HYDROLOGIC FACTORS AFFECTING SINKHOLE DEVELOPMENT IN A WELL FIELD IN THE KARST DOUGHERTY PLAIN, SOUTHWEST OF ALBANY, GEORGIA

Debbie Warner Gordon

AUTHOR: Hydrologist, U.S. Geological Survey, Georgia Water Science Center, Peachtree Business Center, Suite 130, 3039 Amwiler Road, Atlanta, GA 30360.
REFERENCE: *Proceedings of the 2011 Georgia Water Resources Conference*, held April 11–13, 2011, at the University of Georgia.

Abstract. Sinkhole formation has been an ongoing problem in the karst region southwest of Albany, Georgia, where groundwater withdrawals from the Upper Floridan aquifer occur. Since the initiation of well-field pumping in 2003, more than 23 sinkholes have developed in a recently-constructed well-field area. Although sinkhole formation at the well field is not completely understood, the frequency of development is likely related to the excavation of holding ponds and water-level fluctuations in the Upper Floridan Aquifer greater than 30 feet. Most of the sinkholes (18 out of 23) have formed at the Albany well field since the beginning of 2007 when the water level in one well in the northwest part of the well field oscillated above and below the top of the aquifer on a regular basis. However, no sinkholes formed in 2008.

INTRODUCTION

To provide additional water supply and reduce the demand on deep aquifers, the Albany Water, Gas, and Light Commission (WGL) developed a well field consisting of eight production wells southwest of Albany, Georgia (Fig. 1). Production wells withdraw water from the Upper Floridan aquifer, a limestone aquifer that is the major water-supply source in southwestern Georgia. The Upper Floridan aquifer is overlain by 30 to 60 feet (ft) of sand and clay (undifferentiated overburden), and dissolution of carbonate rocks has resulted in the development of a karst topography where sinkhole formation is common. A detailed description of the geohydrology is presented by Torak and Painter (2006). Since well-field pumping began in 2003, more than 23 sinkholes have formed in the well-field area.

To assess the causes of sinkhole formation and determine if groundwater withdrawals are affecting the frequency of sinkhole development, the U.S. Geological Survey, in cooperation with WGL, conducted hydrologic studies at the well field during 2009–2010. Hydrologic data, including groundwater levels, production-well pumping records, and rainfall were compiled and compared to borehole geophysical, geologic, and video data that provide depth and thickness of hydrogeologic units. All of these data were then related to sinkhole occurrence at the well field.

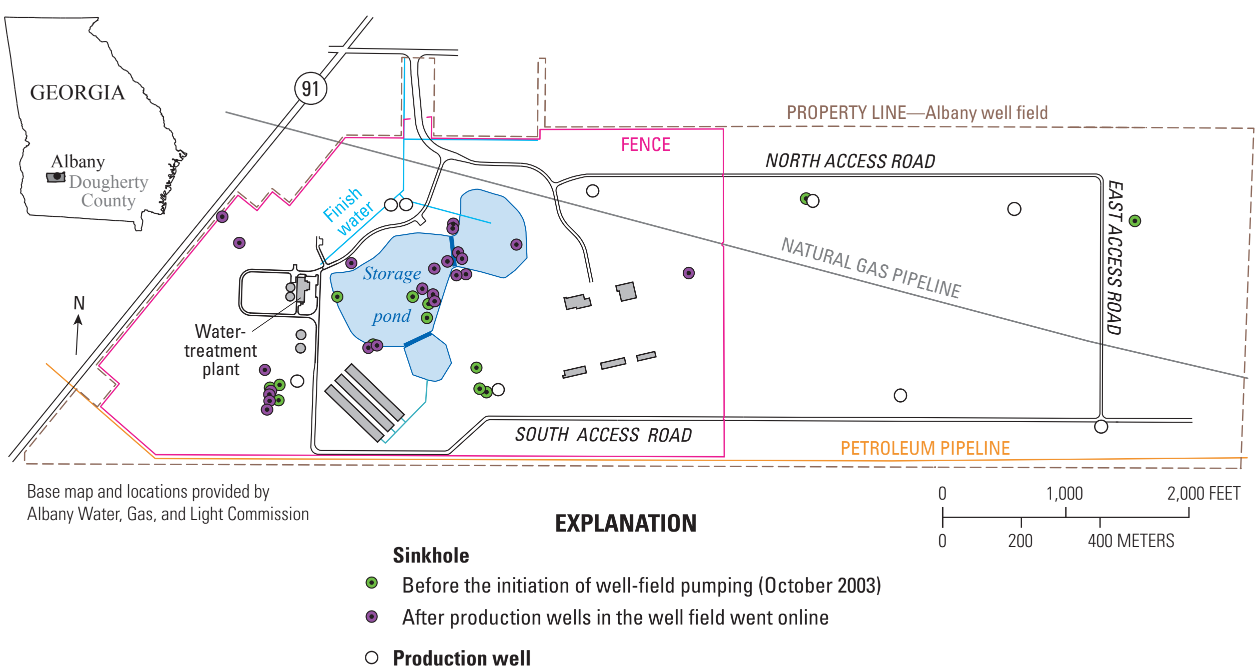

Figure 1. Location of sinkholes and production wells in the Albany well field, Dougherty County, Georgia.

HYDROGEOLOGIC EVALUATIONS

A three-dimensional geologic diagram was created by using depths to hydrologic units and high-permeability zones determined from borehole geophysical logs, borehole video, geologic logs, and geographic information system (GIS) software ArcScene™ (Environmental Systems Research Institute, Inc. [Esri], ArcScene™ 9.3.1; Fig. 2). Borehole data at the well field indicate two zones of high secondary permeability (dissolution features) within the Upper Floridan aquifer ranging from 26 to 66 ft above the National Geodetic Vertical Datum of 1929 (NGVD 29) and 71 to 106 ft above NGVD 29. Each layer in Figure 2 has a vertical exaggeration of 10 times. Space was added between the layers to make each layer easier to see. The software allows the geologic section to be rotated and tilted, to enable viewing from all sides and angles. Similar zones of high secondary permeability were reported for the Upper Floridan aquifer in wells about 2 miles southwest of the well field (Warner, 1997). The zones of high secondary permeability typically are cavernous and may be vulnerable to collapse.

SINKHOLE FORMATION

Sinkholes commonly occur in areas underlain by shallow carbonate aquifers such as the Upper Floridan. The development of land and groundwater resources can increase the frequency of sinkhole formation (Tihansky, 1999). Sinkholes can cause

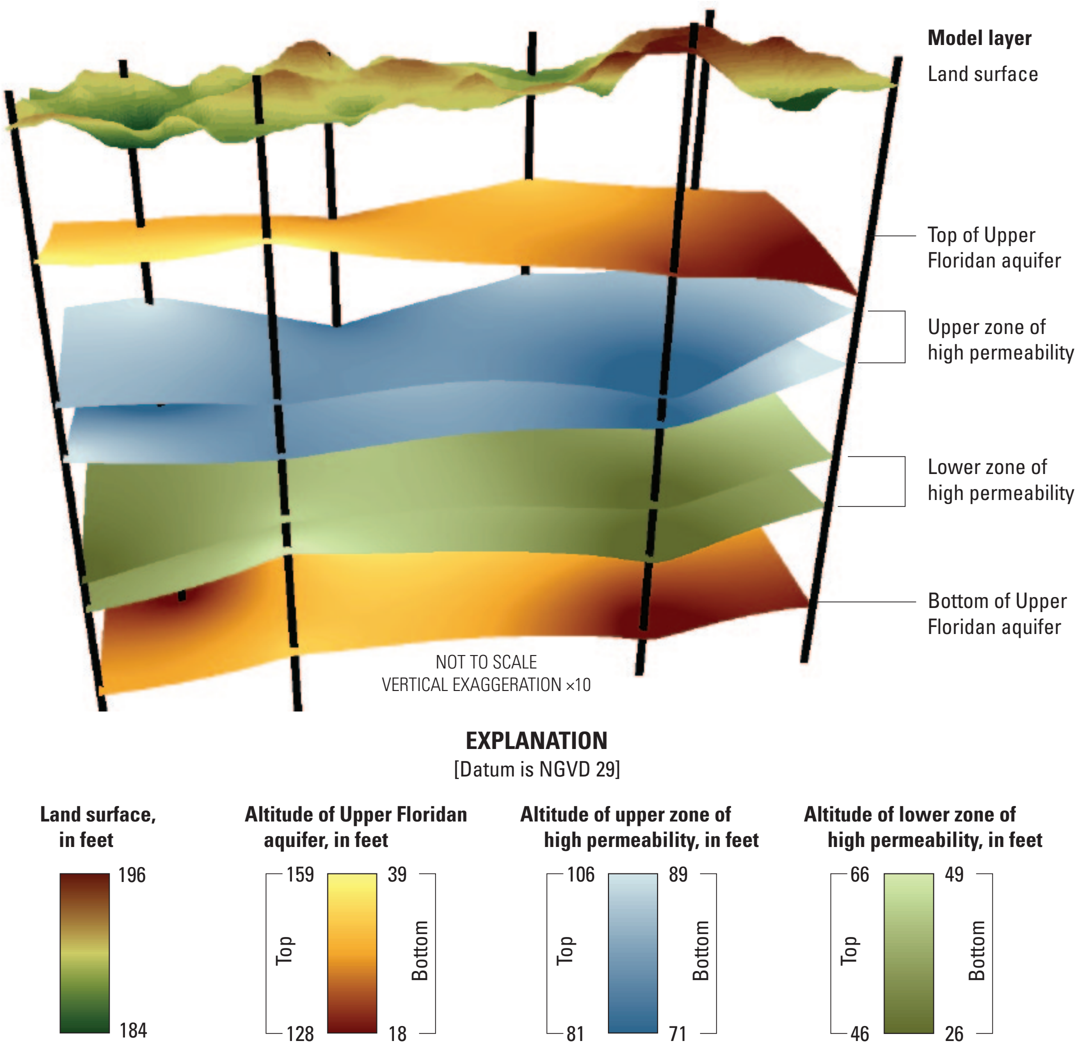

Figure 2. Three-dimensional geologic diagram of the well field. Space was added between each layer for visibility.

property damage and structural problems, and they can create pathways for surface contaminants to enter and degrade the groundwater resources (Tihansky, 1999).

Sinkholes form when overlying material collapses into underlying voids in bedrock. Slightly acidic rainwater percolates vertically into the carbonate rocks through joints and fractures and dissolves the rock, which results in the development of larger voids. When these dissolution features are filled with water, the roof of the void is supported by the buoyancy of the water. When water levels decline below the roof of the cavity, sinkholes often develop as overburden sediments collapse into the cavities.

Increased sinkhole formation may occur when groundwater levels are lowered beyond average levels or when loading at land surface (weight from excess water) increases downward head gradients, increasing recharge (Wilson and Beck, 1992; Tihansky, 1999). Surface loading and rapid or prolonged drawdown associated with groundwater pumping can trigger sinkhole development in karst regions prone to sinkhole activity (Tihansky, 1999). An example of this includes 64 new sinkholes that formed in 1964 within a 1-mile radius of a well field north of Tampa, Florida, within 1 month of nearly tripling the pumping rate (Tihansky, 1999).Wilson and Beck (1992) demonstrated the relation between drawdown and sinkhole formation by comparing the percent frequency of reported sinkhole collapses at any given water level to the percent frequency of that water level. Wilson and Beck (1992) found that sinkholes were 10 times more likely to form when water levels were 10 ft below the statistical mode, or most frequently-measured water level, in the Orlando, Florida area. They also concluded that "Managing consumptive water use to avoid excessive drawdowns in the high recharge areas would minimize sinkhole development induced by human activities."

SINKHOLE MONITORING

A condition of the water-withdrawal permit for the City of Albany well field is the reporting of existing, new, or developing sinkholes to the Georgia Department of Natural Resources Environmental Protection Division (GaEPD) on a quarterly basis (William Frechette, Georgia Department of Natural Resources Environmental Protection Division, written commun., May 18, 2009). WGL personnel record each sinkhole that develops on the well field property and submit a written report to the GaEPD each quarter (Jim Stolze, Albany Water, Gas, and Light Commission, written commun., March 31 and June 30, 2009).

From October 2003 (initiation of well-field pumping) through December 2009, 23 sinkholes developed at the well field (Fig. 1). Most of the sinkholes formed in or adjacent to storage ponds that were excavated during well-field construction. The ponds were excavated 9–14 ft into the undifferentiated overburden. These manmade ponds increase the load on the underlying sediments, which may increase the potential for sinkhole formation (Tihansky, 1999). The cluster of sinkholes southwest of the pond is adjacent to a production well. Sinkholes would form while this well was pumping, so the well has been removed from production. Others were documented farther away but may be linked hydrologically to high permeable zones in the aquifer.

RELATION OF GROUNDWATER LEVELS TO SINKHOLE FORMATION

Sinkholes may form in response to changes in water levels relative to the top of the limestone aquifer or relative to the top of a void in the limestone. A comparison of water levels in well 12L382 during October 2003–December 2009 to the depths to the top of the Upper Floridan aquifer and top of the upper permeable zone shows the relation of sinkhole formation to groundwater levels in the Upper Floridan aquifer (Fig. 3). During October 2003–December 2009, water levels in well 12L382 ranged from 10.8 ft (non-pumping) to 53.17 ft (pumping) below land surface with an average water level of 29.68 ft below land surface. Although two sinkholes formed in both 2003 and 2005, when water levels were almost 20 ft above the top of the aquifer for most of the year, most of the sinkholes at the well field (18 of 23) formed since early 2007 when the water level in well 12L382 oscillated above and below the top of the aquifer on a regular basis. However, no sinkholes formed during 2008, even though water levels and pumping patterns were similar to those during 2007. The formation of sinkholes at the well field is not completely understood, but the frequency of sinkhole occurrence seems to increase when the water level in the Upper Floridan aquifer quickly oscillates above and below the top of the aquifer. It may be possible to reduce the number of new sinkholes by altering pumping at the well field to control groundwater-level fluctuations (Tihansky, 1999).

To further evaluate the relation between groundwater levels and sinkhole formation, a series of maps developed for the period between February 5, 2007, and July 6, 2009, show the potentiometric surface of the Upper Floridan aquifer relative to the top of the aquifer, pumping wells, and sinkhole locations (Fig. 4). Water-level measurements indicate that groundwater levels did not dip below the top of the upper permeable zone during any of the dates studied between February 5, 2007, and July 6, 2009 (Fig. 3). Sinkholes formed at the City of Albany well field when Upper Floridan aquifer water levels were both above and below the top of the aquifer. On February 5, 2007, three sinkholes formed in the western part of the well field when water levels were above the top of the aquifer.

On March 12, 2007, one sinkhole formed in the same general area, but a well was pumping nearby and water levels were below the top of the aquifer. On October 15, 2007, two more sinkholes formed in the same area while two nearby wells were pumping and water levels were greater than 10 ft below the top of the aquifer. No new sinkholes formed at the well field during 2008, even though water-level fluctuations were similar to those during 2007. On January 12, 2009, two sinkholes formed in the west-central part of the well field while a nearby well was pumping, and water levels were below the top of the aquifer. On July 6, 2009, two sinkholes formed on the southwestern part of the well field where water levels were above the top of the Upper Floridan aquifer.

Although sinkhole development does not appear to correlate directly with well-field pumping and Upper Floridan aquifer water levels, data continue to be collected to see if any relations exist. All of the sinkholes that formed in 2007 and 2009 have developed in or adjacent to the storage ponds. Collecting pond water-level data may also indicate a relation between sinkhole development and water levels.

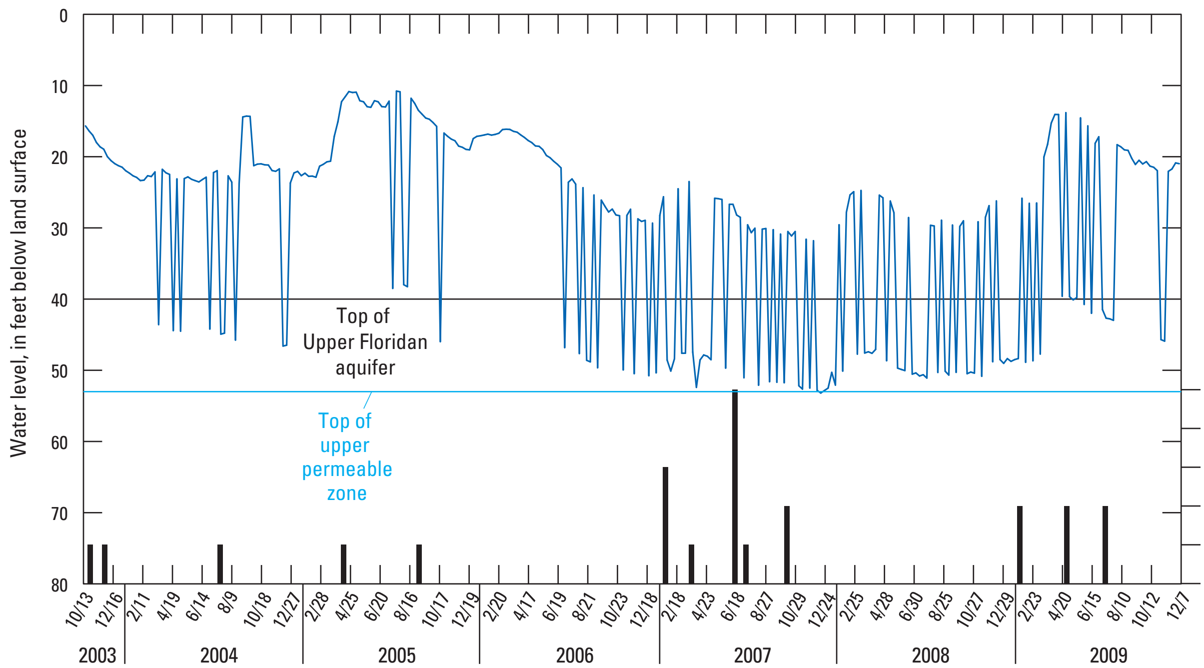

Figure 3. Water-level measurements in well 12L382 with respect to depth to the top of the Upper Floridan aquifer and the top of the upper permeable zone and number of sinkholes reported during October 2003–December 2009. See Figure 4 for well location.

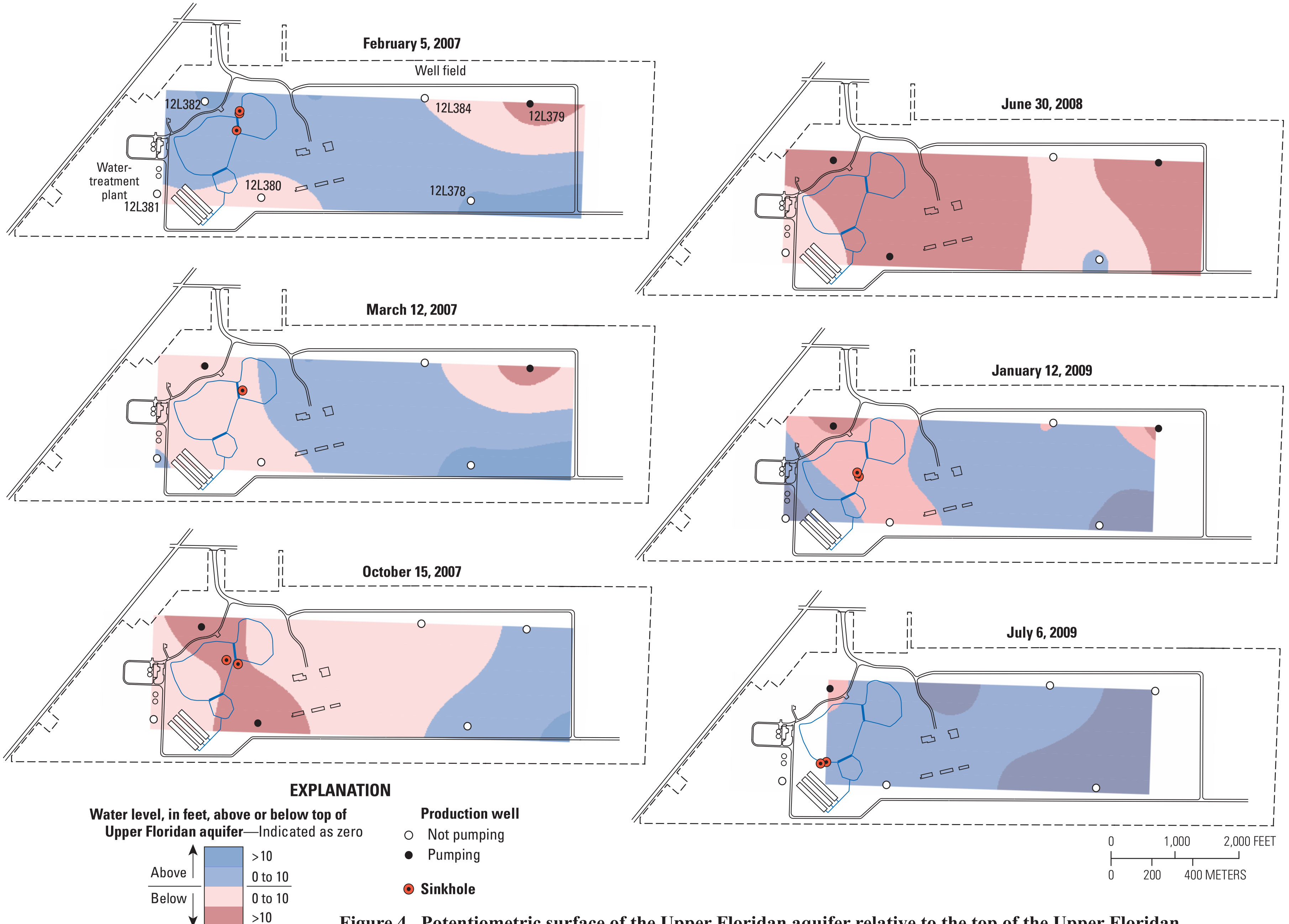

Figure 4. Potentiometric surface of the Upper Floridan aquifer relative to the top of the Upper Floridan aquifer for selected periods at the Albany well field, February 5, 2007, through July 6, 2009.

SUMMARY

Several studies indicate that groundwater-level fluctuations and pond excavation are related to sinkhole formation. At the Water, Gas, and Light well field in Albany, Georgia, sinkholes have developed when groundwater levels oscillate above and below the top of the Upper Floridan aquifer and when water levels remain above the top of the aquifer. Additionally, all of the sinkholes that developed in 2007 and 2009 were adjacent to well-field storage ponds. Continual water-level fluctuations exceeding 20 feet add substantial stress to the hydrologic system. Data continue to be collected, analyzed, and evaluated; and pond water-level data could be added to explain why, when, and where sinkholes develop so that water-supply and water-resources managers can adjust practices to mitigate sinkhole development.

REFERENCES CITED

Tihansky, A.B., 1999, Sinkholes, west-central Florida, *in* Galloway, Devin, Jones, D.R., Ingebritsen, S.E., eds., Land subsidence in the United States: U.S. Geological Survey Circular 1182, p. 121–140.

Torak, L.J., and Painter, J.A, 2006, Geohydrology of the lower Apalachicola–Chattahoochee–Flint River Basin, southwestern Georgia, northwestern Florida, and south-eastern Alabama: U.S. Geological Survey Scientific Investigations Report 2006–5070, 80 p.

Warner, Debbie, 1997, Hydrologic evaluation of the Upper Floridan aquifer in the southwestern Albany area, Georgia: U.S. Geological Survey Water-Resources Investigations Report 97–4129, 28 p.

Wilson, W.L., and Beck, B.F., 1992, Hydrogeologic factors in affecting new sinkhole development in the Orlando area, Florida: Ground Water, v. 30, no. 6, p. 918–930.