vent, or opening in the land surface that is Blue Spring, is in a pool at the head of a spring run that discharges into the St. Johns River. The run is about 0.5-mile long and about 80 to 100 feet wide. The vent is the entrance to a cave system. The upper 60 feet is vertical and continues downward at about a 45-degree angle. Open-water divers are restricted to the first 60 feet; certified cave divers may proceed to a maximum depth of 120 feet. All scuba divers must register at the park office.

Discharge and water-quality data collected by the U.S. Geological Survey (USGS) for Blue Spring as well as many other sites are stored in computer files accessible through the Internet (U.S. Geological Survey, 2007a). Data for Blue Spring can be accessed under the site identification number 02235500 at *http://nwis.waterdata.usgs.gov/nwis*. Data for Blue Spring have also been collected by the St. Johns River Water Management District (2008), and can be accessed at *http://www.sjrwmd.com/springs/index.html*.

How Springs Work

Large springs, such as Blue Spring, are at the end of a complex drainage system in an aquifer that underlies the land surface. An aquifer is any layer of rock, sand, or other material through which water can flow. Blue Spring is a natural breach in a clay layer that separates the surface sands of the surficial aquifer system from the limestone and dolomite rocks of the Floridan aquifer system. The principal features of a spring system include an upland area where rainfall seeps into the surficial aquifer system. There also must be sinkholes or gaps in the clay layer where water can flow downward into the Floridan aquifer system. Interconnected solution cavities and cracks in the rocks of the Floridan aquifer system conduct large quantities of water to the spring vent (fig. 2).

A springshed occupies areas within ground- and surface-water basins that contribute to the discharge of the spring. The boundary of the ground-water basin varies as a result of changes in water pressure in the Floridan aquifer system. The water pressure changes in response to the seasonal pattern of rainfall, and also in response to long-term factors such as drought and the amount of water withdrawn from the Floridan aquifer system.

Water flows upward from a spring vent because the water level of the spring pool is lower than the water level in the aquifers in higher parts of the springshed. Thus, the spring system is analogous to a water-distribution system in which a standpipe, or large water tank, stores water at a higher elevation than homes. Water flows "downhill" from the water tank through the distribution plumbing to the homes.

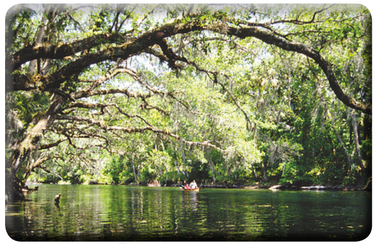
Most of the water discharging from Blue Spring is from rain that falls on the land area within the springshed, which is about 130 square miles (Shoemaker and others, 2004).

The springshed for Blue Spring probably includes areas on both sides of the St. Johns River (fig. 1). The wetland area immediately west of the river, as well as the river itself, is too low in elevation to be part of the springshed. Springshed delineation has some uncertainties (Scott and others, 2004), and may change with variations in rainfall, land use, and ground-water withdrawals.

Computerized ground-water models have indicated that the travel-time of raindrops, from land surface to the spring discharge, is a journey that ranges from a few years to thousands of years, depending on where the raindrop enters the surficial aquifer system. In general, the greater the distance from the rainfall to the spring vent, the longer the traveltime. Speed of water movement in the Floridan aquifer system is not the same everywhere in the springshed. Large systems of interconnected cavities can transport water rapidly through the aquifer system.

Ground water that discharges from the spring is a mixture of water from different parts of the springshed and of various ages. Additionally, some of this water from rainfall mixes with ancient seawater still present in deep layers of rock. The models indicate that about half of the water discharged from the spring is between about 40 and 110 years old. Age dating of spring water by isotopes, conducted in 1996 and 2001 by the St. Johns River Water Management District, indicates that spring flow is dominated by ground water that is less than 43 years old (Osburn and others, 2006). These age estimates indicate that present-day spring water quality could be affected by decades-old or more recent land-use practices.

Not all rain falling on the springshed makes it to the spring vent. Of the almost 15 billion ft^3 of rain that typically falls on the springshed (assuming 50 inches of annual rainfall), only about one-third is accounted for by spring discharge. About two-thirds of the rain returns to the atmosphere by evaporation and transpiration (evaporation of water from plants) before the rain seeps into the Floridan aquifer system.



Swimming, snorkeling, diving, and canoeing are among the most common activities at Blue Spring State Park. (Photographs courtesy of Blue Spring State Park.)

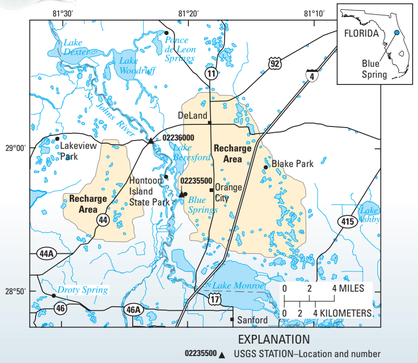


Figure 1. Location of Blue Spring and area contributing recharge to the spring. (The shaded area delineates the springshed and is generalized from Shoemaker and others, 2004.)

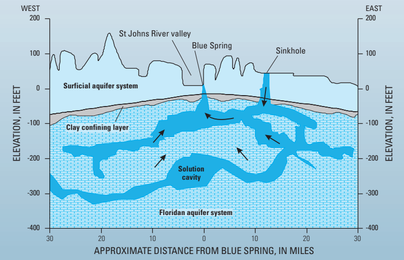


Figure 2. Generalized cross-section west-to-east at Blue Spring. (Scale is approximate, land-form details are generalized, underground details are conceptual. Arrows indicate direction of ground water flow within the springshed.)

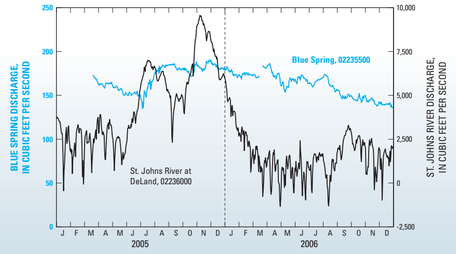


Figure 3. Discharge of Blue Spring and St. Johns River. (Numbers following source name are USGS station identifiers.)

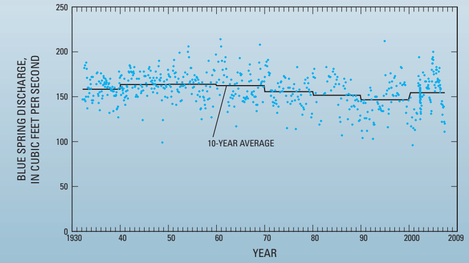


Figure 4. Measured discharge from Blue Spring. (Station identifier is 02235500.)

Spring Flow Characteristics

Springs and spring runs are attractive to wildlife, as well as people, because of the nearly constant flow of water at a uniform temperature. Streams that receive most water from surface runoff, such as the St. Johns River at DeLand (fig. 1, USGS station identifier 02236000), have a large range in discharge during typical years (fig. 3). Discharge in the St. Johns River at DeLand ranged from –1,400 to about 10,000 ft^3/s during 2005-06. Negative discharges in the river occur when surface runoff is low and ocean tides, assisted by strong north winds, push water upstream in the river channel. In contrast, discharge from Blue Spring (fig. 1, station identifier 02235500) is much more constant, ranging only from about 135 to 190 ft^3/s during 2005-06. A downward trend in discharge for Blue Spring occurred in 2006 (fig. 3), which probably is related to low rainfall. In 2006, rainfall in the springshed was low compared to previous years, resulting in lower recharge to the Floridan aquifer system and, hence, lower spring discharge.

The flow of Blue Spring, like most large springs, has been relatively stable over a long time period (fig. 4). Since 1932, measurements (monthly to bimonthly) show that discharge has ranged from 96 to 214 ft^3/s. This range reflects long- and short-term variations in rainfall. For example, during 1998-2002, Florida suffered a drought with a rainfall deficit totaling more than 50 inches (Scott and others, 2004). The reduction in recharge from the drought resulted in a lowering of discharge from Blue Spring as well as many other springs during that period.

Unlike streams, the temperature of spring water discharging from the Floridan aquifer system is nearly constant. Geologic material is a good insulator, and rocks and sediments buffer changes in the temperature of ground water that might result from recent recharge. Spring water temperature tends to reflect the average annual air temperature in the vicinity of the spring, averaging about 84 °F (degrees Fahrenheit) in southern Florida and 70 °F in northern Florida (Fernald and Purdum, 1998).

A comparison of the seasonal characteristics of spring and river water temperatures for 2001 shows the small range in spring temperature compared to the river. Water temperature in the St. Johns River at DeLand ranged from about 53 °F in January to about 87 °F in July and August (fig. 5). During that same year, Blue Spring run water temperatures only ranged from about 73 to 74 °F. This nearly constant temperature makes spring water feel cold to swimmers in the summer in contrast to warmer air temperature, and warm in the winter when spring water temperature is warmer than the air temperature.

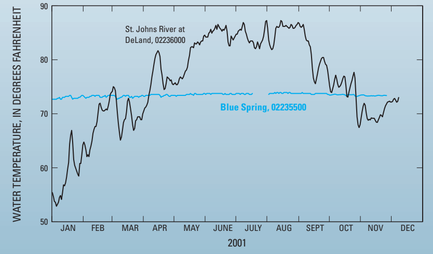


Figure 5. Water temperature in Blue Spring run and St. Johns River. (Numbers following source name are USGS station identifiers.)

Table 1. Selected chemical data for Blue Spring, 1960-2005.

[From Osburn and others, 2006. Concentrations are milligrams per liter. Bicarbonate concentration was calculated from alkalinity]

Constituent	Mean concentration	Number of samples
Calcium	61	47
Magnesium	26	47
Sodium	205	47
Potassium	7.7	47
Chloride	402	199
Bicarbonate	128	46
Sulfate	55	60
Nitrate plus nitrite	.39	42

Water Quality

The dissolving of limestone and dolomite rock creates the caves and solution cavities that are characteristic of the Floridan aquifer system. This dissolving occurs when rain, which becomes acidic due to atmospheric carbon dioxide, percolates through the surficial aquifer sediments and reacts with the limestone and dolomite. The dissolving process also affects the chemistry of water discharged by a spring, adding calcium, magnesium, bicarbonate, and sulfate ions to the water. Most springs in Florida discharge water that contains a predominately calcium-magnesium-bicarbonate mixture of ions (Slack and Rosenau, 1979).

Another major factor affecting water quality is the occurrence of seawater that borders the Florida peninsula, and also underlies the entire State at various depths. Seawater is chemically complex but is predominately a sodium-chloride type of water. At some locations, including along the St. Johns River, ancient seawater can move upward from deep layers of rock and become part of the water discharged by springs. Such is the case for Blue Spring, which discharges water of a predominately sodium-chloride type, although it also contains calcium, magnesium, potassium, bicarbonate, and sulfate in concentrations exceeding 1 mg/L (milligram per liter) (table 1).

Water from Blue Spring generally is not suitable for drinking-water, because the chloride concentration at times exceeds the recommended secondary drinking water level of 250 mg/L (U.S. Environmental Protection Agency, 2006). Chloride concentrations exceeding 250 mg/L may have an objectionable salty taste for many people. The chloride originates from deep within the Floridan aquifer system and probably comes from inflow of old seawater into the spring flow system.

The concentration of chloride has ranged from 110 to 700 mg/L since 1960 (fig. 6). A clear upward or downward trend with time is not discernable, but there appear to be cycles in