DELINEATION OF SPRING-WATER SOURCE AREAS IN THE ICHETUCKNEE SPRINGSHED

Prepared for the
Florida Department of Environmental Protection
Tallahassee, Florida

By

Kyle M. Champion, P.G.
Sam B. Upchurch, P.G., Ph.D

SDII Global Corporation
4509 George Road
Tampa, Florida 33634

Cover photograph: Rose Creek swallet near Columbia City is located on the Ichetucknee Trace. The swallet receives surface water from Rose Creek during runoff events. In 1997 fluorescent dye was introduced into the swallet by cave divers. Several days later, the dye was detected at several springs along the Ichetucknee River, thus giving clear evidence of a direct connection between the Rose Creek swallet and the Ichetucknee Springs.

This report was authored by the undersigned for the use and distribution by the Florida Department of Environmental Protection.
[SDII Project No. 3004390]

________________________________	________________________________
Sam B. Upchurch, Ph.D., P.G. Florida License No. 4 Vice President and Principal Geologist SDII Global Corporation	Kyle M. Champion, P.G. Florida License No. 2044 Senior Hydrogeologist SDII Global Corporation

Date signed: ______________________

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The Ichetucknee Springs are one of north Florida's most valuable natural resources. The springs are one of the State's many first-magnitude springs groups as well as one of the most popular state parks in the region. The springs are important to the natural and scenic beauty of the area, and to the region's rich historical heritage. However, protecting the Ichetucknee Springs, and others like it, will likely prove difficult without a thorough understanding of the geology and hydrology of the regions surrounding the springs and Ichetucknee River.

Much information has been gathered concerning the Ichetucknee Spring system and its drainage basin and the importance of karst to ground water quality since the 1970's. Lawrence and Upchurch (1976), for example, determined that karst features could be used to deduce the vulnerability of ground water to ground-water contamination, and the extent to which ground-water recharge affects water quality in the Upper Floridan aquifer near the town of Lake City. Similar results were obtained Ceryak and others (1983) and Crane (1986) in two regional studies of the upper and lower Suwannee River Basin, respectively. More recently, nitrogen-isotope data collected by Katz and others (1999) suggests that the Ichetucknee Blue Hole Spring is affected by nitrate derived from the use of artificial fertilizers. It has also been discovered that flow through in the Ichetucknee system can be amazingly rapid. A dye trace from Rose Creek Sink in the Ichetucknee drainage basin to the springs resulted in a transport rate of approximately one mile per day (Karst Environmental Services, 1997)!

Given the advances in knowledge and understanding of the hydrology of the Ichetucknee system and surrounding region over the last several decades, the Florida Department of Environmental Protection (FDEP) contracted with SDII Global Corporation (SDII) in February 2003 to investigate spring water-quality trends and delineate source areas for spring water in the Ichetucknee springshed (Figure 1). This report describes the results of this investigation. The main emphasis of the report is to compile and examine all existing chemical data for the Ichetucknee Springs system, and to identify source areas for spring water in the springshed. The report also places considerable emphasis on the structure and function of the karst flow system that conveys ground water from recharge areas to the springs.

DEFINITION OF A SPRINGSHED

In May 2002 the Hydrogeology Consortium held a workshop in Gainesville to develop blue prints for the management and protection of Florida springs. As part of that workshop, a working group on spring basin delineation developed a definition for "springsheds". A springshed was defined as

> *"...those areas within ground-water and surface-water basins that contribute to the discharge of a spring."*

The inclusion of surface-water drainage basins in the definition is important to the Ichetucknee system because several creeks are known to discharge to ground water within the Ichetucknee Spring system ground-water basin. Contaminants transported to the ground-water system from surface-water basins that extend beyond the ground-water basin may constitute a significant threat to the spring system. Therefore, the springshed concept is adopted in this report.

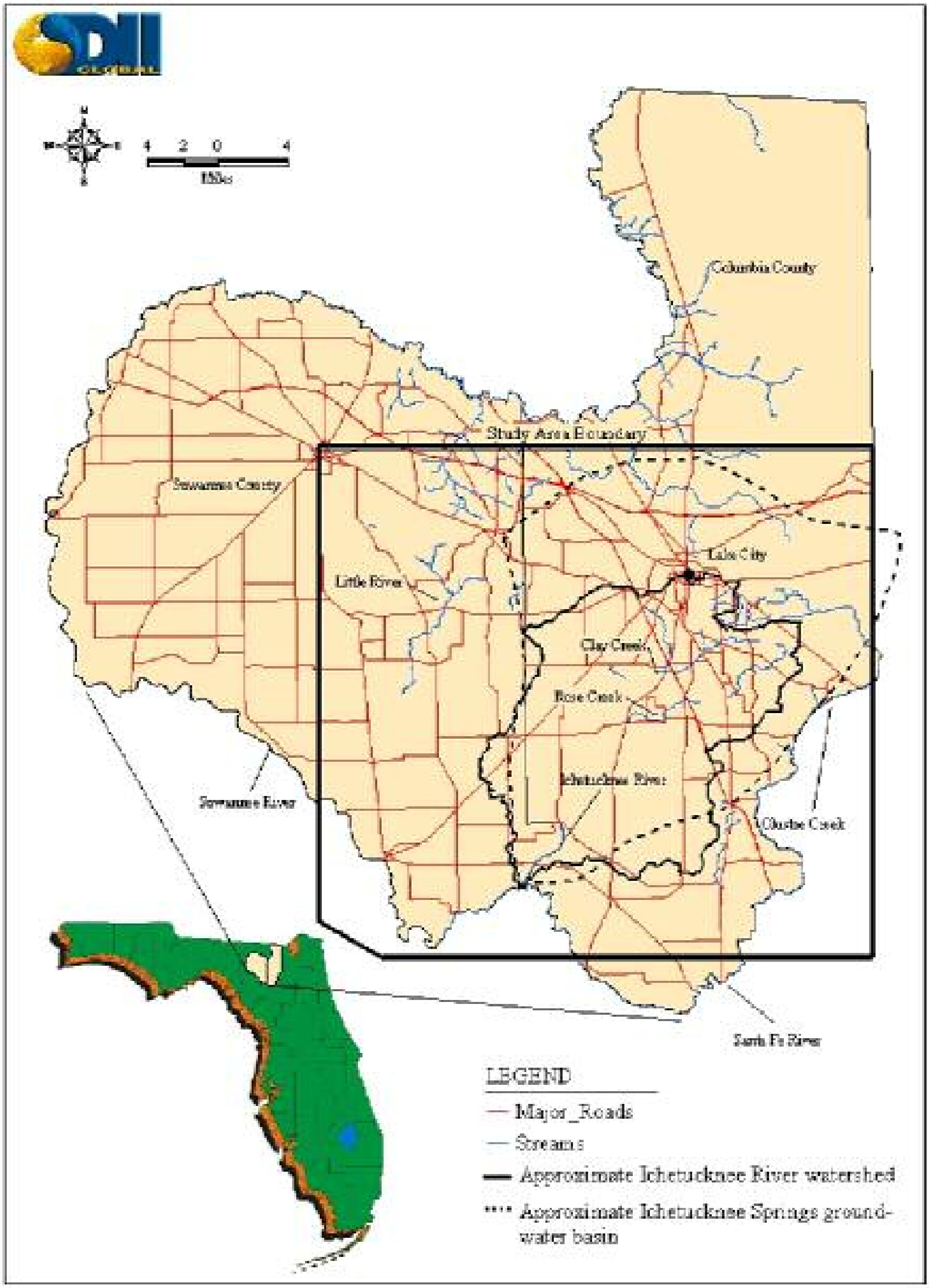


Figure 1. Location of the study area, Ichetucknee River watershed and the IchetuckneeSprings ground-water basin (modified from Upchurch and Champion, 2002).

DESCRIPTION OF STUDY AREA

Geographic Setting

The Ichetucknee Springs study area encompasses approximately 900 square miles of central and southern Columbia County, and eastern Suwannee County (Figure 1). This region contains both the Ichetucknee River watershed, and ground-water basin that contributes subsurface flow to the springs (Upchurch and Champion, 2002). The Ichetucknee River watershed is a small, sub basin of the larger Santa Fe River watershed and, in this report, measures approximately 200 square miles in extent. The Ichetucknee Springs ground-water basin is strictly a subsurface feature and measures approximately 370 square miles in size.

The surface-water drainage basin delineated in Figure 1 is based on surface-water basins delineated by the U.S. Geological Survey (USGS). The ground-water basin was identified and described by Upchurch and Champion (2003, draft) who used geostatistical analysis to better define the basin's boundaries. The Suwannee River Water Management District (SRWMD) is currently developing a monitoring program for the Ichetucknee springshed that will greatly refine the extent of this revised basin delineation (Upchurch and others, 2001).

Note in Figure 1 that most of the surface-water portion of the springshed appears to lie within the ground-water basin. Surface-water basins extend outside of the ground-water basin to the west and east of the ground-water basin, however. For this reason, the study area (Figure 1) was selected to include both surface- and ground-water basins and to extend outside of these basins somewhat.

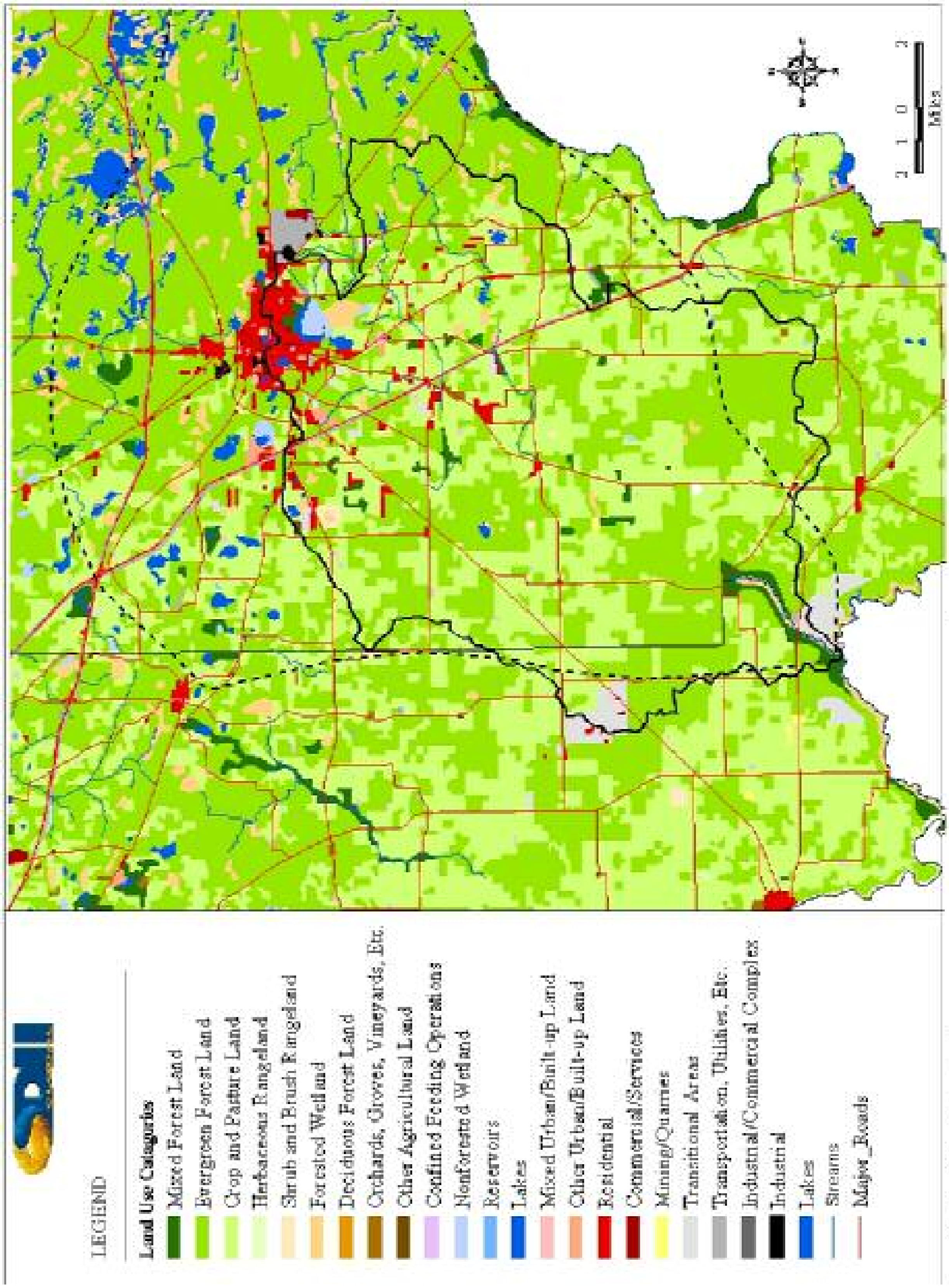
Population and Water Use

Lake City, the largest population center in the study area, contains approximately 12,400 residents. Since 1960, the population of Columbia County has increased 181 percent, from approximately 20,077 to 56,513 (U.S. Census Bureau, 2002). Even with this growth, however, the County retains a decidedly rural character, with a population density of approximately 71 persons per square mile.

According to estimates by Marella (1999), ground water was withdrawn from the upper Floridan aquifer in Columbia County at the rate of approximately 15.9 million gallons per day (mgd) in 1995. Agricultural withdrawals, rural self-supplied, and public water-supply systems accounted for approximately 52.6 percent (8.4 mgd), 28.5 percent (4.5 mgd) and 18.1 percent (2.9 mgd), respectively, of the total withdrawals in the County (Marella, 1999). Cumulatively, these withdrawals accounted for more than 99 percent of the water use in the County in 1995.

Land Use

Land use in the study area was identified using the 1996 USGS Arcview™ land-use coverage. Much of the study area is covered by pasture, cropland and forest (Figure 2). The northeastern portions of the study area are characterized by extensive forest and forested wetlands of the Osceola National Forest. In contrast, the most developed portion of the study areas lies within and in the vicinity of Lake City, where urban development is greatest.



igure 2. Land Use in the study area

4

Topography, Physiography, and Drainage

The topography of the Ichetucknee Springs study area varies considerably. Land-surface elevations range from less than 20 feet above sea level along the southern boundary near the Santa Fe River to heights in excess of 200 feet above sea level in upland areas to the east of Lake City (Figure 3). In the immediate vicinity of the springs, however, elevations typically range between 20 and 60 feet above sea level.

White (1970) divided Columbia County into two physiographic regions: the Northern Highlands and Coastal Lowlands. The Northern Highlands is an upland area (typically greater than 150 feet above sea level) capped by relatively impermeable, clay-rich sediments, which results in considerable surface-water runoff and development of lakes and wetlands (Figure 3). In contrast, the Coastal Lowlands (typically less than 100 feet above sea level) is a mature karst plain characterized by complete, rapid infiltration of runoff, and few, if any, lakes or wetlands (Figure 3). Sinkholes in the Coastal Lowlands are typically small in area, but they are numerous (Upchurch, 2002).

Between the Northern Highlands and Coastal Lowlands is a transitional region characterized by an abundance of sinkholes, sinkhole lakes, and sinking streams (Figure 4). This transitional region was named the Cody Scarp by Puri and Vernon (1964). Surface elevations along the Cody Scarp are generally between 100 and 150 feet above NGVD, and within the study area, a large portion of the surface runoff from the Northern Highlands flows down the Cody Scarp where it drains rapidly into the Upper Floridan aquifer. Because of the thick cover within the Cody Scarp, sinkholes and sinkhole-related karst features tend to be large (Upchurch, 2002).

Geology

Figure 5 is a geologic map showing the stratigraphic units at or near land surface in the study area. Thick sequences of limestone are exposed at or very near (10-20 feet) the land surface in many parts of the study area, especially along the Ichetucknee and Santa Fe rivers. Where limestone is near land surface, the thin veneer of sediment that covers the limestone consists of Quaternary-age, unconsolidated to poorly indurated, siliciclastic deposits dominated by quartz sand. These sands are primarily marine terrace deposits.

The uppermost limestone units in the study area include the Suwannee Limestone of Oligocene age and the Ocala Limestone of Eocene age. The Suwannee Limestone is discontinuous in the study area, and does not crop out in southern Columbia and Suwannee counties. It does, however, sub crop throughout the Northern Highlands, where thick deposits of Quaternary and Hawthorn Group sediments overlie the carbonate bedrock (Crane, 1986). Based on well cuttings, Crane (1986) described the Suwannee Limestone in the study area as consisting of several interbedded lithologies ranging from medium to well-indurated limestone composed of sand-sized particles (calcarenite), to poorly to moderately-indurated limestone composed of calcilutite (silt- and clay-sized particles), and moderately to well-indurated, sugary dolostone. Crane (1986) also noted that upper surface of the Suwannee Limestone (where present) is often highly variable and karstic.

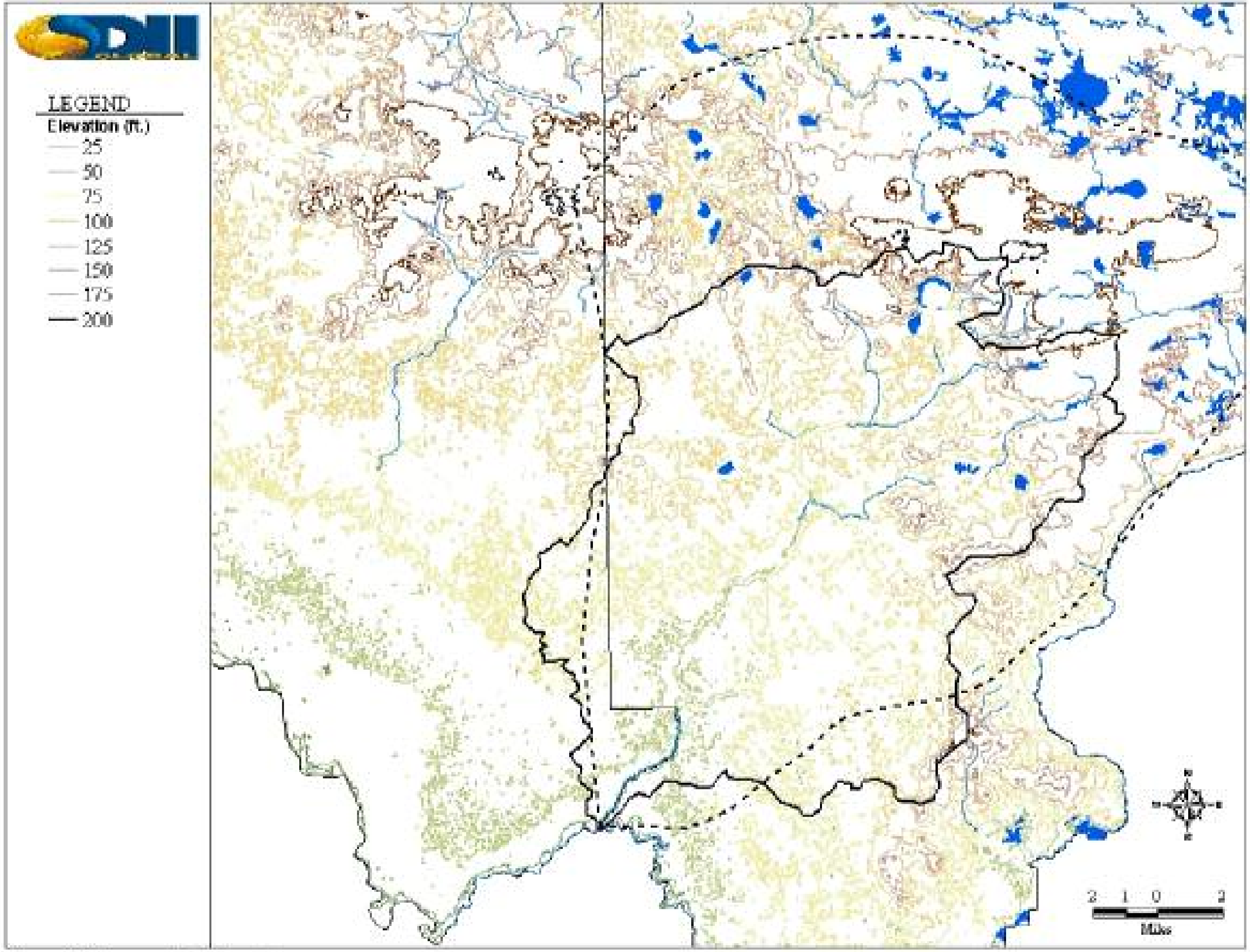


Figure 3. Topography in the study area.

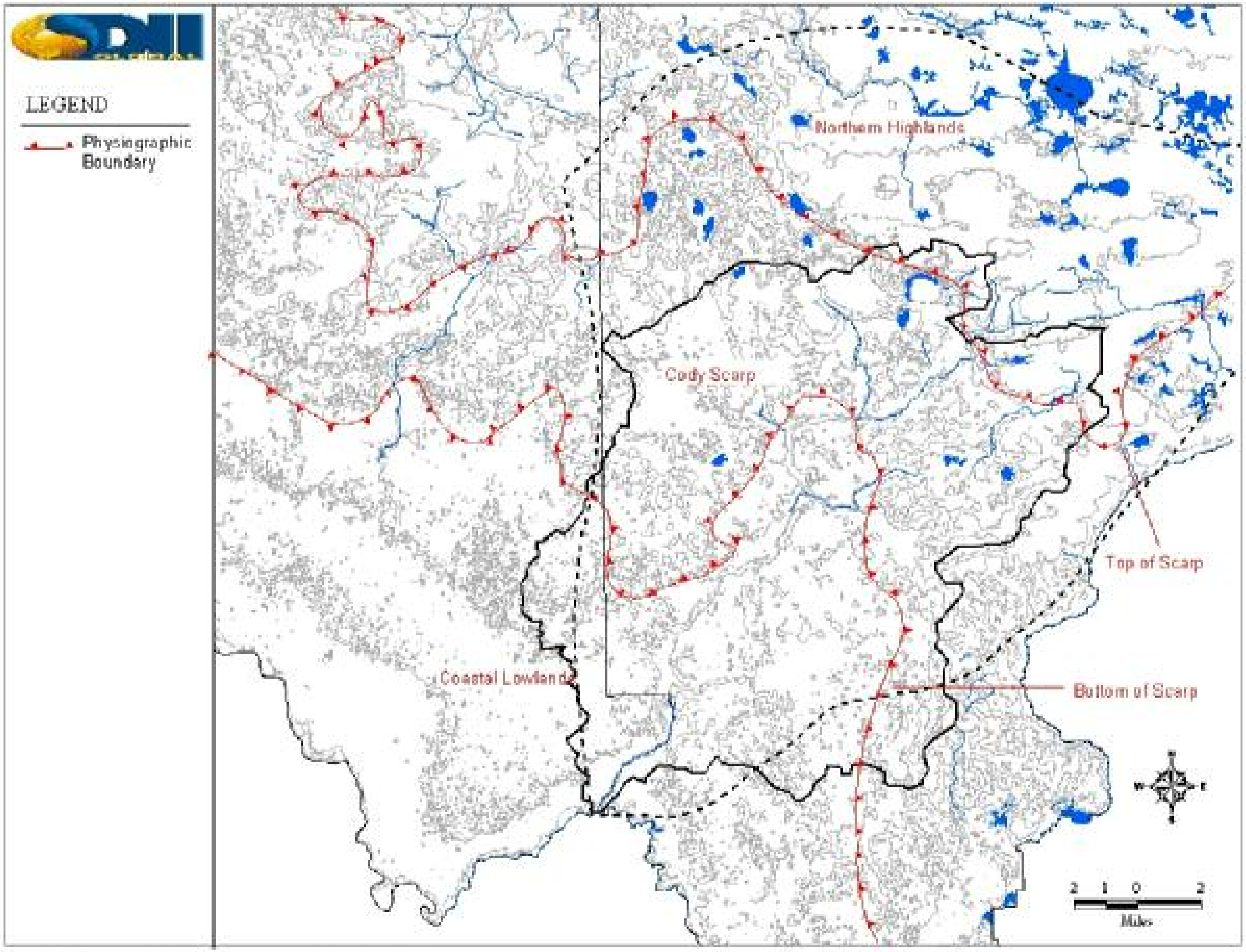


Figure 4. Physiographic regions in the study area.

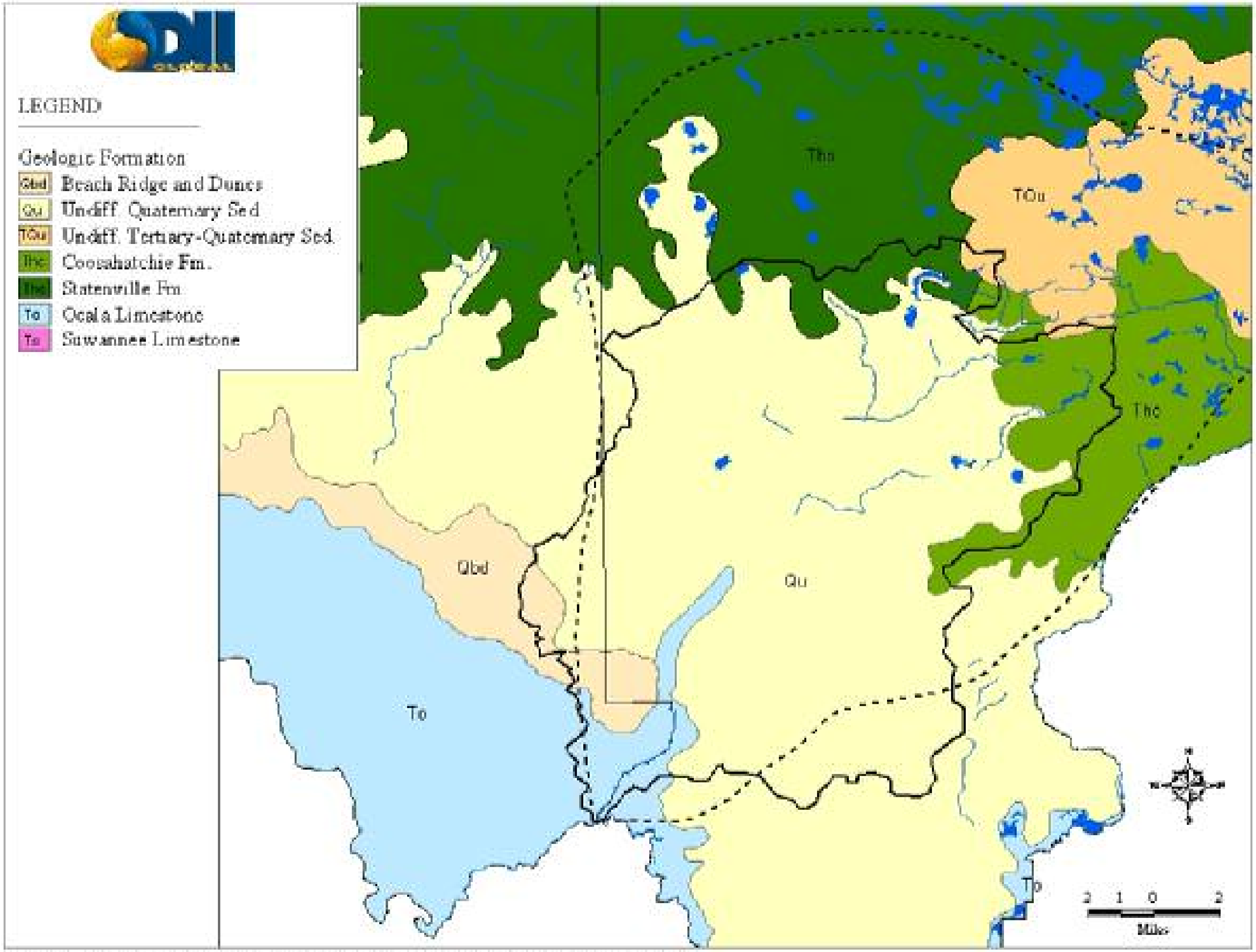


Figure 5. Geologic map of the study area (modified from Scott and others, 2001)

8

The major carbonate unit in the study area is the Ocala Limestone, which crops out along the Ichetucknee and Santa Fe rivers (Figure 5). Based on well cuttings, Crane (1986) described the Ocala Limestone in the study area as consisting of several marine lithologies. The deepest of these lithologies is a medium to well-indurated calcarenite composed of almost entirely of miliolid foraminifer. Above this unit lies a medium to well-indurated calcarenite composed of *Operculinoides* sp. foraminifer and miliolids. Capping these two lower lithologies is an unit that is described as a poorly to moderately indurated calcirudite (limestone composed of coarse particles) composed of *Lepidocyclina* sp. foraminifer. Much like the Suwannee Limestone, the upper surface of the Ocala Limestone is highly variable and karstic (Crane, 1986).

Underlying the Ocala Limestone is the Avon Park Formation of Eocene age. In the study area the Avon Park Formation consists of moderate to well-indurated, sugary dolostone, and moderately to well-indurated calcilutite, calcarenite and calcirudite. Thin seams of peat are often associated with the more dolomitized sections of the Avon Park Formation. In deeper, more calcitic sections of the Avon Park, miliolids and foraminifers, especially *Dictyoconus americanus,* are often present (Crane, 1986). Gypsum is also present in small amounts in the Avon Park Formation, though in the study area, it typically occurs several hundred feet below sea level (e.g., Figures 10-15; Crane, 1986). The Suwannee and Ocala Limestones, as well as the Avon Park Formation, comprise the Upper Floridan aquifer in the study area.

In the Northern Highlands, the carbonate units of the Upper Floridan aquifer are overlain by interbedded phosphatic sands, clays, and dolostones of the Statenville and Coosawhatchie formations of the Hawthorn Group (Scott and others, 2001) (Figure 5). Due to the clayey composition of these two formations, the permeability of the units is generally low and they tend to form an intermediate confining unit above the Upper Floridan aquifer and below the surficial aquifer system. Silicified fossils are common to both formations, and significant deposits of phosphorite are economically important in the Statenville Formation (Scott, 2001).

Weathering of phosphorite in the Hawthorn Group sediments has resulted in dissolution of carbonate-fluorapatite and re-precipitation of carbonate-hydroxylapatite in localized crust and nodules in the Ocala Limestone (Upchurch, 1992, 2002). These deposits of re-precipitated phosphate, which were locally termed "hard-rock phosphate," were extensively mined throughout northern Florida from the late 1880's through the 1960's (Dinkins, 1969). None of the mines were large because the deposits were localized in karst features. Meyer (1962) noted that phosphate-ore deposits were once mined near Fort White.

Surface-Water Hydrology

Surface-water features are abundant in the northern and eastern portions of the study area (Figure 2). Northeast of Lake City, for example, lies the southern edge of the Okefenokee Swamp and the "headwaters" of Falling Creek, a tributary to the Suwannee River. The Santa Fe River and Olustee Creek, a tributary to the Santa Fe, lie along the southern and eastern boundary of the study area, respectively.

Rose, Clay Hole, and Cannon creeks, as well as the Little River (Figure 1), are good examples of sinking streams in the study area. These streams drain surface water from upland areas, across the Cody Scarp, and into sinkholes, where the water recharges the Upper Floridan aquifer. Clay Hole, Cannon, and Rose creeks are particularly important in the Ichetucknee River springshed. Because of the direct connection to the Upper Floridan aquifer, any contaminants washed into these streams has a high probability of reaching the Upper Floridan aquifer and the springs.

The lack of streams and rivers throughout the central and western portions of the study area (the Coastal Lowlands) results from a well-developed underground drainage system in the Upper Floridan aquifer. This portion of the study area is located where Hawthorn Group sediments are generally absent and recharge is highest.

The Ichetucknee Trace is a topographic feature that can be identified by the 50- and 75-foot contours (Figure 3). It is a former stream valley created as the stream eroded its way into the Cody Scarp, which once extended further south than at present. As the stream system eroded its way northward, it cut down through the Hawthorn Group. When the stream cut its way down to the limestone and dolostone under the Hawthorn, its flow was captured by drainage into sinkholes. Thus, the Ichetucknee Trace is a dry stream valley formed as the Cody Scarp retreated. The valley normally carries water upstream from Rose Creek Sink, where we have named the drainage system Rose Creek, and upstream of Clay and Cannon Creek sinks. During extremely heavy rainfall events, the ability of these sinkholes to take the water in the streams may be exceeded. At that time, water flows along the Trace in the former stream valley and flooding can result.

Karst and Ground-Water Hydrology

Karst - A prerequisite to comprehending the ground-water hydrology of the study area is an understanding of the dominant role that karst processes play in moving ground water through the Upper Floridan aquifer. The Coastal Lowlands and Cody Scarp are areas of intensive karst development, characterized by numerous sinkholes, lack of surface drainage, and undulating topography (Figure 6). In karst areas, the dissolution of limestone has created and enlarged cavities along fractures in the limestone, which eventually collapse or reach the surface and form sinkholes. Sinkholes capture surface-water runoff and funnel it underground, which promotes further dissolution of limestone. This leads to progressive integration over time of voids beneath the surface and allows larger and larger amounts of water to be transported through the ground-water system.

Dissolution is most active at the water table or in the zone of water-table fluctuation. In this zone carbonic acid contained in atmospheric precipitation and generated by reaction with soil carbon dioxide reacts with limestone and dolostone (Carroll, 1970). Because the altitude of the water table has shifted in response to changes in sea level over the last 30 million years, many vertical and lateral paths have developed in the underlying carbonate strata in the study area. Many of these paths or conduits lie below the present water table (the Upper Floridan aquifer is essentially unconfined in the Cody Scarp and Coastal Lowlands) and greatly facilitate ground-water flow.

Ground water may flow rapidly through conduits and passages with the limestone, or slowly through minute pore spaces within the rock matrix. Dye-trace studies in Columbia County show that ground water near Ichetucknee Springs may travel approximately one mile per day in active conduits in the Upper Floridan aquifer (Karst Environmental Services, 1997). Similar velocities were recorded near Sulphur Springs in Hillsborough County (Stewart and Mills, 1984). Studies such as these clearly indicate that ground water has the potential to flow rapidly and

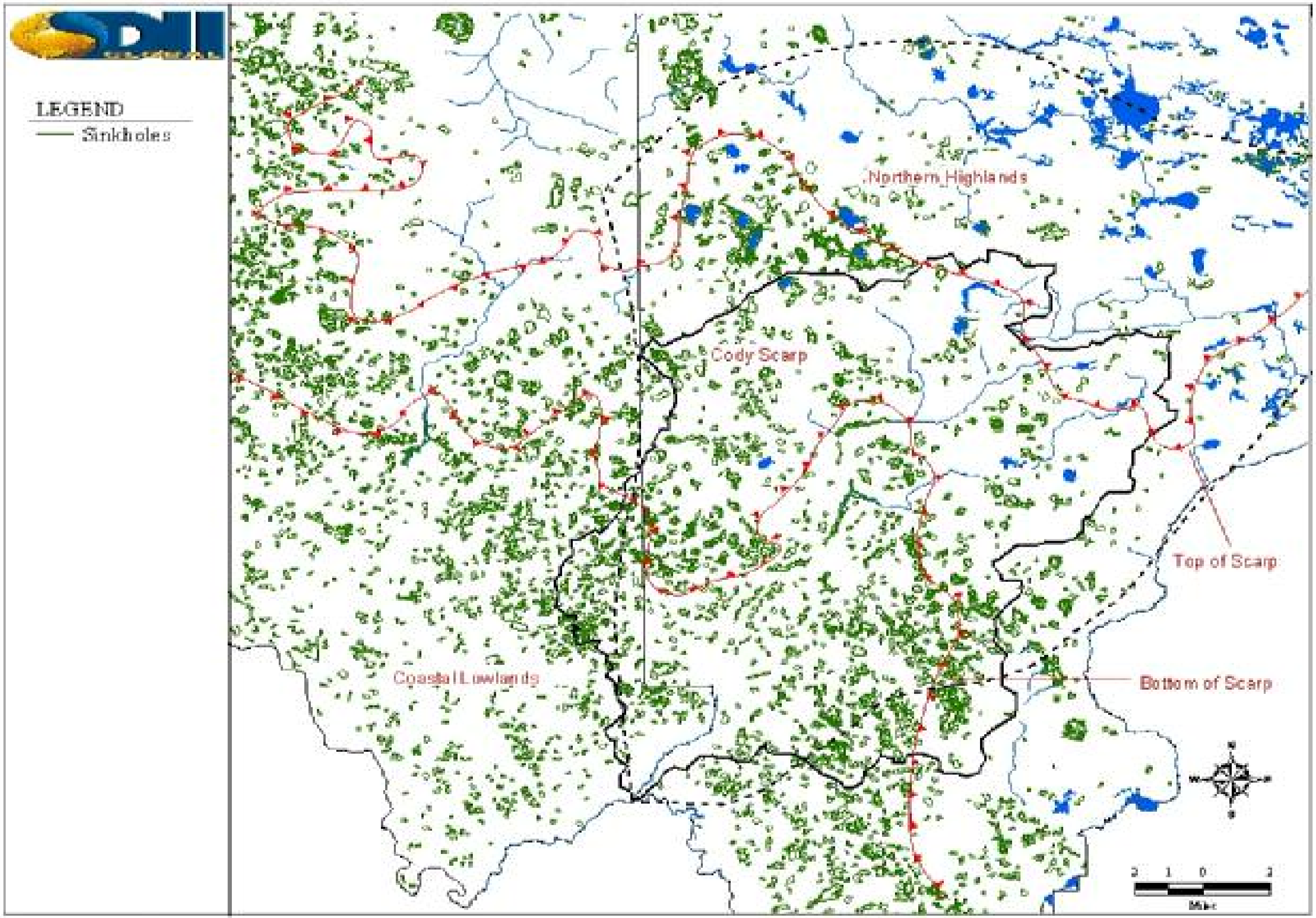


Figure 6. Sinkholes and closed depressions in the study area.

traverse great distances in a short amount of time in karst environments near major springs.

Because the flow in these karst conduits is rapid and direct, dispersion, dilution, and retardation of contaminants is likely to be minimal and the springs are vulnerable. For example, when Lawrence and Upchurch (1976) sampled the Upper Floridan in the vicinity of Lake City, they described a plume of surface water under Alligator Lake that extended to the southwest for several miles. Shortly after completion of the study, the lake drained and residents down gradient reported colored water, organic debris, and other indicators of lake water. We now know that Alligator Lake is part of the headwaters of the Ichetucknee Springs and that the plume of surface water was migrating in a karst conduit system to the springs.

In contrast, recent studies by the USGS and SRWMD have demonstrated that much of the spring water in northern Florida (and the study area) has been in the Upper Floridan aquifer for 10-25 years (Katz and others, 1999). This estimate is based on age-dating techniques using chlorofluorocarbons (CFC's) derived from the use of aerosol propellants and refrigerants. These CFC compounds, released into the atmosphere over the last 50 years, have dissolved in precipitation that recharges ground water (Katz and Hornsby, 1998). The occurrence of CFC's in spring water in the study area indicates that, while a portion of the ground water moves quickly through conduits in the Upper Floridan aquifer, much of the water percolates slowly through the soil and into the aquifer. Once the ground water recharges the aquifer, it begins moving through the smaller pores and openings in the limestone before reaching an active conduit or spring vent. The slower movement of ground water through the aquifer is known as diffuse flow. Because of the diffuse flow and ability of the limestone matrix to clean up the ground water, the springs are typically clear and free of most contaminants.

It is important to understand that rapid conduit flow and slower diffuse flow are, in fact, very useful in deciphering the hydrology of springs in karst regions like the study area. Older ground water that appears to dominate much of the spring flow mixes with younger ground water traveling through active conduits near the spring. Two recent studies by the St. Johns River Water Management District and the SRWMD demonstrate and support this mixing model of ground water at springs (Katz and Hornsby, 1998; Toth, 1999). Therefore, the mixing of ground waters must not be overlooked when assessing the origin, health and history of spring waters in karst environments such as that found in the study area.

Recharge - Recharge to the Upper Floridan aquifer is directly related to the confinement of the system. The highest recharge rates occur where the Upper Floridan is unconfined or poorly confined as in those areas where the aquifer is at or near land surface. Such conditions occur throughout the central and western portions of the study area (Coastal Lowlands and Cody Scarp). Recharge may also be high in areas where the confining layers are breached by karst features, such as sinkholes (Figure 7). Other factors affecting recharge rates include the development of surface-water drainage, variations in water-level gradients between surface water, the surficial aquifer and the Upper Floridan aquifer, and aquifer permeability. Low recharge rates occur where confining materials overlying the aquifer retard downward vertical movement of water, or where an upward water-level gradient exists between the Upper Floridan and surficial aquifers. Figure 7 shows the recharge potential of the Upper Floridan aquifer in the study area.

Potentiometric Surface - The potentiometric surface of the Upper Floridan aquifer in the study

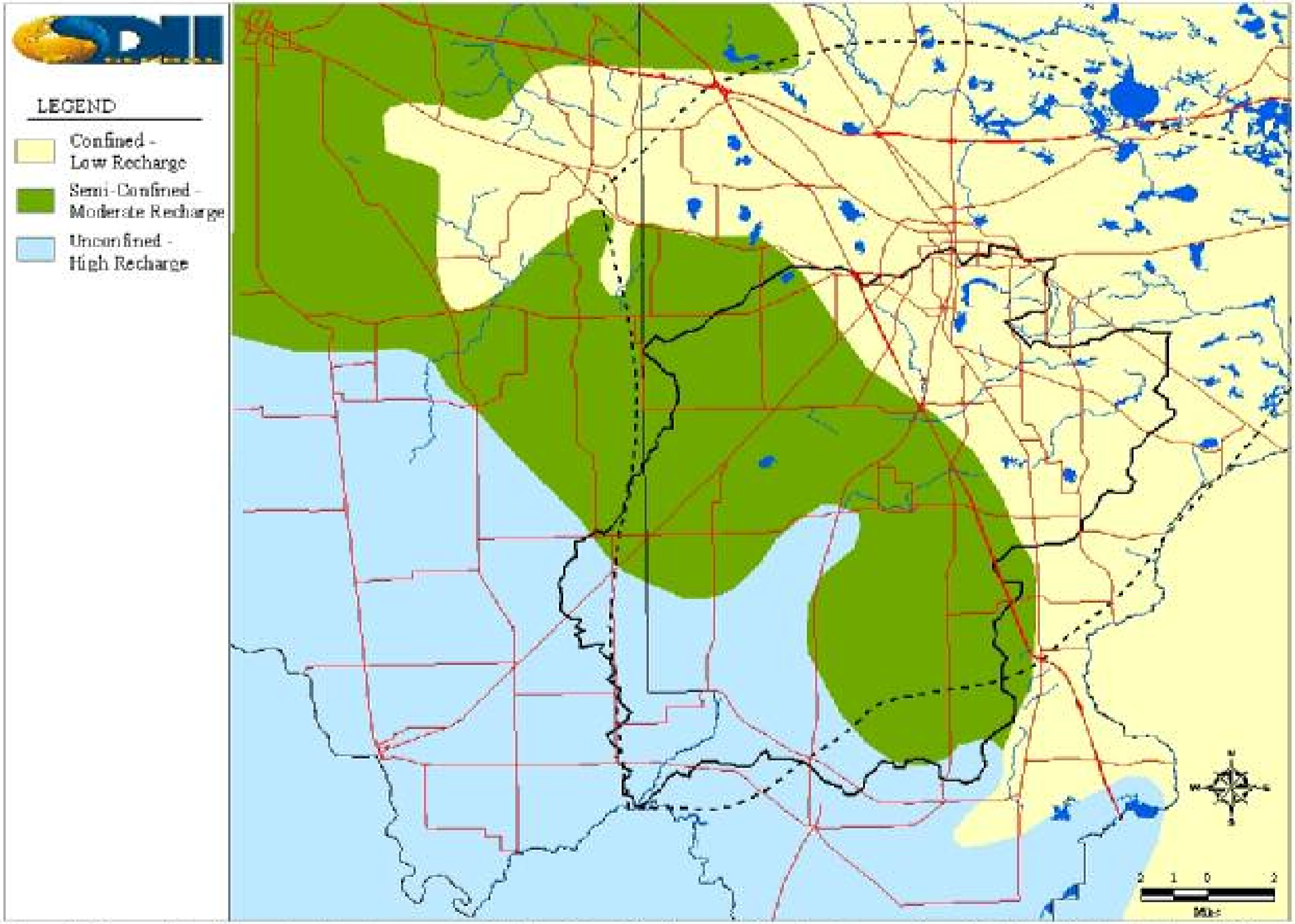


Figure 7. Degree of confinement and recharge pontential of the Upper Floridan aquifer in the study area (modified from Scott and others, 1991).

area is shown in Figure 8. The potentiometric surface is highest (greater than 50 feet above NGVD) in the northeastern portions of the study area, where confinement of the Upper Floridan aquifer is greatest. From this region, the potentiometric surface slopes very gradually to the southwest toward the Ichetucknee and Santa Fe rivers, where ground water discharges to springs and rivers. The wide spacing between the isopotential lines across the southern half of the basin suggests that the Upper Floridan aquifer in this portion of the study area is highly transmissive and able to transmit large quantities of ground water through the subsurface.

The Ichetucknee Springs ground-water basin is also drawn on Figure 8. This basin measures approximately 370 square miles in size and extends from the lower reaches of the Ichetucknee River to the southern portions of the Northern Highlands. The town of Lake City lies in the upper third of the basin along the northern edge of the Ichetucknee springshed.

The Ichetucknee Springs ground-water basin was recently delineated by Upchurch and Champion (2003, draft). This was done by statistically analyzing water levels from approximately 100 monitor wells within the springshed. The geostatistical analysis conducted by Upchurch and Champion (2003, draft) provided a highly accurate picture of the basin's shape, as well as how the basin boundaries shifted in response to seasonal rainfall patterns.

GROUND-WATER CHEMISTRY

Previous ground-water investigations have indicated that the chemistry of ground water in the study area is affected by a number of geologic, hydrologic, and anthropogenic (man-made) factors. These include 1) the dissolution of limestone, 2) the thickness and mineralogy of the Hawthorn Group sediments, 3) high recharge rates (Lawrence and Upchurch, 1976; Crane, 1986; Upchurch, 1992), and 4) the presence of agricultural and other land uses in areas near the springs (Katz and others, 1999). In addition, data presented by Katz and others (1999) suggest that much of the water discharging from the springs has moved through a relatively short, shallow flow system, and has been in the Upper Floridan aquifer for only a few decades at most.

Water quality discharging from the springs has been characterized in a number of studies, including Rosenau and others (1977), Hornsby and others (1998), and Scott and others (2002). In general, the water is of excellent quality, but there is concern for increasing nitrate concentrations in several of the springs within the Ichetucknee Spring system.

Ground-water quality within the study area has been characterized by Upchurch (1990, 1992). The SRWMD updates the results of nitrate monitoring in its Groundwater Quality Monitoring Reports on an annual basis (Hornsby and Ceryak, 1999), as well.

Several studies have examined the connectivity of surface and ground water in the springshed, including Skiles (1991), Hirth (1995), and Martin and Gordon (1998). These studies and the well-known Rose Creek Sink dye trace (Karst Environmental Services, 1997) clearly demonstrate the sensitivity of the ground-water system to surface-water events.

Upper Floridan aquifer water is characterized as a calcium-bicarbonate water type because of interactions with the limestone of the aquifer. Because of the preponderance of karst in the

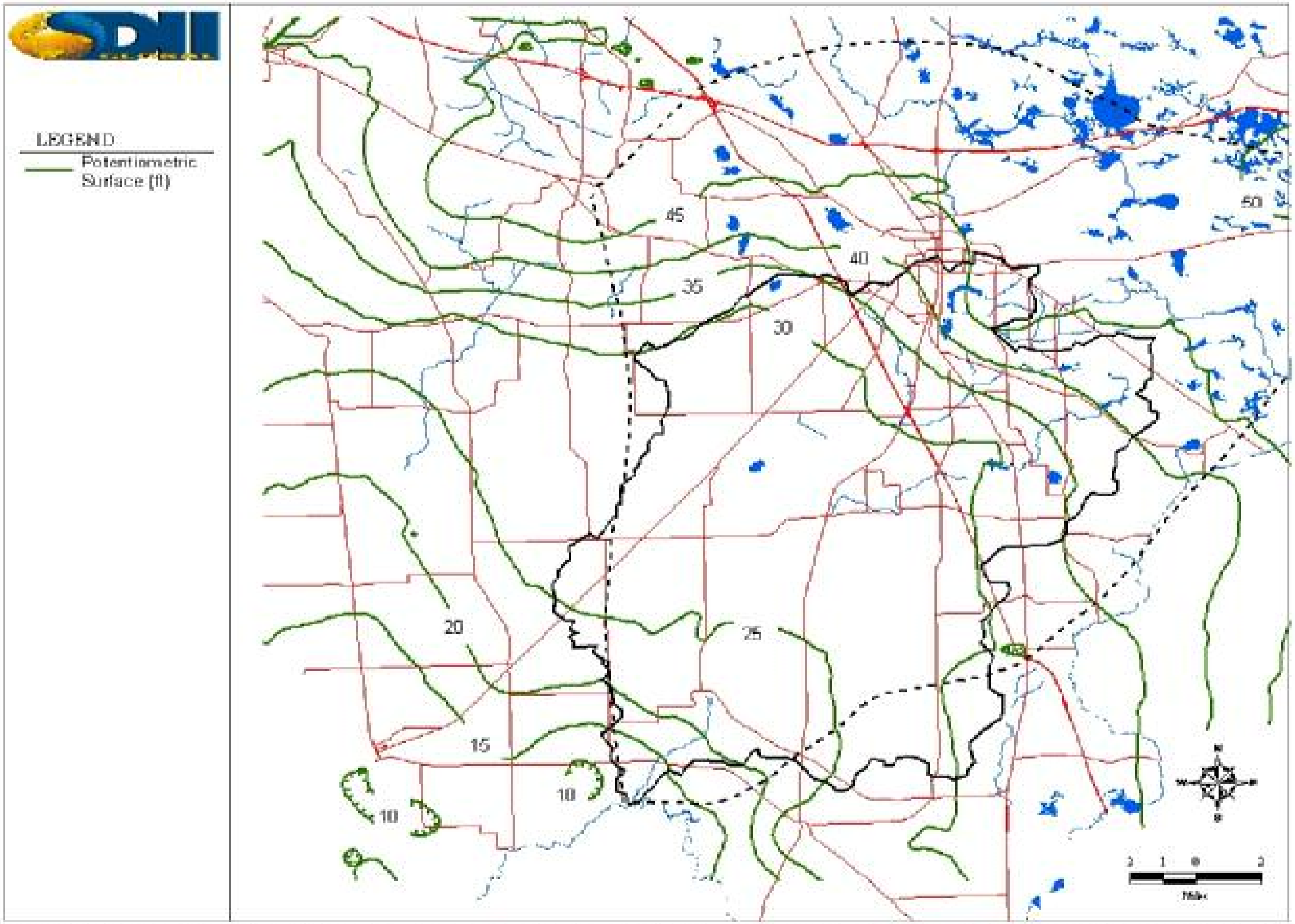


Figure 8. Potentiometric surface of the Upper Floridan aquifer in Sept. 2002 in the study area (modified from Upchurch and Champion (draft), 2003).

Cody Scarp and Coastal Lowlands portions of the springshed, Upper Floridan aquifer water contains numerous indicators of interaction with surface water, including color, high organic carbon, and high dissolved oxygen (Upchurch, 1990). These surface-water indicators demonstrate that the aquifer is highly vulnerable to human activities.

Water quality in the Upper Floridan aquifer underlying the Northern Highlands is strongly affected by clay-rich sediments of the Hawthorn Group. Lawrence and Upchurch (1976) demonstrated that recharge to the Upper Floridan aquifer in this area is slow and that the flow system in the Upper Floridan aquifer is relatively sluggish. This suggests that the aquifer is generally highly confined and that vulnerability to contamination is low.

DELINEATION OF GROUND-WATER QUALITY DOMAINS

Study Area Monitor-Well Network

The most important tool in determining the chemical composition and source areas for spring water in the study area was the water-quality data obtained from a regional monitoring-well network designed and sampled by staff at the Suwannee River Water Management District. The monitor-well network consisted on existing, dedicated monitor wells, and wells used for domestic and public supply. Figures 9a and 9b are maps showing the locations of the 97 wells that make up the most recent SRWMD monitor-well network. The well identification numbers given in Figures 9a and 9b are listed in Appendix I along with well names and relevant water-quality data.

Hydrochemical Facies

Hydrochemical facies analysis (Upchurch, 1992) is an excellent way to place a series of water-quality analyses into a spatial context. The analysis depends on pattern recognition techniques of graphical data presentations. Using the Stanford Graphics® software, individual samples are plotted on "star" diagrams, which show the relative proportions of ions in the sample. Star diagrams were used in preference to other pattern-recognition methods (i.e., Stiff diagrams) because star diagrams utilize non-standard combinations of chemicals and minor constituents can be emphasized. Figures 10a and 10b display the star diagrams for each of the monitor wells in the study area. It is important to remember when looking at the star diagrams in Figures 10a and 10b, that the length of each axis corresponds to the relative concentration of a major constituent in relation to other samples, not other constituents within the same sample; the higher the concentration relative to other samples, the longer the axis. If two or more wells have similar concentrations of the major constituents, the star diagrams will be similar. The analytes were selected for use in the star diagrams on the basis of prior experience.

Based on the patterns of star diagrams, the Upper Floridan aquifer in the study area was divided into four water-quality domains (Figures 11a and 11b). Each domain was found to possess certain chemical patterns that could be used to differentiate water types and hydrochemical facies within the aquifer. Differences in water quality are subtle across the study area and appear to be related to presence or absence of confining layers, sinkhole distribution, and recharge to and discharge from the Upper Floridan aquifer. Table 1 shows the median concentrations of major ions, nutrients and field parameters from wells within each domain.

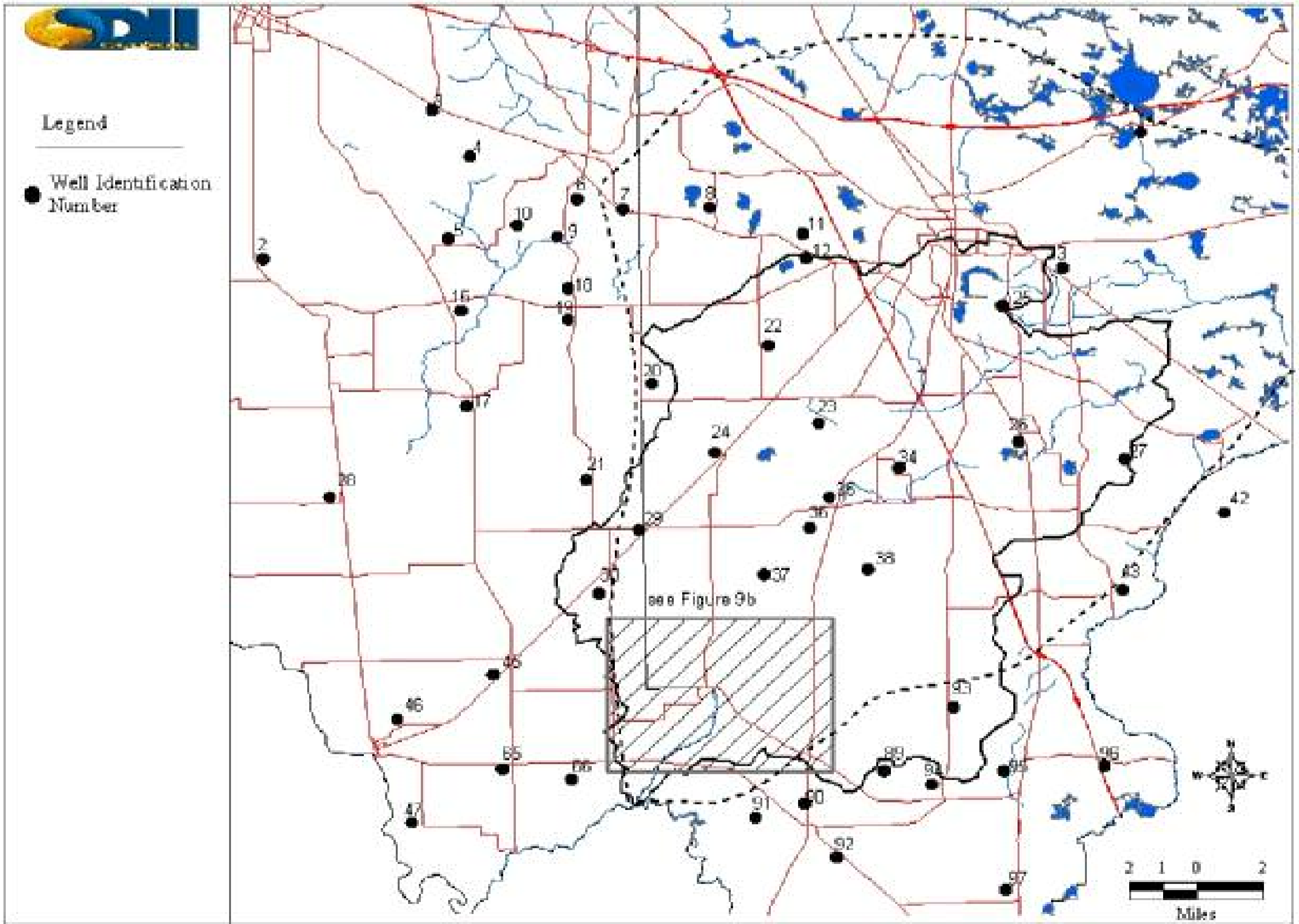


Figure 9a. Monitor-well locations in the study area.

17

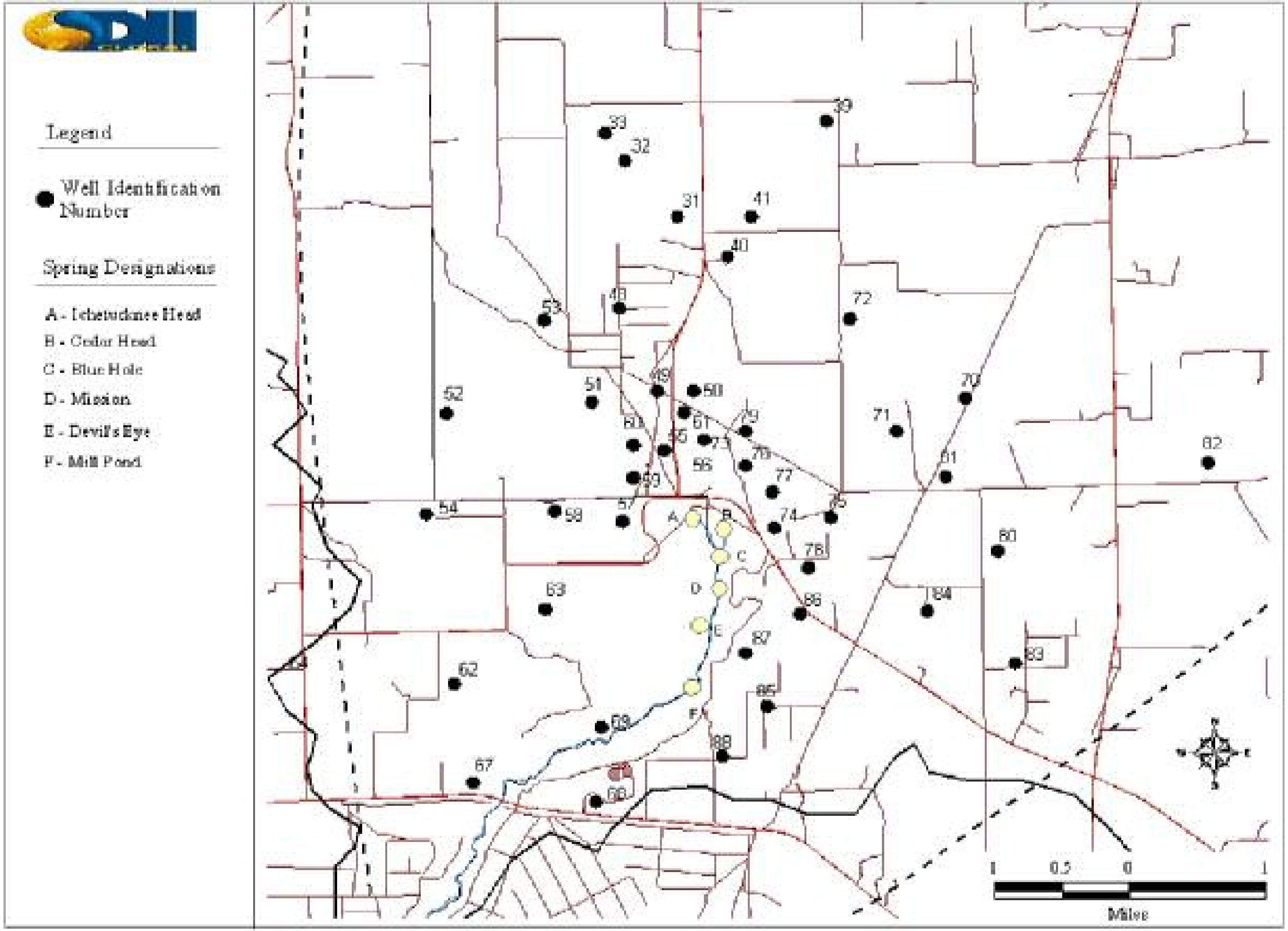


Figure 9b. Monitor-well locations in the study area.

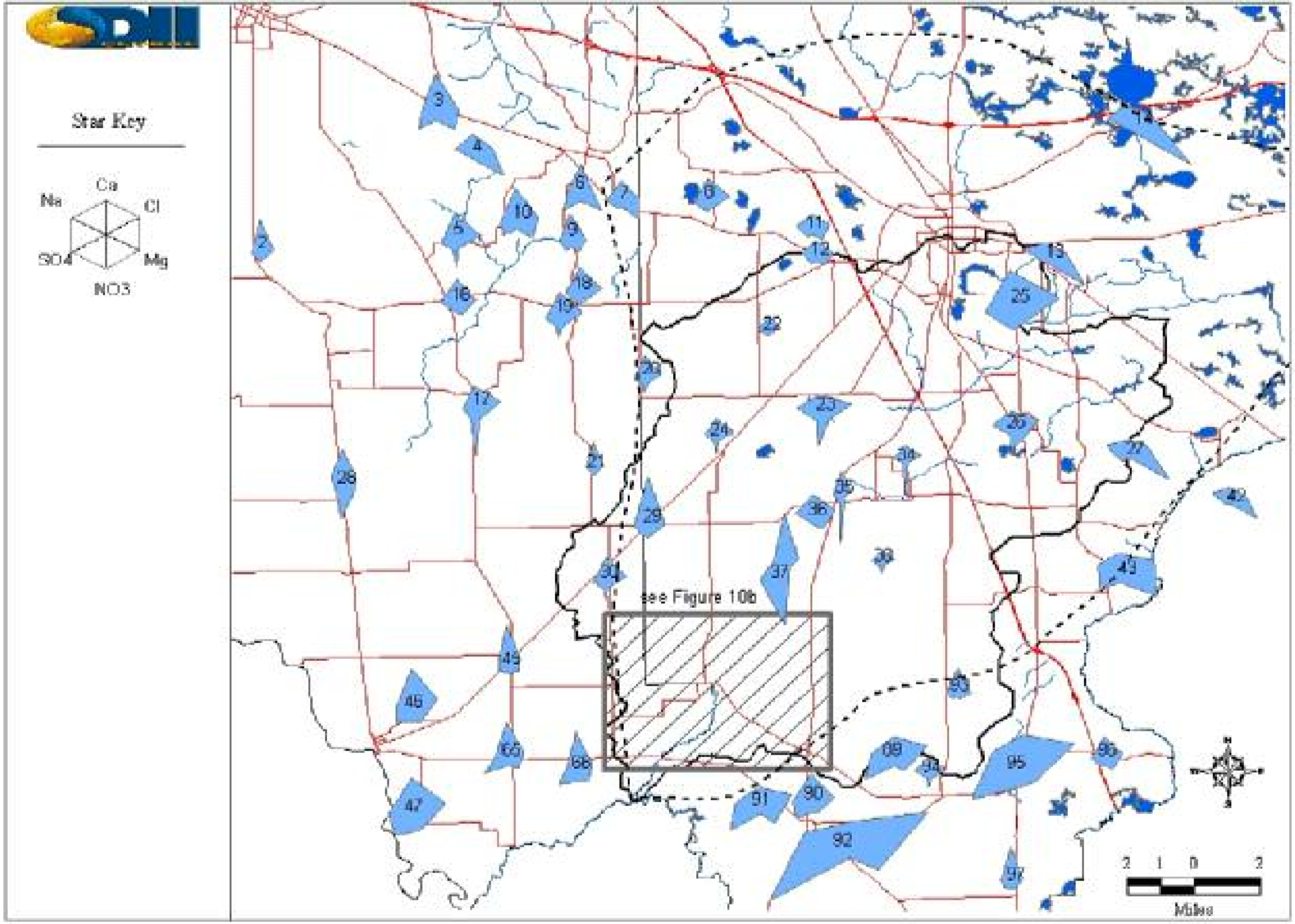


Figure 10a. Star diagrams for monitor wells in the study area.

19

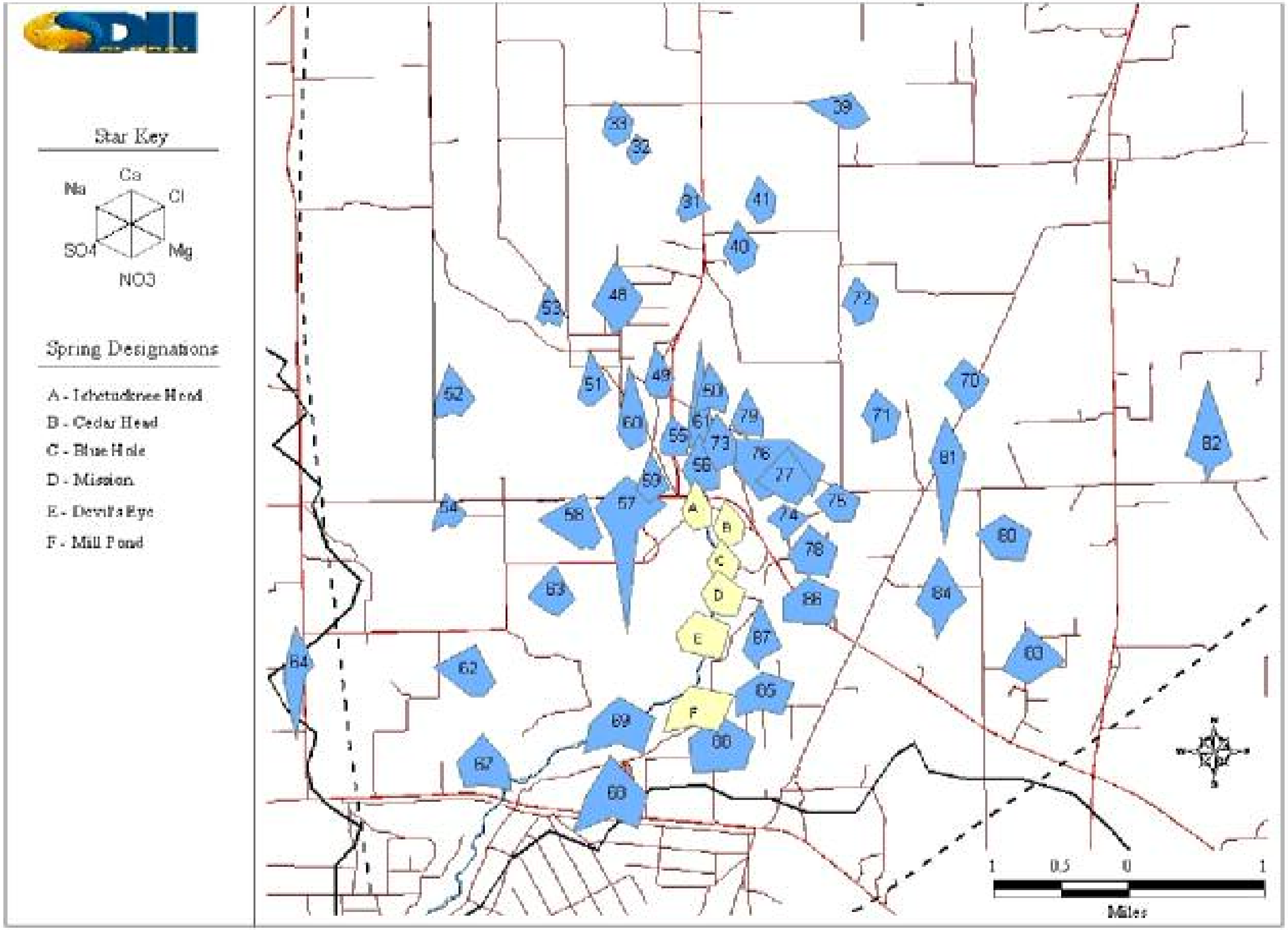


Figure 10b. Star diagrams for monitor wells in the study area.

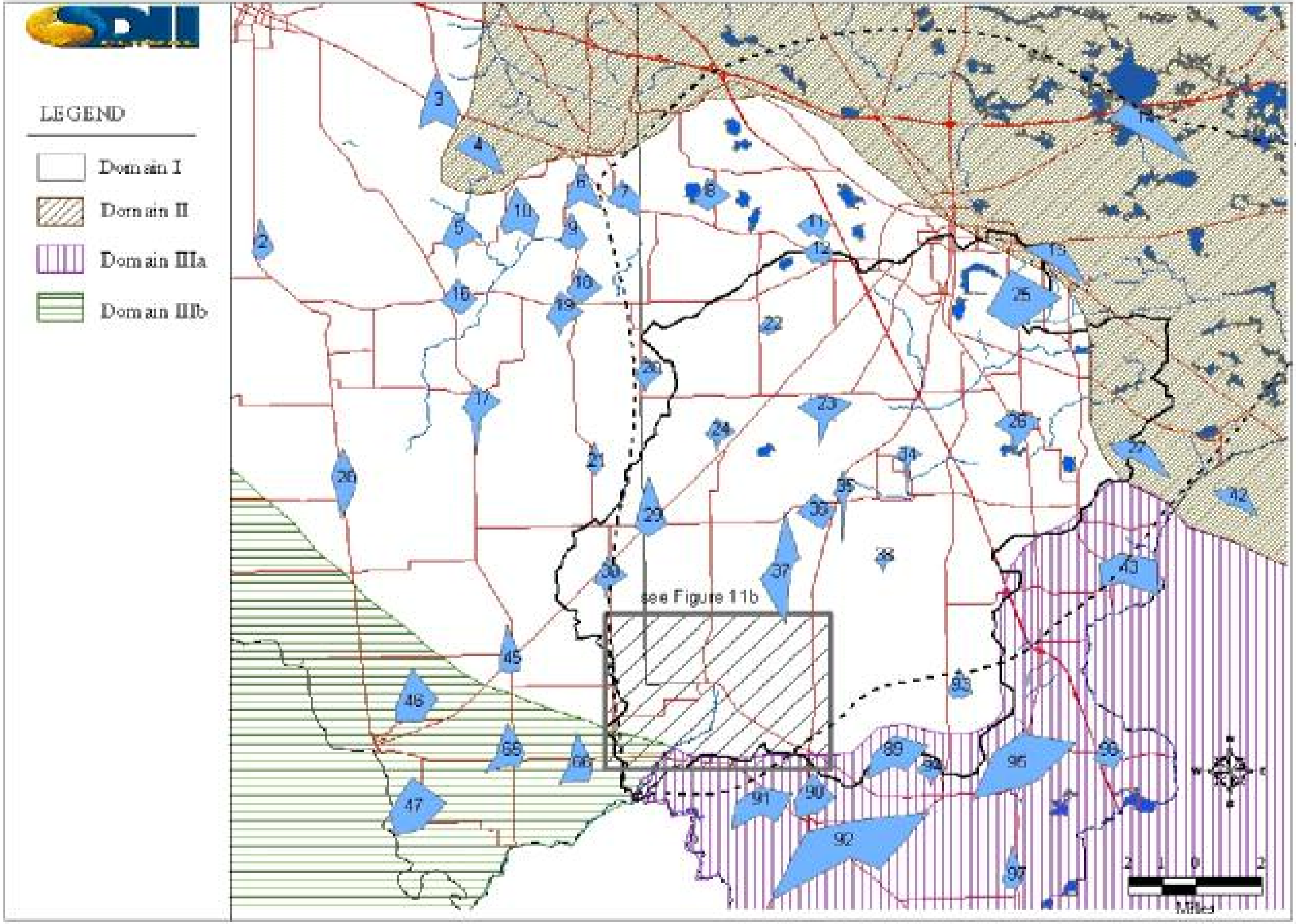


Figure 11a. Ground-water domains in the study area.

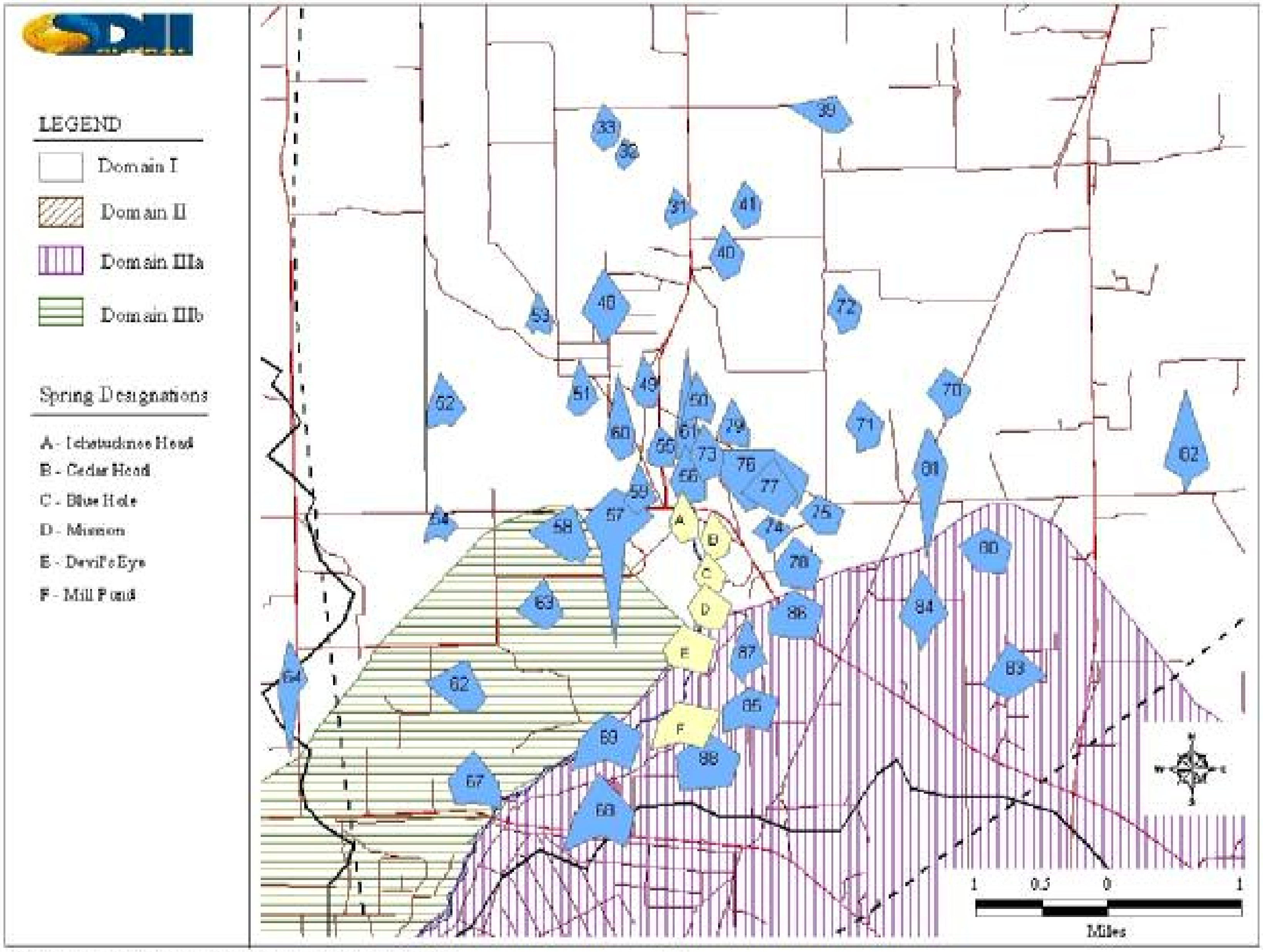


Figure 11b. Ground-water domains in the study area.

22

Table 1. Median analyte concentrations for ground-water domains within the study area. Concentrations in mg/l, unless otherwise noted.

Ground-water Domain	Alk.	NH3	Ca	Cl	F	Fe	Mg	NO3	TOC	pH (s.u.)	TP	K	TDS	Si	Na	Sp. Cond (uhos/cm)	SO4	Temp (Cel)
I	144	0.02	55.3	4.14	0.09	0.04	3.00	0.50	0.38	7.21	0.04	0.27	188	9.29	2.80	312	4.15	19.1
II	166	0.02	41.9	5.19	0.35	0.06	17.1	0.01	1.54	7.54	0.04	1.03	214	25.0	5.69	356	3.24	21.7
IIIa	141	0.02	61.0	7.06	0.15	0.05	7.18	0.27	0.38	7.20	0.10	0.51	230	13.3	5.54	349	25.8	21.8
IIIb	165	0.02	78.4	4.29	0.09	0.12	4.56	0.30	0.38	7.03	0.18	0.61	230	6.36	5.29	327	16.5	22.3

The following discussion describes the process used to delineate the ground-water quality domains within the study area. The establishment of water-quality domains will help demonstrate how water quality differs across the region and help identify source areas for ground water discharging from the Ichetucknee Springs.

Domain I: Recharge Domain

Domain I (Figures 11a and 11b) covers the entire central region of the study area, as well as the western and northwestern portions of the study area. This domain, also called the recharge domain, is centered primarily in the Coastal Lowlands and Cody Scarp Physiographic Provinces, where low-permeability Hawthorn Group sediments are thin to non-existent (Figure 5), sinkholes are abundant (Figure 6), and recharge to the Upper Floridan aquifer is moderate to high (Figure 7). Geochemically, the recharge domain is identified by lower median concentrations of magnesium, potassium, fluoride, total phosphorus, sodium, chloride, total dissolved solids and temperature (Table 1). The recharge domain is also identified by a higher median nitrate concentration (0.5 mg/l), which is significantly elevated above background concentrations of nitrate in the Upper Floridan aquifer (<0.01 mg/l; Upchurch 1992).

Domain II: Highlands Domain

Domain II (Figure 11a) covers the much of the northern and northeastern portions of the study area. This domain, also called the highlands domain, is characterized by the occurrence of Hawthorn Group sediments (Figure 5) and the lack of significant sinkhole features (Figure 6). As noted earlier, the Hawthorn Group sediments tend to be siliciclastic, clay-rich, and phosphatic. Geochemically, the highland domain is identified by elevated median concentrations of magnesium, sodium, potassium, fluoride, silica and pH (Table 1). Elevated concentrations of these six analytes reflect the weathering of clays in the Northern Highlands Physiographic Province (Lawrence and Upchurch, 1976). The highlands domain is also identified by low median concentrations of calcium, sulfate and nitrate (Table 1). Low concentrations of these analytes reflect the siliciclastic nature of the Hawthorn Group sediments, and confinement of the Upper Floridan aquifer in the Northern Highlands.

Domain IIIa: Discharge Domain (Santa Fe River above Ichetucknee River)

Domain IIIa (Figures 11a and 11b) covers the southeastern portion of the study area. This domain, also called the discharge domain along the Santa Fe River above the Ichetucknee River, is characterized by regional discharge of ground water to springs along the Santa Fe River and Olustee Creek. This region is characterized by the lack of Hawthorn Group sediments (Figure 5) and numerous sinkhole features (Figure 6). The discharge domain along the Santa Fe River above the Ichetucknee River is identified by elevated median concentrations of sulfate, chloride and total dissolved solids (Table 1), all of which may reflect the influence of chemically mature ground water and upward movement of ground water from deeper flow paths in the Upper Floridan aquifer.

Domain IIIb: Discharge Domain (Suwannee River)

Domain IIIb (Figures 11a and 11b) covers the southwestern portion of the study area. This domain, also called the discharge domain along the Suwannee River, is characterized by regional discharge of ground water to springs along the Suwannee River. As in Domain IIIa, this region is also characterized by the lack of Hawthorn Group sediments (Figure 5) and numerous sinkhole features (Figure 6). The discharge domain along the Suwannee River is identified by elevated median concentrations of calcium, phosphorus, total dissolved solids and temperature (Table 1). These analytes, like those described in Domain IIIa (sulfate and chloride), may reflect the influence of chemically mature ground water and upward movement of ground water from deeper flow paths in the Upper Floridan aquifer.

DELINEATION OF SPRING-WATER SOURCE AREAS

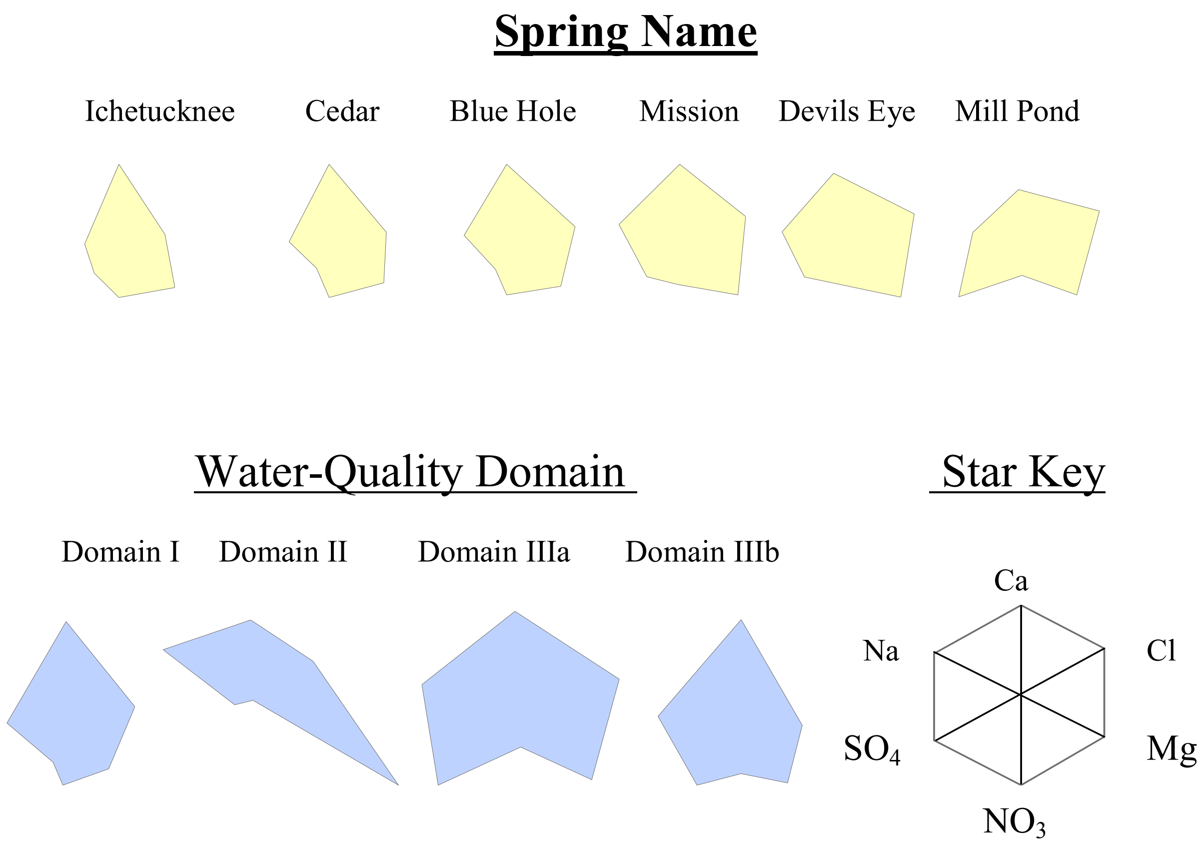
Water-quality data collected in the study area suggest that the regional ground-water system and individual springs along the Ichetucknee River (e.g., Ichetucknee Head Spring, Cedar Head Spring, Blue Hole, Mission and Mill Pond springs) have very similar chemical compositions. However, there are subtle chemical differences between many of the samples, which enables one to distinguish chemical patterns unique to groups of samples across the region. These patterns indicate source areas that yield chemical fingerprints that can be used to identify spring-water source areas.

Because the ground water discharging from the Ichetucknee Springs group differs slightly, the chemistry of the springs was compared to the chemistry of the four water-quality domains described above. This method was particularly useful in determining the source areas for ground water discharging from Rainbow Springs (Jones and others, 1996) and Crystal Springs (Champion and DeWitt, 2000). Figure 12 shows both the star diagrams for the springs and the water-quality domains described above.

Ichetucknee Head, Cedar Head and Blue Hole Springs

A comparison of the star diagrams indicates that Domain I, the recharge domain, is supplying most of the water to Ichetucknee Head, Cedar Head and Blue Hole springs. The high recharge rates in Domain I has produced ground water with very low total dissolved solids and low magnesium, sodium and chloride.

Using this domain strategy, the elevated levels of nitrate in the Ichetucknee Head, Cedar Head and Blue Hole springs most likely originates in recharge areas to the north and northwest of the springs. Nitrate concentrations in Domain I are elevated above background levels in the Upper Floridan aquifer and, in several wells, exceeds 3 mg/l. The levels of nitrate in the Ichetucknee Head, Cedar Head and Blue Hole springs most likely result from the mixing of this high-nitrate ground water with low-nitrate ground water converging on the springs from adjacent areas.



Spring-Ground Water Domain Correspondence

Spring	Matching Ground-Water Domain
Ichetucknee Head	Domain I – Recharge Domain
Cedar Head	Domain I – Recharge Domain
Blue Hole	Domain I – Recharge Domain
Mission	Domains I/IIIa (Mixture of Domains)
Devil's Eye	Domains I/IIIa (Mixture of Domains)
Mill Pond	Domain IIIa – Discharge Domain along Santa Fe River above Ichetucknee River

Figure 12. Star diagrams representing water-quality domains and individual spring vents. Correlations between domains and springs are indicated.

Mill Pond Spring

Another comparison of the star diagrams indicates that Domain IIIa, the discharge domain along the Santa Fe River above the Ichetucknee River, is supplying most of the water to Mill Pond Spring. The discharge of Mill Pond Spring contains elevated levels sulfate and chloride indicative of relatively deep flow through the Upper Floridan aquifer. While the Mill Pond Spring star diagram is very similar to the Domain IIIa pattern, elevated levels of nitrate are also discharging from this spring. This indicates that mixing of ground water from different domains is likely occurring near this spring.

Mission and Devil's Eye springs

A final comparison of the star diagrams indicates that Mission and Devil's Eye springs are likely mixtures of ground water from Domains I and IIIa. The star diagrams for these two springs are intermediate between that of Ichetucknee Head Spring and Mill Pond Spring described above. This mixing of ground water near the springs and the Ichetucknee River is to be expected due to convergent flow of ground water from areas near the springs. While the amount of mixing varies from spring to spring, there appears to be an overall mixing of ground water from the head springs southward along the Ichetucknee River to Mill Pond Spring. The relative amount of mixing at the springs is reflected in the gradual change in the star diagrams from north to south along the Ichetucknee River.

Water-Quality Trends

Figures 13 through 19 show historical nitrate concentrations at each of the springs investigated along the Ichetucknee River. Ichetucknee Head Spring (Figure 13) is the only spring for which long-term historical records are available. As seen in Figure 13, nitrate concentrations have increased over the period of record and are currently around 0.8 mg/l. The "spike" in the nitrate data during the mid- to late 1990s is anomalous, and apparently caused by variations in analytical methods.

Nitrate concentrations at Ichetucknee Head Spring have gradually increased over the last several decades (Figure 13), suggesting that water-quality trends in this spring are slow to change. This indicates that long-term monitoring is needed to detect any possible changes to water quality at the springs or to follow the current increasing trends in nitrate concentrations. With an estimated long-term increase of 0.01 to 0.02 mg/l per year, it is likely that many years, if not decades, will be needed to monitor water-quality trends at Ichetucknee Head Spring and other springs in the region.

The nitrate data shown in Figures 14 through 19 are presented to emphasize the need for more long-term data collection efforts at other springs along the Ichetucknee River. In fact, the lack of data points in the figures should emphasize the need for a more regular sampling schedule for the springs. The springs should be sampled and analyzed using consistent methods at least twice a year to monitor intermediate- to long-term trends in water quality.

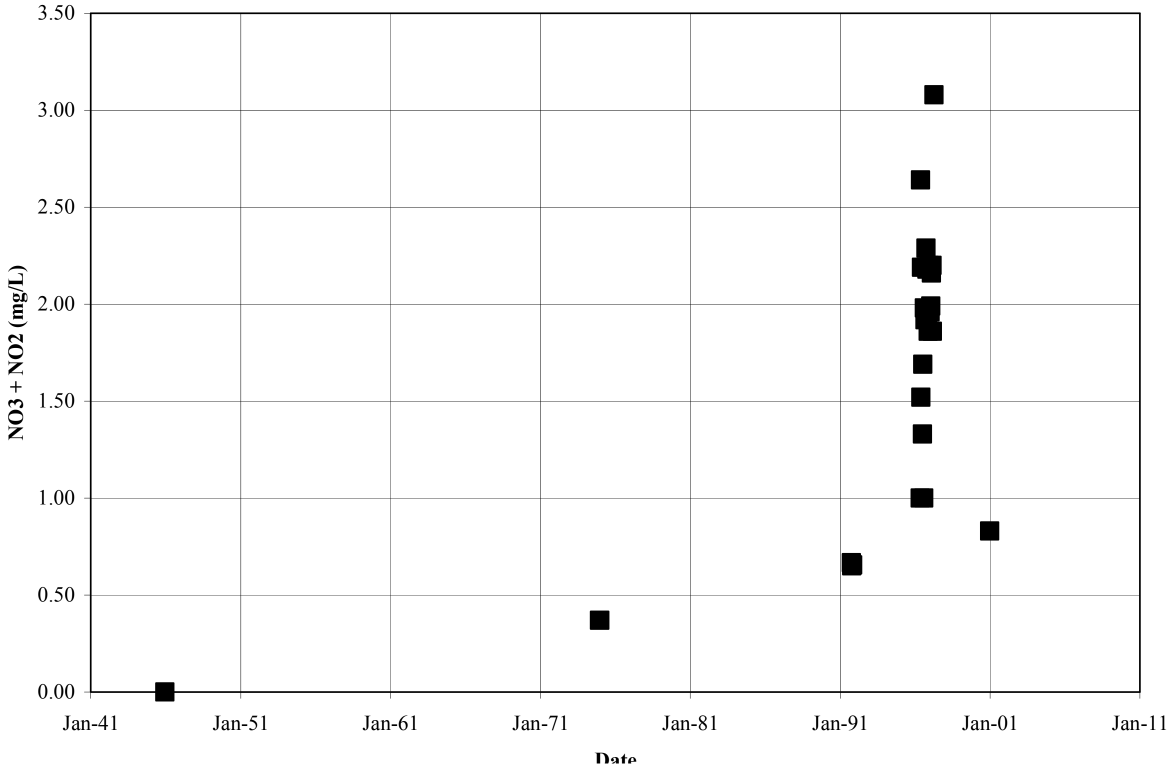


Figure 13. Trend in nitrate plus nitrite concentrations in the Ichetucknee Head Spring.

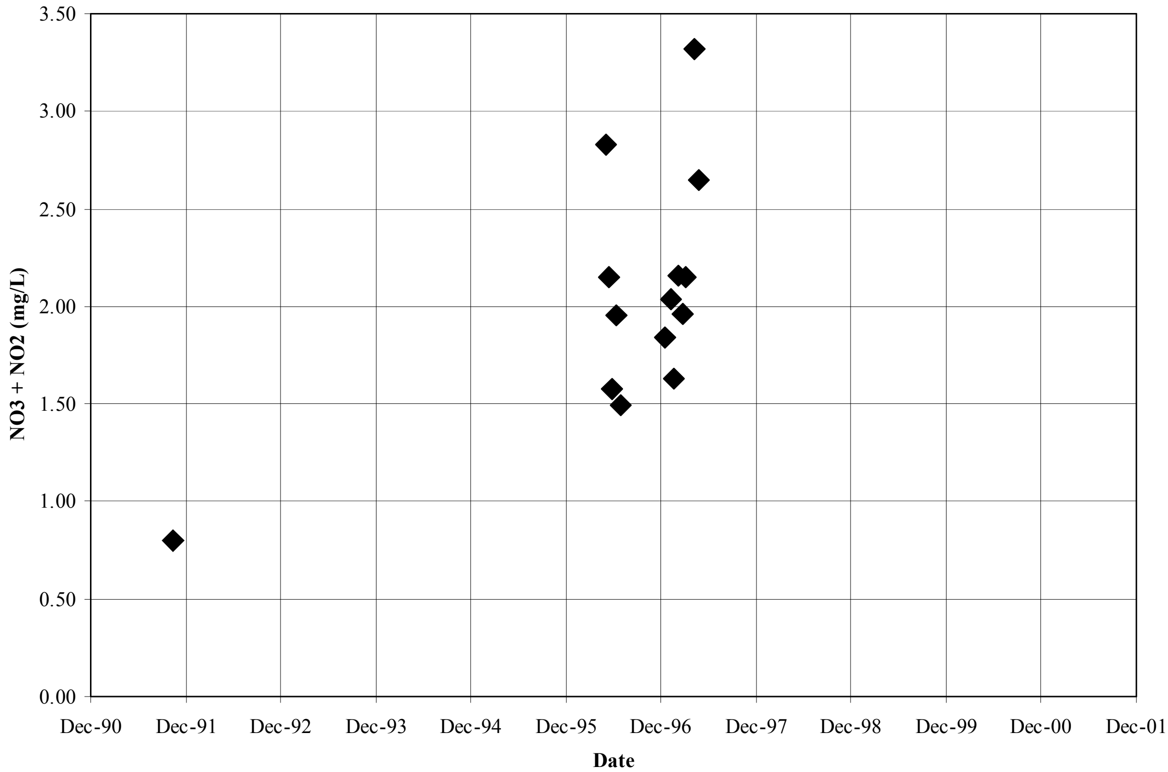


Figure 14. Trend in nitrate plus nitrite concentrations in the Cedar Head Spring.

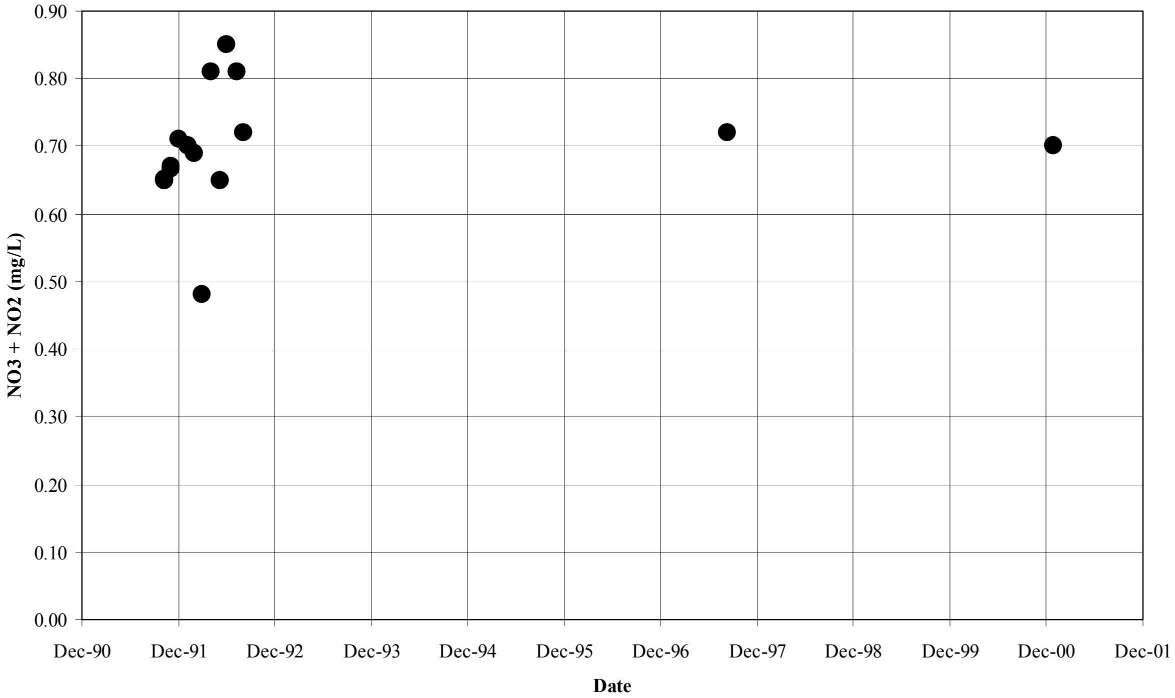


Figure 15. Trend in nitrate plus nitrite concentrations at Blue Hole Spring.

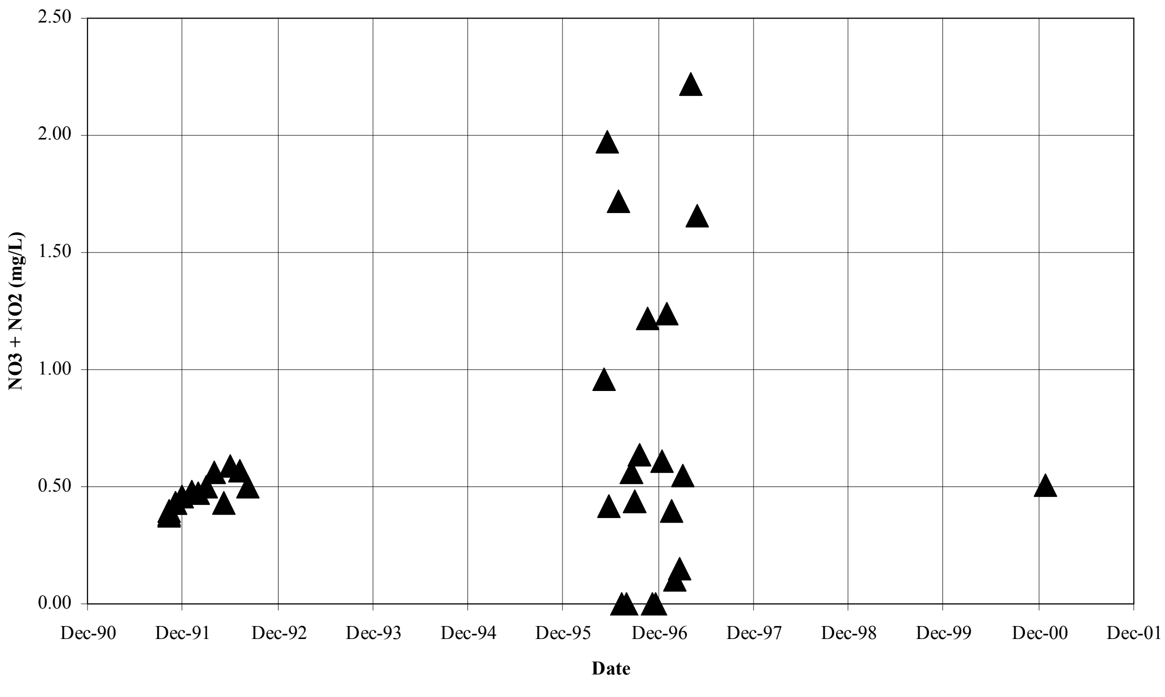


Figure 16. Trend in nitrate plus nitrite concentrations at Mission Spring.

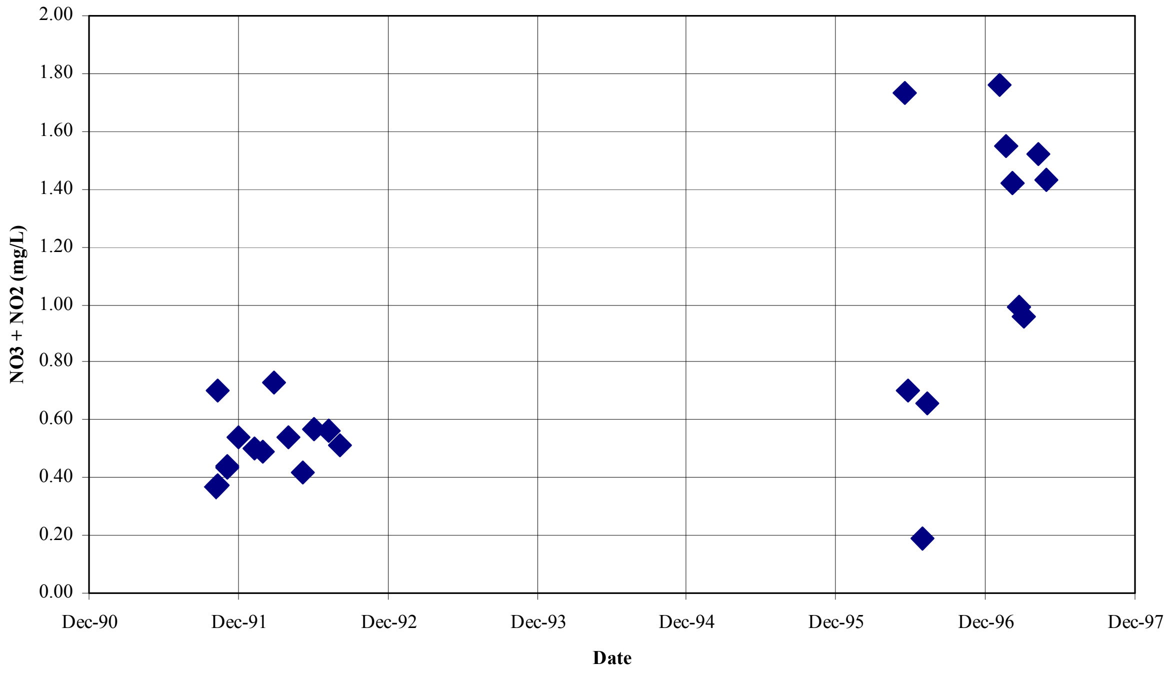


Figure 17. Trend in nitrate plus nitrate concentrations in Devil's Eye Spring.

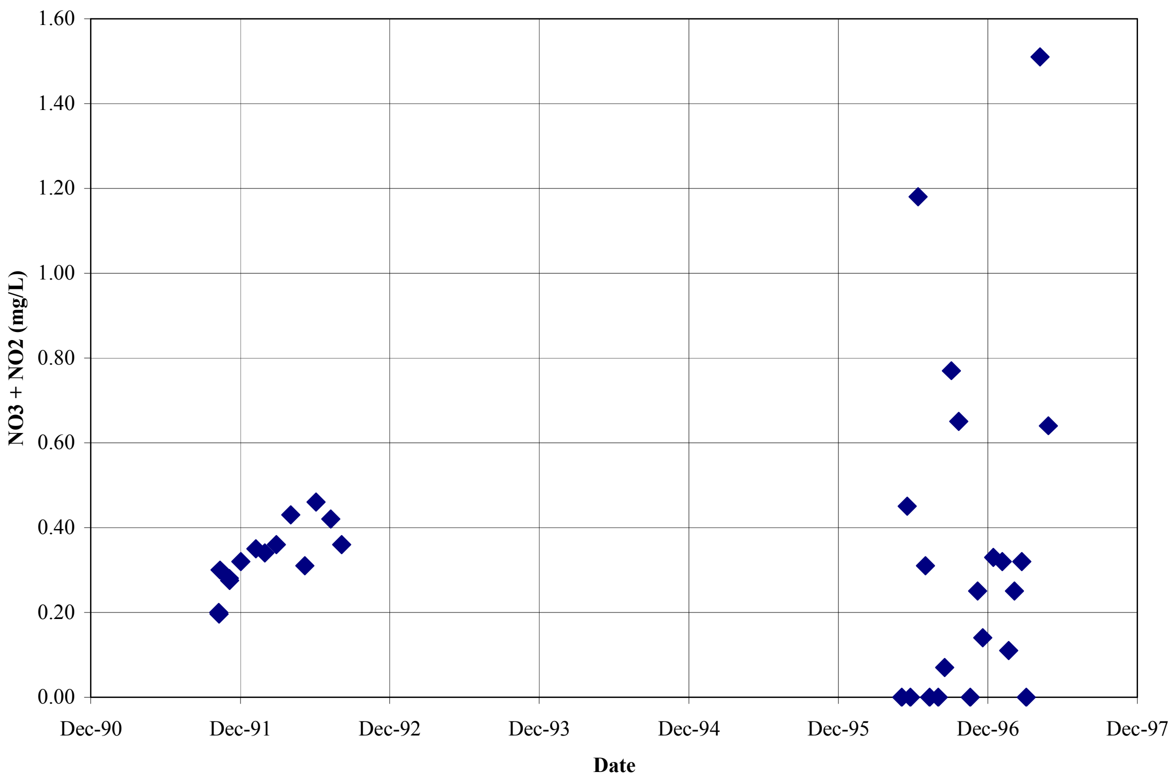


Figure 18. Trend in nitrate plus nitrite concentrations in Mill Pond Spring.

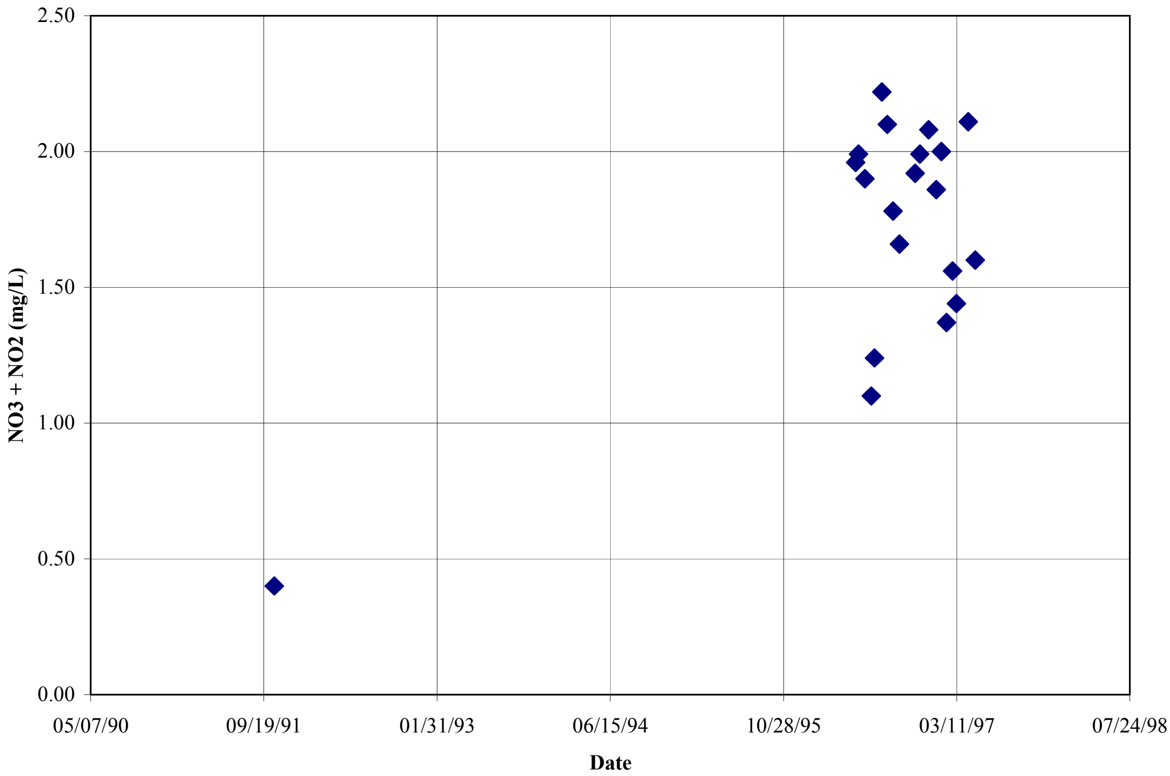


Figure 19. Trend in nitrate plus nitrite concentrations in Coffee Spring.

Summary and Conclusions

The Upper Floridan aquifer in the study area was divided into four water-quality domains, with each possessing certain chemical characteristics that reflected different water types and hydrochemical facies within the aquifer. Differences in water quality across the region are subtle and appear to be related to the presence or absence of confining layers, sinkhole distribution, and recharge to and discharge from the Upper Floridan aquifer. Each of the four domains is summarized below.

Domain I covers the entire central region of the study area, as well as the western and northwestern portions of the study area. This domain, also called the recharge domain, is centered primarily in the Coastal Lowlands and Cody Scarp Physiographic Provinces, where low-permeability Hawthorn Group sediments are thin to non-existent, sinkholes are abundant, and recharge to the Upper Floridan aquifer is moderate to high. Geochemically, the recharge domain is identified by lower median concentrations of magnesium, potassium, fluoride, total phosphorus, sodium, chloride, total dissolved solids and temperature. The recharge domain is also identified by a higher median nitrate concentration (0.5 mg/l), which is significantly elevated above background concentrations of nitrate in the Upper Floridan aquifer.

Domain II covers much of the northern and northeastern portions of the study area. This domain, also called the highlands domain, is characterized by the occurrence of Hawthorn Group sediments and the lack of significant sinkhole features. Geochemically, the highland domain is identified by elevated median concentrations of magnesium, sodium, potassium, fluoride, silica and pH. Elevated concentrations of these six analytes reflect the weathering of clays in the Northern Highlands Physiographic Province (Lawrence and Upchurch, 1976). The highlands domain is also identified by low median concentrations of calcium, sulfate and nitrate. Low concentrations of these analytes reflect the siliciclastic nature of the Hawthorn Group sediments, and confinement of the Upper Floridan aquifer in the Northern Highlands.

Domain IIIa covers the southeastern portion of the study area. This domain, also called the discharge domain along the Santa Fe River above the Ichetucknee River, is characterized by regional discharge of ground water to springs along the Santa Fe River and Olustee Creek. This region is characterized by the lack of Hawthorn Group sediments and numerous sinkhole features. The discharge domain along the Santa Fe River above the Ichetucknee River is identified by elevated median concentrations of sulfate, chloride and total dissolved solids, all of which may reflect the influence of chemically mature ground water and upward movement of ground water from deeper flow paths in the Upper Floridan aquifer.

Domain IIIb covers the southwestern portion of the study area. This domain, also called the discharge domain along the Suwannee River, is characterized by regional discharge of ground water to springs along the Suwannee River. As in Domain IIIa, this region is also characterized by the lack of Hawthorn Group sediments and numerous sinkhole features. The discharge domain along the Suwannee River is identified by elevated median concentrations of calcium, phosphorus, total dissolved solids and temperature. These analytes, like those described in Domain IIIa (sulfate and chloride), may reflect the influence of chemically mature ground water and upward movement of ground water from deeper flow paths in the Upper Floridan aquifer.

A comparison of the star diagrams indicates that Domain I, the recharge domain, is supplying most of the water to Ichetucknee Head, Cedar Head and Blue Hole springs. The high recharge rates in Domain I has produced ground water with very low total dissolved solids and low magnesium, sodium and chloride.

Another comparison of the star diagrams indicates that Domain IIIa, the discharge domain along the Santa Fe River above the Ichetucknee River, is supplying most of the water to Mill Pond Spring. The discharge of Mill Pond Spring contains elevated levels sulfate and chloride indicative of relatively deep flow through the Upper Floridan aquifer. While the Mill Pond Spring star diagram is very similar to the Domain IIIa pattern, elevated levels of nitrate are also discharging from this spring. This indicates that mixing of ground water from different domains is likely occurring near this spring.

A final comparison of the star diagrams indicates that Mission and Devil’s Eye springs are likely mixtures of ground water from Domains I and IIIa. The star diagrams for these two springs are intermediate between that of Ichetucknee Head Spring and Mill Pond Spring described above. This mixing of ground water near the springs and the Ichetucknee River is to be expected due to convergent flow of ground water from areas near the springs. While the amount of mixing varies from spring to spring, there appears to be an overall mixing of ground water from the head springs southward along the Ichetucknee River to Mill Pond Spring. The relative amount of mixing at the springs is reflected in the gradual change in the star diagrams from north to south along the Ichetucknee River.

Nitrate concentrations at Ichetucknee Head Spring have gradually increased over the last several decades, suggesting that water-quality trends in this spring are slow to change. This indicates that long-term monitoring is needed to detect any possible changes to water quality at the springs or to follow the current increasing trends in nitrate concentrations. With an estimated long-term increase of 0.01 to 0.02 mg/l per year, it is likely that many years, if not decades, will be needed to monitor long-term water-quality trends at Ichetucknee Head Spring and other springs in the region. The springs should be sampled at least twice a year to monitor intermediate- to long-term trends in water quality. This sampling program should include analyses for nutrients (e.g., nitrate), major ions (e.g., calcium), trace constituents (e.g., iron), and periodically for nitrogen isotopes to determine the effects of changing land use and to determine the effectiveness of remedial efforts to protect water quality at the springs.

Finally, given the region's karst geology, vulnerability to ground-water contamination, and increasing population, the siting, construction, and monitoring of waste disposal facilities such as wastewater treatment plants and septic tanks should be reviewed and planned carefully. Stormwater should be properly stored and treated to prevent ground-water contamination. In addition, the importance of nitrate sources such as residential and golf course turf fertilization, septic-tank effluent, and sewage disposal will increase as residential and commercial development proceeds in the region. Best management practices should be developed or implemented to reduce the use of fertilizer near the springs.

REFERENCES CITED

Carroll, D., 1970. Rock Weathering: New York, Plenum Press, pp. 101-102.

Ceryak, R., M.S. Knapp, and T. Burnson, 1983. The Geology and Water Resources of the Upper Suwannee River Basin, Florida. Florida Geological Survey Report of Investigation No. 87.

Champion, K.M., and D. J. DeWitt, 2000. Origin of Nitrate in Ground Water Discharging from Crystal Springs, Pasco County, Florida. Southwest Florida Water Management District, Brooksville, Florida.

Crane, J.J, 1986. An Investigation of the Geology, Hydrogeology and Hydrochemistry of the Lower Suwannee River Basin. Florida Geological Survey Report of Investigation No. 96.

Dinkins, J.L, 1969. Dunnellon, Boomtown of the 1890's. St. Petersburg, The Great Outdoors Publishing Company.

Hirth, D.K., 1995. Hydrochemical Characterization of the Ichetucknee River Groundwater Basin Using Multiple Tracers and Computer Modeling Near Lake City, Florida. Masters Thesis, University of Florida, Gainesville.

Hornsby, D., 1998. Springs of the Suwannee River Basin of Florida. Suwannee River Water Management District, Live Oak, Florida, WR99-02.

Hornsby, D., and R. Ceryak, 1998. Groundwater Quality Report. Suwannee River Water Management District, Live Oak, Florida, WR99-03.

Jones, G.W., S.B.Upchurch, and K.M. Champion, 1996. Origin of Nitrate in Ground Water Discharging from Rainbow Springs. Southwest Florida Water Management District, Brooksville, Florida.

Karst Environmental Services, 1997. Ichetucknee Springs Water Quality Working Group Cooperative Dye Trace; Rose Creek Swallet-Ichetucknee Springs Group. An unpublished manuscript produced for the Ichetucknee Springs Working Group and the Suwannee River Water Management District.

Katz, B.G., and H.D. Hornsby, 1998. A Preliminary Assessment of Sources of Nitrate in Springwaters, Suwannee River Basin, Florida. U.S. Geological Survey Open-File Report 98-69.

Katz, B.G., H.D. Hornsby, J.K. Bohlke, and M.F. Mokray, 1999. Sources and Chronology of Nitrate Contamination in Spring Waters, Suwannee River Basin, Florida: U.S. Geological Survey Water-Resources Investigations Report 99-422.

Lawrence, F.W., and S.B. Upchurch, 1976. Identification of geochemical patterns in ground water by numerical analysis. In E.A. Zaleem (ed.), Advances in Groundwater Hydrology, Amer. Water Resources Assoc., p. 199-214.

Marella, R.L., 1999. Water Withdrawals, Use, Discharge, and Trends in Florida, 1995. U.S. Geological Survey Water-Resources Investigations Report 99-4002.

Martin, J.B., and S.L. Gordon, 1998. Surface and Ground Water Mixing, Flow Paths, and Temporal Variations in Chemical Compositions of Karst Springs. Distributed by the Geology Department, University of Florida, Gainesville.

Meyer, F.W., 1962. Reconnaissance of the Geology and Ground-Water Resources of Columbia County, Florida. Florida Geological Survey Report of Investigations No. 30.

North Central Florida Regional Planning Council, 1978. Assessment of Development Potential Ichetucknee River Headwaters Area. Study prepared for the Columbia County Board of County Commissioners for use in the County Comprehensive Plan, Appendix A.

Pratt, T.R., C.J. Richards, K.A. Milla, J.R. Wagner, J.L. Johnson, and R.J Curry, 1996. Hydrogeology of the Northwest Florida Water Management District. Northwest Florida Water Management District Water Resources Special Report 96-4.

Puri, H.S., and R.O. Vernon, 1964. Summary of the Geology of Florida and a Guidebook to the Classic Exposures. Florida Geological Survey Spec. Publication No. 5, (revised), 312 p.

Rosenau, J.C., G.L. Faulkner, C.W. Hendry, Jr., and R.W. Hull, 1977. Springs of Florida. Florida Geological Survey Bulletin 31 (revised).

Scott, T.M., J.M. Lloyd, and G. Maddox, 1991. Florida's Ground Water Quality Monitoring Program: Hydrogeological Framework. Florida Geological Survey Special Publication No. 32.

Scott, T.M., 2001. Text to Accompany the Geologic Map of Florida. Florida Geological Survey Open-File Report No. 80.

Scott, T.M., G.H. Means, R.C. Means, and R.P. Meegan, 2002. First Magnitude Springs of Florida. Florida Geological Survey, Open File Report No. 85.

Skiles, W., 1991. Ichetucknee Hydrogeology Study. Karst Environmental Services, High Springs, Florida.

Stewart, J.W., and L.R. Mills, 1984. Hydrogeology of the Sulphur Springs Area, Tampa, Florida. U.S. Geological Survey Water-Resources Investigations Report 83-4085.

Toth, D.J, 1999. Water Quality and Isotope Concentrations from Selected Springs in the St. Johns River Water Management District. Technical Publication SJ99-2. St. Johns River Water Management District, Palatka, Florida. 67p.

Upchurch, S.B., 1990. Quality of Ground Water in the Suwannee River Water Management District: Results of the First Sampling of the Background Water-Quality Network. Contract report submitted to the Suwannee River Water Management District, Live Oak, Florida.

Upchurch, S.B., 1992. Quality of Waters in Florida's Aquifers. *In* G.L. Maddox, J.M. Lloyd, T.M. Scott, S.B. Upchurch, and R. Copeland (eds.), Florida Ground Water Quality Monitoring Program -- Volume 2, Background Hydrogeochemistry, Florida Geological Survey, Special Publication No. 34, Ch. IV, pp. 12-52, 64-84,90-347.

Upchurch, S.B., D. Hornsby, R. Ceryak, and W. Zwanka, 2001. A Strategy for the Characterization of First Magnitude Springs. Suwannee River Water Management District, Live Oak, FL, WR01/02-01.

Upchurch, S.B., 2002. Hydrogeochemistry of a karst escarpment. In J.B. Martin, C.M. Wicks, and I.D. Sasowsky (eds.), Hydrogeology and Biology of Post-Paleozoic Carbonate Aquifers. Charles Town, WV, Karst Waters Institute, Special Publication 7, pp. 73-75.

Upchurch, S.B., and K.M. Champion, 2002. Development Potential of the Ichetucknee Springshed, Florida. SDII Global Corporation, Tampa, Florida.

Upchurch, S.B., and K.M. Champion, 2003 (draft). Delineation of the Ichetucknee Springs ground-water basin using geostatistical analysis. SDII Global Corporation, Tampa, Florida.

U.S. Census Bureau, 2002. State and County Quick Facts. Accessed via the worldwide web at: http://quickfacts.census.gov/qfd/states/12/12023.html.

White, W.A., 1970. The Geomorphology of the Florida Peninsula. Florida Department of Natural Resources, Bureau of Geology, Geological Bulletin 51, 164 p.

Appendix I

Appendix I. Monitor well water-quality data.

MAP ID	WELL NAME	SITEID	FSPX	FSPY	TURB	TDS	ALKTOT	TOC	DOC	KTOT	NATOT	MGTOT	CATOT	CLTOT	FTOT	SO4TOT	FETOT	PBTOT	NO3NTOT	TKN	NH3NTOT	PTOT	CDTOT	ASTOT	MNTOT	SITOT	SRTOT	SILICA TOT	TSS	VSS	TEMP	SP_COND	PHF	DO
2	DOT - SR 129 & LANDFILL	-031335002	2446261.6	435181.1	1.4	192	165	0.38	2.83	0.16	2.17	1.62	67.8	3.31	0.09	2.21	0.069	0.004	0.289	0.05	0.02	0.054	0.002	0.005	0.005	4.643	0.05	9.94	1.5	1.5	21.5	291	6.81	4.69
3	LARRY RICE	-031403007	2473984.5	458018.6	0.55	210	204	0.38	0.39	0.652	3.97	7.4	87.5	5.61	0.17	20.6	0.166	0.006	0.01	0.05	0.02	0.051	0.002	0.005	0.016	6.57	0.062	14.1	0.7	0.7	17.78	427	7.67	0.52
4	TODD FRIER	-031413001	2480543.2	450760.7	0.46	210	166	1.59	2.12	1.33	4.65	12.4	46.8	5.19	0.28	1.34	0.008	0.007	0.01	0.29	0.15	0.029	0.002	0.005	0.005	7.428	0.074	15.9	0.7	0.7	18.02	356	6.53	
5	DOYLE LAW	-031426002	2477378.5	436744.9	0.2	202	164	0.38	0.53	0.16	3.33	1.17	68.2	6.2	0.15	2.56	0.016	0.006	1.19	0.06	0.02	0.073	0.002	0.005	0.005	4.458	0.05	9.54	0.7	0.7	17.94	324	7.31	2.32
6	JOHN CLARK	-031521002	2497964.9	443815.1	0.25	272	161	0.38	0.12	0.904	3.08	8.47	68.8	3.38	0.18	18.6	0.034	0.005	0.01	0.05	0.02	0.106	0.002	0.005	0.011	7.328	0.067	15.7	0.7	0.7	18.92	325	7.71	0.67
7	BETHEL MISSIONARY BAPTIST CHURCH	-031522007	2502417.9	444056.6	2	188	151	2.02	1.64	0.673	3.22	7.28	47.4	4.4	0.24	1.25	0.213	0.005	0.01	0.38	0.25	0.161	0.002	0.005	0.012	6.666	0.05	14.3	0.7	0.7	18.44	308	6.78	0.5
8	GREGG STUART	-031524001	2516991.2	444654	9	192	141	2.59	3.19	0.706	3.53	0.891	54.9	5.74	0.12	1.93	1.303	0.005	0.01	0.44	0.28	0.245	0.002	0.005	0.021	3.77	0.05	8.07	0.7	0.7	18.23	323	7.15	
9	PAULETTE DANCY	-031529005	2495381	439783.3	4.5	204	168	0.49	0.76	0.455	2.55	3.68	62.1	3.83	0.13	3.86	0.653	0.005	0.01	0.59	0.42	0.124	0.002	0.005	0.008	5.318	0.062	11.4	1	1	19.02	316	7	0.23
10	DON & SUZANNE BRIDGE	-031530002	2486335.1	439933	0.5	252	198	0.66	0.4	0.606	3.76	6.61	75.9	5.4	0.21	13.4	0.099	0.006	0.01	0.06	0.02	0.015	0.002	0.005	0.009	5.553	0.063	11.9	0.7	0.7	17.98	401	7.25	1.46
11	PAUL WREAD	-031628004	2533928.9	439209.9	0.75	160	119	1.14	1.9	0.507	3.68	3.73	38.3	4.6	0.18	4.18	0.246	0.003	0.01	0.05	0.02	0.15	0.002	0.005	0.017	5.254	0.05	11.2	0.7	0.7	18.13	267	7.5	
12	HUNT'S ALUMINUM	-031633008	2534189.7	436720.4	2	188	110	0.42	1.08	0.483	3.25	5.1	37.8	4.14	0.23	3.69	0.591	0.006	0.12	0.05	0.02	0.073	0.002	0.005	0.011	6.486	0.05	13.9	0.7	0.7	18.75	262	7.38	
13	JOHN FOLKS-DOF-LAKE CITY W/C	-031734011	2570874.2	435859.2	1.5	214	158	2.05	2.23	1.68	6.34	16.4	35.5	4.83	0.35	1.58	0.059	0.002	0.007	0.4	0.167	0.121	0.0005	0.023	0.031	14.25	0.072	30.5			22.6	316	7.58	0.11
14	USGS - ONF 9A	-031807001	2585957.6	457332.8	0.8	262	217	0.38	0.38	0.698	4.8	27.6	46.5	6.01	0.19	1.88	0.114	0.003	0.01	0.05	0.02	0.007	0.002	0.005	0.042	13.27	0.057	28.4	0.7	0.7	21.7	427	7.31	0.1
15	US FOREST SERV-OLUSTEE TWR	-031923004	2634566.9	447317.8	0.25	262	171	1.54	1.52	1.2	9.39	19.4	41.9	8.2	0.35	10.4	0.009	0.002	0.005	0.19	0.02	0.035	0.0005	0.023	0.01	15.07	0.47	32.2			22.5	374	7.54	0.11
16	JOHN FOLKS-DOF-ROCKY HILL	-041402002	2477773.6	427352.7	1	190	149	0.38	0.51	0.177	3.91	2.87	58.2	4.93	0.12	3.56	0.054	0.003	0.17	0.05	0.02	0.088	0.002	0.005	0.005	4.514	0.05	9.66	0.7	0.7	20.6	325	7	1.02
17	THERON DASHER	-041426001	2480694.1	406912	0.6	176	129	0.38	0.34	0.248	3.36	2.06	55.2	6.47	0.08	3.83	0.004	0.003	2.6	0.05	0.02	0.048	0.002	0.005	0.005	3.439	0.066	7.36	0.7	0.7	22.9	304	7	6
18	DAN CLARK	-041505002	2496235.2	427947	0.25	180	143	0.38	0.38	0.16	3.39	1.89	60.3	5.22	0.14	3.29	0.042	0.007	0.44	0.05	0.02	0.04	0.002	0.005	0.005	4.801	0.05	10.3	0.7	0.7	18.46	272	7.21	5.51
19	MR. RIEGEL	-041508001	2494857	425823.4	0.3	184	144	0.38	0.38	0.16	3.06	2.43	61	5.94	0.11	3.03	0.039	0.007	0.84	0.05	0.02	0.04	0.002	0.005	0.005	4.495	0.057	9.62	0.7	0.7	19.07	288	7.37	4.46
20	WILLIAM D MOSELY	-041523001	2507956	415371.5	0.5	164	116	0.38	0.38	0.16	2.34	0.974	50.8	4.07	0.08	1.8	0.042	0.005	0.63	0.05	0.02	0.026	0.002	0.005	0.005	3.576	0.05	7.65	0.7	0.7	18.55	261	7.66	
21	DORIS L. HICKS	-041533003	2500007.7	400502.7	1.6	164	127	0.38	0.6	0.16	1.78	1.51	55.3	2.65	0.05	1.27	0.031	0.001	0.278	0.1	0.02	0.025	0.0001	0.023	0.005	4.697	0.063	10.1			21.64	278	7.34	7.94
22	BEN HEBERT	-041608002	2526914.2	423153.3	0.45	118	92.4	0.38	0.38	0.573	2.6	1.2	34.2	3.21	0.08	2.49	0.003	0.001	0.092	0.04	0.02	0.066	0.0005	0.023	0.005	5.068	0.029	10.9			21.2	190	7.54	6.14
23	WARREN ZWANKA	-041627017	2535400	409051.5	0.55	178	130	0.38	0.65	49.3	5.67	2.53	48.4	8.12	0.12	2.31	0.283	0.007	1.68	0.05	0.02	0.048	0.002	0.005	0.005	5.077	0.05	10.9	0.7	0.7	18.07	318	6.47	3.32
24	LUTHER CHARLES	-041630001	2520577.3	405560.8	0.2	148	103	0.38	0.4	0.235	2.71	0.637	44.9	4.19	0.05	1.36	0.027	0.001	0.956	0.06	0.02	0.016	0.0001	0.023	0.005	5.316	0.037	11.4			22.52	242	7.57	8.16
25	FL FRESHWATER GAME & FISH	-041704004	2564117.4	429361.4	65	370	254	17.3	17.2	0.542	5.92	2.02	102	12.6	0.22	1.34	8.484	0.007	0.01	0.89	0.44	1.5	0.002	0.009	0.071	7.322	0.063	15.7	32	12.5	18.22	575	7.05	
26	JOHN FOLKS-DOF-ROSE CREEK	-041734002	2566634.2	406266.6	0.2	166	110	0.38	0.38	0.584	4.32	4.65	40.6	6.03	0.21	2.65	0.014	0.004	1.19	0.04	0.02	0.019	0.0005	0.023	0.005	7.5	0.074	16			21.9	237	7.52	6.9
27	DUANE FRANKLIN	-041831001	2583430.4	403346	0.95	210	161	1.86	2.19	0.58	5.69	17.1	35.1	4.99	0.39	5.65	0.223	0.004	0.01	0.08	0.02	0.20	0.002	0.005	0.027	11.1	0.092	23.8	0.7	0.7	17.6	356	6.8	

Appendix I. Monitor well water-quality data.

MAP ID	WELL NAME	SITEID	FSPX	FSPY	TURB	TDS	ALKTOT	TOC	DOC	KTOT	NATOT	MGTOT	CATOT	CLTOT	FTOT	SO4TOT	FETOT	PBTOT	NO3NTOT	TKN	NH3NTOT	PTOT	CDTOT	ASTOT	MNTOT	SITOT	SRTOT	SILICA TOT	TSS	VSS	TEMP	SP_COND	PHF	DO
										9												5				1					3		9	
28	DOT - O'BRIEN - SR 129 & 77 DRIVE	-051405002	2460433.9	394908.7	0.75	196	152	0.47	4.16	1.05	2.62	5.08	62.2	3.47	0.02	6.66	0.021	0.003	2.42	0.05	0.02	0.042	0.002	0.005	0.005	5.753	0.076	12.3	0.7	0.7	22	345	6.93	5.67
29	S&S FOOD STORES INC #44	-051511002	2508958.2	389522.6	0.1	266	253	0.38	0.54	0.16	3.2	1.69	104	4.45	0.1	2.02	0.026	0.004	0.319	0.04	0.02	0.035	0.0005	0.023	0.005	4.693	0.127	10			21.9	463	7.03	5.57
30	BUCK CARLE	-051521001	2502658.4	380385.1	0.5	152	120	0.38	0.38	0.16	2.67	0.926	56.7	5.03	0.02	2.51	0.051	0.004	0.88	0.05	0.02	0.022	0.002	0.005	0.009	3.019	0.05	6.46	0.7	0.7	18.68	242	7.91	7.24
31	MARGIE EVANS	-051536001	2518291.2	370652.1	2	188	156	0.38	1.23	0.6	2.22	0.915	57.3	4.55	0.02	5.84	0.4	0.006	0.04	0.05	0.02	0.044	0.002	0.005	0.013	1.709	0.076	3.66	0.7	0.7	19.27	337	7.63	
32	TIM ZYGULA	-051536011	2516336.3	372458.9	28	120	94.6	0.38	0.38	0.16	1.78	1.78	39	3.29	0.02	4.92	1.83	0.003	0.333	0.05	0.02	0.039	0.002	0.005	0.02	2.797	0.088	5.99	0.7	0.7	17.85	147		4.79
33	CARL HAGENKOTTER	-051536012	2516105.5	372644.5	0.4	169	129	0.38	0.38	0.16	2.09	5.14	46.4	3.86	0.1	9.41	0.038	0.003	0.9	0.08	0.02	0.023	0.002	0.005	0.005	3.201	0.202	6.85	0.7	0.7	19.28	280		5.18
34	DARRELL PLUNSKE	-051601006	2549577.5	400077.8	0.5	124	87.8	0.38	0.38	0.428	3.11	0.646	34.8	4.18	0.07	1.48	0.02	0.003	2.1	0.05	0.02	0.033	0.002	0.01	0.005	4.749	0.05	10.2	0.7	0.7	19.28	190	7.57	7.24
35	BOB BRENNAN- B&H WOODWORKS	-051610001	2539003.7	394179.1	0.5	204	122	0.38	0.49	0.447	1.78	0.788	50.6	2.37	0.02	4.09	0.101	0.004	3.2	0.05	0.02	0.033	0.002	0.005	0.005	2.742	0.05	5.86	1.5	1.5	20.83	299	6.76	
36	MT SALEM CHURCH	-051610006	2537553.7	392858.1	3	178	137	0.38	0.4	0.484	4	5.21	48.9	4.86	0.06	2.76	1.074	0.002	0.264	0.04	0.02	0.012	0.0005	0.023	0.005	5.567	0.06	11.9			21.8	288	7.45	0.8
37	DEP- ANDERSON MINE	-051621002	2531269.3	384554	3	298	213	0.53	2.45	0.767	2.4	2.06	96.9	3.35	0.08	27.6	0.709	0.003	4.2	0.1	0.02	0.102	0.002	0.005	0.016	2.487	0.159	5.32	3.5	3.5	19.63	496	7.41	2.07
38	CHARLOTTE PARRY	-051624001	2546087.8	384248	0.15	140	77.5	0.38	0.48	0.277	2.47	0.515	28	2.87	0.02	1.54	0.003	0.003	0.45	0.05	0.02	0.011	0.002	0.005	0.005	4.046	0.05	8.66	0.7	0.7	17.97	178	6.74	
39	ICHETUCKNEE MW#14 MUSSELWHITE	-051630002	2522980.1	373672.7	2.4	186	144	0.57	0.74	1.12	9.24	1.47	49.9	3.79	0.05	3.42	0.033	0.001	0.033	0.34	0.035	0.754	0.0005	0.023	0.007	3.692	0.095	7.9			21.86	309	7.4	5.8
40	DEBBIE WATERS	-051631004	2519782.9	369015.9	1	170	139	0.38	0.38	0.175	2.76	5.03	56	4.06	0.1	6.04	0.026	0.003	0.87	0.05	0.02	0.019	0.002	0.005	0.005	3.974	0.174	8.5	0.7	0.7	19.05	297	6.69	4.87
41	HARRY COLLINS	-051631005	2520516.3	370512.3	1	160	144	0.38	0.38	0.182	2.52	4.78	52.3	3.97	0.12	6.08	0.038	0.003	0.88	0.05	0.02	0.022	0.002	0.005	0.005	3.747	0.143	8.02	0.7	0.7	21.5	322	7.13	3.75
42	NEW ZION CEMETARY ASSOC	-051810004	2601096	396442.3	0.4	172	137	0.38	1.03	0.567	5.01	12.4	26.7	3.89	0.42	3.24	0.041	0.003	0.01	0.14	0.02	0.005	0.002	0.005	0.033	11.93	0.05	25.5	0.7	0.7	19.18	292	7.59	
43	DAVID WOOD	-051819001	2583503.1	383321.6	0.25	260	150	0.58	0.55	0.486	5.19	16.5	42.1	8.4	0.41	23.1	0.044	0.006	0.39	0.05	0.02	0.15	0.002	0.005	0.005	13.96	0.287	29.9	0.7	0.7	19	382	7.3	
44	JOHN FOLKS-DOF-UNION TOWER	-051922001	2635572.4	386361.2	3.5	236	196	0.71	0.73	1.03	6.9	22.1	55.9	6.2	0.22	4.31	0.124	0.005	0.005	0.04	0.02	0.498	0.0005	0.023	0.011	11.03	0.51	23.6			22.1	365	7.71	0.17
45	JOHN FOLKS-DOF-BEACHVILLE	-061401003	2486916.2	366433.6	36	212	168	0.54	10.9	0.354	1.99	4.52	74.1	3.44	0.02	8.77	0.512	0.004	0.498	0.05	0.02	0.201	0.002	0.005	0.009	4.235	0.103	9.06	18	3.6	22.3	312	7.06	2.58
46	JOHN WEBB	-061410001	2473305.4	357698.4	0.5	290	201	0.38	5.21	0.303	3.7	4.56	85.8	6.6	0.09	16.5	0.013	0.004	0.38	0.05	0.02	0.015	0.002	0.005	0.005	2.741	0.095	5.87	0.7	0.7	19.08	459	6.87	2.21
47	CARROL HALL	-061434007	2473326.2	339703.7	5.7	298	213	0.82	1.63	5.15	5.5	4.68	86.4	8.88	0.09	21.8	4.717	0.02	0.622	0.19	0.02	0.184	0.0008	0.023	0.02	2.97	0.166	6.36			23.5	474	7.12	0.11
48	BETH WESTON	-061501001	2515627.8	366992.5	1.5	232	180	0.38	0.38	0.283	4.4	4.78	79.2	5.65	0.07	6.94	0.283	0.003	1.06	0.05	0.02	0.161	0.002	0.005	0.012	3.785	0.131	8.1	1	0.7	21.5	398	6.96	4.96
49	STEVE BOWIE	-061501006	2517297.6	365108.4	0.05	196	181	0.38	0.38	0.211	2.2	4.18	65.3	3.56	0.1	5.56	0.042	0.003	0.32	0.05	0.02	0.029	0.002	0.005	0.005	3.151	0.128	6.74	0.7	0.7	18.3	331	7.77	6.45
50	BILL MARCUS	-061501007	2518750.1	363459.4	0.26	160	130	0.38	0.38	0.16	1.63	3.3	47.4	3.14	0.08	8.85	0.9	0.004	0.02	0.07	0.02	0.015	0.002	0.005	0.03	2.833	0.077	6.06	0.7	0.7	18.38	385	7.62	2.9
51	RON PRESTON	-061501008	2515131.4	364130.5	13	198	164	0.38	0.07	0.172	1.65	1.58	54.4	3.3	0.08	1.76	1.147	0.006	0.17	0.05	0.02	0.048	0.002	0.005	0.048	3.277	0.08	7.01	1.5	1.5	18.53	263	7.75	1.93
52	HARVEY DAVIS	-061502002	2510669.4	363381.5	1.5	144	132	0.38	0.38	0.189	2.08	2.32	54.6	3.21	0.09	8.61	0.342	0.004	0.01	0.11	0.04	0.029	0.002	0.005	0.005	3.185	0.064	6.82	0.7	0.7	21.8	292	7.21	2.98

Appendix I. Monitor well water-quality data.

MAP ID	WELL NAME	SITEID	FSPX	FSPY	TURB	TDS	ALKTOT	TOC	DOC	KTOT	NATOT	MGTOT	CATOT	CLTOT	FTOT	SO4TOT	FETOT	PBTOT	NO3NTOT	TKN	NH3NTOT	PTOT	CDTOT	ASTOT	MNTOT	SITOT	SRTOT	SILICATOT	TSS	VSS	TEMP	SP_COND	PHF	DO
53	JOY DELTIEMPO	-061502005	2513651.2	366275.6	0.25	162	128	0.38	0.38	0.16	1.88	3.79	52.6	2.92	0.07	4.88	0.003	0.003	0.03	0.08	0.02	0.023	0.002	0.005	0.005	3.306	0.073	7.07	0.7	0.7	18.76	265	6.51	4.13
54	CECIL KOON	-061511007	2510737.3	359452.5	1	116	91.2	0.38	0.38	0.16	1.96	2.18	43.4	3.96	0.07	12.3	0.467	0.003	0.01	0.05	0.02	0.027	0.002	0.005	0.005	2.608	0.054	5.58	0.7	0.7	19.97	227	6.72	1.55
55	ICHETUCKNEE STATE PARK #2	-061512001	2518243.1	362127.2	0.15	188	141	0.38	0.38	0.16	2.2	5.47	45.1	3.7	0.11	8.22	0.003	0.003	0.55	0.16	0.02	0.018	0.002	0.005	0.005	2.767	0.138	5.92	0.7	0.7	21.5	317	7.2	3.44
56	ICHETUCKNEE STATE PARK #3	-061512006	2518692.8	361594.5	1	236	187	0.38	0.1	0.16	3.27	6.23	66.7	4.29	0.11	7.83	0.043	0.003	0.55	0.05	0.02	0.146	0.002	0.005	0.005	3.638	0.183	7.79	1.5	1.5	21.4	398	7.1	2.51
57	DOROTHY HAWKINS	-061512007	2516299	360435.9	1	258	147	0.38	0.38	2.61	6.26	3.39	76.8	8.26	0.02	15.3	0.031	0.003	6.1	0.05	0.02	0.062	0.002	0.005	0.005	3.045	0.119	6.52	0.7	0.7	19.01	388	6.62	4.96
58	ICHETUCKNEE STATE PARK MW #9	-061512008	2515436	359011.8	75	230	140	0.55	21.8	1.29	9.7	2.25	81.6	3.19	0.05	4.48	3.917	0.013	0.012	0.22	0.02	2.01	0.0028	0.023	0.018	14.67	0.207	31.4			22.15	288	7.11	7.29
59	ICHETUCKNEE STATE PARK MW #10	-061512009	2517222.5	360890.7	15	120	97.8	0.38	0.45	0.22	1.94	0.672	48.3	2.8	0.05	1.97	0.147	0.001	0.052	0.05	0.02	0.398	0.0005	0.023	0.005	4.545	0.064	9.73			22.14	199	7.17	8.29
60	ICHETUCKNEE STATE PARK MW #11	-061512010	2516686.5	362659.5	175	310	228	0.54	18	0.558	2.2	6.85	98	3.68	0.05	8.05	3.104	0.001	0.998	0.24	0.02	1.26	0.0005	0.023	0.052	11.74	0.321	25.1			21.75	342	7.32	5.54
61	ICHETUCKNEE STATE PARK MW #12	-061512011	2518934.7	362890.5	34	328	96.6	0.55	1.07	0.254	2.79	3.24	159	2.87	0.05	5.44	0.823	0.001	1.02	0.15	0.02	0.999	0.0005	0.023	0.056	5.388	0.245	11.5			21.6	551	6.18	3.55
62	ICHETUCKNEE STATE PARK MW #7	-061514002	2511550.1	353992.8	13	214	145	0.38	0.53	0.816	7.79	3.15	58.4	3.42	0.05	4.81	0.119	0.001	0.158	0.06	0.02	0.856	0.0005	0.023	0.005	4.441	0.088	9.5			22.9	308	6.58	7.22
63	ICHETUCKNEE STATE PARK MW #8	-061514003	2514106.1	357466.6	0.5	160	137	0.5	0.54	0.613	5.29	1.99	68.6	4.16	0.05	3.47	0.116	0.002	0.129	0.16	0.02	0.992	0.0005	0.023	0.005	4.09	0.104	8.75			22.11	283	7.28	7.64
64	DAN JUDY	-061515001	2505961.8	353328.7	0.15	216	157	0.38	0.33	0.724	2.34	2.25	77.7	3.55	0.08	8.46	0.005	0.005	3.4	0.05	0.02	0.029	0.002	0.005	0.005	2.753	0.122	5.88	0.7	0.7	18.76	343	7.28	6.73
65	S&S FOOD STORES, INC.	-061519004	2487717.4	350354.3	0.4	236	169	0.38	0.38	0.171	3.12	4.82	72.5	4.29	0.09	25	0.028	0.003	0.3	0.05	0.02	0.029	0.002	0.005	0.005	2.165	0.099	4.63	0.7	0.7	22.8	394	7	0.42
66	WILLIAM LOUD	-061521005	2498595.7	349328.6	1.4	216	165	0.38	4.4	0.268	2.66	4.62	78.4	4.33	0.09	19.4	0.031	0.005	0.438	0.05	0.02	0.039	0.002	0.005	0.005	2.912	0.125	6.23	0.7	0.7	22.3	327	7.03	1.95
67	ICHETUCKNEE STATE PARK #6	-061523002	2512249	350797.7	0.25	208	145	0.38	0.07	0.559	5.73	9.51	61	5.06	0.15	17.8	0.02	0.003	0.49	0.05	0.02	0.051	0.002	0.005	0.005	6.575	0.36	13.3	1	0.7	22	348		3.14
68	ICHETUCKNEE STATE PARK #7	-061524003	2516226.1	350586.4	0.25	232	142	0.38	0.3	0.543	5.54	9.52	91.2	7.82	0.19	33.9	0.138	0.004	0.26	0.05	0.02	0.102	0.002	0.005	0.012	6.235	0.393	13.3	7.5	7.5	22.1	382		1.11
69	ICHETUCKNEE STATE PARK #5	-061524013	2516193.4	352105	0.4	232	141	0.38		0.559	5.73	9.51	61	7.32	0.18	30.7	0.006	0.003	0.27	0.06	0.02	0.04	0.002	0.005	0.005	6.575	0.36	14.1	1	0.7	22.2	374		0.85
70	EARL KINARD	-061605001	2527275.7	364443.6	0.5	182	149	0.38	0.28	0.342	3.38	4.02	48.8	4.89	0.14	4.11	0.028	0.003	0.7	0.05	0.02	0.033	0.002	0.005	0.005	4.202	0.078	8.99	0.7	0.7	18.16	294	7.27	1.63
71	LARRY BATTISTA	-061605004	2524638.8	363347.2	0.45	177	143	0.38	0.38	0.482	2.65	4.4	48.5	4.04	0.09	4.15	0.009	0.003	0.657	0.05	0.02	0.031	0.002	0.005	0.005	4.747	0.081	10.2	0.7	0.7	18.57	282		2.12
72	LARRY WILLIAMS	-061606002	2524138	367153.7	0.55	173	139	0.38	0.38	0.26	2.8	5.38	52.4	4.26	0.07	4.73	0.015	0.003	0.862	0.05	0.02	0.023	0.002	0.005	0.005	4.544	0.113	9.72	0.7	0.7	18.22	299		3.36
73	ICHETUCKNEE STATE PARK #1	-061607001	2519515.5	362436.8	0.35	180	162	0.38	0.38	0.21	2.54	6.1	59.7	4	0.13	6.29	0.023	0.003	0.883	0.04	0.02	0.054	0.0005	0.023	0.005	4.23	0.141	9.05			22	321	7.3	3.61
74	ICHETUCKNEE STATE PARK #4	-061607010	2521875.8	359611.1	0.15	192	142	0.38	0.1	0.437	3.76	5.77	41.4	5.21	0.16	5.61	0.011	0.003	0.59	0.05	0.02	0.04	0.002	0.005	0.005	4.77	0.104	10.2	1	0.7	20.5	283		1.05
75	RONNIE BIAS	-061607011	2523026.3	360538.8	0.2	134	87.4	0.38	0.1	0.351	3.29	3	33.7	5.05	0.6	3.11	0.003	0.003	0.7	0.05	0.02	0.424	0.002	0.005	0.005	3.968	0.05	8.49	0.7	0.7	18.37	190	6.77	11.6
76	ICHETUCKNEE STATE PARK MW #1	-061607012	2520938.8	361681.2	22	260	175	0.42	0.77	2.12	16.7	7.18	65.3	7.06	0.17	27.1	0.238	0.001	0.268	0.04	0.02	2.21	0.0005	0.023	0.027	7.028	0.268	15			22.03	316	5.99	4.06
77	ICHETUCKNEE STATE PARK MW #2B	-061607014	2521582.7	360690.4	1	250	185	3.94	9.45	0.984	6.64	4.51	74.6	5.26	0.11	4.03	0.394	0.001	0.236	1.75	0.816	1.64	0.0005	0.023	0.072	5.486	0.111	11.7			22.31	400	6.75	3.02

Appendix I. Monitor well water-quality data.

MAP ID	WELL NAME	SITEID	FSPX	FSPY	TURB	TDS	ALKTOT	TOC	DOC	KTOT	NATOT	MGTOT	CATOT	CLTOT	FTOT	SO4TOT	FETOT	PBTOT	NO3NTOT	TKN	NH3NTOT	PTOT	CDTOT	ASTOT	MNTOT	SITOT	SRTOT	SILICATOT	TSS	VSS	TEMP	SP_COND	PHF	DO
78	ICHETUCKNEE STATE PARK MW #3	-061607015	2522020.8	358730.3	0.7	222	158	0.38	0.65	0.479	4.27	6.25	64.3	6.07	0.09	11.6	0.044	0.001	0.431	0.12	0.02	0.404	0.0005	0.023	0.005	6.354	0.163	13.6			21.68	376	6.95	3.8
79	ICHETUCKNEE STATE PARK MW #13	-061607016	2520033.8	362732.3	1	228	179	0.38	0.58	0.23	2.8	6.92	70.1	3.81	0.05	7.13	0.104	0.001	0.324	0.11	0.02	0.165	0.0005	0.023	0.008	4.554	0.146	9.75			21.59	390	7.29	3.78
80	MARSHALL BARNARD	-061608001	2528588.3	359210.5	0.3	192	139	0.38	0.31	0.497	5.14	7.15	46.4	5.91	0.16	10.6	0.003	0.003	0.47	0.05	0.02	0.062	0.002	0.005	0.005	5.899	0.128	12.6	0.7	0.7	18.56	310	7.13	0.26
81	LEONARD BUNDY	-061608002	2527897.3	358391.5	0.25	302	223	0.38	0.5	0.48	10.1	4.08	101	14	0.08	2.48	0.013	0.003	4.4	0.05	0.02	0.026	0.002	0.005	0.005	5.33	0.138	11.4	0.7	0.7	17.74	495	6.72	3.67
82	DOT - SR 47	-061608003	2526876.5	360692.6	0.75	224	194	0.38	0.11	0.16	2.59	5.57	77	4.28	0.11	6.36	0.031	0.005	0.69	0.05	0.02	0.033	0.002	0.005	0.03	4.055	0.18	8.68	0.7	0.7	18.78	321	7.59	5.03
83	EDWARD HOLLOMAN	-061610001	2535222	362486.6	15	282	262	0.38	0.57	0.16	4.62	1.67	128	5.22	0.09	1.5	0.081	0.005	0.069	0.04	0.02	0.144	0.0005	0.023	0.005	4.644	0.11	9.94			21.8	481	7.04	5.47
84	BARBARA FRISTENSKY	-061617002	2529792.9	355289.1	0.15	252	11.2	0.38	0.13	0.16	4.7	1.19	77.7	7.69	0.11	1.33	0.003	0.003	1.18	0.05	0.02	0.026	0.002	0.005	0.005	3.776	0.071	8.08	1	0.7	18.85	443	6.89	6.02
85	WALTER NICHOLS	-061617006	2526679.2	357503	0.6	256	221	0.38	0.38	0.184	3.99	2.7	90.7	5.74	0.12	4.65	0.015	0.003	0.29	0.05	0.02	0.033	0.002	0.005	0.005	4.614	0.116	9.87	0.7	0.7	18.23	419	7.74	4.92
86	ICHETUCKNEE STATE PARK MW #4	-061618002	2520933	353636.7	0.2	194	119	0.38	0.38	0.428	5.02	7.07	47.1	6.78	0.17	22.7	0.051	0.004	0.88	0.05	0.02	0.044	0.002	0.005	0.005	5.12	0.263	11	0.7	0.7	19.45	299	7.28	2.71
87	ICHETUCKNEE STATE PARK MW #5	-061618003	2522078.8	357082.3	0.6	210	136	0.38	0.52	0.509	4.82	9.13	49.9	6.77	0.15	19.6	0.018	0.001	0.455	0.05	0.02	0.054	0.0005	0.023	0.005	6.682	0.234	14.3			21.68	349	7.33	3.02
88	ICHETUCKNEE STATE PARK MW #6	-061618004	2520809.3	355056.5	19	180	149	0.38	0.68	0.478	3.51	0.029	88.9	4.19	0.05	5.52	0.148	0.001	0.88	0.1	0.02	0.856	0.0005	0.023	0.016	5.028	0.149	10.8			22.7	414	5.88	3.64
89	C S PATRICK	-061618005	2519589.8	352390.4	0.35	230	145	0.65	0.75	0.586	6.55	8.45	62.1	6.9	0.13	25.8	0.155	0.001	0.007	0.22	0.063	1.02	0.0005	0.023	0.038	6.977	0.275	14.9			22.33	373	6.84	3.44
90	COLUMBIA COUNTY COMM	-061624001	2551065.5	350878.4	2	222	106	0.38	0.38	0.28	5.37	4.57	56	8.7	0.07	31.9	0.403	0.005	0.21	0.05	0.02	0.051	0.002	0.005	0.013	4.496	0.224	9.62	0.7	0.7	18.54	328	7.64	
91	CARL HOLMBERG - ENGEDI	-061628007	2535133.5	344186.7	39	214	158	1.35	0.52	0.185	3.92	2.84	66.5	5.86	0.15	14.4	8.486	0.005	0.01	0.05	0.02	1.08	0.002	0.005	0.108	3.822	0.209	8.18	118	30.5	18.84	328	7.08	0.42
92	COMMUNITY NATIONAL BANK	-061633028	2530817.6	342704.1	1	210	115	1.76	1.77	0.406	5.64	6.88	52	9.26	0.14	31.5	0.508	0.003	0.01	0.05	0.02	0.113	0.002	0.005	0.017	4.621	0.396	9.89	0.7	0.7	22.7	327	7.2	1.05
93	ALFRED M SCHMIDT	-061634003	2536397.1	338116.5	1.6	370	134	8.64	8.78	1.14	11.4	11.8	62.2	20.2	0.21	89.9	0.478	0.003	0.01	0.31	0.02	0.132	0.002	0.005	0.011	5.919	0.707	12.7	1.5	1.5	23	506		0.46
94	DAN BELL	-061708002	2559091.7	364479.1	0.35	162	107	0.38	0.38	0.229	2.77	1.1	51.3	3.52	0.12	3.56	0.066	0.007	0.64	0.05	0.02	0.033	0.002	0.007	0.005	4.343	0.06	9.29	0.7	0.7	18.75	263	7.67	
95	MIKESVILLE PRESBYTERIAN CH	-061719008	2553974.8	350521.5	0.35	132	95.2	0.38	0.25	0.196	3.42	0.882	33.1	4.06	0.07	1.57	0.016	0.003	1.12	0.05	0.02	0.007	0.002	0.005	0.005	3.537	0.078	7.57	0.7	0.7	18.92	207	7.37	8.05
96	LIBBY SCHMIDT	-061722002	2569528.7	350414.4	0.15	292	128	1.96	1.89	0.628	7.82	6.42	68.3	12.9	0.12	57.7	0.017	0.005	0.01	0.1	0.08	0.066	0.002	0.005	0.005	4.772	0.305	10.2	0.7	0.7	19.66	330	7.49	
97	DOT - SR 441	-061724002	2582245.2	354124	3.2	186	150	1.83	2.28	0.558	2.94	3.93	51.9	4.66	0.05	3.59	1.015	0.001	0.005	0.31	0.083	0.083	0.0005	0.023	0.022	4.34	0.098	9.29			22.39	321	6.55	1.9