Springs, located in Sarasota County. Archaeologists recovered human remains from a ledge located 43 ft (13 m) below the current water level that contained preserved brain material. The remains were radiocarbon dated and produced an age of 10,000 +/- 200 years before present (Royal and Clark, 1960). Other archaeological material and fossils were recovered from this site, which has proven to be one of the most important archaeological sites in the southeastern United States.

Florida's abundance of springs does not stop at its present shoreline. Florida has an undocumented number of offshore springs that provided resources to prehistoric people and wildlife when sea level was lower. Evidence for occupation of offshore sites has been discovered by researchers from the Florida State University Department of Anthropology. Dr. Michael Faught and his students have conducted offshore surveys at and near some offshore springs and have recovered an abundance of chert tools (Faught, in prep.). Although offshore springs may be discharging brackish to saline water today, they almost certainly discharged fresh water during times of lowered sea levels when prehistoric human occupation occurred at these sites. Further investigation of Florida's offshore springs is needed to assess the role that these springs play in the hydrogeology and archaeology of the state.

As the Pleistocene Epoch came to a close in Florida, many environmental changes were taking place. The large megafaunal animals that once had roamed the Florida landscape were becoming extinct. Global weather patterns changed, and sea level began to rise. As these drastic changes occurred, Florida's human inhabitants had to adapt. As water tables rose, springs became more abundant and people continued to exploit the resources in and around the springs. Prehistoric peoples living around springs built large shell middens and mounds as they disposed of the inedible portions of their food items and other waste. Numerous examples of these mounds exist throughout the state with some of the best examples being located along spring runs that drain into the St. John's River, the King's Bay Spring Group near Crystal River and the spring-fed Wacissa River system. Abundant supplies of fresh water, aquatic food sources, chert and clay sources made Florida's springs highly desirable habitation sites.

Sediments in and around Florida's springs are time capsules that contain valuable information about our environmental and cultural past. Prehistoric Floridians valued our state's spring resources and now modern Floridians are the stewards of a tradition that has lasted for more than 12,000 years. As our state's population continues to grow, more and more people will be putting demands on our natural resources. It is our modern society's responsibility to see that Florida's springs are preserved in their natural beauty and ecological health for future generations.

HYDROGEOLOGY OF FLORIDA SPRINGS

Florida enjoys a humid, subtropical climate throughout much of the state (Henry, 1998). Rainfall, in the region of the major springs, ranges from 50 inches (127 cm) to 60 inches (152 cm) per year. As a result of this climate and the geologic framework of the state, Florida has an abundance of fresh groundwater. Scott and Schmidt (2000) and Scott (2001) estimated that more than 2.2 quadrillion gallons of fresh water are contained within the Floridan aquifer system (FAS) in Florida. Only a very small percentage of the fresh water is available as a renewable resource for human consumption.

The Florida peninsula is the exposed portion of the broad Florida Platform. The Florida Platform, as measured between the 200 meter below sea level contour (more than 600 ft), is more than 300 miles (483 km) wide. It extends more than 150 miles (240 km) westward under the Gulf of Mexico offshore from Crystal River, and more than 70 miles (113 km) under the Atlantic Ocean from Fernandina Beach. The present day Florida peninsula is less than one half of the total platform.

The Florida Platform is composed of a thick sequence of variably permeable carbonate sediments, limestone and dolostone, lying on older igneous, metamorphic and sedimentary rocks. The Cenozoic carbonate sediments may exceed 4,000 ft (1,220 m) thick. A sequence of sand, silt and clay with variable amounts of limestone and shell overlie the carbonate sequence (see Scott [1992 a, b] for discussion of the Cenozoic sediment sequence and the geologic structure of the platform). In portions of the west-central and north-central peninsula and in the central panhandle, the carbonate rocks, predominantly limestone, occur at or very near the surface. Away from these areas, the overlying sand, silt and clay sequence becomes thicker. As the sediments compacted and were subjected to other geologic forces, fractures formed. These fractures allowed water to move more freely through the sediments and provided the template for the development of Florida's many cave systems.

There are three major aquifer systems in Florida, The Floridan, the Intermediate and the Surficial Aquifer Systems, all of which are very complex (Southeastern Geological Society, 1986; Scott, 1992a). The Floridan aquifer system (FAS) occurs within a thick sequence of permeable carbonate sediments (see Miller [1986] and Berndt et al. [1998] for discussion of the FAS). In some areas, it is overlain by the intermediate aquifer system and confining unit (IAS) which consists of carbonates, sand, silt and clay. The surficial aquifer system (SAS) overlies the IAS, or the FAS where the IAS is absent, and is composed of sand, shell and some carbonate. The vast majority of Florida's springs result from discharge from the FAS.

Natural recharge to the FAS by rainwater, made slightly acidic by carbon dioxide from the atmosphere and organic acids in the soil, dissolved portions of the limestone and enlarged naturally occurring fractures. The dissolution enhanced the permeability of the sediments and formed cavities and caverns. Sinkholes formed by the collapse of overlying sediments into the cavities. Occasionally, the collapse of the roof of a cave creates an opening to the land surface. See Lane (1986) for a description of sinkhole types common in Florida.

Karst springs occur both onshore and offshore in Florida. Currently, little is known about the offshore springs with the exception of the Spring Creek Group - the largest spring group in Florida averaging more than one billion gallons of water discharged per day (maximum flow estimated at more than two billion gallons of water per day [Rosenau et al., 1977]) (Lane, 2001). In order to better understand the water resources of the state, a water budget needs to include a comprehensive assessment of the total amount of recharge and discharge occurring to and from the aquifer. To aid in this characterization, the FGS has initiated a program to investigate the occurrence, discharge and water quality of the offshore springs.

Florida's springs occur primarily in the northern two-thirds of the peninsula and the central panhandle where carbonate rocks are at or near the land surface (Figure 5). All of these springs produce water from the upper FAS (Berndt et al., 1998) which consists of sediments that range in age from Late Eocene (approximately 38 - 36 million years old [my]) to mid-Oligocene (approximately 33 my). Miocene to Pleistocene sediments (24 my to 10,000 years) often are exposed in the springs.

The geomorphology (physiography) of the state, coupled with the geologic framework, controls the distribution of springs. The springs occur in areas where karst features (for example, sinkholes and caves) are common, the potentiometric surface of the FAS is high enough and the surface elevations are low enough to allow groundwater to flow at the surface. These areas are designated karst plains, karst hills and karst hills and valleys on Figure 6. The state's springs occur primarily within the Ocala Karst District and the Dougherty Karst Plain District (Scott, in preparation, 2004). Other springs, including Alexander, Silver Glen and Volusia Blue, occur in the Central Lakes District (Scott, in preparation, 2004). Springs generally occur in lowlands near rivers and streams. There are a number of springs known to flow from vents beneath rivers and many more are thought to exist. Hornsby and Ceryak (1998) identified many newly recognized springs that occur in the channels of the Suwannee and Santa Fe Rivers. Springs that have yet to be described have been found beneath the Apalachicola River between Gadsden and Jackson Counties (H. Means, personal communication, 2004).

Recharge to the FAS occurs over approximately 55% of the state (Berndt et al., 1998). Recharge rates vary from less than one inch (2.54 cm) per year to more than ten inches (25.4 cm) per year. Recharge water entering the upper FAS that eventually discharges from a spring has a variable residence time. Katz et al. (2001) and Katz (2004) found that water flowing from larger springs had an average ground-water residence time of more than 20 years and may reflect the mixing of older and younger waters.

Discharge, water quality and temperature of springs remain reasonably stable over extended periods of time (Berndt et al., 1998). However, because discharge rates are driven by the rate of recharge, climatic fluctuations often have a major effect on spring flow.

During 1998 - 2002, Florida suffered a major drought with a rainfall deficit totaling more than 50 inches (127 cm). The resulting reduction in recharge from the drought and normal withdrawals caused a lowering of the potentiometric surface in the FAS. Many first magnitude springs experienced a significant flow reduction. Some springs, such as Hornsby Spring, ceased flowing completely. The flow data given for each first order magnitude spring (see individual spring descriptions) reflect the drought-influenced flows. Some springs may reverse flow in response to river water levels. Higher river levels may cause a reversal of flow that introduces river water into the aquifer. Once river levels drop, the spring flow resumes, pumping dark, tannic water until the river water is forced from the aquifer. The appearance of the springs also changed during the drought as river and lake levels declined reducing the size of the spring water body and exposing more sediments along the banks.

Factors affecting quality and quantity of spring water include the distribution of karst features within a springshed, thickness of confining units, soil characteristics, topography, potentiometric surfaces, as well as others. The Florida Geological Survey is currently developing a Geographic Information System (GIS) model to estimate the relative vulnera-

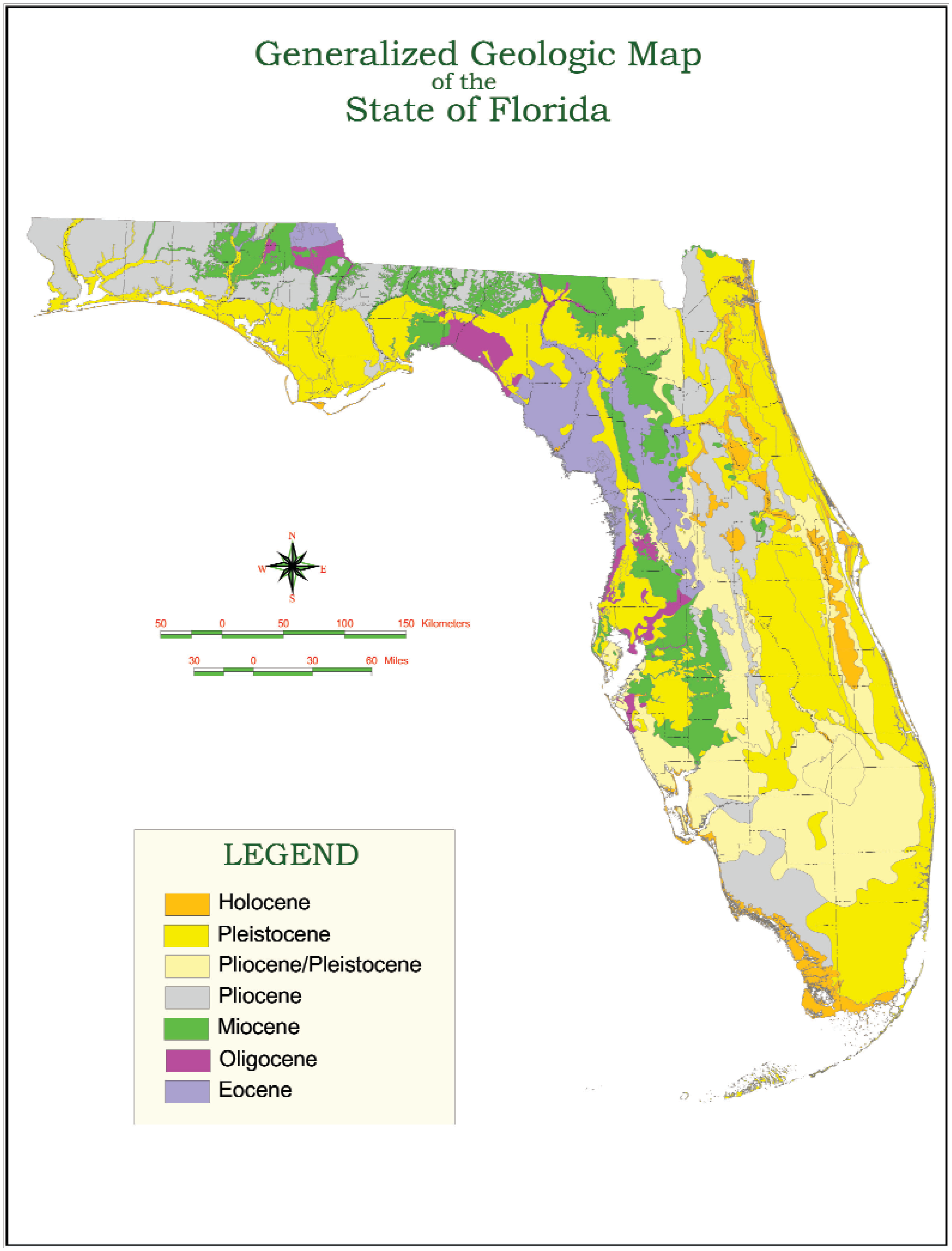

Figure 5. Generalized geologic map of Florida (modified from Scott et al., 2001).

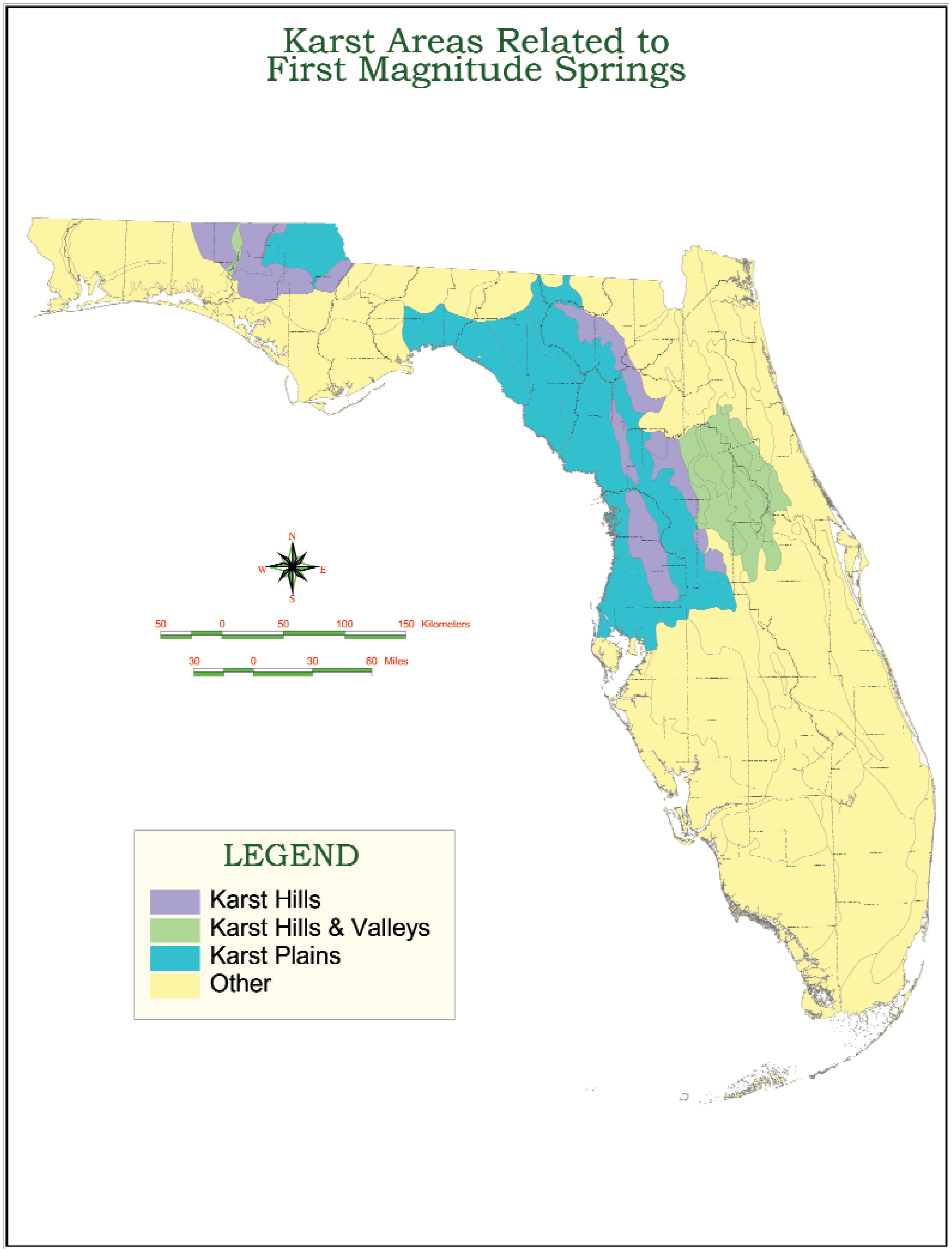

Figure 6. Karst areas related to first magnitude springs (modified from Scott, in preparation).

bility of Florida's aquifer systems: the Florida Aquifer Vulnerability Assessment (FAVA). FAVA uses a statistical method, called Weights of Evidence, to quantify relationships between spatial layers with measured contaminant occurrences. This yields a data-driven predictive model or relative probability map of the aquifer being assessed. The model utilizes many of the following spatial layers: depth to water table, thickness of confining units, soil drainage and spatial distribution of karst features. FAVA will replace a formerly used model and will more accurately define areas that are highly vulnerable to ground-water contamination. FAVA will be a powerful tool for identifying highly vulnerable areas within springsheds and is designed to assist land managers and urban planners in making informed decisions about land use and ground-water resource conservation (Figure 7).

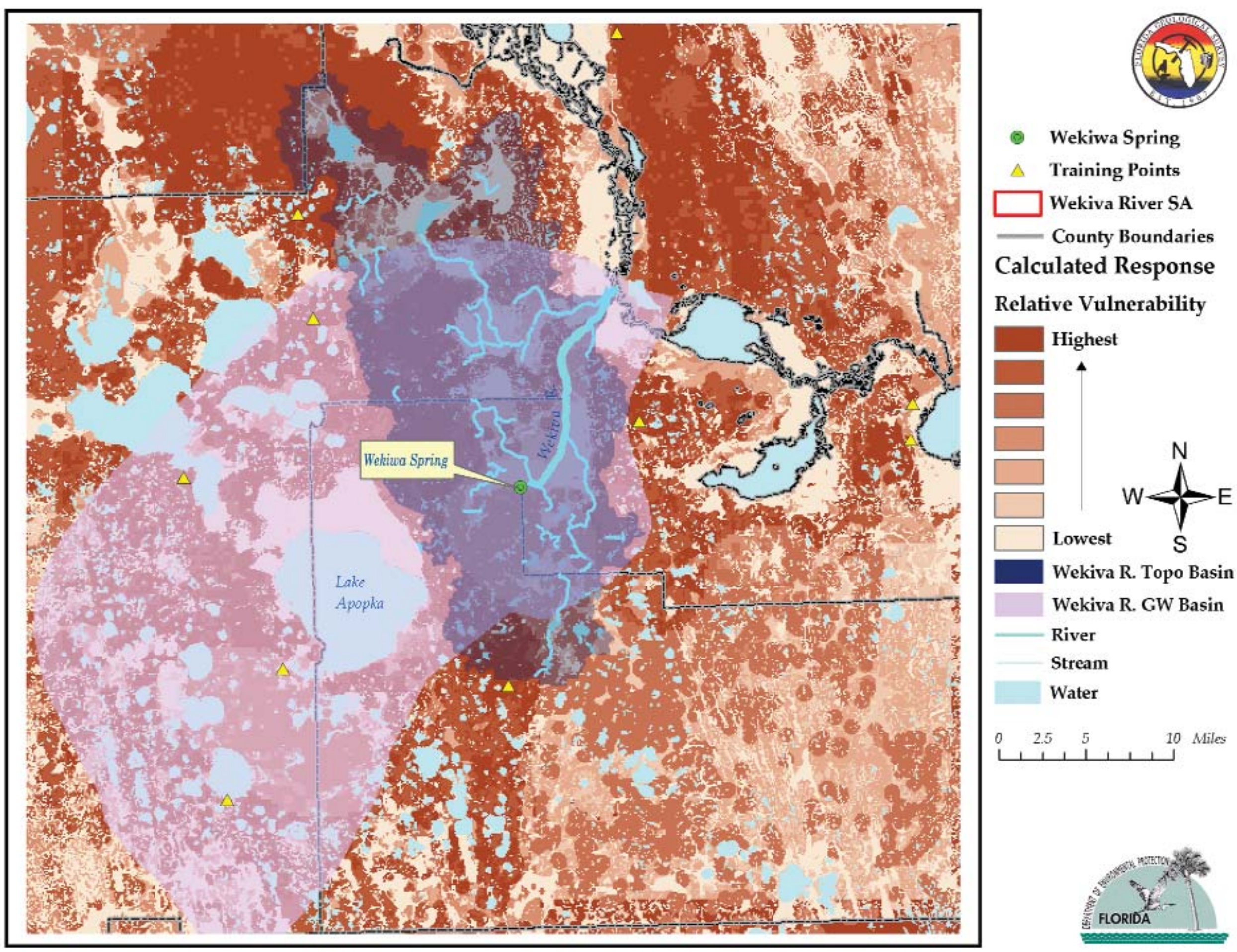

Figure 7. Example of the Florida Aquifer Vulnerability Assessment (FAVA).