COMPUTATION OF LEAKANCE OF THE MIDDLE SEMICONFINING UNIT, FLORIDAN AQUIFER SYSTEM, BERWICK PLANTATION, CHATHAM COUNTY, GEORGIA

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Abstract. Changes in tidal cycle amplitude observed in the Upper Floridan Aquifer during a 72-hour test of the Lower Floridan Aquifer at Berwick Plantation, Chatham County, Georgia were used in conjunction with a ground-water flow model to estimate leakance of the Middle Semiconfiining Unit, between the aquifers. Test discharge was continuous at 718 gallons per minute. Observed water levels in the Upper Floridan Aquifer were influenced by regional pumping and a test-specific drawdown was not obvious. Accordingly, maximum drawdown in the Upper Floridan Aquifer caused by test pumping was estimated by comparing tidal cycle amplitudes prior to and during the test. Maximum amplitude change was about 0.2 feet and was considered the maximum drawdown in the Upper Floridan Aquifer caused by test pumping. This drawdown and site specific hydraulic characteristics of the Upper and Lower Floridan Aquifers were applied to a ground-water flow model to simulate aquifer-test results and estimate Middle Semiconfining Unit leakance. Computed leakance was $5x10^{-8}$ per minute.

INTRODUCTION

Pursuant to obtaining a permit to withdraw water from the Lower Floridan Aquifer at Berwick Plantation, Chatham County, Georgia, the Georgia Environmental Protection Division (GAEPD) required the owners to evaluate the hydraulic characteristics of the Upper and Lower Floridan Aquifers at the well site and to estimate the loss of water from the Upper to the Lower Floridan Aquifer during routine operation of the Lower Floridan Aquifer supply well. Critical to estimating the loss of water from the Upper to the Lower Floridan Aquifer was an accurate determination of leakance of the Middle Semiconfining Unit between the aquifers. Leakance represents the resistance to vertical flow through the confining unit and is dimensioned in terms of inverse time. Leakance can be estimated analytically or by numerical simulation when observed drawdown in the distal aquifer can be directly related to pumping in the stressed aquifer. At Berwick Plantation, the distal aquifer was the Upper Floridan Aquifer and the stressed aquifer was the Lower Floridan Aquifer. Also required by GAEPD was a determination of the hydraulic characteristics of the Upper and Lower Floridan Aquifers at Berwick Plantation. Such characteristics are typically described in terms of transmissivity and storativity, which define the ability of an aquifer to transfer and store water. Transmissivity is defined in units of length squared per time. Storativity is dimensionless. Berwick Plantation is located about 8 miles west-southwest of downtown Savannah, Georgia.

DATA COLLECTION AND ANALYSIS

To determine aquifer characteristics of the Upper Floridan Aquifer at Berwick Plantation a test well was drilled open to the entire interval of the aquifer, approximately 390 to 530 feet (ft) below land surface. An observation well was located 92 feet from the test well, open only to the upper part of the Upper Floridan Aquifer, about 390 to 470 feet below land surface. The finished diameter of the test well was 10 inches. The finished diameter of the observation well was 4 inches. During March 6-7, the test well was pumped at 800 gallons per minute (gpm) for approximately 7 hours and water levels were monitored continuously in both wells during the pumping and recovery phases of the test. Maximum drawdown observed at the test and observation wells was about 6 feet and 3 feet, respectively. Analysis of the time-drawdown and recovery data using Theis nonequilibrium and Theis recovery methods (Krusman and DeRidder, 1983)

indicated a transmissivity of about 46,000 feet squared per day (ft^2/day) and a storativity of about $1x10^{-4}$.

The Upper Floridan Aquifer test well was subsequently drilled to a depth of 1202 feet and left open across the entire interval of the Lower Floridan Aquifer, 718 to 1080 feet. The interval previously open to the Upper Floridan Aquifer was cased and grouted and could no longer contribute water to the well. This Lower Floridan Aquifer test well was pumped continuously at 718 gpm for 72 hours during April 23-26, 2002 and allowed to recover for an equal time during April 26-29. Water levels were monitored continuously during the pumping and recovery phases of the test (Fig. 1) and were analyzed using the Cooper-Jacob single-well test method (Kruseman and DeRidder, 1983). Transmissivity of the Lower Floridan Aquifer at Berwick Plantation was determined to be about 8000 ft^2/day. Head differences between the Upper and Lower Floridan Aquifers at Berwick Plantation during the pumping phase of the test were about 30 feet and leakage from the Upper to the Lower Floridan Aquifer was estimated to occur about 100 minutes after the onset of pumping. Prior to and during the April test of the Lower Floridan Aquifer, water levels were also monitored continuously at the Upper Floridan Aquifer observation well and at USGS observation well 36Q020, also know as the Morrison well (Figs. 2, 3), located about 2 miles from Berwick Plantation.

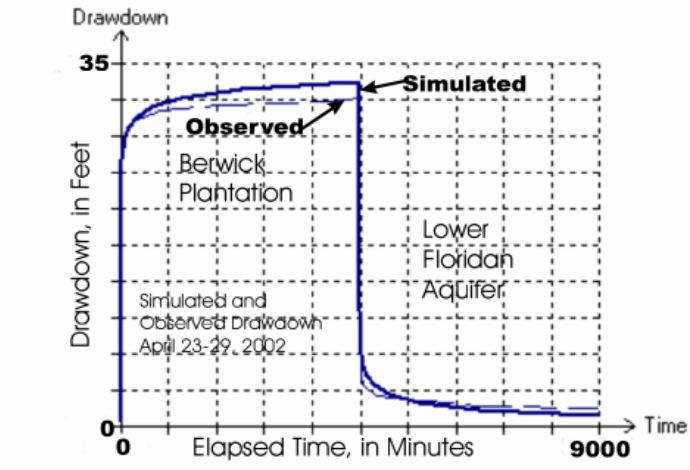

Figure 1. Simulated and observed water levels in the Lower Floridan Aquifer at Berwick Plantation, April 23-29, 2002.

TEST-SPECIFIC DRAWDOWN

Determination of leakance of the Middle Semiconfining Unit required an accurate measurement of test-specific drawdown in the Upper Floridan Aquifer during the pumping phase of the Lower Floridan Aquifer test at Berwick Plantation, April 23-26, 2002. Unfortunately, water levels in the Upper Floridan Aquifer in Chatham County at this time were rapidly declining (Fig. 3), probably as a result of large-scale pumping at and in the vicinity of Savannah. The magnitude of this regional decline in water levels far exceeded the slight changes in Upper Floridan Aquifer water levels at Berwick Plantation caused by the Lower Floridan Aquifer test and prevented a direct observation of test-specific drawdown. Fortunately, remnants of tidal cycle peaks were observed in the water-level record of the Upper Floridan Aquifer observation well at Berwick Plantation during the Lower Floridan Aquifer test (Fig.3). Peaks were identified based on their timing and by comparing phase differences noted between peaks at the Morrison site and at Berwick Plantation prior to the beginning of pumping from the Lower Floridan Aquifer on April 23, 2002 (Fig. 2). Note on Figure 2 that tidal cycle peaks at Berwick Plantation slightly lag peaks at Morrison by about 100 minutes or less. Several peaks between elapsed times 4500 and 5500 minutes are shown to be nearly coincident. The actual phase timing is uncertain because stage measurements at the observation wells were measured at 60-minute intervals. Regardless, the hydrographs shown in Figure 2 indicate a high degree of similarity between tidal cycle peaks and timing at Berwick Plantation and at Morrison.

Water-level data at the Upper Floridan Aquifer observation wells at Berwick Plantation and at Morrison were collected at 5-minute intervals during the pumping and drawdown phases of the Lower Floridan Aquifer test, April 23-29, 2002 (Figs. 2,3). The tidal peak remnants noted on Figure 3 at Berwick Plantation are nearly coincident in time with the peaks measured at Morrison and are almost exactly 720 minutes apart, given a reasonable interpolation of the discrete water-level measurements. Similarly, the earliest peak remnant noted in Figure 3 follows the last tidal peak recorded in the Upper Floridan Aquifer at Berwick Plantation prior to the beginning of the Lower Floridan Aquifer test by about 1440 minutes (Fig. 2). Maximum tidal cycle amplitudes observed in the Upper Floridan Aquifer at Berwick Plantation prior to the April 2002 test of the Lower Floridan Aquifer

were about 0.22 feet (Fig.2). Corresponding amplitudes observed in the Upper Floridan Aquifer at Berwick Plantation during the test and related to the peak remnants described previously are about 0.01 feet or less. This change in amplitude is ascribed totally to pressure changes in the Upper Floridan Aquifer caused by leakage to the Lower Floridan Aquifer during the test and equals slightly more than 0.2 feet. Accordingly, a test-specific drawdown of about 0.2 feet in the Upper Floridan Aquifer at Berwick Plantation was attributed to leakage caused by the Lower Floridan Aquifer test.

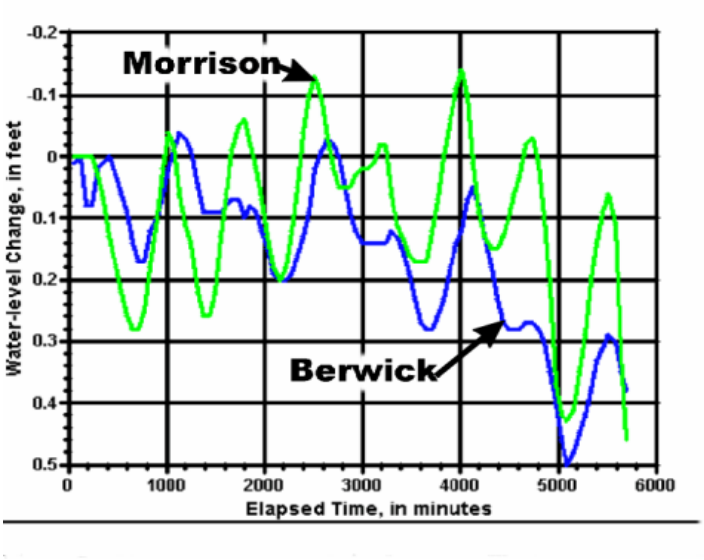

Figure 2. Observed water-level change in the Upper Floridan Aquifer at Berwick Plantation and Morrison prior to the beginning of the Lower Floridan Aquifer test, April 18-23, 2002.

MIDDLE SEMICONFINING UNIT LEAKANCE

To determine the leakance of the Middle Semiconfining Unit, the estimate of test-specific drawdown was used in conjunction with a digital numerical model to simulate the results of the Lower Floridan Aquifer test at Berwick Plantation. Hydraulic characteristics of the Upper and Lower Floridan Aquifers along with geohydrologic framework data acquired during the drilling of the test well at Berwick Plantation were applied to the numerical flow simulator MODFLOW (McDonald and Harbaugh, 1984; Kinzelbach and Chiang, 2001). The MODFLOW grid was constructed as a square with the pumping well at the center. Grid dimensions were variable with the smallest cell located at the center of the grid and the largest cells located at the grid extremities. Model boundaries were assigned as specified head and located about 35,000 feet from the pumping well to minimize boundary influences on simulated results. The Middle Semiconfining Unit was simulated as a quasi three-dimensional layer without storage or horizontal hydraulic conductivity. Water-level response in the observation well open to the Upper Floridan Aquifer to pumping from the Lower Floridan Aquifer occurred less than 100 minutes from the onset of pumping. Model calibration was achieved when water levels observed in the observation well open to the Upper Floridan Aquifer at Berwick Plantation during the March 2002 test and in the Lower Floridan Aquifer during the test of April 2002 test were satisfactorily simulated (Figs. 1, 4). Maximum simulated drawdown in the Upper Floridan Aquifer during the April 2002 test was also required to closely approximate the test-specific drawdown of about 0.2 feet determined from the analyses of tidal cycle records (Fig. 5). Maximum drawdown simulated in the Upper Floridan Aquifer at Berwick Plantation during the April 2002 test was 0.24 feet. Vertical leakance of the Middle Semiconfining Unit was estimated to be 5×10^{-8} /minute.

Simulation of the Semiconfining Unit as a quasi three-dimensional layer tends to underestimate leakance when significant leakage from the confining unit occurs during the aquifer test. Such leakage is indicated by a reduction in the rate-of-change of the time-drawdown relation in the pumped aquifer and an attenuation of the water-level response to pumping in the distal aquifer. Neither condition was observed during the test of the Lower Floridan Aquifer at Berwick Plantation.

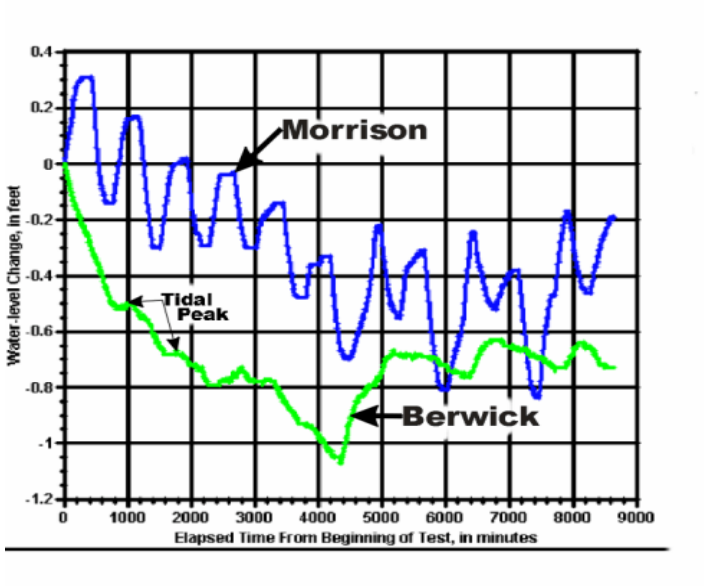

Figure 3. Observed water-level change in the Upper Floridan Aquifer at Berwick Plantation and at Morrison during the Lower Floridan Aquifer Test, April 23-29, 2002.

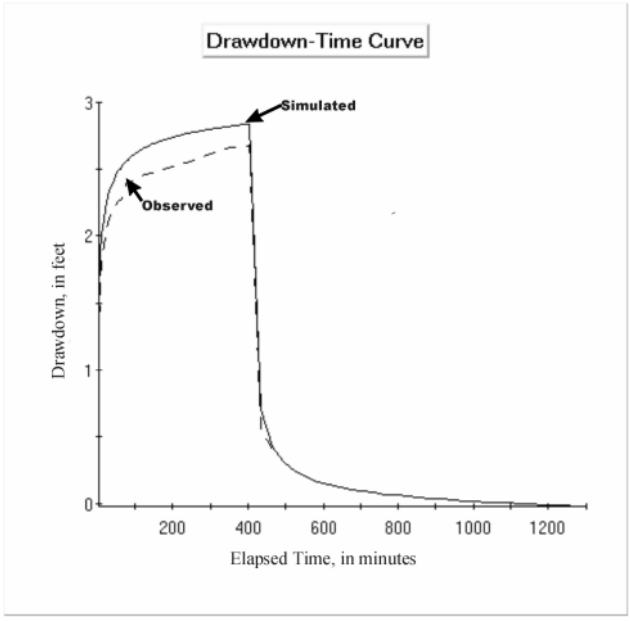

Figure 4. Simulated and observed water levels in the observation well during the Upper Floridan Aquifer test, March 6, 2002.

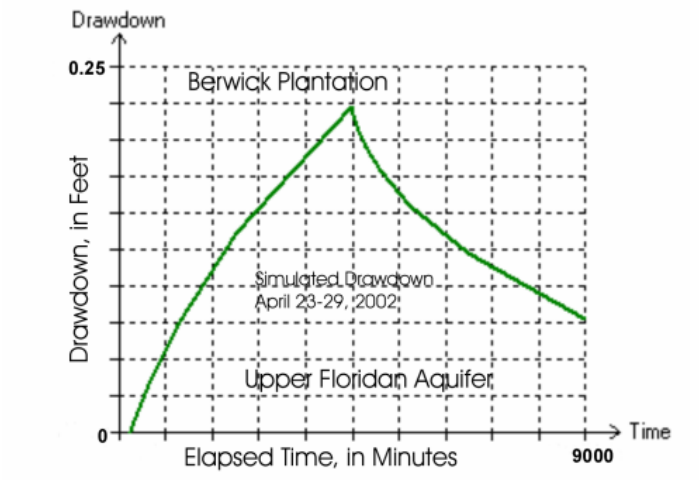

Figure 5. Simulated drawdown in the Upper Floridan Aquifer at Berwick Plantation during the Lower Floridan Aquifer test, April 23-26, 2002.

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