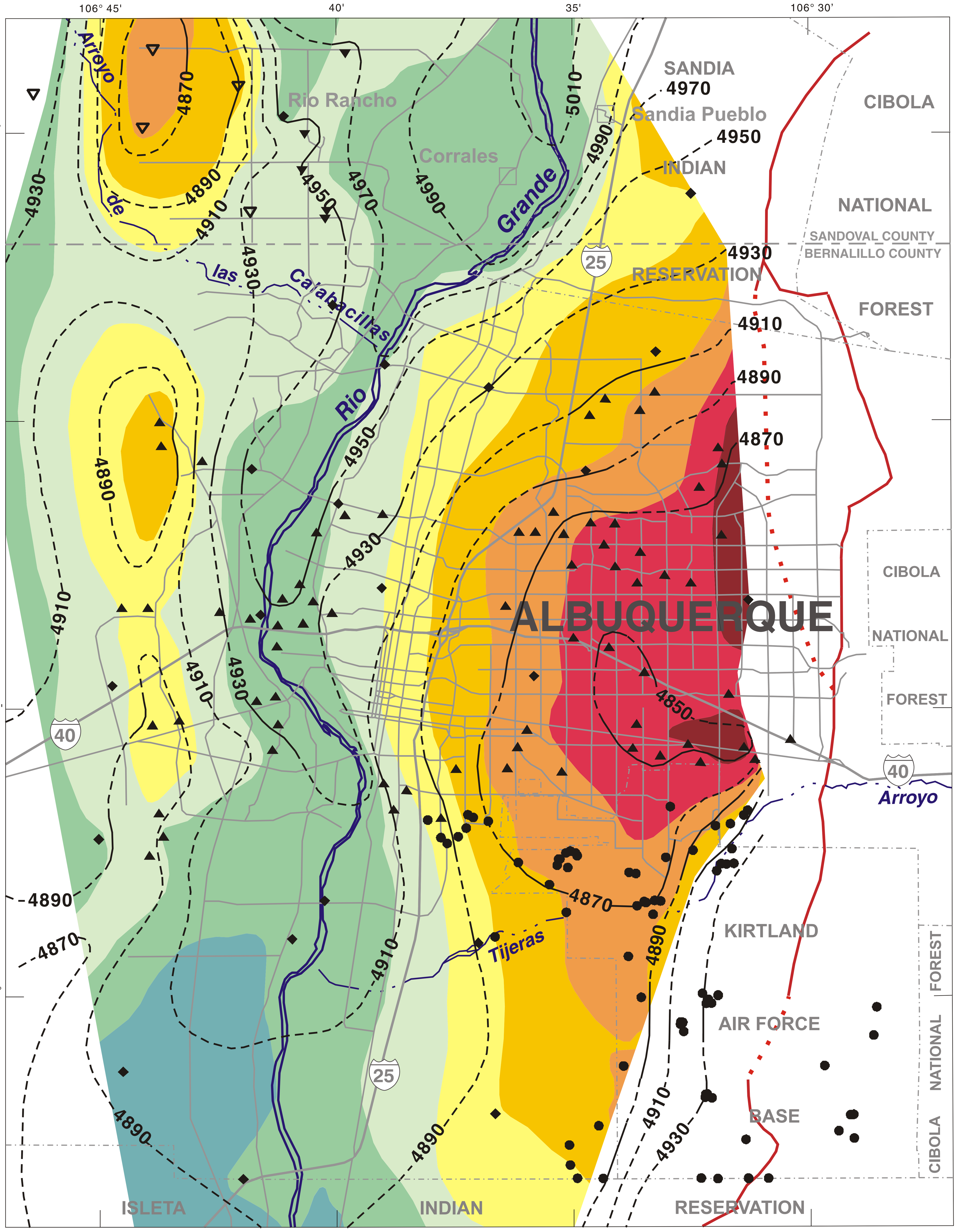

Base compiled from U.S. Geological Survey digital data, 1:100,000, 1977, 1978, and City of Albuquerque digital data, 1:2,400, 1994. Faults modified from Mark Hudson and Scott Minor, U.S. Geological Survey, written commun., 1999

0 2 4 6 MILES
0 2 4 6 KILOMETERS

EXPLANATION

Estimated water-level decline, in feet, 1960 to 2002

- No decline
- 0 to 20
- 20 to 40
- 40 to 60
- 60 to 80
- 80 to 100
- 100 to 120
- More than 120
- Decline not estimated

Basin-bounding fault in the area of a large hydraulic discontinuity, as identified by Bexfield and Anderholm (2000)

Area of apparent hydraulic discontinuity, not near a known fault, as identified by Bexfield and Anderholm (2000)

4930 Water-level contour, 2002--Interval 20 feet. Dashed where inferred. Datum is sea level

Data sources:

- ▲ USGS winter water-level measurement (by steel or electric tape) in City of Albuquerque drinking-water supply well, 1999-2001
- ◆ USGS winter water-level measurement (by transducer or steel tape) in piezometer, 1999-2000
- ▼ USGS winter water-level measurement (by steel or electric tape) in City of Rio Rancho drinking-water supply well, 2002
- ▽ City of Rio Rancho water-level measurement (by air line) in City of Rio Rancho drinking-water supply well, 2000
- ● Kirtland Air Force Base or Sandia National Laboratories water-level measurement (by steel or electric tape) in monitoring well, 1999-2001

Estimated Water-Level Declines in the Santa Fe Group Aquifer System in the Albuquerque Area, Central New Mexico, Predevelopment to 2002

By Laura M. Bexfield and Scott K. Anderholm

INTRODUCTION

In the Albuquerque metropolitan area of central New Mexico, residential water-supply requirements have historically been met almost exclusively by ground-water withdrawal from the Santa Fe Group aquifer system. The rapid population growth of the metropolitan area from about 262,200 residents in 1960 (Karen D. Thompson, U.S. Census Bureau, written commun., 2002) to about 712,700 residents in 2000 (U.S. Census Bureau, 2001) has resulted in a large increase in the number of municipal-supply wells operated in the region and the total quantity of water they withdraw per year. The largest municipal supplier is the City of Albuquerque, which delivered about 35.8 billion gallons of water to approximately 450,000 people during calendar year 1997 (files of the City of Albuquerque) and operates more than 90 municipal-supply wells. Other nearby important suppliers include the City of Rio Rancho and the Town of Bernalillo. The large quantity of ground-water withdrawal in the Albuquerque metropolitan area relative to ground-water recharge has resulted in water-level declines in the Santa Fe Group aquifer system across much of the region. Analysis of the magnitude of and patterns in water-level declines can improve understanding of how the ground-water system responds to withdrawals and how the system might be managed in the future to minimize water-level declines and operating costs of water suppliers.

This report, prepared in cooperation with the City of Albuquerque Public Works Department, presents estimated changes in static water levels in the production zone of the Santa Fe Group aquifer system in the Albuquerque metropolitan area between recent (1999-2002) and predevelopment (pre-1961) conditions. Contours of recent water levels are mapped, along with the ranges of estimated water-level change.

The authors thank those individuals and agencies that have aided in collection of water-level data used for this report. R.K. DeWees, Dale Rankin, and Stephanie Moore of the U.S. Geological Survey (USGS) measured water levels in many municipal-supply and monitoring wells. Pat Gallegos with the City of Albuquerque Water Utility Division and Paul Romero and Pat Gallegos with the City of Rio Rancho Water and Wastewater Department (respectively) provided assistance with access to wells. Franz Lauffer with Sandia National Laboratories generously provided water-level data for monitoring wells located at Kirtland Air Force Base; the data were collected by personnel of Sandia National Laboratories and Kirtland Air Force Base through their own programs. The authors also thank Doug McAda of the USGS for his technical advice and assistance.

DATA SOURCES

To estimate changes in water levels between recent and predevelopment conditions in the Santa Fe Group aquifer system in the Albuquerque area, maps of water levels during the two time periods were needed. A new water-level map representing recent conditions was constructed during this study. All water-level data for the map were obtained at some time between 1999 and 2002, primarily from municipal-supply and monitoring wells, under circumstances representative of near-static local conditions in the Santa Fe Group aquifer (described below). Although the construction of municipal-supply wells is not optimal to obtain discrete vertical head data, use of water levels from these wells was necessary to obtain a sufficient number of data points to delineate recent water-level conditions across the region. These wells are screened (open to the aquifer) across large depth ranges, commonly exceeding 700 feet; therefore, a water level obtained from one these wells represents an "average" water level for the entire screened interval. City of Albuquerque municipal-supply wells typically are screened from within about 200 feet of the water table to 900 feet or more below the water table. This part of the aquifer is commonly referred to as the "production zone." Where available, water-level data for monitoring wells (piezometers) completed near the middle of the production zone of nearby municipal-supply wells also were used; these piezometers typically are screened over much smaller intervals than municipal-supply wells. Thus, in general, the recent water-level data obtained for this report should be representative of conditions near the middle of the production zone.

Although measurements used in this study to represent the recent water-level surface in the production zone were collected over a period of about 3 years, the measurements were determined to be comparable given the general nature of the available data. Most of the data were obtained from municipal-supply wells with long screened intervals, across which water levels are likely to vary by several feet. Data presented by Bexfield and Anderholm (2002) for deep nested piezometers spanning the production zone (described below in greater detail) indicate that water levels commonly differ by about 10 feet or more from the top to the bottom of the zone. Because water-level measurements from different municipal-supply wells may not be representative of precisely the same part of the production zone, even measurements for the same day are broadly--though not exactly--comparable among different wells. The Bexfield and Anderholm study (2002) also showed that current water-level declines in the production zone, as indicated by water levels from piezometers, are about 1 to 2 feet per year in most areas. Therefore, the error induced in comparing water-level measurements collected over a period of about 3 years probably is nearly equivalent to the error in comparing water levels for the same year among wells having long screened intervals. A reasonable estimate of this error probably is about 5 to 10 feet.

Most of the recent water-level data used for this report (see map) were obtained from City of Albuquerque municipal-supply wells under a program funded cooperatively by the City of Albuquerque and the USGS to measure near-static water levels during times of low water demand (winter). Beginning in December 1996, water levels were measured between the months of December and April in as many as 70 municipal-supply wells. Measurements were made only after the well had not been pumped for a period of at least 2 weeks. Water levels were measured using either an electric or steel tape; the use of either should provide measurement accuracy within a foot. Measurements were not made in wells that had no access to the water level through the casing. An electric tape with an interface probe (to distinguish between water and any of the food-grade mineral oil used for lubrication floating on top) was used to measure water levels in selected wells. The most recent winter water level (typically from the winter of 1999-2000 or 2000-2001) was chosen for use in this report.

Water levels for City of Rio Rancho water-supply wells were obtained from two sources. USGS personnel measured water levels in six Rio Rancho wells (see map) between January and April 2002. Measurements were made using an electric or steel tape in wells that had been left idle for at least 2 weeks. Measurements were not made in wells that had no access to the water level through the casing. Water-level measurements obtained by City of Rio Rancho personnel during 2000 using an air line (see map) were provided to the USGS by the City of Rio Rancho Water and Wastewater Department (Paul Romero, written commun., 2001). These measurements were obtained from wells in which the pump had been off for several hours to days. Because they are not true static levels and because air-line measurements may be accurate only to within several feet, they were used in this study only when no other data were available and when the water levels appeared comparable to data for nearby wells.

Additional water levels were obtained from 24 piezometers throughout the metropolitan area (see map; 3 are located outside the area shown). Most of these belong to piezometer nests installed as part of a program started in 1996 by the City of Albuquerque, Bernalillo County, the New Mexico Office of the State Engineer, and the USGS. These well nests generally were located at least 1 mile from municipal-supply wells to minimize the local effects of short-term pumping cycles on measured water levels. The piezometer nests typically include three or more individual piezometers, with at least one piezometer screened at the water table, one near the middle of the production zone of nearby municipal-supply wells, and one near the bottom of or below the production zone. For nests of this type, the water level used for this report was obtained from the piezometer screened near the middle of the production zone; these piezometers typically have a screened interval of only 5 to 10 feet. A few piezometer sites consist of only one piezometer; at these sites, the piezometer is completed within the production zone and has a screened interval of 20 feet or less. Data also were used for a few additional piezometers installed prior to 1996 that are screened in the production zone. In piezometers equipped with transducers, the water level selected for use was the highest water level recorded by the transducer (excluding aberrant spikes) during the winter months of 1999 or 2000. Transducers record water levels once per hour and are calibrated about every 2 months. In a few cases, water-level measurements obtained by steel tape were used because transducers had not yet been installed; all but one of these water-level measurements were made during winter months.

To provide control on water levels southeast of Albuquerque, data were used for several wells located on Kirtland Air Force Base (see map). Personnel from Kirtland Air Force Base or Sandia National Laboratories measured water levels in these wells in 1999 or 2000 using steel or electric tape. Although a few of these wells are screened about 100 to 250 feet below the water table, many are screened at or near the water table. Therefore, water levels in these wells generally are more representative of conditions in shallower parts of the aquifer than are water levels from municipal-supply wells. It is not known whether vertical water-level gradients in the area tend to be upward or downward; thus, whether water-level declines calculated for the production zone of the area are somewhat underpredicted or overpredicted by the use of data from shallower wells cannot be estimated.

To create the contour map of recent water levels, the data described above were plotted using a geographic information system (GIS), then hand contoured. Because nearly every data point was honored in contouring, the measured water level at a point deviated by less than 10 feet from the water level that would be inferred from the contours. Riverbed elevations for the Rio Grande that had been digitized from 7.5-minute quadrangles also were used in creating the contour map. These elevations provide control for areas near the river where water-level measurements in wells are sparse or not available. However, these elevations are representative of the shallow ground-water system (assuming hydraulic connection between the river and the aquifer) rather than the production zone of the aquifer. Therefore, at various points near the river, nested piezometers screened at the water table and in the production zone were used to estimate differences in water levels between the shallow system and the production zone at those points. These differences were then used to estimate where each water-level contour in the production zone should cross the Rio Grande.

For this study, the predevelopment water-level map of Bexfield and Anderholm (2000) was used to represent predevelopment conditions in the aquifer system. That map was intended to represent water levels in the upper few hundred feet of the aquifer system rather than specifically in the production zone or at the water table. Water-level data for the Bexfield and Anderholm (2000) map were obtained from a variety of sources and included data for multiple well types (such as domestic, municipal-supply, and stock wells) of varying construction and for springs. Within the study area of this investigation (see map), all data used for the predevelopment map were collected prior to 1961. More details on data sources for the predevelopment map are available in Bexfield and Anderholm (2000). Although the map by Bexfield and Anderholm was not designed specifically to represent water-level conditions in the production zone of the aquifer system, the map was assumed to provide information comparable to that provided by the newly constructed map of recent water levels in the production zone. Comparison of water levels between the two maps is subject to a level of error that is dependent on vertical head gradients between the water table and the production zone. Water levels presented by Bexfield and Anderholm (2002) for piezometer nests--particularly water levels measured during the winter months--indicate that this error generally should not exceed 5 to 10 feet, the error likely to be associated with the map of recent water levels (as discussed above).

METHODS OF ESTIMATING WATER-LEVEL CHANGE

Water-level change in the production zone of the aquifer from predevelopment to 2002 was estimated using a GIS. The water-level contours of the predevelopment map by Bexfield and Anderholm (2000) and of the newly constructed map of recent water levels were digitized. A grid of points spaced at 500-meter (about 1,640-foot) intervals was created, and water-level elevations were interpolated onto the grid using the contours and selected actual water-level measurements. The interpolated values calculated by the GIS were reviewed for appropriateness. The difference between predevelopment and recent water levels was then calculated at each grid point, and the results were contoured and subsequently color coded to obtain the estimated ranges of water-level decline presented on the map. For 20 individual wells, both predevelopment and recent water-level measurements were available. The differences between water levels at these points were compared with the estimates of water-level change created with the GIS to ensure consistency. The area for which estimates of water-level change are presented (see map) was selected primarily to focus on the area where the most information was available. The eastern edge of the contoured area also was selected with the intent of excluding areas where Bexfield and Anderholm (2000) indicated the existence of hydraulic discontinuities that are probably associated with major faults. Water-level data near these hydraulic discontinuities are too sparse to accurately represent the ground-water levels near faults.

The contours of water-level decline presented in this report are intended to provide only reasonable estimates of the general magnitude, extent, and areal pattern of water-level change in the production zone of the aquifer system in the Albuquerque area. Because of the degree of variability and error inherent in the data (as described in the previous section) and the error introduced by the comparison of interpolated values on a discrete grid, the boundaries shown between the ranges of water-level change are not precisely located. Therefore, use of this map to estimate the exact water-level change at an individual location should be attempted only with great caution and with an awareness of the limitations involved in construction of the map.

IMPLICATIONS FOR GROUND-WATER FLOW AND RESPONSE OF THE AQUIFER SYSTEM TO PUMPING STRESS

The contours of recent water levels presented in this report indicate that ground-water-flow directions have changed considerably since predevelopment (pre-1961). Assuming flow is effectively perpendicular to water-level contours, the predevelopment map of Bexfield and Anderholm (2000) indicates that ground water in the Albuquerque area has historically flowed primarily from northeast to southwest on the west side of the Rio Grande and primarily from north to south-southwest on the east side of the Rio Grande. The recent (1999 to 2002) water levels presented in this report indicate that beneath the Albuquerque metropolitan area, ground water on either side of the Rio Grande currently flows toward the major pumping centers from all directions (see map). In particular, strong northerly and easterly flow components are now present within the study area on either side of the river. The contours of recent water levels also show that hydraulic gradients directed away from the river to both the east and west are currently quite steep, especially as compared with predevelopment gradients.

Estimated water-level changes calculated using the contour maps of recent and predevelopment conditions indicate that declines in the Albuquerque metropolitan area over about the past 40 years have ranged from negligible to more than 120 feet (see map). Water-level declines are smallest in the southwestern part of the study area, where relatively little ground water is pumped, and along the Rio Grande, where recharge from the river reduces declines. Water-level declines are largest in the major pumping centers located several miles east and west of the river. Declines exceed 120 feet near the major basin-bounding faults on the eastern margin of the study area, probably as a result of the juxtaposition of permeable sediments in the basin with relatively impermeable materials present on the east side of these faults. The map of water-level change in the production zone of the aquifer indicates that the average water-level decline resulting from ground-water pumping over about the past 40 years has ranged from about 1 to 3 feet per year across broad parts of the Albuquerque area.

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