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Composite Regional Groundwater Hydrographs for Selected Principal Aquifers in New Mexico, 1980–2019

Open-File Report 2022–1008

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

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U.S. Geological Survey, 2020, USGS water data for the Nation: U.S. Geological Survey National Water Information System database, https://doi.org/10.5066/F7P55KJN.

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I greatly appreciate the feedback and encouragement that my USGS colleagues, Lauren Henson and Amy Galanter, provided in the conceptualization and presentation of the composite hydrographs. In addition, Laura DeCicco, USGS, provided assistance with the R computer programs used to create the composite and normalized composite hydrographs.

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Composite Regional Groundwater Hydrographs for Selected Principal Aquifers in New Mexico, 1980–2019

By Nathan C. Myers

Abstract

Groundwater is an important source of water for New Mexico. An estimated 48 percent of the total water used comes from groundwater sources, and groundwater levels generally are declining over large areas of New Mexico. Groundwater levels are affected by local and regional recharge or discharge processes. Groundwater hydrographs show the history of groundwater-level changes at a well. A single hydrograph is not necessarily representative of the larger regional area; however, individual hydrographs from several wells can be combined into a composite hydrograph to show average groundwater changes for a regional area. The U.S. Geological Survey, in cooperation with the New Mexico Office of the State Engineer, has been measuring groundwater levels in a network of wells since about 1925. Although groundwater levels in the statewide well network have been measured at various frequencies, most wells have been measured in 5-year cycles since about 1980. The composite hydrographs in this report were developed to show groundwater-level changes for selected principal aquifers in New Mexico. Composite hydrographs were developed using wells in the Colorado Plateaus aquifers, the High Plains aquifer, the Pecos River Basin alluvial aquifer, the Rio Grande aquifer system, and the Roswell Basin aquifer system. Statewide, groundwater levels generally have declined or remained steady over the time period in aquifers analyzed for this study. The largest water-level declines occurred in the Colorado Plateaus and High Plains aquifers and in the Rio Grande aquifer system (north-central New Mexico), where median water-level declines ranged from 17 to 40 feet and mean water-level declines ranged from 3.8 to 32 feet. Groundwater-level declines (or rises) were generally smaller in other areas of New Mexico.

Introduction

Groundwater is an important source of water for New Mexico. In 2015, an estimated 48 percent of the total water used came from groundwater sources (Magnuson and others, 2019). Rinehart and others (2015, 2016, 2017) have shown that groundwater levels generally are declining over large areas of New Mexico. Groundwater-level changes are generally determined by measuring the depth to groundwater in one or many wells. A sequence of measurements of the depth to groundwater in a well shows whether groundwater levels are rising, falling, or staying the same over time. Groundwater levels change because of natural and anthropogenic processes that add (recharge) or remove (discharge) water from an aquifer. Groundwater levels can rise because of recharge from precipitation or seepage from rivers, lakes, or playas; groundwater levels can decline because of discharge by groundwater pumping, seepage to rivers and lakes, and, where groundwater is near land surface, evaporation and water uptake by plants (evapotranspiration). Some of these processes, such as recharge from precipitation, can be regional in scale and for that reason can affect groundwater levels over a large area. Other processes, such as groundwater pumping, groundwater interactions with streams, lakes, or playas, or localized rainstorms may only affect groundwater levels at a local scale. In addition, aquifer properties such as hydraulic conductivity and storativity can affect the magnitude of water-level change. For example, under a given rate of groundwater pumping, aquifers with low hydraulic conductivity or low storativity will show a greater decline in water levels than aquifers with higher hydraulic conductivity or storativity. Hydraulic conductivity is a measure of the ease with which water can move through pore spaces or fractures in an aquifer. Storativity is a measure of the volume of water released from a unit area of aquifer per unit decline in hydraulic head.

For any well, a graph of groundwater level plotted against time (hydrograph) shows the history of groundwater-level changes and is a record of the recharge or discharge processes affecting the well. Because some influences on groundwater levels are local, a single hydrograph is not necessarily representative of the larger regional area. However, individual hydrographs from several wells can be combined into a single composite hydrograph to show average groundwater-level changes for wells within a regional area. If data are available for a sufficient number and areal distribution of wells, composite hydrographs provide a useful way to visualize changes in groundwater levels for a region or for an aquifer.

The U.S. Geological Survey (USGS), in cooperation with the New Mexico Office of the State Engineer (NMOSE), has systematically been measuring groundwater levels in New Mexico since about 1925 (Reeder and Doty, 1959). Most of the early groundwater-level measurement work focused on areas where groundwater supplies were undergoing development (Reeder and Doty, 1959). Although groundwater levels in the statewide well network have been measured at various frequencies, an analysis of the water-level data retrieved from the National Water Information System database (U.S. Geological Survey, 2020) for this study indicated that most of the wells have been measured in 5-year cycles since about 1980. The 5-year measurement frequency means that in a 5-year cycle all of the network wells in a selected set of declared groundwater basins (fig. 1) would be measured in the first year, all the network wells in a different set of basins would be measured in the second year, and so on such that all wells in the statewide well network would be measured every 5 years. Over time, the statewide well network has expanded and contracted in response to funding changes and scientific priorities or because wells were no longer available for measurement. As a result, groundwater-level measurement records for some wells extend back to the early part of the 20th century while records for other wells are only a few years long. For composite hydrograph development, the challenge was to find an adequate number of wells in a given area that have sufficiently long periods of groundwater-level measurement.

The groundwater-level data collected in cooperation with the NMOSE and other cooperators have been utilized for many studies, but there are no published reports in which the data are used to produce composite hydrographs that show the general trends of groundwater levels in New Mexico on a regional scale. The composite hydrographs shown in this report were developed by the USGS in cooperation with the NMOSE to show groundwater-level changes for selected principal aquifers (fig. 1; U.S. Geological Survey, 2021d) and declared groundwater basins (fig. 1; New Mexico Office of the State Engineer, 2021) in New Mexico. Some very elongated principal aquifers (the Rio Grande aquifer system and the High Plains aquifer) were subdivided for this analysis to show groundwater-level changes for specific areas. Composite hydrographs were not developed for principal aquifers and other areas of New Mexico lacking sufficient data.

Composite Groundwater-Level Hydrographs

In previous studies, composite groundwater-level hydrographs have been utilized to show average groundwater-level responses. For example, Cohen and others (1969) used average annual groundwater levels from 14 wells to show the effects of the 1962–66 drought on groundwater levels on Long Island, New York. Average groundwater levels also have been used to evaluate water-level changes for regional areas of Kansas (Woods and others, 2000). The Oklahoma Water Resources Board (2018) published composite groundwater hydrographs for various aquifer types and National Weather Service climatologic divisions to provide an “intuitive visual context for average water level in an aquifer over time.” In 2018, the USGS published web pages showing composite hydrographs (U.S. Geological Survey, 2021c) for the principal aquifers of the United States (Miller, 1999). The development of the national principal aquifer composite hydrographs and those for New Mexico, presented in this report, are described in the following sections.

Composite Hydrographs for Principal Aquifers of the United States

Composite groundwater-level hydrographs were developed by the USGS for selected principal aquifers of the United States to show the long-term response of groundwater levels (U.S. Geological Survey, 2021c). Composite hydrographs for the principal aquifers can serve as indicators of depletion of water resources arising from human or climatic influences (U.S. Geological Survey, 2021c). The USGS composite hydrographs for the principal aquifers show two different composite indices: a composite groundwater-level hydrograph and a normalized composite groundwater-level hydrograph. The composite groundwater-level hydrograph is based on the median annual depth to groundwater below land surface for each of a set of wells and the normalized composite groundwater-level hydrograph is based on the difference between the median annual groundwater level and the annual average median groundwater level as a percentage of the historical range of median values for each of a set of wells (U.S. Geological Survey, 2021a). Criteria for a well to qualify for inclusion in a principal aquifer composite hydrograph were that the well had to be located in a principal aquifer and the well had to have at least one groundwater-level measurement in each calendar year of a 30-year period (1988–2018) (U.S. Geological Survey, 2021b). In addition, there had to be at least nine wells in each principal aquifer meeting the above criteria.

For a variety of reasons, composite hydrographs were not developed for all principal aquifers in New Mexico. Of the six principal aquifers in New Mexico (Basin and Range aquifers, Colorado Plateaus aquifers, High Plains aquifer, Pecos River Basin alluvial aquifer, Rio Grande aquifer system, and the Roswell Basin aquifer system), composite hydrographs were developed only for the Basin and Range aquifers, Colorado Plateaus aquifers, and the Rio Grande aquifer system. However, those composite hydrographs do not adequately represent water-level conditions in New Mexico: The composite hydrographs for the Basin and Range aquifers did not include any wells in New Mexico, the composite hydrographs for the Colorado Plateaus aquifers included only two wells in New Mexico, and most of the wells whose data were used for composite hydrographs for the Rio Grande aquifer system are in southern Colorado (U.S. Geological Survey, 2021c).

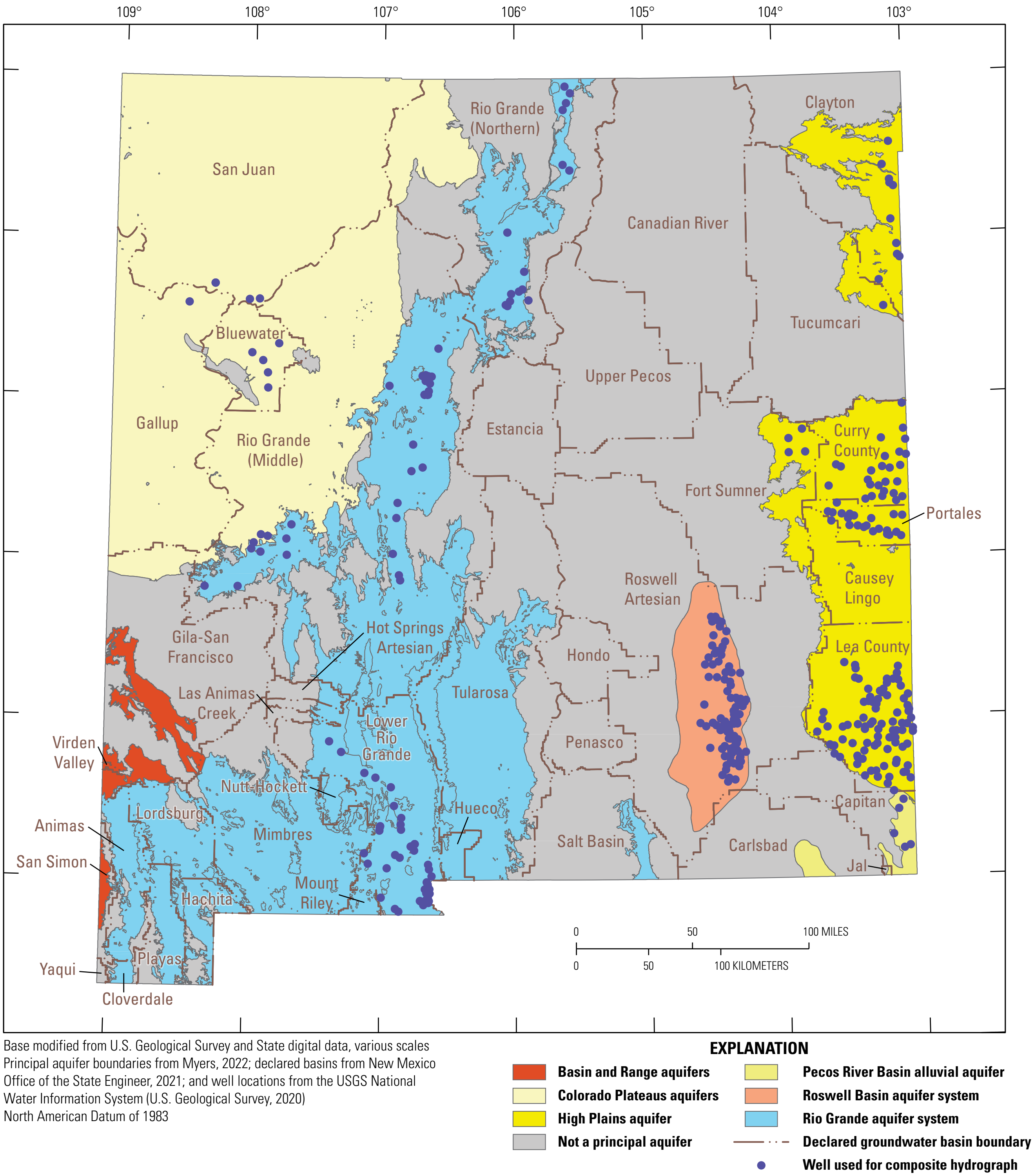


Figure 1. Map showing locations of wells included in a composite or normalized composite hydrograph in this report, refined principal aquifers in New Mexico (Myers, 2022), and declared groundwater basins defined by the New Mexico Office of the State Engineer (2021).

In addition, although a sufficient number of wells were available in New Mexico and other States to develop composite hydrographs for the High Plains aquifer, it was excluded from composite hydrograph development because most of the eligible wells are clustered in Nebraska (which would make the hydrographs more representative of Nebraska than the six other States the aquifer also occupies). In addition, other resources are available to determine groundwater-level trends for the High Plains aquifer (U.S. Geological Survey, 2021b).

Composite Hydrographs for Principal Aquifers in New Mexico

Part of the reason so few New Mexico wells were included in the national composite hydrographs is that most wells in the USGS statewide network have been measured every 5 years since about 1980 and for that reason failed the national criterion of having at least one measurement each year. Therefore, the criteria for including a well in a New Mexico composite groundwater-level hydrograph were that the well was located in a principal aquifer, as determined using the refined principal aquifers shapefile (appendix 1; Myers, 2022), and the well had at least one water-level measurement for each 5-year period for water years 1980–2019 (October 1, 1979–September 30, 2019). A water year is defined as the 12-month period from October 1 through September 30. For example, October 1, 1979, through September 30, 1980, is water year 1980. Wells meeting the above criteria (fig. 1) were aggregated by principal aquifer and location within the aquifer to create groups of wells that were used to make composite hydrographs.

The procedure used to calculate values for composite and normalized composite hydrographs is described below. Table 1 shows depth to water data for three hypothetical wells, and table 2 shows how water-level values from the three hypothetical wells would be used to compute composite and normalized composite hydrographs.

Composite Hydrograph Procedures

1. Wells meeting the selection criteria (well is in a principal aquifer and has at least one measurement in each 5-year period) were aggregated into groups corresponding to principal aquifer and location within the aquifer. For example, wells in the High Plains aquifer were aggregated into northeast, east-central, and southeast New Mexico groups.
2. Depth to water below land surface (water level) values with measurement dates of October 1, 1979–September 30, 2019, were retrieved from the USGS National Water Information System database (U.S. Geological Survey, 2020) for each well in a group.
3. Water levels that were qualified as having been affected by pumping or artesian flow from a measured well or a nearby well were removed from the water-level dataset prior to composite hydrograph analysis. For example, water levels for well 323705104225501 (fig. 2*A*) that were qualified as “A” were removed from the water-level dataset and the remaining values were retained for analysis. The “A” qualifier is assigned in the field and means that the true water level is above (higher in the well) the measured water level. It is not always possible to make a field determination that a well has been affected by pumping or nearby pumping and for that reason many water levels affected by pumping may not be “A” qualified. For example, well 330404104221201 (fig. 2*B*) has many water-level measurements that appear to be affected by pumping but were not “A” qualified, so the well was excluded from composite hydrograph analysis.
4. For each well, water-level values were aggregated into water-year bins. For this report, water-year bins are 5-year periods starting with water year 1980. A total of eight 5-year bins were defined (1980–84, 1985–89, 1990–94, 1995–99, 2000–04, 2005–09, 2010–14, and 2015–19).
5. The median water-level value for water levels in each 5-year bin was computed and retained for analysis. (See example in table 2, median depth to water for hypothetical wells 1, 2, and 3.) The median depth to water values represent the central tendency of water levels in a well during a given 5-year period.
6. The mean and median composite depth to water values (example in table 2) for each 5-year bin were computed using the median water-level values computed in step 5. The mean and median composite depth to water values were then used to make the composite hydrographs shown in this report.

Table 1. Three hypothetical wells, depth to water values, and 5-year bin assignments.

[Depth to water values in the table are used to compute composite and normalized composite water levels shown in table 2]

Hypothetical well 1			Hypothetical well 2			Hypothetical well 3		
Water year of measurement	5-year bin	Depth to water below land surface (feet)	Water year of measurement	5-year bin	Depth to water below land surface (feet)	Water year of measurement	5-year bin	Depth to water below land surface (feet)
1980	1980–84	80.0	1981	1980–84	45.0	1982	1980–84	61.0
1985	1985–89	120.0	1983	1980–84	47.0	1987	1985–89	62.0
1990	1990–94	74.0	1986	1985–89	49.0	1989	1985–89	67.0
1994	1990–94	72.0	1987	1985–89	50.0	1992	1990–94	69.0
1995	1995–99	70.0	1988	1985–89	51.0	1996	1995–99	72.0
1999	1995–99	63.0	1991	1990–94	50.0	1997	1995–99	73.0
2000	2000–04	61.0	1993	1990–94	51.0	1999	1995–99	75.0
2005	2005–09	55.0	1996	1995–99	52.0	2002	2000–04	78.0
2010	2010–14	50.0	2001	2000–04	53.0	2003	2000–04	77.0
2011	2010–14	49.0	2006	2005–09	54.0	2004	2000–04	76.0
2014	2010–14	45.0	2011	2010–14	55.0	2007	2005–09	81.0
2015	2015–19	41.0	2016	2015–19	54.0	2012	2010–14	87.0
2017	2015–19	40.0	2019	2015–19	57.0	2017	2015–19	95.0

Table 2. Hypothetical example of how composite and normalized composite water-level values are computed using the depth to water values in table 1.

[For each well, the median value is determined for each 5-year bin. Minimum, maximum, and mean values are calculated for each well using the median value for each 5-year bin. Finally, composite and normalized composite values are calculated for each 5-year bin for all wells combined. --, not computed]

5-year bin	Median depth to water (feet)			Composite depth to water for wells 1, 2, and 3 combined (feet)		Normalized depth to water (percent departure from the mean)			Normalized composite depth to water for wells 1, 2, and 3 combined (percent departure from the mean)	
	Hypothetical well 1	Hypothetical well 2	Hypothetical well 3	Mean	Median	Hypothetical well 1	Hypothetical well 2	Hypothetical well 3	Mean	Median
1980–84	80.0	46.0	61.0	62.3	61.0	−14.9	63.2	43.9	30.7	43.9
1985–89	120.0	50.0	64.5	78.2	64.5	−65.3	21.1	33.6	−3.5	21.1
1990–94	73.0	50.5	69.0	64.2	69.0	−6.1	15.8	20.4	10.0	15.8
1995–99	66.5	52.0	73.0	63.8	66.5	2.0	0.0	8.6	3.6	2.0
2000–04	61.0	53.0	77.0	63.7	61.0	9.0	−10.5	−3.1	−1.6	−3.1
2005–09	55.0	54.0	81.0	63.3	55.0	16.5	−21.1	−14.9	−6.5	−14.9
2010–14	49.0	55.0	87.0	63.7	55.0	24.1	−31.6	−32.5	−13.4	−31.6
2015–19	40.5	55.5	95.0	63.7	55.5	34.7	−36.8	−56.1	−19.4	−36.8
Minimum	40.5	46.0	61.0	--	--	--	--	--	--	--
Maximum	120.0	55.5	95.0	--	--	--	--	--	--	--
Mean	68.1	52.0	75.9	--	--	--	--	--	--	--

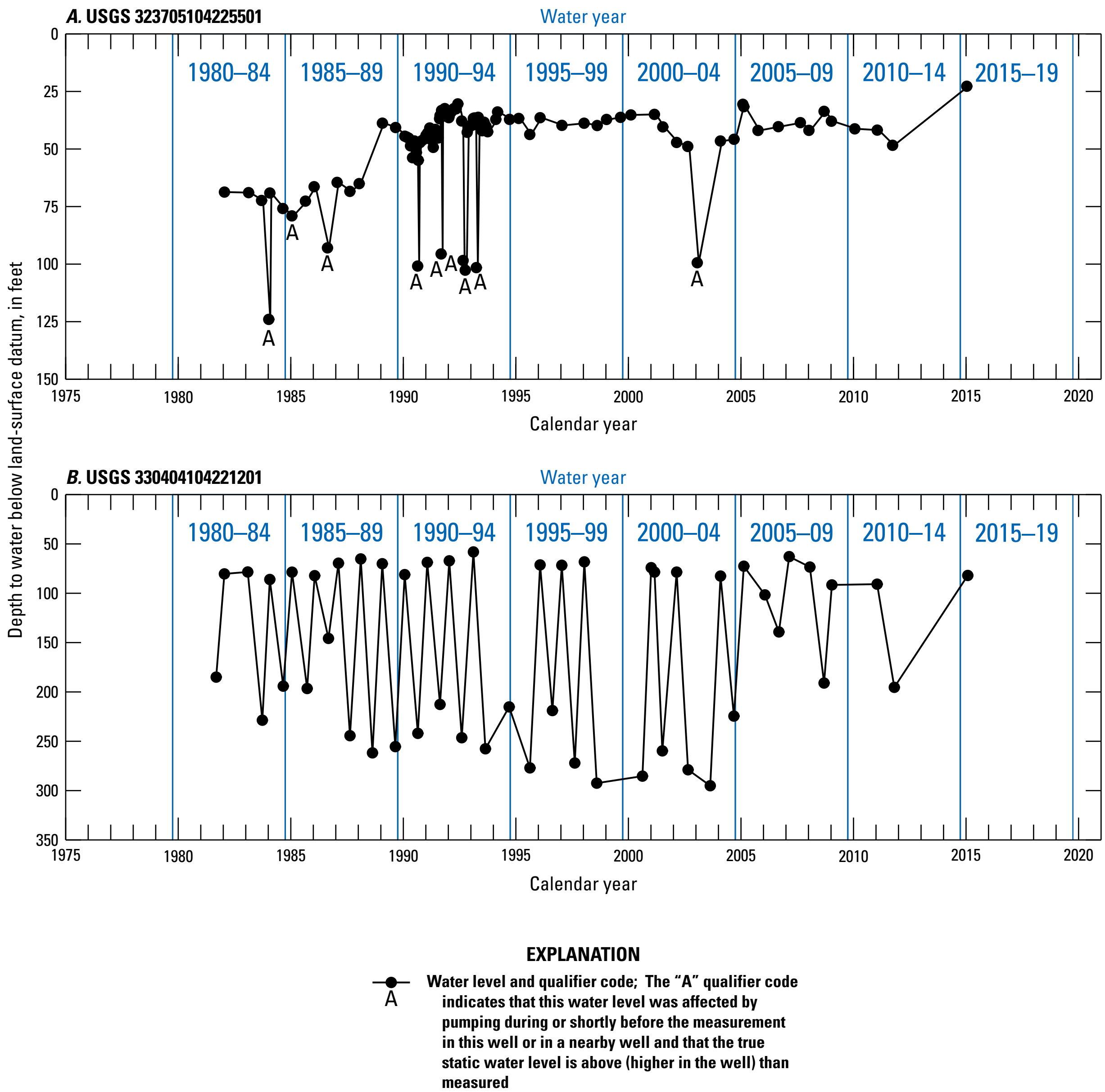


Figure 2. Hydrograph examples showing water-level data affected by pumping, *A*, with qualifier code and, *B*, without qualifier code. USGS, U.S. Geological Survey.

Normalized Composite Hydrograph Procedures

1. Minimum, maximum, and mean values of the median water-level values from step 5 above were computed for each well. (See example in table 2.)

2. A normalized depth to water value, in percent, for each well's median value was calculated using equation 1 below. There are many ways to normalize data, but the normalization shown in equation 1 has the advantage of normalizing the mean of the data for each well to zero; median depth to water values less than the mean (water levels higher in the well) will have positive normalized values and median depth to water values greater than the mean (water levels lower in the well) will have negative normalized values. Each normalized value represents the departure of a median water level from the mean and are presented as percentages in this report.

$$N = -1\left(\frac{(\mathrm{x} - \mathrm{xmean})}{(\mathrm{xmax} - \mathrm{xmin})}\right)100 \tag{1}$$

where

N	is the normalized value, in percent;
−1	is a conversion factor that changes the sign of the value so that normalized values for water levels higher in the well are positive and values for water levels lower in the well are negative;
x	is the median depth to water for a well for a 5-year bin;
xmean	is the mean of all median depths to water for a well;
xmax	is the maximum of all median depths to water for a well;
xmin	is the minimum of all median depths to water for a well; and
100	is a conversion factor that changes the calculated value to a percentage.

3. The mean and median normalized composite depth to water values (see example in table 2) for each 5-year bin were computed using the normalized median water-level values computed in step 2. Conceptually, the mean and median normalized composite water-level values can be thought of as the departure of water levels from the mean water level for the period of analysis. The mean and median normalized composite depth to water values were used to make the composite hydrographs shown in this report.

Composite and Normalized Composite Hydrographs for Selected Aquifers in New Mexico

Composite and normalized composite hydrographs are presented herein for wells grouped by principal aquifer and location within the aquifer. For the smaller principal aquifers, such as the Roswell Basin aquifer system and the Pecos River Basin alluvial aquifer, or where there were few wells representing the aquifer (Colorado Plateaus aquifers), all of the wells for the aquifer were included in a single group. For the High Plains aquifer and Rio Grande aquifer system, wells were grouped by location within the aquifer. In the High Plains aquifer, wells naturally fell into northeast, east-central, and southeast New Mexico groups. In the Rio Grande aquifer system, wells were placed into groups based on location, aquifer material, and depth to water. Wells in the north-central group all produce water from alluvial basin fill along the Rio Grande. Wells in the Albuquerque area and central groups both produce water from alluvial basin fill along the Rio Grande but were placed in separate groups, because wells in the Albuquerque area group have a fundamentally different hydrograph shape that would have dominated a composite hydrograph composed of wells in both the Albuquerque area and central groups. Wells in the Plains of San Agustin group were separated from other wells because they are located in a highland area west of the Rio Grande. Wells in the Rio Grande aquifer system in southern New Mexico were placed in two groups—those in the Rio Grande Valley and those on a mesa west and southwest of Las Cruces—in order to make water-level changes more apparent in the hydrographs. Because of land-surface elevation differences between the Rio Grande Valley and the mesa, depths to water are very different for these groups and the deeper depths to water on the mesa tend to skew the mean water-level values toward the higher (deeper) values.

Both mean and median composite and normalized composite hydrographs are shown in figures 3*B*, *C*–14*B*, *C*. The median composite and normalized hydrographs are probably more representative of the central tendency of the water-level data, because mean values can be highly influenced by data values considered to be outliers. Boxplots of the normalized water-level data used to calculate mean and median normalized values for each water-year bin, shown on the normalized composite hydrograph plots, provide a measure of the scatter of the data about the median and show outlier (outside) data. An outside data point has a value that is between 1.5 and 3 times the interquartile range of the data and is shown as an open circle above or below each box in the boxplots. Comparison of mean normalized composite water-level values and boxplot outside data values in figures 3*C*–14*C* can show how mean normalized values are affected by outside values.

Colorado Plateaus Aquifers, Grants to Crownpoint Area

Despite the large number of wells that have been drilled in the Colorado Plateaus aquifers, only 10 wells in the Grants to Crownpoint, New Mexico, area qualified for composite hydrograph analysis (fig. 3, table 3). The qualifying wells are located within the Bluewater, San Juan, and Gallup declared basins (fig. 1). The mean composite hydrograph shows rising water levels from 1980–84 to 1995–99 and declining water levels thereafter, whereas the median composite hydrograph generally shows declining water levels since 1980–84 (fig. 3*B*). Overall, the mean and median composite hydrographs show a water-level decline of about 3.8 and 35 feet (ft), respectively (fig. 3*B*). Both the mean and median normalized composite hydrographs show rising water levels from 1980–84 to 1985–89 and declining water levels thereafter (fig. 3*C*). These hydrographs represent only a small area within the larger Colorado Plateaus aquifers and are not representative of the entire aquifer.

High Plains Aquifer, Northeast New Mexico

Eleven wells in the High Plains aquifer in northeast New Mexico qualified for composite hydrograph analysis (fig. 4, table 4). The wells are relatively evenly distributed from north to south in the northeastern part of the High Plains aquifer (fig. 4*A*); most of the wells are located in the Clayton declared basin but one well is located in the Tucumcari declared basin (fig. 1). The mean and median composite hydrographs show that water levels have declined about 32 and 40 ft, respectively, from 1980–84 to 2015–19 (fig. 4*B*). Both the mean and median normalized hydrographs show an overall decline in water levels from 1980–84 to 2015–19 (fig. 4*C*).

High Plains Aquifer, East-Central New Mexico

Fifty-three wells in the High Plains aquifer in east-central New Mexico qualified for composite hydrograph analysis (fig. 5, table 5). The wells are located in the east-central part of the High Plains aquifer (fig. 5*A*) in the Curry County, Portales, and Fort Sumner declared basins (fig. 1). The mean and median composite hydrographs show water-level declines of about 28 and 24 ft, respectively, from 1980–84 to 2015–19 (fig. 5*B*). The mean and median normalized composite hydrographs show declining water levels from 1980–84 to 2015–19 (fig. 5*C*).

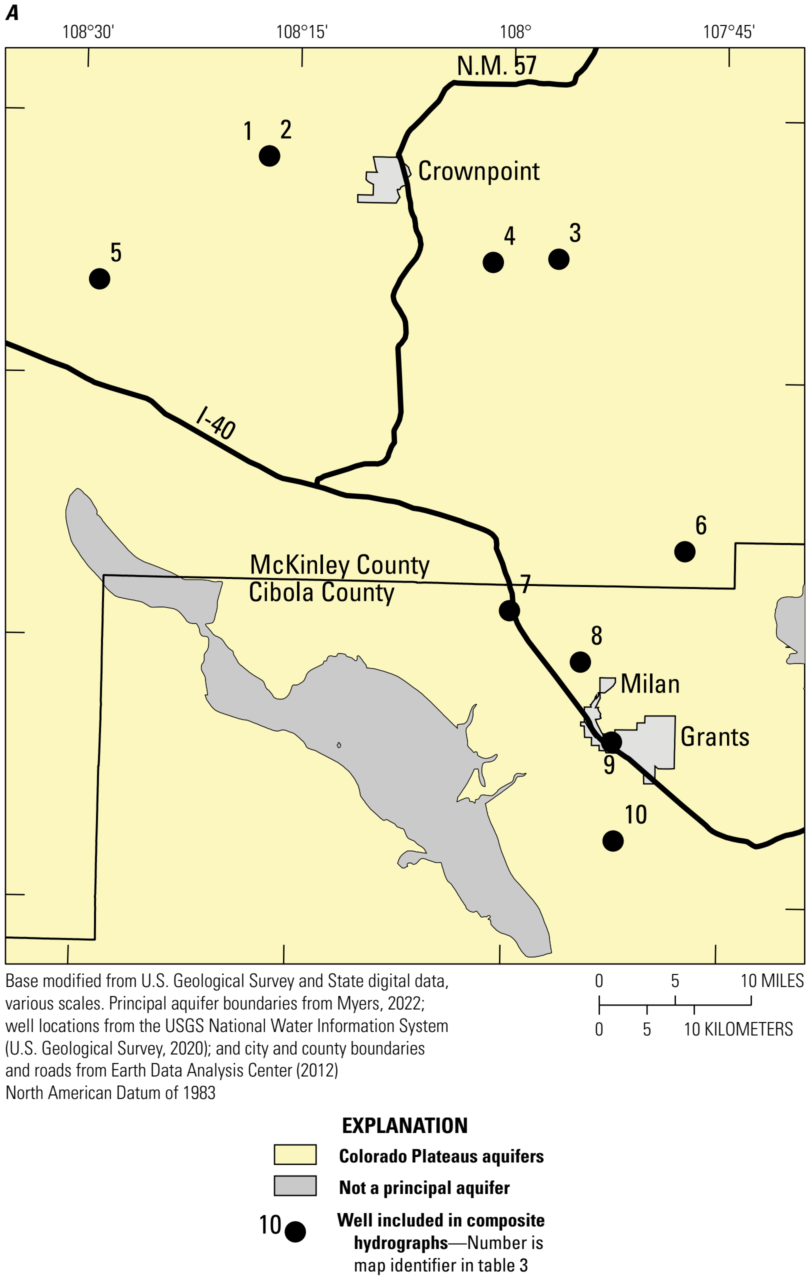


Figure 3. *A*, Ten wells in the Colorado Plateaus aquifers, Grants to Crownpoint area, New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.

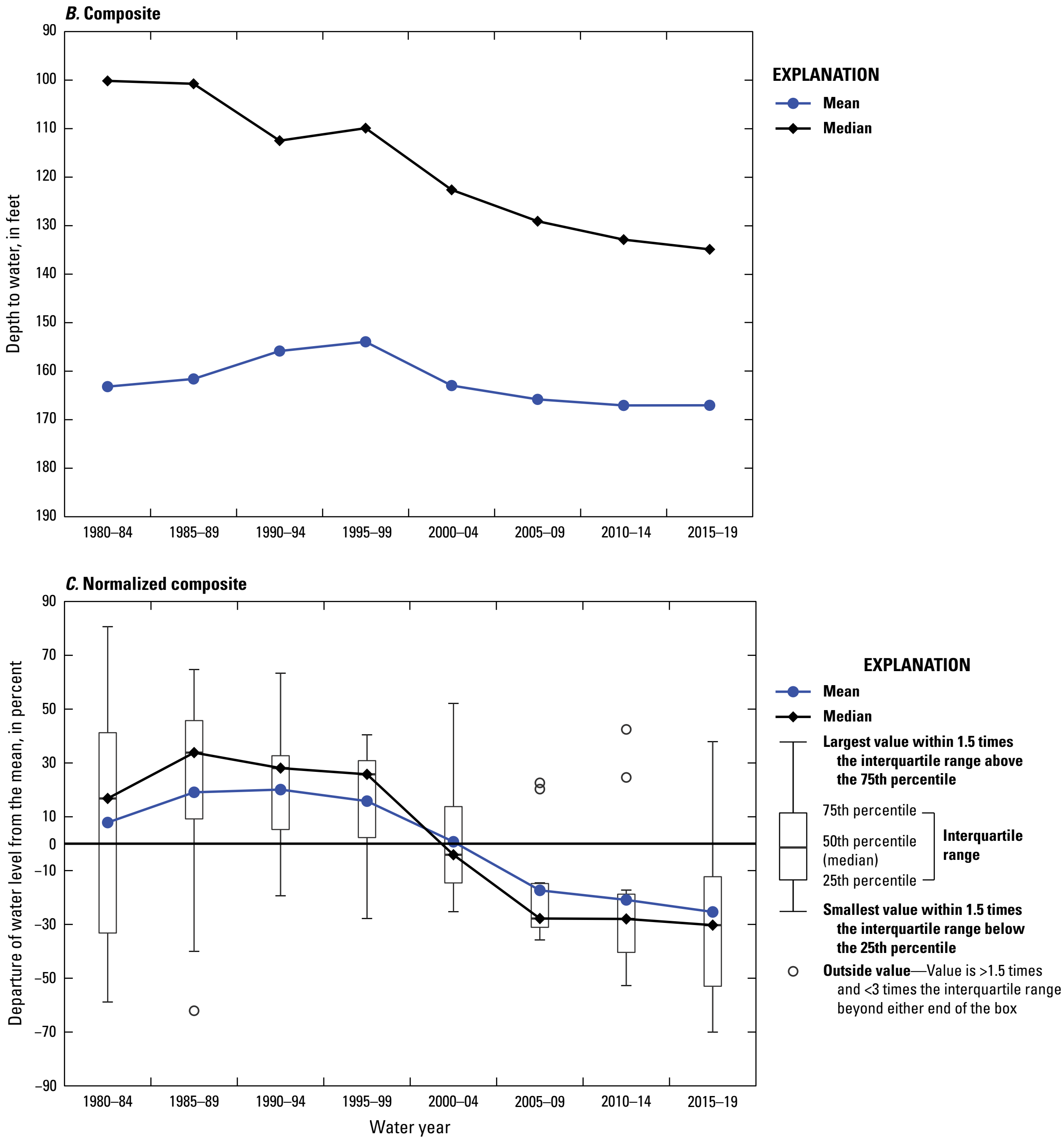


Figure 3. *A*, Ten wells in the Colorado Plateaus aquifers, Grants to Crownpoint area, New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.—Continued

Table 3. Map and site identifiers for wells used to construct composite and normalized composite water-level hydrographs for the Colorado Plateaus aquifers, Grants to Crownpoint area, New Mexico.

[Map identifier locations are shown on figure 3. USGS, U.S. Geological Survey]

Map identifier	USGS site number	Map identifier	USGS site number
1	354235108170702	6	352023107473201
2	354235108170703	7	351651107594501
3	353659107564101	8	351304107543701
4	353645108011501	9	350923107522701
5	353521108284901	10	350346107521201

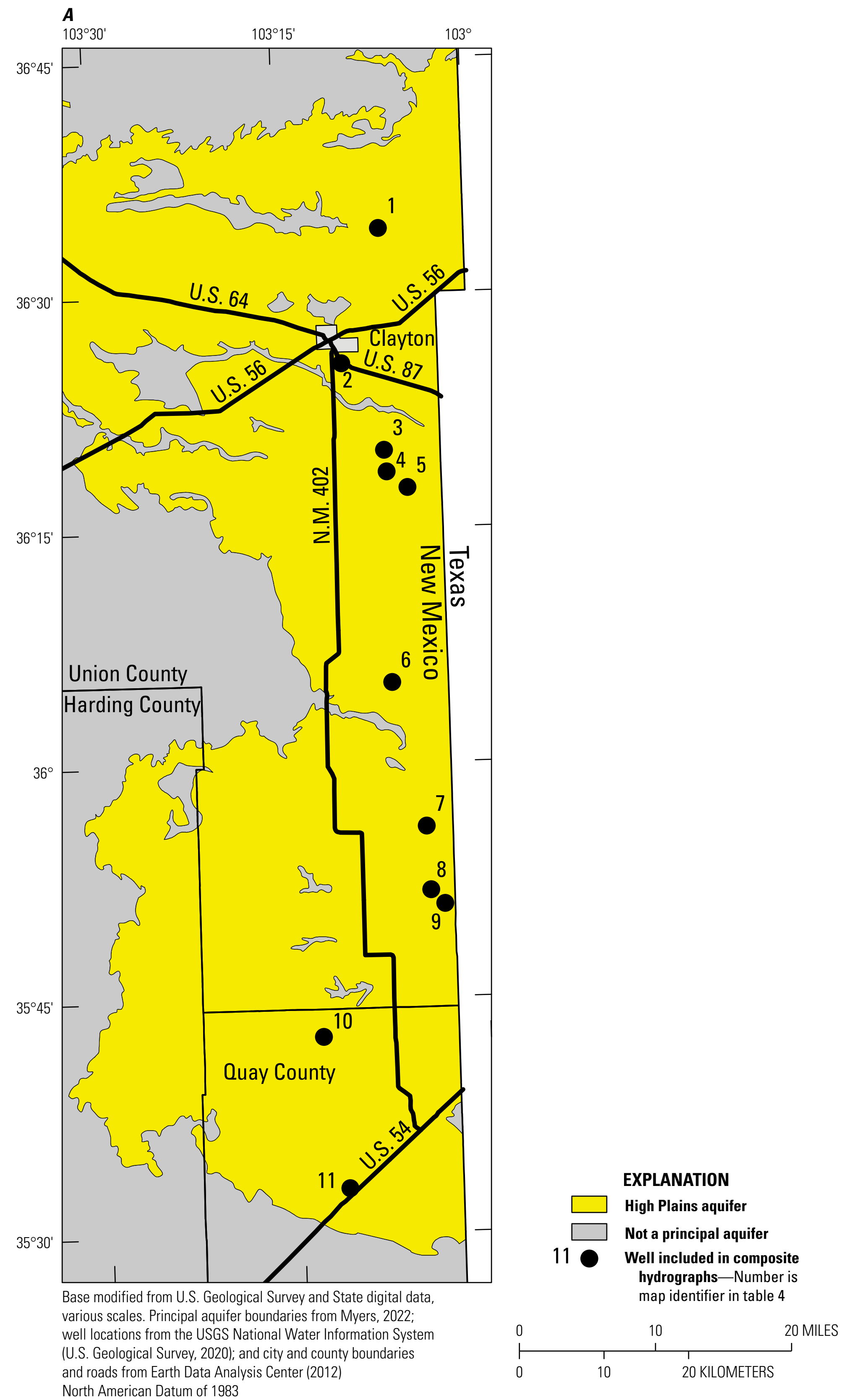


Figure 4. *A*, Eleven wells in the High Plains aquifer, northeast New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.

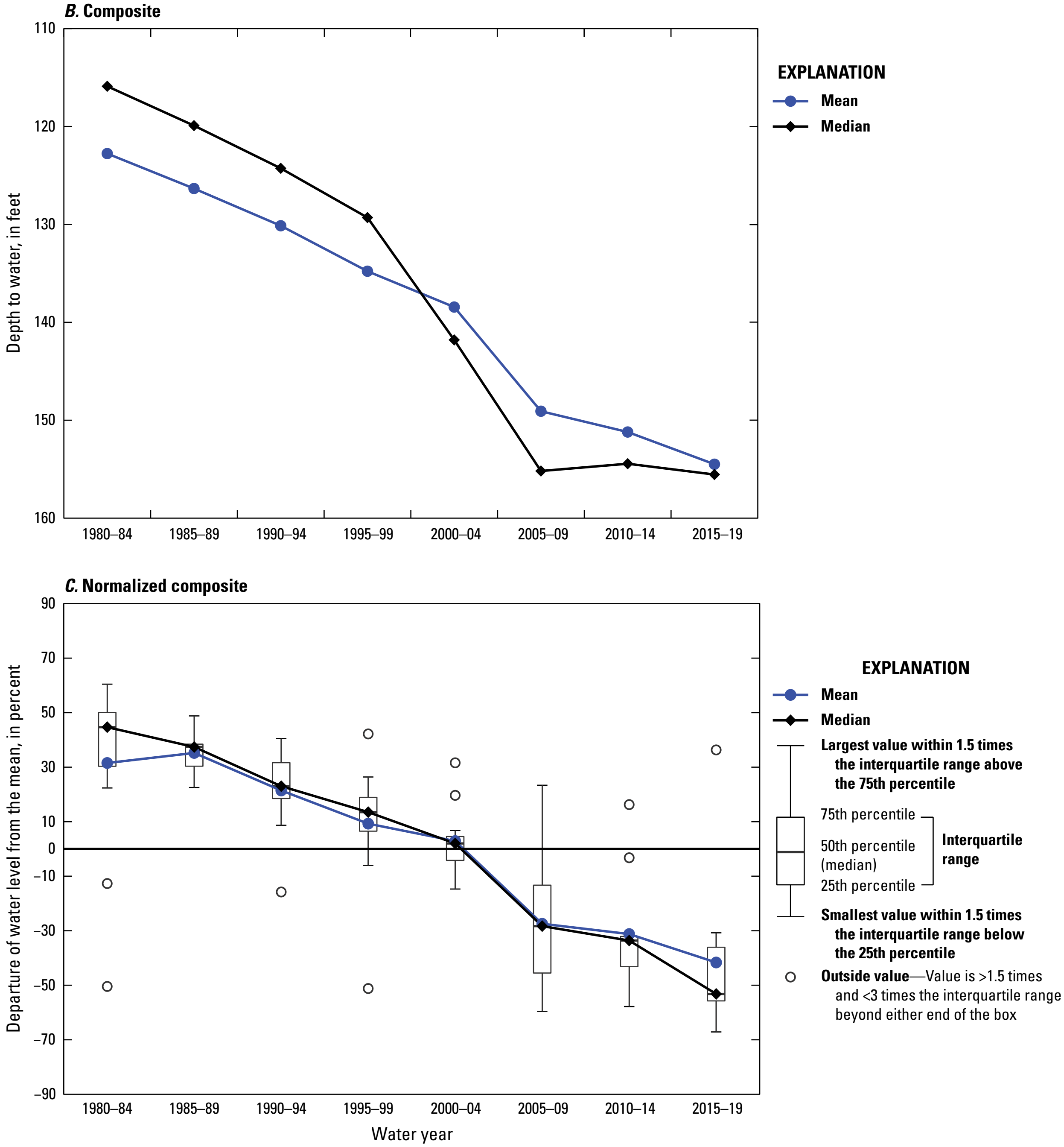


Figure 4. *A*, Eleven wells in the High Plains aquifer, northeast New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs—Continued

Table 4. Map and site identifiers for wells used to construct composite and normalized composite water-level hydrographs for the High Plains aquifer, northeast New Mexico.

[Map identifier locations are shown on figure 4. USGS, U.S. Geological Survey; --, not applicable]

Map identifier	USGS site number	Map identifier	USGS site number
1	363410103064801	7	355550103043101
2	362540103095001	8	355144103041201
3	362004103065501	9	355052103030901
4	361847103064701	10	354238103132301
5	361741103051001	11	353239103111301
6	360420103131601	--	--

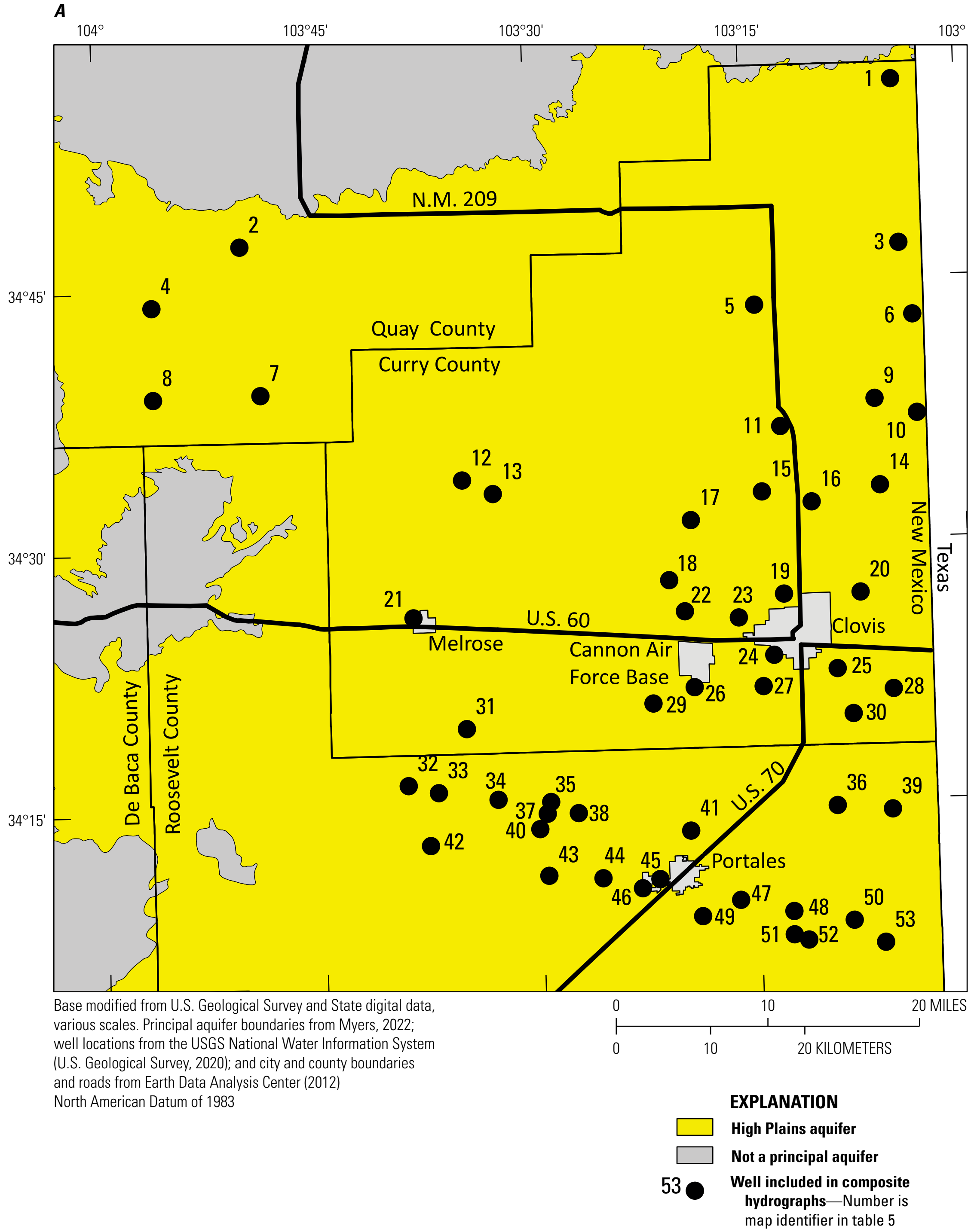


Figure 5. *A*, Fifty-three wells in the High Plains aquifer, east-central New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.

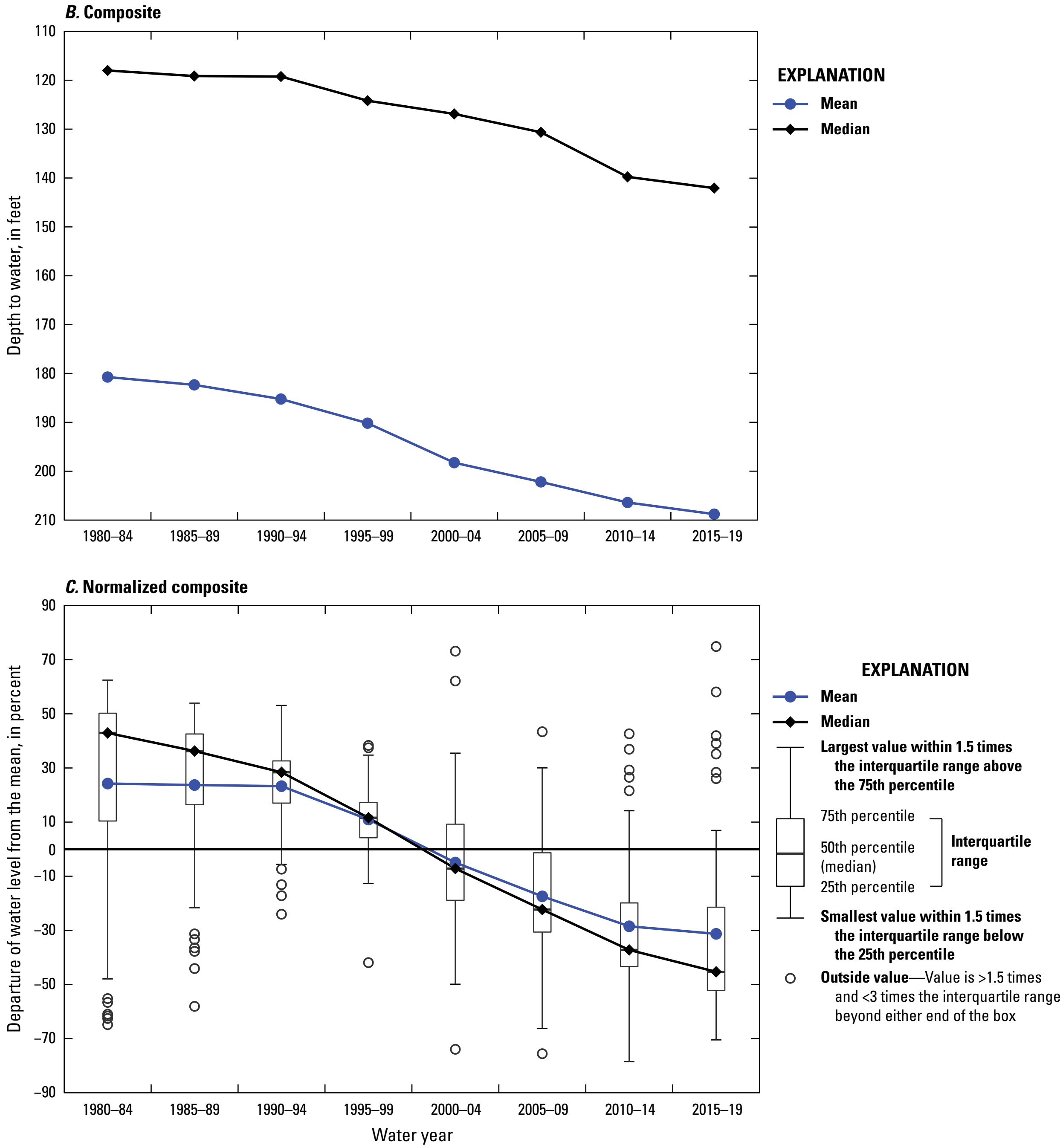


Figure 5. *A*, Fifty-three wells in the High Plains aquifer, east-central New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.—Continued

Table 5. Map and site identifiers for wells used to construct composite and normalized composite water-level hydrographs for the High Plains aquifer, east-central New Mexico.

[Map identifier locations are shown on figure 5. USGS, U.S. Geological Survey; --, not applicable]

Map identifier	USGS site number	Map identifier	USGS site number
1	345557103041301	28	342059103052201
2	344729103494001	29	342036103220001
3	344635103040301	30	341954103080901
4	344406103555501	31	341929103345201
5	344317103140901	32	341627103390301
6	344228103031501	33	341024103364901
7	343855103482901	34	341523103325101
8	343848103555801	35	341514103291401
9	343730103055601	36	341446103094701
10	343647103030901	37	341433103292802
11	343615103123801	38	341427103272301
12	343347103345001	39	341419103053501
13	343252103324001	40	341315103300001
14	343242103055401	41	341324103194101
15	343230103140301	42	341247103373901
16	343149103103701	43	341050103293501
17	343100103190201	44	341037103254501
18	342736103203701	45	341052103214501
19	342636103124301	46	342310103101201
20	342651103073201	47	340909103162001
21	342556103382101	48	340842103123101
22	342548103193601	49	340831103190102
23	342633103155301	50	340753103083101
24	342308103133301	51	340716103124401
25	342214103091301	52	340656103114601
26	342140103190501	53	340631103062601
27	342121103142301	--	--

High Plains Aquifer, Southeast New Mexico

Eighty-eight wells in the High Plains aquifer in southeast New Mexico qualified for composite hydrograph analysis (fig. 6, table 6). The wells are fairly evenly distributed over the southeastern High Plains aquifer (fig. 6*A*), mostly in the Lea County declared basin but with two wells (70 and 72) in the Capitan declared basin (figs. 1, 6*A*). The mean and median composite hydrographs both show water-level declines of about 17 ft from 1980–84 to 2015–19 (fig. 6*B*). Except for slight rises in the mean normalized composite hydrograph from 1980–84 to 1985–89 and from 2000–04 to 2005–09, both the mean and median normalized hydrographs show an overall decline in water levels (fig. 6*C*).

Pecos River Basin Alluvial Aquifer

Although only six wells in the Pecos River Basin alluvial aquifer qualified for composite hydrograph analysis (fig. 7, table 7), those six wells are fairly evenly distributed across the portion of this principal aquifer that falls within New Mexico (fig. 7*A*) and are in the Capitan declared basin (fig. 1). Both the mean and median composite hydrographs show fairly steady water levels from 1980–84 to 2005–09, a decline in water levels for 2010–14, then a rise for 2015–19 (fig. 7*B*). The mean composite hydrograph shows an overall rise of about 0.72 ft and the median composite hydrograph shows an overall decline of about 4.2 ft from 1980–84 to 2015–19. The mean and median normalized composite hydrographs show variable water levels from 1980–84 to 2015–19 with a large negative departure from the mean in 2010–14 (fig. 7*C*). The large negative departure from the mean probably results from the sensitivity of the normalization equation 1 to the roughly 5 ft (mean) and 7 ft (median) 2010–14 declines in composite water levels in the otherwise relatively flat composite hydrographs.

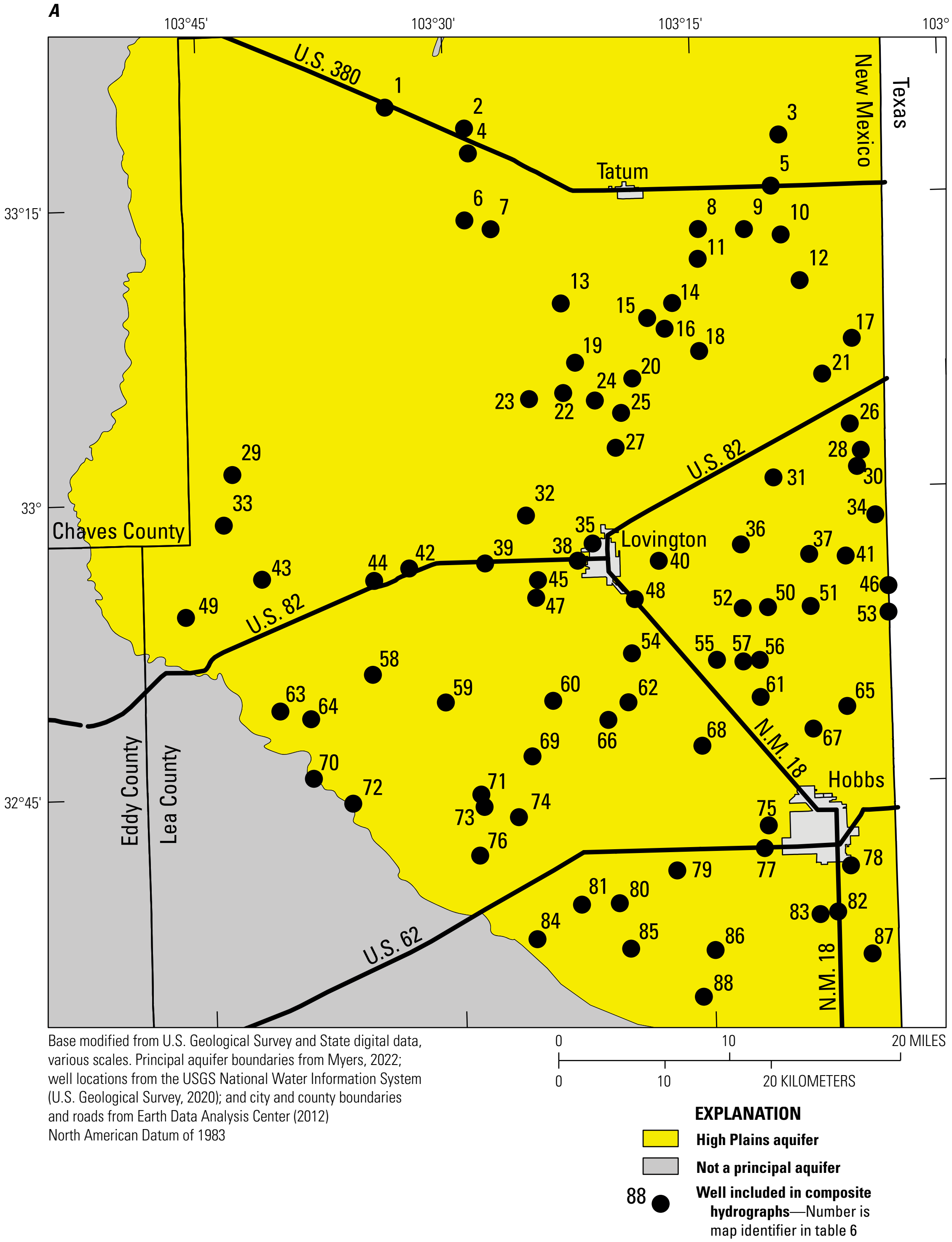


Figure 6. *A*, Eighty-eight wells in the High Plains aquifer, southeast New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.

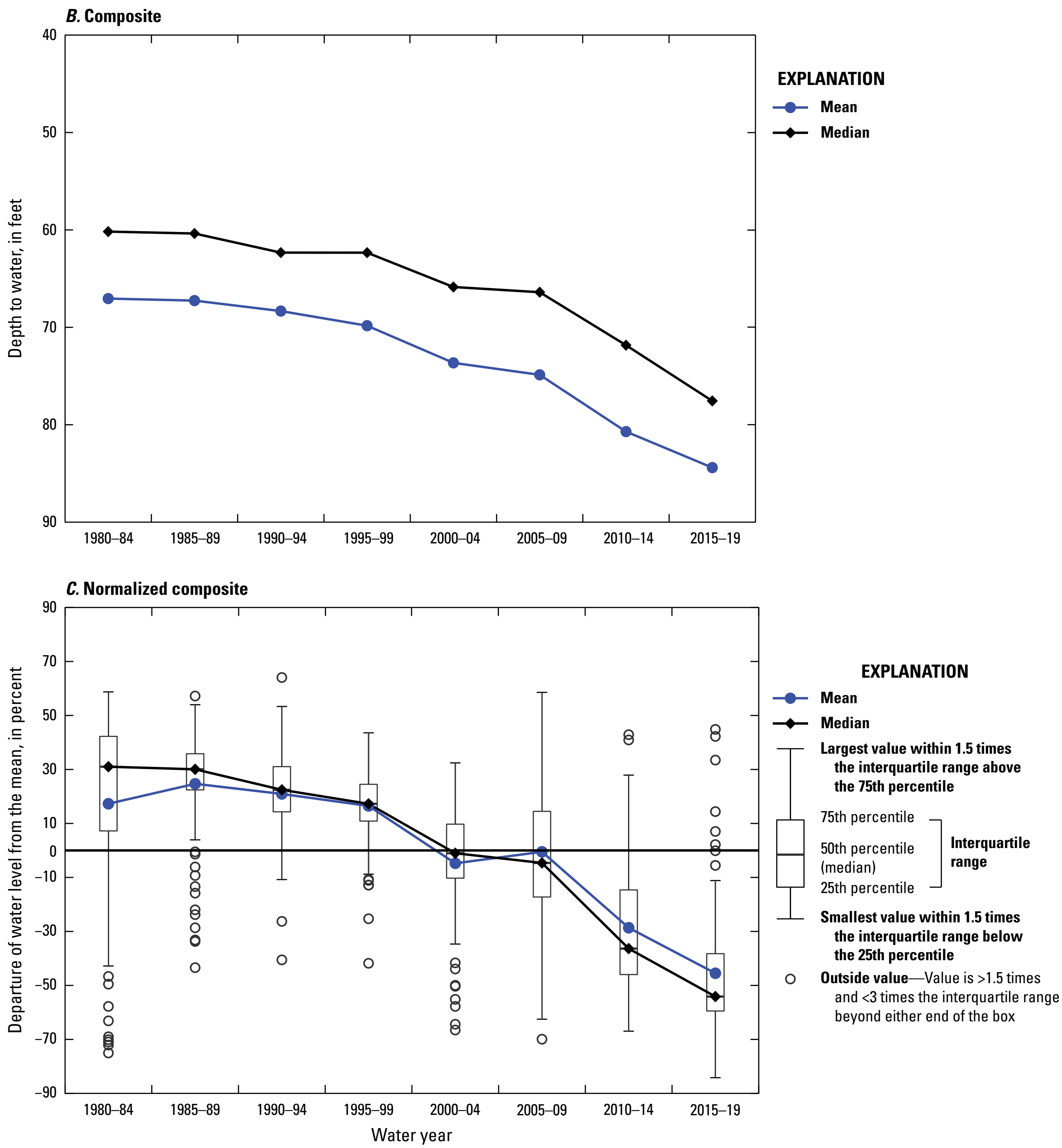


Figure 6. *A*, Eighty-eight wells in the High Plains aquifer, southeast New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.—Continued

Table 6. Map and site identifiers for wells used to construct composite and normalized composite water-level hydrographs for the High Plains aquifer, southeast New Mexico.

[Map identifier locations are shown on figure 6. USGS, U.S. Geological Survey; --, not applicable]

Map identifier	USGS site number	Map identifier	USGS site number	Map identifier	USGS site number
1	331943103332801	31	330045103103001	61	324918103113401
2	331829103284901	32	325848103252601	62	324906103193501
3	331750103093801	33	325846103435401	63	324913103403501
4	331713103283301	34	325815103041001	64	324846103384201
5	331510103100801	35	325730103213901	65	324850103060901
6	331350103285101	36	325750103124001	66	324820103204501
7	331257103271701	37	325655103081501	67	324745103082001
8	331259103144001	38	325624103222001	68	324648103151101
9	331315103121501	39	325628103275601	69	324629103253601
10	331241103094001	40	325645103171501	70	324541103383901
11	331136103144601	41	325623103061501	71	324455103283501
12	331033103083701	42	325619103323101	72	324420103362201
13	330931103230901	43	325600103412401	73	324415103281501
14	330945103163001	44	325543103343601	74	324320103261301
15	330839103175601	45	325545103243001	75	324235103113001
16	330815103164501	46	325448103035001	76	324130103284901
17	330718103053201	47	325455103250501	77	324124103114801
18	331730103145501	48	325436103191001	78	324024103063801
19	330628103222401	49	325356103460801	79	324026103170601
20	330555103185001	50	325307103110001	80	323903103202701
21	330535103072701	51	325415103081501	81	323851103225601
22	330515103224501	52	325350103123501	82	323813103072101
23	330458103251001	53	325435103035001	83	323759103083501
24	330420103220001	54	325137103191701	84	323725103253302
25	330405103194501	55	325115103141501	85	323631103195701
26	330312103054301	56	325132103112501	86	323618103145301
27	330215103193501	57	325113103125001	87	323555103053201
28	330138103051001	58	325055103345201	88	323355103154101
29	330121103432001	59	324925103303501	--	--
30	330050103052501	60	324918103240601	--	--

Rio Grande Aquifer System, North-Central New Mexico

Fifteen wells in the Rio Grande aquifer system in north-central New Mexico qualified for composite hydrograph analysis (fig. 8, table 8). Although these wells cluster into one group north of Taos and another group from Española to just south of Santa Fe, there were too few wells in each group to make separate composite hydrographs (fig. 8*A*). The wells are located in the Rio Grande (northern) declared basin (fig. 1). The mean and median composite hydrographs show water-level declines of about 9.8 and 18 ft, respectively, from 1980–84 to 2015–19 (fig. 8*B*). Overall, the mean and median normalized composite hydrographs show water-level declines from 1980–84 to 2015–19 (fig. 8*C*).

Rio Grande Aquifer System, Central New Mexico

Ten wells in the Rio Grande aquifer system in central New Mexico qualified for composite hydrograph analysis (fig. 9, table 9) and are located in the Rio Grande (middle) declared basin (fig. 1). Wells included in this analysis (fig. 9*A*) did not include wells in the Albuquerque area because the Albuquerque area wells show fundamentally different hydrograph features that are related to changes in municipal well pumping. The mean and median composite hydrographs both show only small water-level declines of about 2.9 and 1.6 ft, respectively, from 1985–89 to 2015–19 (fig. 9*B*). Overall, the mean and median normalized composite hydrographs show water-level declines from 1985–89 to 2015–19 (fig. 9*C*).

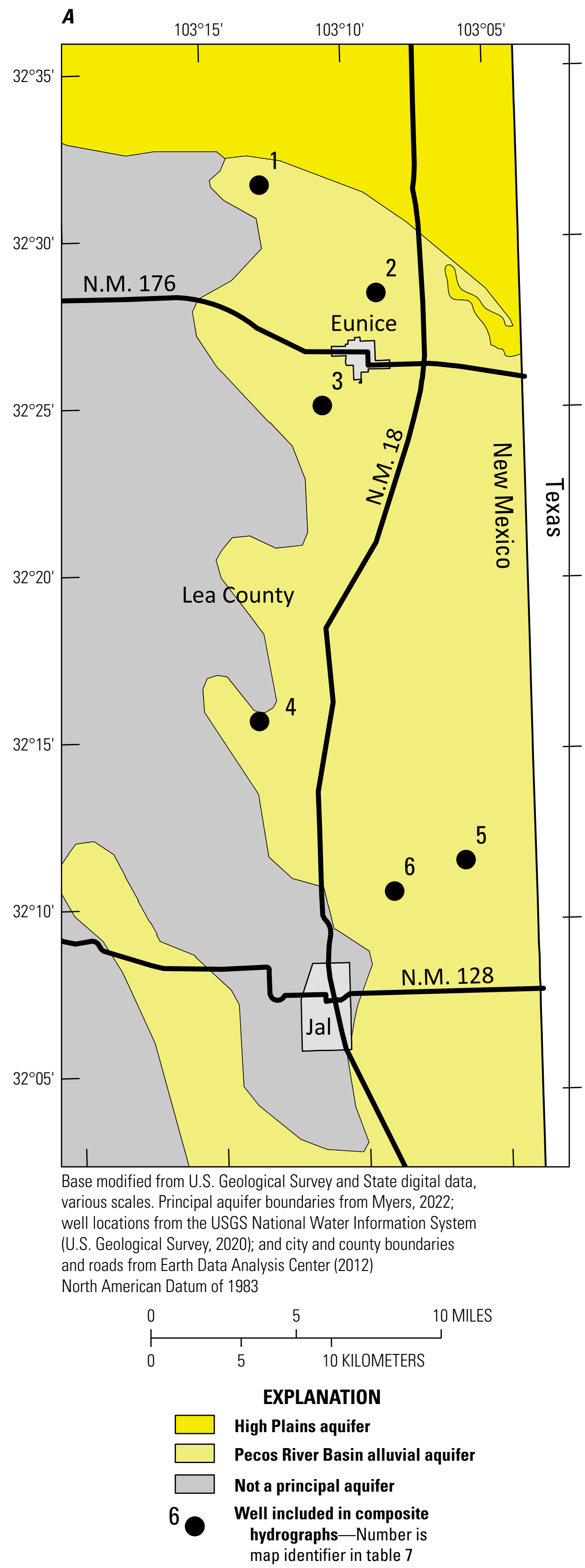


Figure 7. *A*, Six wells in the Pecos River Basin alluvial aquifer, southeast New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.

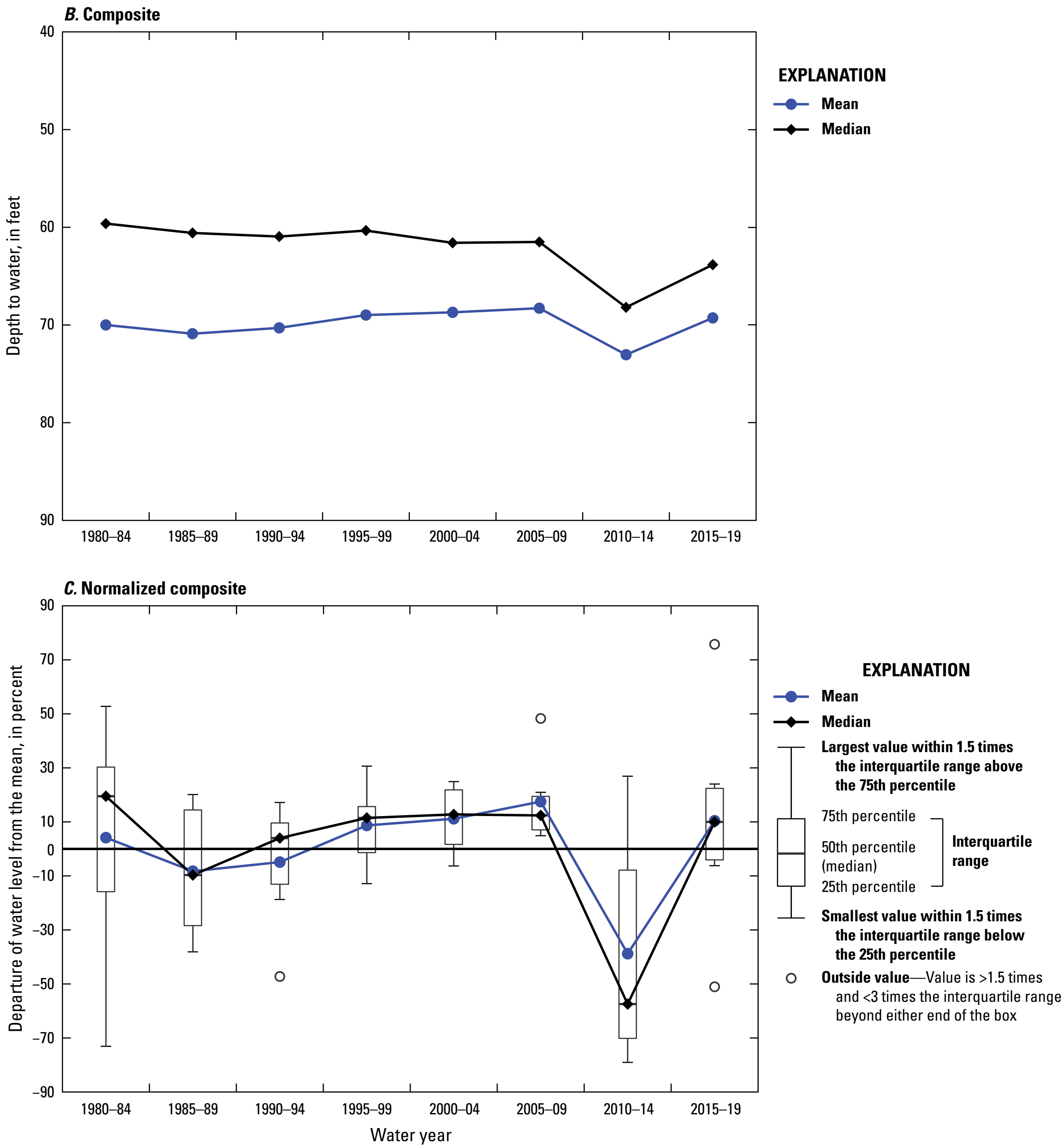


Figure 7. *A*, Six wells in the Pecos River Basin alluvial aquifer, southeast New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.—Continued

Table 7. Map and site identifiers for wells used to construct composite and normalized composite water-level hydrographs for the Pecos River Basin alluvial aquifer, southeast New Mexico.

[Map identifier locations are shown on figure 7. USGS, U.S. Geological Survey]

Map identifier	USGS site number	Map identifier	USGS site number
1	323114103130601	4	321540103125701
2	322804103085701	5	321055103062101
3	322442103105701	6	321003103085201

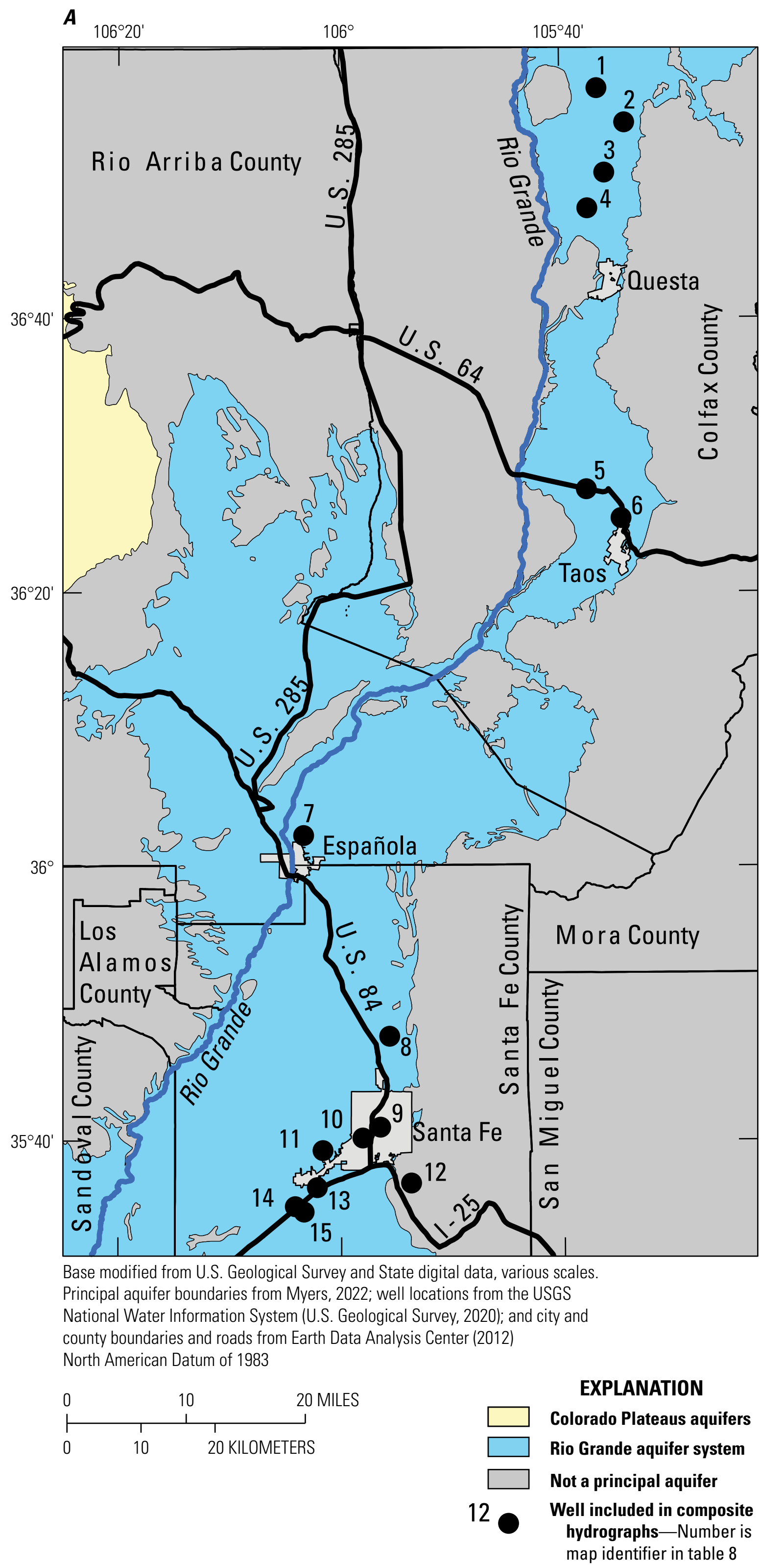


Figure 8. *A*, Fifteen wells in the Rio Grande aquifer system, north-central New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.

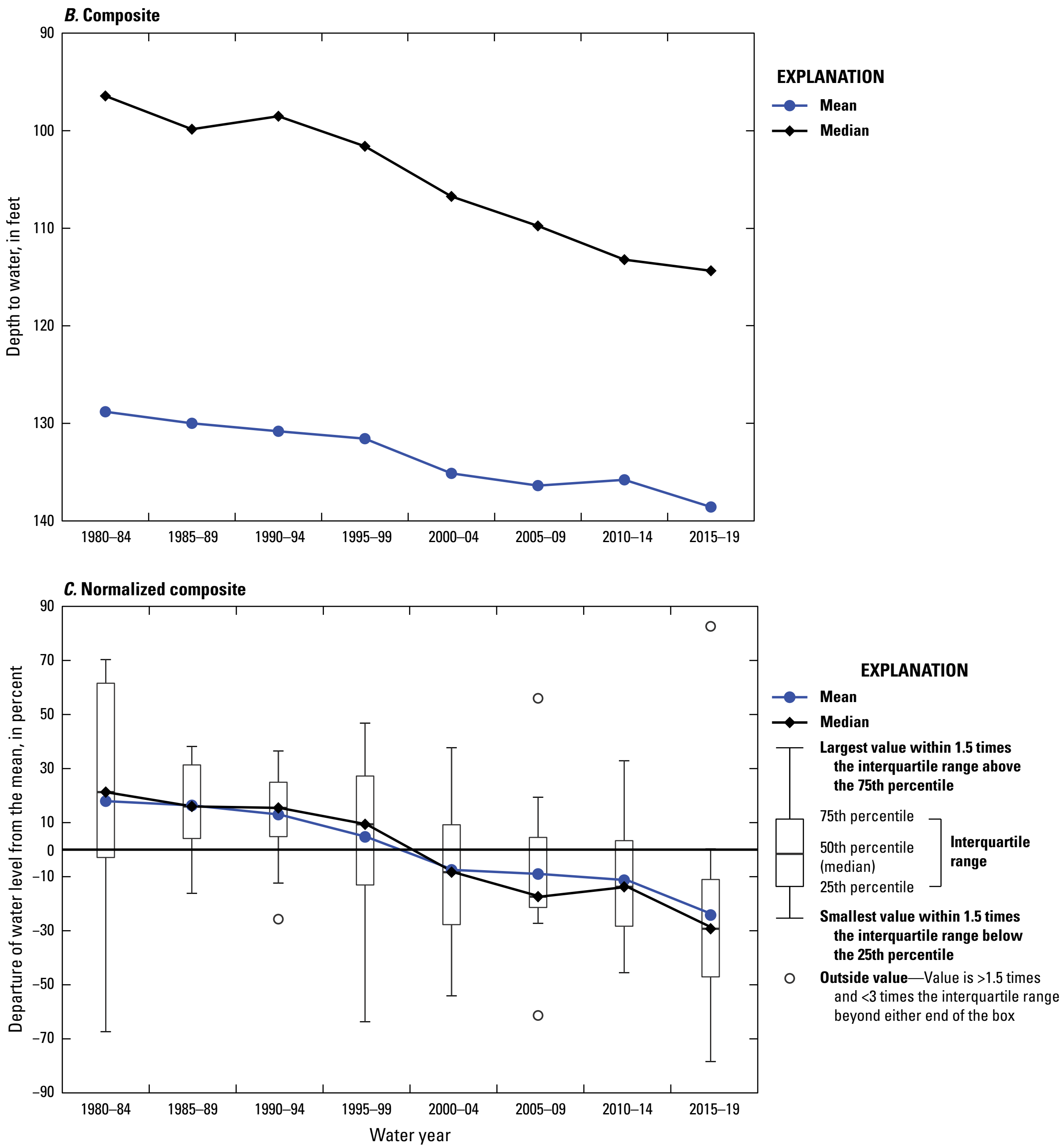


Figure 8. *A*, Fifteen wells in the Rio Grande aquifer system, north-central New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.—Continued

Table 8. Map and site identifiers for wells used to construct composite and normalized composite water-level hydrographs for the Rio Grande aquifer system, north-central New Mexico.

[Map identifier locations are shown on figure 8. USGS, U.S. Geological Survey; --, not applicable]

Map identifier	USGS site number	Map identifier	USGS site number
1	365644105363501	9	354100105562701
2	365414105340401	10	354013105580601
3	365035105360501	11	353918106013701
4	364757105372801	12	353654105534301
5	362820105362001	13	353636106021001
6	362523105343401	14	353516106035801
7	360219106031801	15	353449106031901
8	354738105553901	--	--

Rio Grande Aquifer System, Albuquerque Area, New Mexico

Twenty-six wells in the Rio Grande aquifer system, Albuquerque area, N. Mex., qualified for composite hydrograph analysis (fig. 10, table 10) and are located in the Rio Grande (middle) declared basin. Only 13 individual sites are represented (fig. 10*A*), because many of the 26 wells are in nested configurations having two or three wells in a single borehole with water-intake screens placed at different depths. The hydrographs (fig. 10*B*, *C*) start in 1985–89 because data were not available for some of the wells in 1980–84. From 1985–89 to 2015–19, the mean and median composite hydrographs show a water-level decline of about 1.0 ft and a water-level rise of about 0.65 ft, respectively. But from 1985–89 to 2000–04 (mean) and 1985–89 to 2005–09 (median) water levels declined about 6.0 and 2.6 ft, respectively, and thereafter rose about 5.0 and 3.3 ft, respectively (fig. 10*B*). The normalized composite hydrographs show water-level declines through 2000–04 (mean) and 2005–09 (median) and rising water levels thereafter (fig. 10*C*). The change from declining to rising water levels resulted primarily from decreased groundwater pumping by the Albuquerque Bernalillo County Water Utility Authority (herein referred to as "Water Authority") (Ritchie and others, 2019). In late 2008, the Water Authority began using San Juan-Chama Project surface water from the Rio Grande for public supply and consequently decreased their groundwater pumping from wells located throughout Albuquerque (Albuquerque Bernalillo County Water Utility Authority, 2021). As a result of the decreased pumping, groundwater levels began to rise in early 2009 after reaching lows in the annual minimum (shallowest) water-level values in late 2008 (Myers and Friesz, 2019).

Rio Grande Aquifer System, Plains of San Agustin, New Mexico

Nine wells in the Rio Grande aquifer system, Plains of San Agustin, N. Mex., qualified for composite hydrograph analysis (fig. 11, table 11) and are located in the Rio Grande (middle) declared basin (fig. 1). The hydrographs (fig. 11*B*, *C*) start in 1990–94 because data were not available for some of the wells in 1980–84 and 1985–89. The mean and median composite hydrographs are fairly flat, both showing only small water-level declines of about 1.2 ft from 1990–94 to 2015–19 (fig. 11*B*). The mean and median normalized composite hydrographs show variable but overall declining water levels from 1990–94 to 2015–19 (fig. 11*C*). The variability of the normalized composite hydrographs results from the sensitivity of the normalization equation 1 to small composite water-level changes in the otherwise relatively flat composite hydrographs.

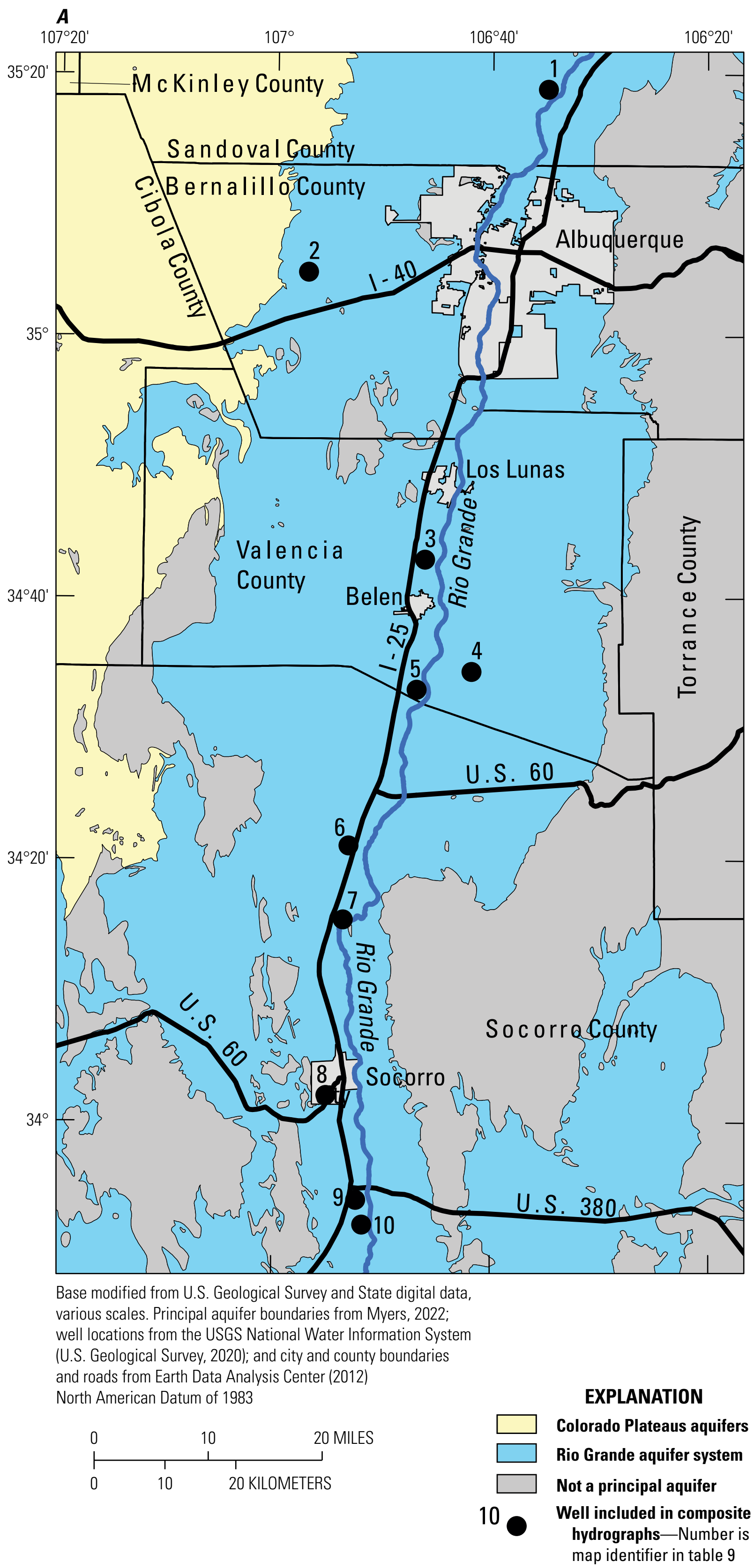


Figure 9. *A*, Ten wells in the Rio Grande aquifer system, central New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.

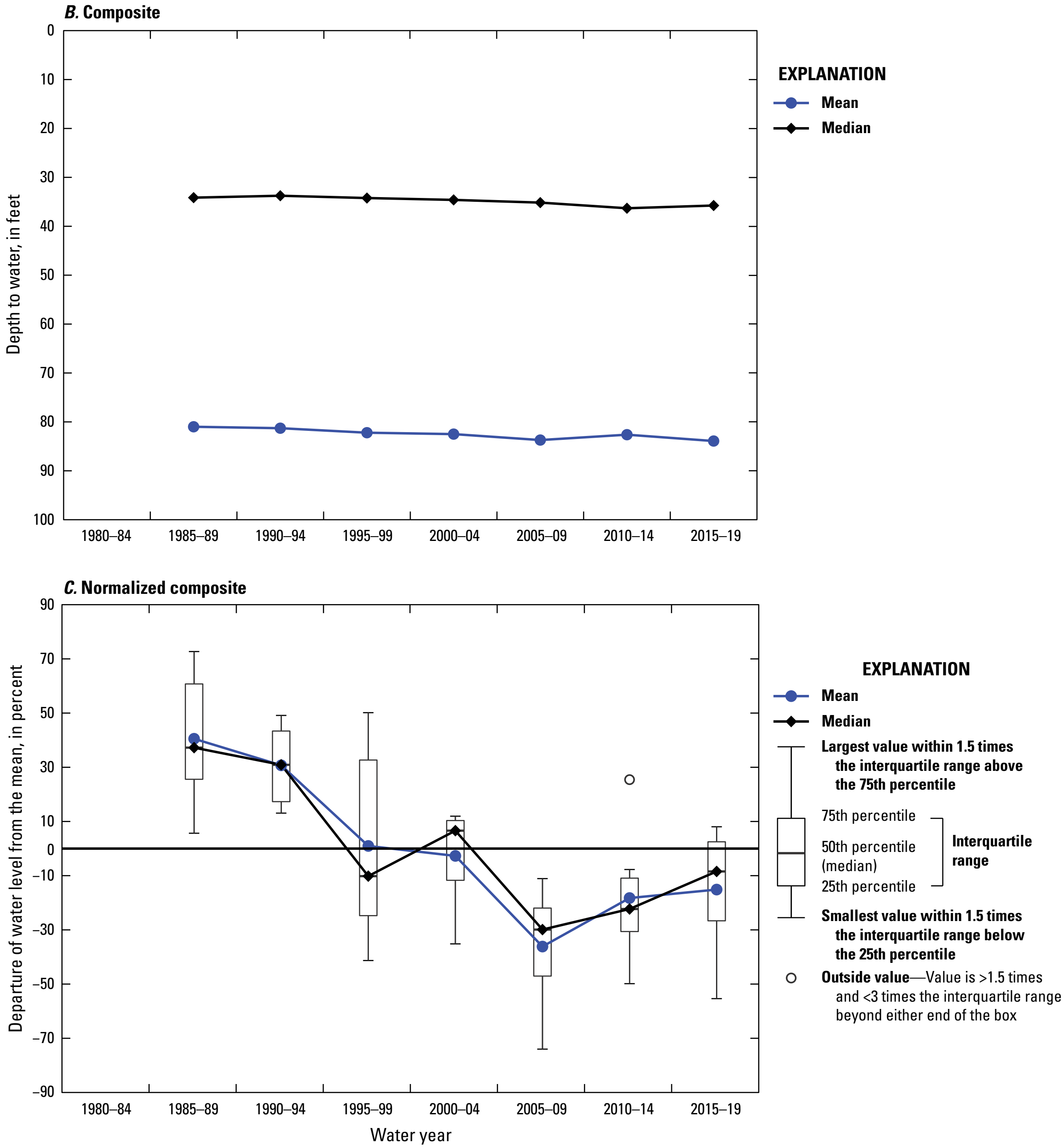


Figure 9. *A*, Ten wells in the Rio Grande aquifer system, central New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.—Continued

Table 9. Map and site identifiers for wells used to construct composite and normalized composite water-level hydrographs for the Rio Grande aquifer system, central New Mexico.

[Map identifier locations are shown on figure 9. USGS, U.S. Geological Survey]

Map identifier	USGS site number	Map identifier	USGS site number
1	351852106344901	6	342107106530401
2	350454106570401	7	341528106533301
3	344258106460901	8	340203106550701
4	343422106414101	9	335404106521701
5	343304106465001	10	335152106512001

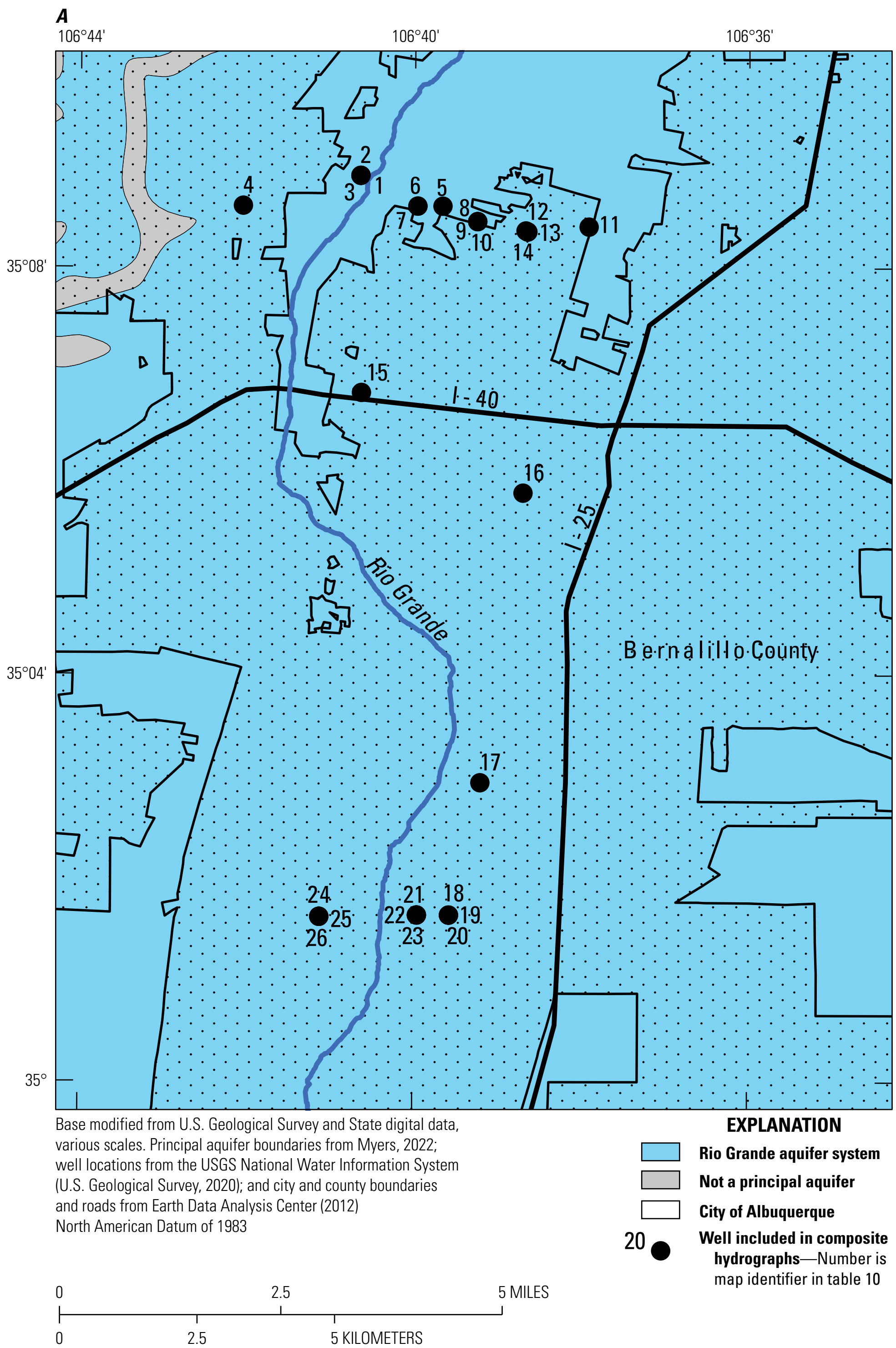


Figure 10. *A*, Twenty-six wells in the Rio Grande aquifer system, Albuquerque area, New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.

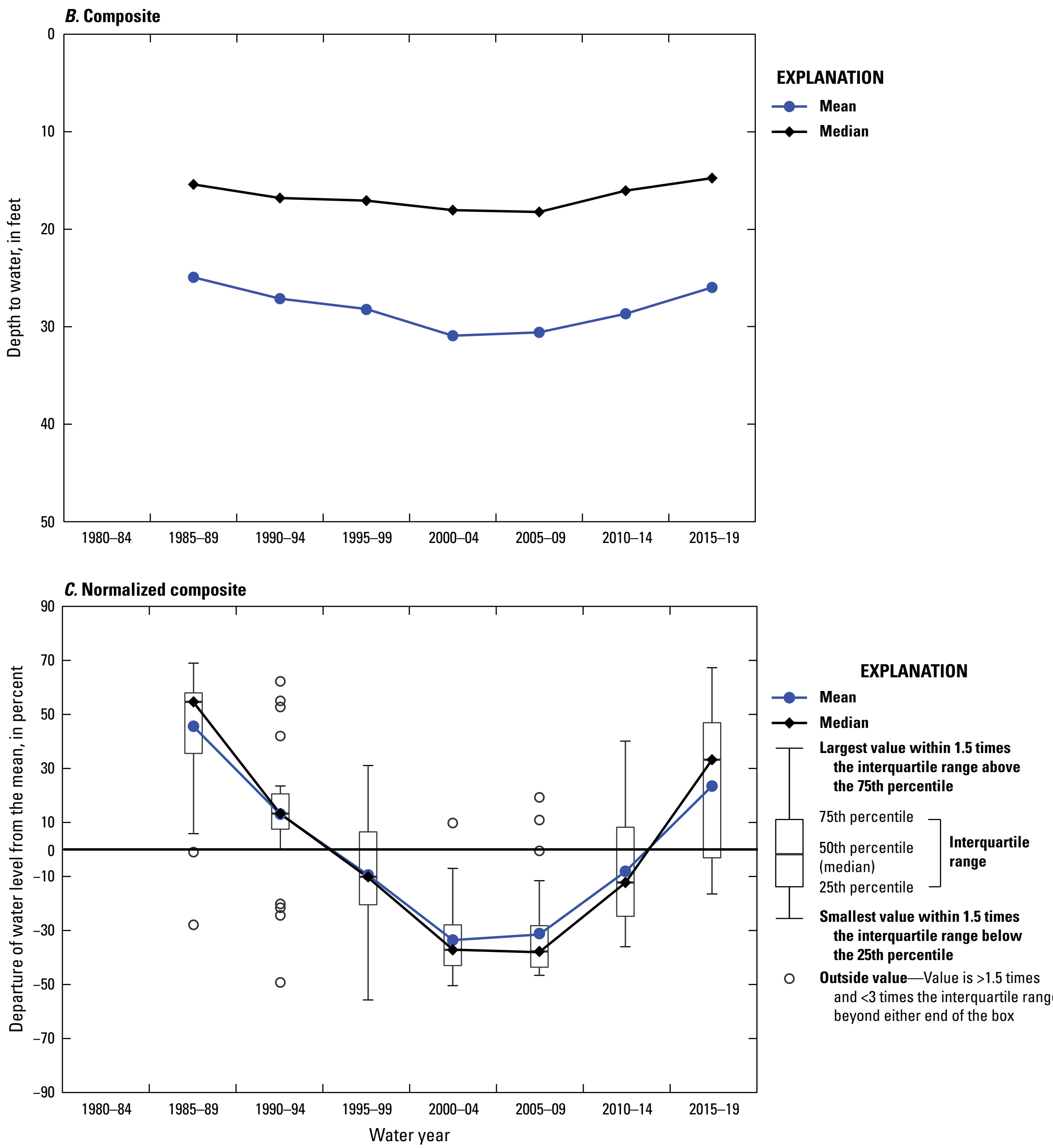


Figure 10. *A*, Twenty-six wells in the Rio Grande aquifer system, Albuquerque area, New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.—Continued

Table 10. Map and site identifiers for wells used to construct composite and normalized composite water-level hydrographs for the Rio Grande aquifer system, Albuquerque area, New Mexico.

[Map identifier locations are shown on figure 10. USGS, U.S. Geological Survey; --, not applicable]

Map identifier	USGS site number	Map identifier	USGS site number	Map identifier	USGS site number
1	350854106403703	10	350827106391301	19	350138106393202
2	350854106403702	11	350824106375301	20	350138106393201
3	350854106403701	12	350821106383703	21	350138106395503
4	350829106420401	13	350821106383702	22	350138106395502
5	350837106393801	14	350821106383701	23	350138106395501
6	350836106395603	15	350646106403601	24	350137106410503
7	350836106395601	16	350548106383901	25	350137106410502
8	350827106391303	17	350256106390801	26	350137106410501
9	350827106391302	18	350138106393203	--	--

Rio Grande Aquifer System, Rio Grande Valley, South-Central New Mexico

Thirty-four wells in the Rio Grande aquifer system, Rio Grande Valley, in south-central New Mexico, qualified for composite hydrograph analysis (fig. 12, table 12) and are located in the Lower Rio Grande declared basin. Wells in the valley were analyzed separately from wells on the mesa lands to the west and southwest because the wells in the valley have shallower depths to water and are near the Rio Grande where they likely are influenced by surface-water fluctuations. The mean and median composite hydrographs show rising water levels from 1980–84 to 1985–89 and declining water levels thereafter (fig. 12*B*). Overall, mean and median water levels declined about 5.6 and 9.3 ft, respectively, from 1980–84 to 2015–19 (fig. 12*B*). The mean and median normalized composite hydrographs initially show rising water levels followed by declining water levels after 1985–89 (fig. 12*C*).

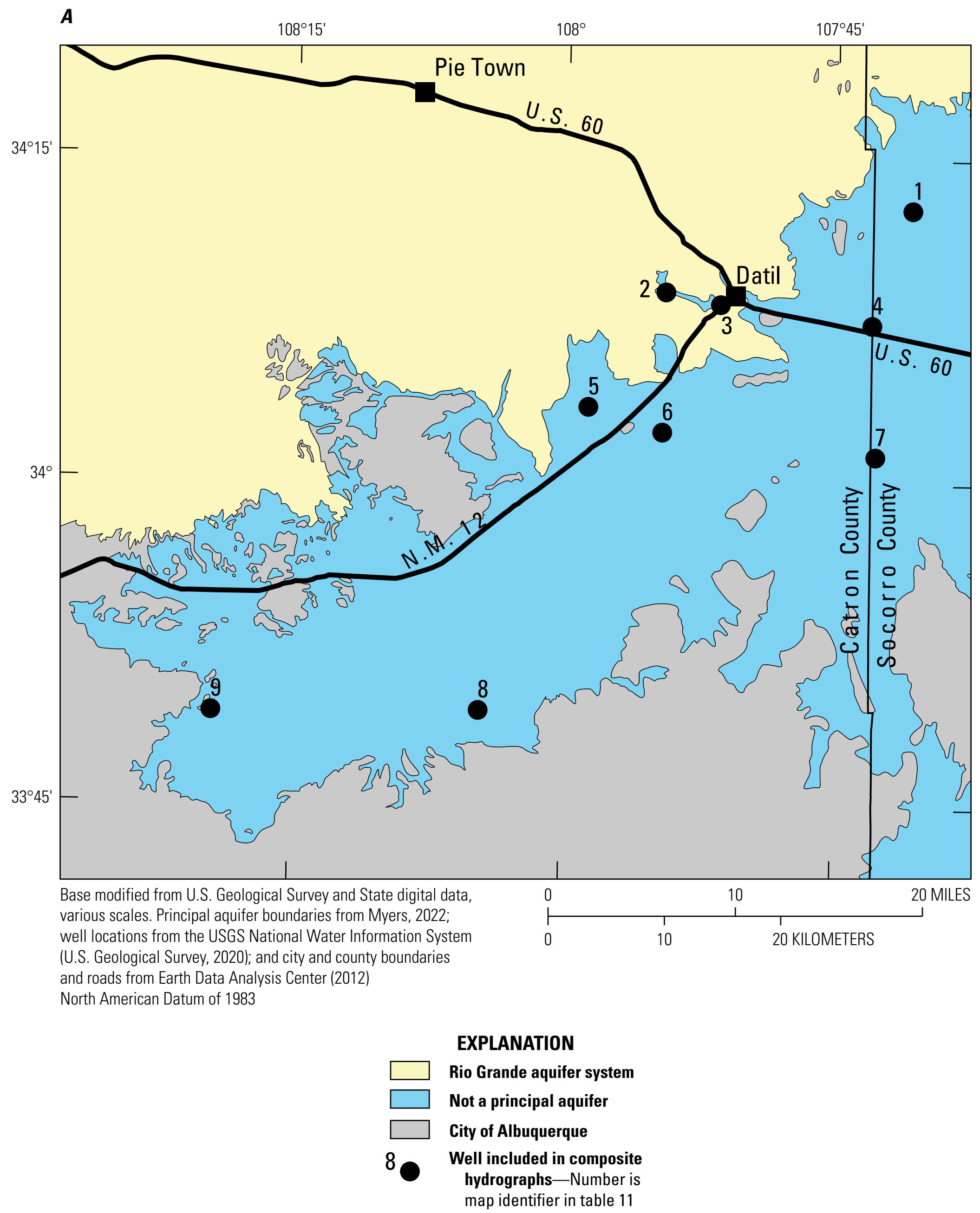
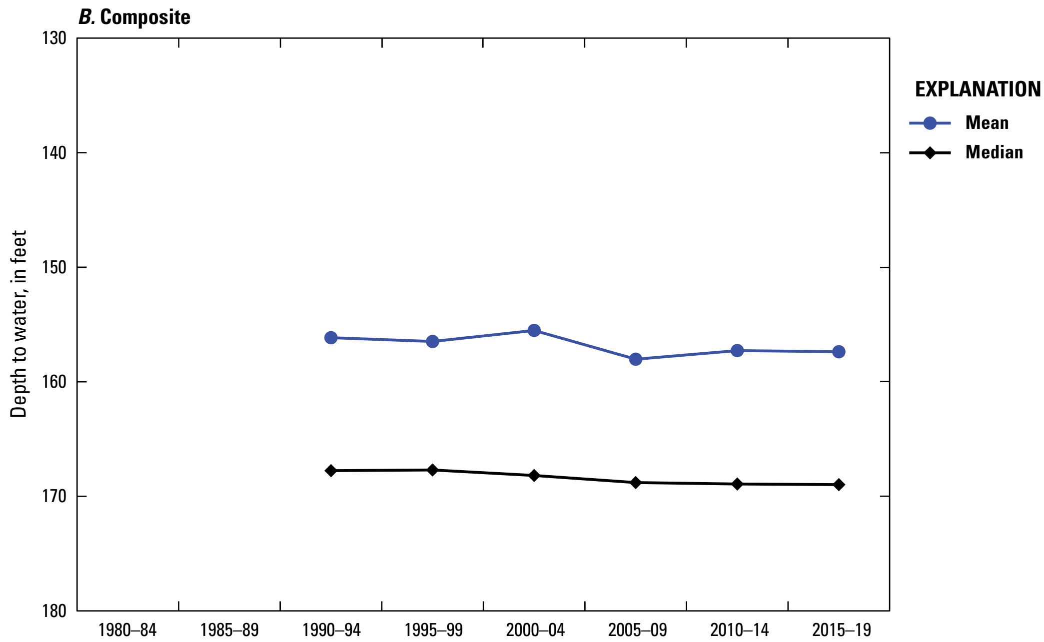


Figure 11. *A*, Nine wells in the Rio Grande aquifer system, Plains of San Agustin, New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.



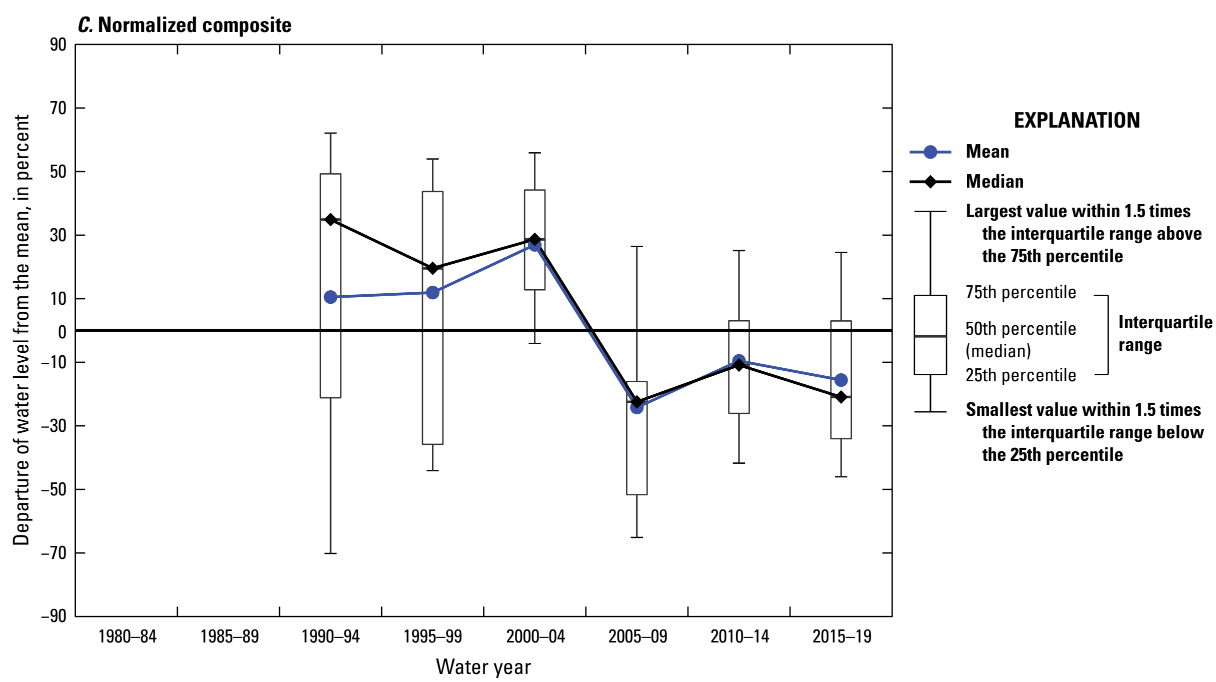


Figure 11. *A*, Nine wells in the Rio Grande aquifer system, Plains of San Agustin, New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.—Continued

Table 11. Map and site identifiers for wells used to construct composite and normalized composite water-level hydrographs for the Rio Grande aquifer system, Plains of San Agustin, New Mexico.

[Map identifier locations are shown on figure 11. USGS, U.S. Geological Survey; --, not applicable]

Map identifier	USGS site number	Map identifier	USGS site number
1	341243107404801	6	340223107543601
2	340850107542801	7	340118107424201
3	340817107512401	8	334930108043201
4	340723107425801	9	334914108191901
5	340329107584201	--	--

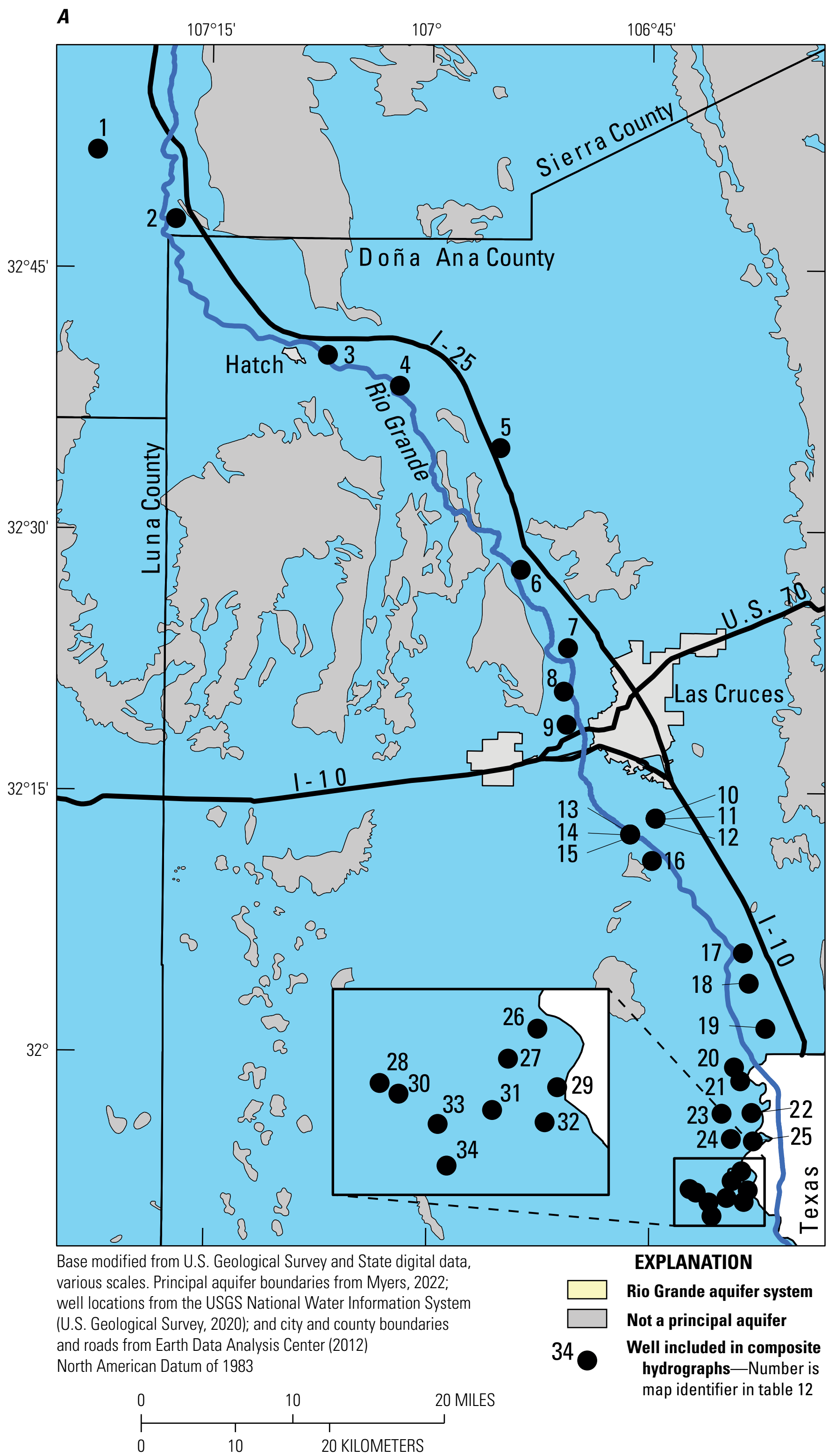


Figure 12. *A*, Thirty-four wells in the Rio Grande aquifer system, Rio Grande Valley, south-central New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.

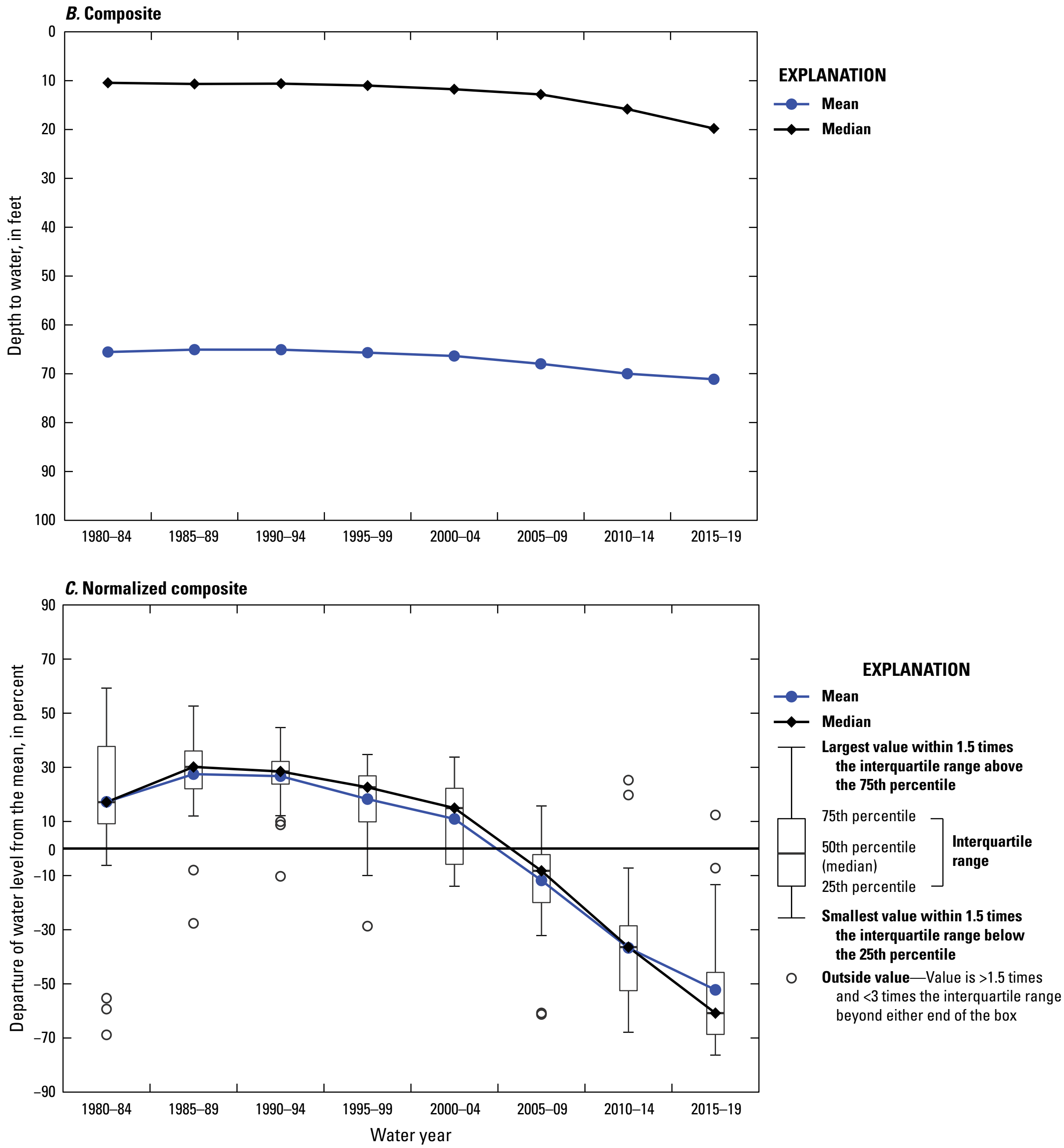


Figure 12. *A*, Thirty-four wells in the Rio Grande aquifer system, Rio Grande Valley, south-central New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.—Continued

Table 12. Map and site identifiers for wells used to construct composite and normalized composite water-level hydrographs for the Rio Grande aquifer system, Rio Grande Valley, south-central New Mexico.

[Map identifier locations are shown on figure 12. USGS, U.S. Geological Survey; --, not applicable]

Map identifier	USGS site number	Map identifier	USGS site number	Map identifier	USGS site number
1	325142107225001	13	321237106462001	24	315515106392801
2	324742107172001	14	321237106462002	25	315453106374701
3	324004107070201	15	321237106462003	26	315318106384301
4	323818107020901	16	321112106445201	27	315238106392301
5	323446106551801	17	320456106383001	28	315212106420901
6	322750106535001	18	320404106381901	29	315204106381601
7	322312106503601	19	320128106371501	30	315154106414401
8	322047106505001	20	315918106391301	31	315144106394101
9	321853106504001	21	315823106384001	32	315126106381801
10	321332106443701	22	315639106380401	33	315124106410001
11	321332106443702	23	315637106394801	34	315046106403201
12	321332106443703	--	--	--	--

Rio Grande Aquifer System, Mesa Lands West and Southwest of Las Cruces, New Mexico

Eleven wells in the Rio Grande aquifer system, mesa lands west and southwest of Las Cruces, N. Mex., qualified for composite hydrograph analysis (fig. 13, table 13) and are located in the Lower Rio Grande declared basin. Although well 4 (fig. 13*A*) is not shown to be located in the Rio Grande Aquifer system, database records (U.S. Geological Survey, 2020) indicate that the well produces water from Santa Fe Group sediments. The well probably is located in an area where a layer of volcaniclastic rock overlies Santa Fe Group sediment. The mean composite hydrograph generally shows a water-level rise of about 6.8 ft from 1980–84 to 2015–19, whereas the median composite hydrograph generally shows water-level declines of about 4.5 ft from 1980–84 to 2015–19 (fig. 13*B*). The mean and median composite hydrographs show different trends in water levels because the mean composite hydrograph is strongly influenced by shallower and rising water levels in the three wells north of Interstate 10 (wells 1, 2, and 3), whereas the median composite hydrograph reflects the relatively flat or slightly declining water levels typical of the eight wells south of Interstate 10 (fig. 13*A*; data for individual wells are available from U.S. Geological Survey, 2020). The mean and median normalized composite hydrographs generally show periods of rising or relatively flat water levels from 1980–84 to 2000–04 followed by generally declining water levels through 2015–19 (fig. 13*C*).

Roswell Basin Aquifer System, New Mexico

Ninety-four wells in the Roswell Basin aquifer system in New Mexico qualified for composite hydrograph analysis (fig. 14, table 14) and are located in the Roswell Artesian declared basin. Although the mean and median composite hydrographs show overall water-level declines of about 1.3 and 2.7 ft, respectively, from 1980–84 to 2015–19, water levels have declined about 10 and 9 ft, respectively, since the water-level high in 1990–94 (fig. 14*B*). A water-level rise from 1980–84 to 1990–94 resulted from higher-than-normal precipitation from the late 1970s to the mid-1990s (Land and Newton, 2007). The mean and median normalized composite hydrographs show a similar pattern of water-level rise through 1990–94 and decline thereafter (fig. 14*C*).

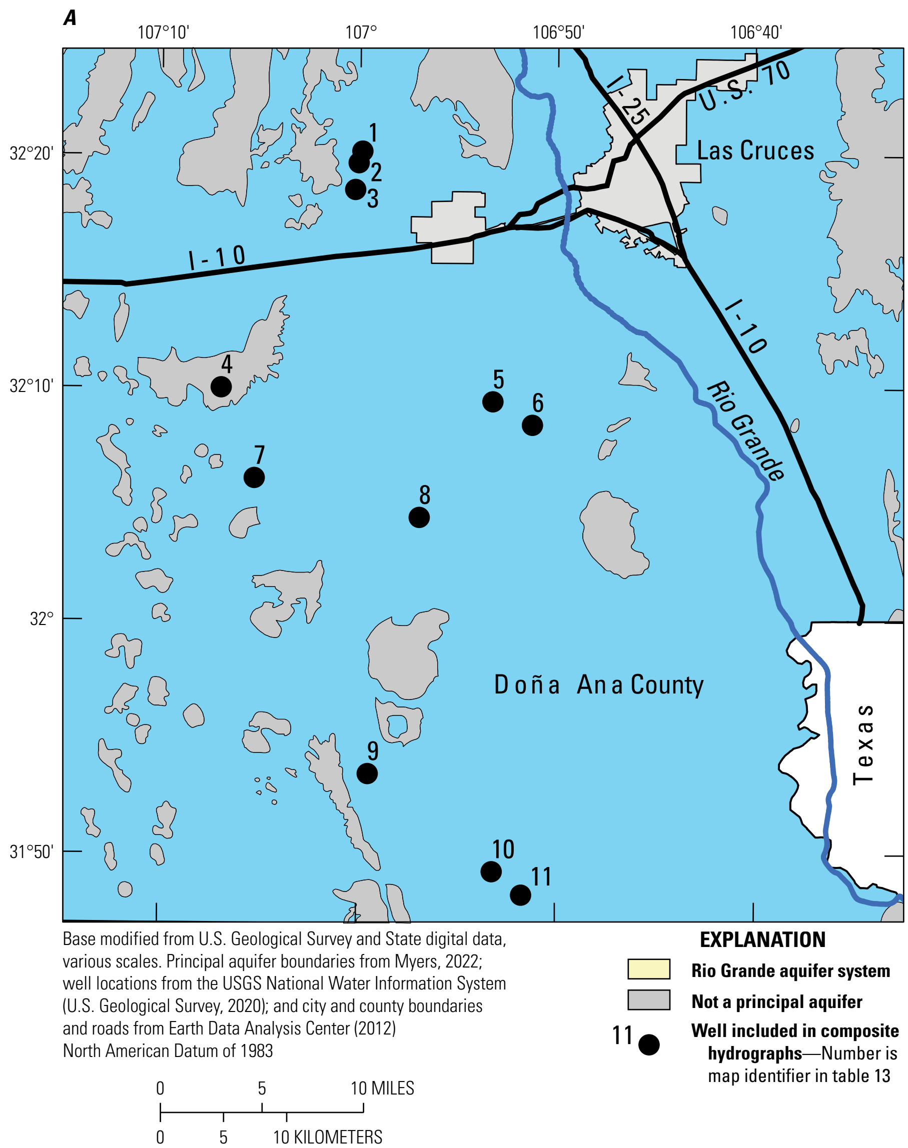


Figure 13. *A*, Eleven wells in the Rio Grande aquifer system, mesa lands west and southwest of Las Cruces, New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.

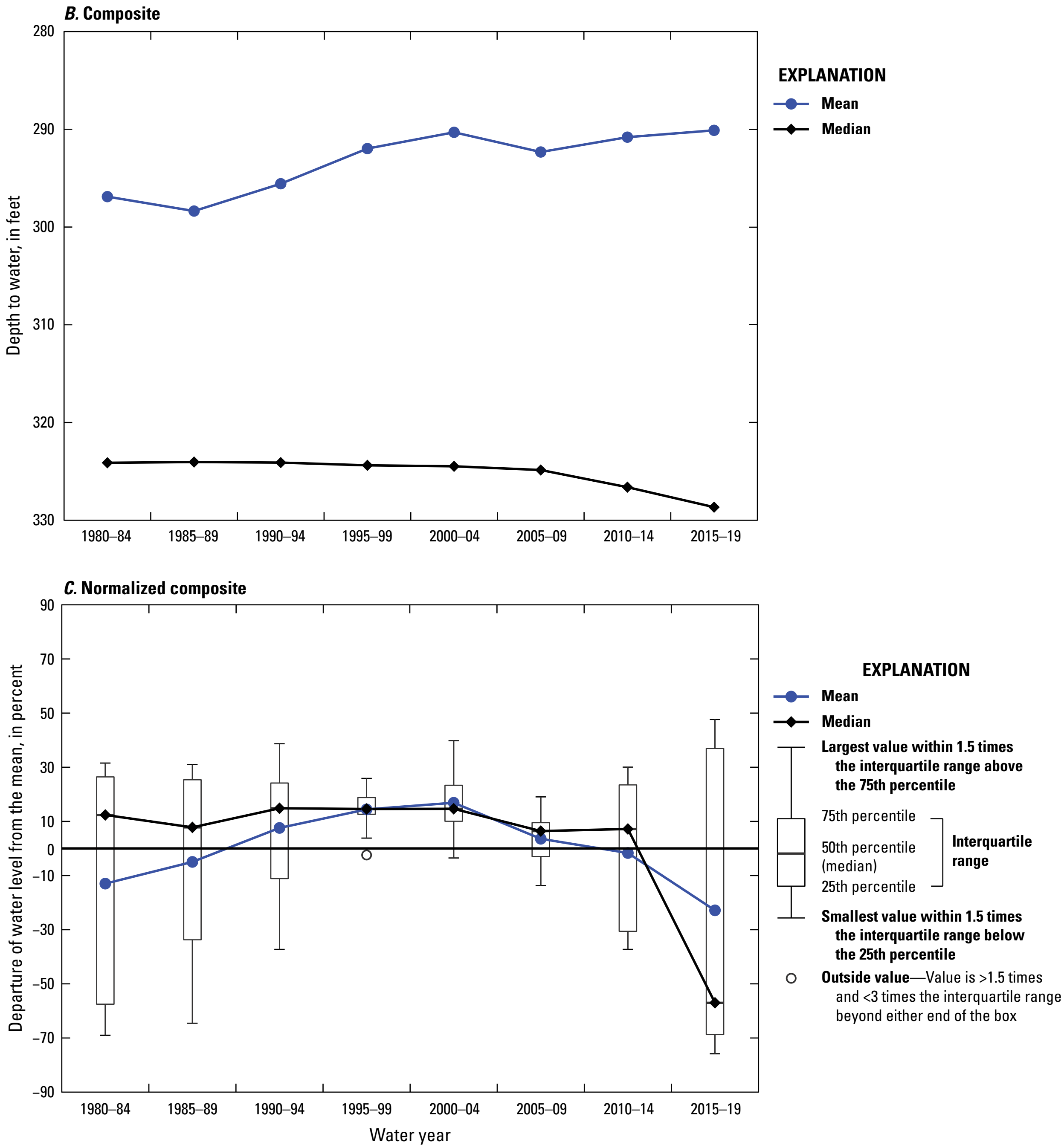


Figure 13. *A*, Eleven wells in the Rio Grande aquifer system, mesa lands west and southwest of Las Cruces, New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.—Continued

Table 13. Map and site identifiers for wells used to construct composite and normalized composite water-level hydrographs for the Rio Grande aquifer system, mesa lands west and southwest of Las Cruces, New Mexico.

[Map identifier locations are shown on figure 13. USGS, U.S. Geological Survey; --, not applicable]

Map identifier	USGS site number	Map identifier	USGS site number
1	322011106591901	7	320602107045601
2	321945106595001	8	320425106565201
3	321828107000501	9	315326106592501
4	321000107065601	10	314914106530501
5	320927106531201	11	314810106513601
6	320824106510801	--	--

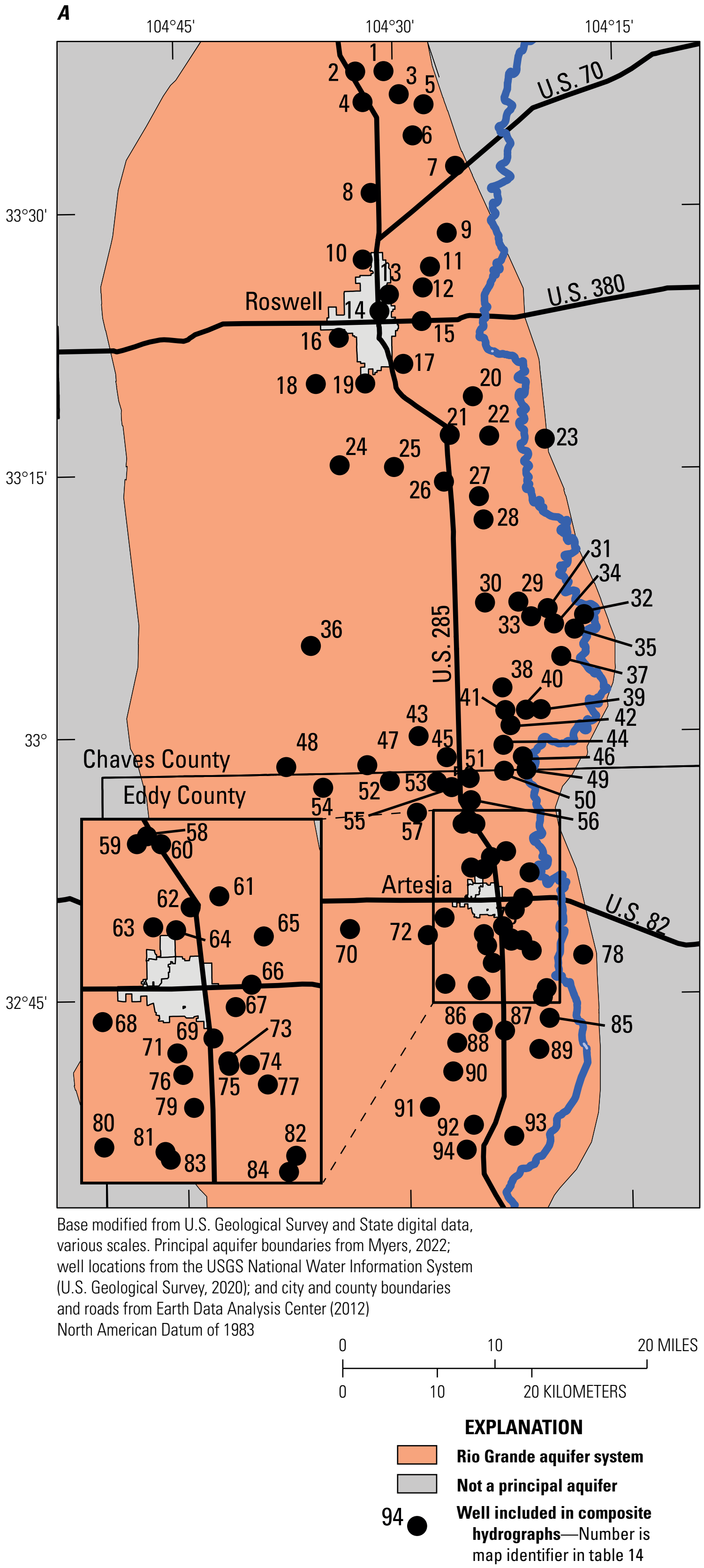


Figure 14. *A*, Ninety-four wells in the Roswell Basin aquifer system, southeast New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.

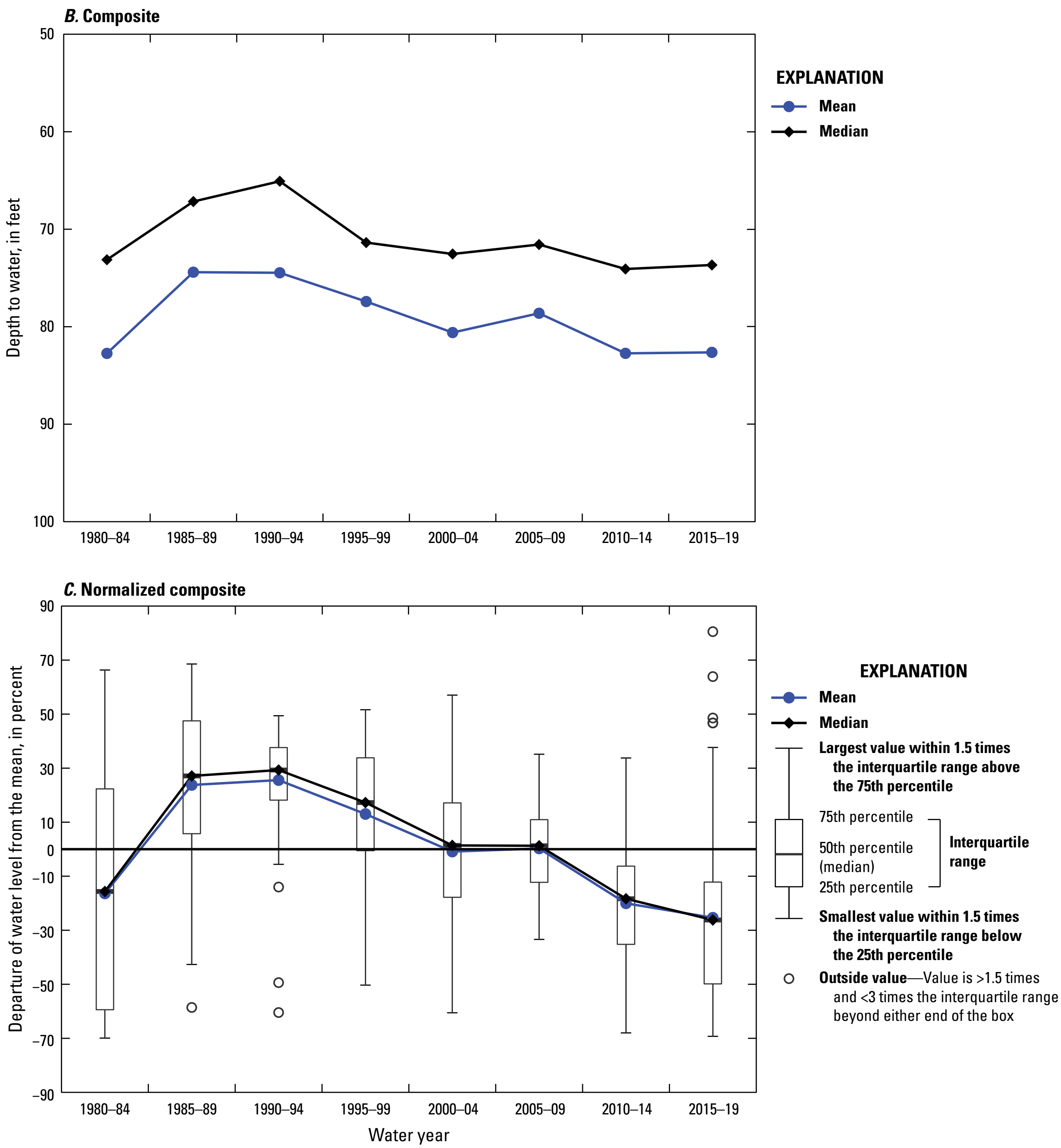


Figure 14. *A*, Ninety-four wells in the Roswell Basin aquifer system, southeast New Mexico, used to construct, *B*, composite groundwater-level hydrographs and, *C*, normalized composite groundwater-level hydrographs.—Continued

Table 14. Map and site identifiers for wells used to construct composite and normalized composite water-level hydrographs for the Roswell Basin aquifer system, southeast, New Mexico.

[Map identifier locations are shown on figure 14. USGS, U.S. Geological Survey; --, not applicable]

Map identifier	USGS site number	Map identifier	USGS site number	Map identifier	USGS site number
1	333756104303401	33	330638104210901	64	325214104244201
2	333756104323001	34	330612104193601	65	325200104213401
3	333636104293301	35	330553104181301	66	325033104220201
4	333611104320201	36	330509104360901	67	324953104223701
5	333600104275201	37	330420104190901	68	324930104272301
6	333414104283901	38	330236104231101	69	324857104232601
7	333227104254701	39	330119104203601	70	324856104334801
8	333059104313501	40	330118104213701	71	324831104244401
9	332838104262601	41	330118104230101	72	324831104283201
10	332711104321202	42	330026104224101	73	324815104225501
11	332643104273701	43	325954104285601	74	324808104220901
12	332532104280801	44	325919104231101	75	324807104225301
13	332510104302701	45	325840104270301	76	324752104243201
14	332413104310701	46	325838104215301	77	324732104213101
15	332337104281501	47	325817104322701	78	324715104180201
16	332244104335501	48	325815104375701	79	324652104241001
17	332111104293301	49	325753104213901	80	324543104272401
18	332007104353201	50	325750104231001	81	324533104251301
19	332006104321001	51	325727104253101	82	324522104203301
20	331916104245101	52	325721104305601	83	324519104250201
21	331705104262801	53	325716104274401	84	324453104204901
22	331700104234701	54	325702104352801	85	324340104202301
23	331646104200001	55	325657104264501	86	324327104245501
24	331527104340001	56	325611104252701	87	324259104232501
25	331518104301801	57	325531104290801	88	324220104264001
26	331425104265501	58	325505104254101	89	324154104210701
27	331333104243301	59	325451104260301	90	324042104265801
28	331213104241601	60	325450104251101	91	323842104283501
29	330729104220001	61	325314104230802	92	323738104253801
30	330728104241601	62	325255104241001	93	323705104225501
31	330705104200101	63	325220104253101	94	323613104260901
32	330642104173301	--	--	--	--

Statewide Groundwater-Level Changes

Statewide, groundwater levels generally have declined or remained steady for the time period in aquifers analyzed for this study. The largest water-level declines occurred in the Colorado Plateaus and High Plains aquifers and in the Rio Grande aquifer system (north-central New Mexico), where median water-level declines ranged from 17 to 40 ft and mean water-level declines ranged from 3.8 to 32 ft (table 15). In contrast, water-level declines (or rises) were generally smaller in other areas of New Mexico (table 15). A variety of factors may be affecting the water-level changes in the principal aquifers. Groundwater pumping is probably one of the most important stresses causing groundwater-level declines (Bartolino and Cunningham, 2003). In contrast, recharge from streams can stabilize or mitigate groundwater-level declines. In the Albuquerque area, a change in groundwater pumping amounts, combined with recharge from the Rio Grande, reversed decades of water-level declines (Myers and Friesz, 2019). For the High Plains aquifer, however, groundwater levels continue to be in steep decline because of groundwater pumping, groundwater recharge in nonplaya areas estimated to be generally less than 1 inch per year (Rawling, 2016), and the lack of major streams that could contribute seepage recharge to the aquifer.

Table 15. Summary of statewide groundwater-level changes in New Mexico.

Aquifer	Number of wells used to calculate mean and median composite water-level changes	Composite water-level change (feet)		Time period
		Mean	Median	
Colorado Plateaus aquifers, Grants to Crownpoint area	10	−3.8	−35	1980–84 to 2015–19
High Plains aquifer, northeast New Mexico	11	−32	−40	1980–84 to 2015–19
High Plains aquifer, east-central New Mexico	53	−28	−24	1980–84 to 2015–19
High Plains aquifer, southeast New Mexico	88	−17	−17	1980–84 to 2015–19
Pecos River Basin alluvial aquifer	6	+0.72	−4.2	1980–84 to 2015–19
Rio Grande aquifer system, north-central New Mexico	15	−9.8	−18	1980–84 to 2015–19
Rio Grande aquifer system, central New Mexico	10	−2.9	−1.6	1985–89 to 2015–19
Rio Grande aquifer system, Albuquerque area, New Mexico	26	−1.0	+0.65	1985–89 to 2015–19
Rio Grande aquifer system, Plains of San Agustin, New Mexico	9	−1.2	−1.2	1990–94 to 2015–19
Rio Grande aquifer system, Rio Grande Valley, south-central New Mexico	34	−5.6	−9.3	1980–84 to 2015–19
Rio Grande aquifer system, mesa lands west and southwest of Las Cruces, New Mexico	11	+6.8	−4.5	1980–84 to 2015–19
Roswell Basin aquifer system, New Mexico	94	−1.3	−2.7	1980–84 to 2015–19

Limitations of Composite Hydrograph Analysis

The composite hydrograph analysis presented in this report provides a general summary of groundwater-level conditions for principal aquifer areas in New Mexico. Groundwater levels will vary according to the local climate, geology, hydrology, sources of recharge, and demands on the groundwater resource. Because these influences vary over time and space, a hydrograph for an individual well could be substantially different than the composite hydrograph for a given area. Although the water-level data have been carefully checked to remove spurious values, such as those affected by pumping or artesian flow, not all data affected by pumping or artesian flow are qualified as such in the National Water Information System database (U.S. Geological Survey, 2020). By selecting the median depth to water, the effects of inclusion of water levels affected by pumping or artesian flow was minimized. However, if only one value was available for a 5-year period and the value was not flagged as affected by pumping or artesian flow, the value would have been included in the analysis. The mean and median composite hydrographs are not always in congruence because the mean is more likely to be affected by outlier (outside) numeric values, whereas the median is a measure of the central tendency of the data.

Summary

Groundwater is an important source of water for New Mexico. An estimated 48 percent of the total water used comes from groundwater sources, and groundwater levels generally are declining over large areas of New Mexico. Groundwater levels can rise because of recharge from precipitation or seepage from rivers, lakes, or playas or can decline because of discharge by groundwater pumping, seepage to rivers and lakes, and evaporation and water uptake by plants. These processes can act at regional or local scales; groundwater hydrographs show the history of groundwater-level changes and recharge or discharge processes affecting a well. In addition, aquifer properties such as hydraulic conductivity and storativity can affect the magnitude of water-level change. A single hydrograph is not necessarily representative of the larger regional area; however, individual hydrographs from several wells can be combined into a composite hydrograph to show average groundwater changes for a regional area.

The U.S. Geological Survey, in cooperation with the New Mexico Office of the State Engineer (NMOSE), has been measuring groundwater levels in a network of wells since about 1925. Most of the early groundwater-level measurement work focused on areas where groundwater supplies were undergoing development. Although groundwater levels in the statewide well network have been measured at various frequencies, an analysis of the water-level data retrieved from the National

Water Information System database for this study indicated that most of the wells have been measured in 5-year cycles since about 1980. The composite hydrographs in this report were developed by the U.S. Geological Survey in cooperation with NMOSE to show groundwater-level changes for selected principal aquifers in New Mexico. Composite hydrographs were developed using wells in the Colorado Plateaus aquifers, the High Plains aquifer, the Pecos River Basin alluvial aquifer, the Rio Grande aquifer system, and the Roswell Basin aquifer system.

In the Colorado Plateaus aquifers, 10 wells located in the Grants to Crownpoint area qualified for composite hydrograph analysis. Overall, the mean and median composite hydrographs show a water-level decline of about 3.8 and 35 feet (ft), respectively. These hydrographs represent only a small area within the larger Colorado Plateaus aquifers and should not be construed to represent the entire aquifer.

In the High Plains aquifer, 11 wells in northeast New Mexico qualified for composite hydrograph analysis. The mean and median composite hydrographs show declines of about 32 and 40 ft, respectively, from 1980–84 to 2015–19. Fifty-three wells in the High Plains aquifer in east-central New Mexico qualified for composite hydrograph analysis. The mean and median composite hydrographs show water-level declines of about 28 and 24 ft, respectively, from 1980–84 to 2015–19. Eighty-eight wells in the High Plains aquifer in southeast New Mexico qualified for composite hydrograph analysis. The mean and median composite hydrographs both show water-level declines of about 17 ft from 1980–84 to 2015–19.

In the Pecos River Basin alluvial aquifer, six wells qualified for composite hydrograph analysis. Overall, the mean composite hydrograph shows a rise of about 0.72 ft, and the median composite hydrograph shows a decline of about 4.2 ft from 1980–84 to 2015–19.

In the Rio Grande aquifer system, 15 wells in north-central New Mexico qualified for composite hydrograph analysis. Although these wells cluster into one group near the northern New Mexico border and another group from Española to just south of Santa Fe, there were too few wells in each group to make separate composite hydrographs. The mean and median composite hydrographs show water-level declines of about 9.8 and 18 ft, respectively, from 1980–84 to 2015–19. Ten wells in the Rio Grande aquifer system in central New Mexico qualified for composite hydrograph analysis. Wells included in this analysis did not include wells in the Albuquerque area. The mean and median composite hydrographs both show only small water-level declines of about 2.9 and 1.6 ft, respectively, from 1985–89 to 2015–19. Twenty-six wells in the Rio Grande aquifer system, Albuquerque area, New Mexico, qualified for composite hydrograph analysis. From 1985–89 to 2015–19, the mean and median composite hydrographs show a water-level decline of about 1.0 ft and a water-level rise of about 0.65 ft, respectively. But from 1985–89 to 2000–04 (mean) and 1985–89 to 2005–09 (median) water levels declined about 6.0 and 2.6 ft, respectively, and thereafter rose about 5.0 and 3.3 ft, respectively. The change from declining to rising water levels resulted primarily from decreased groundwater pumping by the Albuquerque Bernalillo County Water Utility Authority. Nine wells in the Rio Grande aquifer system, Plains of San Agustin, qualified for composite hydrograph analysis. The mean and median composite hydrographs are fairly flat, both showing only small water-level declines of about 1.2 ft from 1990–94 to 2015–19. Thirty-four wells in the Rio Grande aquifer system, Rio Grande Valley, in south-central New Mexico qualified for composite hydrograph analysis. Wells in the valley were analyzed separately from wells on the mesa lands to the west and southwest because the wells in the valley are near the Rio Grande and are likely influenced by surface-water fluctuations. Overall, the mean and median water levels both declined about 5.6 and 9.3 ft, respectively, from 1980–84 to 2015–19. Eleven wells in the Rio Grande aquifer system, mesa lands west and southwest of Las Cruces, N. Mex., qualified for composite hydrograph analysis. The mean composite hydrograph generally shows a water-level rise of about 6.8 ft from 1980–84 to 2015–19, whereas the median composite hydrograph generally shows a water-level decline of about 4.5 ft from 1980–84 to 2015–19.

In the Roswell Basin aquifer system, 94 wells qualified for composite hydrograph analysis. Although the mean and median composite hydrographs show overall water-level declines of about 1.3 and 2.7 ft, respectively, from 1980–84 to 2015–19, water levels have declined about 10 and 9 ft, respectively, since the water-level high in 1990–94.

Statewide, groundwater levels generally have declined or remained steady for the time period in aquifers analyzed for this study. The largest water-level declines occurred in the Colorado Plateaus and High Plains aquifers and in the Rio Grande aquifer system (north-central New Mexico), where median water-level declines ranged from 17 to 40 ft and mean water-level declines ranged from 3.8 to 32 ft. Groundwater-level declines (or rises) were generally smaller in other areas of New Mexico. A variety of factors may be affecting the groundwater-level changes in the principal aquifers, including groundwater pumping and recharge from streams. In the Albuquerque area, a change in groundwater pumping amounts, combined with recharge from the Rio Grande, reversed decades of groundwater-level declines. For the High Plains aquifer, however, groundwater levels continue to be in steep decline because of continued groundwater pumping, groundwater recharge generally less than 1 inch per year, and the lack of major streams that could contribute recharge to the aquifer.

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Appendix 1. Creation of Refined Principal Aquifers Shapefile

Introduction

A more spatially detailed version of the principal aquifer boundaries within New Mexico (fig. 1.1) was created using ArcGIS Pro software (Esri, 2021). This refined principal aquifers shapefile (fig. 1.1; Myers, 2022) was created to assist in the process of assigning U.S. Geological Survey National Aquifer Codes to wells in the New Mexico portion of the U.S. Geological Survey National Water Information System database (U.S. Geological Survey, 2020). In addition, the shapefile was used to select wells to be included in the composite hydrograph analysis described in the body of this report.

Methods

Resources used to create the refined principal aquifers shapefile were the original principal aquifers shapefile (U.S. Geological Survey, 2021), descriptions of rock units composing the principal aquifers (Robson and Banta, 1995; Ryder, 1996), and the 1:500,000-scale geology of New Mexico Lith_Poly shapefile in the NM_500k_geology.gdb geodatabase (New Mexico Bureau of Geology and Mineral Resources, 2003) and descriptions of the rock units shown on the geologic map of New Mexico (New Mexico Bureau of Geology and Mineral Resources, 2003). In their hydrologic atlas publications, Robson and Banta (1995) and Ryder (1996) describe six principal aquifers in New Mexico: the Basin and Range aquifers, the Colorado Plateaus aquifers, the High Plains aquifer, the Pecos River Basin alluvial aquifer, the Rio Grande aquifer system, and the Roswell Basin aquifer system. Rocks and sediments not included in a principal aquifer were designated as "other rocks."

Aquifer boundaries in the refined principal aquifer shapefile were created by selecting geologic-unit polygons from the New Mexico geology shapefile and assigning a principal aquifer code to each polygon on the basis of location and principal aquifer geology as described by Robson and Banta (1995) and Ryder (1996). Geologic-unit polygons classified as "water" in the geology shapefile were assigned the principal aquifer code of the underlying principal aquifer. Once every geologic-unit polygon in the shapefile had been assigned a principal aquifer code, the ArcGIS Pro "Dissolve" function, with dissolve field equal to the principal aquifer code, was used to dissolve polygon boundaries between geologic-unit polygons with the same principal aquifer code.

The original principal aquifer boundaries were honored as closely as possible when assigning principal aquifer codes to geologic-unit polygons. In general, selecting rock units from the State geologic map worked well for the Basin and Range, Colorado Plateaus, and High Plains aquifers, and Rio Grande aquifer system, because those aquifers were largely defined on the basis of geologic units. The principal aquifer boundary lines for the Pecos River Basin alluvial aquifer and Roswell Basin aquifer system, however, do not closely follow outlines of surficial geologic units, because those aquifers were largely defined on the basis of the extent of subsurface geologic structural basins (Robson and Banta, 1995; Ryder, 1996). For that reason, the refined principal aquifer boundaries for the Pecos River Basin alluvial aquifer and Roswell Basin aquifer system were created by digitizing the original aquifer boundaries as closely as possible.

Geologic-unit polygons with formations eligible for inclusion in a refined principal aquifer were not always included in that aquifer. For example, the Ogallala Formation, which makes up most of the High Plains aquifer in eastern New Mexico, becomes thin and discontinuous with isolated patches of the formation to the west of the main part of the aquifer. These isolated patches of Ogallala Formation probably do not have direct hydraulic connections with the High Plains aquifer farther east and thus were not included in the original or the refined principal aquifers shapefiles. Similarly, for other principal aquifers, outlying and isolated geologic units were not incorporated into a principal aquifer if there was no apparent direct hydraulic connection.

It became apparent during creation of the refined aquifer boundaries that extrusive igneous units had been treated somewhat differently in the original principal aquifers study among the principal aquifer areas. For example, although not explicitly stated (Robson and Banta, 1995; Ryder, 1996), it appears that if a basalt flow or other surficial igneous unit was thought to overlie and be hydraulically connected to the underlying Rio Grande aquifer system, the area of the basalt was included as part of the aquifer. In the High Plains aquifer, parts of some surficial igneous units were included in the original principal aquifers shapefile as part of the High Plains aquifer and other parts were excluded. In the southern part of the Colorado Plateaus aquifers, most of the surficial igneous units were included in the Colorado Plateaus aquifers in the original principal aquifers shapefile. In creating the refined aquifer boundaries in areas with surficial igneous units, much deference was given to the original principal aquifer boundaries. Intrusive igneous geologic units, however, were classified as "other rocks" in the refined principal aquifers shapefile—the assumption being that potential aquifer rock or sediment would have been displaced by the intrusive rocks. This resulted in many small areas of "other rocks" in parts of the Colorado Plateaus aquifers and southern Rio Grande aquifer system in the refined principal aquifers shapefile.

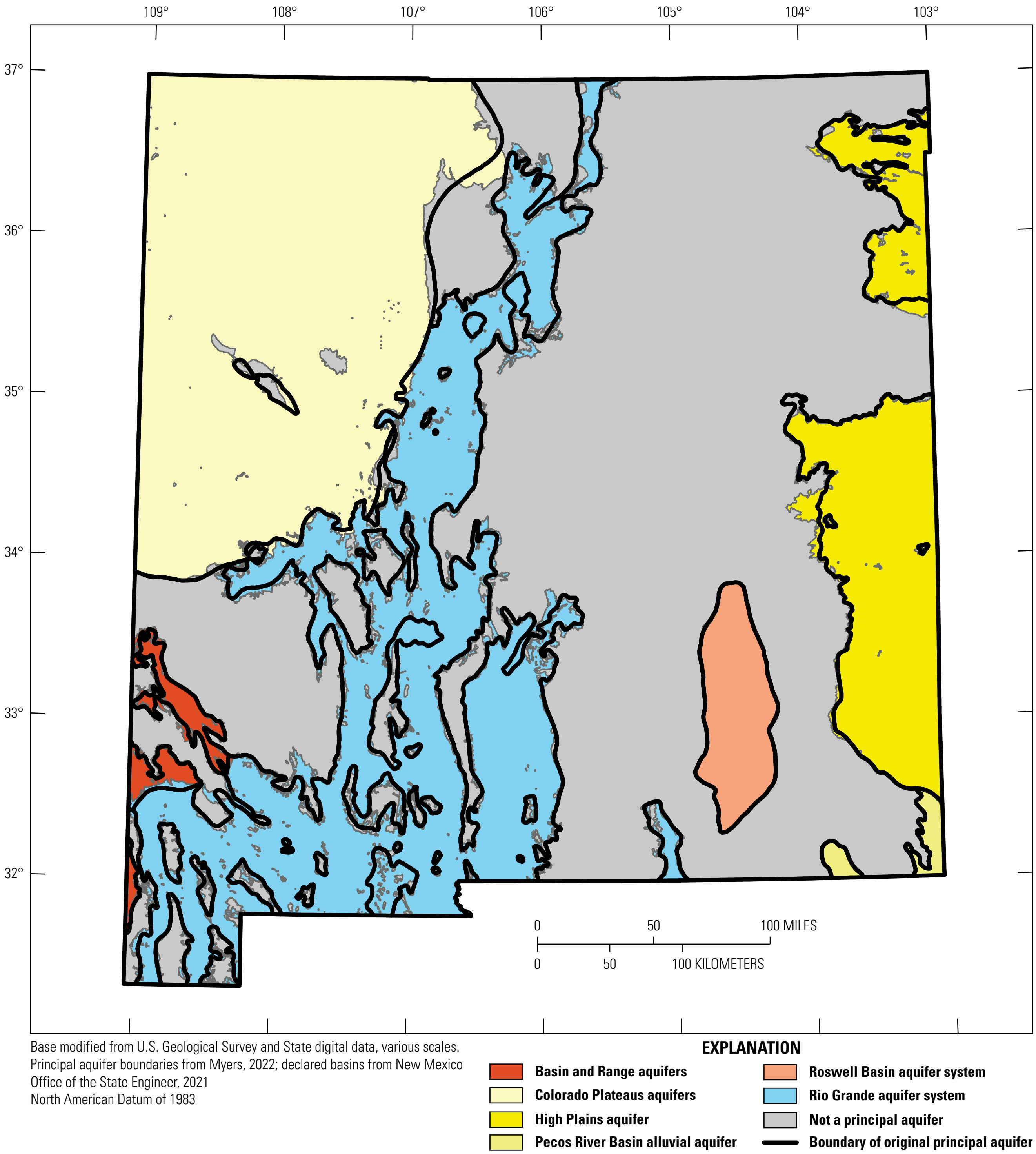

Figure 1.1. Original principal aquifer boundaries and refined principal aquifers for New Mexico.

As a final check of the refined principal aquifer boundaries, all well and spring sites having geologic codes were retrieved from the National Water Information System database (NWIS) (U.S. Geological Survey, 2020) and were compared to the refined principal aquifers. This comparison helped us detect some general errors in the placement of refined principal aquifer boundaries or the inclusion or exclusion of surficial geologic-unit polygons in a principal aquifer. The comparison resulted in the exclusion of a few High Plains aquifer areas in northeast New Mexico where local geologic codes indicated wells were producing from the Dakota Formation below a surficial igneous unit. In the Rio Grande aquifer system, this check resulted in the inclusion of some areas covered by surficial igneous units along or near the Rio Grande in northern and southern New Mexico where the geologic codes in NWIS indicated wells were producing from sediments underlying the igneous unit.

Some limitations should be observed in the use of the refined principal aquifers shapefile. Although the refined principal aquifers shapefile provides a greater level of detail than the original principal aquifers shapefile, its accuracy relies on the original definitions of the principal aquifers and on the New Mexico geologic map. In particular, the presence or absence of a principal aquifer below surficial igneous units may be unknown. If a well is drilled in the area of a surficial igneous unit, geologic data should be collected and used to determine what rock or sediment lies below the igneous unit. In addition, wells drilled in a given principal aquifer may not produce water from that aquifer if they are completed in a rock formation underlying the principal aquifer. Some aquifer material, such as the generally unconsolidated sediments of the Rio Grande aquifer system, may thin or pinch out at the margins of the principal aquifer. Although the principal aquifer is technically present in these locations, wells drilled near principal aquifer margins may actually produce water from another principal aquifer or from other rocks or sediments.

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