SOUTHWEST DISTRICT • SPRINGS COAST BASIN

FINAL TMDL Report

Nutrient TMDLs for Coastal Springs of Pasco and Hernando Counties: Magnolia–Aripeka Springs Group, Jenkins Creek Spring, Wilderness–Mud–Salt Springs Group, (WBIDs 1391B, 1389, and 1382G) and Documentation in Support of Development of Site-Specific Numeric Interpretations of the Narrative Nutrient Criterion

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Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the total maximum daily loads (TMDLs) for nitrate nitrogen (NO_3N) in the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and Wilderness–Mud–Salt Springs Group, located in the Middle Coastal Planning Unit of the Springs Coast Basin. They were verified by the Florida Department of Environmental Protection (DEP) as impaired by nutrients, which contribute to the excessive growth of algae that causes ecological imbalance in spring runs, and were included on the Verified List of impaired waters for the Springs Coast Basin adopted by Secretarial Order in February 2012. The TMDLs establish the allowable level of nitrate loadings to the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and Wilderness–Mud–Salt Springs Group that would restore these waterbodies so that they meet the applicable water quality criterion for nutrients. This report will be used as the basis for discussions during the development of basin management action plans (BMAPs).

1.2 Identification of Waterbodies

For assessment purposes, DEP has divided the waters of the state into water assessment polygons with unique **w**ater**b**ody **id**entification (WBID) numbers for individual waterbodies or waterbody segments. Individual springs or groups of springs are also assigned a WBID. The Magnolia–Aripeka Springs Group is WBID 1391B, Jenkins Creek Spring is WBID 1389, and the Wilderness–Mud–Salt Springs Group is WBID 1382G. The water flowing from these springs comes from groundwater, and there are two estimated groundwater recharge regions or contributing areas associated with these WBIDs. **Figure 1.1** displays the locations of the WBIDs and their contributing areas.

1.2.1 Magnolia–Aripeka Springs Group (WBID 1391B)

The Magnolia–Aripeka Springs Group consists of Aripeka Spring #1, Aripeka Spring #2, Boat Spring, Bobhill Spring, and Magnolia Spring. The Magnolia–Aripeka Springs Group is the source of surface water flowing in Hammock Creek, which flows westward three-quarters of a mile to the Gulf of Mexico. The Magnolia–Aripeka Springs Group supports a complex aquatic ecosystem and is an important cultural and economic resource for the state. **Figure 1.2** displays the major geopolitical and hydrologic features in the estimated contributing area, located in parts of Hernando and Pasco Counties. **Figure 1.3** displays an aerial photograph of this system, showing the named springs, and **Figure 1.4** provides a close-range oblique aerial photograph of the Magnolia–Aripeka Springs Group.

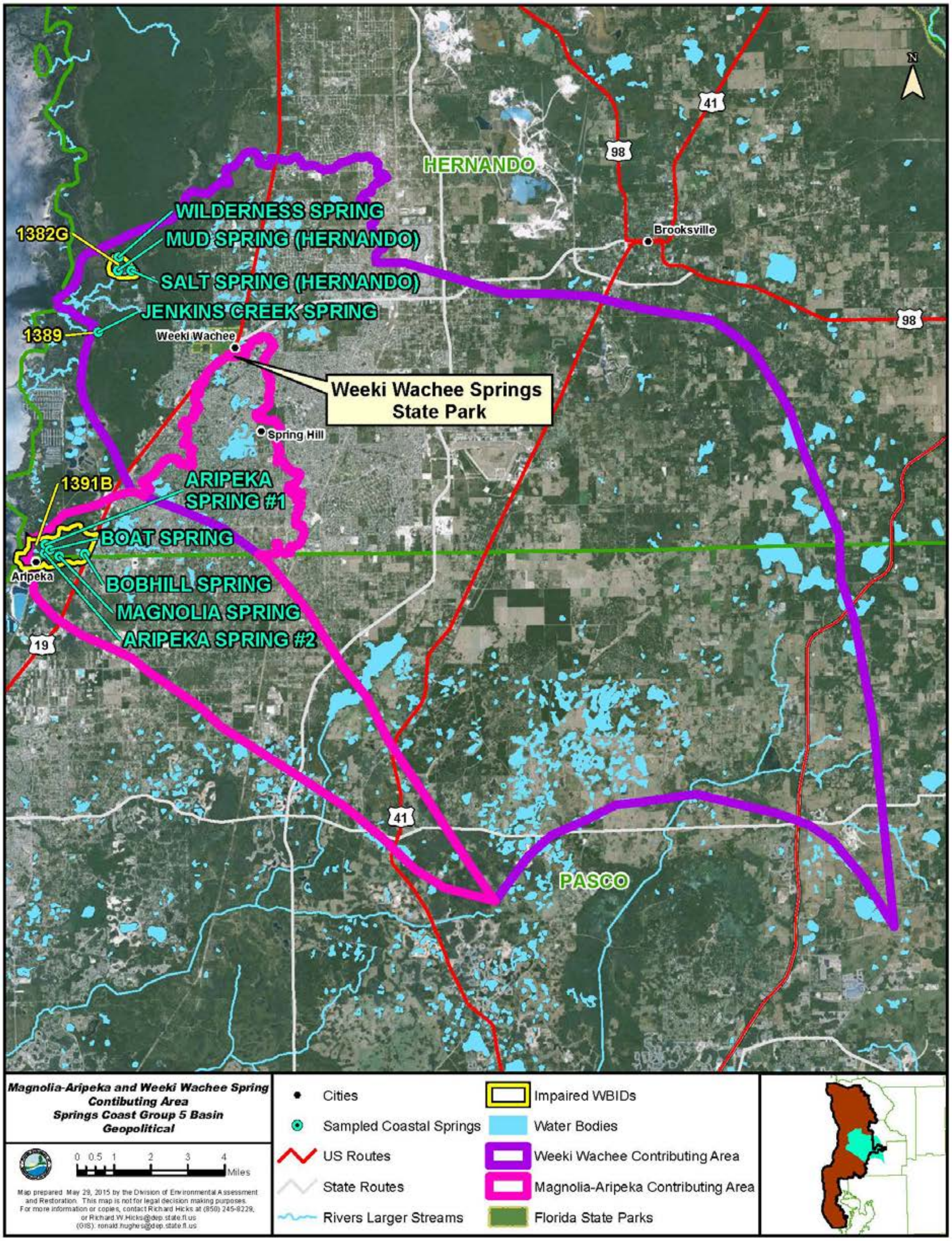


Figure 1.1. Combined map of major geopolitical and hydrologic features in the contributing areas of the springs for which TMDLs are proposed

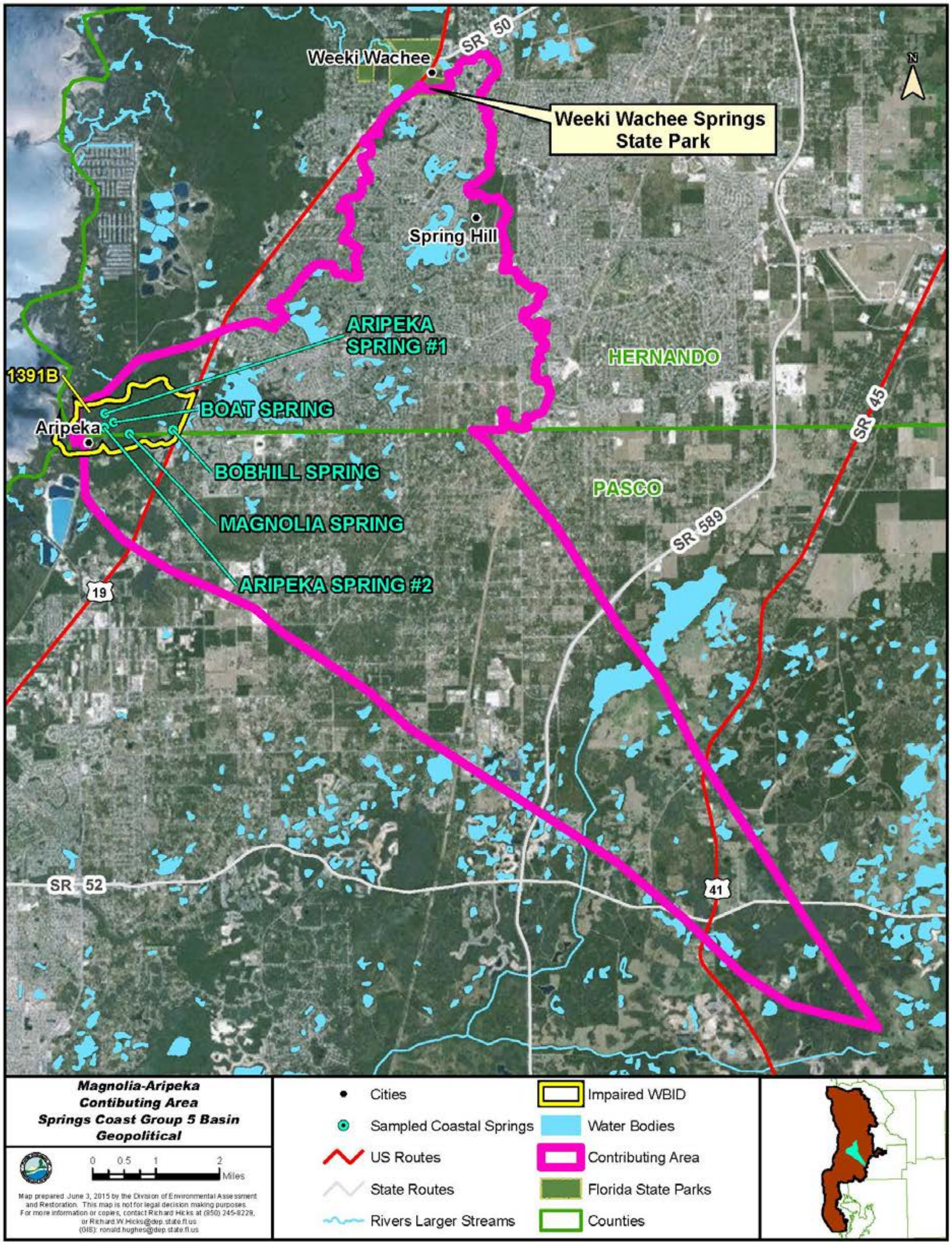


Figure 1.2. Major geopolitical and hydrologic features of the Magnolia–Aripeka Springs Group contributing area

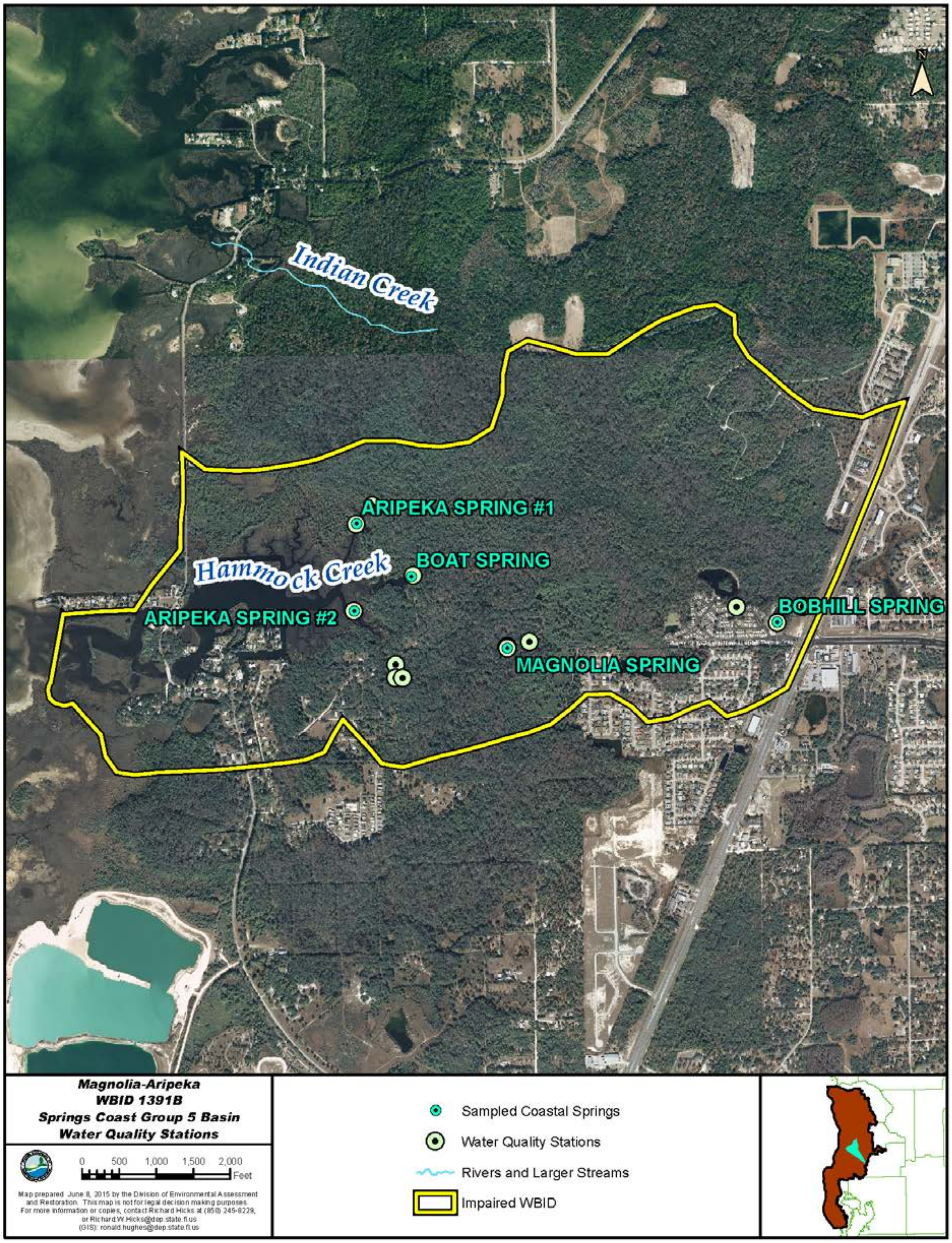


Figure 1.3. Named springs and impaired WBID boundary for the Magnolia–Aripeka Springs Group

Figure 1.4. Aerial photograph of the Magnolia–Aripeka Springs Complex and the headwaters of Hammock Creek, looking east (photo by Leslie Newman)

The Magnolia–Aripeka Springs Group, which includes Aripeka Springs #1 and #2, Boat, Bobhill, Gator, and Magnolia Springs, is located along Florida's Gulf Coast, within the Springs Coast Basin. The Magnolia–Aripeka Springs Group is located in Hernando County immediately north of the Pasco County border, and is situated in about ten feet of water approximately half a mile east of the community of Aripeka. This spring group is part of the Hammock Creek system, a coastal system formed by a number of lesser-magnitude springs and wetlands discharge. The springs are clustered in a one-square-mile area.

As in other areas of the Springs Coast Basin, the source of water discharging from the Magnolia–Aripeka Springs Group is the upper Floridan aquifer (UFA) system. These springs either discharge directly into Hammock Creek or into the lesser creeks flowing into Hammock Creek. Hammock Creek is approximately one mile long and is joined by several lesser tidal creeks before reaching the Gulf of Mexico. The creek's water is brackish to the headsprings, and flow is tidally controlled.

Aripeka Spring #1 is located on the bottom of upper Hammock Creek, about half a mile northeast of the town of Aripeka. The spring occupies a 15-foot-diameter depression on the bottom of the creek. The spring vent is 6.2 feet deep at high tide. A small boil is present on the spring surface over the vent. The spring water is murky and greenish, and the spring bottom consists of soft sand and mud. The discharge is estimated at less than 5 cubic feet per second (cfs) (Maddox 2015).

Hammock Creek in the vicinity of the Aripeka Spring #1 pool is a brackish marsh habitat. Downstream from the spring, northward up the run, several small tidal creeks branch off. A palm-hardwood hammock is located at the head of Hammock Creek, 250 feet north of the spring.

Aripeka Spring #2 is located 300 feet upstream from the mouth of the southernmost tributary of upper Hammock Creek, just northeast of the community of Aripeka. The spring occupies a small circular cove along the north side of Hammock Creek. The spring vent is covered by 6 feet of water at high tide and discharges slightly murky water. A small boil is present over the vent. The spring bottom is soft mud and sand. Aripeka Spring #2 is next to a 5-foot-tall fern thicket surrounding the northern half of the spring cove. The fern thicket is an island of larger vegetation within a wide-open expanse of brackish marsh. The discharge is estimated at less than 5 cfs (Maddox 2015).

Boat Spring is located at the head of the middle tributary to Hammock Creek, half a mile northeast of the north side of the community of Aripeka. The spring occupies an elongated spring pool near the head of a tidal tributary creek to Hammock Creek. The pool is 40 feet long by 20 feet wide and has 5 vents. The spring measures 3.7 feet deep over the vent at high tide, and the water is murky and greenish. Limestone is exposed along the pool edges and bottom, along with dark mud. The spring boil is visible during low tide. There is a small house concrete foundation located 150 feet south of the spring pool (Maddox 2015).

Channel modification or canal digging appears to have altered the tidal creek approximately 200 feet downstream from the spring. Boat Spring discharges through a 0.2-mile-long tidal creek that feeds into the east side of Hammock Creek, approximately 700 feet downstream from Aripeka Spring # 1. Boat Spring is surrounded by dense palm-hardwood-cedar hammock lands. In 1998–99, the discharge averaged 1.25 cfs (Maddox 2015). In December 2014, the Southwest Florida Water Management

District (SWFWMD) purchased Boat Spring. The acquisition consists of 81.69 acres, with approximately 53.4 acres in Hernando County and 28.2 acres in Pasco County (SWFWMD website 2014a).

Bob Hill Spring is situated in a hammock about 600 feet north of the Pasco–Hernando County line. The spring vent is 15 feet deep, and the discharge flows west to the Gulf via Bayou Creek and Bayou Lake (Maddox 2015).

The property where Bob Hill Spring is located was once a 200-acre homestead owned by the Hill family. The property was subdivided in 1953, becoming part of the Gulf Coast Highway Estates subdivision. In the 1970s it was turned into a privately owned recreational and camping facility. The spring was converted to a 100- by 200-foot oval swimming pool with concrete walls and a paved walkway surrounding the entire spring. The spring has been renamed Holiday Springs, which is the name of the RV park, and a major road now divides the land once owned by the Hills. While the spring boil was once prominent and continuous, in 1972 the discharge was significantly reduced after a nearby area was excavated for a lake (Maddox 2015).

Magnolia Spring is located 0.7 miles west of Aripeka at the head of the south fork of Hammock Creek. The spring is on private property and is inaccessible to the public. It sits in an oval depression measuring 45 by 54 feet. The spring pool is shallow, averaging 4 feet deep. The water is clear and light blue, with sparse aquatic vegetation covering a sand bottom. There is a private residence approximately 300 feet to the north. At least a dozen small sand boils are visible on the spring bottom (Maddox 2015).

1.2.2 Wilderness–Mud–Salt Springs Group (WBID 1382G)

The springs in this group discharge into tidal creeks in the vicinity of the Weeki Wachee River. Observations by individuals indicate these three springs may be interconnected (Morton, March 28, 2016, pers. comm.). They are all located in the Weeki Wachee Spring springshed, which is considered their groundwater contributing area. **Figure 1.5** displays the major geopolitical and hydrologic features in the estimated contributing area, which includes parts of Hernando and Pasco Counties. **Figure 1.6** consists of an aerial photograph of this system showing the named springs in WBID 1382G.

Salt Spring (also known as [aka] Hernando Salt Spring) is located approximately 4 miles northwest of Weeki Wachee Spring at the head of Salt Creek. The spring pool of Salt Spring is 40 feet in diameter and 3 feet deep near the vent. Divers report that the spring vent is 6 feet in diameter and 170 feet deep, and consists of many passageways below 60 feet. Salt Spring comprises the headwaters of Salt Creek.

Mud Spring (aka Mud River Spring) is located at the head of Mud River, about 400 feet south of State Road 50, 1.3 miles east of Bayport, and 3,000 feet west of the intersection of State Road 50 and County Road 597 (Rosenau et al. 1977). The head pool of Mud River is about 400 feet in diameter, with a 200-foot-wide run flowing from the east side.

Wilderness Spring is located 600 feet west of Mud Spring, 3,600 feet west of the intersection of State Road 50 and County Road 597. The spring flows south to a culvert under State Road 50 (Rosenau et al. 1977).

During a falling tide, the Weeki Wachee River flows towards Bayport. Inversely, during a rising tide, a component of the Weeki Wachee River will backflow into the Mud River. As this is happening, detritus has been observed moving downward into the Mud Spring vent. When the tide begins reversing, Mud Spring bubbles, indicating the subsurface movement of the captured water from the Mud River (Morton, March 28, 2016, pers. comm.).

Wilderness Spring has no direct surface water connections. Sports fishermen have caught large snook and sheephead, which are saltwater fish, in Wilderness Spring to a point where none of these fish remained in this isolated spring. Approximately a week later, similar sized snook and sheephead were replenished. This anecdotal evidence indicates that Wilderness Spring may have an underground connection to Mud Spring (Morton, March 28, 2016, pers. comm.).

1.2.3 Jenkins Creek Spring (WBID 1389)

Jenkins Creek Spring is included in the Weeki Wachee Springs Group and is located inside Hernando Beach Park off Shoal Line Road in western Hernando County. The spring pool is elliptical in shape, approximately 200 feet long and 60 feet wide (Champion 2011). There are two spring runs: one flows to the south, and the other flows to the northwest. **Figure 1.7** displays an aerial orthophotograph of this system with the named springs of WBID 1389.

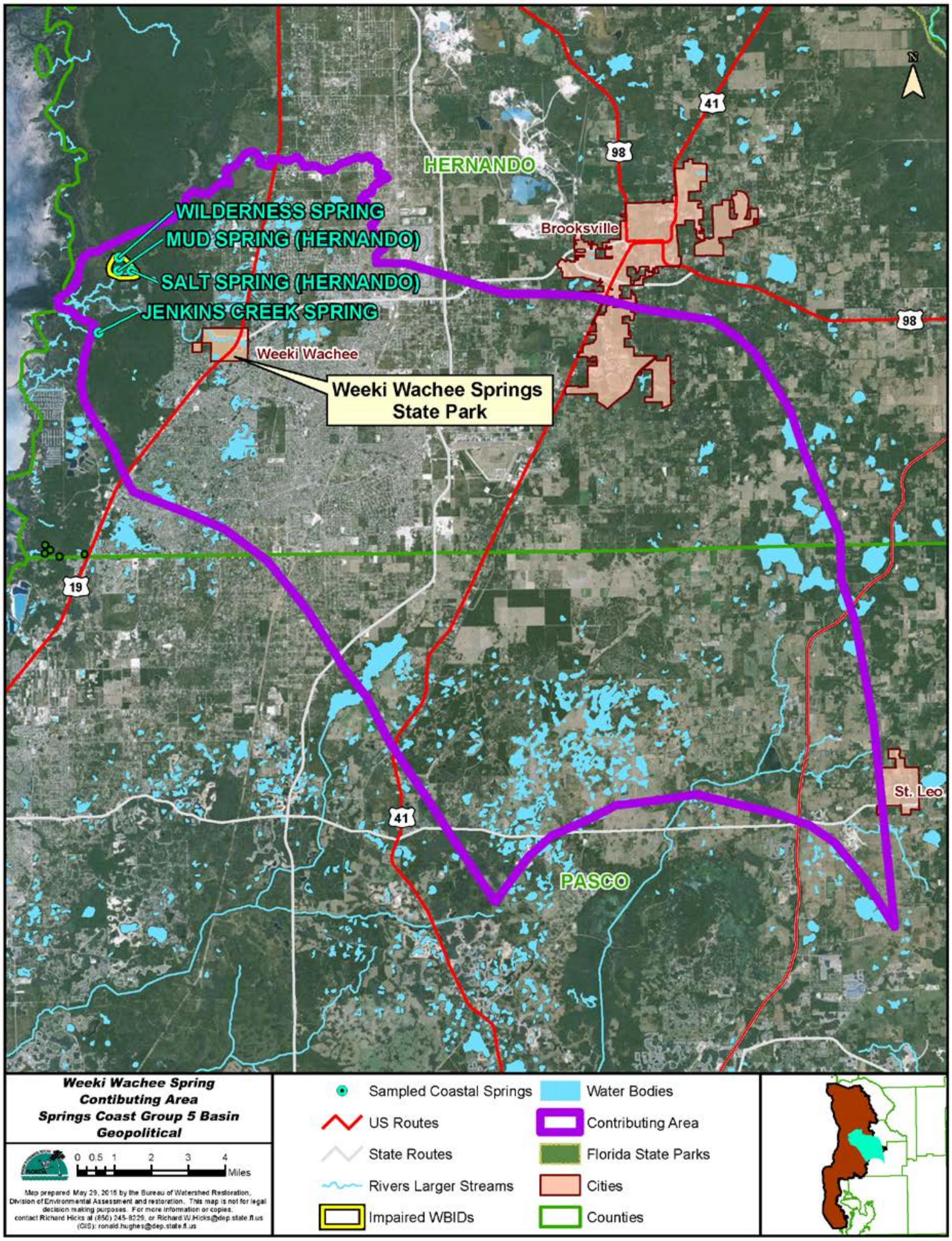


Figure 1.5. Major geopolitical and hydrologic features of the proposed Jenkins Creek Spring and Wilderness–Mud–Salt Springs Group TMDLs in the Weeki Wachee Spring contributing area

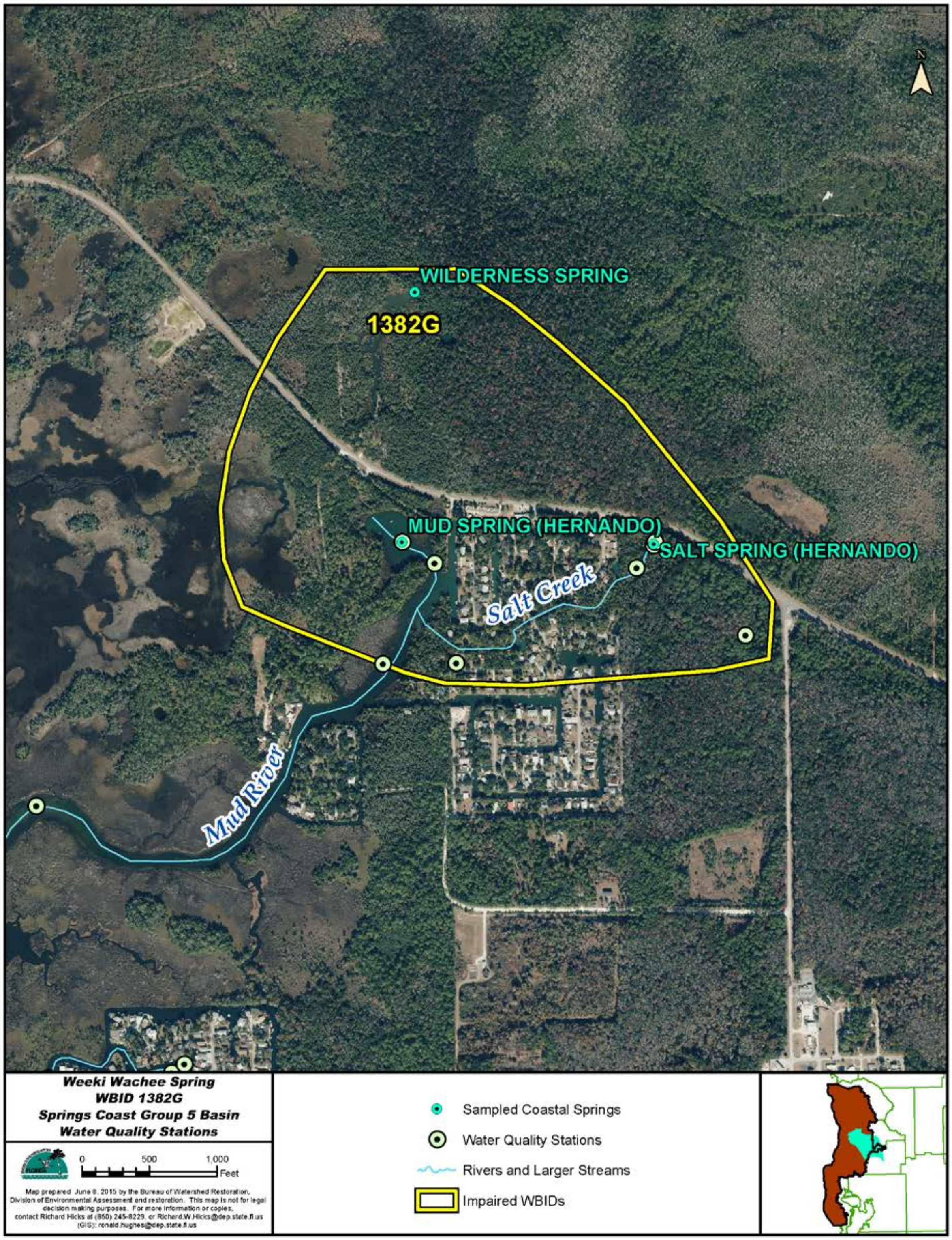
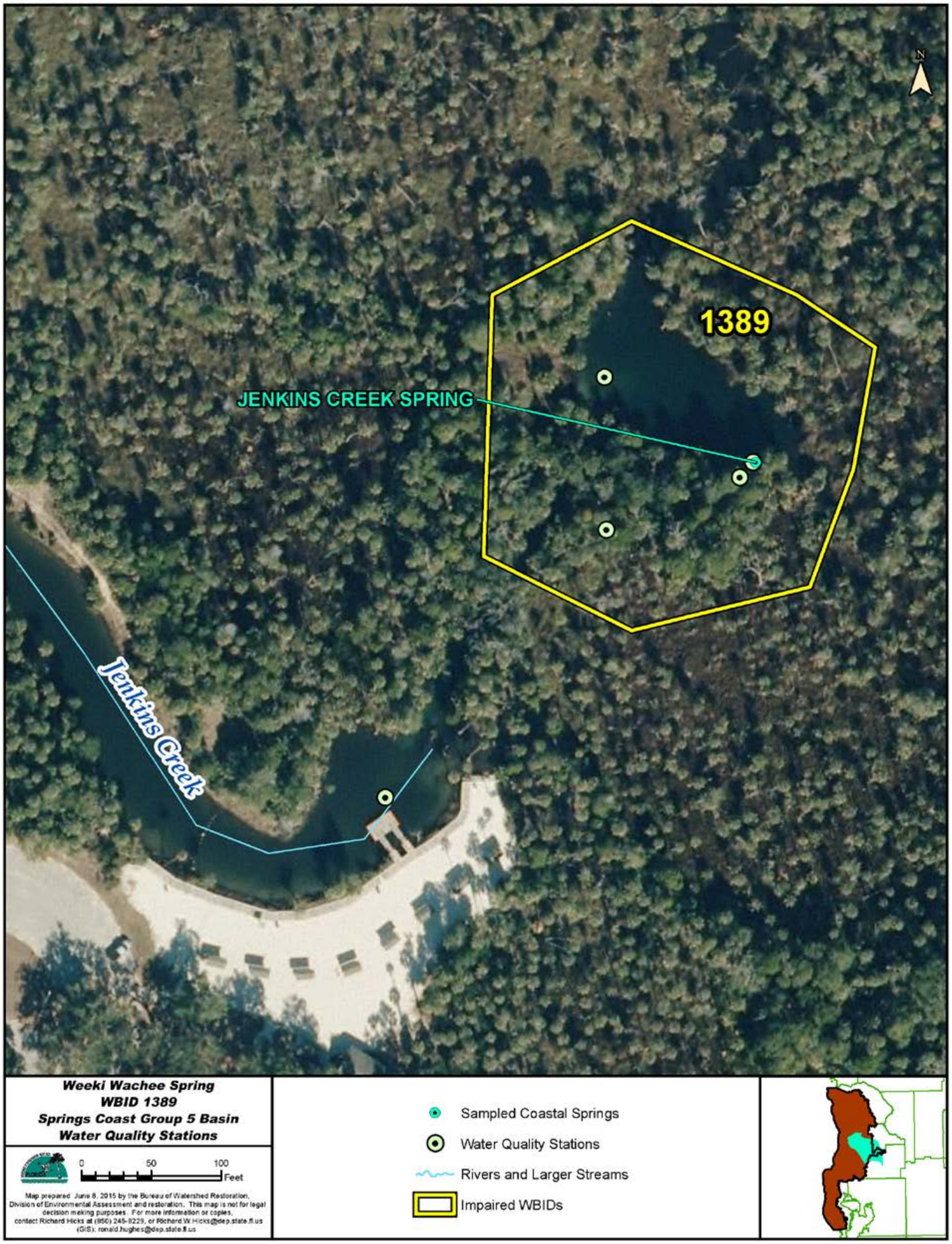


Figure 1.6. Named springs of the Wilderness–Mud–Salt Springs Group (WBID 1382G)



Map prepared June 8, 2015 by the Bureau of Watershed Restoration, Division of Environmental Assessment and restoration. This map is not for legal decision making purposes. For more information or copies, contact Richard Hicks at (850) 245-8229, or Richard.W.Hicks@dep.state.fl.us (GIS): ronald.hughes@dep.state.fl.us

Figure 1.7. Location of Jenkins Creek Spring in WBID 1389

1.3 Geologic Setting and Contributing Areas

In physiographic terms, these WBIDs are located in a karst plain region where the landforms and surface water features are being shaped by the dissolution of shallow underlying limestone. In general, the topographic features and internal drainage in karst regions are caused by the underground dissolution, erosion, and subsidence of near-surface carbonate rocks. Within the rock, slightly acidic rainwater causes the limestone to dissolve, and further dissolution along zones of fractured rock and bedding planes causes the development of caves and interconnected openings known as conduits. Groundwater migrates within these zones, and springs occur where hydraulic head differences in the aquifer coincide with openings in the earth.

The entire area that contributes water to a spring via groundwater and surface water inflows is known as a springshed. Springsheds are bounded by groundwater divides rather than topographic divides because the principal drainage is by way of groundwater flow in the UFA (Knochenmus and Yobbi 2001). Based on an analysis of groundwater elevation maps called potentiometric surface maps, the SWFWMD created generalized springshed boundaries for the Weeki Wachee Springs Group and the Magnolia–Aripeka Springs Group (Jones et al. 1997). Potentiometric surface maps can be used to estimate contributing areas for springs, but they can only represent conditions when groundwater levels were measured and the map resolution possible, based on the number of measurement points used to create them. The contributing area boundaries are also created assuming uniform groundwater flow in the mapped area.

In evaluating the potential sources of nutrients, DEP considered the springshed as well as the combined surface watershed of the impaired receiving waters. The estimated combined contributing area to the Weeki Wachee Springs Group includes the springshed of the springs and the surface watershed of their associated spring runs, as well as includes Jenkins Creek Spring and the Wilderness–Mud–Salt Springs Group. Together, these encompass an area of 254 square miles: 149 square miles in Hernando County and 105 square miles in Pasco County. **Figure 1.2** shows the estimated contributing area and its major geopolitical and hydrologic features.

The estimated combined contributing area of water to the Magnolia–Aripeka Springs Group includes the springshed of the springs group and the overland surface watershed of their associated spring runs. these encompass an area of 59 square miles: 39 square miles in Pasco County and 20 square miles in

Hernando County. **Figure 1.1** shows the estimated contributing area and its major geopolitical and hydrologic features.

The contributing areas of the Weeki Wachee Springs Group and the Magnolia–Aripeka Springs Group have an overlap of approximately 22 square miles because overland surface water drainage boundaries do not match subsurface groundwater flow boundaries. Within this overlap, some surface water drainage may go to the Aripeka contributing area, and any groundwater recharge to the aquifer would travel to the Weeki Wachee contributing area.

The geology of the Springs Coast Basin includes thick sequences of limestone exposed at or very near to (10 to 20 feet) the land surface in the eastern and western portions of the basin. Where the limestone is near the land surface, the thin veneer of sediment covering the limestone consists of unconsolidated deposits of primarily quartz sand. The limestone units include the Suwannee Limestone of Oligocene age and the Ocala Limestone of Eocene age. Underlying these exposed limestone units is the Avon Park Formation of Eocene age. The Avon Park Formation is the deepest formation containing potable water (based on concentrations of total dissolved solids [TDS], which represent salinity). The Suwannee and Ocala Limestones and the Avon Park Formation comprise the UFA system in the basin, and the UFA is the source of water that discharges from springs (Jones et al. 1997).

In the Brooksville Ridge area (a portion of which is in the eastern part of the springshed), undifferentiated quartz sand and sediments of the Hawthorn Group overlie the UFA. The Hawthorn Group sediments were deposited in a variety of environments and consist of sand, silty sand, and waxy green clay. Phosphorite pebbles and fossil oyster bars are common. West of the Brooksville Ridge, the Hawthorn Group sediments are essentially absent, and limestone is near the surface and covered only by sand. These conditions are prevalent in the Coastal Lowlands, which include the river and its springs (Jones et al. 1997).

Karst processes play a dominant role in the rates and directions of groundwater movement through the UFA in the basin. In karst areas, the dissolution of limestone creates and enlarges cavities along fractures in the limestone that eventually collapse and form sinkholes. Sinkholes capture surface water drainage and funnel it underground, promoting the further dissolution of the limestone. This leads to the progressive integration of voids beneath the surface and allows larger and larger amounts of water to be funneled into the underground drainage system. Dissolution is most active at the water table or in the zone of water table fluctuation, where carbonic acid contained in rainwater and generated by reaction with carbon dioxide in the soil reacts with limestone and dolostone.

Over geologic time the elevation of the water table has shifted in response to changes in sea level, and many vertical and lateral paths have developed in the underlying carbonate strata in the basin. Many of these paths or conduits lie below the present water table and greatly facilitate groundwater flow. Openings along these paths or conduits provide easy avenues for water to travel. Groundwater rich in nutrients has the potential to flow rapidly through these passages in the limestone, or slowly through minute pore spaces in the rock matrix (SWFWMD 2001).

Figure 1.8 and **Figure 1.9** show the vulnerability of the Floridan aquifer in the area contributing groundwater to the Magnolia–Aripeka and Weeki Wachee Springs Groups. These maps are based on the statewide Florida Aquifer Vulnerability Assessment (FAVA) model developed by the Florida Geological Survey (FGS) using conditions such as soil characteristics, depth to groundwater, recharge rate, and the prevalence of sinkhole features (Arthur et al. 2007). The figures show that all of this contributing area is vulnerable to groundwater contamination compared with other regions of the state.

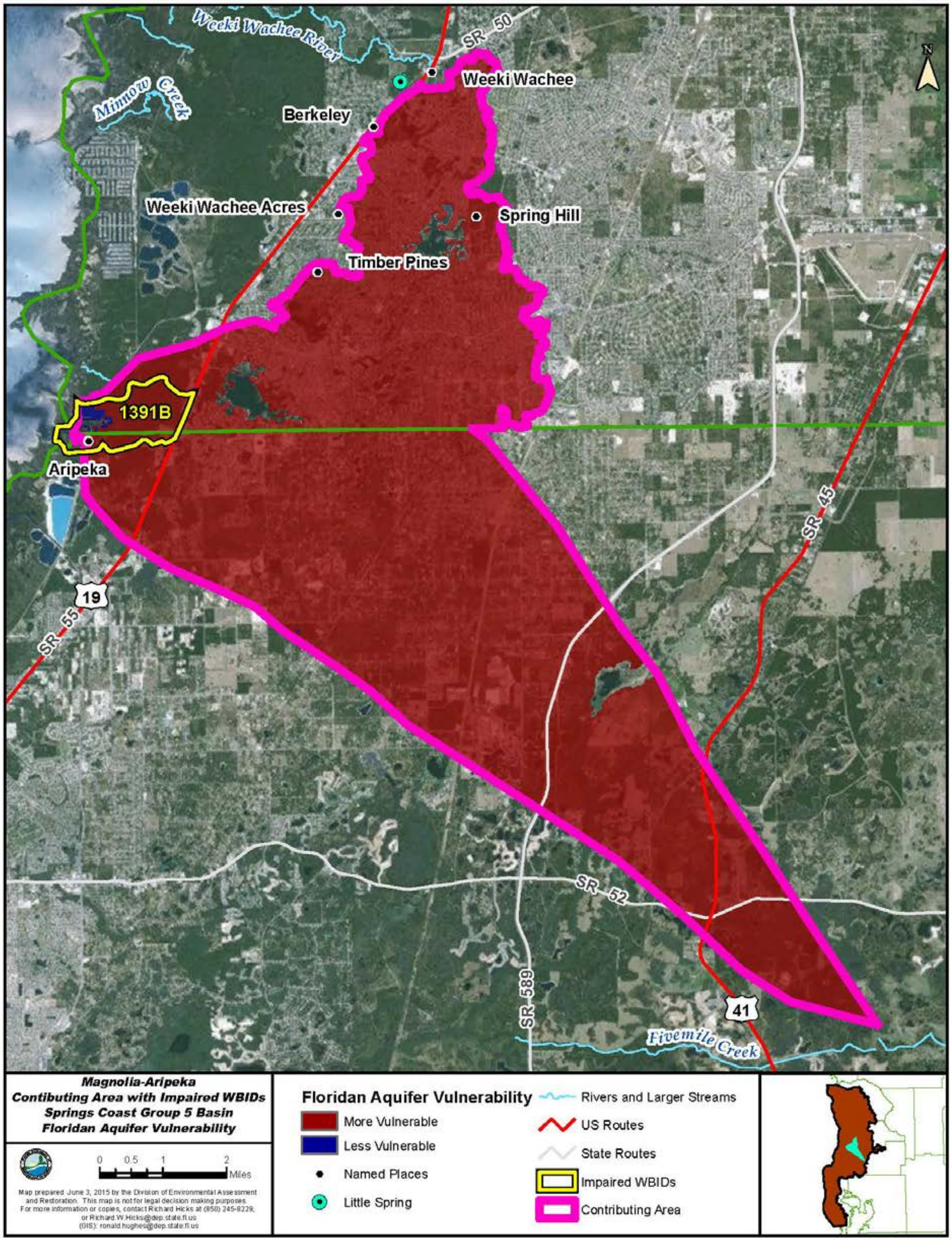


Figure 1.8. FAVA map in the contributing area for the Magnolia–Aripeka Springs Group (Arthur 2007)

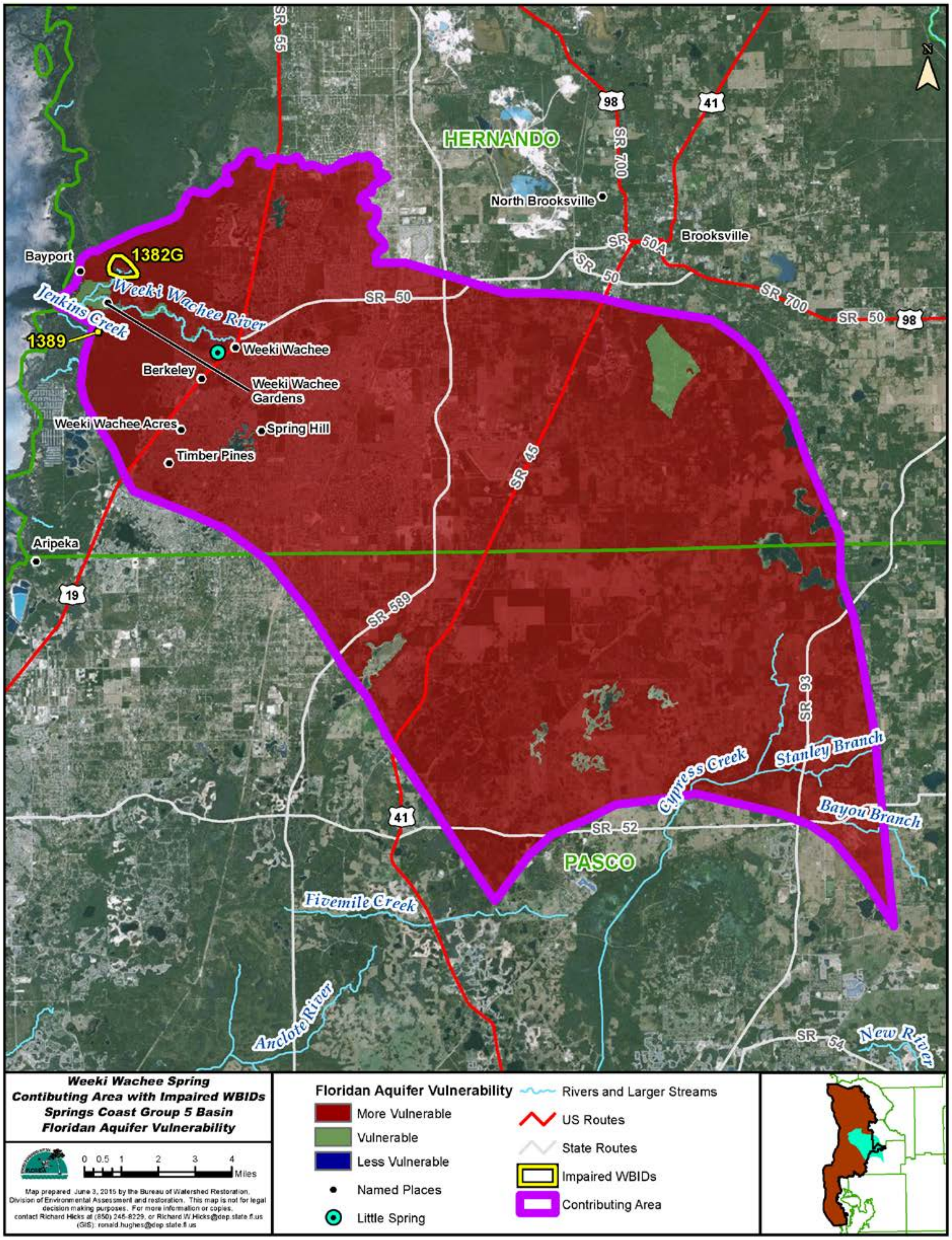


Figure 1.9. FAVA map in the contributing area for the Weeki Wachee Springs Group (Arthur 2007)

1.4 Background

This report was developed as part of DEP's watershed management approach for restoring and protecting state waters and addressing TMDL Program requirements. The watershed approach, which is implemented using a cyclical management process that rotates through the state's 52 river basins over a five-year cycle, provides a framework for implementing the TMDL Program–related requirements of the 1972 federal Clean Water Act and the 1999 Florida Watershed Restoration Act (FWRA) (Chapter 403.67, Laws of Florida).

A TMDL is a scientific determination of the maximum amount of a pollutant that a waterbody can receive each day and still be considered healthy. TMDLs are developed for waterbodies that are verified as not meeting their water quality standards. They provide important water quality restoration goals that will guide restoration activities.

The adoption of nutrient TMDLs for these impaired waters will be followed by the development and implementation of a BMAP to reduce the levels of nitrate that contribute to the ecological imbalance in the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group. The restoration of these waterbodies will depend heavily on the active participation of DEP and stakeholders in the contributing area, including the U.S. Fish and Wildlife Service (FWS), Florida Fish and Wildlife Conservation Commission (FWC), Hernando County, Pasco County, other local community governments, Save the Manatee Club, Hernando Environmental Land Protectors, Hernando County Groundwater Guardians, Gulf Coast Conservancy, agricultural interests, landowners, businesses, and private citizens. The SWFWMD, Florida Department of Transportation (FDOT), and Florida Department of Agriculture and Consumer Services (FDACS) will also play important roles in the implementation of restoration activities.

These springs are ecologically valuable to the state and local communities. The contributing areas of the Weeki Wachee Springs Group and the Magnolia–Aripeka Springs Group provide habitat for a number of threatened and endangered plants and animals, including the West Indian manatee, bald eagle, Florida sandhill crane, red-cockaded woodpecker, gopher tortoise, Florida panther, and least tern (Gulf Coast Conservancy 2015). The West Indian manatee uses Jenkins Creek Spring, Mud Spring, Aripeka #1 Spring, and Aripeka #2 Spring as winter refuges. Also, these coastal expanses contain a small population of Florida black bears, which have been seen frequenting Magnolia Spring and Boat Spring.

Chapter 2: DESCRIPTION OF WATER QUALITY PROBLEM

2.1. Statutory Requirements and Rulemaking History

Section 303(d) of the federal Clean Water Act requires states to submit to the U.S. Environmental Protection Agency (EPA) a list of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant causing the impairment of listed waters on a schedule. DEP has developed such lists, commonly referred to as 303(d) lists, since 1992. The list of impaired waters in each basin, referred to as the Verified List, is also required by the FWRA (Subsection 403.067[4], Florida Statutes [F.S.]), and the state's 303(d) list is amended annually to include basin updates.

Florida's 1998 303(d) list included 22 waterbodies in the Springs Coast Basin. However, the FWRA (Section 403.067, F.S.) stated that all previous Florida 303(d) lists were for planning purposes only and directed DEP to develop, and adopt by rule, a new science-based methodology to identify impaired waters. After a long rulemaking process, the Environmental Regulation Commission adopted the new methodology as Rule 62-303, Florida Administrative Code (F.A.C.) (Identification of Impaired Surface Waters Rule, or IWR), in April 2001. The IWR was modified in 2006 and 2007.

2.2. Information on Verified Impairment

Rule 62-303, F.A.C., includes the methodology for listing nutrient-impaired surface waters based on documentation that supports the determination of a waterbody's imbalance in flora or fauna attributable to nutrients. In 2012, DEP used available water quality data from the SWFWMD, DEP's own monitoring, and other sources to evaluate the impairment status of springs in the Springs Coast Basin based on nitrate concentrations and evidence of ecological imbalance. Water quality data collected by the SWFWMD and DEP comprised the bulk of the nitrate data used in the evaluation.

These springs were listed as impaired by nutrients because of their consistently elevated concentrations of nitrate and the corresponding evidence in their spring runs of imbalances in flora and fauna caused by algal smothering. This information was used in the determination of impairment for the 2012 Verified List of impaired waters. **Table 2.1** lists the waterbodies on the Cycle 2 Verified List that are addressed in this report.

Table 2.1. Cycle 2 verified impaired spring-related segments in this TMDL report

WBID	Waterbody Segment	Parameters Assessed Using the IWR
1391B	Magnolia–Aripeka Springs Group	Nutrients (Algal Mats)
1382G	Wilderness–Mud–Salt Springs Group	Nutrients (Algal Mats)
1389	Jenkins Springs (Jenkins Creek Spring)	Nutrients (Algal Mats)

2.3 Nutrients

Nutrient overenrichment contributes to the impairment of many surface waters, including springs. The two major nutrient parameters monitored are nitrogen (N) and phosphorus (P). These are essential nutrients to plant life, including algae. For aquatic vegetation and algae to grow, both nutrients have to be present. In fact, one can be present in excess, but if the other is absent, the overgrowth of vegetation or algae is unlikely to occur. Historically, many spring systems have had sufficient naturally occurring phosphorus to trigger an imbalance, but nitrogen concentrations were low. It is widely accepted that multiple factors, including nutrients, sunlight, tidal flow, spring discharge, temperature, and salinity, control primary production in brackish spring-fed waterbodies.

The results of previous and ongoing research on many Florida springs have led to a greater understanding of the threshold concentrations of nitrogen or phosphorus that cause the overgrowth of nuisance macroalgae (Stevenson et al. 2007). Macroalgae may also sequester nutrients from groundwater seepage, which may not be apparent from surface water or spring monitoring data. The nutrient inputs contributing to the algal growth in these impaired waters may not be exclusively related to spring discharge, as spring runs can also receive nutrients via stormwater and shallow groundwater inflows from nearby sources. In addition, legacy nutrients found in the sediments can also diffuse from sediments back into the water column.

2.4 Ecological Issues Related to Nutrients

2.4.1 Filamentous Algae and Diatoms

Evidence of an increasing trend in algal coverage and algal smothering, specifically *Lyngbya* sp., has been documented in the Magnolia–Aripeka Springs Group. In addition, the overgrowth of the diatom *Fragilaria* cf *capucina* has been documented in Jenkins Creek Spring and in the Wilderness–Mud–Salt Springs Group.

Lyngbya sp. may form tangles or mats, intermixed with other phytoplankton species. Trapped gases often form in and beneath these algal mats, causing them to break free of the substrate and float to the surface. Once the mats are floating, wind and water currents can move them to other areas, impeding navigation and impairing recreational use of the waterbody. The mats can be several acres in size (University of Florida–Institute of Food and Agricultural Sciences [UF–IFAS] 2009). *Lyngbya* sp. also has the potential to trap sediments, causing the development and accumulation of muck. Upon decomposition the algal cells release a compound (geosmin) with a strong musty odor; this further impairs the aesthetic value of the waterbody (Romie 1990).

At Mud and Wilderness Springs, the dominant algae shifted from *Lyngbya* sp. to *Chaetomorpha* sp., possibly due to increased water salinity in this area. *Chaetomorpha* sp., commonly known as green hair or horse hair algae, is a unique variety of salt-tolerant green algae native to the Gulf of Mexico, Atlantic, and Caribbean. Found in nutrient-rich areas such as bird islands, lagoons, and protected shallow waters (Gulf Coast Ecosystems [GCE] 2010), it features a thick, tangled mass of filaments that resembles fishing line (GCE 2010). *Chaetomorpha* sp. is very hardy because it grows in the intertidal zone, which is often completely exposed at low tide. It will not attach to rocks or substrates. In nutrient-rich environments, it has a competitive advantage over other native species because it is a fast grower and is not palatable to fish or invertebrates.

DEP has not been able to obtain documentation of exactly when the algal overgrowth began in these impaired waters. The earliest mention of diatoms in Mud Spring was in Rosenau et al. (1977), which describes an abundance of "brown flaky material, probably algal."

Unfortunately the overgrowth of algae in response to nutrient enrichment has also been documented in many other spring systems. Frazer et al. (2001; 2006) documented these conditions between 1998 and 2005 in the Chassahowitzka River as well as two other spring-run river systems in the Springs Coast region: the Weeki Wachee River and Homosassa River. Nutrient TMDLs have been developed for Weeki Wachee Spring, the Homosassa Springs Group, and the Chassahowitzka Springs Group because of algal imbalances influenced by elevated nitrate concentrations in the springs. The response of algae to nutrient enrichment in these impaired waters is not unique to this system. It is similar to the conditions documented in the nutrient TMDLs for the Suwannee and Santa Fe Rivers (Hallas and Magley 2008), Wekiva River and Rock Springs Run (Gao 2007), Wakulla River (Gilbert 2012), Silver Springs and

River (Holland and Hicks 2012), Rainbow Springs and River (Holland and Hicks 2013), and Kings Bay (Bridger 2014).

Photographs taken in the past five years document the conditions in the aquatic community in the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and Wilderness–Mud–Salt Springs Group (**Figures 2.1** through **2.6**).

Figure 2.1. Filamentous algae at Boat Spring in the Aripeka Springs Group, April 2015 (photo by K. Bridger, DEP)

Figure 2.2. Algae coating bottom of spring boil at Magnolia Spring in the Magnolia–Aripeka Springs Group, January 2015 (photo by G. Maddox, DEP)

Figure 2.3. Underwater photo of filamentous algae coating the bottom of Bobhill Spring in the Magnolia–Aripeka Springs Group, January 2015 (photo by K. Bridger, DEP)

Figure 2.4. Filamentous algae during low tide at Jenkins Creek Spring Run, April 2015 (photo by K. Bridger, DEP)

Figure 2.5. Filamentous algae during low tide at Wilderness Spring, January 2011 (photo by L. Hester, DEP)

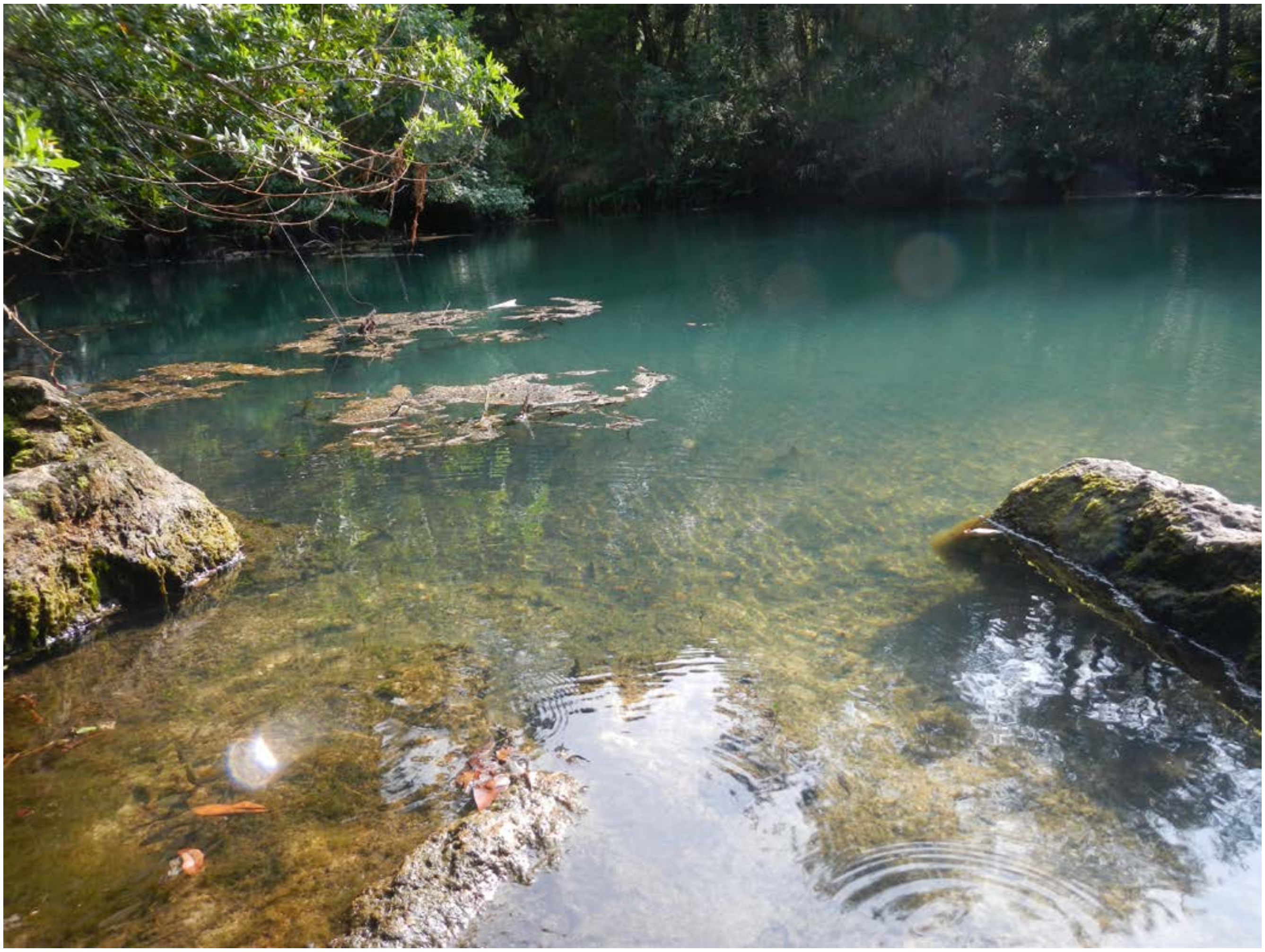


Figure 2.6. Algae floating and coating bottom of Salt Spring, April 2015 (photo by K. Bridger, DEP)

2.4.2 Effects on Fish and Macroinvertebrates

Camp et al. (2012; 2013) found that filamentous algae supported equal or greater densities of small-bodied fish and macroinvertebrates than rooted monospecific stands of macrophytes. However, filamentous algae harbored smaller sized fish and a less diverse population of small-bodied fish and macroinvertebrates (Camp et al. 2013). Also, based on capture-recapture data that Tetzlaff et al. (2010) collected for largemouth bass (*Micropterus salmoides*) populations, the weight-at-age and length-at-age were higher in a patchy heterogeneous distribution of submersed aquatic vegetation (SAV) than SAV limited to primarily filamentous algae.

In addition to contributing to increased algal problems, excess nutrients in springs may also contribute to decreased plant and animal diversity and productivity, increased organic matter deposition, and reduced aesthetics of spring ecosystems (DEP 2012). The potential consequences of nutrient enrichment in springs include an increase in opportunistic primary producers, a decrease in macroinvertebrate communities, and increased organic matter deposition (Mattson 2007).

2.4.3 Other Ecological Impacts

A small amount of the natural land cover around these impaired waters has been extensively altered. A recreational resort has been developed at Bobhill Spring, which is the focal point for the Holiday Springs RV Resort. The business has over 200 units that are occupied both seasonally and all year. A concrete wall and paved walkway have been constructed to enclose the spring pool of Bobhill Spring to make a swimming area (**Figure 2.7**).

Figure 2.7. Concrete deck surrounds Bobhill Spring at Holiday Springs RV Resort. The resort has renamed the spring Holiday Springs (photo by G. Maddox, DEP).

2.5 Monitoring Sites and Sampling

Historical water quality data for the impaired springs and the associated spring runs are limited, but they do provide a glimpse of current versus "background" water quality. Data providers in the Magnolia–Aripeka Springs Group contributing area and the Weeki Wachee Springs contributing area include the SWFWMD, DEP, U.S. Geological Survey (USGS), and LakeWatch (a volunteer monitoring program funded by the University of Florida). Biological and water quality data have been collected from various locations around the springs. The Florida Storage and Retrieval (STORET), USGS National Water Information System (NWIS), and SWFWMD Water Management Information System Databases contain many of these data.

The SWFWMD performed the majority of the water quality sampling and analysis (**Figure 2.8**). The district samples Jenkins Creek Spring, Magnolia Spring, Bobhill Spring, and Wilderness Spring four times a year (January, April, July, and October). Because they are less accessible, the SWFWMD samples Salt Spring and Boat Spring only once per year in July. This schedule is the part of the SWFWMD routine water quality sampling program. Aripeka #1 Spring, Aripeka #2 Spring, and Mud Spring, during the Cycle 2 verified period (January 1, 2004–June 30, 2011) plus more recently (2012–14), were only sampled twice due to accessibility issues. These springs were sampled on September 15, 2010, and January 10, 2013.

Figure 2.9 shows the locations of the current and past routine water quality sampling stations and biological stations represented by data collected by or provided to DEP for the Magnolia–Aripeka Springs Group. **Figure 2.10** shows the same information for Jenkins Creek Spring, and **Figure 2.11** contains information on Wilderness–Mud–Salt Springs. To ensure that the nutrient TMDLs were developed based on current conditions and that recent trends in the springs' water quality were adequately captured, monitoring data were compiled for the seven-year Cycle 2 verified period (January 1, 2004–June 30, 2011) plus more recently (2012–14). The data used for the TMDL are from samples collected by the SWFWMD as well as the USGS, LakeWatch, and DEP.

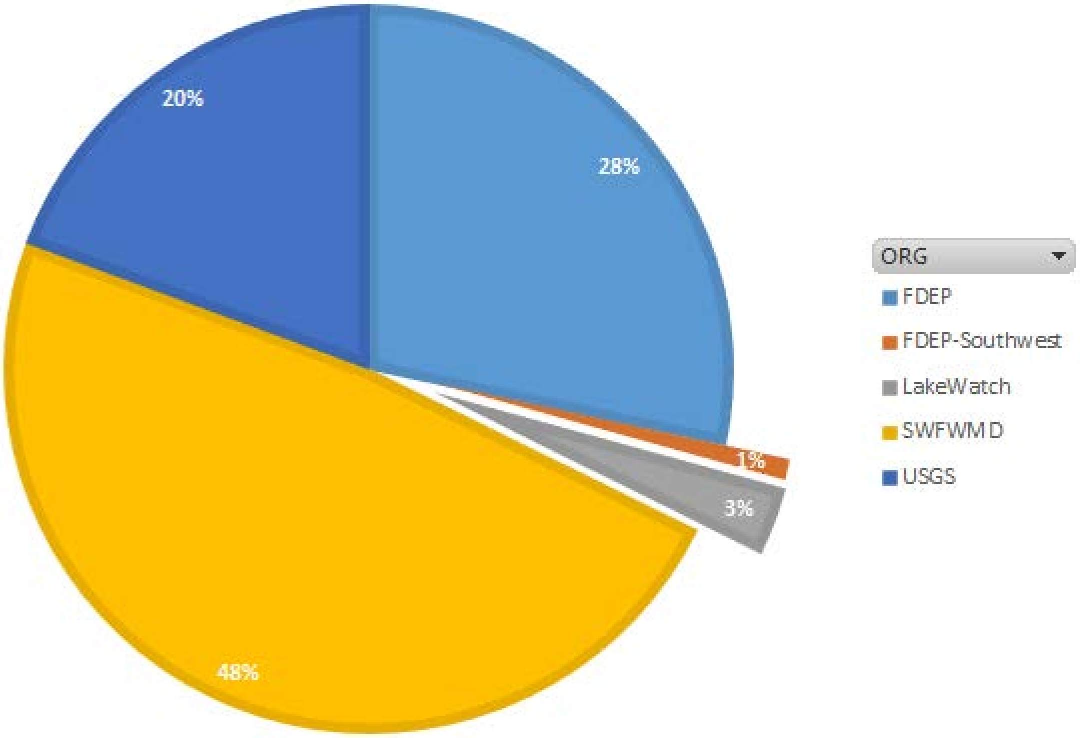


Figure 2.8. Water quality and biological data providers in the contributing areas of the Magnolia–Aripeka Springs Group and the Weeki Wachee Springs Group

Map prepared June 8, 2015 by the Division of Environmental Assessment and Restoration. This map is not for legal decision making purposes. For more information or copies, contact Richard Hicks at (850) 245-8229, or Richard.W.Hicks@dep.state.fl.us (GIS): ronald.hughes@dep.state.fl.us

Figure 2.9. Water monitoring sites associated with the impaired Magnolia–Aripeka Springs Group (WBID 1391B) (based on DEP dataset)

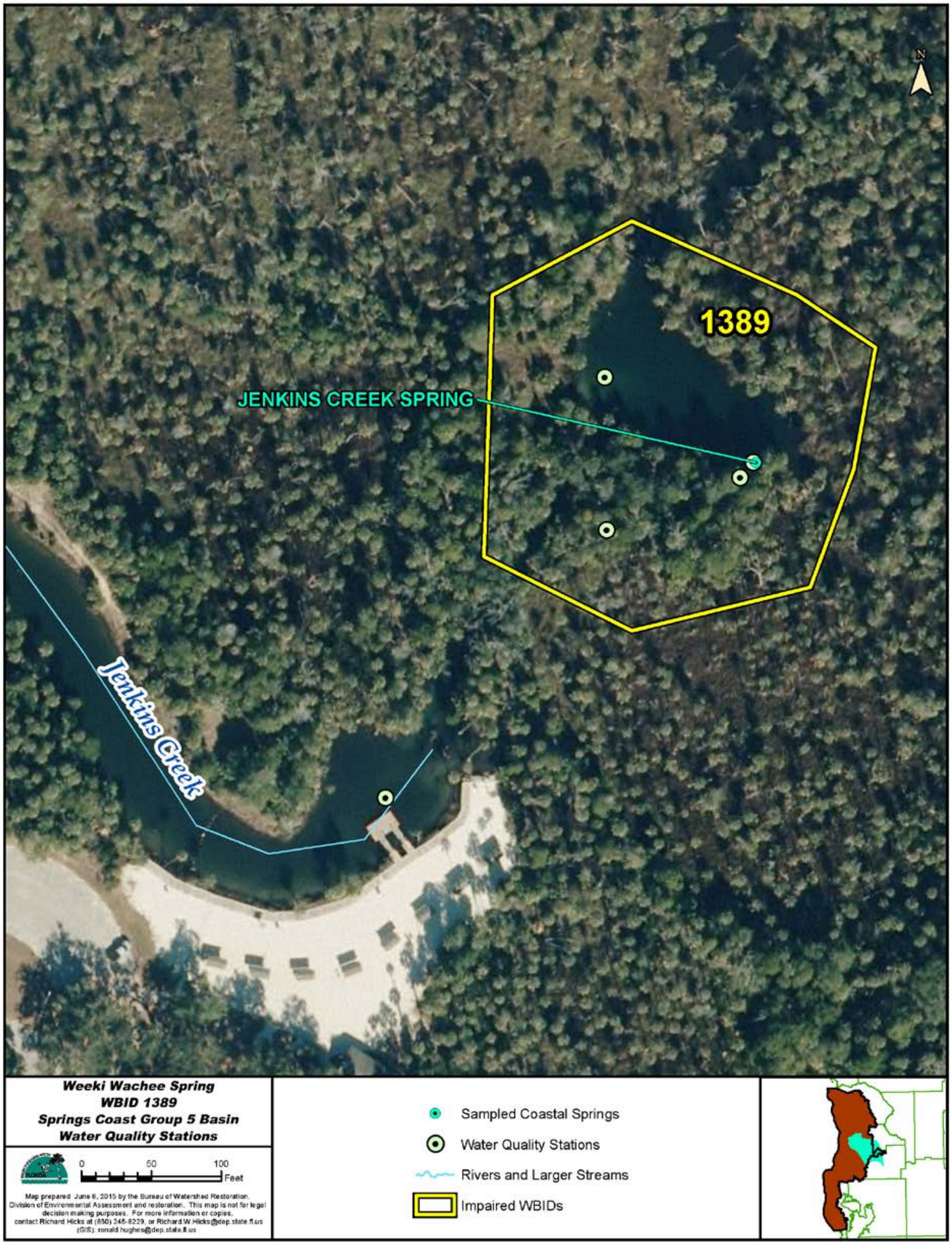
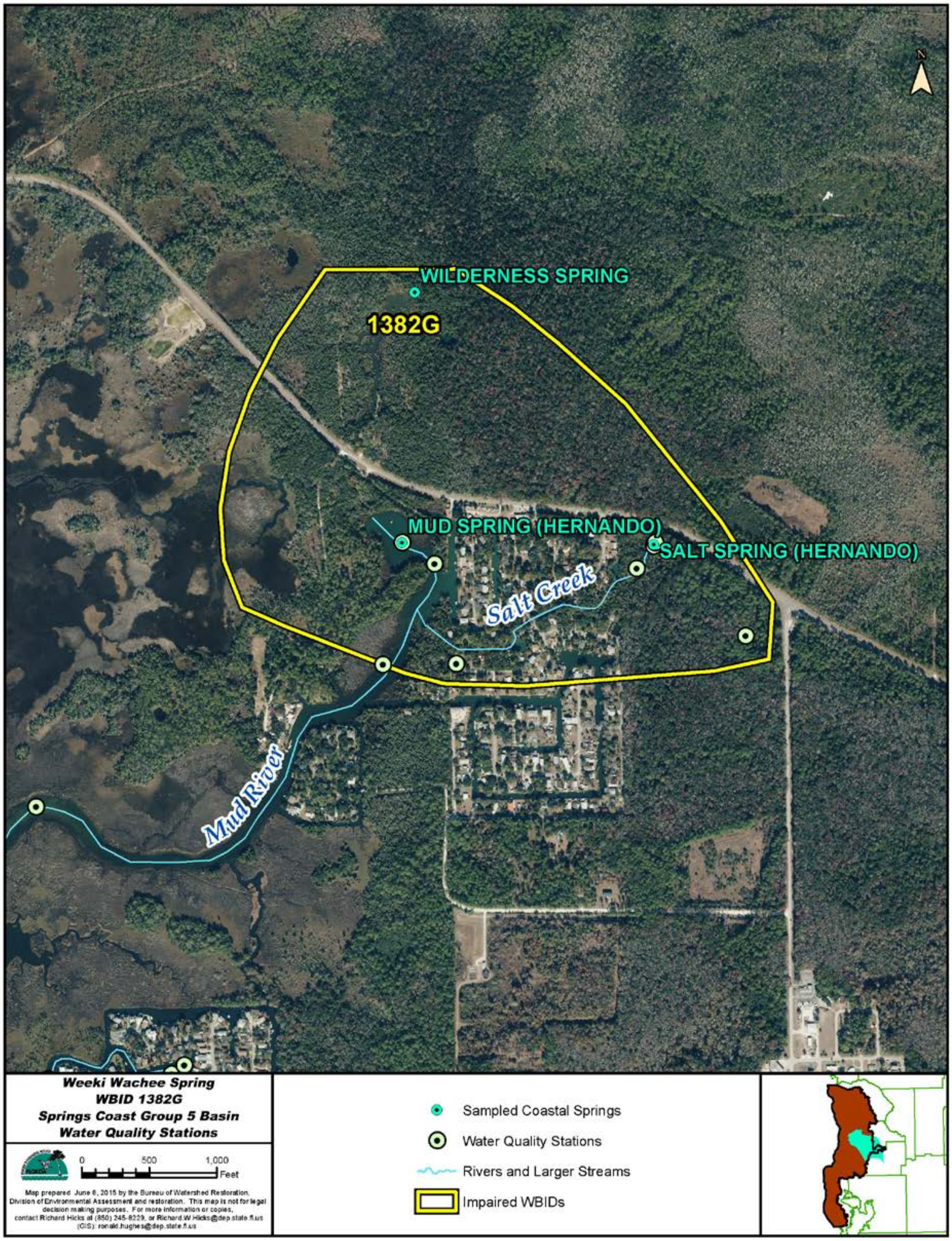


Figure 2.10. Water monitoring sites associated with the impaired Jenkins Creek Spring (WBID 1389) (based on DEP dataset)



Map prepared June 6, 2015 by the Bureau of Watershed Restoration, Division of Environmental Assessment and restoration. This map is not for legal decision making purposes. For more information or copies, contact Richard Hicks at (850) 245-8229, or Richard.W.Hicks@dep.state.fl.us (GIS): ronald.hughes@dep.state.fl.us

Figure 2.11. Water monitoring sites associated with the impaired Wilderness–Mud–Salt Springs (WBID 1382G) (based on DEP dataset)

2.6 Rainfall and Temperature Data

The climate in the Aripeka Springs and Weeki Wachee Spring Group contributing areas is humid and subtropical, with hot, rainy summers and cool, generally dry winters. Recharge to groundwater and flow in springs depend on rainfall. Rainfall amounts for Hernando County were used to reflect precipitation for both contributing areas because they both include portions of Hernando County (SWFWMD 2014a). Rainfall and temperature data were reviewed for the 30-year period of record from January 1985 through December 2014 (**Table 2.2**). Annual rainfall amounts average approximately 51.53 inches per year (in/yr), with an average air temperature of about 71.1° F. (National Oceanic and Atmospheric Administration [NOAA] 2014).

Figure 2.12 shows the 30-year historical rainfall trend measured for Hernando County. Over this period, the lowest annual rainfall of 34.20 inches occurred in 2000, and the highest annual rainfall of 64.45 inches occurred in 1988. Annual rainfall from 1985 to 2014 averaged 51.53 inches.

Table 2.2. Temperature at Weeki Wachee (NOAA Station-089430) and precipitation for Hernando County, January 1985–December 2014

Analysis	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
30-Year Mean–Maximum Temperature (°F.)	79.0	80.1	83.6	88.7	91.8	93.7	94.9	94.1	93.9	88.5	83.2	79.9	**86.5**
30-Year Mean–Minimum Temperature (°F.)	45.0	48.1	52.1	57.1	64.0	70.7	72.1	72.3	70.0	62.4	53.9	47.6	**59.4**
30-Year Mean–Average Temperature (°F.)	57.9	60.7	64.6	69.8	75.7	80.5	81.8	81.9	80.1	73.9	66.3	60.2	**71.1**
30-Year Mean–Precipitation (inches)	2.99	2.59	3.97	2.32	2.74	7.92	8.11	7.74	6.18	2.71	1.98	2.28	**51.53**

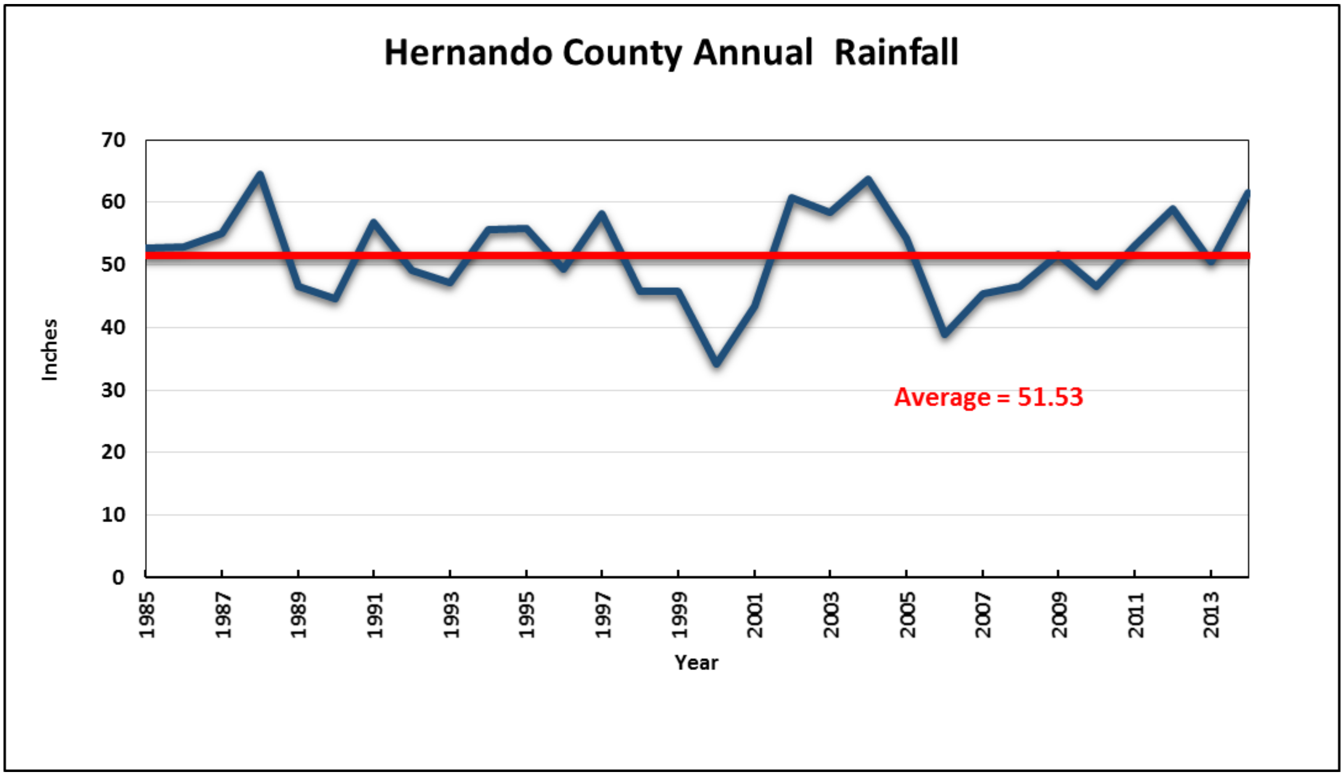


Figure 2.12. Thirty-year precipitation for Hernando County, January 1985–December 2014 (SWFWMD 2015)

2.7 Spring Discharge Information

Minimal information exists on the discharge of these springs. The USGS has stated that spring flow volumes from Bobhill Springs and Magnolia Spring Run in the Magnolia–Aripeka Springs Group are relatively small (Knochnemus and Yobbi 2001). From 1997 to 1998, the USGS-measured spring flow from Bobhill Springs ranged from 0 to 3.56 cfs, with a no-flow condition (point of zero flow) in September 1997. The USGS-measured spring flow from Magnolia Spring Run ranged from 6.3 to 10.4 cfs. The lowest spring flow (6.3 cfs) may not be comparable with other values because the spring run already was under backwater conditions. Backwater conditions are present during high tide in the Gulf of Mexico when the surface water stage is high enough to impede spring flow (Knochnemus and Yobbi 2001).

During the same period, Jones et al. (1997) reported that the average discharge of the springs in the Magnolia–Aripeka Spring Group included in their investigation is probably less than 10 cfs. Although this discharge is low compared with the other large spring complexes, considerably more water probably discharges from diffuse groundwater discharge through sediments in the bottom of Hammock Creek, and in the Gulf of Mexico near the mouth of Hammock Creek (Knochnemus and Yobbi 2001).

Jones et al. (1997) reported that the flow in Salt Spring from 1988 to 1989 averaged 45 cfs. Tidal fluctuations have an effect on discharge, with spring discharges lower during high tide and higher during low tide.

Compared with free-flowing freshwater spring runs (flushing rates on the order of hours), tidally influenced waterbodies such as these spring runs are typically characterized as low-flushing environments (flushing rates on the order of days). Residence time is the time needed to flush a pollutant, such as nitrogen or phosphorus, from a defined point in a waterbody. The residence time (T) is equal to the capacity of the system (V) divided by the flow of the system (q):

$$\mathbf{T = V/q}$$

Where:

T = Residence time.
V = Capacity of the system.
q = Flow of the system.

The effect of residence time on nitrate in the water (rate of flushing) should be taken into consideration when determining appropriate water quality targets for these coastal spring-fed ecosystems with low-flushing environments. Water depth is also a factor to consider, with shallow water depths allowing warming and greater sunlight penetration, resulting in higher plant growth potential (Livingston 2001). In most coastal streams around the world, the combination of increased nutrients and shallow water depths coupled with long residence time yields greater primary productivity, which translates into increased filamentous algae and phytoplankton production.

2.8 Monitoring Results

2.8.1 Nitrate

Nitrogen is the nutrient most commonly causing ecological imbalances in spring systems. It is found in several forms and is ubiquitous in the environment. Seemingly low nitrogen concentrations can actually cause a significant shift in the balance of spring ecological communities, leading to the degradation of biological systems due to the overgrowth of filamentous algal mats, phytoplankton blooms, and sometimes aquatic plants (Harrington et al. 2010).

Nitrate (NO_3) is the form of nitrogen that occurs in the highest concentrations in groundwater and springs. Compared with surface water, the remaining nitrogen content (organic nitrogen and ammonium) in water from springs is low. Nitrite-nitrogen (NO_2), an intermediate form of nitrogen, is almost entirely converted to nitrate in the nitrogen cycle. While nitrate and nitrite are frequently analyzed and reported together as one concentration (nitrate + nitrite-nitrogen), the nitrite contribution is typically low. In this report, nitrate is NO_3 as nitrogen (NO_3N) and, unless otherwise stated, the sum of NO_3 and NO_2 is used to represent NO_3 due to minimal contributions of NO_2.

Historically, nitrogen was only a minor constituent of spring water, and typical nitrate concentrations in Florida were less than 0.2 milligrams per liter (mg/L) until the early 1970s. Since then, elevated concentrations of nitrate have been found in many springs. The UFA's vulnerability to contamination can be observed in the nitrate concentrations at the springs and wells in the contributing area (Jones et al. 1997), where concentrations increased as land use transitioned from natural land to urban development. The main anthropogenic sources of nitrate in spring contributing areas include fertilizers (urban and agricultural) and waste (human and animal).

Figure 2.13 through **Figure 2.19** show the nitrate monitoring results for these impaired springs during the Cycle 2 verified period (January 1, 2004–June 30, 2011) plus more recently (2012–14). **Table 2.3** summarizes the nitrate monitoring results for Aripeka #1 Spring, Aripeka #2 Spring, Boat Spring, Bobhill Spring, Magnolia Spring, Mud Spring, Salt Spring, Wilderness Spring, and Jenkins Creek Spring during the Cycle 2 verified period plus more recently (2004–14).

Table 2.3. Summary of nitrate monitoring results during the Cycle 2 verified period (January 1, 2004–June 30, 2011) plus more recently (2012–14)

Date	Aripeka #1 Spring (1391B)	Aripeka #2 Spring (1391B)	Boat Spring (1391B)	Bobhill Spring (1391B)	Salt Spring (1382G)	Jenkins Creek Spring (1389)	Magnolia Spring (1391B)	Mud Spring (1382G)	Wilderness Spring (1382G)
N (2004–14)	2	2	12	37	14	54	44	18	21
Mean (2004–14)	0.43	0.90	0.55	0.68	0.55	0.68	0.57	0.40	0.45
Median (2004–14)	0.43	0.90	0.54	0.69	0.55	0.75	0.58	0.41	0.45
Minimum (2004–14)	0.34	0.88	0.46	0.01	0.41	0.00	0.48	0.22	0.39
Maximum (2004–14)	0.52	0.91	0.66	1.82	0.63	0.97	0.66	0.54	0.50

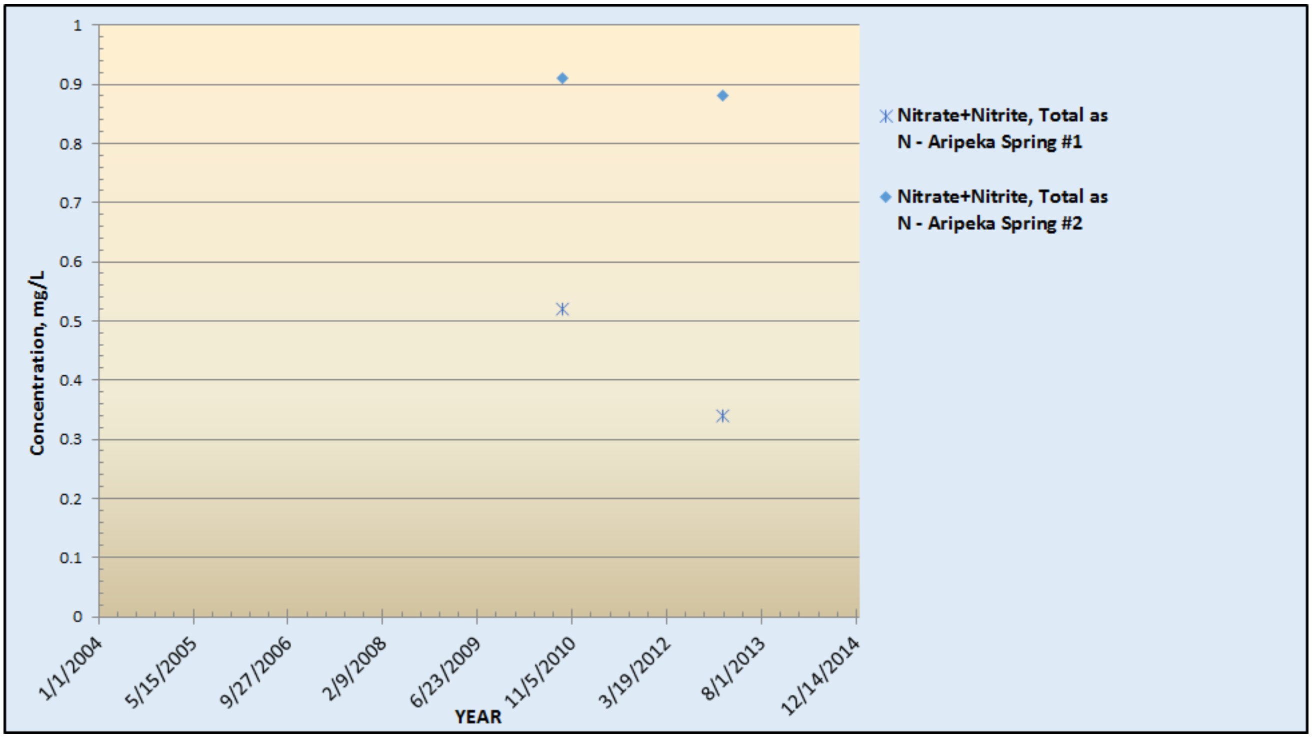


Figure 2.13. Summary of the nitrate monitoring results for Aripeka #1 Spring and Aripeka #2 Spring during the Cycle 2 verified period plus more recently (2004–14)

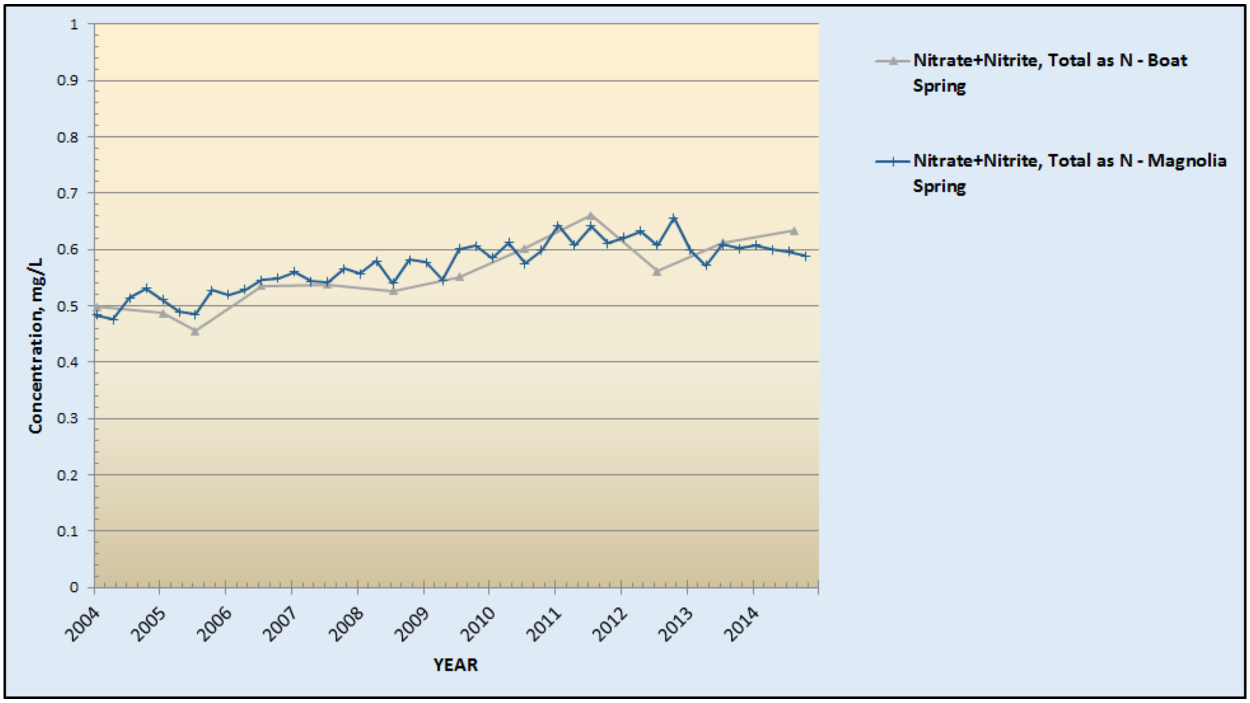


Figure 2.14. Summary of the nitrate monitoring results for Boat Spring and Magnolia Spring during the Cycle 2 verified period plus more recently (2004–14)

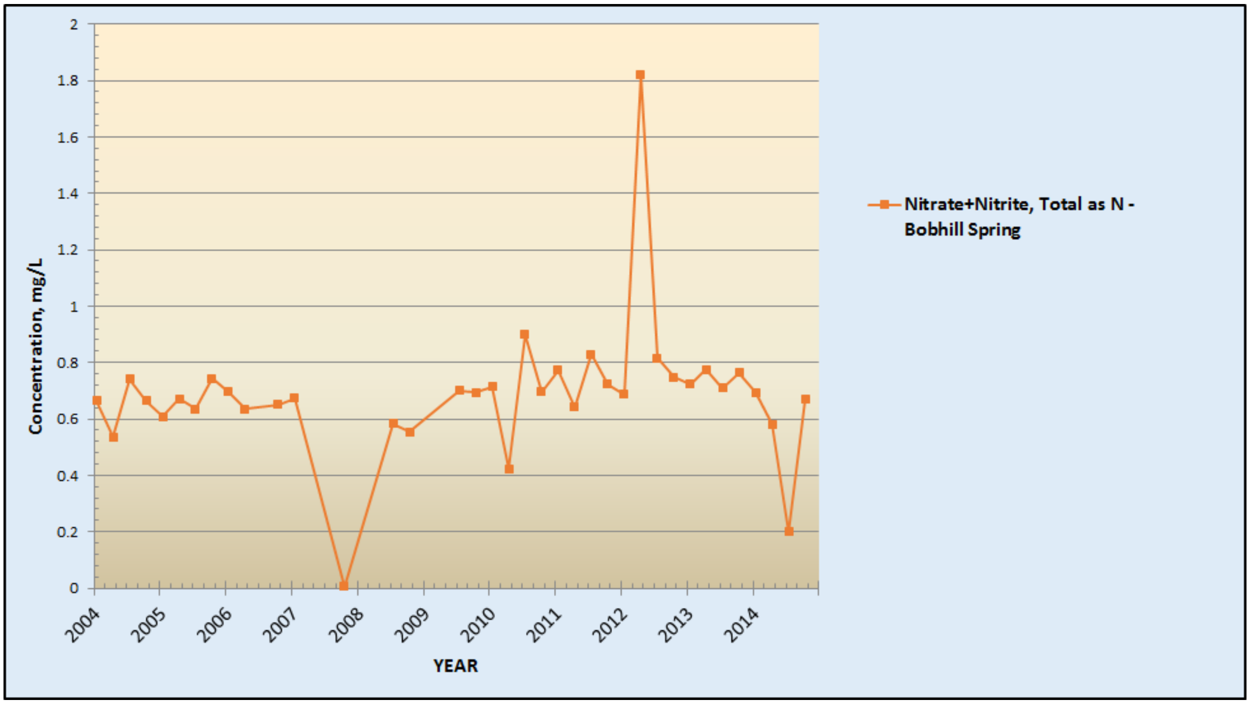


Figure 2.15. Summary of the nitrate monitoring results for Bobhill Spring during the Cycle 2 verified period plus more recently (2004–14)

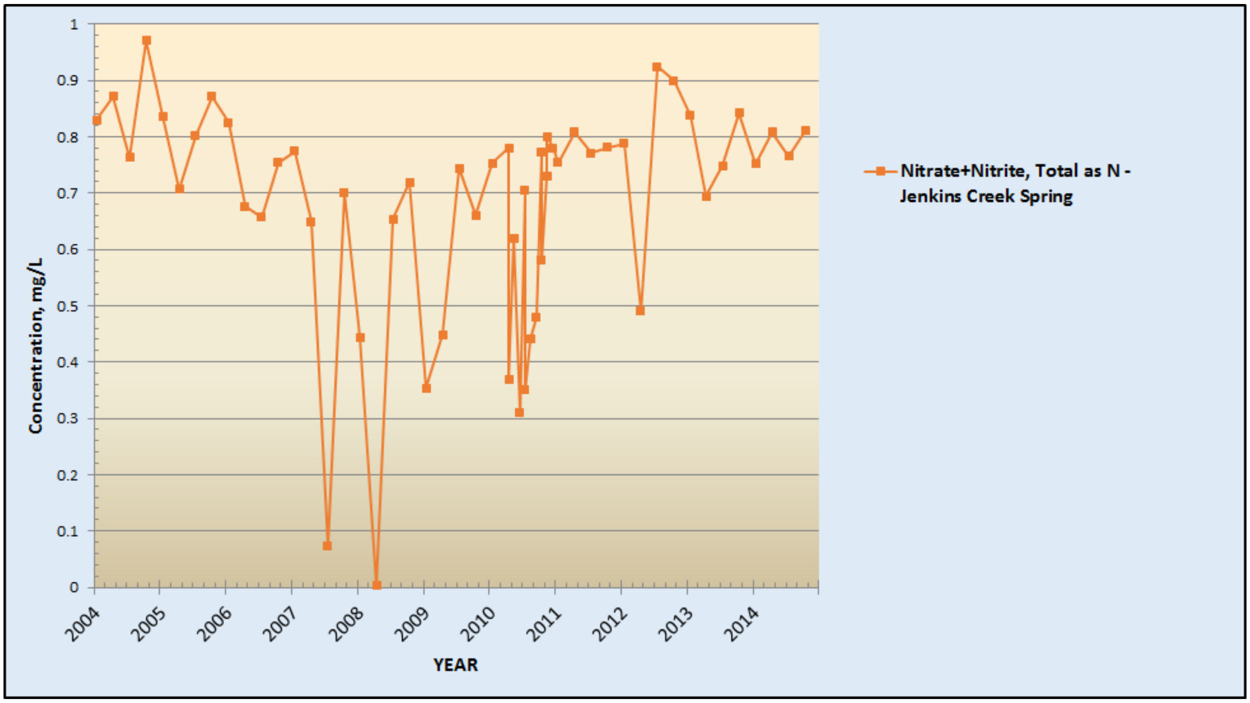


Figure 2.16. Summary of the nitrate monitoring results for Jenkins Creek Spring during the Cycle 2 verified period plus more recently (2004–14)

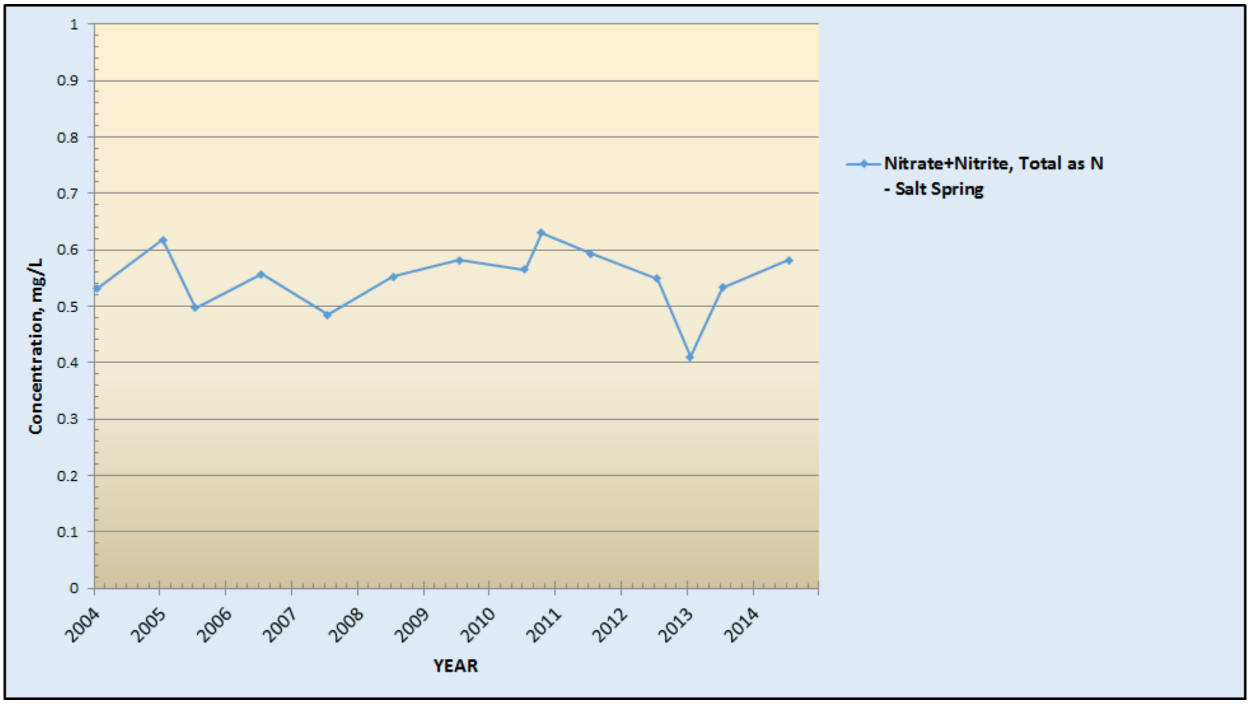


Figure 2.17. Summary of the nitrate monitoring results for Salt Spring during the Cycle 2 verified period plus more recently (2004–14)

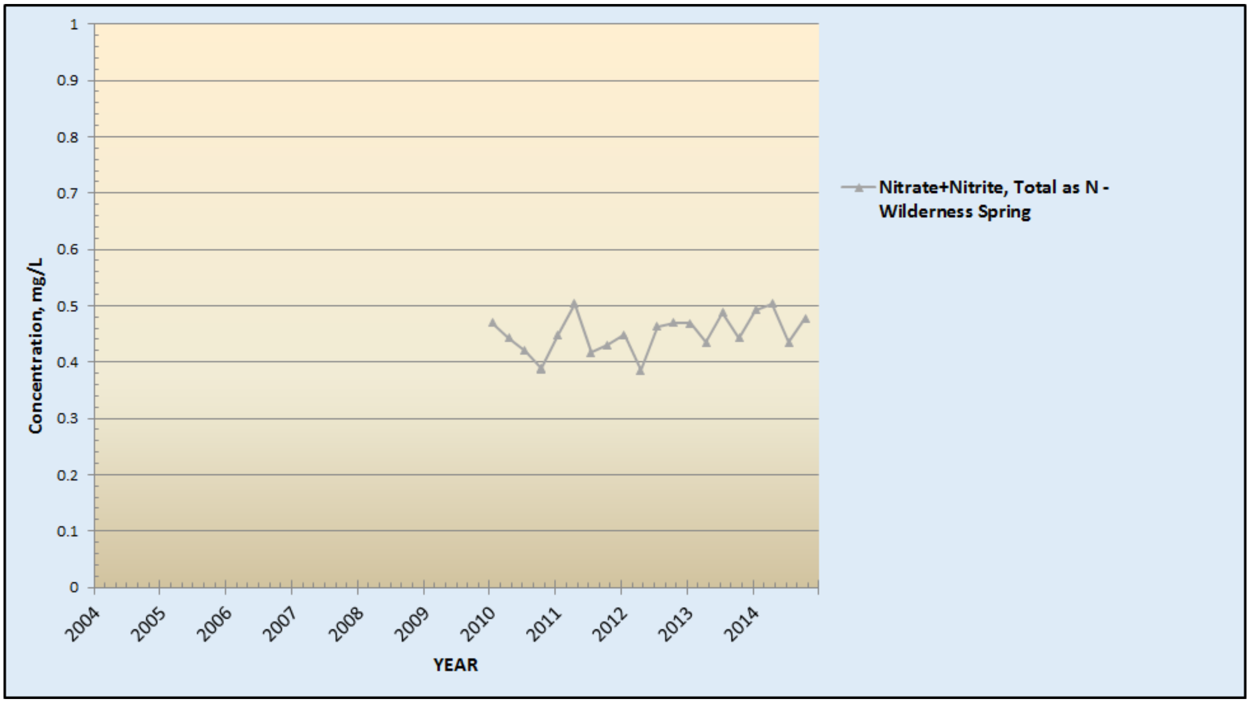


Figure 2.18. Summary of the nitrate monitoring results for Wilderness Spring during the Cycle 2 verified period plus more recently (2004–14)

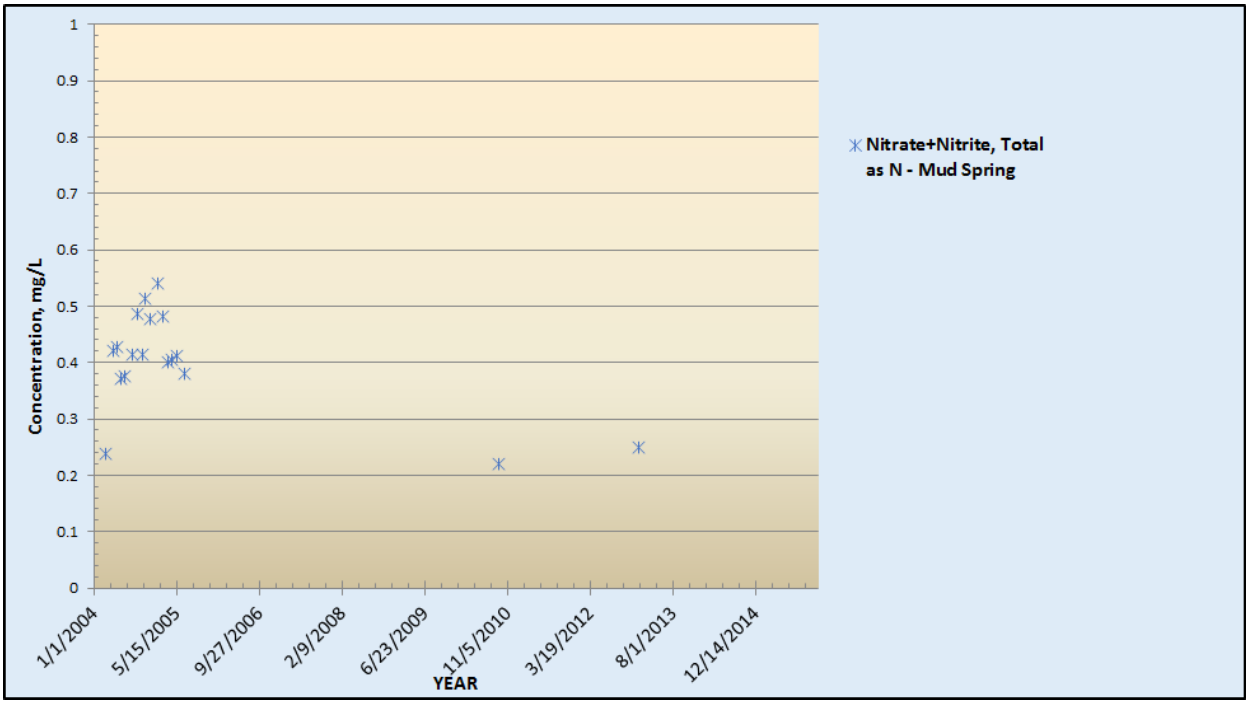


Figure 2.19. Summary of the nitrate monitoring results for Mud Spring during the Cycle 2 verified period plus more recently (2004–14)

Temporal Trends for Nitrate

For each spring, nitrate data from water quality sampling stations for the entire period of record were analyzed to detect temporal trends. A nonparametric test for trends is obtained using the Mann-Kendall statistical test, which examines if there is a general increase or decrease in nitrate concentrations over time (Schwartz 2013). The entire period of record for Boat Spring, Bobhill Spring, and Magnolia Spring is from 1964 to 2014. The entire period of record for Mud Spring and Jenkins Creek Spring is from 1988 to 2014. The entire period of record for Salt Spring is from 1962 to 2014, and the Wilderness Spring period of record is from 2010 to 2014.

The statistical test revealed increasing temporal trends for nitrate in Boat Spring (N [results] = 38, Kendall tau = 0.73, Prob = 0.0001), Bobhill Spring (N [results] = 77, Kendall tau = 0.30, Prob = 0.0001), Magnolia Spring (N [results] = 90, Kendall tau = 0.82, Prob = 0.0001), Mud Spring (N [results] = 28, Kendall tau = 0.38, Prob = 0.004), Salt Spring (N [results] = 45, Kendall tau = 0.61, Prob = 0.0001), Wilderness Spring (N [results] = 21, Kendall tau = 0.30, Prob = 0.05), and Jenkins Creek Spring (N [results] = 73, Kendall tau = 0.28, Prob = 0.0005).

The nitrate data for Aripeka #1 Spring and Aripeka #2 Spring are limited. The period of record for Aripeka #1 Spring and Aripeka #2 Spring is 1994 to 2013. However, due to their inaccessibility from land, Aripeka #1 Spring was only sampled seven times and Aripeka #2 Spring was only sampled nine times. Because of the limited data, a Mann-Kendall test could not be performed for either spring.

Due to the increasing temporal trend in nitrate and nitrate being the main form of nitrogen in spring water, nitrate is considered the target nutrient for Boat Spring, Bobhill Spring, Magnolia Spring, Mud Spring, Salt Spring, Wilderness Spring, and Jenkins Creek Spring. **Chapter 5** discusses the nutrient impairment and the setting of the target concentration.

2.8.2 Orthophosphate

Phosphorus is naturally abundant in the geologic material in much of Florida and is often naturally present in significant concentrations in both surface water and groundwater. The most common form of phosphorus in geologic material is orthophosphate. Orthophosphate is present in limestone because phosphorus has an affinity to bind to the calcium found in the rock formation (Fitts 2013). Only the inorganic form of phosphorus, orthophosphate, is generally found at significant concentrations in groundwater and springs. The organic phosphorus content is normally low in spring water.

Figure 2.20 through **Figure 2.21** display the orthophosphate monitoring results for these impaired springs during the Cycle 2 verified period (January 1, 2004–June 30, 2011) plus more recently (2012–14). **Table 2.4** summarizes the orthophosphate monitoring results for Aripeka #1 Spring, Aripeka #2 Spring, Boat Spring, Bobhill Spring, Magnolia Spring, Mud Spring, Salt Spring, Wilderness Spring, and Jenkins Creek Spring during the Cycle 2 verified period plus more recently (2004–14).

Table 2.4. Summary of orthophosphate monitoring results during the Cycle 2 verified period (January 1, 2004–June 30, 2011) plus more recently (2012–14)

Date	Aripeka #1 Spring (1391B)	Aripeka #2 Spring (1391B)	Boat Spring (1391B)	Bobhill Spring (1391B)	Salt Spring (1382G)	Jenkins Creek Spring (1389)	Magnolia Spring (1391B)	Mud Spring (1382G)	Wilderness Spring (1382G)
N (2004–14)	1	1	12	37	13	44	46	17	20
Mean (2004–14)	0.004	0.008	0.008	0.007	0.012	0.012	0.009	0.011	0.010
Median (2004–14)	0.004	0.008	0.009	0.007	0.012	0.010	0.010	0.010	0.010
Minimum (2004–14)	0.004	0.008	0.006	0.004	0.008	0.006	0.003	0.010	0.007
Maximum (2004–14)	0.004	0.008	0.010	0.011	0.014	0.060	0.014	0.014	0.012

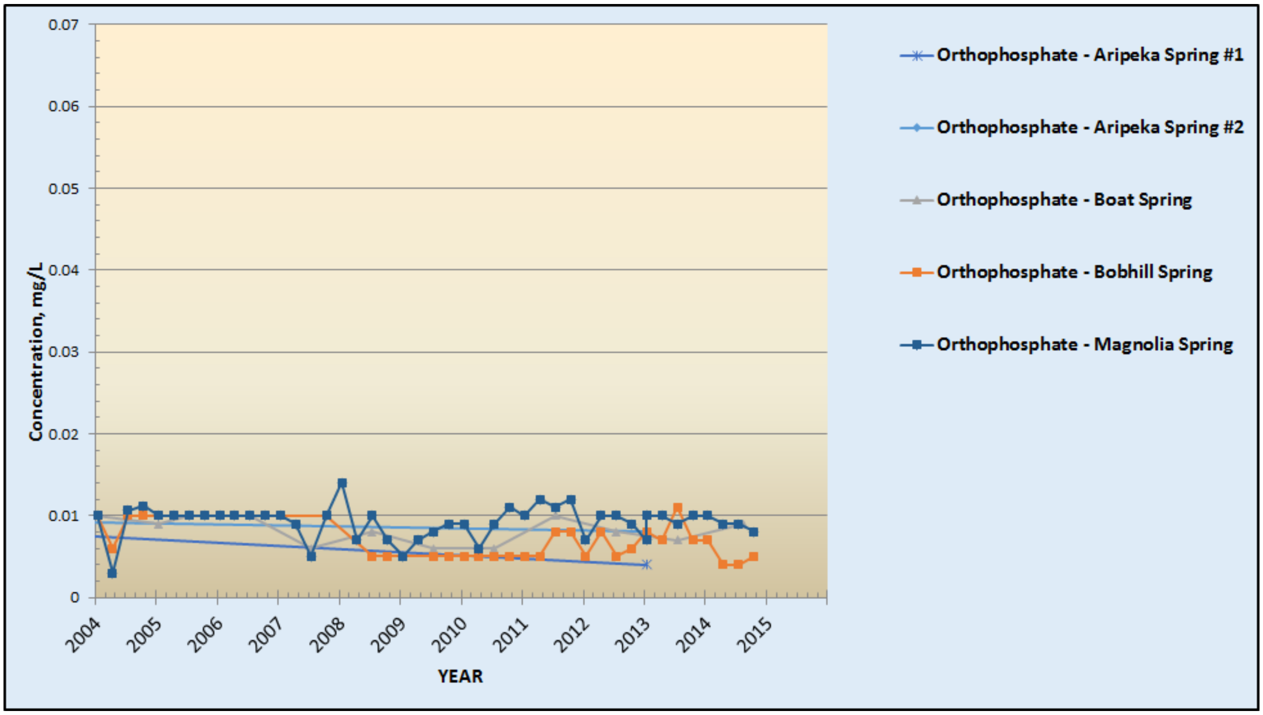


Figure 2.20. Summary of the orthophosphate monitoring results for Aripeka #1 Spring, Aripeka #2 Spring, Boat Spring, Bobhill Spring, and Magnolia Spring during the Cycle 2 verified period plus more recently (2004–14)

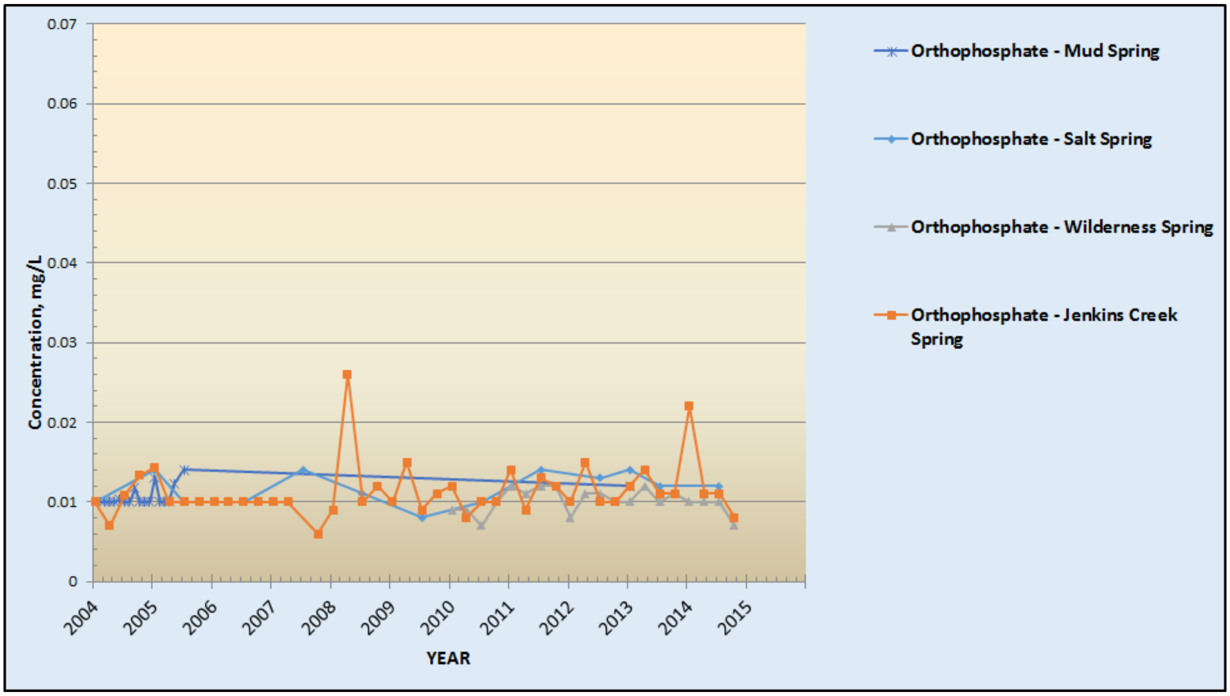


Figure 2.21. Summary of the orthophosphate monitoring results for Mud Spring, Salt Spring, Wilderness Spring, and Jenkins Creek Spring during the Cycle 2 verified period plus more recently (2004–14)

Temporal Trends for Orthophosphate

For each spring, orthophosphate data from water quality sampling stations for the entire period of record were analyzed to detect temporal trends using the Mann-Kendall statistical test. The orthophosphate data for Aripeka #1 Spring and Aripeka #2 Spring are limited. The period of record for Aripeka #1 Spring and Aripeka #2 Spring is 1994 to 2013. However, due to their inaccessibility from land, Aripeka #1 Spring was only sampled eight times and Aripeka #2 Spring was only sampled nine times. Because of the limited data, a Mann-Kendall test could not be performed for either spring.

The periods of record for the other springs are as follows:

- Bobhill Spring, 1983–2014.
- Boat Spring and Magnolia Spring, 1994–2014.
- Mud Spring, 1996–2013.
- Jenkins Creek Spring, 1999–2014.
- Salt Spring, 1993–2014.

- Wilderness Spring, 2010–2014.

The statistical test revealed that from the early 1990s to 2014, orthophosphate concentrations in Mud Spring, Salt Spring, Wilderness Spring, and Jenkins Creek Spring showed a stable temporal trend, and concentrations remained close to background conditions (0.015 mg/L). However, the statistical test revealed, over the entire period of record, decreasing temporal trends for orthophosphate in Boat Spring (N [results] = 35, Kendall tau = -0.37, Prob = 0.003), Bobhill Spring (N [results] = 71, Kendall tau = -0.58, Prob = 0.0001), and Magnolia Spring (N [results] = 85, Kendall tau = -0.34, Prob = 0.0001). For these springs, elevated orthophosphate concentrations during the early 1990s decreased to background conditions in 2014. The decreasing trend in orthophosphate from the 1990s to today could be a result of state and community governments in Florida that actively pushed for phosphate legislation limiting detergent phosphorus.

Due to current orthophosphate concentrations at background conditions, orthophosphate is not considered a target nutrient for the TMDL. These background conditions most likely represent the naturally occurring phosphate in the geologic material.

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criteria Applicable to the TMDL

Florida's surface waters are protected for six designated use classifications, as follows:

Class I	**Potable water supplies**
Class II	**Shellfish propagation or harvesting**
Class III	**Fish consumption, recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife**
Class III	**Limited fish consumption, recreation or limited recreation, and/or propagation and maintenance of a limited population of fish and wildlife**
Class IV	**Agricultural water supplies**
Class V	**Navigation, utility, and industrial use (there are no state waters currently in this class)**

The Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group (WBIDs 1391B, 1389, and 1382G, respectively) are Class III waterbodies (with designated uses of recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife). The Class III water quality criterion applicable to the impairment addressed by this TMDL is nutrients, which have been demonstrated to adversely affect flora or fauna.

3.2 Applicable Water Quality Standards and Numeric Water Quality Targets

3.2.1 Nutrients

The narrative nutrient water quality criterion for the protection of Class III waters, as established by Subsection 62-303.450(2), F.A.C. (IWR), states that nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. This imbalance includes algal mats or blooms that are present in sufficient quantities to pose a nuisance or hinder the reproduction of a threatened or endangered species, as stated in Subsections 62-303.353(3) and 62-303.354(2), F.A.C. Accordingly, the IWR (Subsection 62-303.450[5], F.A.C.) specifically allows the use of alternative, site-specific thresholds that more accurately reflect conditions beyond which an imbalance in flora or fauna occurs in the waterbody.

For the impaired waterbodies, benthic macroalgae mats and epiphytic algae growing on macrophytes were shown to be a significant problem. Algal growth causes a variety of ecological impairments, including, but not limited to, habitat smothering, the production of toxins that may affect biota, the reduction of oxygen levels, and an increase in diurnal swings of the DO regime in the stream. Macroalgal mats can produce human health problems, foul beaches, inhibit navigation, and reduce the aesthetic value of clear springs or spring runs.

Research on filamentous algae has provided evidence that algal growth responds to the introduction of phosphorus and nitrogen in water (Stevenson et al. 2007). Nitrate is considered the target nutrient for the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group. Orthophosphate in the springs is at natural background levels and is not a target nutrient that needs a TMDL.

Chapter 5 discusses the nitrate impairment and the setting of the TMDL target concentration for nitrate. These TMDL target concentrations for the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group will be submitted to the EPA for approval as site-specific (Hierarchy 1) interpretations of the narrative nutrient criterion for these waterbodies, as stated in Rule 62-302.531, F.A.C.

3.2.2 Outstanding Florida Water (OFW) Designation

The OFW criterion in Rule 62-302.700, F.A.C., allows no degradation in water quality for special waters. The Weeki Wachee Riverine System was designated as an OFW in 2003, meaning that it is worthy of special protection because of its natural attributes. Mud Spring, Salt Spring, Wilderness Spring, and Jenkins Creek Spring are located within the Weeki Wachee riverine system OFW boundaries. Aripeka #1 Spring, Aripeka #2 Spring, Boat Spring, Bobhill Spring, and Magnolia Spring are not located in an OFW.

Chapter 4: ASSESSMENT OF SOURCES

4.1 Population and Land Use in the Spring Contributing Areas

4.1.1 Population

The total population of Hernando County was 172,778, and the population of Pasco County was 464,697, according to the U.S. Census Bureau's 2010 data. There are 71,745 households (HH) and 84,504 housing units (HU) in Hernando County, and 189,612 HH and 228,928 HU in Pasco County. Hernando County contains 365.6 people per square mile of land and 178.8 HU per square mile; while Pasco County contains 622.2 people per square mile of land and 306.5 HU per square mile.

As mentioned in **Chapter 1**, there is an overlap of contributing areas between the Magnolia–Aripeka Springs Group and the Weeki Wachee Springs Group because the overland surface water drainage boundaries do not match the subsurface groundwater flow boundaries. Consequently both contributing areas share land use values for a relatively highly populated area. The contributing area for the Magnolia–Aripeka Springs Group is 47% residential. A little over 27% of the contributing area for the Weeki Wachee Spring Group is residential. The highest population for both contributing areas is found in Hernando County, mainly between U.S. Highways 19 and 41 (**Figure 4.1** and **Figure 4.2**).

The largest residential area in this part of Hernando County is Spring Hill. The original subdivision in the community, Spring Hill Unit 1, was platted in February 1967. Beginning in 1974, the part of Spring Hill in the immediate vicinity of Weeki Wachee Spring began to experience significant residential growth with the development of the Spring Hill Unit 25 subdivision. In 2012, the unincorporated community of Spring Hill contained 44,435 dwellings, or more than half the housing units in the entire county (Hernando County 2012).

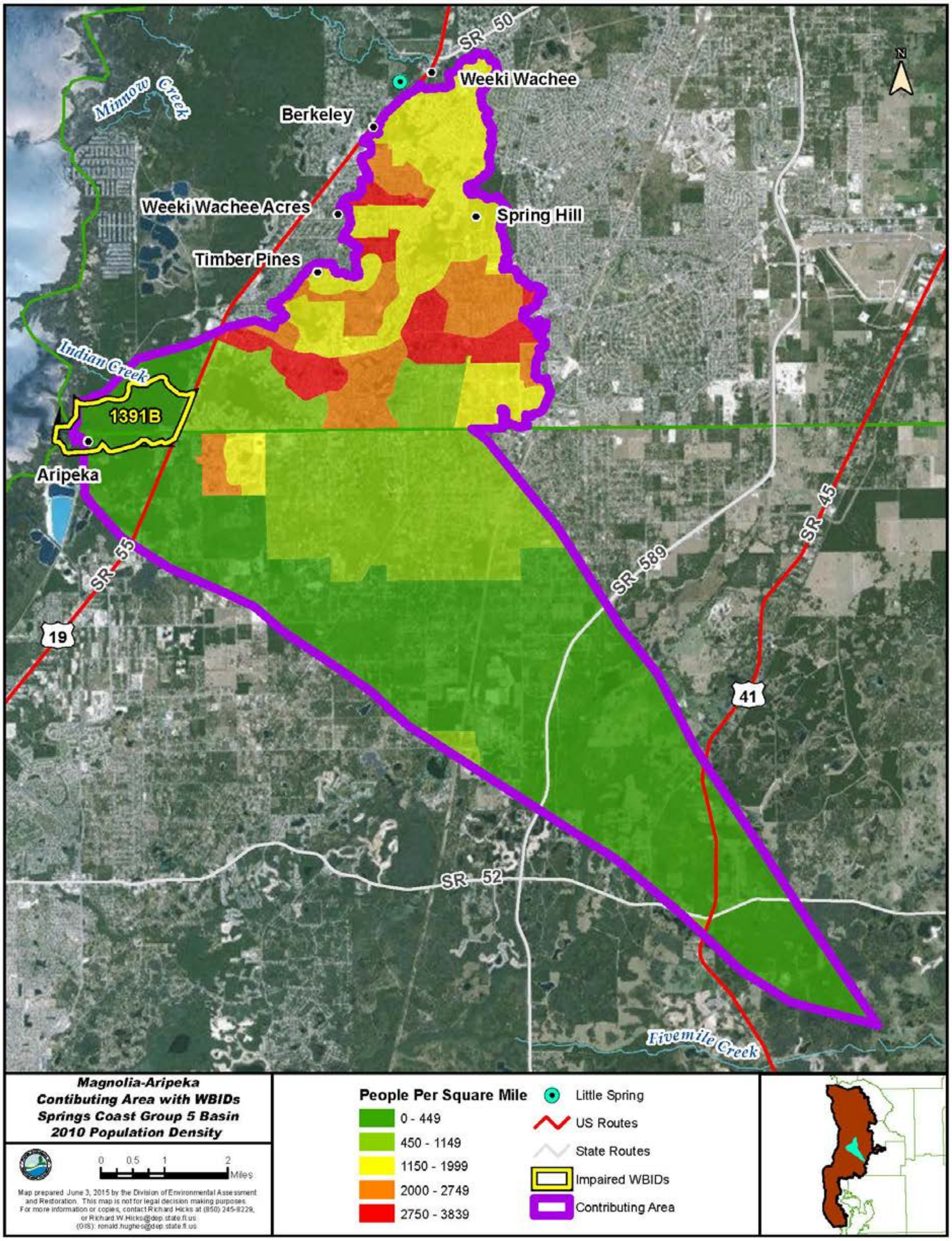


Figure 4.1. Population density for the Magnolia–Aripeka Springs Group contributing area (based on 2010 Census data)

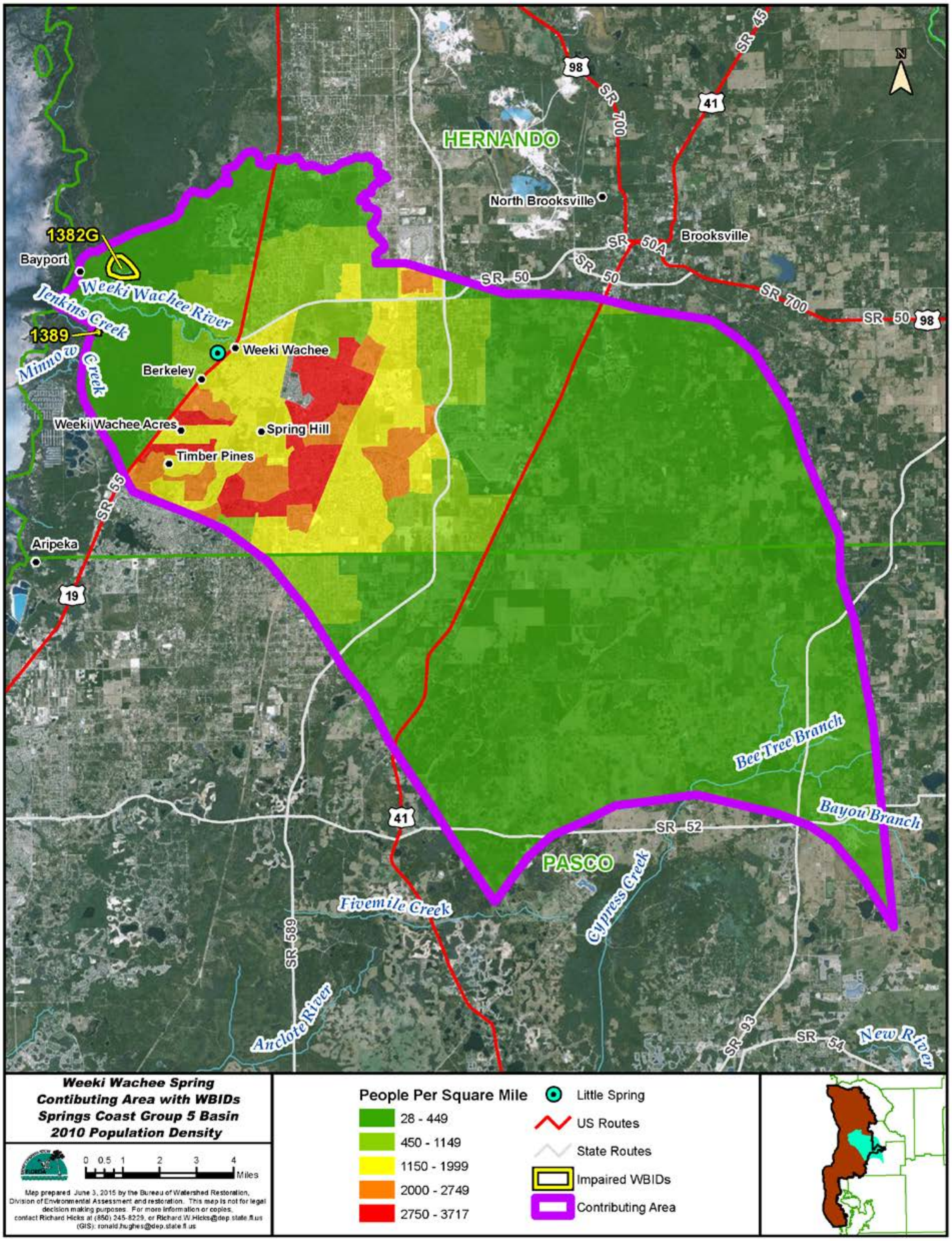


Figure 4.2. Population density for the Weeki Wachee Springs Group contributing area (based on 2010 Census data)

4.1.2 Land Uses

Land use information for the Magnolia–Aripeka Springs Group contributing area and the Weeki Wachee Springs Group contributing area was obtained from the 2009 SWFWMD land use geographic information system (GIS) coverage, which is the most recent land use data available. **Table 4.1** and **Figure 4.3** show the breakdown of the various land use categories in the Weeki Wachee Springs Group contributing area. In 2009 for the Weeki Wachee Springs Group, residential, forest, and agricultural areas were the predominant land uses in the contributing area, covering 27%, 23%, and 23%, respectively. Wetlands were fourth, comprising 15% of the contributing area for the Weeki Wachee Springs Group.

Table 4.2 and **Figure 4.4** show the breakdown of the various land use categories for the Magnolia–Aripeka Springs Group contributing area. In 2009, residential, forest, and wetland areas were the predominant land uses in the contributing area, covering 47%, 17%, and 15%, respectively. Wetlands were fourth, with 15% of the contributing area.

Table 4.1. Percentages of major land uses in the Weeki Wachee Springs Group contributing area in 2009

Code	Land Use	Square Miles	Acreage	% of Contributing Area
1000	Urban Open	0.00	0.00	0.00%
1100	Low-Density Residential	32.34	20,695.55	12.72%
1200	Medium-Density Residential	31.24	19,990.48	12.29%
1300	High-Density Residential	5.95	3,810.89	2.35%
1400	Commercial	3.73	2,390.32	1.47%
1500	Light Industrial	0.54	345.40	0.21%
1600	Extractive/Quarries/Mines	0.00	0.00	0.00%
1700	Institutional	1.33	851.06	0.52%
1800	Recreational (Golf Courses, Parks, Marinas, etc.)	3.48	2,226.63	1.37%
1900	Open Land	5.93	3,796.83	2.33%
2000	Agriculture	57.50	36,800.31	22.62%
3000+7000	Rangeland	7.03	4,499.99	2.77%
4000	Forest/Rural Open	58.94	37,721.89	23.18%
5000	Water	2.42	1,548.87	0.95%
6000	Wetlands	38.58	24,688.87	15.17%
8000	Communication and Transportation	5.23	3,346.65	2.06%
	Total	**221.90**	**162,713.72**	**100%**

Table 4.2. Percentages of major land uses in the Magnolia–Aripeka Springs Group contributing area in 2009

Code	Land Use	Square Miles	Acreage	% of Contributing Area
1000	Urban Open	0.00	0.00	0.00%
1100	Low-Density Residential	13.81	8,838.75	23.27%
1200	Medium-Density Residential	12.42	7,951.16	20.93%
1300	High-Density Residential	1.68	1,077.27	2.83%
1400	Commercial	0.78	501.90	1.31%
1500	Light Industrial	0.20	130.74	0.34%
1600	Extractive/Quarries/Mines	0.12	80.37	0.22%
1700	Institutional	0.44	285.63	0.74%
1800	Recreational (Golf Courses, Parks, Marinas, etc.)	1.05	670.33	1.77%
1900	Open Land	1.62	1,035.30	2.73%
2000	Agriculture	4.11	2,632.76	6.93%
3000+7000	Rangeland	0.87	557.64	1.47%
4000	Forest/Rural Open	10.46	6,696.14	17.63%
5000	Water	0.79	507.46	1.34%
6000	Wetlands	9.13	5,840.59	15.39%
8000	Communication and Transportation	1.83	1,169.94	3.08%
	Total	**59.34**	**37,975.98**	**100%**

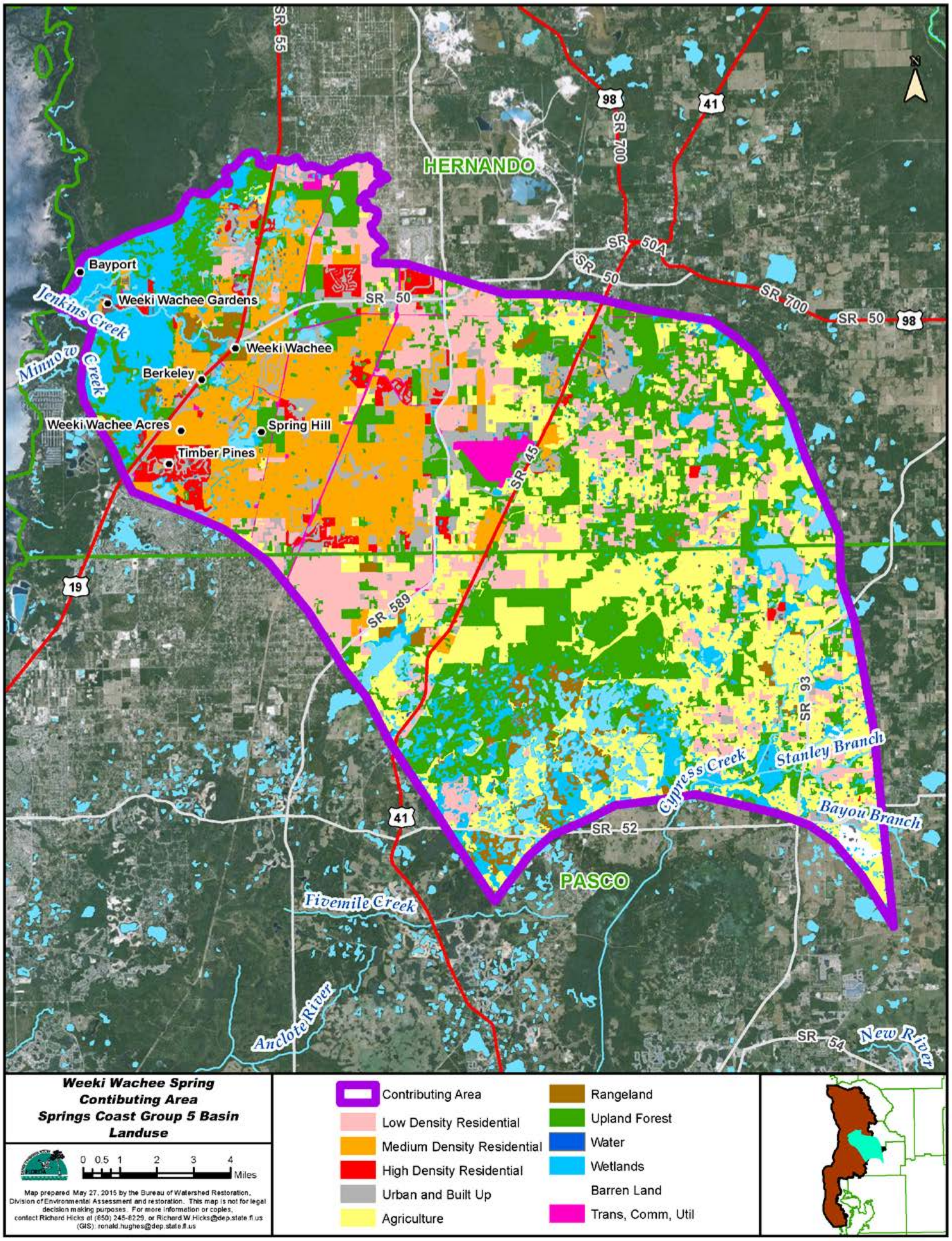


Figure 4.3. Land uses in the Weeki Wachee Springs Group contributing area in 2009

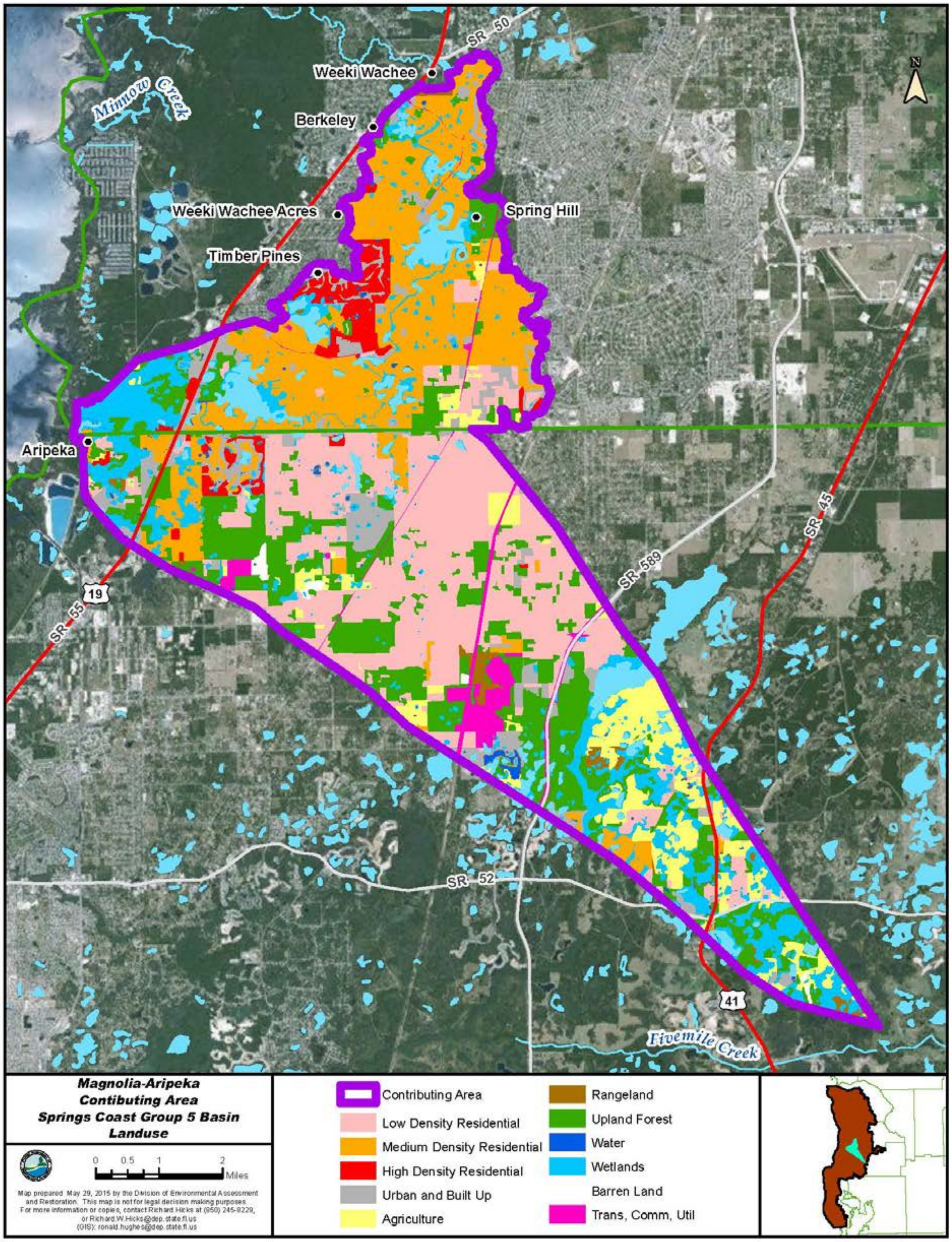


Figure 4.4. Land uses in the Magnolia–Aripeka Springs Group contributing area in 2009

4.2 Pollutant Source Categories

An important part of the TMDL analysis is the identification of pollutant source categories, source subcategories, or individual sources of nutrients in the watershed and the magnitude of pollutant loading contributed by each of these sources. Sources are broadly classified as either "point sources" or "nonpoint sources." Historically, the term "point sources" has meant discharges to surface waters that typically have a continuous flow via a discernible, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) that discharge directly to surface waters and are covered by a National Pollutant Discharge Elimination System (NPDES) permit are examples of traditional point sources.

In contrast, the term "nonpoint sources" refers to intermittent, rainfall-driven, diffuse sources of pollution associated with everyday human activities and those sources that do not directly discharge to an impaired surface water, including runoff from urban land uses, wastewater treatment sites, stormwater drainage wells, agriculture, silviculture, mining, discharges from onsite treatment and disposal systems (OSTDS) (septic systems), and atmospheric deposition. All pollutant sources that discharge to groundwater, including wastewater application sites, are also classified as nonpoint sources.

However, the 1987 amendments to the Clean Water Act redefined certain nonpoint sources of surface water pollution as point sources subject to regulation under the EPA's NPDES Program. These nonpoint sources included certain urban stormwater discharges to surface water, such as those from local government master drainage systems, construction sites with land disturbance greater than one acre, and a wide variety of industries (see **Appendix A** for background information on the federal and state stormwater programs).

To be consistent with Clean Water Act definitions, the term "point source" will be used to describe traditional point sources (such as domestic and industrial wastewater discharges to surface water) and stormwater system discharges to surface water that require an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL (see **Section 6.1**). However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES stormwater discharges and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

4.3 Potential Sources of Nitrate in the Springs Contributing Area

While nitrate occurs naturally in the environment through nitrogen fixation, bacterial processes, and lightning, the elevated and increasing levels of nitrate in the springs may come from a variety of anthropogenic sources. These include permitted domestic waste treatment sites; OSTDS; fertilizer applied to residential landscaping and lawns, golf courses, and agricultural operations; pet and livestock waste; and atmospheric deposition. While not a nitrate source per se, stormwater runoff is an important pathway for nitrate to reach an impaired waterbody.

4.3.1 Domestic Wastewater Discharges to Groundwater

None of the domestic WWTFs has NPDES-permitted discharges to surface water. Thus by definition they are not considered point sources of pollution but are instead classified as nonpoint sources. These domestic wastewater facilities discharge treated effluent to groundwater via spray irrigation, rapid infiltration basins (RIBs), drainfields, and percolation ponds, and in some cases treated effluent is reused as irrigation water on golf courses and public areas. Biosolids (residuals) are spread on the land.

Domestic wastewater application sites can produce a significant load of nitrogen in spring areas. There are 22 permitted domestic wastewater treatment facilities in the contributing area. The contributing area also has two residuals application sites permitted by the Florida Department of Health (FDOH). **Table 4.3** lists the facilities over 0.1 million gallons per day (mgd) and their permit numbers. **Figure 4.5** and **Figure 4.6** shows the locations of the domestic wastewater facilities and FDOH-permitted residual application sites in the Weeki Wachee and Magnolia–Aripeka springs contributing areas. None of the domestic WWTFs has NPDES-permitted discharges to surface water. Thus by definition they are not considered point sources of pollution. They are instead included in the nonpoint source contribution discussion in a subsequent chapter.

These domestic wastewater facilities discharge treated effluent to groundwater via spray irrigation, RIBs, drainfields, or percolation ponds, and in some cases treated effluent is reused as irrigation water on golf courses and public areas. **Table 4.3** lists the four largest domestic facilities in the Weeki Wachee and Magnolia–Aripeka Springs contributing areas with permitted discharges of 0.1 mgd or greater during the period of record (2004–14). Three of these are located in the Weeki Wachee contributing area, and one is located in the Magnolia–Aripeka contributing area. The Weeki Wachee contributing area also has two residuals management facilities (RMFs): AAA White Septic Tank Service and

Appalachian Materials (the latter has a permit to discharge domestic wastewater residuals up to a maximum of 320 dry tons per year).

Table 4.3. Domestic wastewater facilities with permitted capacity over 0.1 mgd and RMFs in the vicinity of the Weeki Wachee and Magnolia–Aripeka Springs contributing areas

[a] Dry tons

Permit Number	Facility Name	Facility Type	NPDES	Design Capacity (mgd)	Contributing Area	County
FLA012741	Pasco County – Shady Hills Subregional WWTF	Domestic Wastewater Program	No	2	Magnolia–Aripeka	Pasco
FLA012052	AAA White's Septic Tank Service RMF	Residuals	No	320.0000a	Weeki Wachee	Hernando
FLA012831	Traveler's Rest RVP WWTF	Domestic Wastewater Program	No	0.1000	Weeki Wachee	Pasco
FLA280348	Appalachian Materials Systems	Residuals	No	1,652.00a	Weeki Wachee	Hernando
FLA017223	Hernando Airport Subregional WWTF	Domestic Wastewater Program	No	0.7500	Weeki Wachee	Hernando
FLA012069	Glen WRF	Domestic Wastewater Program	No	1.0000	Weeki Wachee	Hernando

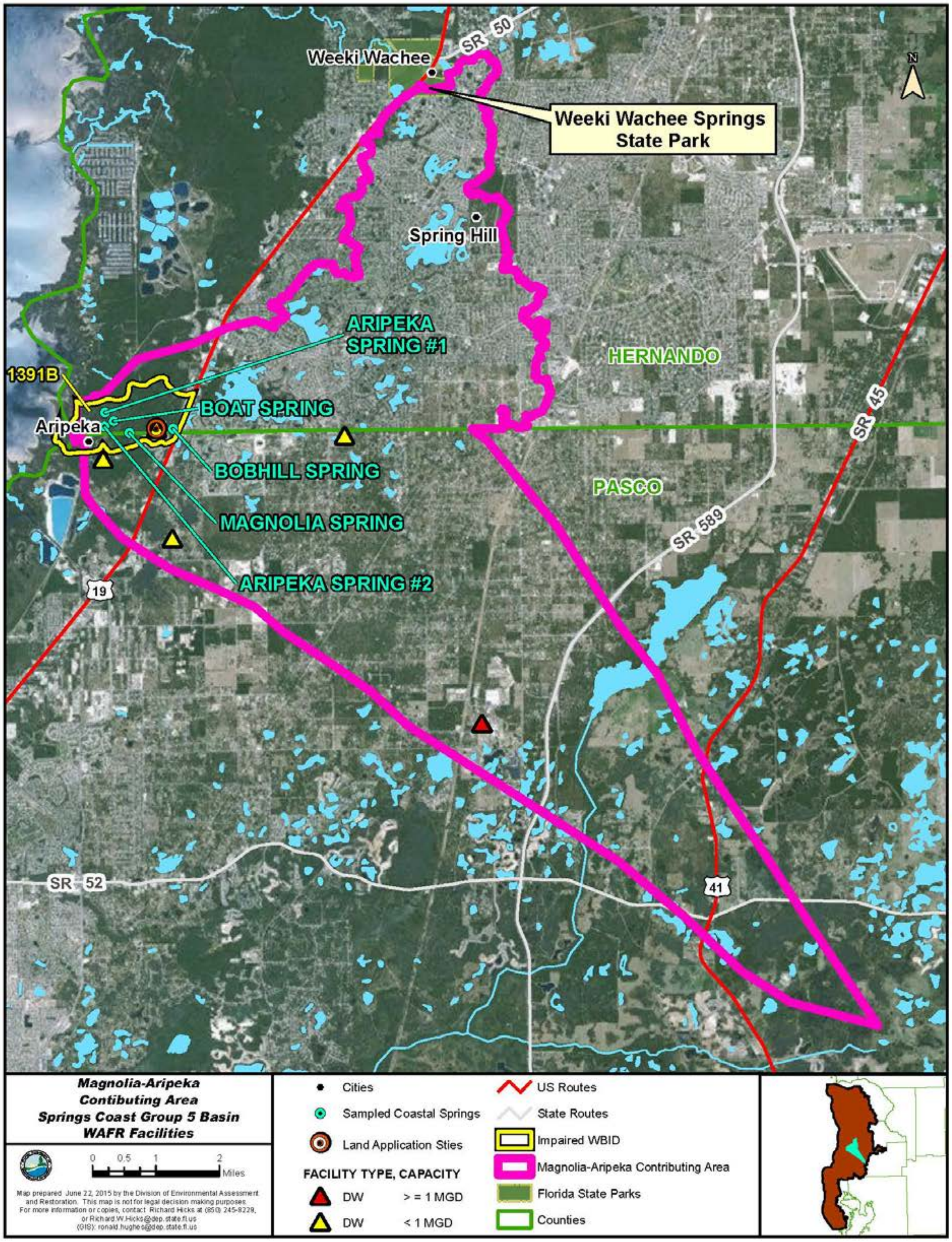


Figure 4.5. Domestic wastewater facilities in the Magnolia–Aripeka Springs Group contributing area

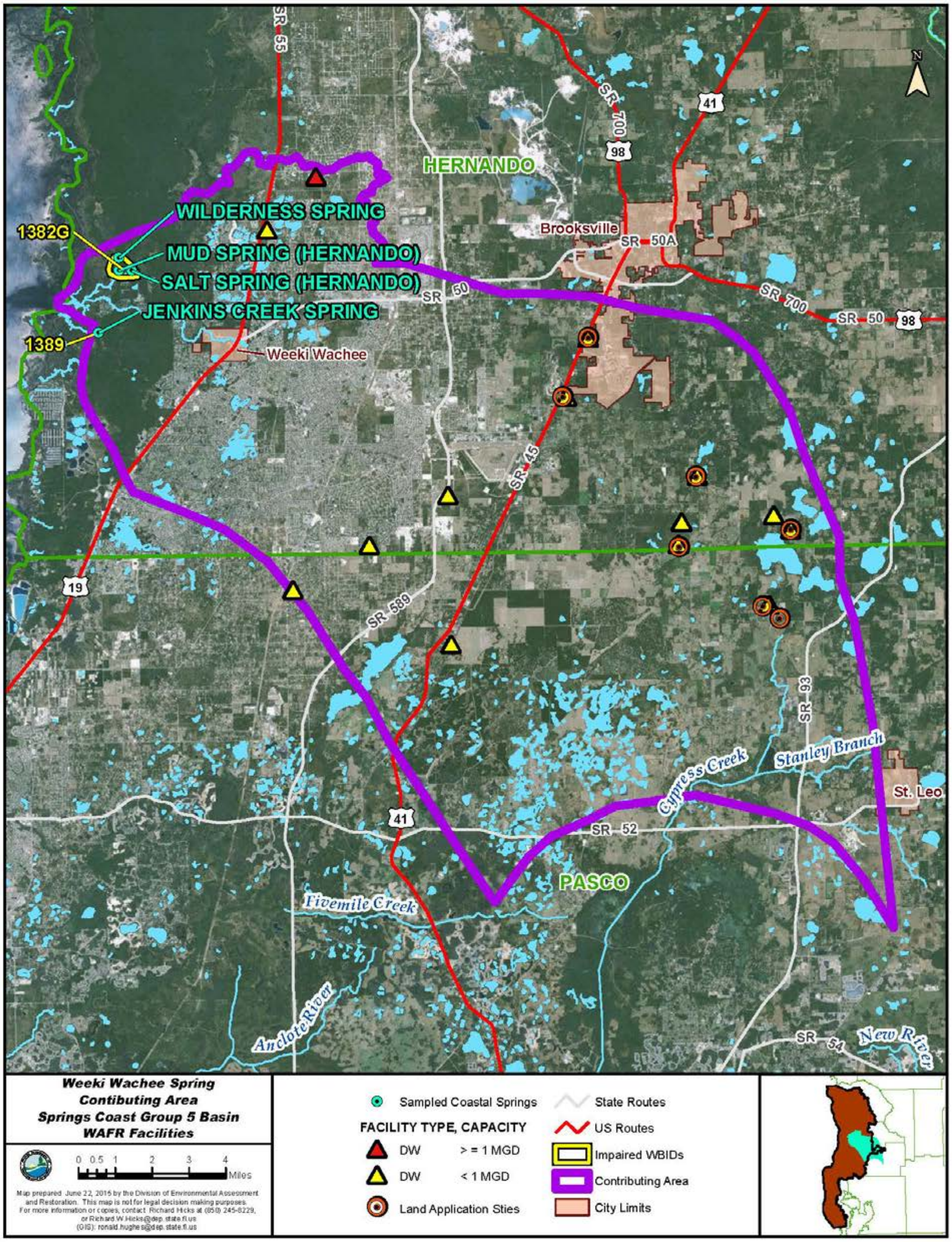


Figure 4.6. Domestic wastewater facilities in the Weeki Wachee Springs Group contributing area

Municipal Separate Storm Sewer Systems (MS4s)

An MS4 under the federal NPDES Program is a publicly owned conveyance or system of conveyances (i.e., ditches, curbs, catch basins, underground pipes, etc.) that is designed or used for collecting or conveying stormwater and that discharges directly to surface waters of the state. The contributing area of the impaired waters include the service area of a local government currently holding an MS4 permit. MS4 entities may discharge nutrients to waterbodies in response to storm events.

The NPDES stormwater collection systems in the springs contributing area are maintained by Hernando County (FLR04E040), FDOT District 7 (FLR04E017–Hernando), Pasco County co-permittee with FDOT District 7 (FLS000032), and Florida Turnpike Enterprise (FLR04E049) (**Figure 4.7** and **Figure 4.8**). Wasteload allocations (WLAs) may be assigned to MS4 entities under their permits if their discharges affect impaired surface waters. The potential involvement of MS4 entities in this area may not be limited to the typical discharges of urban stormwater to surface water.

4.3.2 Nutrient Loading from Urbanized Areas

Urban areas include land uses such as residential, industrial, utility easements, recreational, institutional, commercial, and extractive (mining). Nonpoint source nutrient loading from urban areas (not in an MS4 jurisdiction) is attributable to multiple sources, including discharges of stormwater runoff to groundwater via ponds, sinkholes, and drainage wells; groundwater seepage; OSTDS; fertilizers from home gardens, lawns, and golf courses; and domesticated animal waste. Approximately 54% and 33% of the total land area are designated as urban in the Magnolia–Aripeka and Weeki Wachee contributing areas, respectively.

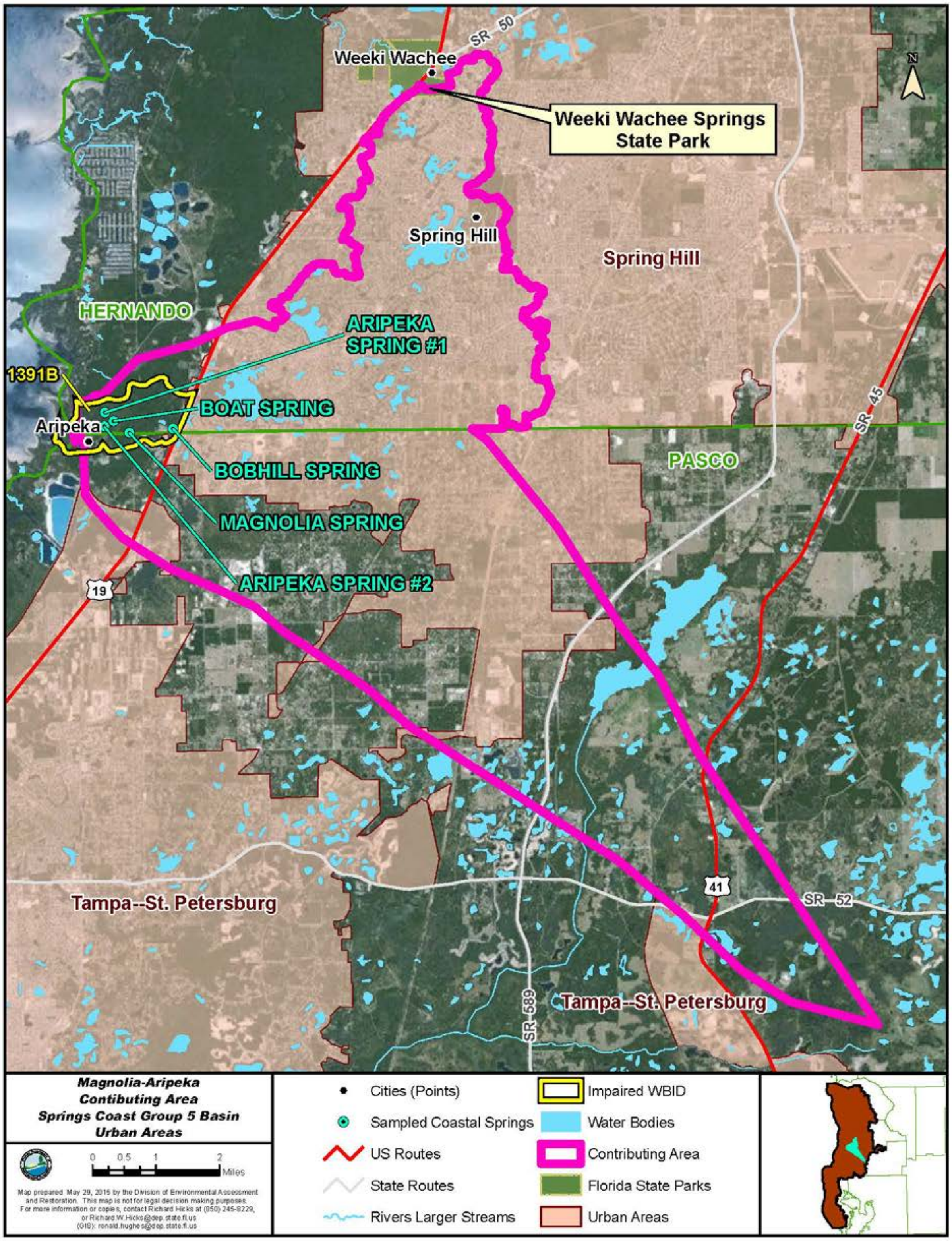


Figure 4.7. MS4 permit boundaries in the Magnolia–Aripeka Springs Group contributing area

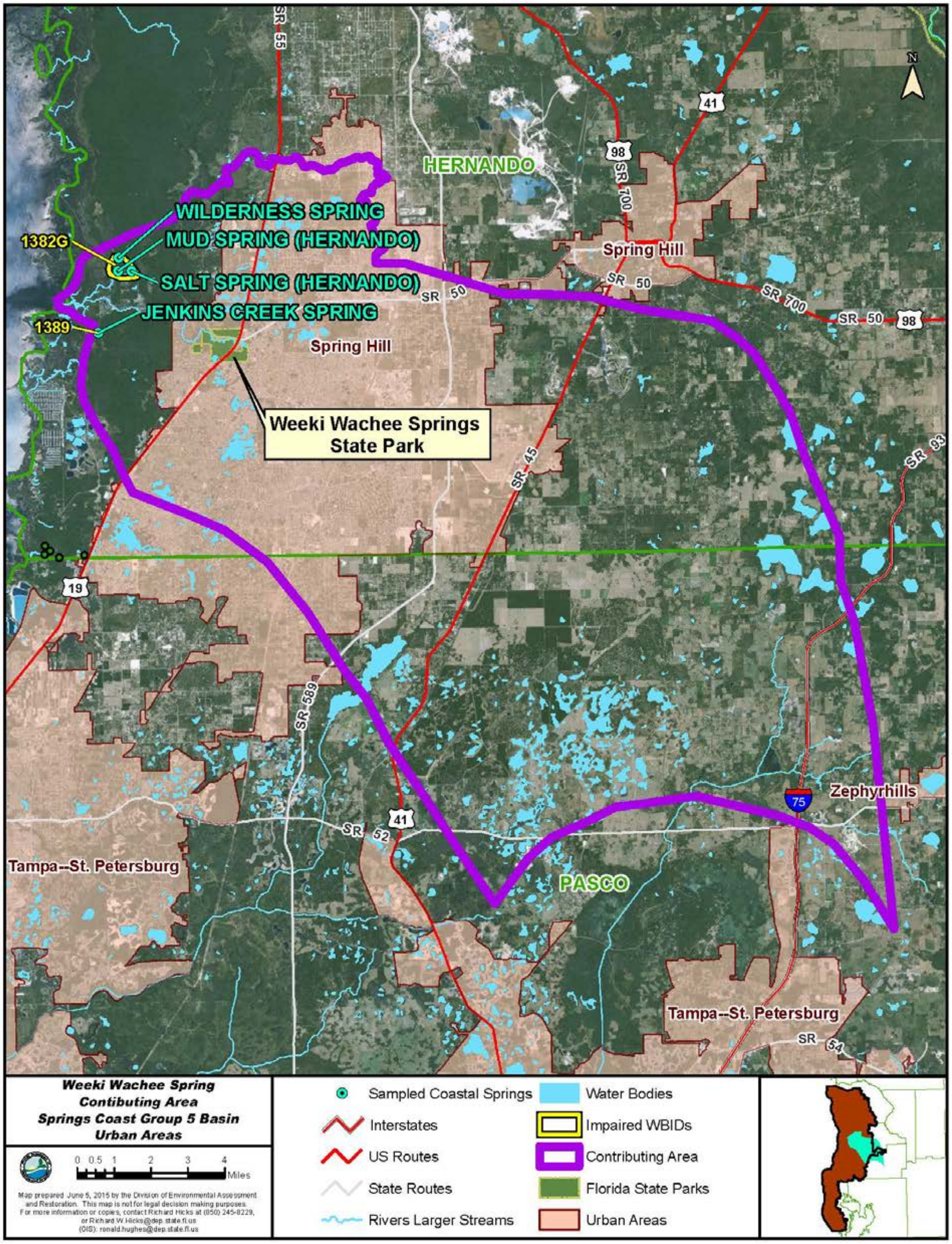


Figure 4.8. MS4 permit boundaries in the Weeki Wachee Springs Group contributing area

Onsite Sewage Treatment and Disposal Systems

OSTDS, or septic tanks, are used for the disposal of domestic waste at homes that are not on central sewer, often because providing central sewer is not available, cost-effective, or practical. When properly sited, designed, constructed, maintained, and operated, OSTDS provide a sanitary means of disposing of domestic waste. The nitrogen concentrations in effluent from OSTDS are considerably higher than those in effluent from typical domestic wastewater facilities, although the wastewater profile can vary from home to home. The physical setting of an OSTDS (soil and aquifer characteristics and proximity) is also a factor in the amount of nitrogen that it can leach to groundwater and springs (USGS 2010). The risk of contamination is greater for unconfined (water table) aquifers than for confined aquifers, because the former usually are nearer the land surface and lack an overlying confining layer to impede the movement of contaminants (USGS 2010).

On average, the TN concentration in the effluent from a typical OSTDS is 57.7 mg/L (Hazen and Sawyer 2009), although this concentration is reduced further as the effluent is discharged to the drainfield and percolates to groundwater. Under a low-density residential setting, nitrogen loadings from OSTDS may not be significant, but under a higher density setting, one could expect the nitrogen input to be approximately 129 pounds per acre per year (lb/ac/yr) (Harrington et al. 2010). However, some nitrogen reduction would occur in the drainfield and soil above the water table, and, as discussed previously, the actual load to groundwater would vary based on actual use and setting. There has been growing concern over the continuing use and even increase in the number of OSTDS in spring areas, particularly in more densely developed areas close to the springs. Data for septic tanks are based on the FDOH statewide inventory of OSTDS (Hall and Clancy 2009). **Figure 4.9** and **Figure 4.10** display the density of OSTDS in the Magnolia–Aripeka and Weeki Wachee contributing areas, respectively.

Sanitary Sewer Overflows (SSOs)

Untreated sewage can be a potential source of nitrogen in areas with leaky underground sewers, breaks, or lift station overflows. Leaks and overflows are common in many older sanitary sewers where capacity is exceeded, high rates of infiltration and inflow occur (i.e., outside water gets into pipes, reducing capacity), frequent blockages occur, or there is pipe deterioration associated with older systems. Power failures at pumping stations can also cause sanitary sewer overflows (SSOs). The greatest risk of an SSO occurs during storm events. However, few comprehensive data are available to quantify SSO frequency and nutrient loads in most watersheds.

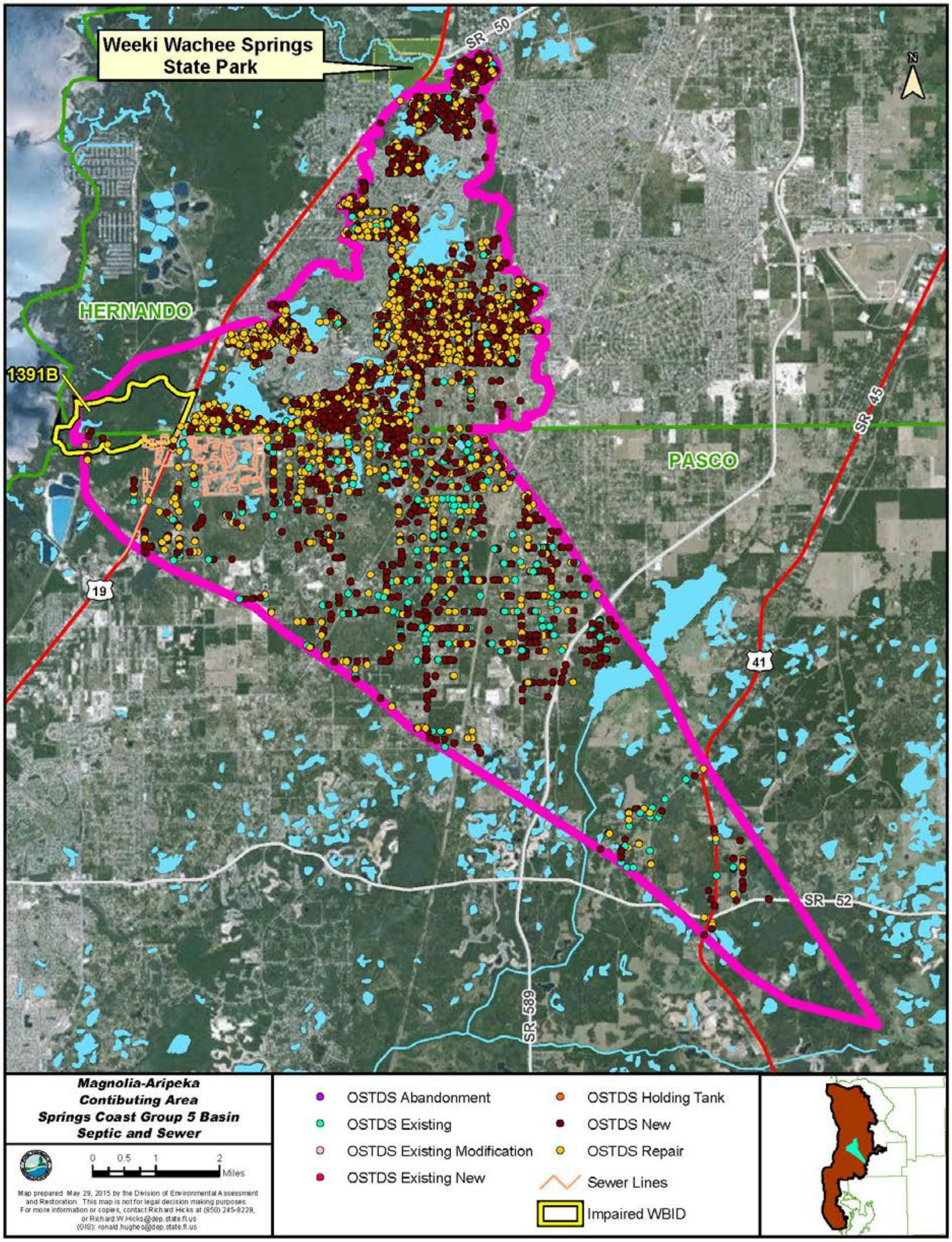


Figure 4.9. Density of OSTDS (septic tanks) in the Magnolia–Aripeka Springs Group contributing area

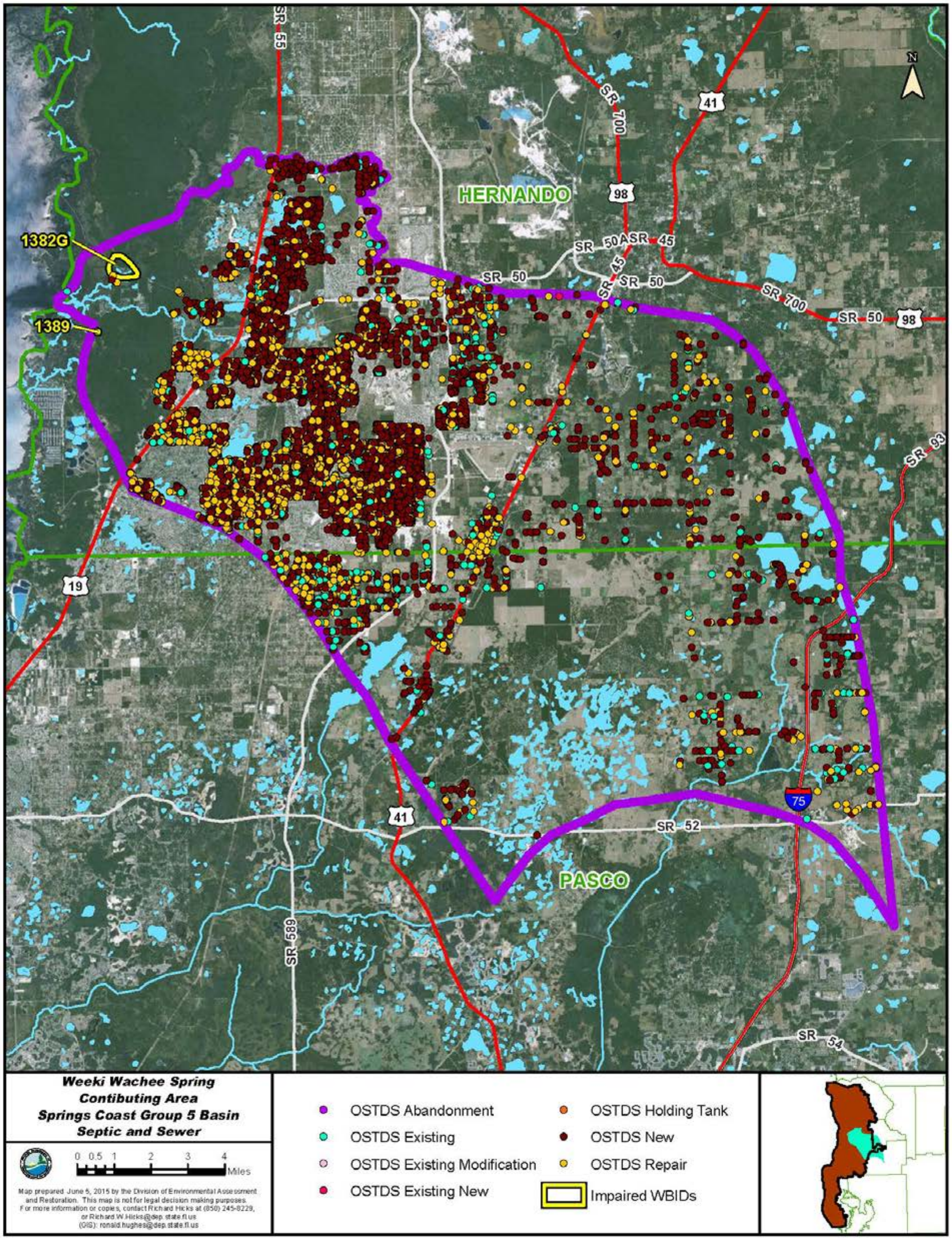


Figure 4.10. Density of OSTDS (septic tanks) in the Weeki Wachee Springs Group contributing area

Fertilizer Use

The high potential for fertilizer to leach through the well-drained, sandy soils typical of spring areas is a major reason that inorganic fertilizer is such a prevalent source of nitrate in groundwater and springs. **Table 4.4** provides the estimated ranges of inorganic nitrogen use as fertilizer for the types of land uses common to the contributing area. In addition to residential lawns and landscaping, land uses with fertilizer that could potentially contribute nitrate to the impaired waters include golf courses and agriculture.

Best management practices (BMPs) and local ordinances and programs are designed to encourage the conservative use of fertilizers and where implemented can reduce fertilizer leaching. Examples include the *Florida Golf Course BMP Manual* developed by DEP; row crop, cow-calf, equine, and container nursery BMP manuals produced by FDACS; and ordinances and programs implemented by Hernando and Pasco Counties.

Table 4.4. Potential fertilizer application ranges for selected land uses in springs contributing areas

Note: Estimated loadings from fertilization are conservative, based on recommended agronomic rates and not actual field data.

Nitrogen Source	Estimated Nitrogen Application Rates Per Year (lb/ac/yr unless otherwise noted)[1]	Comments
Hayfield	80	DEP Nitrogen Source Inventory Loading Tool (NSILT) value
Fertilized pasture	60	DEP NSILT value
Container nursery, controlled-release fertilizer	90	DEP NSILT value
Golf course, turf or lawn, bermudagrass–central Florida	174–261	4 to 6 pounds/1,000 square feet (Sartain et al. 2009)
Golf course, turf or lawn, St. Augustine grass–central Florida	87–131	2 to 3 pounds/1,000 square feet (Sartain et al. 2009)

Atmospheric Deposition

Atmospheric deposition was also identified as an important potential nitrogen source. It is largely a diffuse, albeit continual, source of nitrogen. Nitrogen species and other chemical constituents are measured in wet and dry deposition at discrete locations around the U.S. DEP is currently using a Total Deposition (TDEP) model developed by the EPA to estimate total deposition. The model is based on monitoring data as well as other atmospheric model data.

Sediments

Studies have shown that an additional source of nutrients consists of river sediments resuspended in the water column when conditions are right (Jamieson et al. 2005). No recent studies have quantified the exact amount of nutrient loading coming from sediments in these impaired waterbodies. Therefore, DEP is unable to provide estimates of nutrient loading from sediments in the TMDL analysis.

Decomposing Organic Matter

Decomposing vegetation was also identified as an important potential nitrogen source. Decomposing organic matter, such as vegetation, filamentous algal mats, and decaying aquatic organisms also release nutrients as they break down. As aquatic weeds and algae slowly decompose, nitrogen and phosphorus are released back into the water column, and some of it settles into the sediments (Sickman et al. 2009).

Livestock and Wildlife

Livestock and wildlife contribute nitrogen loading by depositing feces onto land surfaces, where they can be transported to nearby streams during storm events or by direct deposition to the waterbody. Nitrogen loads originating from local wildlife are generally considered to represent natural background concentrations. In most impaired watersheds, the contribution from wildlife is small compared with the load from urban and agricultural areas.

4.3.3 Nitrogen Source Inventory Loading Tool

The NSILT was developed to estimate the nitrogen loading reaching groundwater in a designated BMAP area. Similar estimates have been made in the past and have largely been based on land use. However, the NSILT takes this process a step further. The nitrogen input to the land surface for anthropogenic sources is estimated based on detailed methods specific to each nitrogen source category. These main categories include atmospheric deposition, septic tanks, WWTFs, fertilizers (urban and agricultural), livestock waste, and any additional source category relevant to the specific study area. After estimating the nitrogen input, environmental attenuation is taken into consideration. This attenuation is specific for each source category and related to land application and other factors. The final step in the process is evaluating the influence of groundwater recharge, which varies depending on hydrogeology and soil characteristics. The end product is a report that contains a series of pie charts illustrating the estimated percent contribution of each loading category in a BMAP area.

This process is constantly being improved on and tailored to each specific area as new data become available. Stakeholder involvement is a critical aspect of this process and has been very helpful in

NSILT development. DEP recognizes that no two BMAP areas are the same and attempts to account for these differences with its estimates so that the end product is representative of the hydrogeology, anthropogenic inputs, and nitrogen attenuation in a BMAP-designated area.

The nitrogen source inventory for the Weeki Wachee Springs Group contributing area is currently under development and is anticipated to be completed by the time these TMDLs have been adopted. As part of the BMAP development process, DEP may also develop a nitrogen source inventory for the Magnolia–Aripeka Springs Group contributing area.

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

DEP often uses hydraulic and water quality models to simulate loading and the effects of the loading in a given waterbody. However, there are other appropriate methods to develop a TMDL that are just as credible as a modeling approach. Such an alternative approach was used to estimate existing mean concentrations and calculate TMDLs for the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group.

5.1 Determination of Loading Capacity

Typically, the target loading and existing loading for a stream or watershed are based on hydrologic and water quality modeling. Many of these models depend on the relationship between flow and surface water drainage area, as well as the relationship between land use, soils, and pollutant delivery.

The predominant source of nutrient loading to these tidal creeks is groundwater discharged from the springs. The contributing area of the springs is a karst environment. Rainwater percolates directly through the soil profile, and surface drainage flows toward sinkholes and closed depressions, where it infiltrates and reaches groundwater, which is discharged from the spring vents. Thus, a direct relationship between surface water loadings in the watershed is not appropriate. This diffuse loading situation requires the use of an alternative approach for establishing a nutrient TMDL.

Existing spring loading can be estimated by multiplying the measured spring flow by the measured pollutant concentrations in the spring. To estimate pollutant loading in this way, synoptic flow and concentration data measured at the outlet of each spring vent are required. These data were not available at the time of TMDL development. Therefore, the loads of nitrate could not be explicitly calculated.

Instead, the percent load reduction required to achieve the nitrate concentration target was calculated assuming the percent loading reduction would be the same as the percent concentration reduction. The percent reduction required to achieve the water quality target was calculated using the following formula:

[(existing mean concentration – target concentration)/existing mean concentration] x 100

5.2 Unique Nature of Spring-Fed Tidal Creeks

Compared with free-flowing freshwater spring runs (flushing rates on the order of hours), tidally influenced waterbodies such as these springs are typically characterized as low-flushing environments with long residence times (flushing rates on the order of days). Residence time is the time needed to flush a pollutant, such as nitrogen or phosphorus, from a defined point in a waterbody.

The effect of residence time on nutrients in the water (rate of flushing) should be taken into consideration when determining appropriate water quality targets for coastal spring-fed ecosystems with low-flushing environments. Shallow water depths allow warming and greater sunlight penetration, resulting in higher plant growth potential (Livingston 2001). In most coastal streams and creeks around the world, the combination of increased nutrients and shallow water depths, coupled with long residence time, yields greater primary productivity, which translates into increased filamentous algae production.

Reductions of either nitrogen or phosphorus in the water discharging from springs, nearby stormwater, and nearby groundwater inflows should reduce macroalgal accumulation by slowing the growth rate of macroalgae (Stevenson et al. 2007). The phosphorus concentrations in the springs are at natural background levels. Therefore, it is the purpose of this TMDL document to establish the maximum allowable nitrate target concentration for the impaired springs. These thresholds will be used as targets for restoration actions to meet the applicable water quality criterion for nutrients. DEP believes that reducing the growth rate of diatoms and macroalgae (including *Lyngbya* sp. and *Chaetomorpha*) through nutrient reduction will decrease biomass and productivity.

5.3 Effects of Salinity

DEP acknowledges that multiple factors such as nutrients, flow, salinity, temperature, and light contribute to the distribution, abundance, and growth rate of filamentous algae and phytoplankton production in these spring-fed tidal creeks. Salinity represents a primary determinant of long-term patterns in the distribution of SAV in spring-fed systems along Florida's Gulf Coast (Hoyer et al. 2004). Bishop and Canfield (1995), Terrell and Canfield (1996), and Hoyer et al. (1997) determined that acute variation in salinity resulting from storm surges is one of the major forces affecting aquatic plant biomass. More subtle variations in salinity affecting the ecology of this system arise when weather patterns alter rainfall, groundwater supply, sea level, and spring discharge (Jacoby et al. 2011). In addition, man-made hydrologic alterations can alter the natural flow of the system, cutting off freshwater inflows from natural watershed areas (SWFWMD 2000). Gradual increases in salinities may also be tied to extended periods of lower-than-normal rainfall, sea-level rise, and groundwater withdrawals. From 1920 to 2001, the estimated sea-level rise along the Florida Gulf coast was approximately six inches (Douglas 1991; Zervas 2001).

The lowest salinity areas in the spring-fed tidal creeks are near the spring vents because of their freshwater discharges. Algal biomass and cover are typically higher near headsprings than downstream (Stevenson et al. 2007; Frazer et al. 2001). Freshwater macrophyte and macroalgae biomass decrease in response to increases in salinity and are lowest in saline environments (Hoyer et al. 2004).

5.4 Critical Conditions/Seasonality

Establishing the critical condition for nitrogen inputs that affect algal growth in a given contributing area depends on many factors, including the presence of point sources and the land use pattern in the contributing area. The critical condition for point source loading to a waterbody typically occurs during periods of low flow, when dilution is minimized. Typically, the critical condition for nonpoint source loading is a period of rainfall-related flushing preceded by an extended dry period. During the wet weather period, rainfall mobilizes nitrogen that has accumulated on the land surface and in the soil under dry conditions, resulting in higher pollutant concentrations. However, significant nonpoint source contributions can also appear under dry conditions without any major surface runoff event. Also, there can be a lag time between nitrogen inputs into groundwater and discharge from the spring vents.

The nitrate data for Aripeka #1 Spring and Aripeka #2 Spring are limited. During the Cycle 2 verified period (January 1, 2004–June 30, 2011) plus more recently (2012–14), Aripeka #1 Spring and Aripeka #2 Spring were only sampled twice due to their inaccessibility from land. Because of the limited data, a seasonal average could not be calculated. **Table 5.1** summarizes the results of the Kruskal-Wallis test and seasonal average nitrate concentrations for Boat Spring, Bobhill Spring, Magnolia Spring, Jenkins Creek Spring, Mud Spring, Salt Spring, and Wilderness Spring during the Cycle 2 verified period and more recently (2004–14).

A Kruskal-Wallis statistical test was used to detect significant variation between seasons. Based on the nitrate data available, nitrate concentrations in the springs are relatively consistent (not significant) from season to season, with the exception of Jenkins Creek Spring. For Jenkins Creek Spring, comparing nitrate concentrations in the second quarter to those in the fourth quarter revealed a slight significant difference (Prob > ChiSquare = 0.05). In general, there does not appear to be any strong significant period when higher loading occurs for any of these springs.

Table 5.1. Summary of the seasonal average nitrate concentrations and Kruskal-Wallis test for Boat Spring, Bobhill Spring, Magnolia Spring, Jenkins Creek Spring, Mud Spring, Salt Spring, and Wilderness Spring during the Cycle 2 verified period (January 1, 2004–June 30, 2011) and more recently (2004–14)

First Quarter

Spring Name	N	Mean	Maximum	Minimum
Boat Spring	2	0.49	0.50	0.49
Bobhill Spring	9	0.69	0.77	0.61
Salt Spring	3	0.52	0.62	0.41
Jenkins Creek Spring	11	0.72	0.84	0.35
Magnolia Spring	11	0.57	0.64	0.48
Mud Spring	5	0.40	0.54	0.24
Wilderness Spring	5	0.47	0.49	0.45

Second Quarter

Spring Name	N	Mean	Maximum	Minimum
Boat Spring	-	-	-	-
Bobhill Spring	8	0.76	1.82	0.42
Salt Spring	-	-	-	-
Jenkins Creek Spring	14	0.58	0.87	0.00
Magnolia Spring	11	0.56	0.63	0.48
Mud Spring	5	0.40	0.43	0.37
Wilderness Spring	5	0.45	0.50	0.39

Third Quarter

Spring Name	N	Mean	Maximum	Minimum
Boat Spring	10	0.60	0.66	0.46
Bobhill Spring	9	0.68	0.90	0.20
Salt Spring	10	0.55	0.59	0.49
Jenkins Creek Spring	14	0.63	0.93	0.07
Magnolia Spring	11	0.57	0.64	0.49
Mud Spring	5	0.38	0.49	0.22
Wilderness Spring	5	0.44	0.49	0.42

Fourth Quarter

Spring Name	N	Mean	Maximum	Minimum
Boat Spring				
Bobhill Spring	11	0.63	0.76	0.01
Salt Spring	1	0.63	0.63	0.63
Jenkins Creek Spring	15	0.78	0.97	0.58
Magnolia Spring	11	0.58	0.66	0.53
Mud Spring	3	0.47	0.51	0.41
Wilderness Spring	6	0.43	0.48	0.39

Kruskal-Wallis Test

Note: Boldface type in red indicates slight significant difference.

Spring Name	Total N	Chi Square	DF	Prob > ChiSq
Boat Spring	12	2.95	1	0.09
Bobhill Spring	37	1.95	3	0.58
Salt Spring	14	2.83	2	0.24
Jenkins Creek Spring	54	8.46	3	**0.05**
Magnolia Spring	44	0.73	3	0.86
Mud Spring	18	2.60	3	0.45
Wilderness Spring	21	2.53	3	0.47

5.5 TMDL Development Process

5.5.1 Use of Site-Specific Information

To develop the nitrate water quality target concentrations for the springs, DEP used a combination of site-specific historical documentation of algal mats, laboratory studies, and field surveys instead of a value based on the statewide criterion for nitrate. For instance, the applicable numeric criterion for freshwater spring vents in Paragraph 62-301.530(47)(b), F.A.C., is 0.35 mg/L of nitrate-nitrite (NO_3 + NO_2) as an annual geometric mean, not to be exceeded more than once in any three consecutive calendar years. In many cases, this criterion can serve as the concentration-based TMDL target for spring waters. However, TMDLs can also serve as site-specific alternative criteria where an alternative threshold is more appropriate based on waterbody-specific information. These springs are not similar to the free-flowing freshwater springs to which the 0.35 mg/L criterion more directly applies and require an alternative threshold to address the impairment.

Field Observations at Mud Spring

In 2013 and 2015, DEP's Ground Water Management Section (GWMS) recorded multiple field observations at Mud Spring. These revealed the predominant aquatic plant to be filamentous algae at nitrate concentrations less than the 0.35 mg/L numeric criterion for freshwater spring vents.

Filamentous Algae Studies in Florida Springs

Nuisance algal growth has been observed in many springs and is associated with increases in anthropogenic activities and nutrient concentrations (Stevenson et al. 2007). Several studies described in this section have evaluated the growth of filamentous algae in response to nutrients in Florida springs. These studies were performed in the laboratory under different flow regimes. Similar types of studies were used in the development of Florida's nitrate standard of 0.35 mg/L for free-flowing freshwater spring runs. Additional information is available on DEP's Surface Water Quality Standards website.

GROWTH RESPONSE OF *LYNGBYA WOLLEI* TO NITRATE ADDITIONS

In one study, Albertin (2009) used a series of recirculating stream channels (**Figure 5.1**), operated under controlled laboratory conditions, to determine threshold nitrate values for *L. wollei* growth. The experiments were performed under optimal light and temperature, and in high-flushing environments. The nutrient concentration at which macroalgae growth is predicted to be elevated by 90%, above which no effects of nutrient reduction would be expected, is referred to as the 90% saturating concentration. Under these laboratory conditions, the threshold concentration for the growth of *Lyngbya* sp. had a saturating nitrate concentration of 0.11 mg/L (**Figure 5.2**).

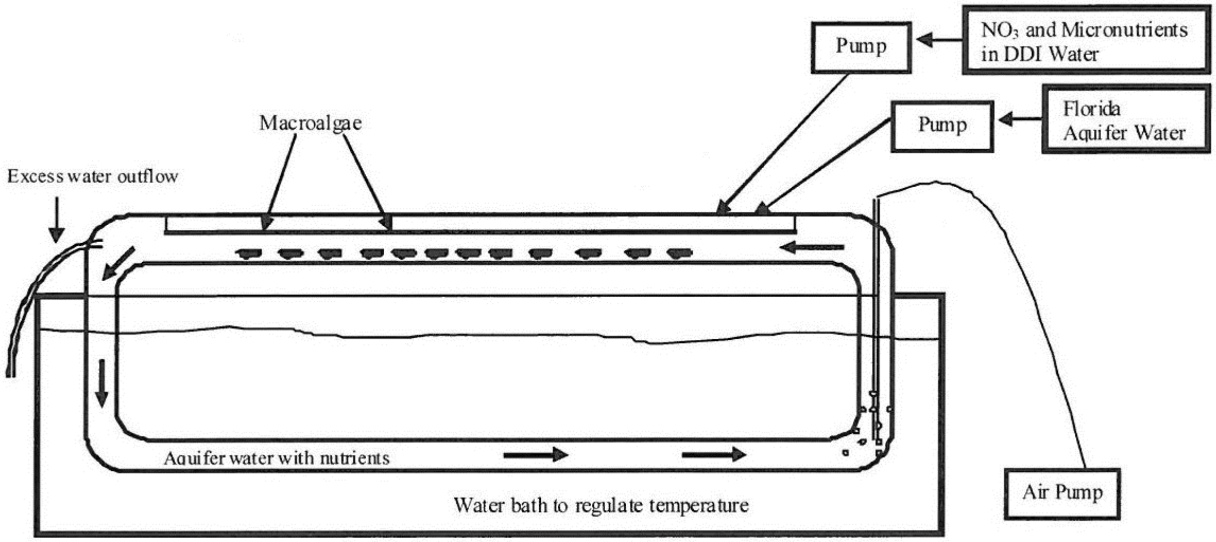


Figure 5.1. Albertin (2009) recirculating stream channel experimental design

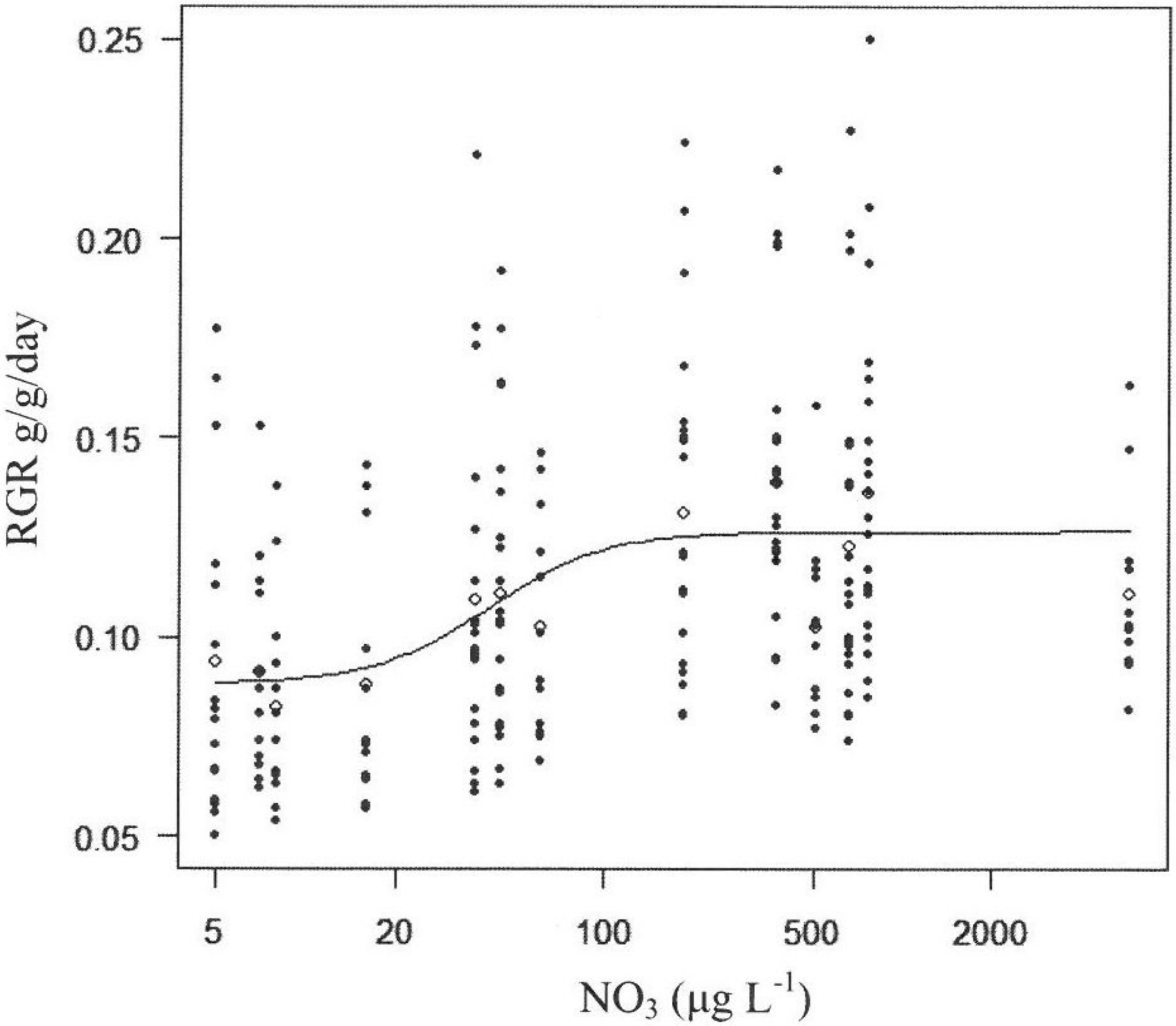


Figure 5.2. Relative growth rates (RGR) of *L. wollei* at different nitrate concentrations in recirculating stream channels (Albertin 2009)

GROWTH AND NITRATE-NITROGEN UPTAKE BY THE CYANOBACTERIUM *L. WOLLEI*

The nutrient amendment bioassay work conducted by Cowell and Dawes (2004) examined the required nitrate concentration in the Rainbow River, Marion County, to achieve a reduction of biomass of *L. wollei*. In the laboratory, the experiment was conducted in 400 milliliter (mL) flasks, and water was continuously replenished at a rate of 960 mL per day (a low-flushing environment). Using *Lyngbya* sp. cultures incubated in a series of nitrate increments (concentrations of 1.5, 1.2, 0.9, 0.6, 0.30, and 0.07 mg/L), Cowell and Dawes (2004) found that at the end of the nutrient amendment experiments, both the biomass and growth rates were low in treatment groups with nitrate concentrations at or below 0.30

mg/L, and significantly higher in groups with nitrate concentrations at or higher than 0.60 mg/L. Significant differences in growth rate and biomass between the above-0.60 mg/L treatment groups and the below-0.30 mg/L treatment groups were not observed until 8 to 12 days after the nutrient amendment study started. This apparently suggested a time lag between a change in nitrate concentration and a response from the *Lyngbya* sp. A decrease in growth rate response was observed at nitrate concentrations equal to or less than 0.30 mg/L.

EXAMINING THE ECOLOGICAL CONDITION OF ALGAE AND NUTRIENTS IN THE 2007 FLORIDA SPRINGS REPORT

This study evaluated algal growth response in 28 springs throughout Florida, including nearby Weeki Wachee, Homosassa, and Chassahowitzka Springs (**Figure 5.3**). Surveys of Florida springs conducted during this study found that almost all springs had macroscopic algae growing in them, that an average of 50% of the spring bottoms were covered by macroalgae, and that the macroalgal mats were commonly 0.5 meters (m) thick and as thick as 2 m in one spring boil. *L. wollei* and *Vaucheria* sp. were the two most common taxa of macroalgae occurring in areas with extensive growths in the studied springs. However, 23 different macroalgal taxa were observed in the spring survey.

The 90% saturating concentration was documented in a laboratory setting by Stevenson et al. (2007) for two species of macroalgae (*L. wollei* and *Vaucheria* sp.) that have been documented to produce extensive algal mats. The microcosms consisted of microcentrifuge tubes filled with growth media and placed in circular raceways (donut-shaped), which mimic low-flushing environments. The microcosms used for the laboratory experiments measured algal growth rates for the following experiments:

- 11 different nitrate concentrations under nonflowing conditions with orthophosphate in luxury supply.

- 10 different orthophosphate concentrations under nonflowing conditions with nitrate in luxury supply.

Using *L. wollei* cultures incubated in a series of refined nitrate increments (concentrations of 5, 2.5, 1.5, 1.0, 0.75, 0.50, 0.25, 0.125, 0.06, 0.03, and 0.01 mg/L), the threshold concentration for growth of *Lyngbya* sp. under these conditions was found to have a 90% saturating nitrate concentration of 0.23 mg/L (**Figure 5.4**). Using *L. wollei* cultures incubated in a series of refined orthophosphate increments (concentrations of 0.25, 0.1, 0.08, 0.06, 0.04, 0.03, 0.02, 0.01, 0.005, and 0.001 mg/L), the threshold concentration for the growth of *Lyngbya* sp. under these conditions was found to have a 90% saturating orthophosphate concentration of 0.028 mg/L (**Figure 5.4**). According to Stevenson et al. (2007), the most accurate and conservative experimental results, those from microcentrifuge tube experiments, suggest that nutrient concentrations less than 0.028 mg/L orthophosphate and 0.23 mg/L nitrate are needed to slow the growth of *L. wollei*.

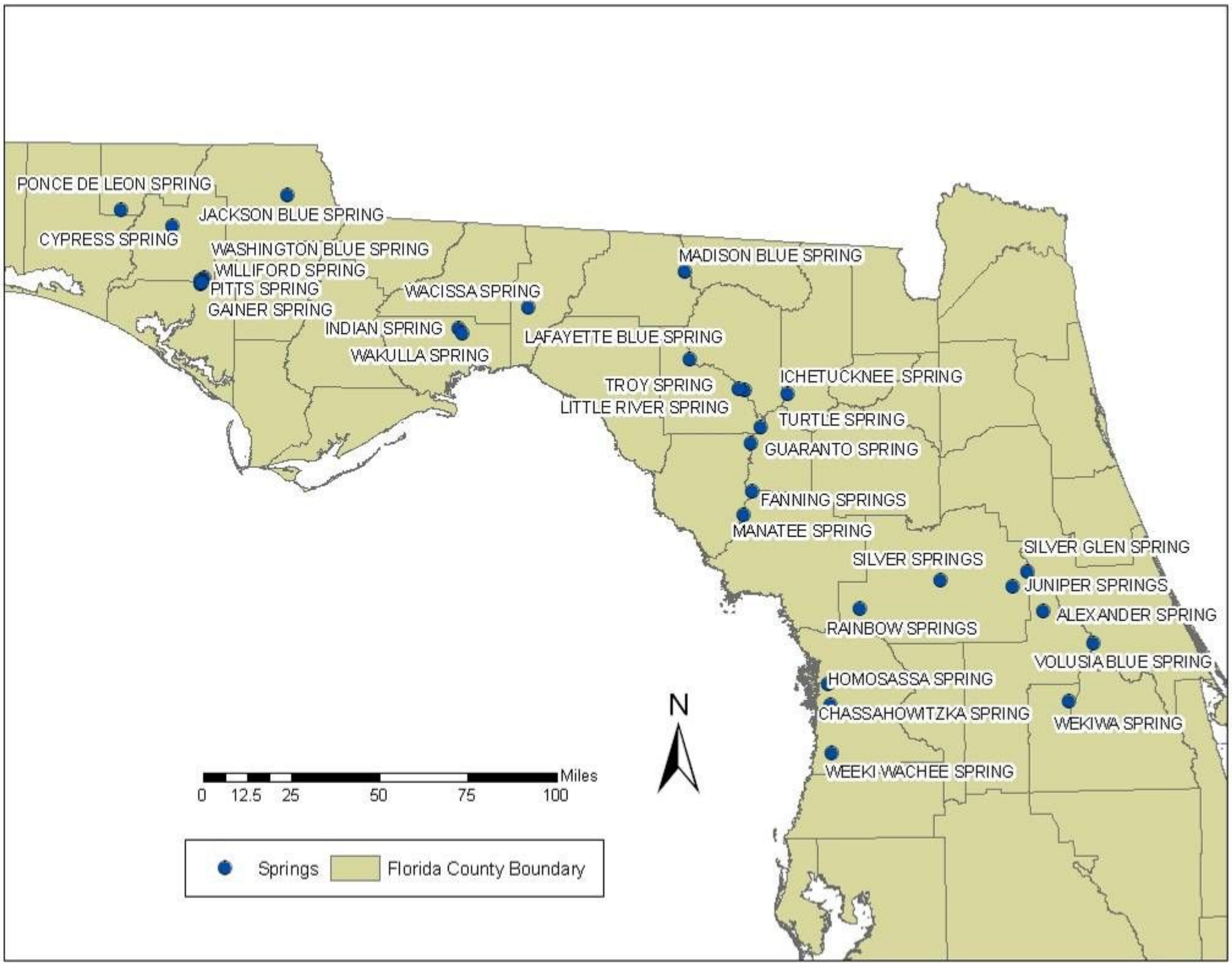


Figure 5.3. Springs included in the Florida Springs Report (Stevenson et al. 2007)

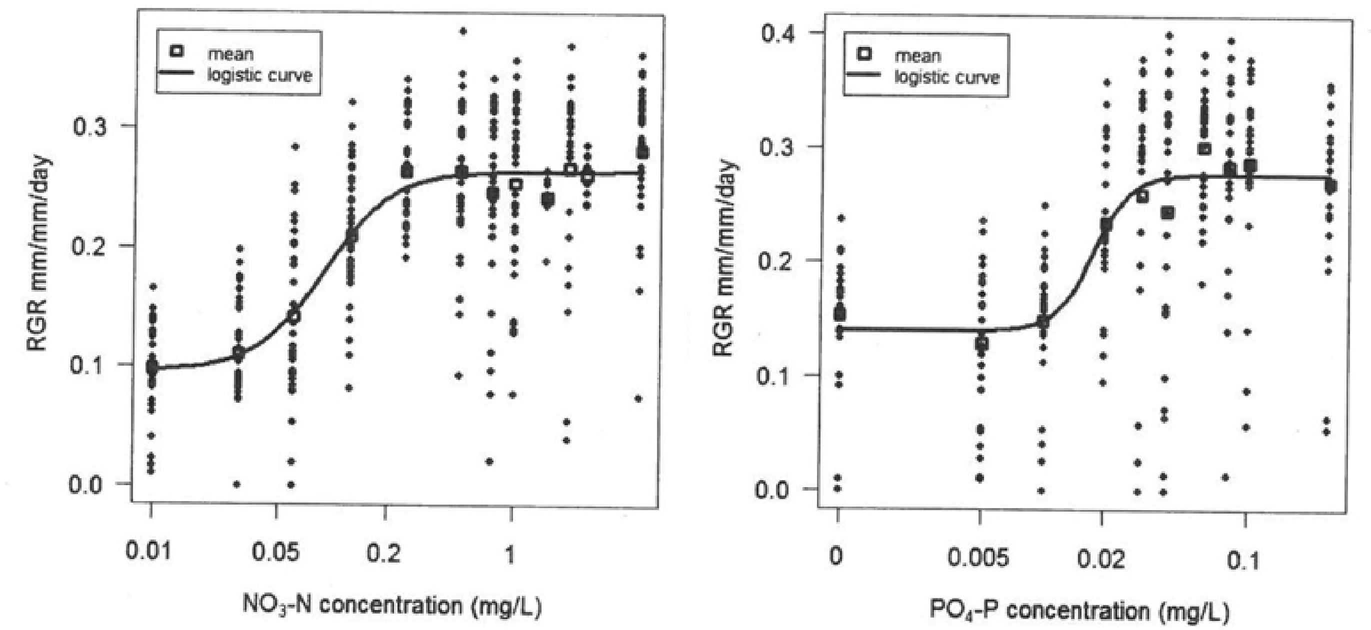


Figure 5.4. RGR of *L. wollei* at different nitrate and orthophosphate concentrations in microcentrifuge tubes (Stevenson et al. 2007)

Filamentous Algae in Field Surveys

For 6 years (1998–2000 and 2003–05), the SWFWMD contracted with the University of Florida for a study to quantify the physical, chemical, and vegetative characteristics of 5 Gulf Coast spring-fed rivers, including the Homosassa and Chassahowitzka. During the study, water chemistry and physical samples for each of the 5 rivers were collected during quarterly sampling events. The water chemistry sampling sites traversed the entire length of the river, from the headspring to the Gulf of Mexico. Water chemistry sampling transect/sites were sequentially numbered from 1 (headspring) to 20 (Gulf of Mexico), and SAV sampling transect/sites were sequentially numbered from 1 (headspring) to 10 (mid-river). Macrophytes and macroalgae were sampled at 20 regularly spaced transects/sites from the headspring to mid-river. Data on SAV were collected annually during the summer for the 6 years to determine the species composition and coverage of plants. Ten SAV transects/sites corresponded to those where water chemistry was measured.

According to Frazer et al. (2006), during the 2003 to 2005 sampling period, calculated nitrate loading rates in the headspring regions of the Homosassa and Chassahowitzka Rivers increased by 56% and 43%, respectively, over the 1998 to 2000 sampling period. During both sampling periods (1998–2000 and 2003–05), macroalgae were most abundant at the upper sampling transect/sites near the headsprings, though their occurrence was not restricted to the upper sampling areas for the Homosassa and Chassahowitzka Rivers (**Figure 5.5**). The combination of increased nitrate-enriched spring discharge, low salinity, and shallow water depths coupled with long residence time yielded greater primary productivity, which translated into increased filamentous algae production. Similar conditions can be found in Hammock Creek, Jenkins Creek, Mud River, and Salt Creek, which are all tidally influenced.

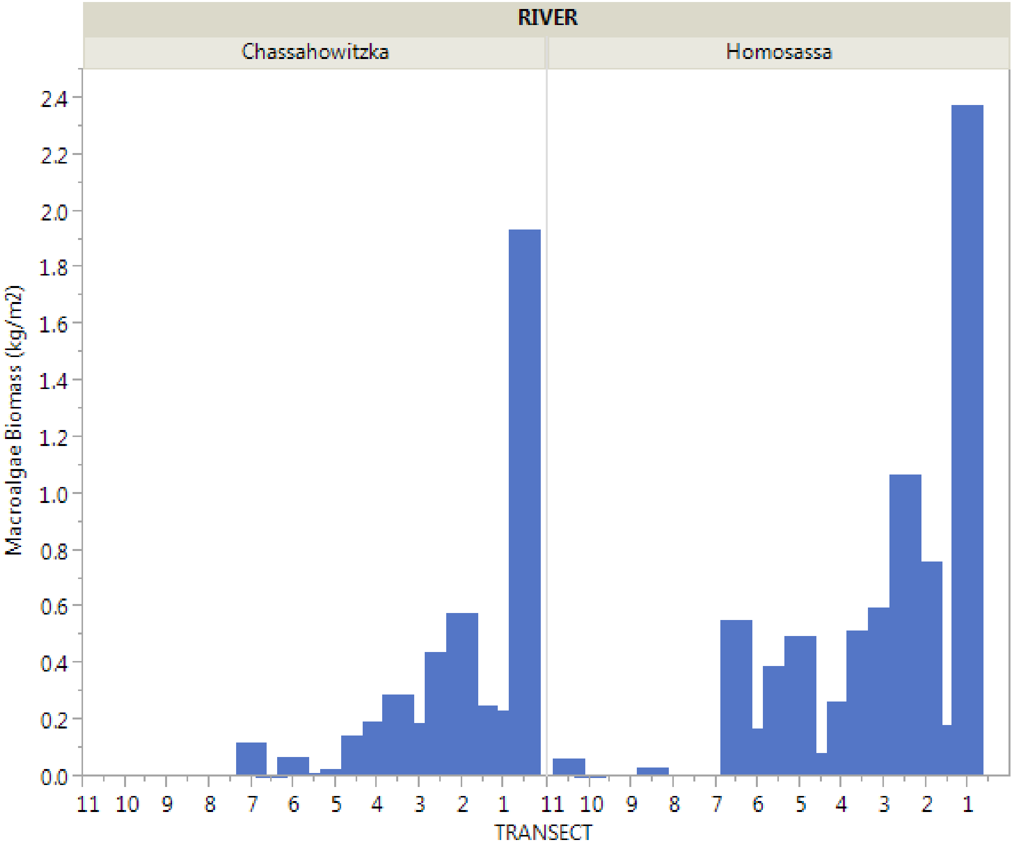


Figure 5.5. Mean macroalgae biomass and chlorophyll concentration by site for the Homosassa and Chassahowitzka Rivers, 1998–2000 and 2003–05

5.6 Setting the Nitrate Water Quality Target

Multiple abiotic factors (flow, salinity, temperature, light) and biotic factors (nutrients and food web complexity) contribute to the distribution and growth of filamentous algae. Understanding the described studies and the constraints associated with each study will help develop an appropriate nitrate target concentration that would apply to the springs. A site-specific alternative criterion is needed because field observations at Mud Spring by DEP's Ground Water Management Section revealed the predominant aquatic plant to be filamentous algae at nitrate concentrations less than the 0.35 mg/L numeric criterion for freshwater spring vents.

The field surveys performed by Frazer et al. (2001; 2006) in the Homosassa and Chassahowitzka Rivers found macroalgae were most abundant at the upper sampling transect/sites near the headsprings, though their occurrence was not restricted to the upper sampling areas for the Homosassa and Chassahowitzka Rivers. The combination of increased nitrate-enriched spring discharge, low salinity, and shallow water depths coupled with long residence time yielded greater primary productivity, which translated into increased filamentous algae production. Similar conditions can be found in Hammock Creek, Jenkins Creek, Mud River, and Salt Creek, which are all tidally influenced.

Lyngbya sp. is present near the spring vents and lower salinity areas of these spring-fed tidal creeks and has the most available research data on algal growth response to nitrate. The laboratory studies examined *L. wollei* growth rates under two different flushing environments. The laboratory study conducted by Albertin (2009) was performed in a high-flushing environment. The laboratory studies conducted by Cowell and Dawes (2004) and Stevenson et al. (2007) were performed in low-flushing environments. The effect of residence time (rate of flushing) on nitrate-enriched water discharging from springs into a low-flushing environment should be taken into consideration when determining appropriate water quality targets.

Compared with free-flowing spring runs (flushing rates on the order of hours), the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group discharge into tidal creeks with long residence times (flushing rates on the order of days). The Albertin (2009) laboratory experiments were conducted in high-flushing conditions, which are not representative of the low-flushing (long residence time) tidal creeks. The studies by Cowell and Dawes (2004) and Stevenson et al. (2007) examined *L. wollei* growth rates under conditions that modeled low-flushing environments with long residence times.

When examining *L. wollei* growth rates, Cowell and Dawes (2004) measured algal growth under 6 nitrate concentration increments and could only provide a relatively broad range of concentrations at which a response was observed. Stevenson et al. (2007) provided a more refined growth response prediction by using 11 nitrate concentration increments. Stevenson et al. (2007) also examined the growth rates of *L. wollei* at different orthophosphate concentrations. According to Stevenson et al. (2007), nitrate concentrations lower than 0 0.23 mg/L are needed to reduce the growth rate of *L. wollei*.

5.7 Magnitude, Frequency, and Duration of the Water Quality Target

After carefully reviewing the previously mentioned studies, DEP selected the Stevenson et al. (2007) 90% saturating nitrate concentration of 0.23 mg/L as the nitrate water quality target concentration for the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group. Nitrate is the most abundant form of nitrogen available in spring discharge. As discussed previously, the nitrate water quality target for springs is based on algal growth studies performed in low-flushing (long residence time) conditions similar to those of the tidal creeks into which these impaired springs discharge. This target was selected because it would be protective of the Class III designated use. DEP believes that reducing the growth rate of macroalgae (including *Lyngbya* and *Chaetomorpha*) through nitrate reduction will decrease filamentous algae biomass and phytoplankton productivity.

The nitrate water quality target of 0.23 mg/L will be established as an annual arithmetic average not to be exceeded in any year. An annual arithmetic average was chosen due to the minimal seasonal variation, as described in **Section 5.4**.

These nitrate water quality target concentrations for Boat Spring, Bobhill Spring, Magnolia Spring, Jenkins Creek Spring, Mud Spring, Salt Spring, and Wilderness Spring will be submitted to the EPA for approval as site-specific (Hierarchy 1) interpretations of the narrative nutrient criterion for these waterbodies, as stated in Section 62-302.531, F.A.C.

5.8 Protection of Downstream Waters

The Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group are the headwaters for Hammock Creek, Jenkins Creek, Salt Creek, and Mud River. The set nitrate water quality target was determined to be protective. Therefore, setting it for the headwaters should be protective of downstream waters.

5.9 Setting the TMDL Annual Arithmetic Average Concentration for Nitrate

During the Cycle 2 verified period (January 1, 2004–June 30, 2011) and more recently (2012–14), Aripeka #1 Spring and Aripeka #2 Spring were only sampled twice due to their inaccessibility from land. The nitrate data for Aripeka #1 Spring and Aripeka #2 Spring are limited. Because of the limited data, an annual average could not be calculated for either spring. The SWFWMD performed the majority of the water quality sampling. Jenkins Creek Spring, Magnolia Spring, Bobhill Spring, and Wilderness Spring are sampled four times a year (January, April, July, and October). Because they are less accessible, Salt Spring and Boat Spring are sampled only once per year in July. This schedule is part of the SWFWMD routine water quality sampling program.

For Boat Spring, Magnolia Spring, Bobhill Spring, Jenkins Creek Spring, Mud Spring, Salt Spring, and Wilderness Spring, the annual average nitrate concentrations were calculated for each year (**Table 5.2a** through **Table 5.2g**, respectively). For these impaired waters, the percent reductions required for the TMDL were calculated using the water quality values averaged for each year over the most recent ten-year period (January 1, 2004–December 31, 2014).

Due to the minimal seasonal variation of nitrate concentrations for Boat Spring, Magnolia Spring, Bobhill Spring, Jenkins Creek Spring, Mud Spring, Salt Spring, and Wilderness Spring, the percent reductions were established based on the data for the year with the highest annual arithmetic average concentration to ensure that the annual arithmetic average concentrations will meet the target concentration even under the worst-case scenario. For these springs, annual average targets are most appropriate because algal growth does not respond to instantaneous changes in nutrient concentrations. This approach adds to the margin of safety (MOS) of these TMDLs and will be protective for all seasons, adding to the implicit MOS.

Table 5.2a. Yearly average nitrate concentrations for Boat Spring (1391B), 2004–14

Note: Maximum annual average is shown with an asterisk and highlighted in red.

Year	N	Average	Maximum	Minimum
2004	1	0.50	0.50	0.50
2005	2	0.47	0.49	0.46
2006	1	0.54	0.54	0.54
2007	1	0.54	0.54	0.54
2008	1	0.53	0.53	0.53
2009	1	0.55	0.55	0.55
2010	1	0.60	0.60	0.60
2011*	1	0.66	0.66	0.66
2012	1	0.56	0.56	0.56
2013	1	0.61	0.61	0.61
2014	1	0.63	0.63	0.63

Table 5.2b. Yearly average nitrate concentrations for Bobhill Spring (1391B), 2004–14

Note: Maximum annual average is shown with an asterisk and highlighted in red.

Year	N	Average	Maximum	Minimum
2004	4	0.65	0.74	0.54
2005	4	0.66	0.74	0.61
2006	3	0.66	0.70	0.64
2007	2	0.34	0.67	0.01
2008	2	0.57	0.58	0.56
2009	2	0.70	0.70	0.69
2010	4	0.68	0.90	0.42
2011	4	0.74	0.83	0.64
2012*	4	1.02	1.82	0.69
2013	4	0.74	0.78	0.71
2014	4	0.54	0.69	0.20

Table 5.2c. Yearly average nitrate concentrations for Salt Spring (1382G), 2004–14

Note: Maximum annual average is shown with an asterisk and highlighted in red.

Year	N	Mean	Maximum	Minimum
2004	1	0.53	0.53	0.53
2005	2	0.56	0.62	0.50
2006	1	0.56	0.56	0.56
2007	1	0.49	0.49	0.49
2008	1	0.55	0.55	0.55
2009	1	0.58	0.58	0.58
2010*	2	0.60	0.63	0.57
2011	1	0.59	0.59	0.59
2012	1	0.55	0.55	0.55
2013	2	0.47	0.53	0.41
2014	1	0.58	0.58	0.58

Table 5.2d. Yearly average nitrate concentrations for Jenkins Creek Spring (1389), 2004–14

Note: Maximum annual average is shown with an asterisk and highlighted in red.

Year	N	Mean	Maximum	Minimum
2004*	4	0.86	0.97	0.76
2005	4	0.80	0.87	0.71
2006	4	0.73	0.83	0.66
2007	4	0.55	0.77	0.07
2008	4	0.46	0.72	0.00
2009	4	0.55	0.74	0.35
2010	14	0.60	0.80	0.31
2011	4	0.78	0.81	0.75
2012	4	0.78	0.93	0.49
2013	4	0.78	0.84	0.69
2014	4	0.78	0.81	0.75

Table 5.2e. Yearly average nitrate concentrations for Magnolia Spring (1391B), 2004–14

Note: Maximum annual average is shown with an asterisk and highlighted in red.

Year	N	Mean	Maximum	Minimum
2004	4	0.50	0.53	0.48
2005	4	0.50	0.53	0.49
2006	4	0.54	0.55	0.52
2007	4	0.55	0.57	0.54
2008	4	0.56	0.58	0.54
2009	4	0.58	0.61	0.55
2010	4	0.59	0.61	0.58
2011*	4	0.63	0.64	0.61
2012*	4	0.63	0.66	0.61
2013	4	0.60	0.61	0.57
2014	4	0.60	0.61	0.59

Table 5.2f. Yearly average nitrate concentrations for Mud Spring (1382G), 2004–14

Note: Maximum annual average is shown with an asterisk and highlighted in red.

Year	N	Mean	Maximum	Minimum
2004	10	0.41	0.51	0.24
2005*	6	0.44	0.54	0.38
2006				
2007				
2008				
2009				
2010	1	0.22	0.22	0.22
2011				
2012				
2013	1	0.25	0.25	0.25
2014				

Table 5.2g. Yearly average nitrate concentrations for Wilderness Spring (1382G), 2004–14

Note: Maximum annual average is shown with an asterisk and highlighted in red.

Year	N	Mean	Maximum	Minimum
2004				
2005				
2006				
2007				
2008				
2009				
2010	5	0.42	0.47	0.39
2011	4	0.45	0.50	0.42
2012	4	0.44	0.47	0.39
2013	4	0.46	0.49	0.44
2014*	4	0.48	0.50	0.44

5.10 Calculation of the TMDL Percent Reduction

The maximum annual average nitrate concentrations for individual springs within the three WBIDs were calculated from data available during the Cycle 2 verified period plus more recently (January 1, 2004–December 31, 2014), as follows:

- WBID 1391B: Boat Spring, 0.66 mg/L in 2011.
- WBID 1391B: Bobhill Spring, 1.02 mg/L in 2012.
- WBID 1391B: Magnolia Spring, 0.63 mg/L in 2011 and 2012.
- WBID 1385: Jenkins Creek Spring, 0.64 mg/L in 2004.
- WBID 1382G: Mud Spring, 0.44 mg/L in 2005.
- WBID 1382G: Salt Spring, 0.60 mg/L in 2010.
- WBID 1382G: Wilderness Spring, 0.48 mg/L in 2014.

The springs with the greatest maximum annual average nitrate concentrations for the three WBIDs are Boat Spring (for WBID 1391B). Jenkins Creek Spring (1385); and Salt Spring (WBID 1382G).

To obtain percent reductions that are reasonably representative of the seven springs and will be adequately protective, the maximum annual average nitrate concentrations were used. The percent reduction to achieve the water quality targets for each of the springs was calculated using the following formula:

[(existing mean concentration – target concentration)/existing mean concentration] x 100

Percent Reduction Calculations:

- **Boat Spring (WBID 1391B):** [(0.66 mg/L – 0.23 mg/L) / 0.66 mg/L] * 100

  Equals a 65% reduction in nitrate.

- **Bobhill Spring (WBID 1391B):** [(1.02 mg/L – 0.23 mg/L) / 1.02 mg/L] * 100

  Equals a 77% reduction in nitrate.

- **Magnolia Spring (WBID 1391B):** [(0.63 mg/L – 0.23 mg/L) / 0.63 mg/L] * 100

  Equals a 63% reduction in nitrate.

- **Jenkins Creek Spring (WBID 1389):** [(0.86 mg/L – 0.23 mg/L) / 0.86 mg/L] * 100

  Equals a 73% reduction in nitrate.

- **Mud Spring (WBID 1382G):** [(0.44 mg/L – 0.23 mg/L) / 0.44 mg/L] * 100

  Equals a 48% reduction in nitrate.

- **Salt Spring (WBID 1382G):** [(0.60 mg/L – 0.23 mg/L) / 0.60 mg/L] * 100

  Equals a 62% reduction in nitrate.

- **Wilderness Spring (WBID 1382G):** [(0.48 mg/L – 0.23 mg/L) / 0.48 mg/L] * 100

  Equals a 52% reduction in nitrate.

Reductions in nitrate concentrations of 65% in Boat Spring, 63% in Magnolia Spring, 77% in Bobhill Spring, 73% in Jenkins Creek Spring, 48% in Mud Spring, 62% in Salt Spring, and 52% in Wilderness Spring would be needed to cause filamentous algae biomass and epiphytic phytoplankton productivity to decrease.

By WBID, the maximum percent reductions needed are as follows: WBID 1391B (77%); WBID 1389 (73%); and WBID 1382G (62%). Once the target concentrations are consistently achieved, each WBID will be reevaluated to determine if nitrogen continues to contribute to an imbalance of flora or fauna as a result of algal smothering. If such a condition still exists, the waterbodies will be reassessed as part of DEP's watershed assessment cycle. The TMDL target concentrations may be changed if DEP determines that further reductions in nitrogen concentrations are needed to address the imbalance. The purpose of a TMDL is to set a pollutant reduction goal that, if achieved, will result in the attainment of designated uses for that waterbody.

Chapter 6: DETERMINATION OF THE TMDL

6.1 Expression and Allocation of the TMDL

The percent concentration reductions listed in **Section 5.8** should achieve the annual average nutrient target concentration for all springs in the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and all springs in the Wilderness–Mud–Salt Springs Group. While these percent reductions are the expression of the TMDLs that will be implemented, the EPA recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increment in conjunction with other appropriate temporal expressions that may be necessary to implement the relevant water quality standard.

The nitrogen TMDL targets are presented as annual averages instead of daily values because the nitrate concentrations in these springs are relatively consistent (not significant) from season to season. Also, changes in aquatic vegetation biomass do not respond instantaneously to changes in nutrient concentrations. Murray et al. (1999) found that nutrient enrichment response differed for SAV on the order of months (two to two-and-a-half months).

Also, due to limited economic resources, it is impractical to collect daily nitrate water quality data to evaluate water quality for the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group. Maximum monthly concentration (MMC) targets for nitrate were established using the equation below, which was established by the EPA (2006). In the following equation, it is assumed that the nitrate data distributions are lognormal:

$$\mathbf{MMC = LTA * exp(Z_p\sigma_y - 0.5\sigma y^2)}$$

$$\mathbf{\sigma y = sqrt(ln(CV^2 + 1))}$$

Where:

LTA = Long-term average.
Z_p = p^{th} percentage point of the standard normal distribution, at 95% (Z_p = 1.645).
σ = Standard deviation.
CV = Coefficient of variance.

6.1.1 Calculation of the MMC for Nitrogen

For the monthly maximum nitrogen concentration, it was assumed that the average annual target concentration should be the same as the average monthly concentration. Also, assuming the target dataset will have the same CV as the existing measured dataset and allowing a 5% exceedance (EPA 2007, pp. 19 and 20), **Table 6.1** lists the monthly maximum nitrate concentrations for Boat Spring, Bobhill Spring, Magnolia Spring, Jenkins Creek Spring, Mud Spring, Salt Spring, and Wilderness Spring. It should be emphasized that these monthly maximum targets were developed for illustrative purposes and that the implementation of the TMDLs will be based on the annual average concentration targets.

Table 6.1. Monthly maximums for target TN and nitrate concentrations for individual springs in WBIDs 1391B, 1389 and 1382G (mg/L)

Waterbody Name	Parameter	Standard Deviation	Long-Term Average Nitrate Target (mg/L)	CV	Monthly Maximum To Achieve Annual Average Nitrogen Target
Boat Spring	Nitrate	0.0621	0.23	0.1120	0.27
Bobhill Spring	Nitrate	0.2502	0.23	0.3653	0.38
Magnolia Spring	Nitrate	0.0456	0.23	0.0799	0.26
Jenkins Creek Spring	Nitrate	0.1998	0.23	0.2937	0.35
Mud Spring	Nitrate	0.0899	0.23	0.2238	0.32
Salt Spring	Nitrate	0.0572	0.23	0.1042	0.27
Wilderness Spring	Nitrate	0.0359	0.23	0.0801	0.26

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (wasteload allocations, or WLAs), nonpoint source loads (load allocations, or LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\textbf{TMDL} = \sum \textbf{WLAs} + \sum \textbf{LAs} + \textbf{MOS}$$

As discussed earlier, the WLA is broken out into separate subcategories for wastewater discharges (if present) and stormwater discharges regulated under the NPDES Program:

$$\mathbf{TMDL \cong \sum WLAs_{wastewater} + \sum WLAs_{NPDES\ Stormwater} + \sum LAs + MOS}$$

It should be noted that the various components of a TMDL equation may not sum up to the value of the TMDL because (1) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is also accounted for within the LA, and (2) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction, and the WLA for wastewater is typically expressed as mass per day).

WLAs for stormwater discharges are typically expressed as a percent reduction because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges also differs from the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored, and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the "maximum extent practical" through the implementation of BMPs.

This approach is consistent with federal regulations (40 Code of Federal Regulations § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or **other appropriate measure**. To be conservative, the TMDLs for WBIDs 1391B, 1389 and 1382G were selected based on the spring within each WBIDs that required the greatest reduction to achieve restoration. These TMDLs are expressed in terms of concentration of nitrate-nitrogen and represent the loading the springs and tidal creeks can assimilate and maintain healthy levels of algal growth that do not contribute to an ecological imbalance (**Table 6.2**). Because no target loads were explicitly calculated in this TMDL report, the TMDLs are represented as the percent reduction in existing nitrate concentrations required to achieve the nitrate targets. The percent reductions assigned to all the nonpoint source areas (LAs) are the same as those defined for the TMDL percent reductions.

Table 6.2. TMDL components for springs in WBIDs 1391B, 1389, and 1382G

N/A = Not applicable

WBID	Parameter	TMDL (mg/L)	TMDL % Reduction	Wasteload Allocation for Wastewater	Wasteload Allocation for NPDES Stormwater % Reduction	Load Allocation % Reduction	MOS
1391B	Nitrate as Annual Average	0.23	77%	N/A	77%	77%	Implicit
1389	Nitrate as Annual Average	0.23	73%	N/A	73%	73%	Implicit
1382G	Nitrate as Annual Average	0.23	62%	N/A	62%	62%	Implicit

6.2 Wasteload Allocation (Point Sources)

6.2.1 NPDES Wastewater Discharges

Currently, no NPDES wastewater facilities discharge directly into the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group. Any new potential discharger is expected to comply with the Class III criterion for nutrients and with nitrate limits consistent with this TMDL. If it is determined that any of the wastewater facilities discharge into these impaired waterbodies, they will be subject to the assigned WLA.

6.2.2 NPDES Stormwater Discharges

Table 6.2 provides the NPDES stormwater percent reductions, which represent the allowable nutrient loads that would result in ecosystem improvement. The NPDES stormwater collection systems in the springs contributing area are maintained by Hernando County (FLR04E040), FDOT District 7 (FLR04E017–Hernando), Pasco County co-permittee with FDOT District 7 (FLS000032), and Florida Turnpike Enterprise (FLR04E049). It should be noted that any future MS4 permittee is only responsible for reducing the anthropogenic loads associated with stormwater outfalls that it owns or otherwise has responsible control over, and it is not responsible for reducing other nonpoint source loads in its jurisdiction.

6.3 Load Allocation (Nonpoint Sources)

Reductions in nitrate concentrations of 77% in WBID 1391B, 73% in WBID 1389, and 62% in WBID 1382G are needed from the nonpoint source areas contributing to these impaired springs. The target annual average nitrate concentrations and the percent reductions represent estimates of the maximum reductions required to meet the targets. It may be possible to meet the targets before achieving the percent reductions. It should be noted that the LA could also include loading from stormwater discharges regulated by DEP and the water management district that are not part of the NPDES Stormwater Program (see **Appendix A**).

6.4 Margin of Safety

Consistent with the recommendations of the Allocation Technical Advisory Committee (DEP 2001), an implicit MOS was used in the development of this TMDL, and was provided by the conservative decisions associated with a number of assumptions and the development of assimilative capacity. Also, when estimating the required percent reduction to achieve the water quality target, the highest annual average of measured nitrogen concentration in the ten-year data period (2004–14) was used instead of the average of the annual averages. Due to the minimal seasonal variation of the nitrate concentrations for springs within these WBIDs, the percent reductions were established based on the data for the year with the highest annual average concentration. This will also be protective for all seasons, adding to the implicit MOS. Both of these will make estimating the required percent load reduction more conservative and therefore add to the MOS.

Chapter 7: NEXT STEPS—IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

7.1 Basin Management Action Plan

Following the adoption of these TMDLs by rule, DEP will determine the best course of action regarding its implementation. Depending on the pollutant(s) causing the waterbody impairment and the significance of the waterbody, DEP will select the best course of action leading to the development of a plan to restore the waterbody. Often this will be accomplished cooperatively with stakeholders by creating a basin management action plan, referred to as the BMAP. BMAPs are the primary mechanism through which TMDLs are implemented in Florida (see Subsection 403.067[7], F.S.). A single BMAP may provide the conceptual plan for the restoration of one or many impaired waterbodies. A BMAP can take into account the sources of nitrogen in the contributing area, including legacy loads from past land use activities, as well as the complexity of the aquifer system that conveys pollutants to the impaired waters.

If DEP determines that a BMAP is needed to support the implementation of these TMDLs, it will be developed through a transparent, stakeholder-driven process intended to result in a plan that is cost-effective, is technically feasible, and meets the restoration needs of the applicable waterbodies.

Once adopted by order of the DEP Secretary, BMAPs are enforceable through wastewater and municipal stormwater permits for point sources and through BMP implementation for nonpoint sources. Among other components, BMAPs typically include the following:

- Water quality goals (based directly on the TMDLs).
- Refined source identification.
- Load reduction requirements for stakeholders (quantitative detailed allocations, if technically feasible).
- A description of the load reduction activities to be undertaken, including structural projects, nonstructural BMPs, and public education and outreach.
- A description of further research, data collection, or source identification needed to achieve the TMDLs.

- Timetables for implementation.
- Implementation funding mechanisms.
- An evaluation of future increases in pollutant loading due to population growth.
- Implementation milestones, project tracking, water quality monitoring, and adaptive management procedures.
- Stakeholder statements of commitment (typically a local government resolution).

BMAPs are updated through annual meetings and may be officially revised every five years. Completed BMAPs in the state have improved communication and cooperation among local stakeholders and state agencies; improved internal communication within local governments; applied high-quality science and local information to the management of water resources; clarified the obligations of wastewater point source, MS4, and non-MS4 stakeholders in TMDL implementation; enhanced transparency in DEP's decision making; and built strong relationships between DEP and local stakeholders that have benefited other program areas.

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Appendices

Appendix A: Background Information on Federal and State Stormwater Programs

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, F.S., was established as a technology-based program that relies on the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, F.A.C. In 1994, DEP's stormwater treatment requirements were integrated with the stormwater flood control requirements of the water management districts, along with wetland protection requirements, into the Environmental Resource Permit (ERP) regulations.

Chapter 62-40, F.A.C., also requires the state's water management districts to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a surface water improvement and management (SWIM) plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, they have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka.

In 1987, the U.S. Congress established Section 402(p) as part of the federal Clean Water Act Reauthorization. This section of the law amended the scope of the federal NPDES permitting program to designate certain stormwater discharges as "point sources" of pollution. The EPA promulgated regulations and began implementing the Phase I NPDES Stormwater Program in 1990. These stormwater discharges include certain discharges that are associated with industrial activities designated by specific standard industrial classification (SIC) codes, construction sites disturbing 5 or more acres of land, and the master drainage systems of local governments with a population above 100,000, which are better known as MS4s. However, because the master drainage systems of most local governments in Florida are interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 urban water control districts, and FDOT throughout the 15 counties meeting the population criteria. DEP received authorization to implement the NPDES Stormwater Program in 2000.

An important difference between the federal NPDES and the state's Stormwater/ERP Programs is that the NPDES Program covers both new and existing discharges, while the state's program focuses on new discharges only. Additionally, Phase II of the NPDES Program, implemented in 2003, expands the need for these permits to construction sites between one and five acres, and to local governments with as few as 1,000 people. While these urban stormwater discharges are now technically referred to as "point sources" for the purpose of regulation, they are still diffuse sources of pollution that cannot be easily collected and treated by a central treatment facility, as are other point sources of pollution such as domestic and industrial wastewater discharges.

It should be noted that all MS4 permits issued in Florida include a reopener clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.

Appendix B: Information in Support of Site-Specific Interpretations of the Narrative Nutrient Criterion

Table B-1. Spatial extent of the numeric interpretation of the narrative nutrient criterion

— *Documents location and descriptive information.*

Waterbody Location Information	Description of Waterbody Location Information
Waterbody Name	1. Magnolia–Aripeka Springs Group (Aripeka Springs #1, Aripeka Springs #2, Boat Spring, Bobhill Spring, and Magnolia Spring) 2. Wilderness–Mud–Salt Springs Group (Wilderness Spring, Salt Spring, and Mud Spring) 3. Jenkins Creek Spring
Waterbody Type(s)	Springs
Waterbody ID (WBID)	WBIDs 1391B, 1382G, and 1389 (see **Figure 1.1** of the TMDL report)
Description	The Magnolia–Aripeka Springs Group is located one-half mile east of the community of Aripeka in Hernando County immediately north of the Pasco County border. The surface area of the spring group is approximately 5 acres, and the spring contributing area encompasses 37,976 acres. The average depth of the spring group is 6 feet. The primary outlet is Hammock Creek, which flows into the Gulf of Mexico. The Wilderness–Mud–Salt Springs Group is located 3 miles west of the town of Weeki Wachee Springs in Hernando County. The surface area of the spring group is approximately 5 acres. The spring group is located inside the Weeki Wachee Spring contributing area, which encompasses 162,713 acres. The average depth of the spring group is 6 feet. The primary outlet is Mud River. Jenkins Creek Spring is located inside Hernando Beach Park off Shoal Line Road in Hernando County. The surface area of the spring is approximately one-eighth of an acre. Jenkins Creek Spring is included in the Weeki Wachee Spring contributing area. The average depth of the spring is 6 feet. The primary outlet is Jenkins Creek, which flows to the Gulf of Mexico.
Specific Location (Latitude/Longitude or River Miles)	The center of the Magnolia–Aripeka Springs Group is located at Latitude N: $28^0$26'1.93" / W: -82^0 39'8.96". The center of the Wilderness–Mud–Salt Springs Group is located at Latitude N: $28^0$32'46.75" / W: -82^0 37'8.28". The center of Jenkins Creek Spring is located at Latitude N: $28^0$31'19.31" / W: -82^0 38'2.64". The site-specific criteria apply as a spatial average for the springs group, as defined by WBIDs 1391B, 1389, and 1382G.
Map	The general location of the Magnolia–Aripeka Springs Group in the Magnolia–Aripeka contributing area is shown in **Figure 1.1** of this TMDL report, and land uses in the contributing area are shown in **Figure 4.4**. Land use is predominately residential (47%) and upland forest (17.6%). Surface waters cover about 1.34% of the contributing area. The general location of the Wilderness–Mud–Salt Springs Group and Jenkins Creek Spring in the Weeki Wachee contributing area are shown in **Figure 1.1** of this TMDL report, and land uses in the contributing area are shown in **Figure 4.3**. Land use is predominately residential (27.36%), upland forest (23.18%), and agriculture (22.62%). Surface water covers about 1% of the contributing area.
Classification(s)	Class III Freshwater
Basin Name (Hydrologic Unit Code [HUC] 8)	Crystal–Pithlachascotee (03100207)

Table B-2. Description of the numeric interpretation of the narrative nutrient criterion

- ***Provides specific list of parameters/constituents for which state NNC are adopted, site-specific numeric interpretations are proposed.***
- ***Provides sufficient detail on magnitude, duration, and frequency to ensure that criteria can be used to verify impairment or delisting in the future.***
- ***Indicates how criteria developed are spatially and temporally representative of the waterbody or critical condition.***

Numeric Interpretation of Narrative Nutrient Criterion	Parameter Information Related to Numeric Interpretation of the Narrative Nutrient Criterion
NNC Summary: Default nutrient watershed region or lake classification (if applicable) and corresponding NNC	The narrative nutrient water quality criterion for the protection of Class III waters, as established in Paragraph 62-302.530(47)(b), F.A.C ., states that nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. This imbalance includes algal mats or blooms that are present in sufficient quantities to pose a nuisance or hinder the reproduction of a threatened or endangered species, as stated in Subsections 62-303.351(3) and 62-303.354(2), F.A.C.
Proposed nitrate+nitrite (magnitude, duration, and frequency)	DEP selected the Stevenson et al. (2007) 90% saturating nitrate concentration of 0.23 mg/L as the nitrate water quality target concentration for the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group. Nitrate is the most abundant form of nitrogen available in spring discharge. As discussed previously, the nitrate water quality target for springs is based on algal growth studies performed in low-flushing (long residence time) conditions similar to those of the tidal creeks into which these impaired springs discharge. This target was selected because it would be protective of the Class III designated use. DEP believes that reducing the growth rate of macroalgae (including *Lyngbya* and *Chaetomorpha*) through nitrate reduction will decrease filamentous algae biomass and phytoplankton productivity. The nitrate water quality target of 0.23 mg/L will be established as an annual arithmetic average not to be exceeded in any year. An annual arithmetic average was chosen due to the minimal seasonal variation, as described in **Section 5.4**.
Period of record used to develop the numeric interpretations of the narrative nutrient criterion for nitrate+nitrite criteria	To ensure that the proposed nitrate TMDL was developed based on current conditions and that recent trends in the springs' water quality were adequately captured, monitoring data were used for the seven-year Cycle 2 verified period (January 1, 2004–June 30, 2011) plus more recently (2012–14).

Numeric Interpretation of Narrative Nutrient Criterion	Parameter Information Related to Numeric Interpretation of the Narrative Nutrient Criterion
Indicate how criteria developed are spatially and temporally representative of the waterbody or critical condition. **Are the stations used representative of the entire extent of the WBID and where the criteria are applied? In addition, for older TMDLs, an explanation of the representativeness of the data period is needed (e.g., have data or information become available since the TMDL analysis?). These details are critical to demonstrate why the resulting criteria will be protective as opposed to the otherwise applicable criteria (in cases where a numeric criterion is otherwise in effect, unlike this case).**	The data used were spatially representative of the waterbodies because the samples were collected at the spring vents. **Figure 2.9** shows the locations of the current and historical routine water quality sampling stations and biological stations represented by data collected by or provided to DEP for the Magnolia–Aripeka Springs Group. **Figure 2.10** shows the same information for Jenkins Creek Spring, and **Figure 2.11** contains information on the Wilderness–Mud–Salt Springs Group. To ensure that the nutrient TMDLs were developed based on current conditions and that recent trends in the springs' water quality were adequately captured, monitoring data were compiled for the seven-year Cycle 2 verified period (January 1, 2004–June 30, 2011) plus more recently (2012–14). The data used for the TMDLs are from samples collected by the SWFWMD as well as the USGS, LakeWatch, and DEP. **Figure 2.13** through **Figure 2.19** show the nitrate monitoring results for these impaired springs during the Cycle 2 verified period (January 1, 2004–June 30, 2011) plus more recently (2012–14). **Table 2.3** summarizes the nitrate monitoring results for Aripeka #1 Spring, Aripeka #2 Spring, Boat Spring, Bobhill Spring, Magnolia Spring, Mud Spring, Salt Spring, Wilderness Spring, and Jenkins Creek Spring during the Cycle 2 verified period plus more recently (2004–14). Establishing the critical condition for nitrogen inputs that affect algal growth in a given contributing area depends on many factors, including the presence of point sources and the land use pattern in the contributing area. The critical condition for point source loading to a waterbody typically occurs during periods of low flow, when dilution is minimized. Typically, the critical condition for nonpoint source loading is a period of rainfall-related flushing preceded by an extended dry period. During the wet weather period, rainfall mobilizes nitrogen that has accumulated on the land surface and in the soil under dry conditions, resulting in higher pollutant concentrations. However, significant nonpoint source contributions can also appear under dry conditions without any major surface runoff event. Also, there can be a lag time between nitrogen inputs into groundwater and discharge from the spring vents. Nitrate data for Aripeka #1 Spring and Aripeka #2 Spring are limited. During the Cycle 2 verified period (January 1, 2004–June 30, 2011) plus more recently (2012–14), Aripeka #1 Spring and Aripeka #2 Spring were only sampled twice due to their inaccessibility from land. Because of the limited data, a seasonal average could not be calculated. **Table 5.1** summarizes the results of the Kruskal-Wallis test and seasonal average nitrate concentrations for Boat Spring, Bobhill Spring, Magnolia Spring, Jenkins Creek Spring, Mud Spring, Salt Spring, and Wilderness Spring during the Cycle 2 verified period and more recently (2004–14). A Kruskal-Wallis statistical test was used to detect significant variation between seasons. Based on the nitrate data available, nitrate concentrations in the springs are relatively consistent (not significant) from season to season, with the exception of Jenkins Creek Spring. For Jenkins Creek Spring, comparing nitrate concentrations in the second quarter to those in the fourth quarter revealed a slight significant difference (Prob > ChiSquare = 0.05). In general, there does not appear to be any significant period when higher loading occurs for any of these springs.

Table B-3. Designated use, verified impairment, and approach to establish protective restoration targets

— ***Summarizes how designated use (or uses) is demonstrated to be protected by the criteria.***

— ***Summarizes the review associated with more recent data collected since TMDL development.***

— ***Evaluates the current relevance of assumptions made in TMDL development.***

Designated Use Requirements	Information Related to Designated Use Requirements
History of assessment of designated use support	These springs were listed as impaired by nutrients because of their consistently elevated concentrations of nitrate and the corresponding evidence in their spring runs of imbalances in flora and fauna caused by algal smothering. This information was used in the determination of impairment for the 2012 Verified List of impaired waters. **Table 2.1** lists the waterbodies on the Cycle 2 Verified List that are addressed in this report.
Basis for use support	DEP selected the Stevenson et al. (2007) 90% saturating nitrate concentration of 0.23 mg/L as the nitrate water quality target concentration for the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group. Nitrate is the most abundant form of nitrogen available in spring discharge. As discussed previously, the nitrate water quality target for springs is based on algal growth studies performed in low-flushing (long residence time) conditions that are similar to the tidal creeks into which these impaired springs discharge. This target was selected because it would be protective of the Class III designated use. DEP believes that reducing the growth rate of macroalgae (including *Lyngbya* and *Chaetomorpha*) through nitrate reduction will decrease filamentous algae biomass and phytoplankton productivity.
Summarize approach used to develop criteria and how it protects uses	The numeric interpretations for nitrate+nitrite were based on field and laboratory studies, which examined *L. wollei* growth rates under conditions that modeled low-flushing environments with long residence times. Compared with free-flowing spring runs (flushing rates on the order of hours), the Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group discharge into tidal creeks with long residence times (flushing rates on the order of days). This target was selected because it would be protective of the Class III designated use. DEP believes that reducing the growth rate of macroalgae (including *Lyngbya* and *Chaetomorpha*) through nitrate reduction will decrease filamentous algae biomass and phytoplankton productivity.

Designated Use Requirements	Information Related to Designated Use Requirements
Discuss how the TMDL will ensure that nutrient-related parameters are attained to demonstrate that the TMDL will not negatively impact other water quality criteria. These parameters must be analyzed with the appropriate frequency and duration. If compliance with 47(a) is not indicated in the TMDL, it should be clear that further reductions may be required in the future.	Reductions in nitrate concentrations of 77% for WBID 1391B (based on concentrations in Bobhill Spring), 73% for WBID 1389 (based on concentrations in Jenkins Creek Spring), and 62% for WBID 1382G (based on concentrations in Salt Spring) are proposed because they are protective values that, when achieved, will cause filamentous algae biomass and epiphytic phytoplankton productivity to decrease. The proposed reductions in nutrient inputs will result in further improvements in water quality. Once the target concentrations are consistently achieved, each WBID will be reevaluated to determine if nitrogen continues to contribute to an imbalance of flora or fauna as a result of algal smothering. If such a condition still exists, the waterbodies will be reassessed as part of DEP's watershed assessment cycle. The TMDL target concentrations may be changed if DEP determines that further reductions in the nitrogen concentrations are needed to address the imbalance. The purpose of a TMDL is to set a pollutant reduction goal that, if achieved, will result in attainment of the designated uses for that waterbody.

Table B-4. Documentation of the means to attain and maintain water quality standards in downstream waters

Downstream Waters Protection and Monitoring Requirements	Information Related to Downstream Waters Protection and Monitoring Requirements
Identification of Downstream Waters: List receiving waters and identify technical justification for concluding downstream waters are protected.	The Magnolia–Aripeka Springs Group, Jenkins Creek Spring, and the Wilderness–Mud–Salt Springs Group are the headwaters for Hammock Creek, Jenkins Creek, Salt Creek, and Mud River. The set nitrate water quality target was determined to be protective; therefore, setting it for the headwaters should be protective of downstream waters.
Provide summary of existing monitoring and assessment related to implementation of Subsection 62-302.531(4), F.A.C., and trends tests in Chapter 62-303, F.A.C.	The SWFWMD performed the majority of the water quality sampling and analysis (**Figure 2.8**). The district samples Jenkins Creek Spring, Magnolia Spring, Bobhill Spring, and Wilderness Spring four times a year (January, April, July, and October). Because they are less accessible, the SWFWMD samples Salt Spring and Boat Spring only once per year in July. This schedule is the part of the SWFWMD routine water quality sampling program. This frequency of sampling of these waterbodies meets minimum sampling requirements for future assessments, including trend tests.