INCIDENTS AND CAUSES OF LAND SUBSIDENCE IN THE KARST OF FLORIDA

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Land subsidence has damaged at least 500 homes in Pinellas County (fig. 1) since 1990 according to the county property appraiser. Land subsidence has been attributed to compaction—natural compaction, liquefaction (see Kappel abstract), hydrocompaction, withdrawal of subsurface fluids (for example, see Hanson, Farrar and others, and Pool #1 abstracts); tectonic deformation (see Farrar and others, Morton, Ward and others abstracts); drainage of organic soils; and collapse into subsurface voids—mining and sinkholes (National Research Council, 1991). The Florida Sinkhole Research Institute conservatively estimates that sinkholes alone cause on the order of $10 million in damage each year in the State (Beck and Sayed, 1991). Geotechnical engineers estimate that about 20 percent of the subsidence problems in Florida are caused by sinkholes.

The carbonate rocks that underlie the Florida peninsula to depths of several thousand feet are susceptible to chemical solution by mildly acidic water that percolates through the soil as natural recharge. The development of karst can occur as water acidified by dissolution of carbon dioxide in the soil zone moves down vertical fractures and solution pipes, dissolving limestone all along the way to the water table. Upon reaching the water table, the still slightly corrosive water moves down gradient. Thus, limestone dissolution continues in a thin, nearly horizontal zone just below the water table. As the water table rises and falls, a complex horizontal system of interconnected caves and porous zones is formed. Eventually, the flowing ground water may return to the surface at a lower elevation through a system of springs. By then, the acid in the water has been neutralized, and the spring water is carrying all the lime it can dissolve. The natural rate of denudation of Florida limestone is estimated to be about 1 ft in 5,000 or 6,000 years. Pumping induces recharge and may artificially speed up the rate of denudation to 1 ft in 1,700 years in local areas (Sinclair, 1982).

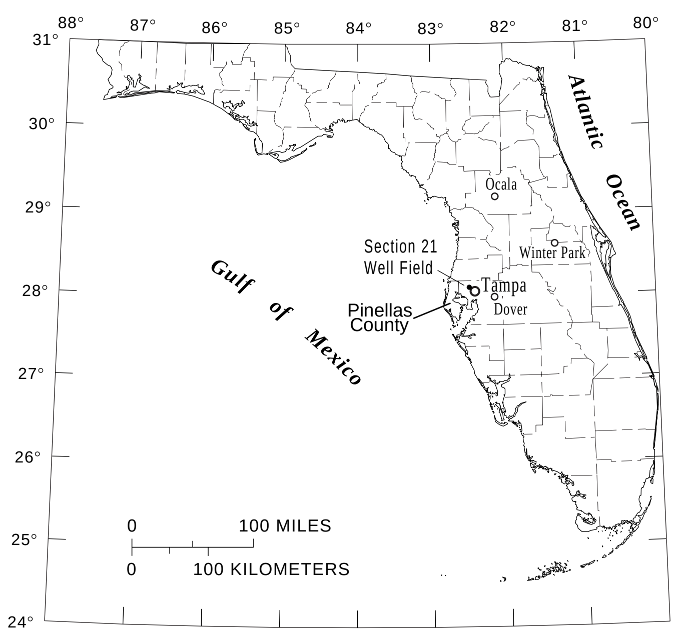

Figure 1. Locations of sinkhole study sites in Florida.

Sinkhole collapse can be triggered by sudden changes in ground-water levels, especially where the limestone aquifer is confined and under artesian pressure. An increase in the pumping rate of 3 million gal/d at the Section 21 well field near Tampa in April 1964 resulted in the formation of 64 new sinkholes within a 1-month period (Beck and Sinclair, 1986). Apparently, the sudden decline in artesian pressure triggered the collapse of cavities whose size had already become critical with respect to their bearing strength and the weight of the overlying overburden. Heavy rains also can trigger sinkholes in a similar way by raising the water table and thus the weight of the overburden with respect to the bearing strength of the limestone. Such an event occurred near Ocala in April 1992 when 12 in. of rain fell within an 8-hour period, triggering the formation of about 200 sinkholes. The effects of raising the water table and lowering the artesian pressure were combined in January 1977 near Dover when strawberry farmers protected their crops from freezing by irrigating with warm ground water. The artesian level of the limestone aquifer declined as much as 60 ft (pressure expressed as equivalent height of water) overnight and the water table rose a few feet, which resulted in reports of 22 new sinkholes.

The most dramatic example of sinkhole activity and damage in the history of the United States was the formation of the huge Winter Park sinkhole in May 1981. At the site, relatively loose sand forms a surficial aquifer about 60 ft thick, and an underlying clay forms an intermediate confining unit about 100 ft thick, above limestone that occurs about 160 ft below land surface. The water table is about 10 ft below land surface and the artesian level of the limestone aquifer is about 110 ft above sea level or about 50 ft below land surface. A cone-shaped sinkhole 40 ft in diameter and 20 ft deep appeared at about 8 p.m. on May 8 and slowly enlarged overnight to a diameter of 80 ft. Between 10 a.m. and noon on May 9, the sinkhole rapidly expanded to 300 ft in diameter and deepened to 110 ft. This sudden increase in activity probably resulted from the complete collapse of the roof of a huge cavern. During the rapid expansion phase, a house, three automobiles, and a municipal swimming pool were funneled into the sinkhole. The funneling of sand was so rapid that, apparently, the turbidity greatly increased the density of water in the sinkhole pool. The water level in the sinkhole formed a pool 10 ft in diameter and 50 ft below the artesian level of the limestone aquifer. The funnel tube was later measured to be 60 ft in diameter. Subtraction of the 10-ft pool indicates that a 25-ft thick ring of sand was flowing downward through the annulus between the edge of the pool and the cylindrical funnel tube. By May 10, the pond level coincided with the artesian level of the limestone aquifer where it remained for 2 weeks despite the water flowing in from the sand aquifer above. Over the next 4 months, sediment gradually plugged the erosion pipe to form a lake 300 ft in diameter. The natural lake resembles thousands of circular sinkhole lakes that dot the landscape of Florida.

A set of fifty-six 35-mm slides that relate to land subsidence in Florida was prepared for presentation at the U.S. Geological Survey Subsidence Interest Group Conference. Many of the slides were provided by Dr. Frank Kujawa of the University of Central Florida and by Dr. Barry Beck of the Florida Sinkhole Research Institute. The slides and accompanying text are available at the U.S. Geological Survey office in Tampa, Florida.