United States Department of the Interior

U. S. GEOLOGICAL SURVEY

Placer Hall, 6000 J St.
Sacramento, CA 95819
Phone: 916-278-3172

February 28, 2006

MEMORANDUM

To: Devin Galloway, Ground-Water Specialist, ORH-Western Region

From: Doug Maurer, Hydrologist, Nevada WSC

Keith J. Halford, Ground-Water Specialist, California WSC

Subject: AQUIFER TESTS—Analysis of multiple-well, aquifer test, Carson Valley, Nevada

Pumping from an isolated well south of the Carson Valley airport, Nevada (Figure 1) was analyzed as an aquifer test. Hydraulic conductivity and vertical anisotropy of alluvial fill from 0 to 400 ft below land surface were estimated. The aquifer test was 365 days in duration and started on January 1, 2005 and ended on December 31, 2005. Water supply and ground-water management models were constrained with results from this aquifer test.

Figure 1.—Location of wells for aquifer test in Carson Valley, Nevada.

SITE

The aquifer test occurred southeast of the Minden airport in Carson Valley, Nevada (Figure 1). The alluvial fill was comprised of gravel, sand, silt, and clay intervals from 0 to 410 ft below land surface. Clay predominated in units more than 400 ft below land surface (Figure 2). This contact was the base of the aquifer.

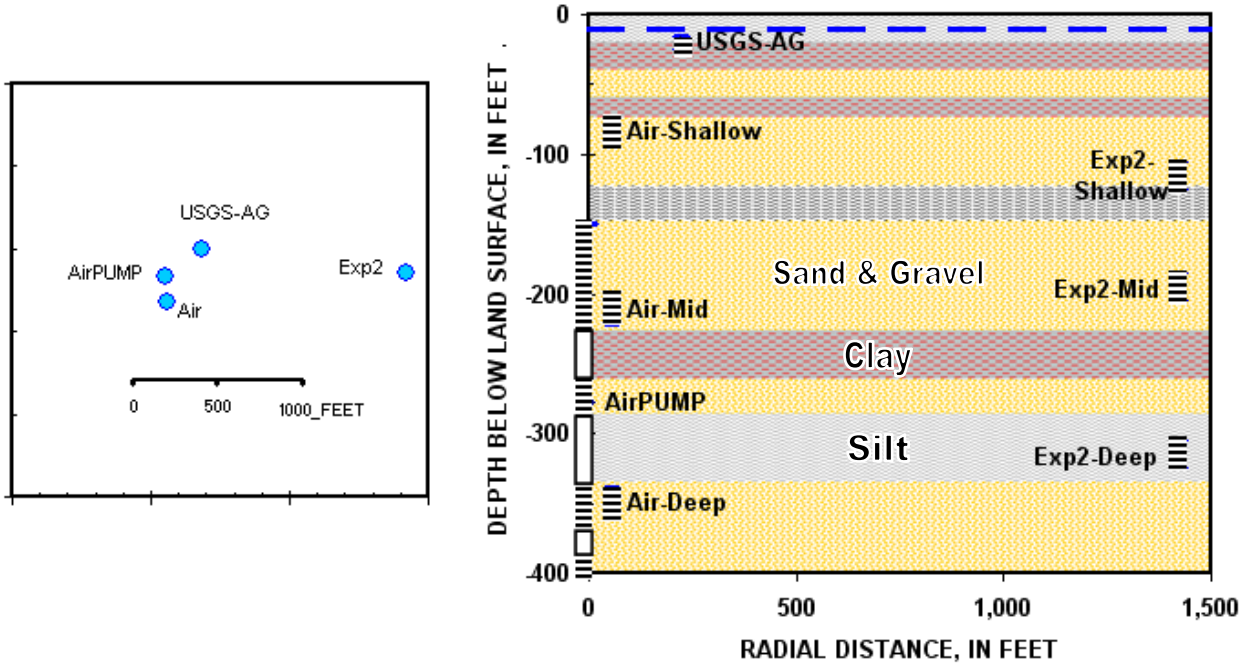

Figure 2.—Plan view and radial section of wells used in aquifer test.

PROCEDURES

A production well and seven observation wells were used for the aquifer test (Table 1, Figure 1). Water levels and pumping rates were monitored continuously in the production well during 2005 (Figure 3). Water levels were measured periodically in observation wells and typically were measured when the AIRPUMP well was not pumping (Figure 4). Water levels in observation wells were measured under pumping conditions during the summer because pumping did not cease.

Table 1.—Location and construction of wells used in Carson Valley airport, Nevada aquifer test.

[All values in feet]

WELL	Site ID	Latitude	Longitude	Static Water Level	Total Depth Drilled, BLS	Top of Screen	Bottom of Screen
AirPUMP	385926119451201	38°59'26"	119°45'12"	**10.0**	**470**	**150**	**405**
Air-Shallow	385926119451103	38°59'26"	119°45'12"	**10.0**	**93**	**73**	**93**
Air-Mid	385926119451102	38°59'26"	119°45'12"	**10.0**	**221**	**201**	**221**
Air-Deep	385926119451101	38°59'26"	119°45'12"	**10.0**	**359**	**339**	**359**
USGS-AG	385927119451201	38°59'27"	119°45'09"	**10.0**	**25**	**15**	**25**
Exp2-Shallow	385927119445603	38°59'27"	119°44'54"	**10.0**	**125**	**105**	**125**
Exp2-Mid	385927119445602	38°59'27"	119°44'54"	**10.0**	**205**	**185**	**205**
Exp2-Deep	385927119445601	38°59'27"	119°44'54"	**10.0**	**325**	**305**	**325**

Volumes of produced water were monitored with an in-line, totalizing flow meter at 10-minute intervals. Weekly discharges from the AIRPUMP well that ranged between 0 and 1,300 gpm (Figure 3) were analyzed.

Drawdowns had large uncertainties compared to average weekly pumping rates because instantaneous discharges ranged between 0 and 1,400 gpm (Figure 3). Drawdowns were estimated relative to water-levels measured in late December 2005.

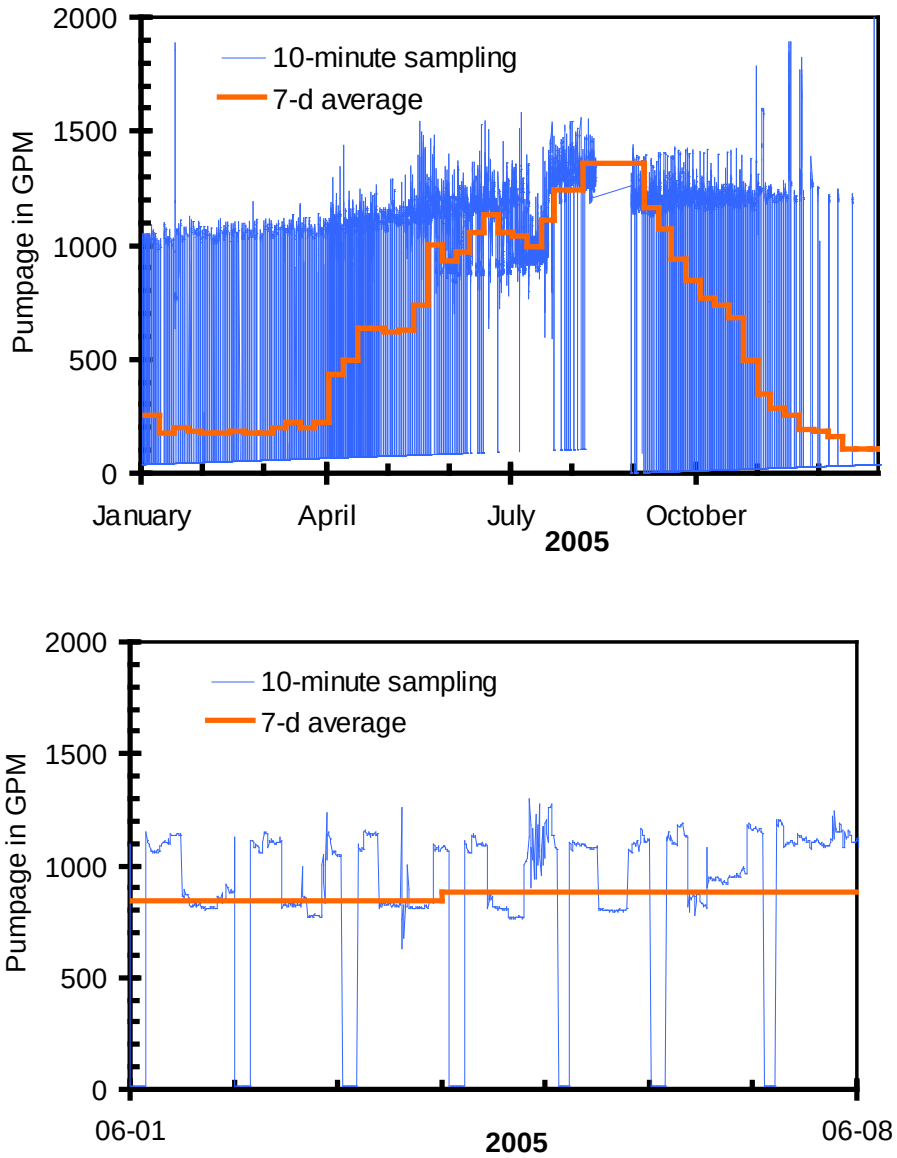

Figure 3.—Pumping changes during the Minden-airport aquifer test.

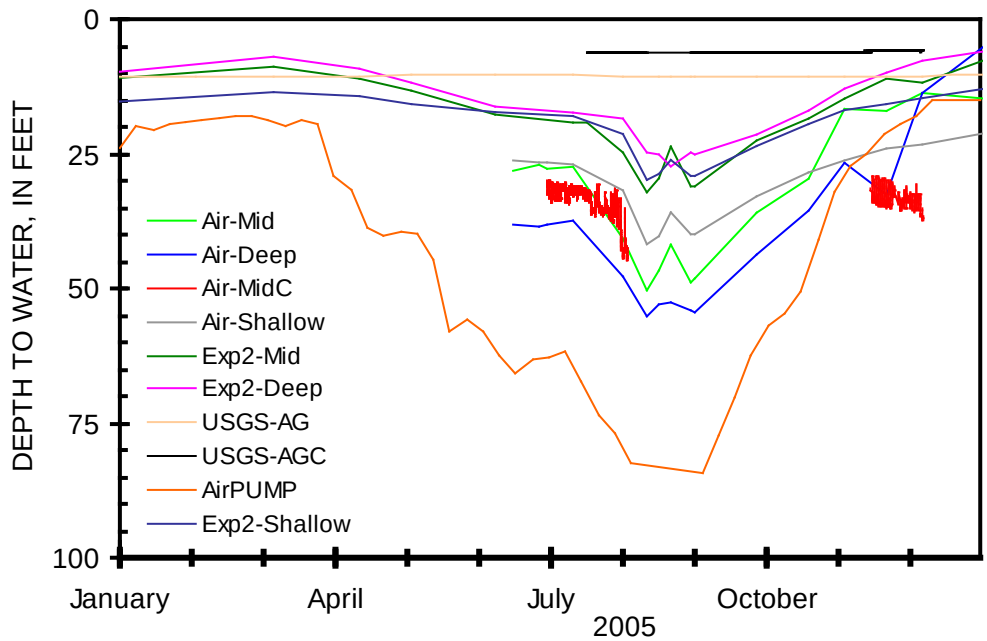

Figure 4.—Water levels during 2005 that were analyzed in the Minden-airport aquifer test.

ANALYSIS

The hydraulic properties of the geohydrologic column were estimated for 3 lithologies (Figure 2) by minimizing differences between simulated and measured drawdowns. Drawdowns were simulated with a two-dimensional, radial MODFLOW model (McDonald and Harbaugh 1988; Harbaugh and McDonald, 1996). Parameter estimation was performed by minimizing a weighted sum-of-squares objective function with MODOPTIM (Halford, 2006).

The production well and aquifer system were simulated with an axisymmetric, radial geometry in a single MODFLOW layer. Radial distance increased with increasing column indices and depth increased with increasing row indices. Hydraulic conductivities and storages of the ith column were multiplied by $2\pi r_i$ to simulate radial flow where r_i was the distance from the outer edge of the first column to the center of the ith column.

The model extended from a production well to more than 200,000 ft away and from the water table to 280 ft below land surface. The model domain was discretized into a layer of 73 rows of 89 columns (Figure 4). Cell widths ranged from 0.2 ft adjacent to the production well to 25,000 ft in the farthest column. Vertical discretization was a uniform 1 m. All external boundaries were specified as no-flow. Changes in the wetted thickness of the aquifer were not simulated because the maximum drawdown near the water table was small relative to the total thickness. Weekly discharges from the AIRPUMP well were simulated with 49 stress periods. Initial heads were specified as 0.

The production well was simulated as a high conductivity zone with vertical conductances multiplied by 10^7. Water was removed from the uppermost node in a well and MODFLOW was allowed to apportion inflow to the well. Wellbore storage associated with the production well was not simulated and was addressed by not comparing the first 5 minutes of drawdowns during a test.

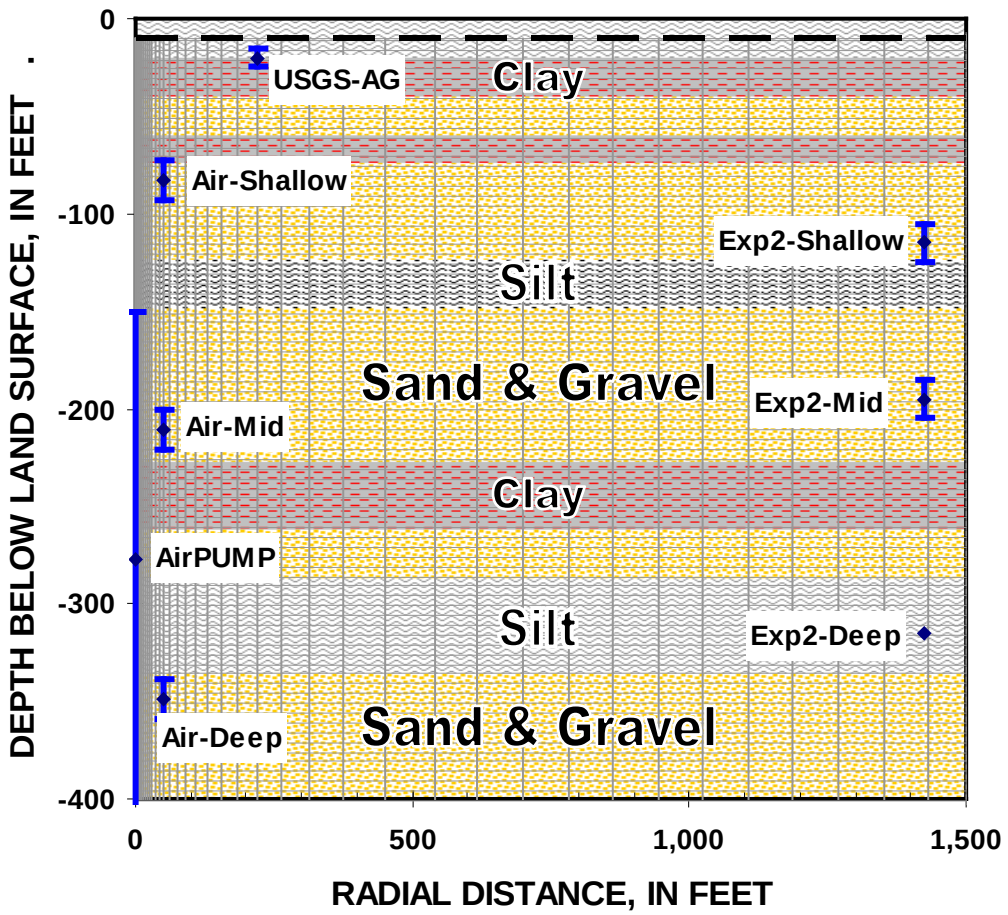

Figure 5.—Radial cross-section about the AIRPUMP well that shows model grid.

HYDRAULIC PROPERTY ESTIMATES

The hydraulic properties of the geohydrologic column were defined with seven parameters, the horizontal hydraulic conductivity of sand & gravel, silt, clays shallower than 100 ft below land surface, and clays deeper than 100 ft below land surface. A uniform vertical–to-horizontal anisotropy was assigned from the water table to the base of the aquifer. Specific storage and specific yield were assumed to be uniform throughout the geohydrologic column and was defined with a single parameter. Parameter estimation was limited to the horizontal hydraulic conductivities.

Simulated drawdowns matched measured drawdowns reasonably well (Figures 6, 7, and 8). The RMS error was 1.2 ft relative to measured drawdowns of more than 70 ft.

Transmissivity of the alluvial fill was 7,300 ft^2/d. Hydraulic conductivity estimates ranged from 0.0004 to 30 ft/d (Table 2). Weekly averages of highly variable pumping rates masked many transient responses so specific storage, and specific yield could not be estimated. Vertical–to-horizontal anisotropy was not estimated either because it is usually correlated with specific yield. Reasonable vertical–to-horizontal anisotropy, specific storage, and specific yield values for alluvial sediments were assigned (Table 2).

Table 2.—Parameter estimates and relative sensitivities of the hydraulic properties that were estimated and assigned in the Carson Valley airport model.

[--, value assigned, relative sensitivity not computed.]

Hydraulic Property	Estimate	Relative Sensitivity
Hydraulic conductivity, Silt, ft/d	0.4	0.05
Hydraulic conductivity, ShallowClay, ft/d	0.0004	0.08
Hydraulic conductivity, Sand&Gravel, ft/d	30	1.00
Hydraulic conductivity, Clay, ft/d	0.02	0.01
Vertical-to-horizontal anisotropy, d'less	0.2	--
Specific Storage, 1/ft	0.000002	--
Specific Yield, d'less	0.05	--

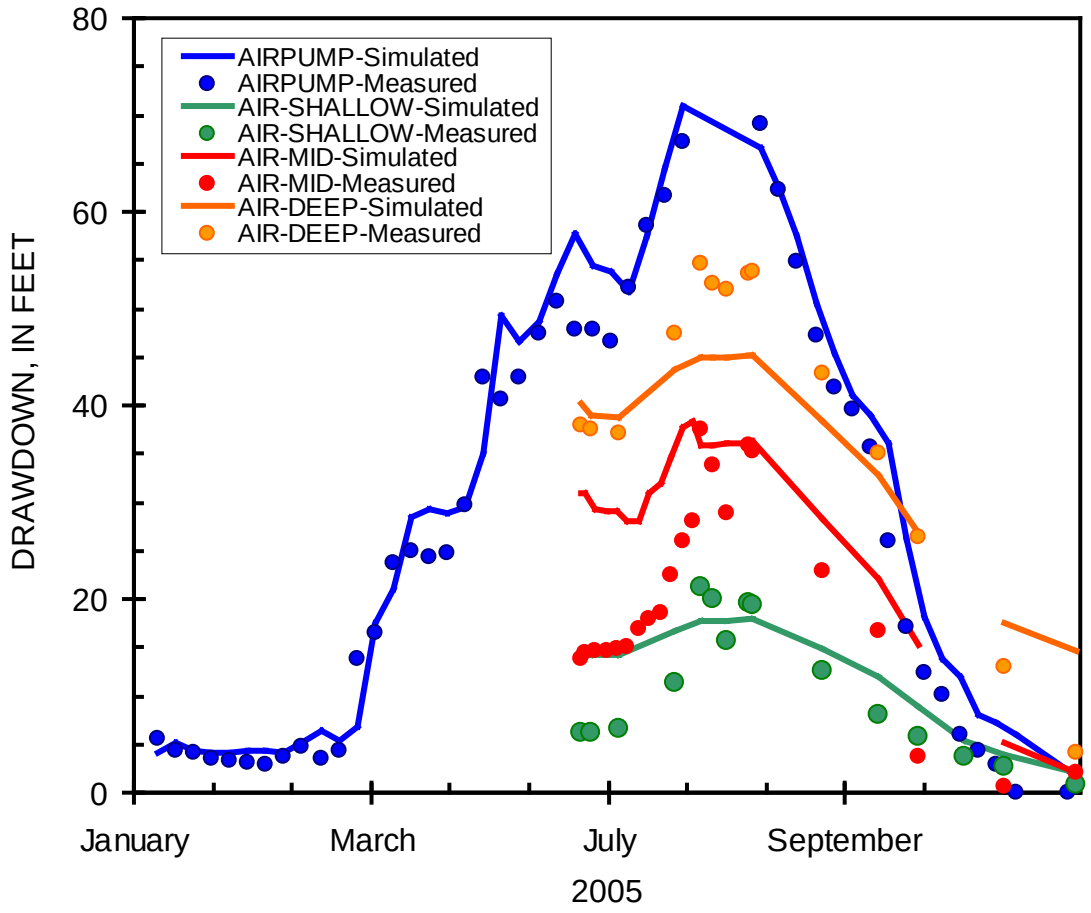

Figure 6.—Measured and simulated drawdowns the AIRPUMP, AIR-SHALLOW, AIR-MID, and AIR-DEEP wells during 2005.

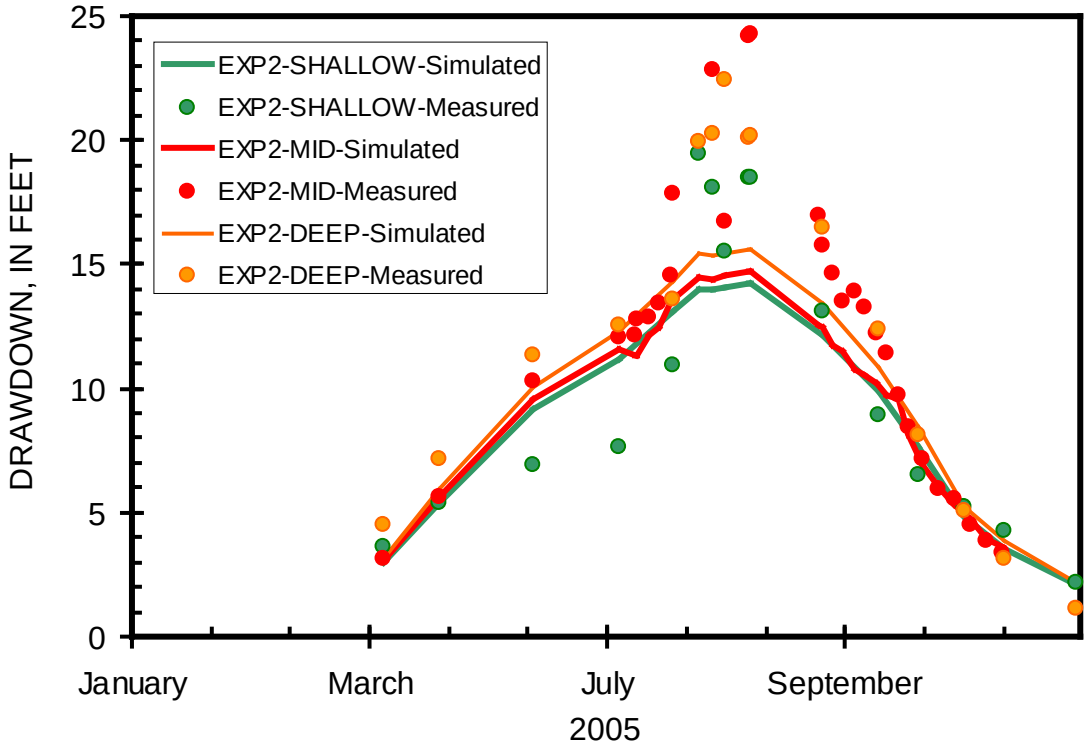

Figure 7.—Measured and simulated drawdowns in the EXP2-SHALLOW, EXP2-MID, and EXP2-DEEP wells during 2005.

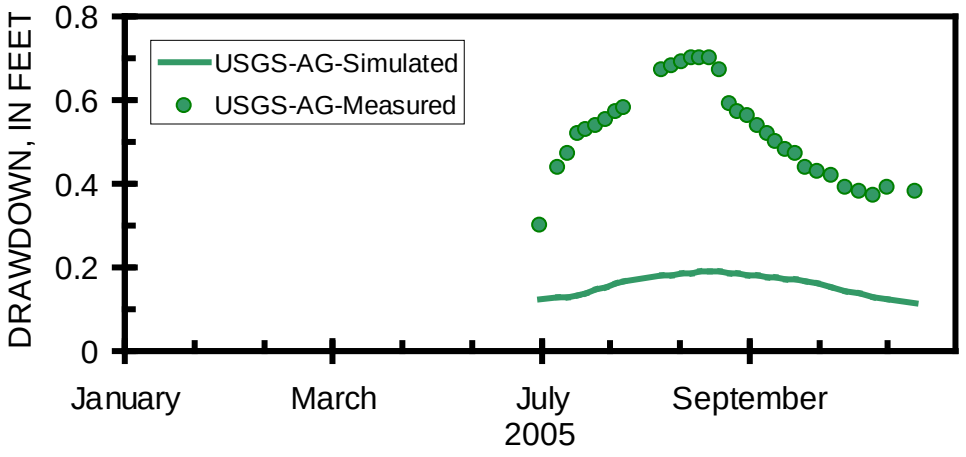

Figure 8.—Measured and simulated drawdowns in the USGS-AG well during 2005.

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