U.S. Department of the Interior
U.S. Geological Survey

Prepared in cooperation with the
Albuquerque Bernalillo County Water Utility Authority

Scientific Investigations Map 3305

Abstract

The City of Albuquerque, the major population center in New Mexico, underwent a more than fivefold population increase between 1950 and 2010. Before 2009, groundwater was the primary source of the City of Albuquerque's municipal water supply, but since that time, the city has diverted water through the San Juan-Chama Drinking Water Project to augment municipal water supplies. Consequently, there is interest in understanding how groundwater levels changed in response to groundwater pumping, surface-water diversions, and conservation measures. To give a more detailed history of water-level changes from 1950 through 2012, the U.S. Geological Survey, in cooperation with the Albuquerque Bernalillo County Water Utility Authority, created maps showing water-level contours and changes by contouring water-table elevations and production-zone hydraulic heads that were simulated with a recently updated regional-scale transient groundwater-flow model at 10-year intervals from 1950 to 2000 and again for 2008.

Both the water-table elevations and production-zone hydraulic heads declined over time with the largest change occurring between 1970 and 1980, which was a period of rapid population growth and groundwater use. Declines in the water-table elevations and production-zone hydraulic heads are focused around major pumping centers and are largest in the production zone. Hydrographs from nine production-zone piezometers in the modeled area indicated varying responses to the increased use of surface-water diversions during 2009–12, with responses related to the locations of the wells within the study area and their proximity to pumping centers and the Rio Grande.

Introduction

The Albuquerque metropolitan area (study area), located in the Middle Rio Grande Basin of central New Mexico (fig. 1), relied almost exclusively on groundwater resources of the Santa Fe Group aquifer system for its water supply over the past several decades. Rapid development over this time period is indicated in a more than fivefold increase in the population (from 96,815 to 545,852) of the City of Albuquerque (Albuquerque) between 1950 and 2010 (fig. 2) (U.S. Census Bureau, 2010). Accompanying this population growth has been an increase in demand on the groundwater of the Santa Fe Group aquifer system that has resulted in water-level declines across the study area (fig. 2) (Bexfield and Anderholm, 2002; Falk and others, 2011).

Several investigations to improve understanding of the hydrology of the Middle Rio Grande Basin and the Santa Fe Group aquifer system have been conducted since the 1990s. These investigations have shown that the extent of the highly productive parts of the aquifer is less widespread than previously thought (Hawley and Haase, 1992; Thorn and others, 1993) and that the water users in the study area have consistently withdrawn groundwater in excess of natural recharge (Bartolino and Cole, 2002). Predevelopment (pre-1950 for the purposes of this report) hydraulic gradients in the study area east of the Rio Grande were oriented roughly northeast to southwest following the axis of the Rio Grande in the center of the basin. More recent investigations, such as Falk and others (2011), indicated that hydraulic gradients are now directed towards pumping centers in the eastern, western, and northern parts of the study area.

The Albuquerque Bernalillo County Water Utility Authority (ABCWUA) has addressed water-level declines through a number of actions to achieve a sustainable water supply, including augmenting the groundwater supply with surface water, enacting conservation measures to reduce per capita water use, retaining the current groundwater supply as a drought reserve, and performing targeted recharge to the groundwater system during periods of low demand (Albuquerque Bernalillo County Water Utility Authority, 2007). With the completion of the San Juan-Chama Drinking Water Project diversion infrastructure on the Rio Grande in December 2008 (Albuquerque Bernalillo County Water Utility Authority, 2009), the ABCWUA began diverting and treating surface water for delivery to Albuquerque water customers, thus reducing reliance on groundwater. Consequently, there is interest in understanding how groundwater levels changed in response to groundwater pumping, surface-water diversions, and conservation measures.

To give a more detailed history of water-level changes from 1950 through 2012, the U.S. Geological Survey (USGS), in cooperation with the ABCWUA, created maps showing water-level contours and changes by contouring water-table elevations and production-zone hydraulic heads that were simulated with a recently updated regional-scale transient groundwater-flow model (Bexfield and others, 2011) at 10-year intervals from 1950 to 2000 and again for 2008.

Examination of simulated and measured water-level changes over decadal time scales can provide better understanding of how variables such as groundwater withdrawal rates, spatial distribution and depth of supply wells, and trends in water demand affect the Santa Fe Group aquifer system. This information may inform the development of strategies for maintaining a sustainable groundwater reserve in the future.

Purpose and Scope

This report describes changes in water levels over 10-year intervals in the study area from 1950 and 2000 and again for 2008 as simulated by a recently updated regional-scale transient groundwater-flow model (Bexfield and others, 2011) in both the water table and the production zone (the depth interval where most groundwater withdrawal occurs). Some previous studies have described water-level changes from estimated pre-1960 values to 2002 (Bexfield and Anderholm, 2002) and from estimated pre-1960 values to 2008 (Falk and others, 2011) based on manual measurements of water levels, whereas this report provides a history of spatial and temporal water-level changes across the study area on a decadal scale. Hydrographs from nine study area production-zone piezometers were compared to the model results from 2000 to 2008 and were examined to determine water-level responses during 2009–12 to the reduction in groundwater withdrawal after beginning deliveries of San Juan-Chama Drinking Water Project surface water to the Albuquerque area in December 2008.

Description of Study Area

The study area is located in the Middle Rio Grande Basin (fig. 1), which is part of a larger structural rift valley that extends from southern Colorado to northern Mexico. The basin is bounded by faults on the east and west, which uplift primarily Precambrian basement rocks on the east and Paleozoic sedimentary and Cenozoic volcanic rocks on the west to form the basin margins (Hawley and others, 1995). The basin margins slope down towards the Rio Grande inner valley (the historical flood plain) from the east and west, with the Rio Grande running through the center of the basin from north to south. The Middle Rio Grande Basin is defined hydrologically as the extent of the Cenozoic sediments—primarily composed of sand, gravel, silt, and clay—that make up the Santa Fe Group aquifer system (Thorn and others, 1993). The Santa Fe Group aquifer system is generally unconfined in the study area but is semiconfined at depth because of interbedded fine-grained layers (Bexfield and others, 2011). Recharge to the Santa Fe Group aquifer system is primarily from mountain-front recharge on the basin margins, from subflow entering from adjacent basins to the north, and from leakage from the Rio Grande (Anderholm, 2000; McAda and Barroll, 2002).

Wells installed in the early 1900s were hand dug and located in the inner valley near the Rio Grande. As Albuquerque expanded with population increases in the 1920s and 1930s, new wells were installed into deeper groundwater reserves (Thorn and others, 1993). Annual withdrawal of groundwater for Albuquerque peaked in 1989 at nearly 127,000 acre-feet (fig. 2); since then, withdrawal has been generally decreasing, even with increasing population (fig. 2), in part because of conservation methods reducing per capita usage (Albuquerque Bernalillo County Water Utility Authority, 2009). To further reduce groundwater withdrawals and therefore mitigate continued water-level declines, Albuquerque developed a surface-water treatment and delivery system to use water from the San Juan-Chama Drinking Water Project (Albuquerque Bernalillo County Water Utility Authority, 2009). Although surface-water use is increasing and is projected to meet most of the future demand of Albuquerque, groundwater continues to be the primary source of public supply to the remainder of the Middle Rio Grande Basin (Bexfield and others, 2012).

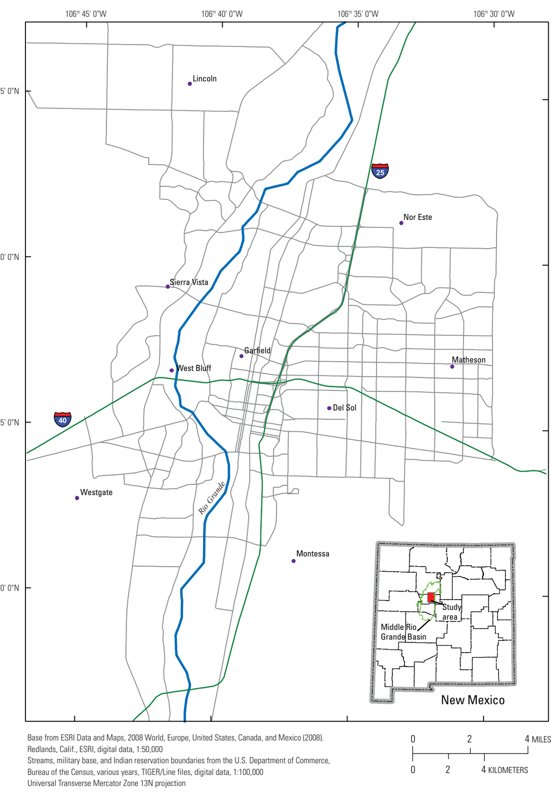


Figure 1. Study area of the Albuquerque metropolitan area, New Mexico.

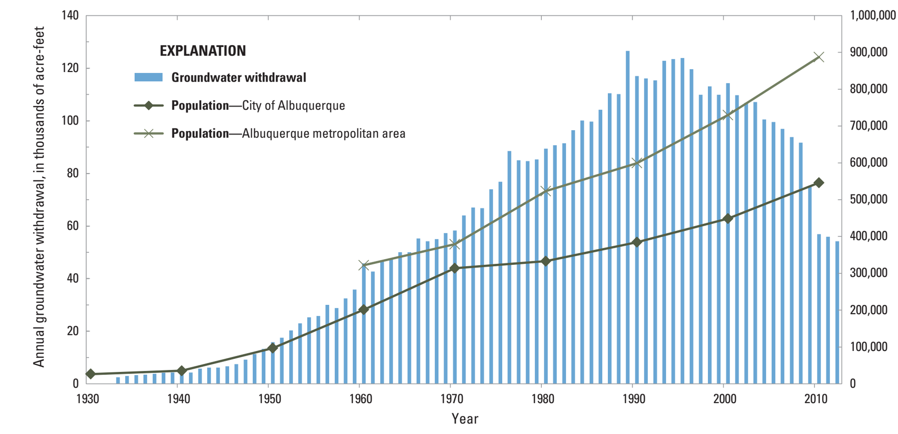


Figure 2. City of Albuquerque (1930–2010) and Albuquerque metropolitan area (1960–2010) populations and annual City of Albuquerque groundwater withdrawals (1933–2012), New Mexico.

Methods for Estimating Water-Level Contours and Change Since Steady-State Conditions in the Water Table and Production Zone

Water-table elevations and production-zone hydraulic heads (the elevation to which water will rise in a well completed in a confined aquifer) were simulated by using a regional-scale transient groundwater-flow model of the Middle Rio Grande Basin (Bexfield and others, 2011) and were compared to the steady-state conditions of the model, defined as the year 1900. Although the model covers the entire basin, the study area was limited to the Albuquerque metropolitan area (fig. 1). The model comprises nine layers extending from post-Santa Fe Group alluvium to the basement rock underlying the Santa Fe Group aquifer. Layers 1–4 can be represented under confined or unconfined conditions depending on the location in the study area and groundwater withdrawal scenario being modeled. Water-table elevations were simulated in layers 1–3 of the model depending on the location in the study area, and layer 5 generally is representative of the production zone. The accuracy of the model simulations was determined by comparing model results to measured water levels at several sites within the study area; measured and simulated water levels were generally within 16 feet (ft) of one another. Additional information regarding model calibration and uncertainty is described in Bexfield and others (2011).

Estimating Water-Table Elevations and Production-Zone Hydraulic Heads

Simulated water-table elevations and production-zone hydraulic heads were output from the model in 10-year intervals from 1950 to 2000 and again for 2008 in a tabular point format, in which each data value represents one cell center in the model. Point output values from the model simulations of the mostly 10-year intervals of both water-table elevations and production-zone hydraulic head were then imported into ArcMap 10.1 (Environmental Systems Research Institute, Inc., 2012), and rasters were created for each interval by using the Inverse Distance Weighted (IDW) interpolation tool. IDW is an exact interpolation technique, in which the raster is constrained by the provided values so that the minimum and maximum values of the interpolated raster correspond to actual values. The interpolated rasters of simulated water-table elevations and production-zone hydraulic heads across the study area were then contoured to delineate areas of equal elevation and head. Contours were generated at 20-ft intervals in ArcMap 10.1 for each of the time intervals for both the water table and the production zone on the basis of the individual rasters (figs. 3 and 4).

Change in Water-Table Elevations and Production-Zone Hydraulic Heads

To determine how water-table elevations and hydraulic heads have changed since steady-state conditions, simulated water-table elevations and production-zone hydraulic heads were compared to the steady-state water level generated for 1900. Water-table elevations and production-zone hydraulic heads for each time interval were subtracted from the steady-state water levels in layers 1–3 and 5, respectively, in ArcMap 10.1, such that the subtracted values represent the difference between steady-state and modeled conditions for both the water table and the production zone. After the change was calculated for each point in the model grid for the 10-year intervals from 1950 to 2000 and again for 2008, a change surface was interpolated by using IDW in ArcMap 10.1 (Environmental Systems Research Institute, Inc., 2012). The magnitudes of water-level change were grouped into 20-ft intervals for each time interval.

Because the water levels and areas of water-level change presented in figures 3 and 4 are derived from model simulations, they are intended to provide only estimates of the general magnitude, extent, and areal patterns of water-level change. Additionally, because of the error introduced by interpolating point values to a surface, the boundaries between intervals of simulated water-level change are not precisely located. It is not appropriate to use these maps to estimate the exact water level or water-level change at a specific location.

Changes in Water-Table Elevations and Production-Zone Hydraulic Heads, 1950–2008

The maps representing 1950 and 1960 simulated change in water-table elevations and production-zone hydraulic heads (figs. 3A, 3B, 4A, and 4B) show only minor water-level declines near the center of the study area. Prior to 1960, groundwater withdrawals were reported as a total volume for Albuquerque rather than by individual well or well field (Kernodle and others, 1995). Groundwater withdrawals for the 1950 and 1960 stress periods were therefore simulated as occurring near the center of the Albuquerque population in 1950–60 (figs. 3A, 3B, 4A, and 4B). More detailed withdrawal information is available for wells and well fields throughout the study area after 1960, and simulated water-level changes incorporate these pumping centers beginning with the 1970 map (figs. 3C and 4C). Contours along the northeastern boundary of the study area indicate perturbations of the water table that likely do not reflect actual conditions. These perturbations are shown as dashed lines on figures 3 and 4 for not being representative of actual conditions and likely are a result of the model output values for a complex area containing many basin-bounding faults (Hawley and others, 1995).

The largest changes in both water-table elevations and production-zone hydraulic heads occur between the 1970 and 1980 maps (figs. 3C, 3D, 4C, and 4D), in part because of increased groundwater use from rapid population growth during this period and few in-place water conservation measures. Total groundwater withdrawal in Albuquerque decreased after peaking in 1989 (fig. 2), but simulated water-table elevations and the production-zone hydraulic heads continued to decline for 1990, 2000, and 2008 (figs. 3E, 3F, 3G, 4E, 4F, and 4G), likely indicating that the reduced pumping rates were still in excess of aquifer recharge. The largest declines in both the water table and the production zone are near major pumping centers, the largest of which is located in eastern Albuquerque where water-level declines greater than 140 ft below steady-state conditions in both water-table elevation and production-zone hydraulic head in the model for 2008 (figs. 3G and 4G). These declines are likely the result of concentrated withdrawals of groundwater from clusters of supply wells and the effect of basin-bounding faults that juxtapose productive units of the Santa Fe Group aquifer system against less permeable units of the aquifer and (or) bedrock (Connell, 2006). Other major pumping centers in the study area, indicated by water-table and hydraulic head declines, are on the western side of the Rio Grande in both the central and northern parts of the study area (figs. 3 and 4).

Water-Table Elevations and Change Since Steady-State Conditions

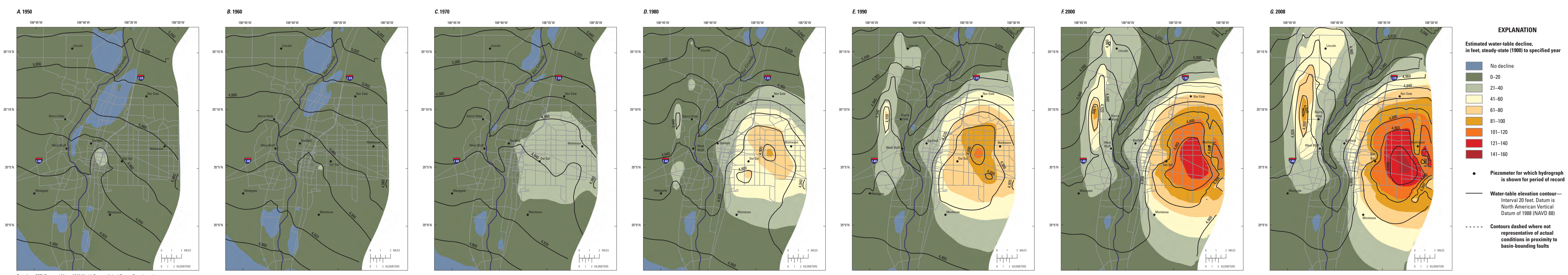
Simulated declines in water-table elevations (fig. 3) are generally less spatially extensive than those seen in production-zone hydraulic heads, but there are areas with similar declines around the major pumping centers. Water-level declines from steady-state conditions were generally 0–20 ft throughout the study area until the 1970 time period in the model. Simulated water levels for 1970 and 1980 indicated that the most substantial reductions in water-table water levels were in eastern Albuquerque. Substantial water-level declines west of the Rio Grande are evident in the map representing 1990 conditions, and declines in the northern part of the study area is more substantial between the 1990 and 2000 time periods.

Groundwater pumping has had a lesser effect on water-table elevations near the Rio Grande inner valley. Seepage from the Rio Grande, riverside drains, and irrigation within the inner valley recharge the upper parts of the Santa Fe Group aquifer system, thereby mitigating some of the effects of pumping on water levels at the water table (Bexfield and others, 2011). Water-level declines are consistently smallest along the southwestern and northwestern parts of the study area where historical and current groundwater withdrawals have been minimal.

Production-Zone Hydraulic Head and Change Since Steady-State Conditions

In the Albuquerque area, the production zone is typically from less than about 200 to 900 ft or more below the water table (Bexfield and others, 2011). In general, patterns of simulated declines in production-zone hydraulic heads are similar to those in the water table over the period from 1950 to 2008, with the largest declines seen in proximity to major pumping centers (fig. 4); however, the production-zone maps show a more extensive area of decline because this is the depth interval where the majority of the withdrawal stresses are being applied to the Santa Fe Group aquifer system.

Simulated declines in production-zone hydraulic heads are more consistent among the eastern, western, and northern pumping centers than in the water table. Seepage from the Rio Grande, riverside drains, and irrigation conveyances is less effective in mitigating the effects of pumping on water levels in the deeper production zone than on water levels in the shallower water-table zone because of low hydraulic conductivity units separating the two zones. The smallest declines in water levels over the period from 1950 to 2008 were also in the southwest and northeast, but areas with minimal declines in the production zone over the simulation period were less spatially extensive than those indicated in the water-table maps.



Base from ESRI Data and Maps, 2008 World, Europe, United States, Canada, and Mexico (2008). Redlands, Calif., ESRI, digital data, 1:50,000
River from the U.S. Department of Commerce, Bureau of the Census, various years, TIGER/Line files, digital data, 1:100,000
Lambert Conformal Conic projection
Modeled water-table elevations and drawdown are D Clarke 1866 Datum
Wells are North American Datum of 1983 and North American Vertical Datum of 1988

Figure 3. Simulated water-level contours and change since steady-state (1900) conditions in the water table, 1950–2008, Albuquerque metropolitan area, New Mexico.

Comparison of Simulated and Measured Water-Level Data

The measured water-level data from the selected production-zone piezometers cannot be compared directly to the entire period of simulated water-level declines presented in figures 3 and 4, but there is a comparison period to the modeled water-level decline maps for 2000–8 (figs. 3G and 4G). The period of record for the continuously monitored piezometers generally began in the late 1990s through 2000 and continued through 2012. Five piezometers are located to the east of the Rio Grande (Del Sol, Garfield, Matheson, Montessa, and Nor Este), and four are located to the west (Lincoln, Sierra Vista, West Bluff, and Westgate) (fig. 5; site locations on figs. 3 and 4).

Measured water-level data used to create the hydrographs analyzed for this report (fig. 5) were collected by using methods described by Beman (2013). Production-zone piezometers selected for analysis were identified as locations with continuous water-level records in areas that provide good spatial distribution across the study area and that were developed in geologic units representative of the Santa Fe Group aquifer system in the Albuquerque area (figs. 3 and 4). Water-level data from each piezometer were recorded by using a pressure transducer connected to an external data logger that collected hourly water-level data (Freeman and others, 2004). The hourly values for each day were later reduced to daily maximum values and plotted as hydrographs.

Generally, the hydrograph data agree with the simulated hydraulic head changes for 2000–8 in the production zone but demonstrate a finer temporal resolution that is not included in the map series. The map series illustrates decadal-scale aggregate change in potentiometric surfaces, whereas the hydrographs often indicate long-term trends and seasonal fluctuations, as well as individual years where water levels change in a direction contrary to the overall trend.

Water-Table Elevations 2000–8

Hydrographs of each of the nine production-zone piezometers exhibit seasonal fluctuations, likely in response to annual groundwater pumping cycles (fig. 5). Water supply wells are pumped more during higher demand periods in the summer and less during the winter, and water levels in the piezometers fluctuate in accord with these changes. Annual fluctuations are included in multiyear trends, and for the period 2000–8, 7 of the 9 piezometers show trends of declining water levels, agreeing with the continued hydraulic head declines from the simulated results for the production zone over the same period.

The Garfield piezometer, located in the inner valley, was the only site east of the Rio Grande to exhibit increases in production-zone water level over the period 2000–8. The response at this site could be influenced by proximity to the Rio Grande and unlined drain seepage. The rest of the piezometers to the east of the Rio Grande (Del Sol, Matheson, Montessa, and Nor Este) indicate an average water-level decline rate of about -0.2 feet per year (ft/yr) over the period 2000–8. Rates of change were estimated from the slope of trend lines generated by a least squares regression analysis (Helsel and Hirsch, 2002) over the respective period of time and do not account for seasonal fluctuations.

To the west of the Rio Grande, water-level declines are present at 3 of the 4 piezometers investigated over the period 2000–8 (Sierra Vista, West Bluff, and Lincoln), with an average annual water-level decline rate of about -0.9 ft/yr among the three piezometers. The Westgate piezometer, located near the western boundary of the basin, exhibited a water-level increase of about 1.3 ft/yr over the period 2000–8.

Water-Table Elevations 2009–12

In December 2008, Albuquerque began augmenting its municipal supply with water from the San Juan-Chama Drinking Water Project, thereby decreasing demand on groundwater (fig. 2). Continuous water-level data from the same nine production-zone piezometers were examined for changes in trends during 2009–12. Few supply wells have been shut off completely since the introduction of San Juan-Chama Drinking Water Project water, but most supply wells have substantially reduced annual withdrawal volumes since then (Albuquerque Bernalillo County Water Utility Authority, unpub. data, 2013). The City of Rio Rancho, at the northern part of the study area, continues to be solely supplied by groundwater (Water Prospecting and Resource Consulting, 2007).

Increases in water levels were found in 6 of the 9 piezometers examined during 2009–12. Rates of increase ranged from about 1.1 ft/yr to 3.5 ft/yr, with an average of about 2.3 ft/yr. This rate of water-level increase during 2009–12 is greater than the average water-level decline rate of the seven declining piezometers over the period 2000–8 of about -0.5 ft/yr.

All five of the piezometers east of the Rio Grande indicated increases in water levels over the period 2009–12. During this time period, these increases ranged from about 1.1 ft/yr at the Montessa site to about 3.5 ft/yr at the Matheson site. On the western side of the Rio Grande, responses were more varied. Three of the four piezometer sites continued to exhibit decreases in water level over the period 2009–12. The West Bluff site had the most substantial water-level decline rate at about -3.7 ft/yr. This site is in proximity to the Gonzales well field, the only Albuquerque well cluster that increased groundwater withdrawal over the period 2009–12. The Lincoln piezometer site is in the City of Rio Rancho, where groundwater remains the sole source of supply. The Westgate site is the only one of the selected piezometers on the western side of the Rio Grande with an increase in water level over the period 2009–12. This site is located in the southwestern part of the study area, where the closest supply well cluster (Leavitt) decreased groundwater withdrawals more than thirtyfold from 2010 to 2012.

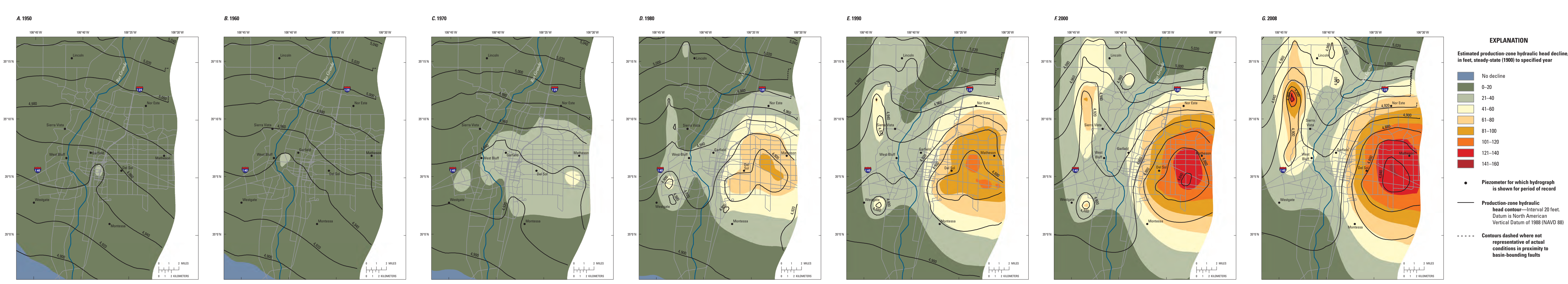


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Figure 4. Simulated hydraulic head contours and change since steady-state (1900) conditions in the production zone, 1950–2008, Albuquerque metropolitan area, New Mexico.

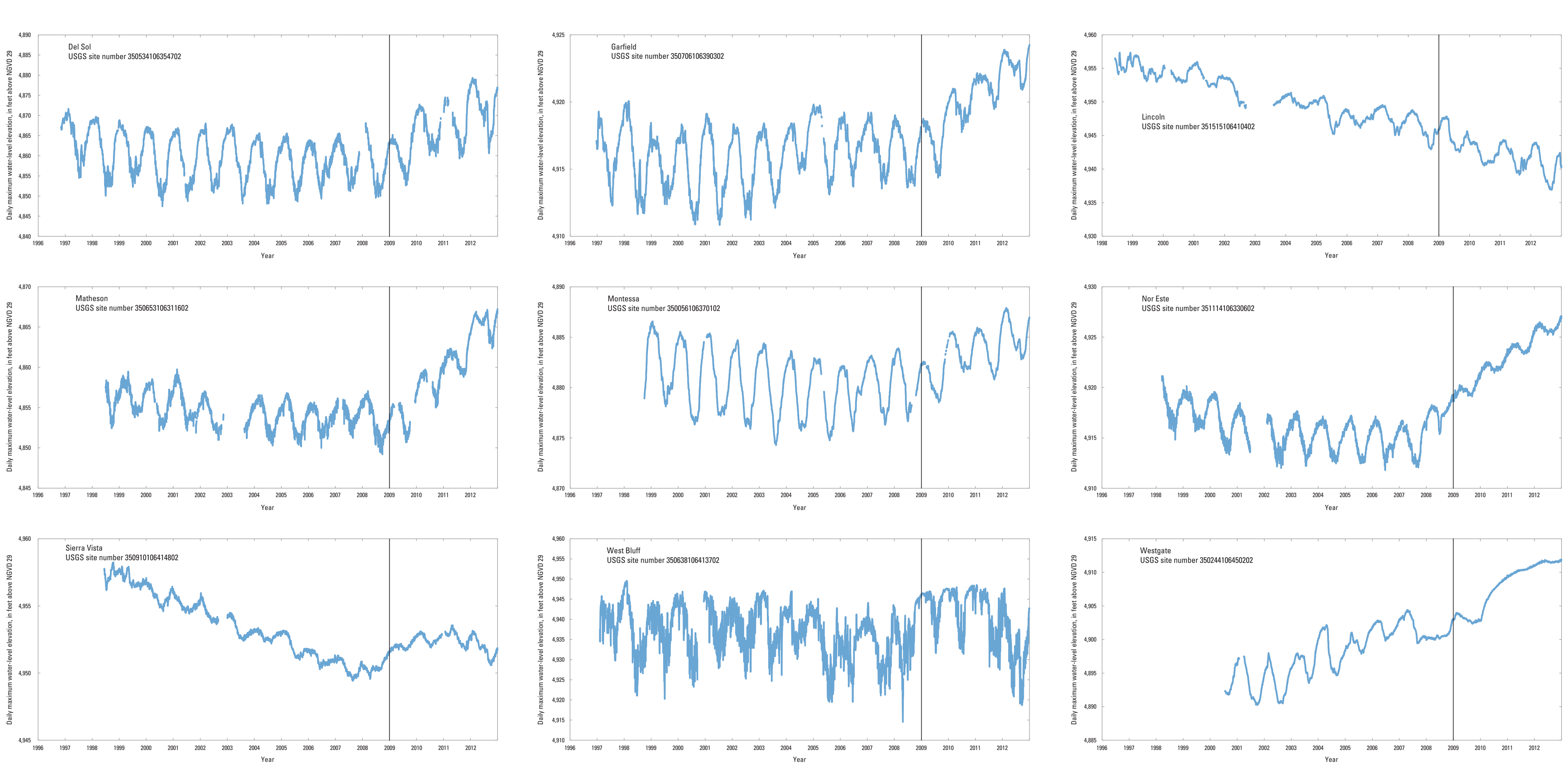

Figure 5. Production-zone hydrographs of selected piezometers (locations shown on figs. 3 and 4) for the period of record through December 31, 2012, in the Albuquerque metropolitan area, New Mexico.

Acknowledgments

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Simulated and Measured Water Levels and Estimated Water-Level Changes in the Albuquerque Area, Central New Mexico, 1950–2012

By
Steven Rice, Gretchen Oelsner, and Charles Heywood

2014