5. Water Supply

This section provides an overview of the water supply in the Southwest Region, including weather conditions (Section 5.1), surface water and groundwater supplies (Sections 5.2 and 5.3), and water quality (Section 5.4). The information presented is drawn from water supply studies conducted in the planning region by a number of researchers, as referenced throughout this section; a complete bibliography of reference materials available to the DBS&A team is provided in Appendix A1. In conjunction with preparing this regional water plan, DBS&A identified uncertainties in the available data regarding supply and demand in the Southwest Region. These data gaps are discussed in Appendix D1. Section 7, which discusses groundwater budgets, provides further detail regarding the knowledge of the groundwater system in each geologic basin and the reconciliation of surface water and groundwater supplies with projected demand.

5.1 Climate

The varied terrain of the Southwest Region, which ranges from mountains to the Chihuahuan Desert, results in significant climate variations. For example, temperatures range from lows well below 0 degrees Fahrenheit (°F) in the mountains to highs in excess of 100°F in the plains.

DBS&A identified 48 climate data collection stations that have historically been and/or are currently located in the Southwest Region. Of these 48 stations, 19 were used to characterize climatic conditions in the region. Only stations that had complete data sets were used for evaluation. In addition to completeness of the records, the 19 weather stations were selected based on location and how well they represented conditions in the county. For example, where two stations are located in close proximity, the station with the longest record was selected to be representative of local conditions in that area. Table 5-1 lists the periods of record for the 48 identified weather stations in the Southwest Region and indicates the 19 stations analyzed in more detail; Figure 5-1 shows the locations of the 19 selected stations.

Table 5-1. Climate Stations in the Southwest Region
Page 1 of 3

Station Name [a]	Data Start	Data End	Lat	Long	Elevation (ft msl)	Source
Hidalgo County						
Animas 3 ESE	09/01/23	Present	31°56'N	108°46'W	4436	http://www.wrcc.dri.edu/summary/climsmnm.html
Antelope Wells	02/01/88	Present	31°20'N	108°32'W	4661	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Cloverdale 4 WNW	09/04/92	04/01/93	31°26'N	108°59'W	5319	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Gray Ranch	08/01/62	09/01/69	31°31'N	108°52'W	5104	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Lordsburg 4 SE	01/11/14	Present	32°18'N	108°39'W	4249	http://www.wrcc.dri.edu/summary/climsmnm.html
Rodeo	07/01/46	04/30/78	31°50'N	109°02'W	4113	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Rodeo CAA Airport	06/01/32	01/31/54	31°56'N	108°59'W	4116	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Virden	07/01/46	04/30/75	32°41'N	108°59'W	3782	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Luna County						
Columbus	01/01/25	Present	31°50'N	107°38'W	4064	http://www.wrcc.dri.edu/summary/climsmnm.html
Deming	01/01/14	Present	32°15'N	107°45'W	4299	http://www.wrcc.dri.edu/summary/climsmnm.html
Deming Municipal Airport	06/01/50	Present	32°16'N	107°43'W	4300	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Florida	01/01/39	05/31/92	32°26'N	107°29'W	4449	http://www.wrcc.dri.edu/summary/climsmnm.html
Gage 4 ESE	01/01/14	Present	32°14'N	108°05'W	4478	http://www.wrcc.dri.edu/summary/climsmnm.html
Grant County						
Buckhorn	07/01/47	Present	33°02'N	108°43'W	4799	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Cliff 11 SE	01/01/37	Present	32°50'N	108°30'W	4775	http://www.wrcc.dri.edu/summary/climsmnm.html
Faywood	07/01/46	Present	32°38'N	107°52'W	5190	http://www.wrcc.dri.edu/summary/climsmnm.html
Fort Bayard	02/01/1897	Present	32°48'N	108°09'W	6141	http://www.wrcc.dri.edu/summary/climsmnm.html
Gila 6 NNE	10/01/54	01/31/60	33°02'N	108°32'W	4651	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Gila Hot Springs	12/01/15	Present	33°12'N	108°12'W	5599	http://www.wrcc.dri.edu/summary/climsmnm.html
Hachita	01/01/14	Present	31°55'N	108°19'W	4516	http://www.wrcc.dri.edu/summary/climsmnm.html

[a] Stations in **bold** type were selected for detailed analysis.

ft msl = Feet above mean sea level

Table 5-1. Climate Stations in the Southwest Region
Page 2 of 3

Station Name [a]	Data Start	Data End	Lat	Long	Elevation (ft msl)	Source
Mimbres Ranger Station	01/01/14	Present	32°56'N	108°01'W	6236	http://www.wrcc.dri.edu/summary/climsmnm.html
Pinos Altos	07/01/46	02/07/73	32°52'N	108°13'W	7003	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Redrock 1 NNE	01/01/14	Present	32°42'N	108°44'W	4049	http://www.wrcc.dri.edu/summary/climsmnm.html
Santa Rita	12/01/48	04/30/53	32°48'N	108°04'W	6314	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Silver City	01/01/14	Present	32°47'N	108°16'W	5918	http://www.wrcc.dri.edu/summary/climsmnm.html
Silver City Grant Co	05/01/60	09/01/68	32°38'N	108°10'W	5376	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Thompson Canyon Ranch	07/01/47	Present	32°33'N	108°38'W	5199	www.ncdc.noaa.gov/oa/climate/stationlocator.html
White Signal	11/01/48	Present	32°33'N	108°22'W	6066	http://www.wrcc.dri.edu/summary/climsmnm.html
Whitewater	07/01/47	Present	32°33'N	108°08'W	5019	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Catron County						
Adobe Ranch	07/01/46	04/01/94	33°34'N	107°54'W	7416	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Beaverhead Ranger Station	01/01/39	Present	33°26'N	108°06'W	6668	http://www.wrcc.dri.edu/summary/climsmnm.html
Datil	07/01/46	06/30/52	34°09'N	107°51'W	7104	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Glenwood	01/01/39	Present	33°19'N	108°53'W	4741	http://www.wrcc.dri.edu/summary/climsmnm.html
Hickman	08/01/65	03/31/85	34°31'N	107°56'W	7803	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Jewett Work Center	07/01/46	01/12/70	33°59'N	108°38'W	7403	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Luna Ranger Station	01/01/14	Present	33°49'N	108°57'W	7048	http://www.wrcc.dri.edu/summary/climsmnm.html
Mogollon	02/01/37	10/01/73	33°23'N	108°47'W	6802	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Pie Town	06/01/48	10/31/53	34°18'N	108°08'W	7754	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Pietown 19 NE	09/01/88	Present	34°30'N	107°53'W	7959	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Quemado	08/01/15	Present	34°21'N	108°30'W	6876	http://www.wrcc.dri.edu/summary/climsmnm.html
Quemado Lake	11/06/86	09/09/93	34°08'N	108°31'W	7658	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Quemado Lake Estates	09/01/93	Present	34°10'N	108°30'W	7818	www.ncdc.noaa.gov/oa/climate/stationlocator.html

[a] Stations in **bold** type were selected for detailed analysis.

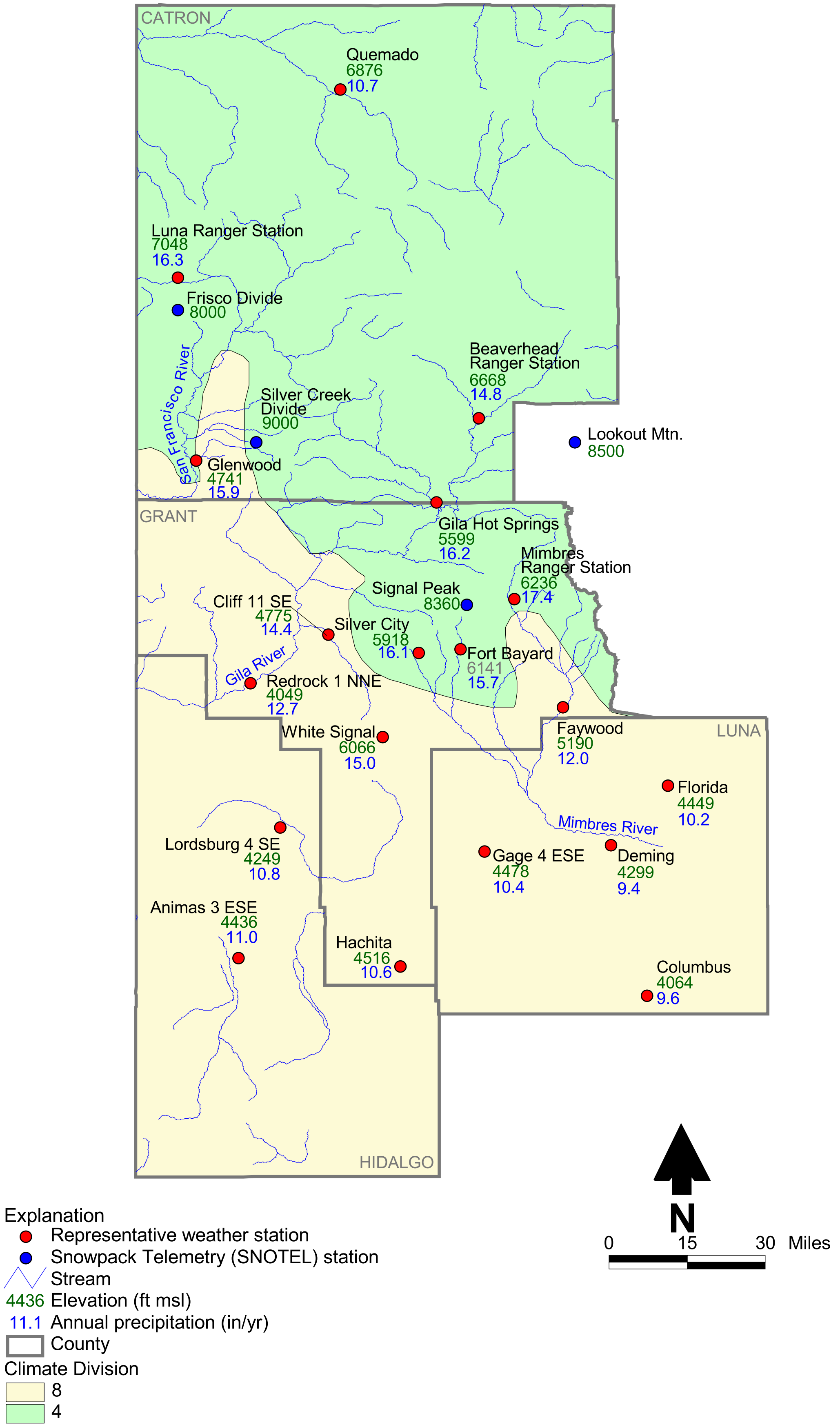
ft msl = Feet above mean sea level

Table 5-1. Climate Stations in the Southwest Region
Page 3 of 3

Station Name [a]	Data Start	Data End	Lat	Long	Elevation (ft msl)	Source
Red Hill 12 NW	04/01/92	01/01/96	34°19'N	109°02'W	6838	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Reserve Ranger Station	07/01/46	Present	33°43'N	108°47'W	5846	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Salt Lake 4 NE	09/01/51	11/01/71	34°28'N	108°42'W	6583	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Willow Creek Ranger Station	07/01/46	11/30/76	33°24'N	108°35'W	8105	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Y-Ranch	01/01/77	02/28/81	33°48'N	108°19'W	6924	www.ncdc.noaa.gov/oa/climate/stationlocator.html
York Ranch	07/01/46	08/31/76	33°48'N	108°20'W	6802	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Snotel Stations						
Signal Peak	10/01/80	Present	32°55’N	108°09’W	8360	http://www.wrcc.dri.edu/inventory/snotelNM.html
Silver Creek Divide	10/01/80	Present	33°22’N	108°42’W	9000	http://www.wrcc.dri.edu/inventory/snotelNM.html
Lookout Mountain	10/28/81	Present	33°22’N	107°5’W	8500	http://www.wrcc.dri.edu/inventory/snotelNM.html
Frisco Divide	10/01/80	Present	33°44’N	108°56’W	8000	http://www.wrcc.dri.edu/inventory/snotelNM.html

[a] Stations in **bold** type were selected for detailed analysis.

ft msl = Feet above mean sea level



SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Weather Stations

Figure 5-1

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Table 5-1 also lists 4 snowpack telemetry (SNOTEL) stations in the region that were used to document snowfall in the higher elevations. Three of these SNOTEL stations are within the planning region; the fourth is located a short distance outside the region, in Sierra County (Figure 5-1).

5.1.1 Temperature

Table 5-2 presents minimum, maximum, and average annual temperatures for the 19 selected stations. As shown in Table 5-2, the average temperature at the 19 stations was highly varied, ranging between about 46 and 63 degrees Fahrenheit. Appendix D2 contains figures showing the long-term monthly average, minimum, and maximum temperatures and the annual average temperatures at eight stations representative of the range of climates found in the region.

5.1.2 Precipitation

Precipitation varies considerably across the region and is influenced by both location and elevation. Weather systems may enter the planning region from the west (Pacific), northeast (Arctic air masses from the plains), and southwest (Gulf of Mexico), and each of these systems brings a unique set of temperatures and moisture to the region. Table 5-2 shows the maximum, minimum, and long-term average annual precipitation (rainfall and snowmelt) at the 19 representative stations, and figures showing the long-term average monthly precipitation amounts and annual precipitation at 8 of these stations are provided in Appendix D2. Average precipitation, including both snowmelt and rainfall, ranges from about 9.5 to 16 inches. Contoured precipitation throughout the planning region is illustrated in Figure A2-4 (Appendix A2). Figure 5-2 shows the total annual precipitation at Fort Bayard, which has the longest period of record (1897 to present) in the region. This figure demonstrates the large annual variability in precipitation that is common in the region.

The four SNOTEL stations (Table 5-1) provide both rainfall and snow water equivalent (SWE) data. Appendix D2 contains figures showing daily SWE values and monthly average, minimum, and maximum snowpack from each of the stations for the period of record available. As indicated by these figures, snowpack is highly variable from year to year.

Table 5-2. Precipitation and Temperature at Representative Climate Stations in the Southwest Region

Station Name	Precipitation (inches)				Temperature (°F)			
	Annual Average	Annual Minimum	Annual Maximum	% of Possible Observations [a]	Annual Average	Annual Average Minimum	Annual Average Maximum	% of Possible Observations [a]
Animas 3 ESE	11.03	4.73	19.67	97	60.2	43.1	77.3	63
Lordsburg 4 SE	10.83	4.68	19.70	96	60.8	43.1	78.4	59
Columbus	9.60	3.37	16.10	77	62.5	46.7	78.2	74
Deming	9.44	2.76	22.01	87	60.3	44.0	76.5	81
Florida	10.15	3.88	18.72	93	59.0	40.9	77.0	76
Gage 4 ESE	10.40	2.84	19.01	93	59.8	42.9	76.6	67
Cliff 11 SE	14.42	5.71	21.11	89	56.1	37.7	74.6	82
Faywood	12.00	2.94	23.63	96	57.8	41.8	73.8	66
Fort Bayard	15.70	7.10	31.08	98	55.1	40.5	69.6	97
Gila Hot Springs	16.20	11.28	25.73	51	52.9	33.7	72.2	50
Hachita	10.59	3.40	18.02	96	60.0	43.4	76.6	77
Mimbres Ranger Station	17.37	9.11	28.80	84	51.7	33.8	69.7	48
Redrock 1 NNE	12.74	4.36	21.31	93	59.1	41.0	77.2	49
Silver City [b]	16.08	6.77	24.92	98	54.9	40.3	69.5	40
White Signal	14.97	7.01	23.36	99	54.4	39.3	69.5	75
Beaverhead Ranger Station	14.79	6.82	25.50	88	47.7	28.8	66.6	69
Glenwood [c]	15.91	6.90	25.57	82	57.6	40.4	74.8	80
Luna Ranger Station	16.25	7.95	26.72	93	46.0	26.3	65.7	64
Quemado	10.73	3.82	16.23	76	48.0	29.6	66.5	67

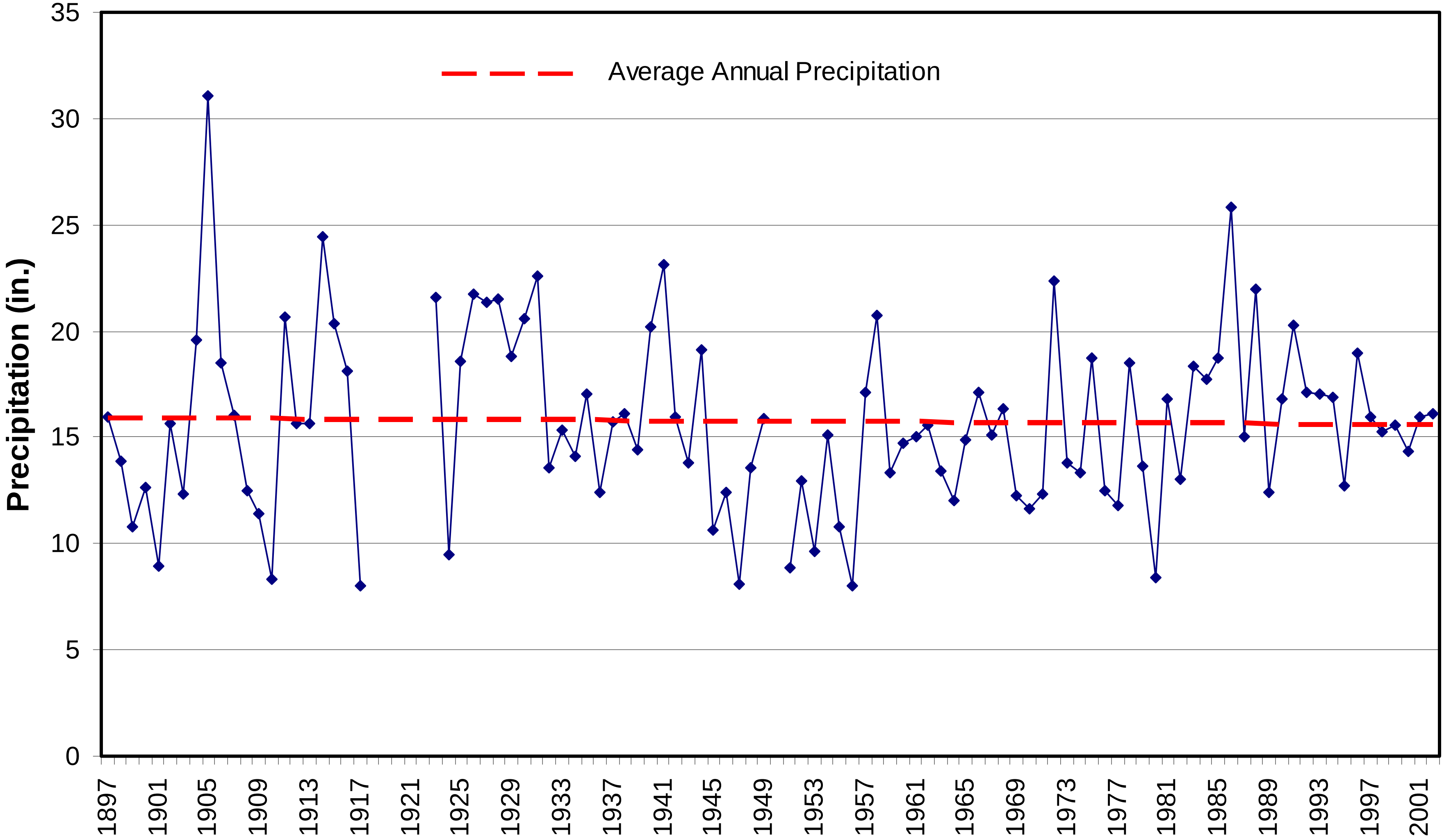
Source: Western Regional Climate Center web site

Annual average is a multi-year, unsmoothed average of all values; annual average minimum is a multi-year, unsmoothed average of the minimum values; annual average maximum is a multi-year, unsmoothed average of the maximum values.

[a] For period of record shown on Table 5-1 (for active stations, through December 31, 2001 unless otherwise noted), percentage of observations that were available; for example, 90% indicates that data were missing for 10% of the months.

[b] Statistics for January 1, 1914 through October 31, 1964.

[c] Statistics for January 1, 1939 through June 30, 2000.



SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Total Annual Precipitation

Fort Bayard Climate Station

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Figure 5-2

As indicated by the figures in Appendix D2, annual precipitation amounts vary substantially by location and year. Figure 5-3 shows the average annual precipitation for the 19 selected stations (Table 5-2) in relation to elevation. Analysis of the data in this figure yields a correlation coefficient of 0.63 between average precipitation and elevation within the region.

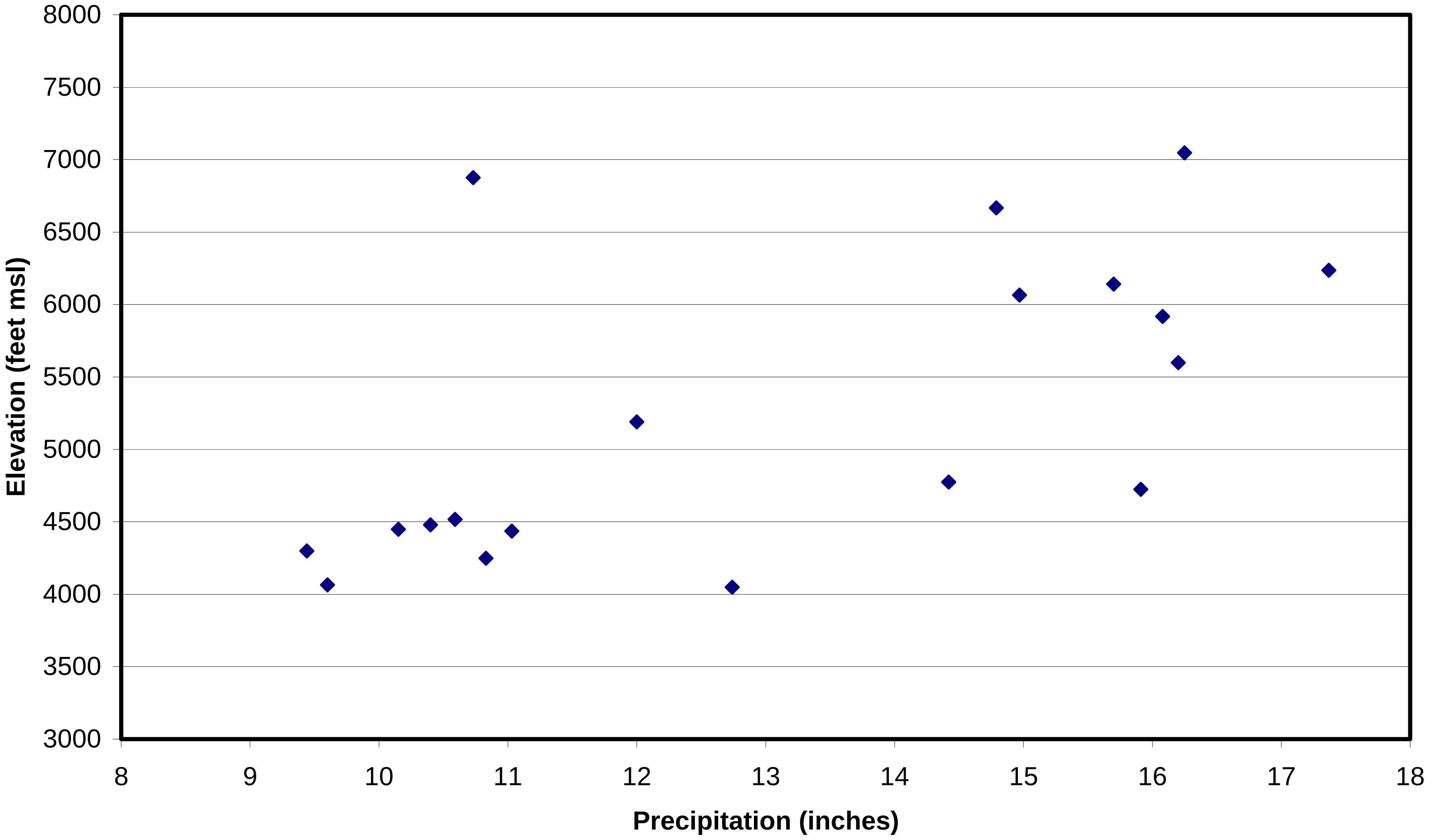
5.1.2.1 The Palmer Drought Severity Index

A drought index consists of a ranking system derived from the assimilation of data, including rainfall, snowpack, streamflow, and other water supply indicators for a given region. Consulting drought indices can aid in water supply and agricultural planning and decision making. The PDSI was created by W.C. Palmer (1965) to measure the variations in the moisture supply and is based upon the supply-and-demand concept of the water balance equation. Hayes (1999) provides a thorough explanation of the PDSI, which is summarized here.

The PDSI is calculated using precipitation and temperature data as well as the available water content (AWC) of the soil. These data are used to calculate all the components of the water balance equation, including evapotranspiration, soil recharge, runoff, and moisture loss from the surface layer. Moisture conditions are standardized so that comparisons among different locations and months can be made. The index is widely used because it provides a comparison of recent weather relative to historical conditions. The PDSI classifications for wet to dry periods are provided in Table 5-3.

Table 5-3. Palmer Drought Severity Index

PDSI Ranking	Climatic Condition
+ 4.00 or more	Extremely wet
+3.00 to +3.99	Very wet
+2.00 to +2.99	Moderately wet
+1.00 to +1.99	Slightly wet
+0.50 to +0.99	Incipient wet spell
+0.49 to –0.49	Near normal
–0.50 to –0.99	Incipient dry spell
–1.00 to –1.99	Mild drought
–2.00 to –2.99	Moderate drought
–3.00 to –3.99	Severe drought
–4.00 or less	Extreme drought



Note: Additional information on climate station names, elevations, and locations is provided in Table 5-1.

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Average Annual Precipitation by Station Elevation

Figure 5-3

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Use of the PDSI has considerable limitations, as described by Alley (1984) and Karl and Knight (1985). One drawback of the PDSI is that it does not adequately represent conditions in regions that have extreme variability in rainfall, runoff, or elevation (Smith et al., 1993). The PDSI may also lag emerging droughts by several months. Yet, even with its limitations, many states incorporate the PDSI into their drought monitoring systems.

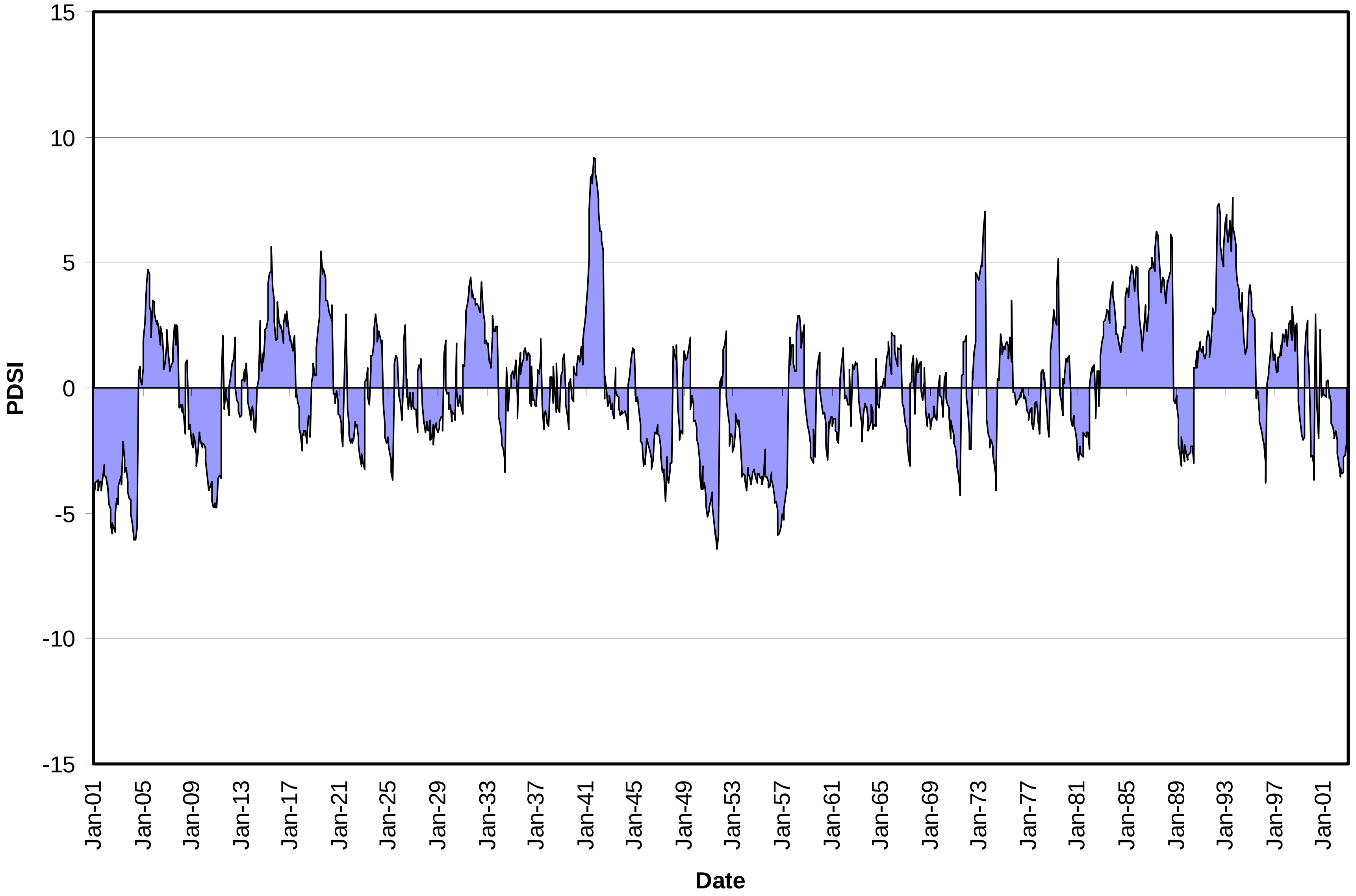
The PDSI is calculated for climate divisions throughout the United States. As shown in Figure 5-1, the Southwest Region encompasses New Mexico Climate Divisions 4 and 8. Figures 5-4 and 5-5 show the long-term PDSI for these divisions. Of interest are the large variations from year to year and the generally wet conditions in the 1980s and most of the 1990s.

5.1.2.2 Pacific Decadal Oscillation Index

Much like the PDSI, the Pacific Decadal Oscillation index (PDOI) serves as an indicator of climatic trends that can help us predict long-term precipitation amounts. Figure 5-6 presents the PDOI for the previous century.

Fisheries scientist Steven Hare coined the term "Pacific Decadal Oscillation" (PDO) in 1996 while researching connections between Alaska salmon production cycles and Pacific climate. The PDO is a long-lived El Niño-like pattern of Pacific climate variability, specifically, a long-term fluctuation of the Pacific Ocean, that waxes and wanes approximately every 20 to 30 years. The PDO is defined as the leading principal component of North Pacific monthly sea surface temperature variability (Mantua, 2000).

The North American climate anomalies associated with the PDO are broadly similar to those connected with El Niño and La Niña, though generally not as extreme (Latif and Barnett, 1994, as cited in Mantua, 2002). Warm phases of the PDO are correlated with El Niño-like North American temperature and precipitation anomalies, while cool phases of the PDO are correlated with La Niña-like climate patterns. PDO variability is strongly expressed in regional snowpack and streamflow anomalies, especially in western North America (Cayan, 1996; Mantua et al., 1997; as cited in Mantua, 2002), and may also influence summer rainfall and drought in the U.S. (Nigam et al., 1999, as cited in Mantua, 2002).



Source: NCDC, 2003

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Palmer Drought Severity Index

New Mexico Climate Division 4

Figure 5-4

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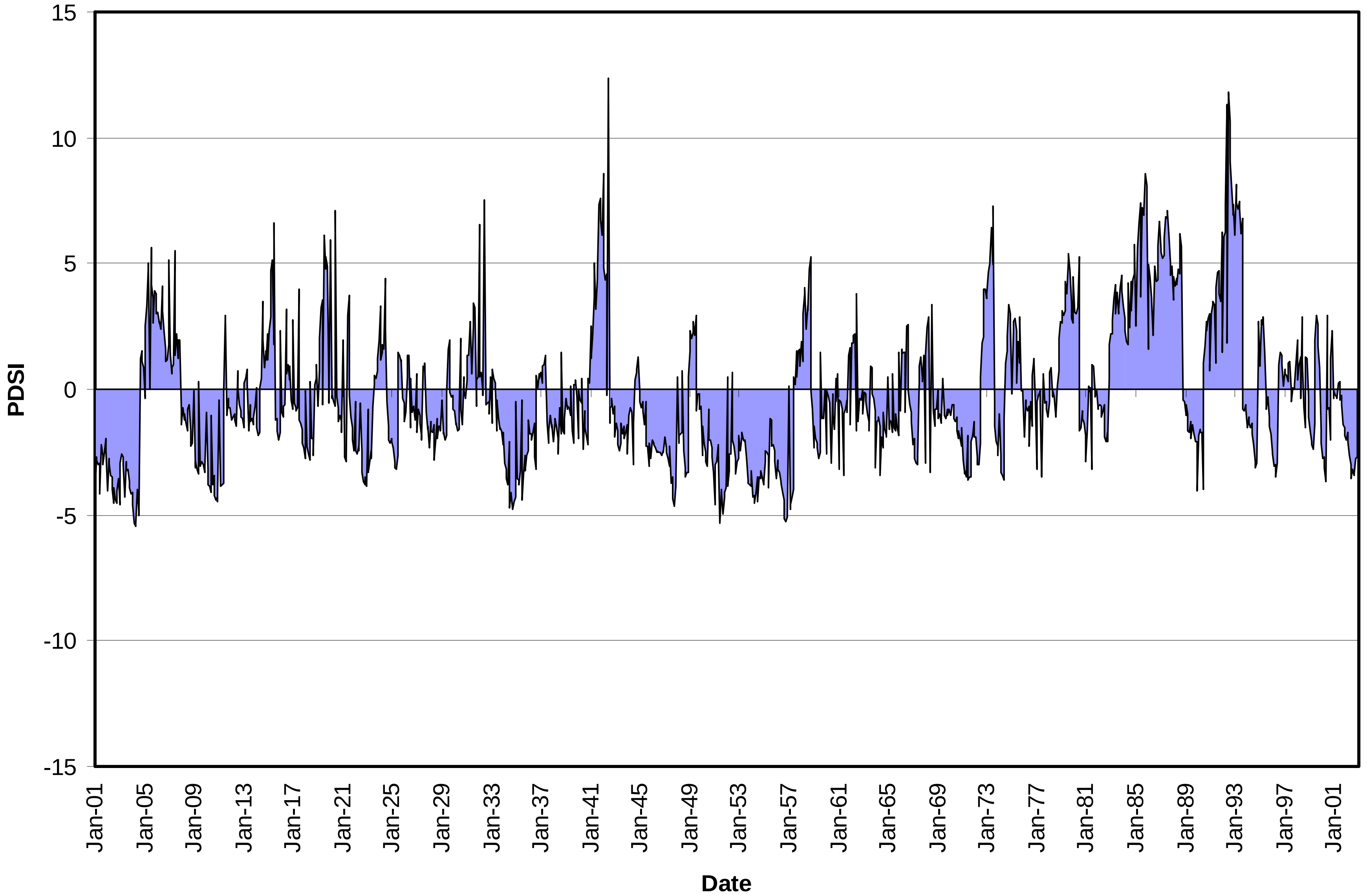

Source: NCDC, 2003

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Palmer Drought Severity Index
New Mexico Climate Division 8

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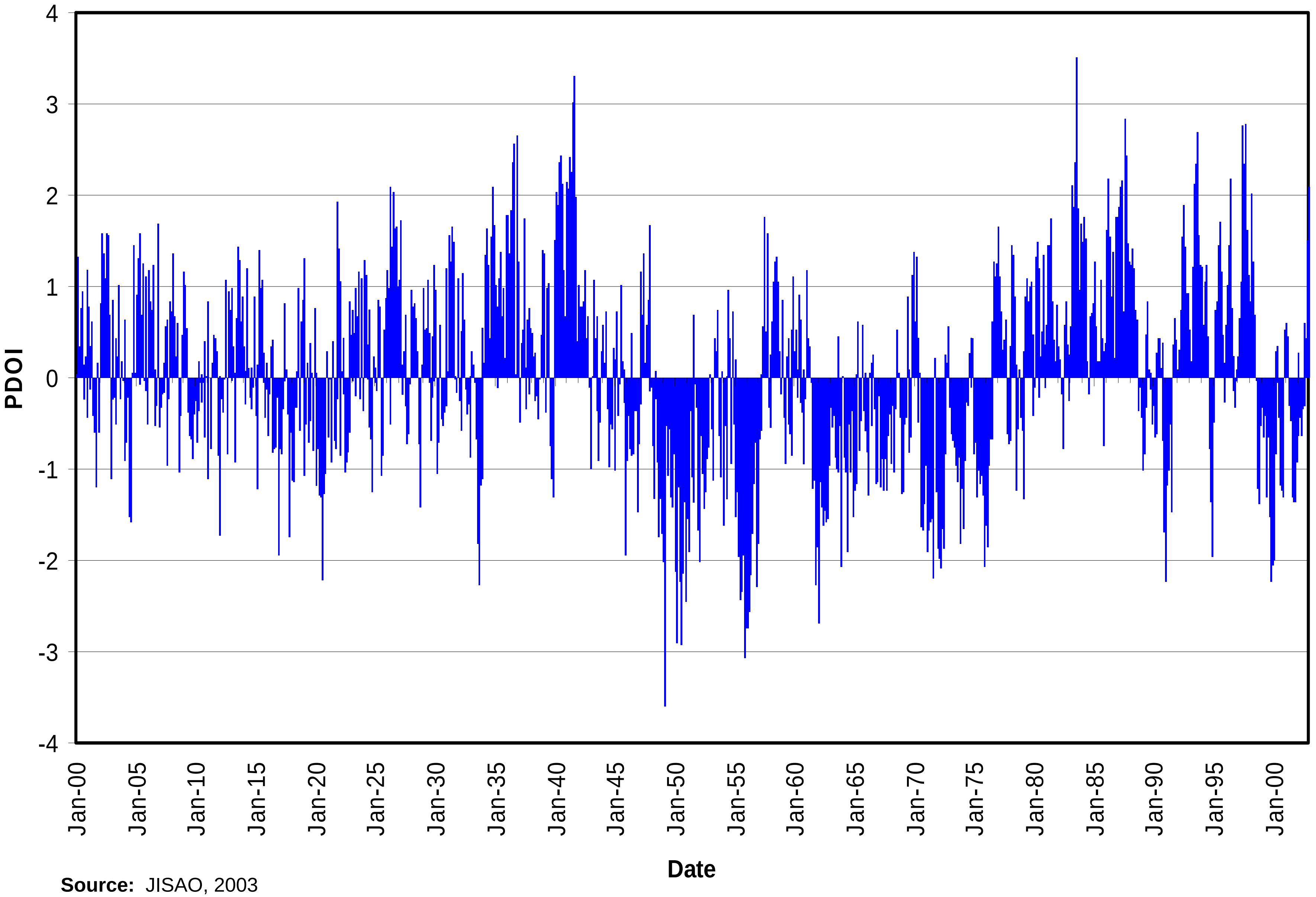
Figure 5-5



Source: JISAO, 2003

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Pacific Decadal Oscillation Index

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5/25/05

Figure 5-6

5.1.2.3 Interpretation and Relevancy of PDSI and PDOI to Water Resources

As discussed in Section 5.1.2.1, the PDSI shows that large variations in precipitation are common. Perhaps the most important insight to draw from the Climate Regions 4 and 8 PDSI in terms of water planning is that the current drought conditions are not atypical of historical conditions. Conditions at the turn of the century and in the mid-1950s were substantially drier than current conditions, and the 1980s through the mid-1990s were wet in comparison to much of the 20th Century.

It is believed that the years since 1999 have been in the “cool phase” of the PDO, as indicated by the presence of a wedge of lower than normal sea-surface heights and ocean temperatures in the eastern equatorial Pacific and a warm horseshoe pattern of higher than normal sea-surface heights connecting the north, west, and southern Pacific. In the “warm” or “positive” phase, which appears to have lasted from 1977 through 1999, the western Pacific Ocean becomes cool and the wedge in the east warms.

During a cool phase of the PDO, New Mexico generally experiences more dry years than wet compared to the long-term average. During the 18 cool-phase years that occurred over the past century, the state as a whole had 1 wet year, 10 dry years, and 7 normal years; during those years, Divisions 7 and 8 (both in southern New Mexico) had the greatest number of dry years in the state (12 of the 18) (Liles, 2003). It also appears the negative (cold) side of the cycle is related to longer-term droughts such as the one in the 1950s.

Conversely, during the 19 warm-phase years that occurred in the past century, the state’s average precipitation was roughly 114 percent of normal, with the greatest anomalies occurring in the south and west. The southwestern divisions average as much as 5 or 6 more inches of precipitation during the strongly positive PDO years compared to the strongly negative PDO years, and of the 19 warm-phase years, Climate Division 4 (southwest New Mexico) had 14 wet years, 3 normal years, and only 2 dry years.

It should be noted that because many parameters are not measured directly, there is a lot of variability in the data. Additional information regarding the relationship between PDSI, PDO, and streamflow is presented in Section 5.2.1.

5.1.3 Evaporation and Evapotranspiration

Free water surface (FWS) evaporation rate isopleths for the planning region are depicted in Appendix A2, Figure A2-5. The FWS evaporation rate represents the rate of evaporation from an extensive free water surface, such as a lake. The evaporation data shown in this figure are from the NOAA and present the average FWS evaporation for the region between 1931 and 1960. In general, the FWS evaporation rates in the planning region increase from north to south, from about 45 inches per year (in/yr) in Catron County to approximately 75 in/yr in Hidalgo and Luna Counties.

Recorded evaporation data are available for four climate stations within the region, located in Catron, Hidalgo and Luna Counties (Table 5-4). Of these, only the Reserve Ranger Station continues to collect evaporation data, for one to five months each year.

Table 5-4. Climate Stations with Evaporation Data

Climate Station	Coop ID	County	Data Collected	Comments
Reserve Ranger Station	297386	Catron	1966 to present	Daily data collected for 1 to 7 months each year.
Animas 3 ESE	290417	Hidalgo	1967 to 1979	Daily data collected for 6 to 10 months each year. Daily data for the entire year collected in 1968, 1970, and 1973.
Cloverdale 4 WNW	291935	Hidalgo	1992	Daily data collected for 1 month in 1992 only.
Florida	293225	Luna	1966 to 1992	Daily data collected for 1 to 11 months each year. No data collected in 1985 and 1988.

Source: NCDC, 2003

Annual FWS evaporation greatly exceeds annual precipitation throughout the study area. Despite this annual trend, precipitation for a given storm event may exceed the evaporation during the same time period, thus resulting in recharge. A portion of the precipitation that seeps into the ground to become soil moisture is taken up by plant roots and returned to the atmosphere through the process of transpiration. It is difficult to separate this quantity from evaporation, so they are typically combined into a single term known as evapotranspiration (ET).

DBS&A estimated annual ET losses from riparian corridors within the planning region by multiplying estimated riparian areas by a representative riparian ET rate. However, vegetation or soils data delineating riparian vegetation were not available for the entire planning region. Coverage investigated for this purpose included the New Mexico Gap Analysis Program (GAP), USGS Landuse/Landcover data, National Land Cover Data (NLCD), State Soil Geographic Database (STATSGO), and the Natural Heritage New Mexico programs assessment data, all of which had either incomplete or unreliable coverage for the planning region. The USFWS National Wetland Inventory had the best information, but it was based on 1970s aerial photography and was not available electronically.

Given the lack of data, riparian areas for all perennial streams in the planning region were estimated from USGS 10-meter digital elevation model (DEM) topographic coverage and 1996 through 1998 aerial photographs. Using GIS software, the DEM topographic coverage and land surface slope maps derived from the DEM were compared to aerial photographs showing riparian vegetation along selected portions of the San Francisco and Gila Rivers and their tributaries to determine estimates of average riparian vegetation widths along the perennial stream lengths for the entire region. In this manner, riparian vegetation within the planning region was estimated to be approximately 6,700 acres.

A representative average annual ET rate for riparian areas was developed by averaging data collected along the Rio Grande by Thorn (1995) and Hong et al. (2000) (riparian ET data specific to the Southwest Region were not available):

- ET from grass-covered areas ranged between 0.15 and 4.70 millimeters per day (mm/d) or 2.16 to 67.5 in/yr over a 19-month period and averaged 2.43 mm/d or 34.9 in/yr (Thorn, 1995).

- ET from areas with cottonwood vegetation ranged from 4.5 to 5.7 mm/d (64.7 to 81.9 in/yr) during a single day in September 2000 (Hong et al., 2000) and averaged

5.1 mm/d (73.3 in/yr). DBS&A assumed the annual average ET for cottonwood vegetation to be 50 percent of the September measurements, or 2.55 mm/d (36.6 in/yr).

Using these two averages, DBS&A estimated an average ET rate of 2.49 mm/d (35.8 in/yr) for riparian areas based on the assumption that riparian areas in the planning region are made up of 50 percent grass and 50 percent cottonwood vegetation. Although some salt cedar is present in the planning region, it is not widespread and was thus not considered in the calculation. This daily rate is equivalent to an average annual rate of 2.98 feet per year, which was multiplied by the estimated riparian acreage to generate the total volume of riparian ET (19,900 ac-ft/yr).

This riparian ET estimate is used in Section 7 to calculate the water budgets for the planning region. However, this is a very rough estimate of the regional ET. Field ET measurements and more accurate mapping of riparian coverage would be needed to develop a more accurate estimate.

5.2 Surface Water Supply

Surface water supplies approximately 20 percent of the water currently used in the Southwest Region and is used primarily for irrigated agriculture (Section 6.1). Surface flows originate largely in the higher elevations, as snowmelt during the spring and as monsoonal rainfall during the late summer. Flows are highly varied from year to year, and the streams are typically characterized by short-duration, high flows, with prolonged durations of low flows. An understanding of the frequency of surface flows of various magnitudes is essential in evaluating the region's available surface water supply.

A total of 13 surface drainage basins are present either completely or partially in the Southwest Region. Surface water in these basins drains either toward the Colorado River or the Rio Grande, or it exists within closed basins with no surface water inflow or outflow:

- Surface basins that drain toward the Lower Colorado River Basin include the Little Colorado, San Francisco, Gila, San Bernadino, and San Simon Basins (Figure A2-6).

- The only surface basins that drain toward the Rio Grande are the Rio Salado Basin, in the northeast corner of the region, and the Nutt-Hockett Basin in the northeast corner of Luna County (Figure A2-6).

- Closed basins, which do not have surface water outflow, include the North Plains Basin, San Agustin Basin, Mimbres Basin, Animas Basin, Playas-San Basilio Basin, and Hachita-Moscos Basin (Figure A2-6). The North Plains and San Agustin Basins are in the northern portion of Catron County and are referred to herein as the “western closed basins.” The remainder are in the southwestern part of the planning region and are referred to as the “southwestern closed basins.”

Of these 13 basins in the planning region, only 3—the San Francisco, Gila, and Mimbres—contain perennial water courses. Important perennial and intermittent streams within the planning region are shown on Figure 5-7 herein and in Figure A2-6 in Appendix A2.

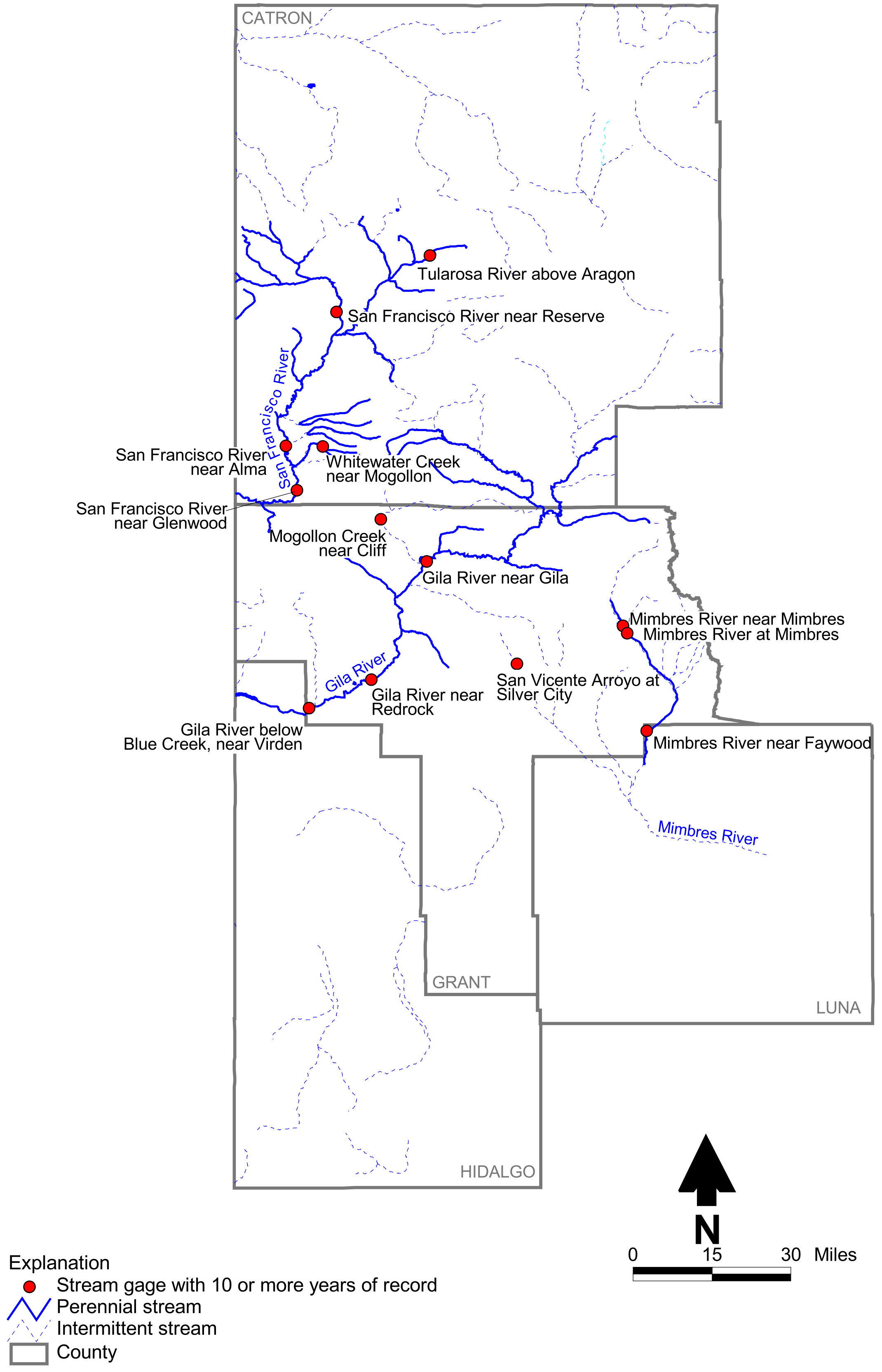
The dominant surface water resources in the region are in the Gila Basin, San Francisco Basin, and Mimbres Basin:

- The Gila Basin covers 3,352 square miles within the planning region. Headwaters of the Gila originate in Sierra County, east of the region, and the basin includes parts of Catron, Grant, and Hidalgo Counties and continues to the west, into Arizona.

- The San Francisco Basin watershed begins and ends in Arizona, with 1,841 square miles in Catron and Hidalgo Counties.

- The Mimbres Basin (3,651 square miles) headwaters are in Grant County, and the basin drains to Luna County. Parts of the Mimbres Basin are in Sierra and Doña Ana Counties, outside the planning region.

Section 5.2.1 discusses the region’s rivers and the variability in their supply, and Section 5.2.2 presents information on the lakes and reservoirs within the planning region.



SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Locations of Stream Gages

Daniel B. Stephens & Associates, Inc.

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Figure 5-7

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5.2.1 Streams and Rivers

Streamflow data are collected by the USGS at several gage sites in the planning region. A detailed table listing all active and inactive USGS gage sites is contained in Appendix D3. Figure 5-7 shows the locations of USGS gage stations with 10 or more years of record, and Table 5-5 lists the locations, periods of record, and types of records collected at these stream gages, as well as the estimated acreage irrigated by surface water diversions upstream of the station, as reported in USGS publications. Table 5-6 summarizes the minimum, median, average, maximum, and standard deviation of annual water yields based on data available from the USGS for the entire period of record for each of these stations.

For this water planning study, six stream gage stations were selected for detailed analysis as key stations based on their locations in the hydrologic system, length and completeness of record, and representativeness as key sources of supply. Water yield data from these stations for calendar years 1950 through 2002 were analyzed to develop a comparison between stations for a consistent period of record. Figure 5-8 shows descriptive statistics for annual water yield at these stations for the period of analysis, and Table 5-7 provides summary statistics for each of the key stations. Hydrographs illustrating annual streamflow for the key stations, including the monthly distribution of streamflow over a year, are presented in Appendix D3. These hydrographs include data through the end of calendar year 2002, where available. An explanation of the treatment of data gaps is provided in Appendix D3.

The San Francisco River originates in eastern Arizona and flows into the west-central border of Catron County, where it converges with the Tularosa River and flows south to the Catron-Grant County boundary. From there it bends 90 degrees to the west, returning to Arizona. Key stream gages on the San Francisco River are the San Francisco River near Reserve, upstream of the confluence with the Tularosa River, and the San Francisco River near Glenwood gages.

The median flow at the gage near Reserve from 1950 to 2002 was 12,161 ac-ft/yr, whereas the median flow at the downstream gage near Glenwood was 50,034 ac-ft/yr. This gain of 37,873 ac-ft/yr is due to the tributary and groundwater inflows for the larger watershed of the downstream reach.

Table 5-5. USGS Stream Gage Information for Stations with 10 or More Years of Record
Page 1 of 2

USGS Site Name	USGS Site Number	Elevation (ft msl)	Drainage Area (acres)	Irrigated Land Upstream of Gage (acres)	Type of Record	Start Date	End Date
Catron County, New Mexico							
Tularosa River above Aragon, NM	09442692	6,750.0	60,160	0	Daily streamflow	07/01/1966	09/30/1996
					Peak streamflow	07/24/1967	05/18/1996
					Water quality samples	01/08/1976	12/10/1976
San Francisco River near Reserve, NM	09442680	5,820.0	224,000	280	Daily streamflow	03/01/1959	09/30/2001
					Peak streamflow	07/19/1959	08/03/1999
					Water quality samples	01/07/1976	12/10/1976
San Francisco River near Alma, NM	09443000	4,842.0	989,440	1600 [a]	Daily streamflow	02/01/1964	09/30/1986
					Peak streamflow	07/18/1964	07/16/1986
					Water quality samples	01/04/1976	11/26/1976
Whitewater Creek near Mogollon, NM [b]	09443500	NA [c]	21,760	NA [c]	Daily streamflow	10/01/1909	06/30/1923
San Francisco River near Glenwood, NM	09444000	4,560.0	1,057,920	2000	Daily streamflow	10/01/1927	09/30/2001
					Peak streamflow	07/28/1928	09/13/1999
					Water quality samples	04/02/1963	08/22/2001
Grant County, New Mexico							
Mimbres River near Mimbres, NM	08477000	5,972.0	97,280	300	Daily streamflow	10/01/1930	09/30/1976
					Peak streamflow	08/10/1931	09/15/1976
					Water quality samples	01/15/1976	11/16/1979
Mimbres River at Mimbres, NM	08477110	5,920.0	138,240	None reported	Daily streamflow	03/01/1978	09/30/2001
					Peak streamflow	11/25/1978	08/05/1999
					Water quality samples	01/20/1978	08/20/1986

[a] Station is not active; unable to confirm irrigated acreage above gage.
[b] Station was moved at least three times; drainage area was 15,360 acres before October 1, 1911.
[c] Station records ended before this information was routinely reported

ft msl = Feet above mean sea level
NA = Not available

Table 5-5. USGS Stream Gage Information for Stations with 10 or More Years of Record
Page 2 of 2

USGS Site Name	USGS Site Number	Elevation (ft msl)	Drainage Area (acres)	Irrigated Land Upstream of Gage (acres)	Type of Record	Start Date	End Date
Grant County, New Mexico (continued)							
San Vicente Arroyo at Silver City, NM	08477600	5,862.6	16,960	None reported	Daily streamflow	10/01/1953	09/30/1965
					Peak streamflow	09/09/1938	09/01/1965
Mogollon Creek near Cliff, NM	09430600	5,440.0	44,160	None reported	Daily streamflow	02/21/1967	09/30/2001
					Peak streamflow	08/12/1967	08/05/1999
					Water quality samples	02/21/1967	01/10/1996
Gila River near Gila, NM	09430500	4,654.8	1,192,960	500	Daily streamflow	12/01/1927	09/30/2001
					Peak streamflow	08/23/1928	08/06/1999
					Water quality samples	12/26/1959	11/25/1976
Gila River near Redrock, NM	09431500	4,090.0	1,810,560	5000	Daily streamflow	10/01/1930	09/30/2001
					Peak streamflow	11/26/1905	08/05/1999
					Water quality samples	07/19/1967	08/22/2001
Gila River below Blue Creek, near Virden NM	09432000	3,875.0	2,049,920	6200	Daily streamflow	07/01/1927	09/30/2001
					Peak streamflow	09/22/1997	08/06/1999
					Water quality samples	03/25/1987	06/05/2001
Luna County, New Mexico							
Mimbres River near Faywood, NM	08477500	5,033.0	281,600	1750	Daily streamflow	10/01/1930	09/30/1968
					Peak streamflow	08/10/1931	08/06/1968

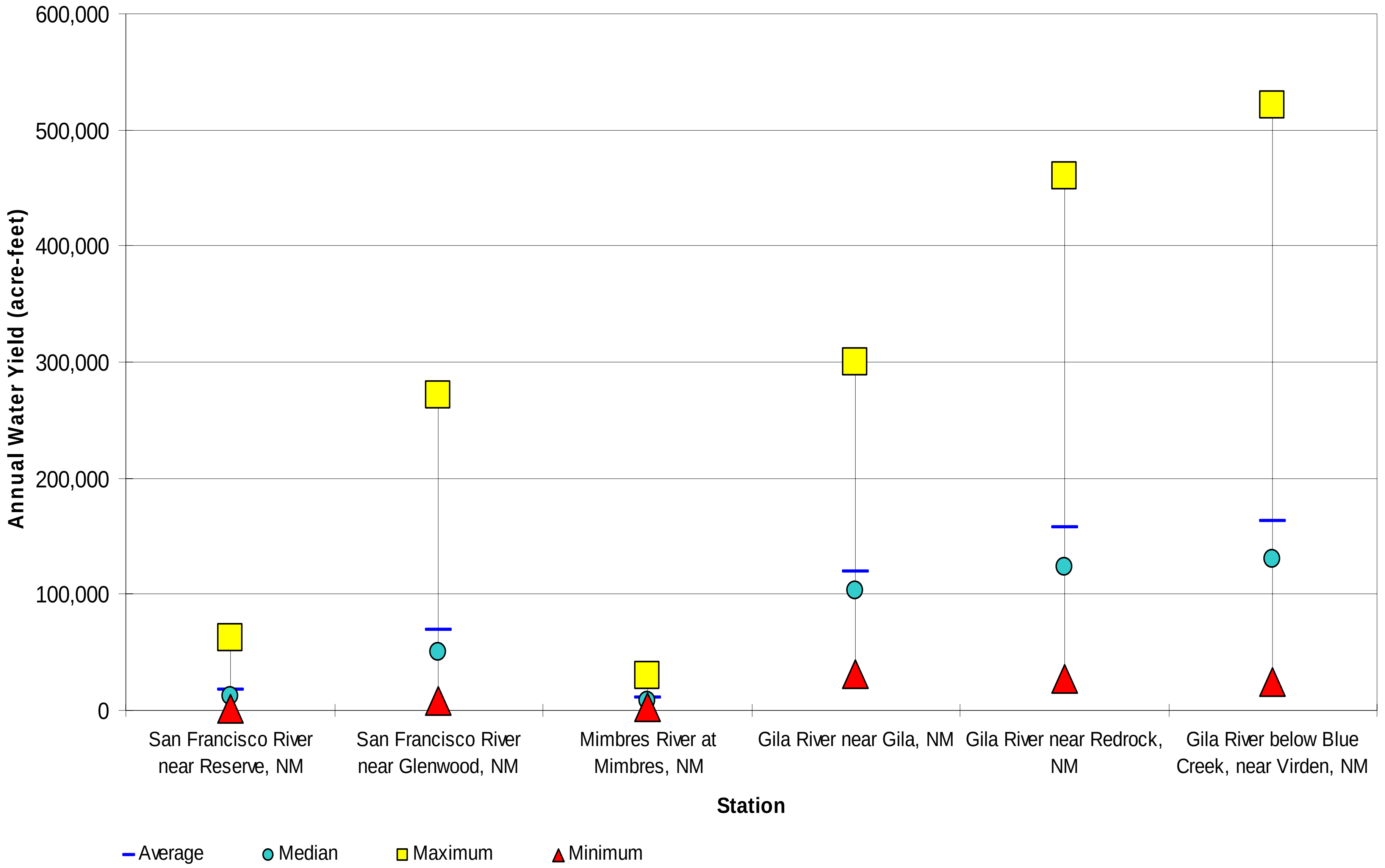
ft msl = Feet above mean sea level

Table 5-6. Water Yield Statistics for Stream Gaging Stations with 10 or More Years of Record

USGS Site Name	USGS Site Number	Period of Record	Water Yield [a] (acre-feet)				
			Minimum	Median	Average	Maximum	Standard Deviation
Mimbres River near Mimbres, NM	08477000	1931 to 1975	2,100	6,452	8,193	23,246	5,881
Mimbres River at Mimbres, NM	08477110	1979 to 2000	3,215	13,144	14,594	30,197	8,517
Mimbres River near Faywood, NM	08477500	1931 to 1933, 1935 to 1954, 1964 to 1967	1,188	7,531	10,230	37,801	9,551
San Vicente Arroyo at Silver City, NM	08477600	1954 to 1964	326	521	600	1,217	262
Gila River near Gila, NM	09430500	1928 to 2000	31,066	86,175	114,234	299,802	67,316
Mogollon Creek near Cliff, NM	09430600	1968 to 2000	3,621	20,059	22,963	61,698	16,042
Gila River near Redrock, NM	09431500	1931 to 1954, 1963 to 2000	36,498	115,866	159,245	460,566	105,648
Gila River below Blue Creek, near Virden, NM	09432000	1928 to 1978, 1981 to 2001	23,752	115,141	153,202	521,395	105,606
San Francisco River near Reserve, NM	09442680	1960 to 2000	4,801	14,773	19,955	62,785	15,357
Tularosa River above Aragon, NM	09442692	1967 to 1995	1,977	2,288	2,545	4,012	560
San Francisco River Near Alma, NM	09443000	1965 to 1985	5,250	54,022	64,820	238,249	59,272
Whitewater Creek near Mogollon, NM	09443500	1913, 1915 to 1922	3,049	11,369	15,237	37,656	12,483
San Francisco River near Glenwood, NM	09444000	1928 to 2000	8,690	43,088	64,757	271,560	53,403

[a] Data presented in this table are based on the calendar year streamflow statistics for each station available on the USGS website (http://waterdata.usgs.gov/nwis/annual).

[b] Although the Mimbres River at Mimbres, NM gage was a replacement for the Mimbres River near Mimbres, NM gage (which was destroyed by a flood in 1976), these two gages are shown separately to highlight the effects of the 1950s drought and the 1980s-1990s wet period.



SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Annual Water Yield, 1950 through 2002

Figure 5-8

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Table 5-7. Summary of Water Yield and Flow Distribution Statistics for Key Stream Gaging Stations from 1950 to 2002

USGS Site Name	Average Daily Streamflow (cfs)	Annual Yield (ac-ft)					Percentile Flows (ac-ft)				
		Minimum	Median	Average	Maximum	Standard Deviation	Q_{10}[a]	Q_{25}[b]	Q_{50}[c]	Q_{75}[d]	Q_{90}[e]
San Francisco River near Reserve, NM	24	1,521	12,161	17,429	62,770	14,675	4,849	6,415	12,161	23,083	39,145
San Francisco River near Glenwood, NM	96	8,744	50,034	69,869	271,455	57,543	22,173	26,927	50,034	91,262	146,458
Mimbres River at Mimbres, NM	15	2,256	7,509	11,140	30,312	7,879	2,737	5,474	7,509	18,369	22,158
Gila River near Gila, NM	164	31,186	102,656	118,826	299,568	70,095	50,207	58,097	102,656	158,117	228,127
Gila River near Redrock, NM	218	26,808	122,943	157,795	460,242	103,476	54,253	76,303	122,943	213,314	313,748
Gila River below Blue Creek, near Virden, NM	226	23,833	130,788	163,384	521,582	110,807	58,785	73,218	130,788	213,455	317,847

[a] Water yields were below this value in 10 percent of the years from 1950 through 2002.
[b] Water yields were below this value in 25 percent of the years from 1950 through 2002.
[c] Water yields were below this value in 50 percent of the years from 1950 through 2002 (same as median).
[d] Water yields were below this value in 75 percent of the years from 1950 through 2002.
[e] Water yields were below this value in 90 percent of the years from 1950 through 2002.

cfs = Cubic feet per second
ac-ft = Acre-feet

Note: All sites have either a few days to several years of water yields estimated by various techniques in order to have comparable record lengths for these key sites. Details of the estimations are presented in Section 5.2.1 and Appendix D3.

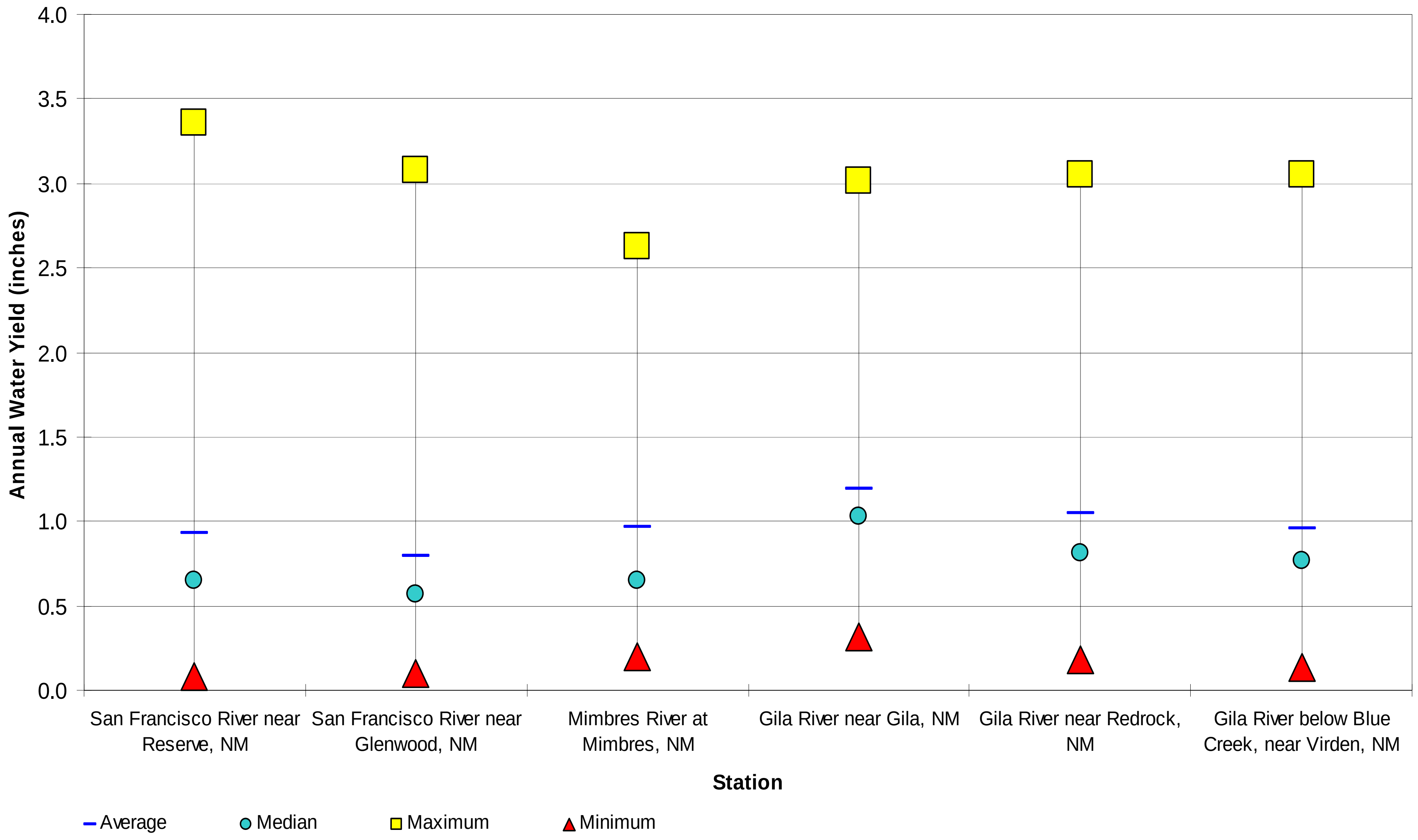
Adjusting for the surface water irrigation diversions of 17,560 ac-ft/yr and riparian ET of 4,493 ac-ft/yr, the total natural gain between these gages would be 59,930 ac-ft/yr.

A comparison of the yields at each gage, based on the area of the respective watersheds, is shown in Figure 5-9. To standardize the yield values, the annual yield was divided by the area of the watershed to give a normalized yield. The large gain in streamflow between the San Francisco River near Reserve and the San Francisco River near Glenwood gages corresponds to the large difference in drainage area between these two stations, but standardized annual water yields for these two stations are similar (Figure 5-9), with median yields ranging from about 0.7 inch near Reserve to about 0.6 inch near Glenwood.

The Gila River watershed is a complex system of tributaries, including the East Fork of the Gila River and Black Canyon Creek, which drain from the west side of the Black Range, the Middle and West Forks of the Gila, which drain from the east side of the Mogollon Mountains, and Sapillo Creek, with contributions from the Pinos Altos Range and several other tributaries, such as Turkey Creek, Mangas Creek, and Duck Creek. The gage on the Gila River near Gila is below the confluence of these tributaries, with the exception of Mangas and Duck Creeks, which enter above the Gila River near Redrock gage. On the boundary between Grant and Hidalgo Counties is the most downstream gage, below the confluence with Blue Creek, near Virden.

The hydrographs illustrating annual streamflow for the key stations (Appendix D3) show large variability of annual flows. Particularly noticeable are the large annual yields that occurred on the Gila River in 1941 and 1993, when extreme flows caused flooding in areas of the planning region.

The median flow at the Gila River near Gila gage is 102,656 ac-ft/yr compared to the flow at the most downstream gage near Virden of 130,788 ac-ft/yr. This gain from tributary flow and direct groundwater recharge of 28,132 ac-ft/yr, when adjusted for surface water diversions for irrigation (22,462 ac-ft/yr) and riparian ET (4,000 ac-ft/yr), increases to about 54,600 ac-ft/yr. As with the San Francisco River, the standardized yield based on the area of each watershed is similar at the two stations, showing an annual yield of about 1.0 inch near Gila and 0.8 inch near Virden.



SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Standardized Annual Water Yield
1950 through 2002

Figure 5-9

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Monthly and annual yield varies greatly from year to year (Figure 5-10); the very dry 1950s and the extended wet period in the 1980s and 1990s show the extremes for the period of record. Figure 5-10 illustrates the relationship between PDSI (Section 5.1.2.1) and streamflow in the Southwest Region. This figure shows a 10-year (120-month) moving average that compares the monthly PDSI for New Mexico Climate Division 8 (in the southern portion of planning region) with the monthly water yields for the Gila River near Gila gaging station, which is located near the border of Climate Divisions 4 and 8 (the data for this station correlates more closely with the Division 8 PDSI). When the PDSI is increasing, the water yields tend to also be increasing, and when the PDSI is decreasing, the water yields decrease. This correlation is to be expected as precipitation, which directly impacts streamflow, is one of the factors used to calculate the PDSI.

Figure 5-11 compares the monthly water yields for the Gila River near Gila gaging station to the monthly PDO using a 10-year (120-month) moving average. In general, the streamflow follows the sinusoidal pattern of the PDO (Section 5.1.2.2), but it does not have as strong a correlation as it does to the PDSI (Figure 5-10). Because local precipitation is not used to calculate the PDO, however, PDO may be a better indicator of future streamflow conditions.

The Mimbres River is perennial in its upper reaches and ephemeral below the gage at Faywood, where the stream flow recharges the closed basin. San Vicente Arroyo receives stormwater from the Town of Silver City and discharges to the Mimbres River below the gage at Faywood. The median flow at the Mimbres River near Mimbres gage for the period from 1950 to 2002 was 7,509 ac-ft/yr.

The hydrographs illustrating the monthly distribution of streamflow over a year (Appendix D3) indicate the monthly variation in flow throughout the year. Monthly variability or short-term storms can have flooding impacts, even when annual yields are low or average, as was the case in the 1902 Silver City flood when 7 inches of rain fell during the month of August. For these key stations, average flows tend to peak first in March due to spring runoff and again in the late summer and fall months due to runoff from monsoonal rains. Between these runoff peaks, a period of low flows occurs, primarily in June and July. The highest peak events for the period of record at these key stations have occurred in either October or December (Appendix D3).

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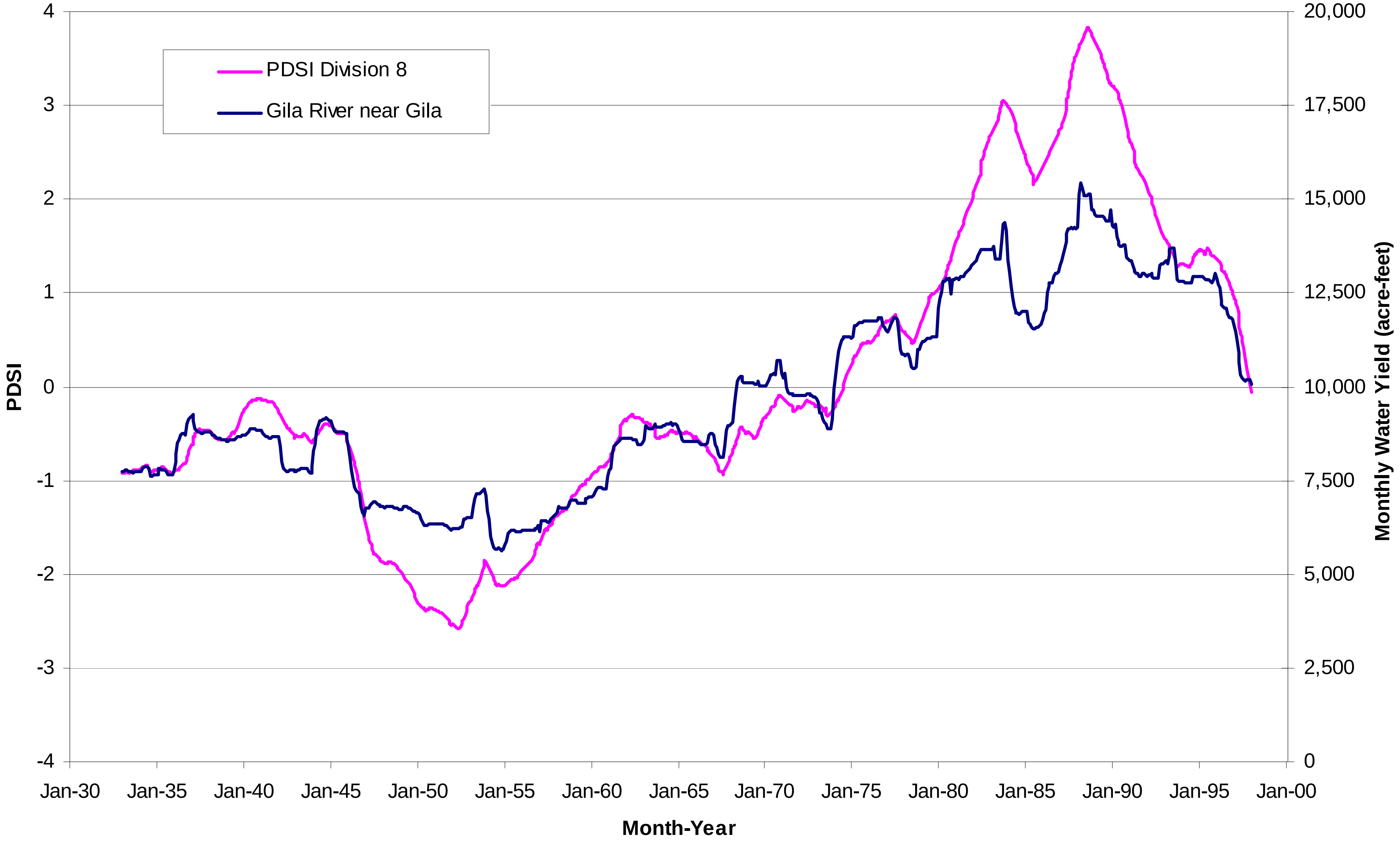

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Monthly Water Yield at Gila River near Gila and the Palmer Drought Severity Index 10-Year (120-Month) Moving Average

Figure 5-10

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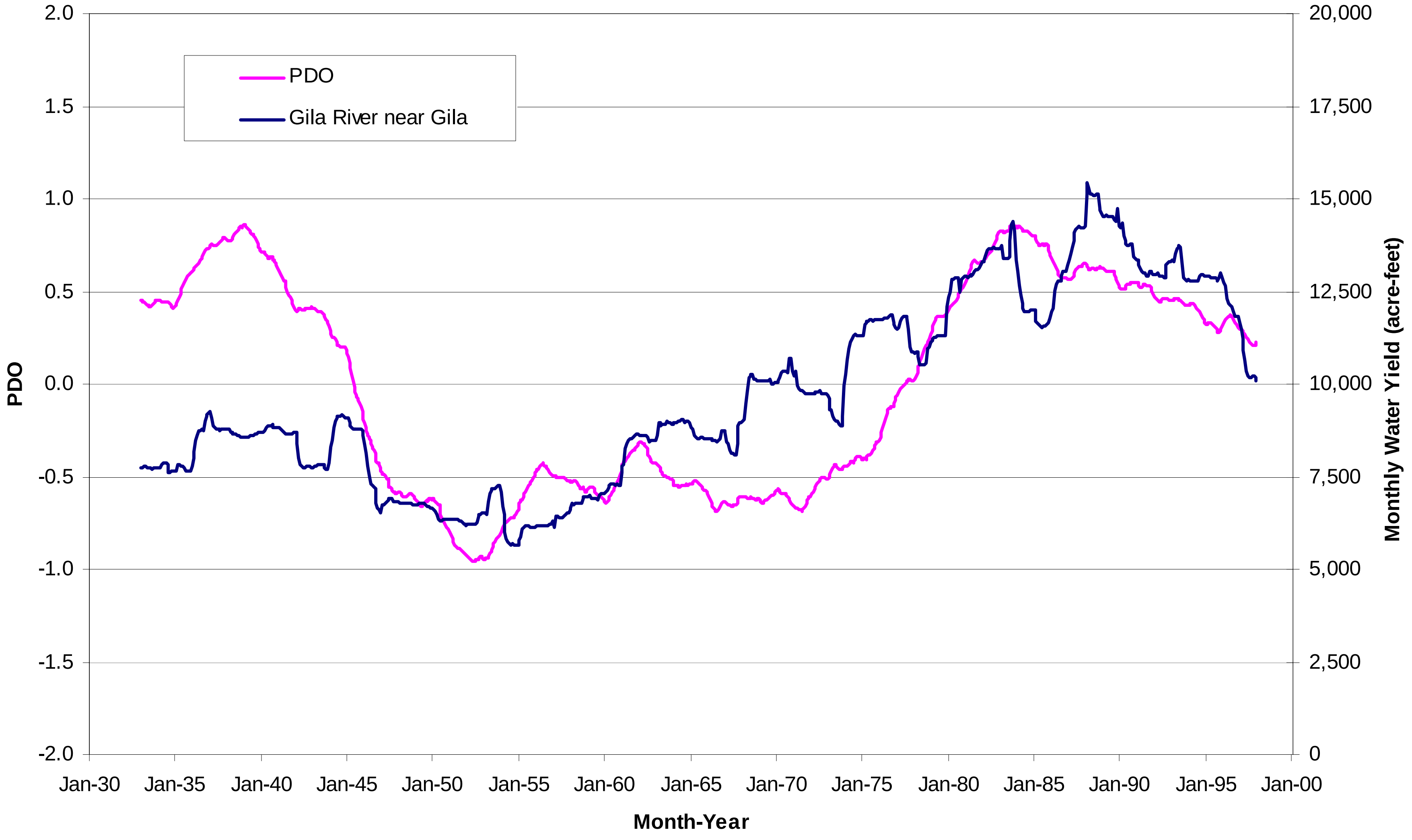

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Monthly Water Yield at Gila River near Gila and Pacific Decadal Oscillation 10-Year (120-Month) Moving Average

Figure 5-11

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The large difference in flows between the closely located Mimbres River near Mimbres and Mimbres River at Mimbres gages is due to the time period recorded for each gage (the Mimbres River at Mimbres gage was a replacement for the Mimbres River near Mimbres gage, which was destroyed by a flood in September 1976). The period of record for the Mimbres River at Mimbres gage (from 1978 to 2001) reflects the wet period in the 1980s and 1990s, while the Mimbres River near Mimbres period of record (from 1930 to 1976) reflects the drought of the 1950s.

5.2.2 Reservoirs and Lakes

Several lakes and reservoirs are present in the planning region (Appendix A2, Figure A2-6). Table 5-8 summarizes the characteristics of these lakes and reservoirs, including a lake (Luna Lake) that is located a short distance outside the planning boundary and has some bearing on the potential water supply for Catron County. Information contained in Table 5-8 was gathered primarily from the OSE (personal communication with Brian Wilson), from previous water planning efforts (RTI, 1991), and from communication with both the New Mexico and Arizona Game and Fish Departments.

The lakes and reservoirs within the planning region, which range from numerous stock ponds to several major reservoirs, are commonly used to store water produced during storm events. In general, their primary purpose is for recreation, except for reservoirs used in mining activity, such as Bill Evans Lake, which is fed by a pipeline from the Gila River and stores water for use at the Tyrone Mine. Table 5-8 also contains information regarding the natural playa lakes present in Hidalgo County, which are typically dry.

5.3 Groundwater Supply

Identifying and understanding the available groundwater supply is essential to water planning in the Southwest Region, where approximately 84 percent of all water depletions are from the area’s aquifers. This section summarizes the groundwater supplies in the Southwest Region and the general characteristics of hydrogeologic units, including both water-bearing aquifers and relatively impermeable units. Because the scope of work for this water plan did not include field

Table 5-8. Southwest New Mexico Counties Reservoir Summary

Reservoir	Sub-Basin (Basin)	Purpose [a]	Operator	Total Storage Capacity (ac-ft)	Surface Area at Spillway Elevation (acres)	Average Surface Area (acres)	Gross Evaporation Rate (in/yr)	Net Evaporation Rate (in/yr)	Total Evaporation Losses (ac-ft)	Surface Water Withdrawal (ac-ft)	Surface Water Depletion (ac-ft)
Catron County											
Snow Lake–Snow Creek	Gila River Basin (Lower Colorado)	FW, REC	NM Game & Fish Dept.	1500 (4000 [b])	100 [b]	55	41.04 (44.8 [b])	21.00	374 [b]	96.25	96.25
Wall Lake–Gila River East Fork	Gila River Basin (Lower Colorado)	REC	Private land owner [c]	188 (6 [b])	73 [b]	20	39.96 (47 [b])	24.00	286 [b]	40.00	40.00
Quemado Lake–Largo Creek	Little Colorado River Basin (Lower Colorado)	FW, REC	NM Game & Fish Dept.	2550 (2400 [b])	187 [b]	112	41.04 (45 [b])	25.08	701 [b]	234.08	234.08
Sweazea [b]	Little Colorado River Basin (Lower Colorado)	---	---	---	5	---	45.00	---	19	---	---
Salt Lake [b]	Little Colorado River Basin (Lower Colorado)	---	---	---	195	---	48.00	---	780	---	---
Agua Fria [b]	Little Colorado River Basin (Lower Colorado)	---	---	---	291	---	47.00	---	1140	---	---
Blaines Lake [b]	Little Colorado River Basin (Lower Colorado)	---	---	---	116	---	45.00	---	435	---	---
Toriette Lakes [b]	San Francisco River Basin (Lower Colorado)	---	---	---	62	---	44.50	---	230	---	---
Glenwood Ponds [b]	San Francisco River Basin (Lower Colorado)	---	---	---	1	---	45.00	---	4	---	---
Rancho Grande Pond [b]	San Francisco River Basin (Lower Colorado)	---	---	---	2	---	44.50	---	8	---	---
Luna Lake (Arizona) [d]	San Francisco River Basin (Lower Colorado)	IR	---	932.3	113.7	---	42.00	21.60	---	---	---
Grant County											
Bill Evans Dam–Gila River	Gila River Basin (Lower Colorado)	MI, REC	Phelps Dodge Tyrone, Inc.	2120 (2300 [b])	64 [c]	62	60.00 (50 [b])	44.04	259 [b]	227.54	227.54
Lake Roberts–Sapillo Creek	Gila River Basin (Lower Colorado)	REC	NM Game & Fish Dept.	1870 (1300 [b]) [e]	66 [c]	70	44.04 (49 [b])	28.08	270 [b]	163.8	163.8
Bear Canyon Reservoir–Bear Canyon	Mimbres River Basin	REC, IR [c]	NM Game & Fish Dept.	1025 (120 [b])	35 [c]	22	45.96 (49 [b])	30.00	143 [b]	55.00	55.00
3A Reservoir [b]	Mimbres River Basin	MI	Chino Mines Company	---	---	---	---	---	---	---	---
James Canyon Reservoir [b]	Mimbres River Basin	MI	Chino Mines Company	950 [f]	---	---	---	---	---	---	---
Hidalgo County											
Rock Tank [b]	Gila River Basin (Lower Colorado)	---	---	---	558	---	67.00	---	3116	---	---
Playas Lakes [b]	Playas Basin (Rio Grande)	---	---	---	---	2036	72.00	---	12216	---	---
Playas Lakes [b]	Animas Basin (Lower Colorado)	---	---	---	---	4500	82.00	---	30750	---	---
Luna County											
King Reservoir	Rio Grande River Basin	IR	---	---	---	3	69.00	59.04	---	14.76	14.76

Source: Data compiled by B.C. Wilson, New Mexico Office of the State Engineer, unless otherwise noted.

ac-ft = Acre-feet

in/yr = Inches per year

--- = Information not available

[a] FW = Fish and wildlife

REC = Recreation

IR = Irrigation

MI = Municipal/industrial

[b] Source: RTI, 1991, Table 10.1

[c] Source: Personal communication with New Mexico Game & Fish Department

[d] Source: Personal communication with Arizona Game & Fish Department

[e] A 1988 study prior to dredging activities at this lake indicates an original surface area of 69.3 acres and storage capacity of 1,009 ac-ft. At that time, the study estimated the lake's surface area to be 55.7 acres with an 826-ac-ft capacity due to sedimentation (Isaacson & Arfman, 1988).

[f] URS Greiner-Woodward Clyde, 2000

investigations, this section summarizes existing information only; collection of additional data would enhance the understanding of the groundwater supplies in the Southwest Region.

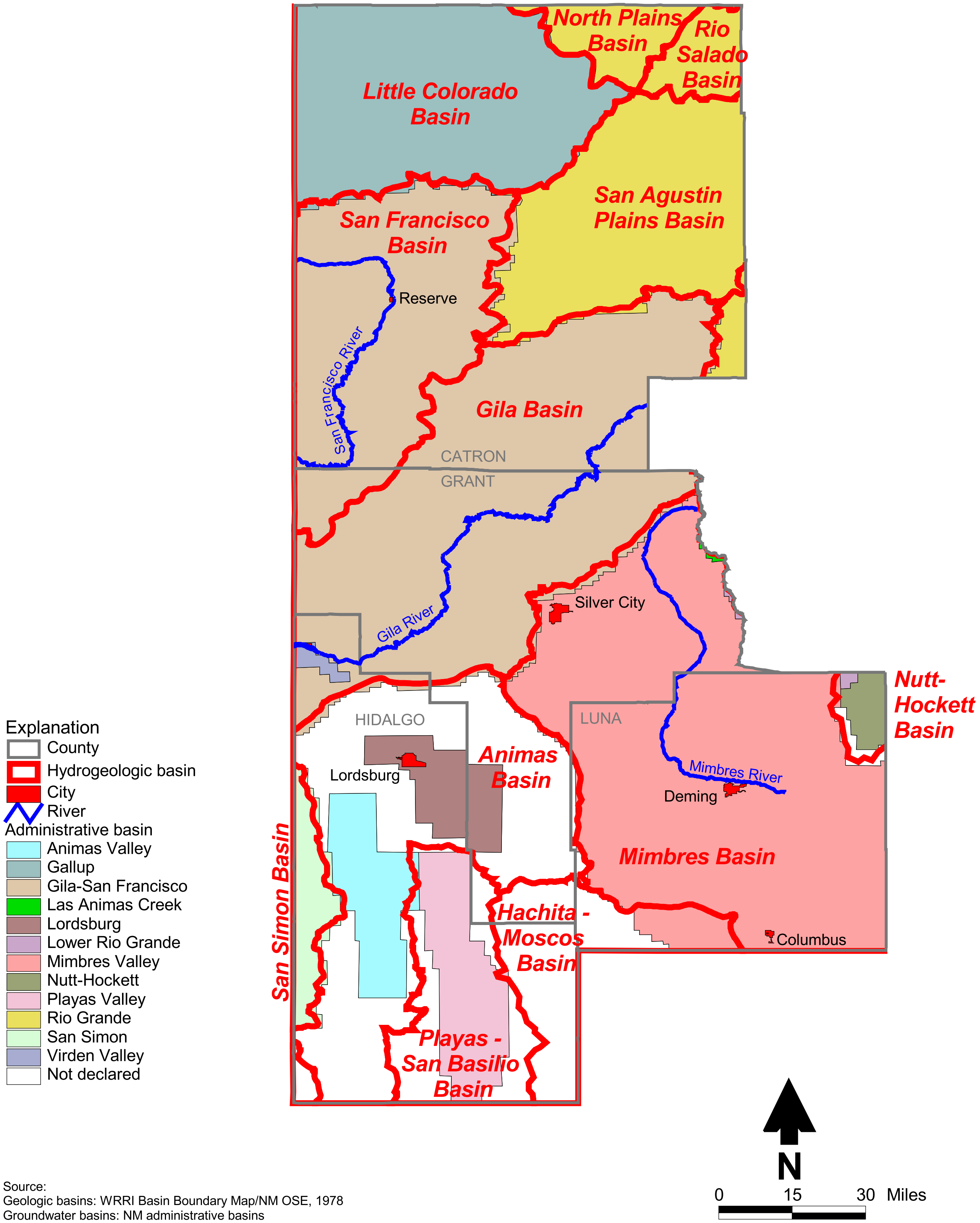
As discussed in Section 4.5, the OSE has designated for administrative purposes certain groundwater areas that are referred to as “declared” groundwater basins. These declared basins do not always coincide precisely with the physical hydrogeologic basins in the planning region, and some hydrogeologic basins that are present in the planning area are undeclared. Whereas Section 4.5 discussed the OSE-declared basins in relation to the legal availability of water, the discussion in this section, which relates to the physical availability of water, is of the hydrogeologic groundwater basins, as defined by physical hydrogeologic boundaries. Table 5-9 lists the 10 declared groundwater basins in the Southwest Region, along with the surface area of each and the corresponding hydrogeologic basin(s). Figure 5-12 shows the declared basin boundaries in comparison to the actual hydrologic basin boundaries.

Table 5-9. Groundwater Basins in the Planning Region

OSE Administrative Groundwater Basin	Area (square miles)	Corresponding Hydrogeologic Basin(s) [a]
Animas Valley	426	Animas
Lordsburg	329	Animas
Playas Valley	515	Playas-San Basilio
Mimbres Valley	3,799 [b]	Mimbres, Hachita-Moscos
San Simon	263	San Simon
Nutt-Hockett	98 [b]	Nutt-Hockett, Lower Rio Grande
Virden Valley	19	Gila
Gallup	1,924 [b]	Little Colorado
Rio Grande	2,158 [b]	San Agustin, Rio Salado, North Plains
Gila-San Francisco	5,659	Gila, San Francisco
Undeclared	2,710	San Bernadino, Hachita-Moscos, Animas, Playas-San Basilio

[a] Because the administrative and hydrogeologic basin boundaries do not match, in many cases only part of the hydrogeologic basin is present within the administrative basin (and vice versa).

[b] Area of the basin that falls within the Southwest Region



Source:
Geologic basins: WRRI Basin Boundary Map/NM OSE, 1978
Groundwater basins: NM administrative basins

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SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Hydrogeologic and Administrative Basin Boundaries

Daniel B. Stephens & Associates, Inc.

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Figure 5-12

Section 5.3.1 discusses the general geologic setting as it relates to groundwater supply and identifies the regional geology and major aquifers that exist within the planning region. Water supply in each of the 12 hydrogeologic groundwater basins (Figure 5-12), aquifer characteristics, and recharge are discussed in Sections 5.3.2 through 5.3.4, respectively. Section 5.3.5 identifies and describes the major well fields that exist within the region. Finally, Section 5.3.6 presents estimates of sustainable yields in the areas of highest water consumption and identifies those areas most likely to face severe water shortages in the next 20 to 60 years.

5.3.1 Regional Hydrogeology

According to Hawley et al. (2000), the first detailed geologic mapping and hydrologic investigations in the area that encompasses the Southwest Region were conducted in the early 19th Century by numerous investigators, including N.H. Darton (1916), W.T. Lee (1907), O.E. Meinzer (1911, 1916), S. Paige (1916), and A.T. Schwennesen (1918). These early investigations focused primarily on understanding the general geologic boundaries and controls on groundwater occurrence. More recent investigations (e.g., Reeder, 1957; Doty, 1960; Trauger and Herrick, 1962; Trauger and Doty, 1965; Trauger, 1972; McLean, 1977; O'Brien and Stone, 1981; Wilkins, 1986; Kernodle, 1992; Hanson et al., 1994, Hawley et al., 2000; Johnson et al., 2002) have helped quantify groundwater supply, rates of movement, recharge, and quality.

These and other existing sources of information were used to help determine the past and current regional groundwater supply in the Southwest Region. This information included documents prepared by federal, state, and local agencies, academic research, and industry funded studies, as well as data from numerous wells found within the region, including monitoring wells maintained by the USGS, irrigation and municipal supply wells, and private domestic supply wells. A bibliography is provided in Appendix A1. In addition, available geologic cross sections are included in Section 5.3.2 to illustrate the hydrogeology, and groundwater level hydrographs developed to show trends in aquifer water levels over time are included in Appendix D4.

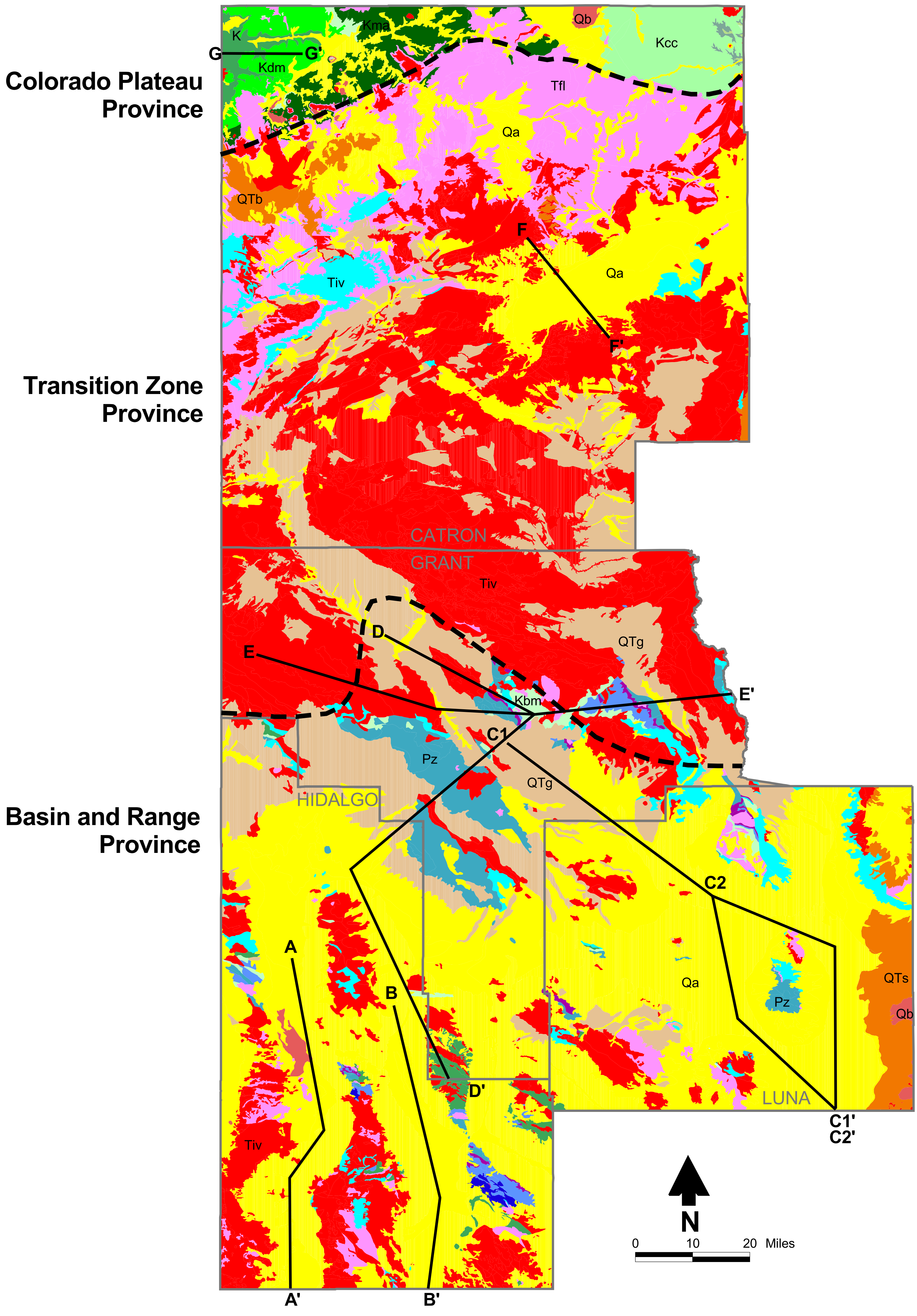
The geology and hydrogeology of the Southwest Region is highly varied and falls into three different geologic or physiographic provinces: the Colorado Plateau Province, the Transition Zone Province, and the Basin and Range province (Figure 5-13). The different provinces have distinct geologies that control to a large extent the groundwater quantity, depth, quality, and recharge rates. Sections 5.3.1.1 through 5.3.1.3 generally describe the geology and lithologies found in each of the three provinces.

5.3.1.1 Colorado Plateau Province

The northwestern corner of the Southwest Region (northern Catron County) lies within the Navajo Section of the Colorado Plateau Province (RTI, 1991). The Colorado Plateau extends throughout a vast area, including portions of New Mexico, Arizona, Colorado, and Utah, but into only a small portion of the planning region. The topography is characterized by large flat plateaus and buttes separated by wide valleys and locally incised canyons (RTI, 1991). The Colorado Plateau Province is comprised mainly of numerous sedimentary rock formations that were deposited in shallow marine and fluvial environments between 65 and 250 million years ago (Cretaceous-Permian) (Basabilvazo, 1997). Sedimentary formations of the Colorado Plateau are locally overlain by Quaternary alluvium and basalt.

Quaternary alluvium is found in arroyos, washes, and stream channels. The most significant alluvial groundwater source in the Colorado Plateau Province portion of the planning region is along Carrizo Creek; however, insufficient data exist to adequately assess the quantity of water available in alluvium in this part of the region (Basabilvazo, 1997). The alluvial fill supplies limited water for stock wells, but does not form important regional aquifers as it does in the southern part of the planning region. Quaternary and Upper Tertiary basalts are also found in the area, but are above the water table and are not associated with any known wells (BLM, 1990).

The Cretaceous Mesaverde Group comprises the youngest of the sedimentary rocks in this part of the Colorado Plateau Province. In the northwestern corner of Catron County, the Mesaverde Group has been divided by McLellan et al. (1984) into the Moreno Hill Formation and the Atarque Sandstone (Basabilvazo, 1997).



Explanation

A—A' Cross section location
Physiographic province
☐ County

Geology

- 🟨 Qa - Alluvium; upper and middle Quaternary
- 🟥 Qb - Basalt and andesite flows and locally vent deposits
- 🟧 QTb - Basaltic and andesitic volcanics interbedded with Pleistocene and Pliocene sedimentary units
- 🟫 QTg - Gila Group
- 🟧 QTs - Upper Santa Fe Group
- 🟥 Tiv - Tertiary intrusive volcanics
- 🟪 Tsv - Tertiary sedimentary volcanics
- 🟩 Kma - Moreno Hill Formation and Atarque Sandstone; in Salt Lake coal field and extreme southern Zuni basin
- 🟩 Kbm - Mancos Formation and Beartooth Quartzite (and Sarten Sandstone)
- 🟩 Kdm - Intertongued Dakota-Mancos sequence of west-central New Mexico
- 🟩 Kth - Tres Hermanos Formation; formerly designated as Lower Gallup Sandstone in the Zuni Basin; Turonian
- 🟩 Kmg - Gallup Sandstone and underlying D-Cross Tongue of the Mancos Shale; Turonian
- 🟩 Kcc - Crevasse Canyon Formation
- 🟩 K - Cretaceous rocks, undivided
- 🟦 P - Permian and Pennsylvanian rocks
- 🟦 Pys - Yeso, Glorieta and San Andres Formations, undivided
- 🟦 PIP- Permian rocks, undivided
- 🟦 Ph - Hueco Formation; limestone unit restricted to south-central area; Pendejo
- 🟦 Pa - Abo Formation; red beds, arkosic at base, finer and more mature above
- 🟪 IPme - Madera Limestone, exotic blocks; present only in the Chloride area of Sierra County
- 🟪 M - Mississippian rocks, undivided; Arroyo Penasco Group in Sangre de Cristo
- 🟦 Pz - Paleozoic rocks, undivided

Source:
Modified from Green and Jones (1997)

Figure 5-13

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN
Geology

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- The Moreno Hill Formation is between 800 and 1,000 feet thick. It is predominantly shale, with lesser amounts of lenticular and discontinuous sandstones and thin coal seams. Although much of the shale is saturated, it does not yield substantial water. The sandstone lenses within the Moreno Hill Formation may provide water for domestic and stock uses (BLM, 1990).

- The Atarque Sandstone is approximately 20 to 30 feet thick (BLM, 1990) with poorly defined hydraulic characteristics. The BLM reports that the Atarque Sandstone may also supply water for some of the area's stock wells (BLM, 1990).

In the northeastern portion of Catron County, the Mesaverde Group has been separated into the Crevasse Canyon Formation and the Gallup Sandstone. Few hydrologic data are available for the Gallup Sandstone. Yields from the Crevasse Canyon Formation range from 0.5 to 1.5 gallons per minute (gpm) (Basabilvazo, 1997).

The Mancos Shale underlies the Mesaverde Group and is approximately 600 feet thick. It is a dark shale, consisting of three members, that intertongues with the underlying Dakota Sandstone (discussed below). The Mancos Shale yields little water and in fact acts as an aquiclude (i.e., it absorbs water, but does not transmit it very rapidly) between the overlying Mesaverde Group and the underlying Dakota Sandstone. Thin sandstone layers that separate the three shale members contain limited water that may provide water for stock wells in the area.

Underlying the Mancos Shale is the Dakota Sandstone, which is approximately 50 feet thick and consists of cross-bedded sandstone, carbonaceous siltstones, shales, and coal. The Dakota Sandstone was reported to produce as much as 200 gpm within the vicinity of Fence Lake, even though it is between 400 and 600 feet deep in that area (BLM, 1990). The Dakota Sandstone has relatively high transmissivities and generally good water quality in northern Catron County.

The Zuni Sandstone is a thin eolian sandstone that underlies the Dakota Sandstone in parts of the region. The hydrologic properties of the Zuni Sandstone are not clear, but it is likely not a significant source of water because it is not areally extensive and is only approximately 15 feet thick (BLM, 1990).

The Chinle Formation underlies the Zuni Sandstone in northwest Catron County, where it is approximately 1,500 feet thick. In northwestern Catron County it consists of reddish brown to purple and light-green-gray to white claystones, shales, siltstones, and mudstones interbedded with thin lenses of sandstone and conglomerates (Willard and Weber, 1958; Foster, 1964; and McClellan et al., 1984, as cited in Basabilvazo, 1997). A few wells completed in the sandstone lenses supply small amounts of water with generally high total dissolved solids (TDS) contents.

Beneath the Chinle Formation lie several Triassic and Permian units, including the Moenkopi Formation, Kaibab Limestone, and Coconino Sandstone. No wells completed in these units are known to exist in Catron County, due to the fact that the Dakota Sandstone provides an ample water supply much closer to the surface. The Kaibab Limestone and the Coconino Sandstone are both known to produce good amounts of water in parts of the Colorado Plateau Province to the west, but because area demand is currently not high enough to warrant exploration of these deeper units, little is known of their hydrologic characteristics within New Mexico.

In summary, groundwater within the Colorado Plateau portion of the planning region exists primarily in sedimentary formations, most predominantly the Dakota Sandstone (Basabilvazo, 1997). Although groundwater is known to exist in older (Permian) formations such as the Coconino Sandstone and Kaibab Limestone, the depth of these units (1,000 to 2,000 feet bgs) (BLM, 1990) largely deters their use for groundwater supply. Tertiary volcanics and Quaternary alluvium also contain localized groundwater, but they are not extensive enough to be considered a regionally important groundwater source.

5.3.1.2 Transition Zone Province

The remainder of Catron County and much of Grant County lie within the Datil-Mogollon Section of the Transition Zone Province (Figure 5-13). As the name implies, this area is a transitional zone between the Colorado Plateau Province and the Basin and Range province to the south (RTI, 1991). The Datil-Mogollon Section was formed during uplift along the Colorado Plateau margin, which resulted in the formation of intermontane basins that then filled with sediments derived from the adjacent uplifts. Uplift and basin formation was followed by the emplacement of large-scale intrusive plutons and associated extrusive volcanics between 40 and 20 million years ago (Miocene-Oligocene) (Basabilvazo, 1997). The Datil-Mogollon volcanic field is the dominant geologic feature in this section, and lavas and tuffs are the main rock types. The primary volcanic units are the Baca Formation, the Datil Group, and the Bearwallow Mountain Andesite.

The Datil-Mogollon Section straddles the Continental Divide. The area west of the divide is drained by the San Francisco River, which is responsible for much of the deeply dissected tableland topography of the upper Gila River Basin (Hawley et al., 2000). The area east of the divide is characterized by numerous ephemeral washes that flow out of the planning region to the Rio Grande and to internally drained basins.

Alluvium exists primarily in the Carrizo Wash Basin of western Catron County and in the San Agustin Basin of eastern Catron County. Alluvial waters are used for domestic, stock, irrigation, and public supply purposes near Glenwood (Basabilvazo, 1997). The alluvium in these basins is reported to be as thick as 190 feet, but it is not clear how thick the saturated zone is (BLM, 1990). Alluvium deposits are also found along the Gila-San Francisco River system, where streams have cut deep canyons into the igneous rock bodies (Hawley et al., 2000). The available long-term water level data for these basins are insufficient to allow determination of water level trends.

The Gila Group (referred to as the Gila Conglomerate by Basabilvazo [1997]) underlies the alluvium in parts of the Datil-Mogollon Section and represents the infilling of the intermontane basins by alluvial fan processes. The thickness of the Gila Group varies depending upon where it was deposited, but is reported to be as much as 600 feet near Reserve and 750 feet near Beaverhead (Basabilvazo, 1997). While the upper part of the Gila Group supplies small to moderate amounts of water to wells, the lower part is a poor aquifer due to cementation and compaction.

The Bearwallow Mountain Andesite consists of basaltic andesite, basalt, dark andesite, dark latite flows, lesser amounts of red scoria, and agglomerate (Coney, 1976 [as cited in

Basabilvazo, 1997]). The thickness of this unit ranges from 100 feet to 2,000 feet. The Bearwallow Mountain Andesite has only recently been determined to contain enough water to supply wells. Three wells that reportedly yield adequate water for domestic and livestock use are known to be completed in the unit (Basabilvazo, 1997).

The Datil Group contains many interbedded igneous, volcanic, and sedimentary rocks. This unit is present in the Little Colorado, San Agustin, San Francisco, and Gila geologic basins. Water levels of wells completed in the Datil Group range from 60 to 1,260 feet bgs and typical well yields are 1 to 15 gpm.

The Baca Formation overlies the Datil Group and unconformably lies on top of the Mesaverde Group near the margin with the Colorado Plateau Province. The Baca Formation consists of a redbed sequence of mudstone, sandstone, and conglomerate (Johnson, 1978; Cather, 1980 [as cited in Basabilvazo, 1997]). The formation is typically unconfined, but may be confined at depth. Yields from wells completed in the Baca Formation range between 5 and 20 gpm.

Beneath the Baca Formation, the Mesaverde Group and subsequent Cretaceous sedimentary units described in Section 5.3.1.1 exist near the margin with the Colorado Plateau. A number of wells are completed in these units, as discussed in Section 5.3.1.1.

5.3.1.3 Basin and Range Province

South of the Transition Zone Province lies the Mexican Highland Section of the Basin and Range province (Figure 5-13), which covers the remainder of the Southwest Region. The geology of the Basin and Range province is the result of extensional geotectonics that have occurred over the last 25 million years. The province is characterized by north-south trending mountain ranges separated by basins that have been partially filled with sediment eroded from the mountains. The mountains are comprised of bedrock and encompass approximately 20 percent of the Basin and Range province in New Mexico (Hawley et al., 2000). The occurrence of water within bedrock material is limited to localized fracture flow. Except for local areas of very limited interbasin flow, bedrock is thought to not provide hydraulic connectivity between basins (Hawley et al., 2000).

Two general types of basins are found in the Basin and Range province:

- A *closed basin* has a radial flow direction due to a confining bottom that gently slopes toward the middle of the basin from all directions. Water in closed basins does not flow out of the basin.

- An *open basin* has a lateral flow direction and either an inlet or discharge point that connects it to another basin(s).

The two types of basins are often distinguished through use of the term “bolson” to indicate closed basins while using the term basin only for open basins; however, this convention is not rigorously observed in the available literature. To avoid confusion, this report refers to both open and closed basins as “basins” and avoids using the term “bolson.” In addition to the physical characteristics context, the term “closed basin” in a legal context refers to an OSE-declared basin that has been closed to further appropriations of water. All discussion in this section of this regional water plan refers to closed or open basins in the physical, rather than the legal administrative, sense.

Basin fill includes several units of Quaternary alluvial and lacustrine deposits, as well as the Tertiary Gila Group (Figure 5-13). The basin fill within the Basin and Range province contains most of the readily available (i.e., economically viable) groundwater resources within the Southwest Region. In general, the water table in the basin fill is within 200 feet of ground surface, the basin aquifers are moderately to highly permeable, and the water is of good quality. Basin fill is typically deeper in the middle of the basin, exceeding 2,000 feet in places, and thins toward the edges.

5.3.2 Hydrogeologic Groundwater Basins

This section discusses the groundwater supply in each of the 12 hydrogeologic basins that fall either completely or partly within the planning region. Table 5-10 lists those 12 basins, along with the surface area of each. Although not generally the case in other areas, groundwater basins within the Southwest Planning Region in many cases coincide with the surface water basins. The locations of the hydrogeologic basins are shown in Figure 5-12, which also shows the OSE-declared basins discussed in Section 4.5. As shown in Figure 5-12, the boundaries of declared basins are in some cases close to the hydrogeologic basin boundaries, while in other cases, the boundaries vary significantly.

Table 5-10. Hydrogeologic Groundwater Basins in the Planning Region

Groundwater Basin	Area Within Southwest Region [a]	
	(acres)	(square miles)
San Simon	155,697	243
Animas	1,533,292	2,396
Playas-San Basilio	592,774	926
Hachita-Moscos	481,529	752
Mimbres	2,330,414	3,651
Nutt-Hockett	88,846	139
Gila	2,145,516	3,352
San Francisco	1,193,029	1,864
San Agustin	985,813	1,540
Little Colorado	1,155,541	1,806
North Plains	188,770	295
Rio Salado	151,613	237

[a] As determined from DBS&A GIS

The small area of the San Bernadino Basin (36 square miles) is not included in this discussion. Due to lack of data and the sparse population, the small section of the Lower Rio Grande Basin that falls in the southeast corner of Catron County is also not discussed.

Sections 5.3.2.1 through 5.3.2.12 describe the general hydrogeologic setting and groundwater conditions for the portion of each hydrogeologic basin that lies within the Southwest Region. The following definitions are included to help the reader who may not be familiar with the exact meaning of some of the hydrogeologic terms used in the discussions:

- *Hydraulic conductivity.* A rate of proportionality (generally expressed in units of feet per day or centimeters per second) describing the rate at which water can move through a permeable medium. The density and kinematic viscosity of the water must be considered in determining hydraulic conductivity.

- *Specific yield.* The quantity of water that a unit volume of aquifer will yield by gravity after it is saturated, expressed as either a ratio or a percentage of the aquifer volume. In practical terms, specific yield is a measure of the water available to wells.

- *Transmissivity.* The rate (generally presented in units of gallons per day per foot or square feet per day) at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. Transmissivity is a function of properties of the liquid, the porous media, and the thickness of the porous media.

- *Specific capacity.* The yield of a well per unit of drawdown of the water table. Usually expressed as gallons pumped per minute per foot of drawdown (gpm/ft). Specific capacity generally varies with duration of pumping: as pumping time increases, specific capacity decreases. Specific capacity will also typically decrease as the pumping rate decreases.

Additional terms are defined in the Glossary at the end of this report.

5.3.2.1 San Simon Basin

The San Simon Basin covers an area of 243 square miles (Table 5-10) in southwestern Hidalgo County, along the New Mexico-Arizona border (Figure 5-12). The primary land use is grazing, with cultivated agriculture being the second largest land use. Wilson et al. (2003) estimates that 683 acres were irrigated in 1999. The largest population center is the town of Rodeo.

In general, the regional groundwater flow direction in the San Simon Basin is from the south to the northwest. In the central portion of the basin, however, the flow direction changes to northeast. Depths to water in the USGS's observation wells in the San Simon Basin were measured at 126 feet and 122 feet in 1996 (NMBHO, 2003).

5.3.2.2 Animas Basin

The Animas Basin is present in central Hidalgo County and the southern panhandle portion of Grant County (Figure 5-12) and covers an area of 2,396 square miles in the Southwest Region (Table 5-10). The primary land use is rangeland, and the second largest land use is cultivated agriculture. Estimates of irrigated acres range from 7,322 acres in 1995 (Hawley et al., 2000) to 8,209 acres in 1999 (Wilson et al., 2003). U.S. Interstate 10 runs through the northern portion of the basin, and the largest urban centers are the towns of Lordsburg, Animas, and Cotton City.

In its southern portion, the Animas Basin is bounded on the west by the Pelloncillo Mountains and on the east by the Animas Mountains, the crest of which is the Continental Divide. The southern boundary of the basin is located approximately 25 miles south of the U.S.-Mexico border. The northern portion of the basin is defined by the Summit Hills and Lordsburg Mesa, and the western portion is bounded by the Continental Divide. The mountains bounding the basin not only prevent flow out of the basin, but also direct rainfall to the basin floor, where some of it recharges the aquifer.

The general groundwater flow direction is toward the northwestern corner of the basin, although some underflow to Mexico occurs at the south end of the basin and a small amount of discharge to the Mimbres Basin may occur along the eastern border. Investigations suggest that approximately 12,700 acre-feet of groundwater is discharged from the Animas Basin to the Gila Valley each year (Hawley, 2000).

The Animas Basin contains four interconnected sub-basins: Lordsburg, Lower Animas, Upper Animas, and Cloverdale:

- *Lordsburg Sub-basin:* The principal groundwater-bearing geologic unit of the Lordsburg Sub-basin is the Gila Group (Johnson et al., 2002). The Quaternary alluvium, an important water-bearing formation in other basins of the Basin and Range province, is generally above the water table in the Lordsburg Sub-basin area (Hawley et al., 2000). Available data indicate that the depth to the water table ranges between 80 and 125 feet (Johnson et al., 2002) and the average saturated thickness of the productive zone is approximately 360 feet (Hawley et al., 2000).

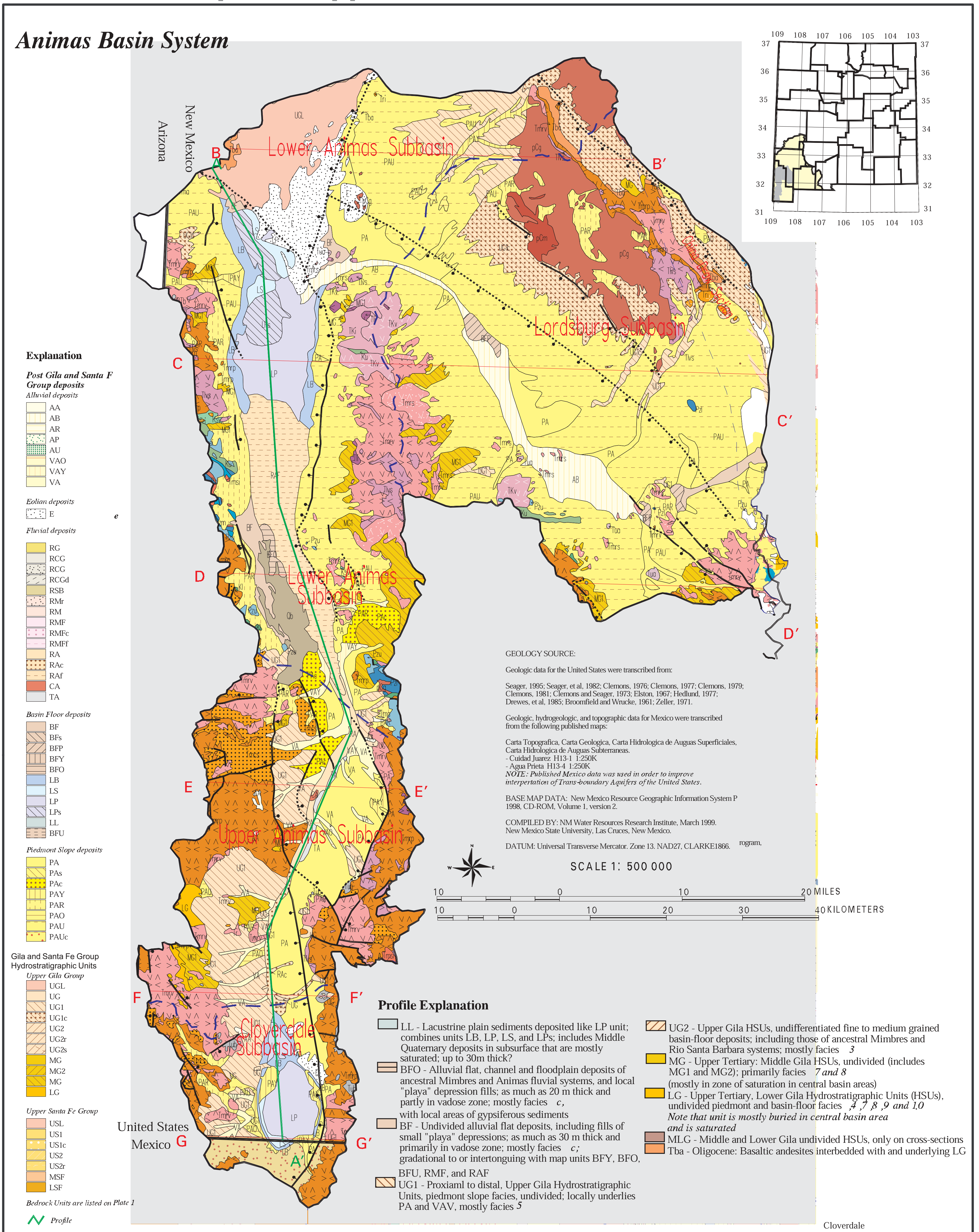
The majority of groundwater use in the Lordsburg Sub-basin is for cultivated agriculture, power production, and municipal supply. During the past century, these uses have been supported by groundwater pumped from within 500 feet of ground surface. Some wells in the Lordsburg Sub-basin have exhibited a decline in the water table of more than 50 feet since 1950 (Appendix D4). Irrigation and municipal withdrawals of more than 29,000 ac-ft/yr have contributed to this water table drawdown (Wilson et al., 2003).

- *Upper and Lower Animas Sub-basins:* Groundwater in these sub-basins exists primarily within two units: Quaternary alluvium and the Tertiary Gila Group, which together are often referred to as basin fill. The basin fill ranges in depth from 500 to approximately 2,000 feet (Hawley et al., 2000) (Figure 5-14). Depth to water in the central part of the valley is typically 50 to 100 feet deep, but can be as great as 500 feet on piedmont slopes near the sides of the valley (Hawley et al., 2000). Some isolated instances of perched water occur in gravel beds at shallower depths in the inner valley of Animas Creek (Hawley et al., 2000). The deepest well in the Animas Valley is about 1,000 feet, but most are less than 500 feet deep (Hawley et al., 2000).

  The most productive zone of the basin fill material is generally found from ground surface to depths of 1,000 feet, within the Quaternary alluvium and the Upper Gila Group (Hawley et al., 2000). Calculated transmissivities range between 22,000 gallons per day per foot (gpd/ft) (2,941 ft^2/d) and 246,000 gpd/ft (32,887 ft^2/d) and average 50,000 gpd/ft (6,685 ft^2/d) (Reeder, 1957). Specific capacities range from 5 to 70 gallons per minute per foot (gpm/ft), with an average of 29 gpm/ft (Reeder, 1957).

- *Cloverdale Sub-basin:* The Cloverdale Sub-basin is small relative to the other three, but is important because it exists on both sides of the U.S.-Mexico border and because there is a groundwater divide beneath it. Water in the southern portion of the Cloverdale flows toward Mexico, and water in the northern portion flows into the U.S.

The Animas Basin also contains geothermal waters, most notably in the Lightning Dock Known Geothermal Resource Area, which is located approximately halfway between Animas and Lordsburg, immediately west of the Pyramid Mountains. The heat is derived from fractures in



GEOLOGY SOURCE:

Geologic data for the United States were transcribed from:

Seager, 1995; Seager, et al, 1982; Clemons, 1976; Clemons, 1977; Clemons, 1979; Clemons, 1981; Clemons and Seager, 1973; Elston, 1967; Hedlund, 1977; Drewes, et al, 1985; Broomfield and Wrucke, 1961; Zeller, 1971.

Geologic, hydrogeologic, and topographic data for Mexico were transcribed from the following published maps:

Carta Topografica, Carta Geologica, Carta Hidrologica de Auguas Superficiales, Carta Hidrologica de Auguas Subterraneas.
- Cuidad Juarez H13-1 1:250K
- Agua Prieta H13-4 1:250K

NOTE: Published Mexico data was used in order to improve interpertation of Trans-boundary Aquifers of the United States.

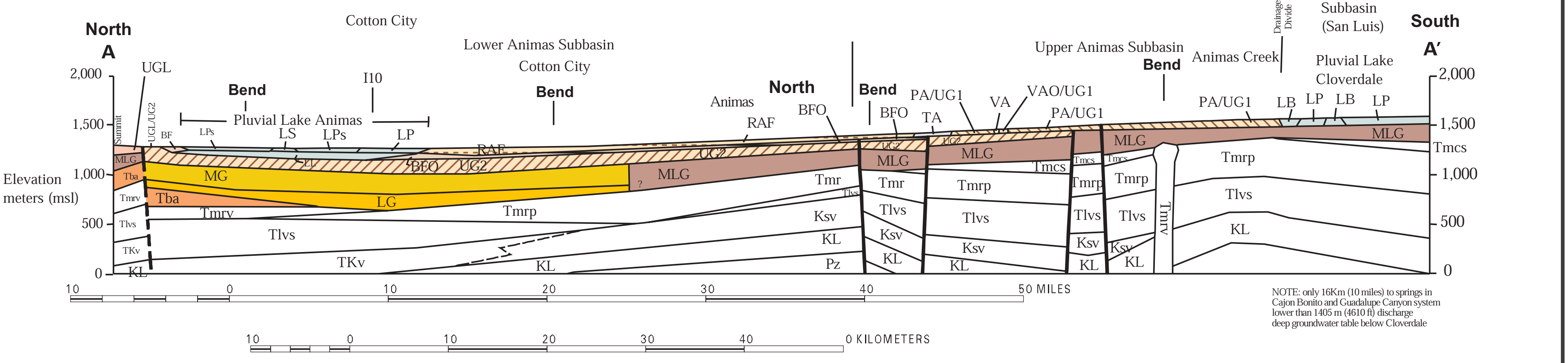
BASE MAP DATA: New Mexico Resource Geographic Information System P 1998, CD-ROM, Volume 1, version 2.

COMPILED BY: NM Water Resources Research Institute, March 1999. New Mexico State University, Las Cruces, New Mexico.

DATUM: Universal Transverse Mercator. Zone 13. NAD27, CLARKE1866. rogram,

Profile Explanation

- LL - Lacustrine plain sediments deposited like LP unit; combines units LB, LP, LS, and LPs; includes Middle Quaternary deposits in subsurface that are mostly saturated; up to 30m thick?
- BFO - Alluvial flat, channel and floodplain deposits of ancestral Mimbres and Animas fluvial systems, and local "playa" depression fills; as much as 20 m thick and partly in vadose zone; mostly facies *c,* with local areas of gypsiferous sediments
- BF - Undivided alluvial flat deposits, including fills of small "playa" depressions; as much as 30 m thick and primarily in vadose zone; mostly facies *c;* gradational to or intertonguing with map units BFY, BFO, BFU, RMF, and RAF
- UG1 - Proxiaml to distal, Upper Gila Hydrostratigraphic Units, piedmont slope facies, undivided; locally underlies PA and VAV, mostly facies *5*
- UG2 - Upper Gila HSUs, undifferentiated fine to medium grained basin-floor deposits; including those of ancestral Mimbres and Rio Santa Barbara systems; mostly facies *3*
- MG - Upper Tertiary: Middle Gila HSUs, undivided (includes MG1 and MG2); primarily facies *7 and 8* (mostly in zone of saturation in central basin areas)
- LG - Upper Tertiary, Lower Gila Hydrostratigraphic Units (HSUs), undivided piedmont and basin-floor facies *,4 ,7 ,8 ,9 and 1.0* *Note that unit is mostly buried in central basin area and is saturated*
- MLG - Middle and Lower Gila undivided HSUs, only on cross-sections
- Tba - Oligocene: Basaltic andesites interbedded with and underlying LG



Note: Non-colored units are listed on Figure 7-2a and Plate 1 of source web site.
Source: New Mexico State University web site: wrri.nmsu.edu/publish/otherrpt/swnm/downl.html, Figure 7-2a and 7-2b.

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN
Animas Basin Geologic Cross Section

Figure 5-14

Tertiary intrusive volcanics. The geothermal reservoir is thought to be relatively small and of limited economic potential (Elston et al., 1983). The geothermal waters are used primarily by local farmers for greenhouse warming, crop drying, and food processing (Elston et al., 1983).

The total amount of usable groundwater within the productive portion (uppermost 1,000 feet) of the entire Animas Basin system was roughly estimated to be 9.5 million acre-feet (Hawley et al., 2000). This estimate, which was based on an area of 180,000 acres, an average saturated thickness of 330 feet, and a specific yield of 0.1 (Hawley et al., 2000), is considered to be a liberal one. Additionally, economic and legal constraints were not considered in the development of the estimate, and consequently, it does not portray water that is readily available to meet the future needs of the region.

5.3.2.3 Playas-San Basilio Basin

The Playas-San Basilio Basin is present in eastern Hidalgo County (Figure 5-12) and covers an area of 926 square miles in the Southwest Region (Table 5-10). The primary land use is rangeland, with cultivated agriculture accounting for the second largest land use. Irrigated agriculture in the basin, estimated at 375 acres (Wilson et al., 2003), decreased during the 1990s, as many irrigation water rights were purchased for mineral processing at the Playas Smelter operated by Phelps-Dodge Mining Company. The only urban centers in the basin are Playas and the border town of Antelope Wells-El Berrendo.

The Playas-San Basilio Basin is bounded on the west by the Animas Mountains and on the east by a series of north-south trending mountains including the Little Hatchet Mountains, Big Hatchet Mountains, and Alamo Hueco Mountains. The northern basin boundary is at the Brockman-Pyramid Gap (10 miles north of Playas), and the southern boundary within the planning region is the U.S.-Mexico border.

Recharge occurs from precipitation over the entire basin, as well as from runoff along mountain fronts. Estimates of total recharge from precipitation range from approximately 1 percent of precipitation over the valley and contributing mountain fronts, which is equivalent to 5,670 ac-ft/yr (Hawley et al., 2000), to about 8,000 ac-ft/yr based on the analysis discussed in Section 5.3.4.

The Playas-San Basilio Basin is a closed and drained basin that contains two sub-basins: the Upper Playas and the Lower Playas. No groundwater flows into the basin; the only recharge to the aquifer comes from precipitation. Existing groundwater moves radially inward toward the center of the basin and collects beneath the Playas Lake depression. Consequently, groundwater movement north of Playas Lake is from the north to the south, while south of the lake, groundwater movement is from the south to the north. Previous investigators have identified several locations where groundwater discharge may occur, including Hatchet Gap, Animas-Pyramid Gap, and Brockman-Pyramid Gap; however, discharge from these areas is largely inferred and the amounts have not been quantified. An estimate of the total underflow out of the basin is 7 ac-ft/yr (Hawley et al., 2000).

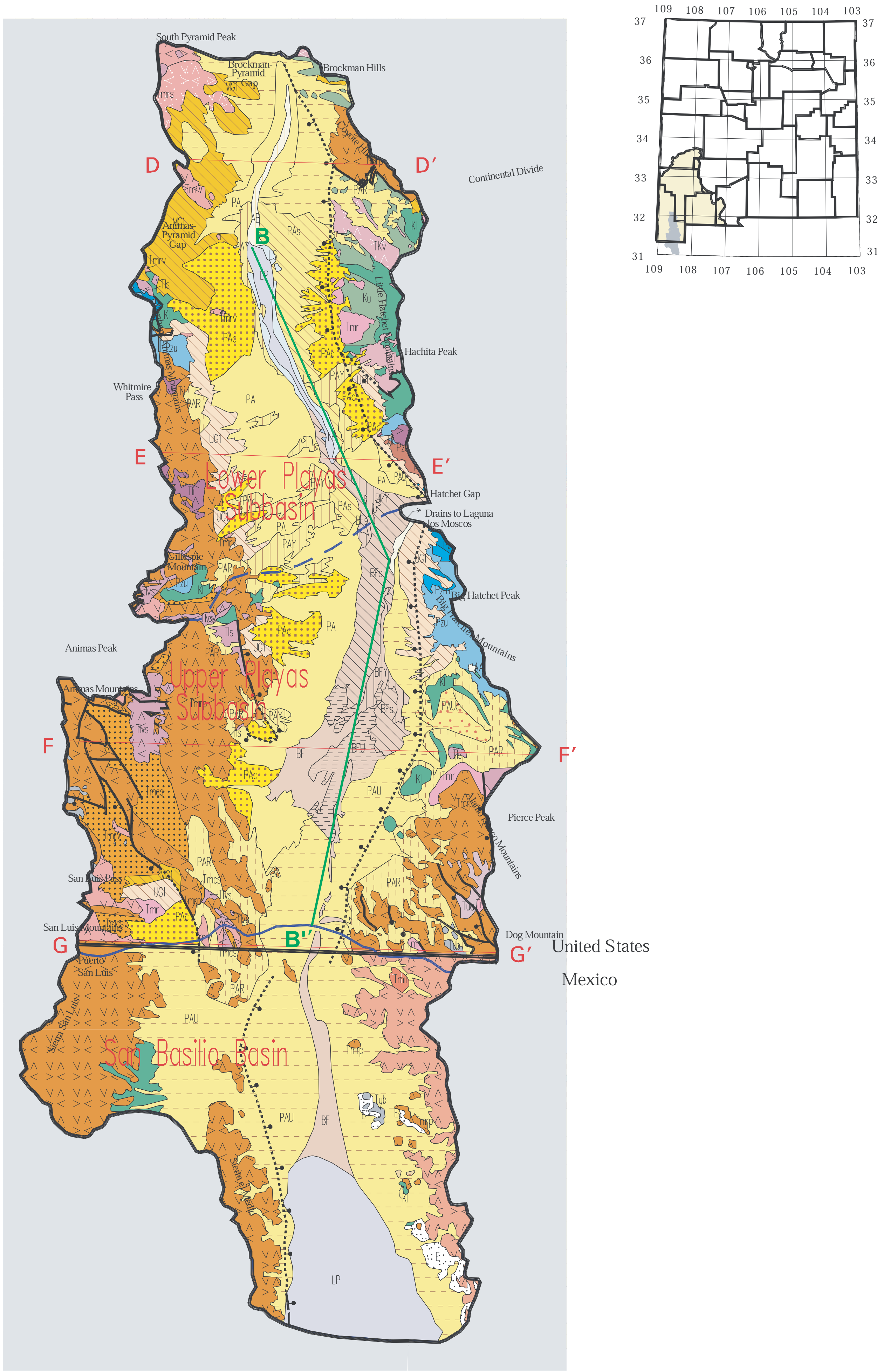
Similar to the other basins in the Basin and Range province, groundwater in the Playas-San Basilio Basin exists almost entirely within two geologic units: Quaternary alluvium and Tertiary Gila Group, referred to collectively as basin fill. The basin fill in the Playas-San Basilio Basin has a maximum thickness between 1,650 and 2,000 feet (Figure 5-15). The maximum saturated thickness of the basin fill is approximately 1,000 feet, but the productive zone is likely limited to the upper approximately 500 feet.

Calculated transmissivities range from 20,000 gpd/ft (2,674 ft^2/d) to 80,000 gpd/ft (10,695 ft^2/d), with an average value of 50,000 gpd/ft (6,685 ft^2/d). Published records of irrigation well performance between 1948 and 1955 indicate a specific capacity of 6 to 14 gpm/ft (Hawley et al., 2000). A rough approximation of the volume of water remaining in storage is 4,860,000 acre-feet (Hawley et al., 2000). This approximation was made by assuming an area of 234 square miles, an average saturated thickness of 330 feet, and a specific yield of 0.1, and is considered to be a liberal estimate. Additionally, economic and legal constraints were not considered in the development of the estimate, and consequently, it does not portray water that is readily available to meet the future needs of the region.

5.3.2.4 Hachita-Moscos Basin

The Hachita-Moscos Basin is located in the southern part of the planning region, covering portions of southern Grant, southwestern Luna, and southeastern Hidalgo Counties. Approximately one-half of the basin is within Mexico. The basin is comprised of three

Playas and San Basilio Basin System



GEOLOGY SOURCE:

Geologic data for the United States were transcribed from:

Seager, 1995; Seager, et al, 1982; Clemons, 1976; Clemons, 1977; Clemons, 1979; Clemons, 1981; Clemons and Seager, 1973; Elston, 1967; Hedlund, 1977; Drewes, et al, 1985; Broomfield and Wrucke, 1961; Zeller, 1971.

Geologic, hydrogeologic, and topographic data for Mexico were transcribed from the following published maps:

Carta Topografica, Carta Geologica, Carta Hidrologica de Auguas Superficiales, Carta Hidrologica de Auguas Subterraneas.
- Cuidad Juarez H13-1 1:250K
- Agua Prieta H13-4 1:250K

NOTE: Published Mexico data was used in order to improve interpertation of Trans-boundary Aquifers of the United States.

BASE MAP DATA: New Mexico Resource Geographic Information System Program 1998, CD-ROM, Volume 1, version 2.

COMPILED BY: NM Water Resources Research Institute, March 1999.
New Mexico State University, Las Cruces, New Mexico.

DATUM: Universal Transverse Mercator. Zone 13. NAD27, CLARKE1866.

Explanation

Post Gila and Santa Fe Group deposits

Alluvial deposits

▨ AA
▨ AB
▨ AR
▨ AP
▨ AU
▨ VAO
▨ VAY
▨ VA

Eolian deposits

▨ E

Fluvial deposits

▨ RG
▨ RCG
▨ RCG
▨ RCGd
▨ RSB
▨ RMr
▨ RM
▨ RMF
▨ RMFc
▨ RMFf
▨ RA
▨ RAc
▨ RAf
▨ CA
▨ TA

Basin Floor deposits

▨ BF
▨ BFs
▨ BFP
▨ BFY
▨ BFO
▨ LB
▨ LS
▨ LP
▨ LPs
▨ LL
▨ BFU

Piedmont Slope deposits

▨ PA
▨ PAs
▨ PAc
▨ PAY
▨ PAR
▨ PAO
▨ PAU
▨ PAUc

Gila and Santa Fe Group Hydrostratigraphic Units

Upper Gila Group

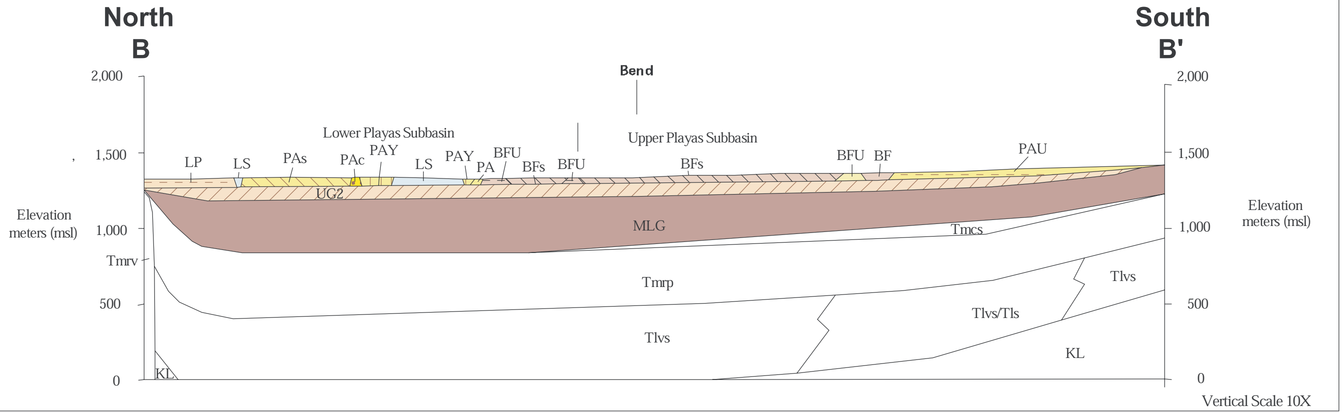
▨ UGL
▨ UG
▨ UG1
▨ UG1c
▨ UG2
▨ UG2r
▨ UG2s
▨ MG
▨ MG2
▨ MG
▨ LG

Upper Santa Fe Group

▨ USL
▨ US1
▨ US1c
▨ US2
▨ US2r
▨ MSF
▨ LSF

Bedrock Units are listed on Plate 1

Profile



▨ UG2 - Upper Gila HSUs, undifferentiated fine to medium grained basin-floor deposits; including those of ancestral Mimbres and Rio Santa Barbara systems; mostly facies !fnt93714;3
▨ MLG - Middle and Lower Gila undivided HSUs, only on cross-sections

SCALE 1. 500 000

10 0 10 20 30 40 50 MILES

10 0 10 20 30 40 50 KILOMETERS

Source: New Mexico State University web site: wrri.nmsu.edu/publish/otherrpt/swnm/downl.html, Figure 6-2

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN
Playas-San Basilio Basin Geologic Cross Section

Figure 5-15

interconnected hydrogeologic sub-basins (the Upper Hachita, Wamel-Moscos, and Lower Hachita sub-basins), which cover an area of approximately 800 square miles within the planning region. All of the Hachita-Moscos Basin is in the Mexican Highland Section of the Basin and Range physiographic province (Hawley et al., 2000). No perennial streams are present in the basin.

Land use in the basin is primarily for rangeland, and the only urban area is the town of Hachita. No crops are irrigated; stock and domestic wells are the only water uses in the basin.

Groundwater in the Hachita-Moscos Basin occurs within the basin fill alluvium and the Gila Conglomerate. The basin fill is up to 100 feet thick, and the Gila Conglomerate ranges from approximately 200 feet to as much as 400 feet in the southern part of the basin. In general, the flow direction is from the northwest toward the southeast, with groundwater moving across the border from the U.S. toward Mexico. In some locations near the border, the potentiometric surface approaches the land surface, and seeps and springs are found on both sides of the border. Hawley et al. (2000) estimate a groundwater flow of approximately 2,000 ac-ft/yr across the border from the U.S. into Mexico. Very little development of groundwater has occurred within the Hachita-Moscos Basin, and current conditions are believed to be unchanged from historical conditions.

It is estimated that the saturated thickness reaches as much as 3,000 feet in places; however the productive saturated thickness is likely only about 300 feet (Hawley et al., 2000). Using an area of 2,700 square miles and a storativity of 0.1, Hawley et al. (2000) estimated that there are 51,000,000 acre-feet of water in storage in the basin. Recharge from precipitation to the basin aquifers is estimated to be 4,800 ac-ft/yr (Hawley et al., 2000).

5.3.2.5 Mimbres Basin

Of the total 4,279 square miles in the Mimbres Basin, approximately 3,651 fall in the planning region (Table 5-10), covering nearly all of Luna County and southeastern Grant County (Figure 5-12). Most of the basin lies within the Basin and Range province, but the northern portion extends into the Datil-Mogollon Section of the Transition Zone Province. The largest land use category is rangeland, the second is forest land (which dominates in the northern portion of the basin), and the third is irrigated agriculture.

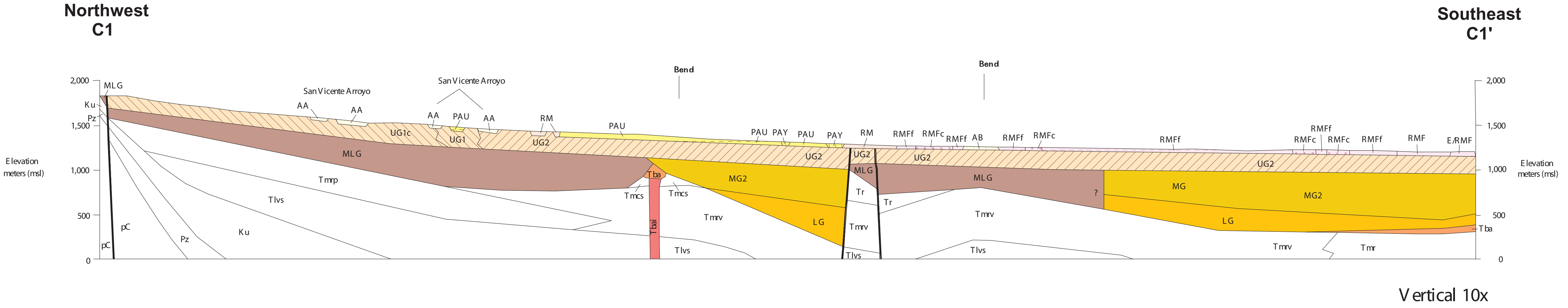
The Mimbres Basin is bounded on the north and west by the Continental Divide, on the south by the U.S.-Mexico border, and on the east by the Lower Rio Grande Basin in Doña Ana County. The only perennial stream reach in the basin is the Mimbres River, which flows south from the Mimbres Mountains and becomes ephemeral by the time it reaches Deming.

The overall province-scale geology of the Mimbres Basin is relatively complex; however, the geology that affects groundwater occurrence is limited mostly to near-surface basin fill stratigraphy. Intrabasin-scale structures divide the Mimbres Basin into seven different sub-basins that contain the vast majority of groundwater (Hawley et al., 2000):

- Upper Mimbres Sub-basin
- San Vicente Sub-basin
- Dwyer Sub-basin
- Florida Sub-basin
- Deming Sub-basin
- Hermanas Sub-basin
- Columbus Sub-basin

The subsurface geology of the Mimbres Basin is depicted in cross section in Figures 5-16 and 5-17. Within the seven identified sub-basins, groundwater occurs primarily within basin fill materials comprised of Quaternary alluvium and the Tertiary Gila Group. Basin fill is more than 1,000 feet thick in some areas, but the productive zone rarely exceeds 660 feet thick (Hawley et al., 2000). Basaltic volcanics interbedded with basin fill can be locally important aquifers as well, mostly in the Upper Mimbres, Columbus, and San Vicente sub-basins.

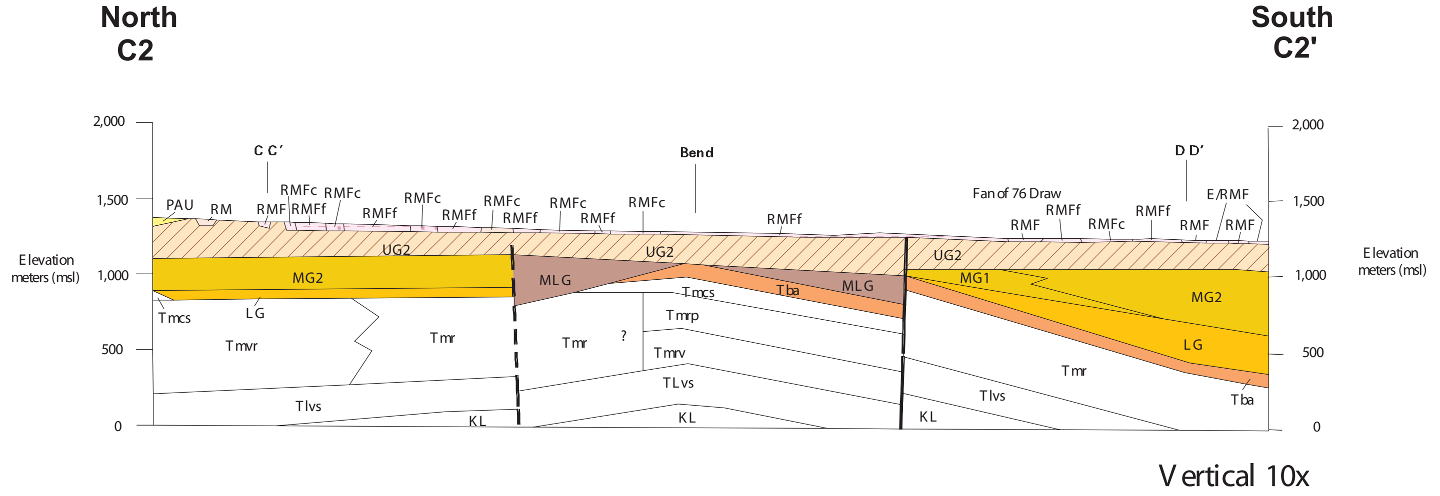
The Mimbres Basin system contains unconfined, semiconfined, and confined aquifers, depending on location. Inter-sub-basin hydrologic interactions are not well understood, but the general groundwater flow direction is from the northern highlands toward the U.S.-Mexico border. Pre-development discharge across the border is estimated to have been 6,500 ac-ft/yr



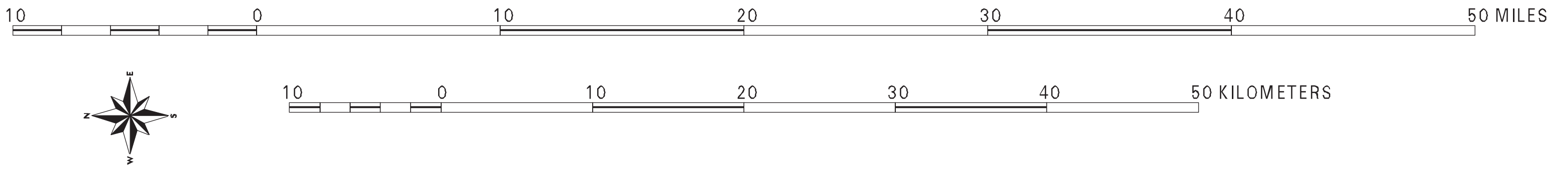
Profile Explanation

- ▢ AA - Alluvial deposits in axial arroyo channel systems; facies *b* (like *5a*)
- ▢ AB - Unchanneled alluvial deposits of axial basin floodways; facies *b and c* (like *3*)
- 🟨 PAU - Older and younger piedmont-slope deposits and correlative Upper Gila (UG1) and Upper Santa Fe piedmont facies (*5 to 8*), undivided
- ▥ PAY - Younger piedmont-slope deposits of late Quaternary age; mostly facies *5*
- ▢ RM - Channel, floodplain and low terrace deposits of the Lower Mimbres River; mostly facies *a* and *b*
- ▢ RMF, E/RMF - Fluvial-fan deposits of the ancestral and modern Mimbres River, undivided; up to 20 m thick and primarily in vadose zone; facies *a*
- ▒ RMFc - Fluvial-fan deposits of the Mimbres River, course-grained facies; mostly facies *a2*
- ▒ RMFf - Fluvial-fan deposits of the Mimbres River, fine-grained facies; *mostly lithofacies a3 and c*; includes extensive gypsiferous and alkali impregnated sediments in the Florida subbasin
- ▨ UG1, UG1c - Proxiaml to distal, Upper Gila Hydrostratigraphic Units, piedmont slope facies, undivided; mostly facies *5*
- ▨ UG2 - Upper Gila HSUs, undifferentiated fine to medium grained basin-floor deposits; including those of ancestral Mimbres and Rio Santa Barbara systems; mostly facies *3*
- 🟨 MG - Upper Tertiary: Middle Gila HSUs, undivided (includes MG1 and MG2); primarily facies *7 and 8* (mostly in zone of saturation in central basin areas)
- 🟧 LG - Upper Tertiary, Lower Gila Hydrostratigraphic Units (HSUs), undivided piedmont and basin-floor facies *4, 7, 8, 9, and 10. Note that unit is mostly buried in central basin area and is saturated*
- 🟫 MLG - Middle and Lower Gila undivided HSUs, only on cross-sections
- 🟥 Tbai - Middle-Upper Tertiary: Basaltic Andesite-intrusive masses
- 🟧 Tba - Oligocene: Basaltic andesites interbedded with and underlying LG

Note that non-colored units are listed on Figure 4-2a and Plate 1.



SCALE 1: 500 000



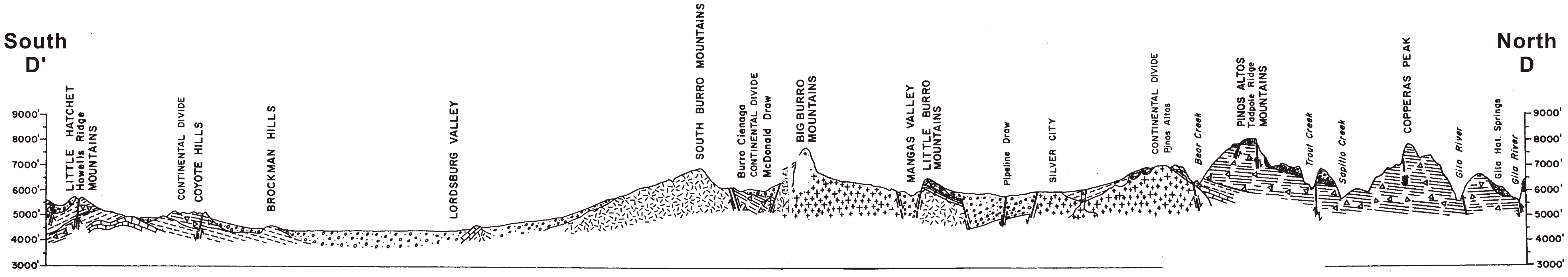
T:\VDR0-VDR-PROJECTS\00-WATER-RESOURCES\WR03_004\ADOBE ACROBAT\WR03_004_05W.PDF

Source: Modified from New Mexico State University web site: wrri.nmsu.edu/publish/otherrpt/swnm/downl.html, Figure 4-2b

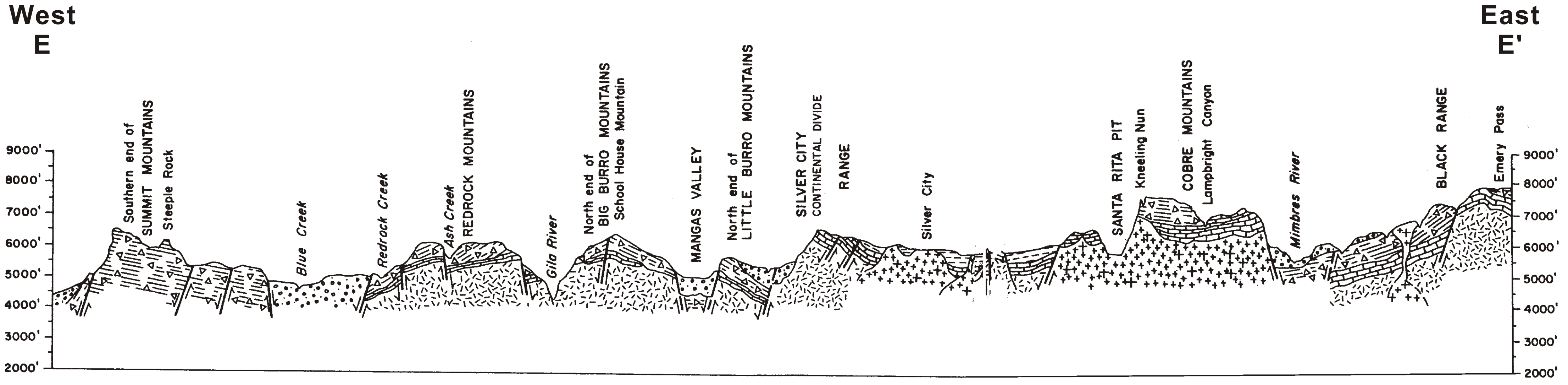
SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Mimbres Basin Geologic Cross Sections

Figure 5-16



Note: D-D' spans the Lordsburg Basin, some undeclared areas, and the Gila-San Francisco Basin.



Note: E-E' spans the Gila-San Francisco and Mimbres Basins.

EXPLANATION

- ▨ Alluvium, valley and bolson fill, and conglomerate
- ▨ Limestone and associated marine sediments
- ▨ Shale and locally interbedded limestone, sandstone, and conglomerate
- ▨ Pyroclastic rocks and associated sediments and flows
- ▨ Andesitic and basaltic flows
- ▨ Intrusive rocks
- ▨ Rocks of Precambrian age, mostly of granite and granite gneiss
- Contact between geologic formations, dashed where approximate
- Fault—arrows show relative direction of movement

0 5 10 MILES

Vertical scale greatly exaggerated

Source: Trauger, 1972

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Grant and Hidalgo County Cross Sections

Figure 5-17

VDR\0-VDR-PROJECTS\00-WATER_RES\WR03_004\WR03_0004_10W.CDR from the U.S. into Mexico (Hanson et al., 1994). However, groundwater development has caused a local reversal in the flow direction across the border, and it is currently from the south to the north in the vicinity of Columbus (Hawley et al., 2000). Recharge from precipitation is estimated to be no more than 2 percent of the precipitation that falls across the area, an amount equal to approximately 63,145 ac-ft/yr (Hawley et al., 2000). Estimates of recharge described in Section 5.3.4 suggest that recharge may be about 25,000 ac-ft/yr.

Specific capacity data compiled by Hanson et al. (1994) for 278 wells completed in the basin fill indicate that specific capacity decreases with depth. In general, specific capacities are between 13 and 17 gpm/ft in wells completed within 330 feet of ground surface, between 8 and 12 gpm/ft in wells completed between 330 and 660 feet bgs, and between 7 and 9 gpm/ft in wells completed below 660 feet bgs. Transmissivities ranged from 75 to 375,000 gpd/ft (10 to 50,100 ft^2/d), but the lower end of this range may reflect poor test conditions rather than actual aquifer characteristics (Hawley et al., 2000). A liberal estimate of available water of good quality remaining in the entire Mimbres Basin is 30,060,000 acre-feet (Hawley et al., 2000). However, because economic and legal constraints were not considered in the development of the estimate, it does not portray water that is readily available to meet the future needs of the region.

5.3.2.6 Nutt-Hockett Basin

The Nutt-Hockett Basin is located in the extreme northeast corner of Luna County. The basin covers an area of 139 square miles within the planning region. There are no municipalities within the basin and agriculture is the primary land use category, with 6,321 acres irrigated in 1999 (Wilson et al., 2003). Surface water supplies in the basin are essentially zero.

Groundwater in the Nutt-Hockett Basin occurs in several aquifers, primarily the Uvas Basaltic Andesite, the Bell Top Formation, and the Santa Fe Group. The Santa Fe Group is the major aquifer, and most wells in the basin are completed in it. Groundwater flow is from the mountains toward the northeast and toward the Rio Grande (Clemons, 1979).

5.3.2.7 Gila Basin

The Gila Basin is present in the southeastern portion of Catron County and the northwestern portion of Grant County (Figure 5-12), covering an area of approximately 3,352 square miles (Table 5-10) within the Southwest Region. The primary land uses in the basin are forest land and rangeland. An estimated 3,681 acres were cultivated for irrigation in 1999 (Wilson et al., 2003). The basin is bounded on the south and east by the Continental Divide and on the north by the Mogollon Mountains, and it extends westward into Arizona. The Gila Basin is almost entirely contained within the Datil-Mogollon Section of the Transition Zone Province; a small portion in the southernmost part of the basin extends into the Basin and Range province. The Gila Basin contains four sub-basins: the Upper Gila, Cliff, Redrock, and Virden-Duncan Sub-basins.

The geology of the Gila Basin is typified by localized uplifts separated by intermontane basins that have subsequently filled with alluvial, fluvial, and lacustrine deposits. Downcutting along the Gila River, followed by subsequent sedimentation, has formed important aquifers in the floodplains of the river. The primary hydrologic units in the basin are Quaternary and upper Tertiary alluvial deposits, with some Tertiary volcanics and Cretaceous to Upper Cambrian marine sedimentary rocks.

The direction of groundwater movement is similar to drainage patterns in the land surface. The sub-basins are interconnected, and water moves from areas of higher elevations to areas of lower elevations, in general from northeast to southwest (Hawley et al., 2000).

Quaternary and Upper Tertiary alluvial deposits include streambed deposits, basin fill, and the Gila Group:

- Streambed deposits are found primarily beneath streambeds and within floodplains along the Gila River and major tributaries. In general, the alluvium along the Gila River is less than 40 feet thick, although core drilling encountered alluvium more than 100 feet thick at one location. Along the major tributaries of the Gila, alluvium is generally less than 20 feet thick. Wells in the alluvium of the Gila River yield as much as 2,500 gpm (Trauger, 1972), and wells tapping the alluvium near San Lorenzo, just south of the basin, yield approximately 800 gpm. Along the Gila River, water levels in the alluvium are constantly recharged by the river, so the groundwater supply is reliable. Groundwater extraction does, however, impact surface water flow in the river. In the tributaries, the alluvial aquifers are too thin and narrow to support significant continual pumping; however, they can supply significant quantities of water on a seasonal basis.

- Quaternary and Upper Tertiary basin fill alluvium is found in the southwesternmost portion of the Gila-San Francisco Basin, near Redrock, but does not constitute as important a source of groundwater as it does in the Basin and Range groundwater basins to the south. Transmissivities in basin fill have been calculated to range from 13,200 gpd/ft (Myers, 1992) to 359,000 gpd/ft (Basabilvazo, 1997), and storage coefficient estimates range from 0.04 to 0.53 (Trauger, 1972).

- The Gila Group exists beneath alluvial fill throughout most of the Gila Basin. The upper member is on the order of 1,000 feet thick, and the lower member is approximately 1,500 feet thick (Trauger, 1972). The aquifer in the Gila Group is typically unconfined, and the water table occurs between 230 and 450 feet bgs (Basabilvazo, 1997). Wells completed in the Gila Group can yield anywhere from 10 gpm to 1,000 gpm (Johnson et al., 2002). Transmissivities in the upper Gila Group have been calculated to range from 13,200 gpd/ft (Myers, 1992) to 22,240 gpd/ft (Trauger, 1972), and storage coefficients range from 0.02 to 0.15 (Trauger, 1972).

Tertiary volcanics generally underlie Quaternary alluvium (where alluvium is present) and occur throughout the Gila Basin. Trauger (1972) identified at least 15 individual Tertiary volcanic units. Correlation of the volcanic rocks in the basin has been the subject of debate for years. This report uses the currently accepted convention of considering all Tertiary volcanics in the Gila Basin to be part of the Datil Group. The combined thickness of the Datil Group ranges from a few hundred feet in the southern portion of the transition zone near Cliff to as much as 10,000 feet near Mogollon Mountain in the north (Trauger, 1972). The Datil Group yields generally small amounts of water (less than 10 gpm) locally, although localized yields up to 400 gpm have been encountered in poorly consolidated near-surface water contained in tuffs (Trauger, 1972).

Marine sedimentary rocks ranging in age from Cretaceous to Upper Cambrian exist throughout the San Francisco Basin. In some locations, sedimentary rocks are found at ground surface, and in other areas they are overlain by Tertiary extrusive volcanics. Both carbonate (limestone) and clastic (shale, siltstone, conglomerate) sedimentary rocks are found in alternating layers throughout the basin. The marine sedimentary rocks are thinnest in the south and become progressively thicker to the north. In the Silver City area, the total thickness of the marine sediments ranges from 3,200 to 4,400 feet, with the carbonate rocks accounting for approximately 55 percent of the total. In the Little Hatchet Mountain area, the total thickness of marine sedimentary rock is as much as 26,500 feet, with carbonate rocks comprising approximately 33 percent of the total thickness (Lasky, 1947 [as cited in Trauger, 1972]).

Within the Gila Basin, carbonate rocks are more likely to yield water than clastic rocks (Trauger, 1972). Yields to wells vary considerably depending upon location and depth. Deep wells are more likely to intersect fractures and joints, which produce higher yields. One well completed 1,000 feet bgs yields 185 feet per minute, while another deep well completed 2,115 feet bgs yields 235 gpm. Conversely, shallow wells (completed less than 100 feet below the water table) will generally provide less than 5 gpm (Trauger, 1972). Marine sedimentary formations known to yield reliable water include the Colorado Formation (up to 15 gpm), the Lake Valley Limestone (up to 150 gpm), the Montoya Dolomite (up to 50 gpm), and the El Paso Limestone (up to 200 gpm). Numerous other deposits yield up to 10 gpm locally.

The Virden-Duncan Sub-basin is located in the southwest corner of the Gila Basin (northernmost portion of Hidalgo County) and covers an area of approximately 100 square miles within New Mexico. The dominant land use category in the sub-basin is irrigated agriculture. Stone and O'Brien (1990) indicate that the main aquifer in the Virden-Duncan Sub-basin is the floodplain deposits underlying the Gila River Valley. The aquifer thickness is several feet along the valley margins, approximately 75 feet in the center of the floodplain, and more than 100 feet in some of the deepest areas. The Gila Group underlies the floodplain deposits, but is generally not used for water supply due to the ample water in the overlying alluvium. Near the Hidalgo-Grant County line, the underflow discharge through the valley fill aquifer is about 160 ac-ft/yr (Hawley et al., 2000).

Trauger (1972) investigated portions of the Gila River Valley further upstream (northeast) in the Redrock Sub-basin and indicated that the conditions there would likely be similar to those found along the portion within the Virden-Duncan Sub-basin. Trauger (1972) indicated that water levels in wells completed in the Gila River Valley show little seasonal or annual fluctuation. The Gila River is perennial and the valley fill is highly permeable, and groundwater removed by pumping is rapidly replaced by infiltration of excess irrigation water and seepage from the stream.

5.3.2.8 San Francisco Basin

The San Francisco Basin is present in the southwestern portion of Catron County and a small section of northwest Grant County (Figure 5-12), covering an area of approximately 1,864 square miles in the Southwest Region (Table 5-10). An estimated 1,242 acres of the basin were irrigated in 1999 (Wilson et al., 2003). The basin is bounded on the south and east by the Continental Divide and Mogollon Mountains, and on the north by the boundary of the Colorado Plateau. The basin extends westward into Arizona. The San Francisco Basin is almost entirely contained within the Datil-Mogollon Section of the Transition Zone Province, but contains some of the sedimentary rock units typically found to the north on the Colorado Plateau.

The geology of the San Francisco Basin is very similar to that of the Gila Basin, typified by localized uplifts separated by intermontane basins that have subsequently filled with alluvial, fluvial, and lacustrine deposits. Downcutting along the San Francisco River, followed by subsequent sedimentation, has formed important aquifers in the floodplains of the river. The primary hydrologic units in the basin are Quaternary alluvial deposits, Tertiary volcanics, both intrusive and extrusive, and Cretaceous marine sediments.

Streambed deposits are found primarily beneath streambeds and within floodplains along the San Francisco River and major tributaries. Alluvial deposits along the San Francisco River are important local aquifers. The San Francisco River, which supplies water to the alluvial aquifer beneath it, is generally perennial throughout its reach in New Mexico; however, it sometimes runs dry near Glenwood, decreasing the reliability of the shallow groundwater supply in this vicinity.

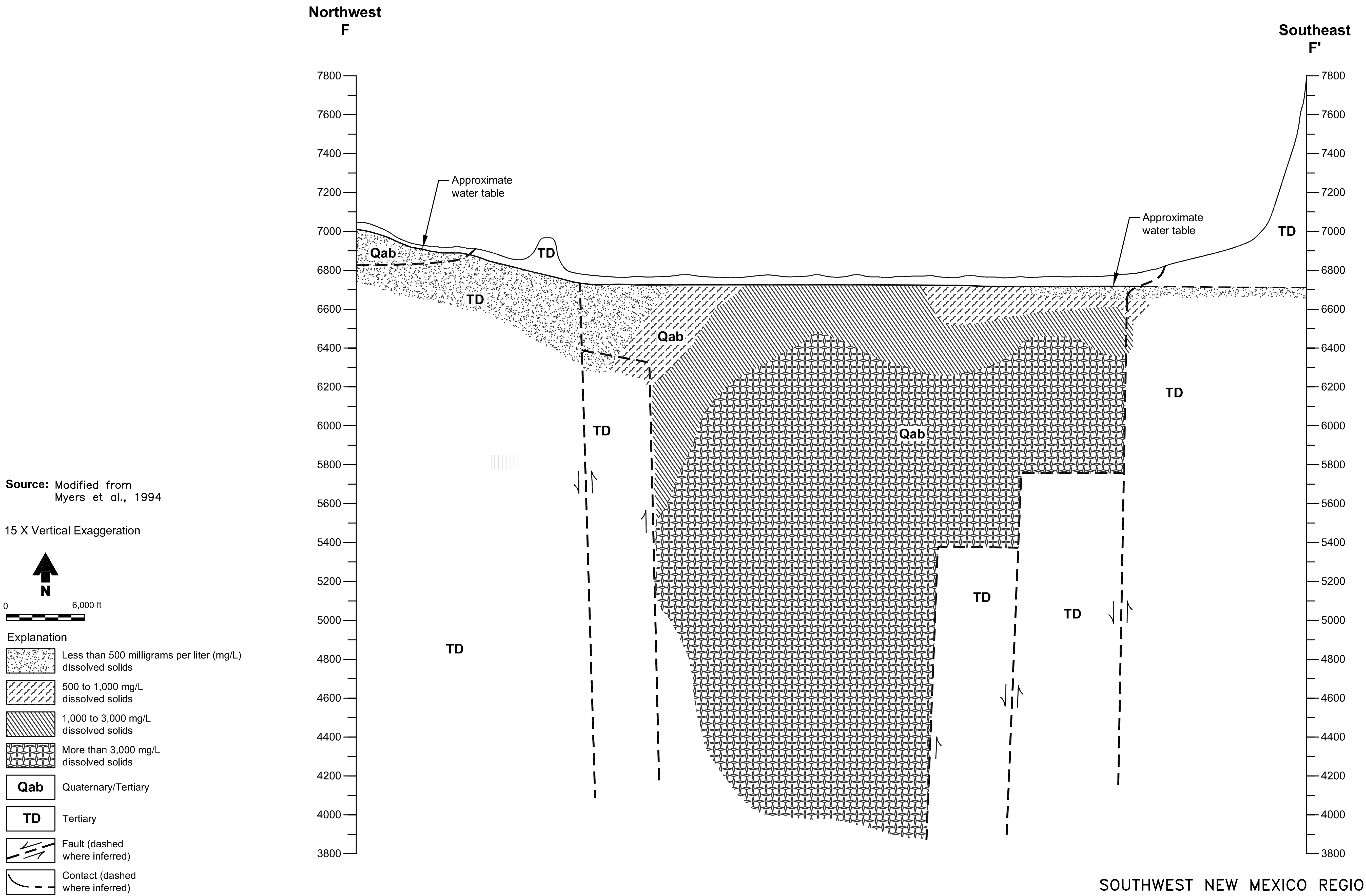
The Gila Group aquifer within the San Francisco Basin is typically unconfined, and the water table occurs between 230 and 450 feet bgs (Basabilvazo, 1997). Wells completed in the Gila Group can yield anywhere from 10 gpm to 1,000 gpm (Johnson et al., 2002). Transmissivities in the upper Gila Group have been calculated to range from 13,200 gpd/ft (Myers, 1992) to 22,240 gpd/ft (Trauger, 1972), and storage coefficients range from 0.02 to 0.15 (Trauger, 1972).

Tertiary volcanics occur throughout the San Francisco Basin. This report uses the currently accepted convention of considering all Tertiary volcanics in the San Francisco Basin to be part of the Datil Group. The combined thickness of the Datil Group ranges from a few hundred feet in the southern portion of the transition zone near Cliff (Gila Basin) to as much as 10,000 feet near Mogollon Mountain in the north (Trauger, 1972). The Datil Group yields generally small amounts of water (less than 10 gpm) locally, although localized yields up to 400 gpm have been encountered in poorly consolidated near-surface water contained in tuffs (Trauger, 1972).

Several sedimentary units generally associated with the Colorado Plateau Province can be found in the northernmost portion of the San Francisco Basin. These include the Mesaverde Group, Mancos Shale, Dakota Sandstone, Zuni Sandstone, and the Chinle Formation. Although these formations comprise the major aquifers to the north in the Little Colorado Basin, none of them are considered important aquifers within the San Francisco Basin because they are areally limited. The volume of groundwater resources in the San Francisco Basin is significant, but is so widely distributed that recovery in large quantities would be economically impractical. However, nearly everywhere in the basin, adequate groundwater exists for domestic and stock purposes.

5.3.2.9 San Agustin Basin

The most extensive groundwater resource in the northern part of the Southwest Region (Catron County) is the basin-fill aquifer of the San Agustin Basin (Myers et al., 1994). The San Agustin Basin covers an area of approximately 1,540 square miles in the Southwest Region (Table 5-10). Groundwater in the San Agustin Basin flows from east to west with a gradient of approximately 5 feet per mile. The thickness of the Quaternary/Tertiary alluvial/lacustral fill is as much as 4,000 feet (Figure 5-18). Groundwater is usually between 150 and 300 feet bgs, and the average saturated thickness is 277 to 477 feet (Myers et al., 1994). The basin fill aquifer is



Source: Modified from Myers et al., 1994

15 X Vertical Exaggeration

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

San Agustin Basin
Geologic Cross Section

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Figure 5-18

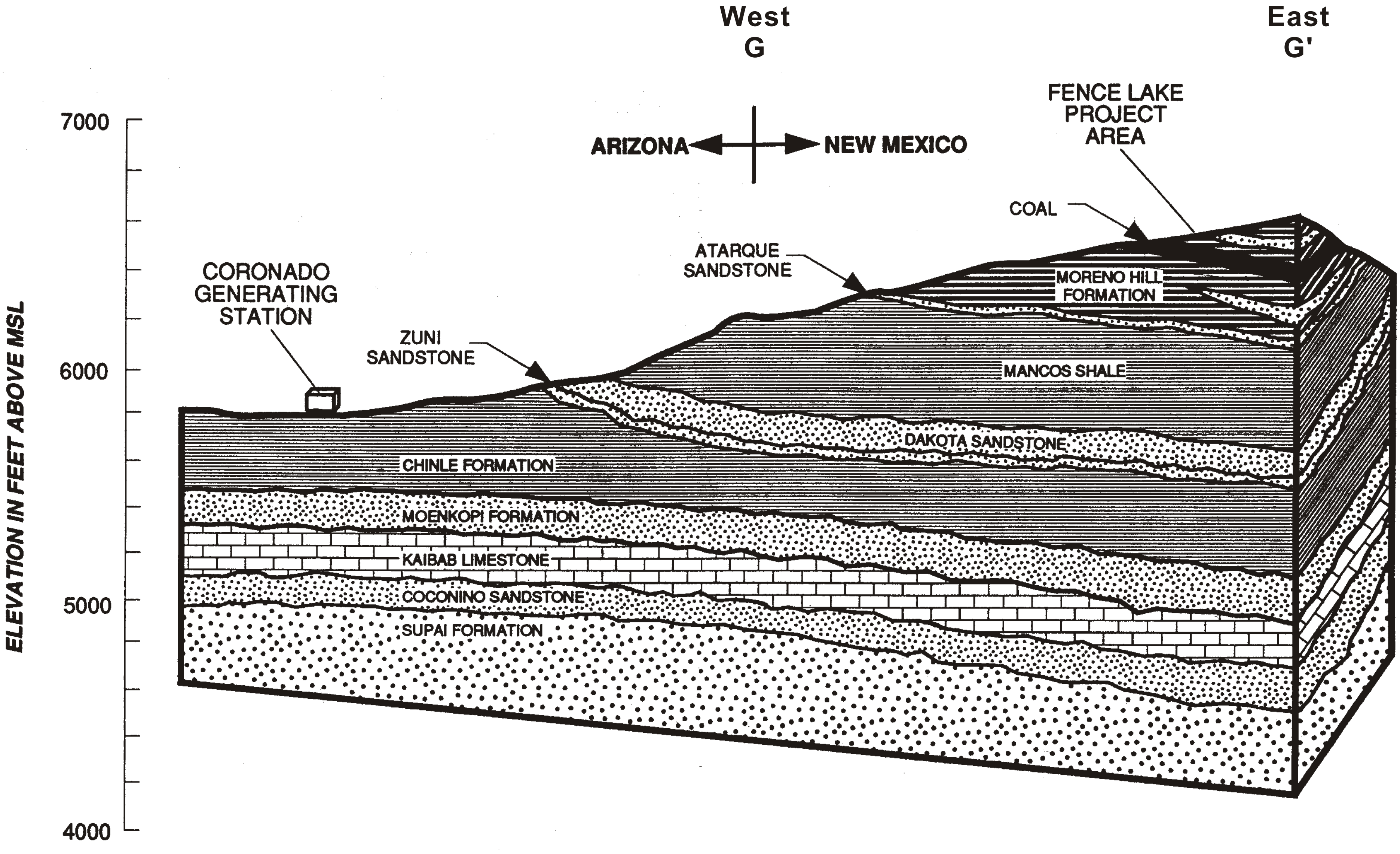
recharged by direct precipitation and mountain front recharge and from the underlying Datil Aquifer (discussed below). Short-term aquifer tests indicate transmissivities ranging from 17,200 to 362,000 gpd/ft (2,300 to 48,400 ft^2/d), specific capacities ranging from 5.7 to 90 gpm/ft, specific yields ranging from 13.0 to 19.3 percent, and storage coefficients ranging from 0.130 to 0.195 (Myers et al., 1994).

Tertiary volcanics (Datil Group, Baca Formation) also form an extensive aquifer (the Datil Aquifer) underneath the basin fill material of the San Agustin Basin, which extends into the Gila and San Francisco Basins as well. Depth to water in the Datil Aquifer is usually less than 1,270 feet bgs (Myers et al., 1994), and the saturated thickness ranges from 225 to 425 feet (Roybal, 1991). Wells typically yield water at rates less than 10 gpm (Myers et al., 1994). Water within the Datil Aquifer flows toward the southwest and discharges into the Gila Basin, and some evidence indicates that the basin fill and Datil aquifers are hydrologically connected near the basin’s northern and southern margins (Roybal, 1991).

5.3.2.10 Little Colorado Basin

The Little Colorado Basin covers an area of approximately 5,400 square miles in the Southwest Region, 1,806 (Table 5-10) of which are located within the northwestern portion of Catron County (Figure 5-12). The dominant land use in the Little Colorado Basin is stock grazing; relatively little irrigated agriculture takes place compared to other basins in the planning region (Wilson et al. [2003] estimates that only 595 acres are irrigated, with surface water, in the vicinity of Quemado). Accordingly, water use is mainly limited to stock tanks and private domestic wells. The population density is low: the region is rural, with the largest population centers being in and near the towns of Quemado and Pie Town.

Geology of both the Colorado Plateau and Transition Zone Provinces is found within the basin (Figure 5-19). The primary groundwater-bearing formations in the Little Colorado Basin are alluvial deposits and the Dakota Sandstone (BLM, 1990). The alluvial fill of Carizzo Wash is an important groundwater resource locally. Small quantities of water are derived from several other formations, including the Bearwallow Mountain Andesite, Baca Formation, Mancos Shale, and Mesaverde Group. Wells completed in these units are used primarily for stock tanks and private domestic wells.



Source: U.S. BLM, 1990, Figure 3-3

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Little Colorado River Basin Geologic Cross Section

Figure 5-19

The Little Colorado Basin has the least developed groundwater resources in the planning region, and little detailed data on aquifer characteristics are available for this part of the region. No long-term hydrographs have been located for the portion of the Little Colorado Basin that falls within Catron County.

5.3.2.11 North Plains Basin

While the North Plains Basin covers a total area of 1,325 square miles (NM OSE, 1995), only about 295 square miles lie within the Southwest Region (Table 5-10); the remainder extends northward into Valencia County. The North Plains Basin is bounded on the east by the Cebolita Mesa, on the west by the Continental Divide, and on the south by the Datil Mountains.

The North Plains Basin contains Quaternary alluvium, Tertiary and Quaternary volcanics, and the same Cretaceous to Permian sedimentary sequences found in the Little Colorado Basin (Section 5.3.2.10). The principal aquifer in the North Plains Basin is Quaternary basalt, which can be up to 600 feet thick and is found beneath half the basin. Other units known to yield small quantities of water include the Mesaverde Group, Mancos Shale, Dakota Sandstone, Zuni Sandstone, Chinle Formation, San Andres Limestone, Glorieta Sandstone, and Yeso Formation.

5.3.2.12 Rio Salado Basin

The Rio Salado Basin extends along the Rio Grande from the Colorado border to the southern end of Elephant Butte Reservoir near Truth or Consequences, with a total area of 26,209 square miles. Only about 1 percent of the basin, or 237 square miles, lies within the Southwest Region (Table 5-10). The portion of the basin within the planning region encompasses the northeastern portion of Catron County (Figure 5-12), bounded on the west and south by the Continental Divide. The rest of the basin lies to the north and east of Catron County. Within the Southwest Region, the Rio Salado Basin contains geology of both the Colorado Plateau and Transition Zone Provinces.

Small volumes of water in the Rio Salado Basin are also yielded by shallow upland aquifers comprised of alluvial fill. The alluvial fill is normally less than 50 feet thick, and water levels are less than 75 feet bgs. Yields from these formations are typically low (less than 10 gpm) (NM OSE, 1995).

5.3.3 Aquifer Characteristics and Groundwater in Storage

An inventory of quantitative data on aquifer properties was compiled by reviewing available information found in the documents listed in the bibliography (Appendix A1). The inventory is shown in Appendix D5 and is organized by hydrogeologic basin, with all aquifers that occur within a given basin listed. Much of the information contained in the table is used by hydrologists to quantify well performance and water availability. As indicated by the data in Appendix D5, aquifer performance in the southern closed basins has been fairly well characterized, while the aquifers in the northern part of the region are less well understood.

In addition to the aquifer characteristics shown in Appendix D5, hydrographs from numerous wells in the region were inspected to determine water level trends. In general, water levels region-wide are decreasing. Considering the relatively limited amount of recharge that occurs (Section 5.3.4), this trend is not surprising. However, water table fluctuations do appear to be influenced by climatic conditions: during drier periods the water table decreases at a faster rate, and during wetter periods the water table may even rise in some locations. The greatest depletions are occurring in municipal well fields (Silver City, Deming, Lordsburg) and in areas of intense agriculture (Animas, Playas Valleys). Representative hydrographs from throughout the region have been compiled in Appendix D4.

The amount of subsurface characterization (i.e., well logs) within the region is not adequate to allow highly accurate determination of groundwater in storage. In addition, the quality of water varies throughout the region, and although some locations may contain brackish or slightly saline waters that could be treated for use in the future, such treatment may not be practical at this time. Nevertheless, because quantification of groundwater reserves is of obvious value to the regional planning process, DBS&A developed rough estimates of the groundwater supply in each of the hydrogeologic basins within the region, based on the areal extent of the geologic formations and information on aquifer thickness and specific yields (Table 5-11). Appendix D5 provides details on DBS&A’s storage estimates by geologic unit.

Table 5-11. Amount of Groundwater in Storage by Basin and County

County	Hydrogeologic Basin	Groundwater in Storage (acre-feet)
Catron	Little Colorado	19,956,000
	North Plains	573,000
	Rio Salado	9,792,000
	San Agustin	49,908,000
	Gila	27,485,000
	San Francisco	40,864,000
Grant	San Francisco	4,578,000
	Gila	26,200,000
	Hachita-Moscos	2,962,000
	Animas	7,200,000
	Playas-San Basilio	548,000
	Mimbres	13,060,000
Luna	Animas	714,000
	Hachita-Moscos	3,315,000
	Mimbres	32,383,000
	Nutt-Hockett	2,665,000
Hidalgo	San Simon	860,000
	Animas	38,943,000
	Gila	5,580,000
	Hachita-Moscos	9,001,000
	Playas-San Basilio	5,990,000
	San Bernadino	400,000

As they are just an approximation, the values provided in this table should be used only as a general guide in the water planning process. The DBS&A estimates include all water, as the available data were insufficient to evaluate water quality limitations in all areas. In some basins that have been studied in more detail, such as the Mimbres (Hawley et al., 2000), the storage estimates in the literature are approximately one-third lower (30 million acre-feet in the case of the Mimbres) than DBS&A's estimate, as only high-quality water was included in the literature estimates.

In addition to the water quality issue, DBS&A’s estimates do not consider legal (water right) restraints or the economics of development in remote areas. Consequently, they cannot be considered estimates of water that is readily available for use in the Southwest Region.

5.3.4 Recharge

Recharge is simply the addition of water to an aquifer. Natural recharge to groundwater commonly occurs as areal recharge, localized recharge, and recharge from mountain fronts (DBS&A, 1996).

- Areal recharge is natural recharge derived from precipitation that falls on large portions of the landscape and percolates downward through the vadose zone to the aquifer.

- Localized recharge occurs where there is prolonged ponding on the surface, such as a losing stream (i.e., a stream from which water is flowing to groundwater), reservoir, or flood irrigation.

- Mountain front recharge typically involves complex processes of saturated and unsaturated flow in bedrock and downslope migration into aquifers at the base of the mountains.

Recharge to the aquifers in the Southwest Region occurs through direct rainfall and mountain front recharge. Localized recharge also occurs along portions of the Gila, San Francisco, and Mimbres Rivers, which recharge the underlying alluvial aquifers.

5.3.4.1 Documented Recharge Estimates

Recharge to aquifers in the Southwest Region has been estimated by numerous investigators to range from less than 1 percent to 4.8 percent of total rainfall (Reeder, 1957, Trauger, 1972; Hanson et al., 1994; Hawley et al., 2000), as summarized in Table 5-12.

Table 5-12. Summary of Estimates of Recharge to Groundwater in the Southwest New Mexico Water Planning Region

Hydrogeo-logic Basin	Estimated Recharge (ac-ft/yr)	Precipitation (inches)	Percentage of Precipitation (%)	Area of Basin (mi^2)	Area of Basin in NM (mi^2)	Area of Recharge (mi^2)	Reference
Mimbres	55,300	NA	<2	5,140	4,410	NA	Hawley et al., 2000, p. 38-39
	61,000	NA	NA	NA	NA	NA	Hanson et al., 1994, p. 41 [a]
	NA	>18	4.8	NA	NA	NA	Trauger, 1972
Hachita-Moscos	4,860	12	1	1,040	620	770	Hawley et al., 2000, p. 54-55
Animas	12,758	10-12	1	2,448	2,448	1,740	Hawley et al., 2000, p. 90
	NA	10	0.7	NA	NA	NA	Reeder, 1957
Playas	5,670	14	1	NA	925	770	Hawley et al., 2000, p. 70
Gila (inc. SF)	60,000	18	4.6	12,900	5,600	NA	Trauger, 1972 [b]
San Bernadino	6,480	16	2	422	35	NA	Hawley et al., 2000, p. 113

[a] Based on Hearne and Dewey, 1988

[b] Based on theoretical baseflow of the Gila

NA = Not addressed in this study

In the Colorado Plateau Province in northern Catron County, recharge has not been determined for most of the formations present, but it is likely much lower because the regional aquifers are overlain by less permeable units. The BLM (1990) estimated recharge to shallow alluvial aquifers to be 0.08 inch per year and recharge to an unspecified underlying sandstone unit to be 0.05 inch per year. Based on the average annual precipitation of 10.7 inches reported at Quemado (Table 5-2), these values correspond to 0.75 percent and 0.47 percent of rainfall, respectively.

5.3.4.2 Modeled Recharge Estimates

In order to obtain approximations of recharge in basins where previous work was not available, DBS&A estimated recharge using the Maxey-Eakin method. The Maxey-Eakin approach to recharge estimation has been independently evaluated by Watson et al. (1976) and Avon and

Durbin (1994). Watson et al. (1976) found the Maxey-Eakin approach to yield reliable "first approximation" estimates of basin recharge. Avon and Durbin (1994) compared Maxey-Eakin recharge estimates to independently estimated recharge values for 146 basins and found the Maxey-Eakin estimate to generally lie within 50 percent of the independent estimates.

Maxey and Eakin (1949) hypothesized that a direct relationship exists between annual precipitation and annual recharge: the higher the annual precipitation, the higher the annual recharge. This hypothesis was supported by basin water balance studies (Maxey and Eakin, 1949) that indicated that higher-elevation, wetter groundwater basins in Nevada exhibited higher annual discharge rates (in the absence of significant groundwater pumping, discharge from a basin should be roughly equal to recharge) than lower-elevation, drier basins. Upon this premise, and using a contoured precipitation map of the state of Nevada prepared by Hardman (1936), they defined average annual recharge to a groundwater basin in Nevada as:

$$\text{Volume recharge} = A_1R_1 + A_2R_2 + A_3R_3 + A_4R_4 + A_5R_5 \qquad (1)$$

where: A_i = the land surface area (L_2) in a groundwater basin encompassed between two iso-precipitation contours and

$$R_i = r_i P_i \qquad (2)$$

where: i = precipitation contour

R_i = recharge rate (L/T) computed within precipitation zone i

r_i = the percentage of precipitation that becomes recharge within precipitation zone i

P_i = the average annual precipitation in zone i

Given the pre-existence of the contoured precipitation map of the state (Hardman, 1936), from which areas could be determined, the only set of unknowns in this recharge model are the percent recharge values (r_i). To estimate r_i, Maxey and Eakin (1949) used independent water balance results from 21 groundwater basins in the state of Nevada. These studies provided volume recharge for those 21 basins, and the contoured precipitation map (Hardman, 1936) provided the required A_i. Using these two known quantities, Maxey and Eakin (1949) solved for the r_i values using multiple regression. Table 5-13 summarizes the results of their analysis.

Table 5-13. Maxey-Eakin Recharge Percentages for Precipitation Ranges

Precipitation Range (inches)	Percentage of Precipitation That Becomes Recharge
0 to 8	0
8 to 12	3
12 to 15	7
15 to 20	15
>20	25

Many hydrogeologic and climatic similarities can be found between the Southwest Region and most of the basins studied by Maxey and Eakin in Nevada. Both lie within the Basin and Range province and are characterized by block faulted mountain ranges separated by broad valleys underlain by thick sequences of alluvial bolson-fill materials. Furthermore, much of Nevada and the planning region share semiarid to arid climatic regimes.

To assess the applicability of the Maxey-Eakin method in southwest New Mexico, the recharge estimates for the Southwest Region shown in Table 5-12 were analyzed for the percentage of precipitation. Based on this review, the percentage of precipitation that recharges basins in southwestern New Mexico ranges from about 1 percent to 4.8 percent, much lower than the rates in Nevada. The studies cited in Table 5-12 were used to develop the percentage of precipitation that recharges the basins for several precipitation ranges. The percentages so developed for southwestern New Mexico are compared to the Nevada values in Table 5-14.

Recharge in the Southwest Region was estimated by calculating the area of each precipitation contour within each basin and county and multiplying the result by the percentage ranges in Table 5-14. The estimates compare favorably to previous estimates of recharge where available. For instance, recharge to the Upper Animas Basin in Hidalgo County is calculated to be 13,450 ac-ft/yr for an area of 1,682 square miles as compared to an estimate of

12,760 ac-ft/yr by Hawley et al. (2000) for a 1,740-square-mile area. Table 5-15 compares DBS&A recharge estimates to available estimates from previous investigations.

Table 5-14. Comparison of Values for the Percentage of Precipitation that Recharges Groundwater

Precipitation Zone (inches)	Percentage of Precipitation that Recharges Groundwater (%)	
	Maxey-Eakin Coefficient [a]	Basins in Southwest New Mexico [b]
>20	25	NA
15-20	15	4.7
12-15	7	1.5
8-12	3	1
<8	0	0

[a] Based on the Maxey Eakin method developed for Nevada
[b] Values used for this planning study
NA = Not available

Table 5-15. Comparison of DBS&A Recharge Estimates to Estimates from Other Investigations

Hydrogeologic Basin / County	DBS&A Estimate		Previous Estimates		
	Estimated Recharge (ac-ft/yr)	Basin Area (mi^2)	Estimated Recharge (ac-ft/yr)	Basin Area (mi^2)	Source
Animas / Hidalgo	13,450	1,682	12,760	1,740	Hawley et al., 2000, p. 90
Gila / Grant	40,230	1,867	60,000	1,340	Trauger, 1972, p. 61
Hachita-Moscos	4,230	493	4,860	770	Hawley et al., 2000, p. 54
Mimbres / Grant	22,415	1,118	25,200	1,118	Hanson et al., 1994, p. 39
			14,300	308	Trauger, 1972, p. 62
Mimbres / Luna	2,570	2,562	30,000	2,562	Hanson et al., 1994, p. 39
Playas / Hidalgo	7,800	883	5,670	770	Hawley et al., 2000, p. 70

The differences among the estimates in Table 5-15 underscore the uncertainty associated with recharge estimates and the need for local field and modeling studies to more accurately estimate recharge. While most of the DBS&A recharge estimates listed in Table 5-15 compare well to estimates made previously, the estimate for the Mimbres Basin in Luna County is significantly lower than one previous estimate. The reason for this discrepancy is that the method used by DBS&A assumes that no recharge occurs in areas that receive less than 8 inches of precipitation, which is true for most of Luna County. In reality, more recharge may occur during intense thunderstorms.

DBS&A's recharge estimates for each basin are presented in Table 5-16. The total groundwater withdrawals in the planning region during 2000 were 169,000 acre-feet (Section 6), slightly exceeding the alternate regional recharge estimate shown in Table 5-16. However, because it is not economically viable to pump groundwater from remote areas throughout the region, the region-wide recharge estimate is not a good indicator that recharge water will be available to the pumping centers. In locations where pumping is concentrated, withdrawals are already greatly exceeding recharge.

Table 5-16. Calculated Recharge to Hydrogeologic Groundwater Basins Using a Modified Maxey Eakin Method

Hydrogeologic Basin	Annual Recharge	
	ac-ft	% ppt
San Simon	2,914	2.0
Animas	16,130	1.2
Playas-San Basilio	8,050	1.5
Hachita-Moscos Basin	4,234	1.0
Mimbres	24,987	1.3
Nutt-Hockett	265	0.4
Gila	72,976	3.0
San Francisco	55,954	3.7
San Agustin	18,322	1.9
Little Colorado	18,285	1.7
North Plains	985	0.7
Rio Salado	1,803	1.3
Total	224,905	1.98

ac-ft = Acre-feet
% ppt = Percent of precipitation

5.3.5 Major Well Fields

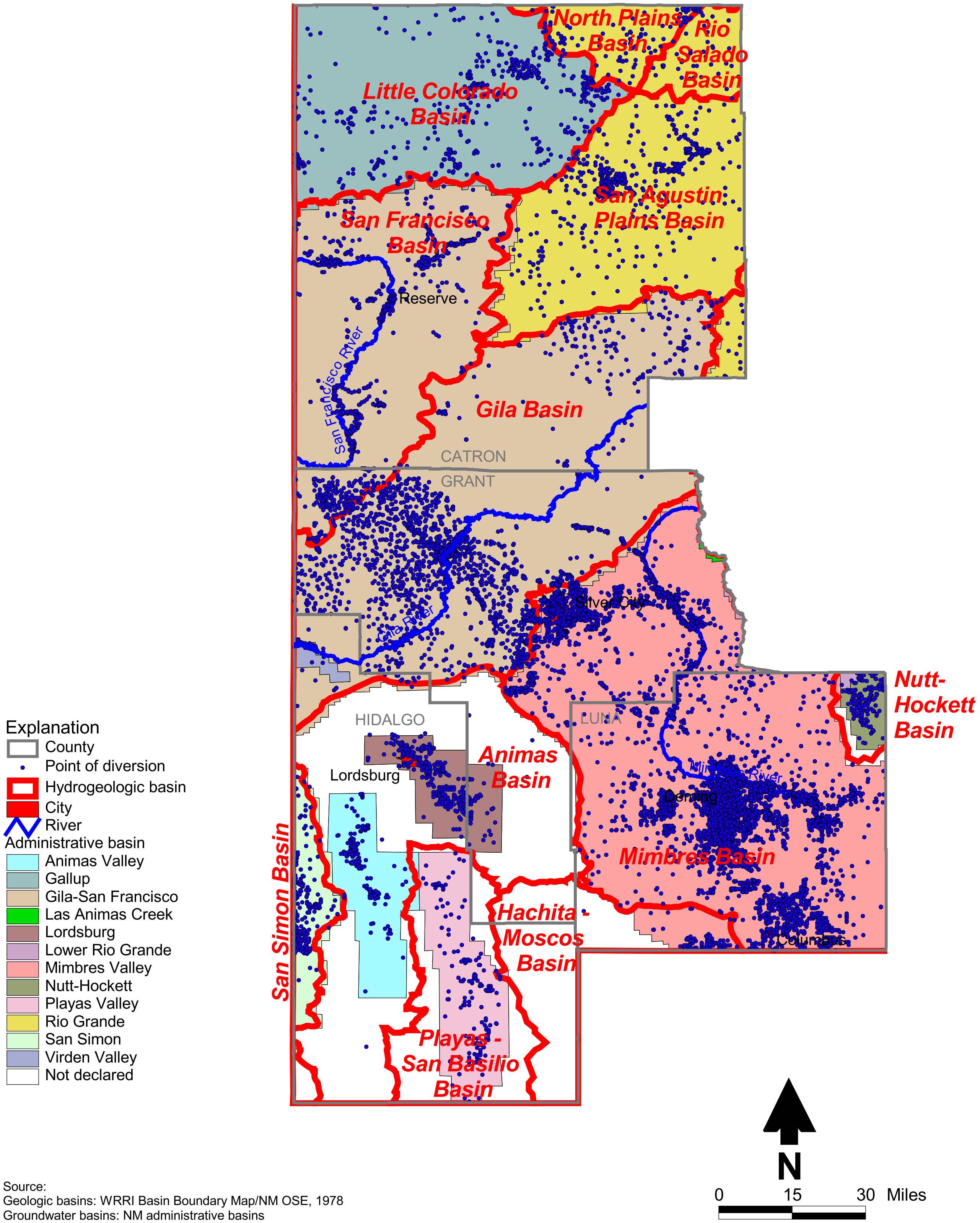
The major municipal and private well fields in the region, along with the hydrogeologic basins they draw from, are:

- Lordsburg (Animas Basin)
- Lordsburg Power Plant (Animas Basin)
- Pyramid facility (Animas Basin)
- Santa Clara (Mimbres Basin)
- Bayard (Mimbres Basin)
- Deming (Mimbres Basin)
- Columbus (Mimbres Basin)
- Silver City municipal well fields, including Franks, Woodward, Anderson, and Hayes (Mimbres and Gila Basins)

Figure 5-20, which shows the points of diversion contained in the OSE WATERS database, illustrates the concentration of pumping in the region. This figure includes domestic wells, which supply more than 20,000 people in the region. The density of domestic wells mirrors the population density, and three-fourths of the domestic wells in the region are therefore located in the Mimbres Basin, in the vicinity of Silver City and Deming where 80 percent of the population resides. In addition, numerous irrigation wells are located throughout the Animas, Mimbres, and Nutt-Hockett Basins. Further information regarding sustainable yields and production in the major well fields in the Southwest Region is provided in Sections 5.3.6 and 6, respectively.

5.3.6 Sustainable Yields

The concept of sustainable yield generally refers to limiting pumping withdrawals to an amount that can be maintained over a long time period or that will not be detrimental to other resources. However, there is no universally accepted definition of sustainable yield in groundwater management. Sustainable development has been defined as development that meets the needs of the present without compromising the ability of future generations to meet their own



Source:
Geologic basins: WRRI Basin Boundary Map/NM OSE, 1978
Groundwater basins: NM administrative basins

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Points of Diversion

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Figure 5-20

(S:\PROJECTS\WR03.0004\GIS\PROJECTS (PROJECT = geologic_basins.apr) (VIEW EXTENTS = TEMP) (VIEW NAME = V09 - P) (LAYOUT = L09 - P 400221) needs (Sophocleous, 1998). Some of the common definitions of “sustainable water supply” (Shomaker, 2001) include:

- Limiting consumptive use to the net surface supply in any given year
- Limiting the amount of water that can be withdrawn to an amount that has no unacceptable effects on drawdown or streamflows

For example, in a recent study completed in Arizona, sustainable yield was defined as “yield that would not significantly affect the availability of the groundwater system to sustain riparian habitat and perennial springs” (Springer et al., 2002). In any case, depletions that exceed recharge will ultimately be unsustainable.

The concept of how much can be sustainably developed is impacted by the location and magnitude of pumping within a groundwater basin. Whereas a sustainable yield estimate could be developed from a basin-wide perspective, it may be meaningless if most of the pumping is occurring in a few localities or close to a sensitive wetland or stream. Therefore, sustainable yield is best addressed at a local level, where a more accurate accounting of water budget terms and impacts can be developed.

Though no quantitative estimates of sustainable yields have been developed specifically for any groundwater basins in the Southwest Region, predictions of future drawdowns and the ability of selected well fields to meet future demands were developed for three of the declared groundwater basins in the Southwest Region (Sections 5.3.6.1 through 5.3.6.3). In addition, projected declines for the Silver City well field, which draws from both the Mimbres and Gila-San Francisco Basins, are discussed in Section 5.3.6.3. In order to develop quantitative estimates of sustainable yields for all the basins in the region, additional field studies and modeling efforts are required. The discussions of water budgets in Section 7 provide a general idea of the current level of stress on the aquifer. Locations of wells in the Southwest Region, indicating key pumping centers, are shown on Figure 5-20.

5.3.6.1 Animas Valley Basin

During the past century, irrigation in the Animas Valley has been supported by groundwater pumped from within 500 feet of ground surface. Basin-wide, depletions (17,343 acre-feet) (Wilson et al., 2003) exceed the annual recharge from precipitation of 16,130 acre-feet calculated by DBS&A (Section 5.3.4). As a result, some wells in the Animas Valley Basin have exhibited a decline in the water table of nearly 100 feet since 1950 (Appendix D4). A recent study (Johnson et al., 2002) predicted that by 2020 drawdown could be greater than 130 feet in some parts of the basin, with average drawdown in irrigated areas reaching 100 feet. By 2040 it was estimated that average drawdown would be 120 feet, and by 2060 the average drawdown would be 140 feet, with a maximum drawdown of 177 feet.

Given the estimated average predevelopment saturated thickness of 470 feet, the average saturated thickness remaining in 2060 would be 330 feet. Due to the relatively large saturated thickness of the basin fill aquifer, supply in the foreseeable future is ample; however, many wells will need to be deepened as water levels continue to decline. Additionally, these numbers are averages, and some wells located in areas of above average drawdown or below average saturated thickness may not be able to maintain an adequate production yield.

A recent study (Johnson et al., 2002) of drawdown related to irrigation, power, and municipal uses estimated that drawdown in the Lordsburg municipal well field between 1950 and 2000 was 30 feet. Other results of the study were:

- Municipal well field drawdown was predicted to reach 50 feet by 2020, 63 feet by 2040, and 75 feet by 2060 (Johnson et al., 2002).

- Maximum drawdown for the Lordsburg power plant well field for the years 2020, 2040, and 2060 was predicted to be 51 feet, 62 feet, and 73 feet, respectively (Johnson et al., 2002). By 2060, all existing wells in the power plant well field were predicted to have more than 100 feet of water column (saturated thickness) and to retain 60 to 70 percent of their initial water columns.

- Modeled drawdown at the Pyramid Facility well field for 2020, 2040, and 2060 was predicted to be 65 feet, 77 feet, and 89 feet, respectively, with all wells retaining 80 percent or more of their initial water columns.

- In the irrigated section of the basin, modeled average drawdown for 2020, 2040, and 2060 was 60 feet, 70 feet, and 80 feet, respectively.

Due to the relatively large initial saturated thickness of the Gila Group (360 feet), ample supply is available for municipal, power, and agriculture uses in the foreseeable future; however, many irrigation wells will need to be deepened as water levels continue to decline, thereby increasing pumping costs. Additionally, these numbers are averages, and some wells located in areas of above average drawdown or below average saturated thickness (away from the center of the valley) may not be able to maintain adequate production rates.

5.3.6.2 Mimbres Basin

Recent studies considered historical and predicted future impacts to water tables in the vicinity of the Lone Mountain (formerly Central, serving Santa Clara), Bayard, Deming, and Columbus municipal well fields, and Luna County agricultural centers. Results from this study are summarized below. Although the town of Silver City lies within the Mimbres Basin, its well fields are located in both the Mimbres and the Gila groundwater basins, and the Silver City water supply is therefore discussed separately in Section 5.3.6.3.

Santa Clara obtains water from the Lone Mountain well field, which consists of four wells completed in the Gila Group. Between 1954 and 1979, water levels in the Lone Mountain well field declined between 0.7 and 1.0 foot per year (Trauger et al., 1980). Johnson et al. (2002) predicted that drawdown in the Lone Mountain well field will be 244 feet by the year 2040, leaving approximately 80 feet of available water column in the well field.

Bayard obtains groundwater from the Bayard well field, which is located in the Cameron Creek drainage and consists of wells completed in Quaternary alluvium, Gila Group, and Tertiary volcanics. Johnson et al. (2002) predicted that drawdown in the Bayard well field would reach 299 feet by 2040, leaving approximately 61 feet of water column in the well field.

Estimated drawdowns indicate that the existing well fields for both Santa Clara and Bayard will not be capable of meeting demands through 2040. Deepening the wells to maintain production is not practical due to the relatively small saturated thickness of the aquifers. The report concluded that connection to a regional water supply system may be necessary.

The Deming well field has 12 active wells, and is located in the vicinity of some of the deepest basin fill deposits (over 4,200 feet) found in the Mimbres Basin (Johnson et al., 2002). The current depth to water in these wells ranges from 55 feet bgs to 140 feet bgs. Data from aquifer tests indicate that the transmissivities of wells in the well field range from 11,250 gpd/ft (1,500 ft^2/d) to 120,000 gpd/ft (16,000 ft^2/d). Yields for individual wells range from 300 to 650 gpm, and the total well field yield is 5,900 gpm. Drawdown estimates for 2020, 2040, and 2060 indicate that the water table will decline on average approximately 1.75 feet per year between 2000 and 2060. Of the 12 wells, 10 will retain at least a 100-foot water column, and the well field is likely to meet demand through 2060.

The Columbus well field contains three active wells located in an area where basin fill ranges from 550 to 1,000 feet thick (Hanson et al., 1994). Depth to water in these wells ranges from 109 to 149.5 feet bgs. Data from aquifer tests indicate that transmissivities range from 33,750 gpd/ft (4,500 ft^2/d) to 375,000 gpd/ft (50,100 ft^2/d). Yields for individual wells range from 85 to 350 gpm, and the total well field yield is 538 gpm. Drawdown estimates for 2020, 2040, and 2060 (Table 5-17) indicate that water levels will decline on average approximately 3 feet per year between 2000 and 2060, and by 2040, the well field will not be capable of meeting demand (Johnson et al., 2002).

Table 5-17. Estimated Drawdown at Deming and Columbus Well Fields

Well Field	Drawdown (feet) / Consumption of Currently Available Water Column (%)		
	2020	2040	2060
Deming	99 to 183 / 30 to 60	116 to 225 / 35 to 85	141 to 292 / 47 to 100
Columbus	300 to 367 / 58 to 66	362 to 492 / 60 to 100	446 to 662 / 100

Luna County contains many irrigation wells, probably well over 1,000. The USGS Ground Water Sites Inventory (GWSI) database contains water column data for 966 irrigation wells within the Mimbres Basin. The average water column of these wells is 258 feet. Johnson et al. (2002) estimated that water levels have declined by as much as 200 feet since 1935 in some parts of the basin, but concluded that most irrigation wells in the Mimbres Basin could be deepened enough to maintain production through 2060. However, as water levels decline and groundwater becomes increasingly expensive to pump, the economic feasibility of irrigating with groundwater in the future is questionable.

5.3.6.3 Silver City

The Silver City well fields derive water from both the Mimbres Basin and the Gila Basin. Silver City has four primary well fields: the Franks Well Field, Woodward Well Field, Anderson Well Field, and Hayes Well Field. The Franks well field is the only one of the four that is located in the Gila Basin, and it provides approximately 30 percent of Silver City's water (Johnson, 2000). A recent study (Johnson et al., 2002) simulated the effect of projected demands on water levels in these well fields; results of that study are summarized in Table 5-18.

Table 5-18. Estimated Drawdown at Silver City Well Fields Under Scenario 1

Well Field	Drawdown (feet) / Consumption of Currently Available Water Column (%)		
	2020	2040	2060
Franks	143 to 363 / 43	195 to 476 / 57	244 to 510 / 69
Woodward	264 to 297 / 49	346 to 391 / 65	412 to 467 / 76
Anderson	185 / 42	249 / 56	299 / 67
Hayes	393 / 94	495 / 100	578 / 100

Source: Johnson et al., 2002

Deepening the wells in the four Silver City well fields is generally not feasible because the aquifers have a limited productive saturated thickness. It may be feasible to increase production by completing additional wells away from the existing wells.

5.4 Water Quality Assessment

Ability to meet future water demands requires not only sufficient quantity of water, but also water that is of sufficient quality for the intended use. In order to meet drinking water quality standards, most water supplies require at least a minimal amount of treatment. Should the water quality of the drinking water supply become significantly degraded, additional and costly treatment must be provided or additional water supplies located. Where drinking water supply options are limited, water quality impairment can be a significant and expensive problem. Although standards are generally not as high for other uses (i.e., irrigation and livestock uses), water quality must nevertheless be high enough to meet these uses, or expensive treatment will be required.

Water quality for Southwest Region was assessed through existing documents and databases. Surface water studies that were especially helpful were two documents prepared pursuant to Section 305(b) of the Federal Clean Water Act: (1) a list of surface waters within New Mexico that are either not meeting or not expected to meet water quality standards (NMED, 2002a), as discussed in Section 5.4.1.2, and (2) *Water Quality and Water Pollution Control in New Mexico, 2002,* a report prepared by the State of New Mexico for submission to the United States Congress (NMWQCC, 2002). Information regarding groundwater quality was obtained primarily from this latter document, and information on specific sites and facilities that may potentially impact groundwater quality was obtained from various NMED and EPA databases.

5.4.1 Surface Water

Potential sources of contamination and measured impacts to surface waterbodies are described in Sections 5.4.1.1 and 5.4.1.2, respectively.

5.4.1.1 Potential Sources of Contamination

Sources of contamination are considered point sources if they originate from a single location or nonpoint sources if they originate over a more widespread or unspecified location. Potential point source discharges must comply with the Clean Water Act and the New Mexico Water Quality Standards by obtaining a permit to discharge. These permits are referred to as National Pollutant Discharge Elimination System (NPDES) permits. Table 5-19 summarizes NPDES permitted discharges in the Southwest Region (NMED, 2003d).

Table 5-19. Southwest New Mexico Counties Regional Water Plan Municipal and Industrial NPDES Permittees

Permit No.	Municipality/Industry	County
Municipalities:		
NM0024163	Reserve Wastewater Treatment Plant	Catron
NM0020109	Silver City	Grant
NM0020231	Bayard	Grant
Industries:		
NM0030163	Glenwood Fish Hatchery	Catron
NM0030244	North American Coal/Fence Lake Mine	Catron
NM0027375	Rio de Arenas Mobile Manor	Grant
Industries not discharging:		
NM0020435	Chino Mines Company	Grant
Applications Pending:		
NM0030309	Lordsburg	Hidalgo

Source: NMED, 2003d

Nonpoint sources of pollutants are also a concern for surface water in the Southwest Region. The probable sources of pollutants or threats to surface waters are grazing, cultivated agriculture, recreation, hydromodification, road and highway maintenance, silvicultural activities, resource extraction, road runoff, nutrient-enriched waters, and natural and unknown sources (NMWQCC, 2002). Specific pollutants or threats to surface water quality resulting from these nonpoint sources are turbidity, stream bottom deposits, metals, problems with pH, dissolved oxygen, temperature extremes, pathogens, plant nutrients, forest management such as fire suppression, streambank destabilization, and conductivity (NMWQCC, 2002).

In addition to the potential for direct discharges from mining activities, other sources of contamination are the stockpiles, open pits, and tailing ponds, which contain mineral sulfides that, when oxidized, generate acidic solutions that can impact stormwater. In addition, process water used in mining operations that is transported and stored on-site typically contains metals, TDS, and sulfate above standards and has a pH below the acceptable range (NMED, 2003a, 2003c). If engineering controls are not in place, the impacted stormwater and/or mine process solutions can contaminate nearby ephemeral stream sediments and seasonal flows.

5.4.1.2 Existing Surface Water Quality

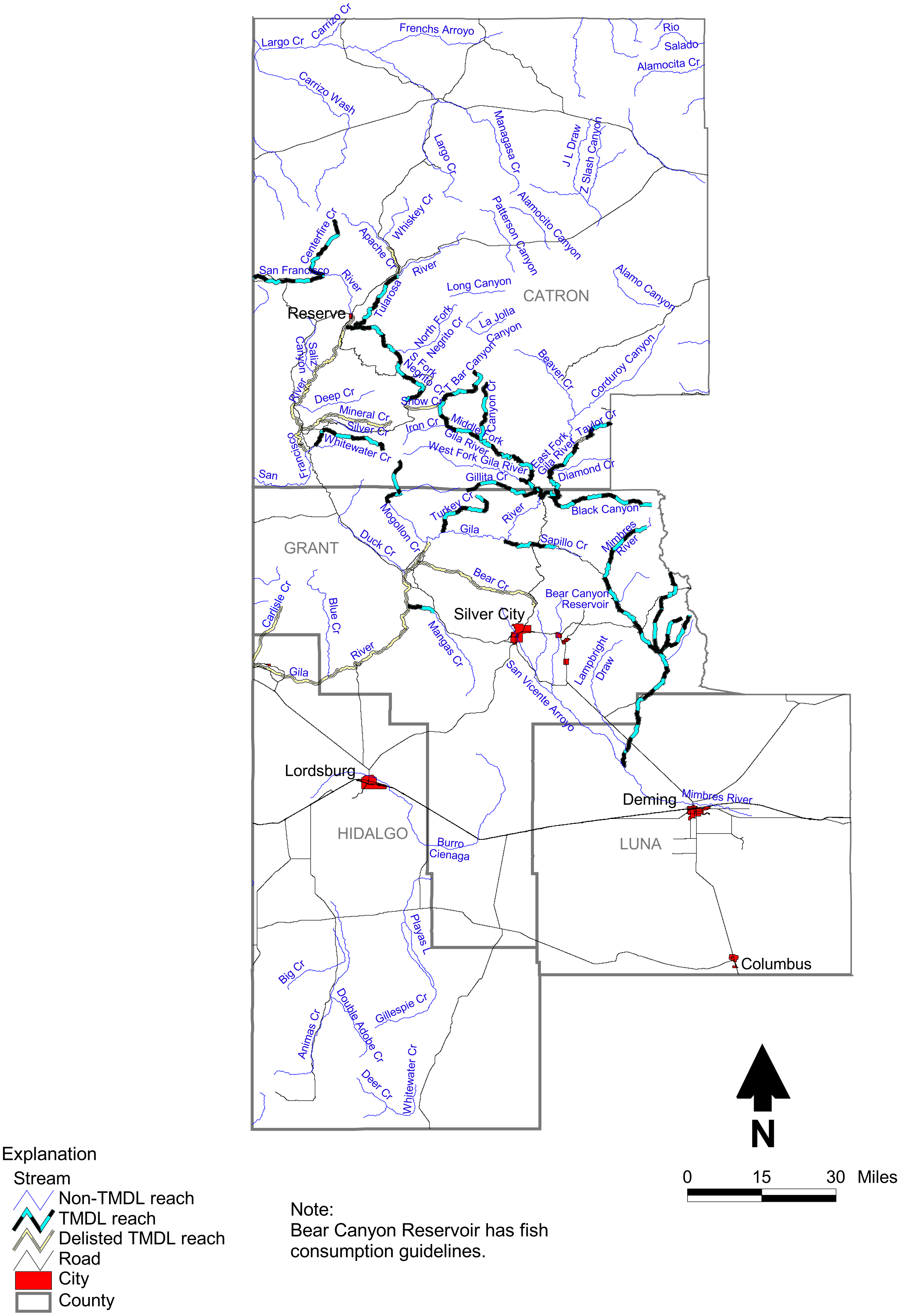
The Southwest Region is mostly drained by the Upper Gila River, San Francisco River, and Upper Mimbres River and their tributaries. Water quality is generally very good throughout the region; however, several river reaches within the Gila, San Francisco, and Upper Mimbres watersheds have been listed on the 2002-2004 New Mexico 303(d) list (NMED, 2002a). This list is prepared by NMED to comply with Section 303(d) of the federal Clean Water Act, which requires each state to identify surface waters within its boundaries that are not meeting or are not expected to meet water quality standards. Appendix D6 lists each of the reaches in the planning region that are on the 303(d) list; the locations of these reaches are shown on Figure 5-21.

Section 303(d) further requires the states to prioritize their listed waters for development of total maximum daily load (TMDL) management plans. A TMDL documents the amount of a pollutant that a waterbody can assimilate without violating a state water quality standard. It also allocates that load capacity to known point sources and nonpoint sources at a given flow. As shown in Appendix D6, numerous TMDL management plans have already been developed for streams in the planning region, including for the Gila River and other listed streams in the Gila River watershed, listed streams in the San Francisco River watershed including Centerfire Creek, Negrito Creek, Tularosa River, San Francisco River and Whitewater Creek, and listed streams in the Upper Mimbres watershed.

The Gila River watershed was listed as a high-priority watershed, and ten TMDL management plans have already been developed and approved by the EPA for streams in the Gila River Basin. These streams include the Gila River, Black Canyon Creek, Canyon Creek, Mogollon Creek, Sapillo Creek, Taylor Creek, and Mangas Creek. The specific pollutants and their probably sources are:

- Aluminum: Resource extraction, range grazing, off-road vehicles, mill tailings, forest management (fire suppression), cultivated agriculture, and natural sources.

- Temperature: Recreation, forest management (fire suppression), and natural sources.



Note:
Bear Canyon Reservoir has fish consumption guidelines.

SOUTHWEST NEW MEXICO REGIONAL WATER PLAN

Water Quality-Impaired Reaches in Southwest Region

Daniel B. Stephens & Associates, Inc.

8-25-03 4:02PM

JN WR03.0004

Figure 5-21

(S:\PROJECTS\WR03.0004\GIS\PROJECTS (PROJECT = tmdl_reach.apr) (VIEW NAME = V00 - T) (VIEW EXTENTS = TEMP) (LAYOUT = L00 - T 305280)

- Turbidity: Removal of riparian vegetation, range grazing, highway maintenance and runoff, habitat modification, upstream impoundments, and streambank destabilization/ modification.

- Plant nutrients: Grazing, streambank destabilization/modification, and silviculture.

- Total organic carbon: Hydromodification, road maintenance and runoff, removal of riparian vegetation, streambank destabilization/modification, nuisance algae, and unknown sources.

The additional streams without TMDL management plans in place in the Gila River watershed are portions of the Gila River, Gilita Creek, Taylor Creek, and Turkey Creek; these plans are due by December 31, 2006. Appendix D6 lists the probable causes and sources of impairment in these areas. There are no active NPDES permits in the listed reaches of the Gila River watershed.

Five TMDL management plans for the San Francisco watershed have been completed and approved by the U.S. EPA (2003b). These plans address exceedances for plant nutrients, conductivity, temperature, and turbidity. The probable sources of impairment are recreation, grazing, off-road vehicles, forest management (fire suppression), cultivated agriculture, removal of riparian vegetation, road maintenance and runoff, habitat modification, hydromodification, streambank modification/destabilization and natural sources. TMDL management plans for two listed areas in the San Francisco River watershed (reaches of Negrito Creek [temperature] and reaches of Whitewater Creek [aluminum]) are not currently in place, but are expected to be completed by December 31, 2006. There is an active NPDES permit on Whitewater Creek (San Francisco River to Whitewater Campground) for the Glenwood Fish Hatchery.

No TMDL management plans have been completed for listed streams (shown in Figure 5-21) in the Upper Mimbres River watershed (303 (d) list, NMED, 2002a); however, some are expected to be completed by 2017. The Chino Mines Company has an active NPDES permit for the perennial reaches below Sheppard Canyon of the Mimbres River, although they are not currently discharging.

The State of New Mexico has also included Bear Canyon Reservoir, Wall Lake, and Lake Roberts on the 303(d) listing for impairments caused by plant nutrients, pH, temperature, dissolved oxygen, and bottom deposits. The expected completion date for TMDL management plans on these waterbodies is 2017.

In addition to the 303(d) listings, the State of New Mexico has listed the Bear Canyon Reservoir on the impaired lakes list and has issued fish consumption advisories for the reservoir. This advisory was issued because mercury has been found in some fish at concentrations that could lead to significant adverse human health effects. Although the levels of mercury in the water of this lake are moderate, very low levels of elemental mercury found in bottom sediments are passed through the food chain progressively from smaller to larger fish, resulting in elevated levels in the larger fish.

Additionally the State of New Mexico has delisted several streams in the Gila River and San Francisco watersheds that were previously on the 303(d) list (Appendix D6). In some cases, a stream segment was delisted for one or more constituents, but continues to be listed for other constituents. Both listed and delisted segments, along with the associated constituents, are presented in Appendix D6. Several of the streams in the watersheds were delisted because they are non-perennial and the associated standards therefore do not apply. In several cases, new data or a re-examination of existing data supported the delisting. When waters are removed from the 303(d) list, TMDL management plans are no longer required.

In evaluating the impacts of the 303(d) list on the regional water planning process, it is important to consider the nature of impairment and its effect on potential use. Problems such as stream bottom deposits and turbidity will not necessarily make the water unusable for irrigation or even for domestic water supply (if the water is treated prior to use). However, the presence of the impaired reaches illustrates the degradation that can occur in the water supply.

5.4.2 Groundwater

Groundwater in the planning region is generally of high quality. It is suitable for agriculture and for private domestic consumption, and it can easily be treated for public water supply systems.

Groundwater contamination has, however, occurred in some areas of the planning region from both point and nonpoint sources. Prevention of future groundwater contamination can be a very important means of protecting the region's groundwater resources. A review of NMED records of existing facilities that may have the potential to impact groundwater quality indicated that the majority of groundwater concerns in the planning region are from leaking underground storage tanks (USTs), nitrates from septic tanks, metals from mineral leaching operations, and TDS, metals, and sulfates from mining operations (NMWQCC, 2002).

5.4.2.1 Underground Storage Tanks

Leaking USTs are one of the most significant point source contaminant threats. As of March 2003, NMED (2003b) had reported 111 leaking UST cases, 46 of which are active in the planning region (Table 5-20). Active cases include those in the pre-investigation, investigation, cleanup, and monitoring phases. Information on the status of the active sites is summarized in Table 5-20.

These leaking USTs may represent releases of oil, gasoline, diesel, and aviation fuel containing petroleum constituents that are common groundwater contaminants, such as benzene, toluene, ethylbenzene, xylenes, and methyl tertiary-butyl ether (MTBE), although the presence of a leaking UST site does not necessarily indicate that groundwater contamination or water supply well impacts have actually occurred.

The majority of leaking UST sites are concentrated around municipal and industrial areas and are therefore generally close to the water supply sources serving these communities. Currently, 2 of the leaking UST sites in the planning region have impacted the water supply, and 12 sites have unknown impacts (Table 5-20). Details indicating whether groundwater has been impacted and the status of site investigation and cleanup efforts for individual sites can be obtained from the NMED database, at www.nmenv.state.nm.us/ust/leakcity.html.

Many additional facilities with registered USTs that are not leaking are included in the NMED UST database. These USTs present a potential for groundwater quality impacts that could affect available water resources in and near the population centers in the region. A list of these sites is available from the NMED web site (www.nmenv.state.nm.us/ust/leakcity.html).

Table 5-20. Leaking Underground Storage Tanks in the Southwest Region
Page 1 of 3

Name	Facility ID	Contact	Physical Address	City	Status[a]	Water Supply Impacts[b]
Al's Transmission	26552	Ed Stevens	310 N Central	Bayard	I-NS	N
Buttermilks Shamrock	27181	Las Cruces Oil	314 Tom Foy Blvd	Bayard	I-NS	N
Hwy Texaco/Food Mart	28538	Housley Distrib	204 Tom Foy Blvd	Bayard	I-NS	N
NMSHTD-Cliff	29647	NM Highway & Tr	US 180	Cliff	C-NS	N
Eagle Guest Ranch	27454	Kenneth Coker	Hwy 60 and S Rd 12	Datil	C-NS	N
Navajo Lodge & Gas	29578	Bradley Jessica	Interchange of Hwy 60	Datil	I-NS	N
Ray's Garage	30165	Unknown	Interchange of Hwy 60	Datil	I-NS	N
Bowlins Akela Flats	984	Bowlins Inc.	20 miles E of Deming on I	Deming	PI-C	N
Deming Service Center	27655	City of Deming	Airport Rd	Deming	I-NS	U
Downtown Shell	1204	Brewer Oil Co.	201 W Pine	Deming	C-NS	N
Firestone Bulk Plant	28040	Barker Oil Co.	1617 E Spruce	Deming	I-NS	N
Gonzales Self Serve	31494	Jackson	422 W Pine	Deming	C-S	N
Luna County Sheriff	29201	Luna County	700 S Silver	Deming	I-NS	N
On Sale Tire Co	27082	Tony Perrault	101 W Pine St	Deming	I-NS	N
Poplar Fina	30031	Barker Oil Co.	755 S Platinum	Deming	PI-C	U
Sav-o-Mat	30493	Sav-o-Mat Inc.	321 W Pine St	Deming	PI-C	U
Snappy-Mart #258	1805	Bell Gas Inc.	306 E Pine St	Deming	M-S	N
Stuckeys Deming	1843	Bowlins Inc.	15 miles W of Deming on I	Deming	I-SP	Y
SW Cotton Irrigator	30859	SW Irrigated Gr	Corner of Cardenas and A St	Deming	C-NS	N
Triangle Truck Stop	31200	Barker Oil Co.	1300 W Pine	Deming	PI-C	U

Source: NMED web site (www.nmenv.state.nm.us/ust/leakcity.html)

[a]
C-NS = Cleanup, no settlement agreement
C-S = Cleanup, settlement agreement
I-NS = Investigation, no settlement agreement
I-SP = Investigation, settlement pending
M-LT = Monitoring, LUST Trust Fund
M-NS = Monitoring, no settlement agreement
M-S = Monitoring, settlement agreement
PI-C = Pre-investigation, confirmed release
PI-S = Pre-investigation, suspected release

[b]
N = No
U = Unknown
Y = Yes

Table 5-20. Leaking Underground Storage Tanks in the Southwest Region
Page 2 of 3

Name	Facility ID	Contact	Physical Address	City	Status[a]	Water Supply Impacts[b]
USA Truckstop 801	31405	USA Petroleum Co.	1310 W Spruce St	Deming	PI-C	U
Gila Mill Works	28333	Guardiana	120 N Hurley Rd	Hurley	I-NS	N
Snappy Mart 1153	1801	Brewer Oil Co.	Corner Main and Cortez	Hurley	PI-C	N
Border Cowboy Restrt	27013	Moller Oil Co.	984 E Railroad	Lordsburg	I-NS	N
Border Cowboy T-Stop	27014	Moller Oil Co.	992 E Railroad	Lordsburg	I-NS	N
Freeway Chevron	28172	Collins William	1150 E Motel Dr	Lordsburg	PI-C	U
Quick Shop/Calico Gr	30096	Gavin Enterprises	628 E Motel Dr	Lordsburg	PI-C	U
Star Texaco	30755	EJ Short and Sons	1130 E Motel Dr	Lordsburg	I-NS	N
Sun Texaco Pronto	30813	EJ Short and Sons	1421 S Main	Lordsburg	I-NS	N
Westside Texaco	28307	Basabilvazo	400 W Motel Dr	Lordsburg	I-NS	N
Old Kelly's Store	29750	Chamberlain	Main St N Side	Mogollon	M-LT	N
Country Store	27550	Carlton Armstro	Hwy 60	Quemado	C-NS	Y
Black Gold Service S	26960	Szombathy T	SR 435 Main St	Reserve	I-NS	N
Martinez 66	29275	Henry’s Corner I	Hwy 12	Reserve	I-NS	N
Reserve Conoco	30198	Latasa Mariano	SR 435	Reserve	M-NS	N
NMSHTD/Fred's Home C	28169	Silva	NE corner of Bayard	Santa Clara	I-NS	N
A&R Garage	26319	Colby	101 W College	Silver City	M-NS	N
Bell Gas #191	958	Unknown	Hwy 180 E	Silver City	PI-S	U
Ford/Lincoln Mercury	30613	Silver City Ford/Lncn	Hwy 180 E	Silver City	M-NS	N
Fuel Center Plus 1	28194	Buckingham Equi	855 E Silver Heights Blvd	Silver City	PI-C	U

Source: NMED web site (www.nmenv.state.nm.us/ust/leakcity.html)

[a] C-NS = Cleanup, no settlement agreement
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PI-S = Pre-investigation, suspected release

[b] N = No
U = Unknown
Y = Yes

Table 5-20. Leaking Underground Storage Tanks in the Southwest Region
Page 3 of 3

Name	Facility ID	Contact	Physical Address	City	Status[a]	Water Supply Impacts[b]
Fuel Center Plus 1	28194	Unknown	855 E Silver Heights Blvd	Silver City	PI-C	U
Silvercrest Texaco	28772	Housley Distrib	1510 Silver Heights Blvd	Silver City	I-NS	N
Snappy Mart #19	30653	Snappy Mart Stores	1810 Swan St	Silver City	I-NS	N
Snappy Mart #4	30652	Snappy Mart Stores	206 N Hudson	Silver City	C-NS	N
Snappy Mart 256	1804	Bell Gas Inc.	US Hwy 180	Silver City	PI-C	U
The Price Company	31084	TPRC Inc	803 S Bard	Silver City	C-NS	N
Victory Self Service	31495	Happy Girls LLC	Self Serve	Silver City	I-NS	U

Source: NMED web site (www.nmenv.state.nm.us/ust/leakcity.html)

[a] C-NS = Cleanup, no settlement agreement
C-S = Cleanup, settlement agreement
I-NS = Investigation, no settlement agreement
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M-S = Monitoring, settlement agreement
PI-C = Pre-investigation, confirmed release
PI-S = Pre-investigation, suspected release

[b] N = No
U = Unknown
Y = Yes

5.4.2.2 Mining

The prevalence of mining in Catron, Grant, Hidalgo, and Luna Counties makes mine sites an important consideration for protection of groundwater quality in the planning region. Active mining operations are registered with the Mining and Minerals Division (MMD) of the New Mexico Energy, Minerals and Natural Resources Department (NMEMNRD). An excerpt from the publication *Mines, Mills and Quarries in New Mexico* (NMEMNRD, 2001), which contains general information on the mines and mills operating in the Southwest Region, is provided in Appendix D7. Quarries for sand and gravel extraction are not generally considered potential contaminant sources and are not included.

Most of the groundwater problems associated with Luna and Hidalgo Counties and the southeast parts of Grant County are from sulfates, metals, TDS, and low pH. The primary sources for these contaminants are heap-leach, copper milling, and lead milling operations. Two major copper mines in the region are the Chino Mine (located 10 miles east of Silver City off New Mexico Highway 180) and the Tyrone Mine (located 10 miles southwest of Silver City off New Mexico Highway 90). As detailed in their supplemental discharge permits for closure that were issued in 2003 (NMED, 2003a, 2003c), both mines encompass more than 9,000 acres each and include numerous stockpiles, tailing ponds, and several open pits. These closure permits contain conditions to prevent exceedances of groundwater quality standards after mining operations stop.

Currently, regional groundwater at the Chino Mine has a TDS concentration between 300 and 1,500 mg/L (NMED, 2003a), and there is a 22-mile TDS and sulfate plume extending from the mine (NMED, 2003f). Groundwater at the Tyrone Mine in the regional aquifer ranges from 210 to 1,500 mg/L for TDS (NMED, 2003c). The NMED has noted groundwater quality exceedances for operational discharge permits (Section 5.4.2.3) at both mines (NMED, 2003f).

Many more abandoned mining operations are scattered throughout the mining districts of this region. These mines present a potential threat to groundwater quality because of some of the toxic compounds used in mineral extraction, including mercury and cyanide. Abandoned mines can also generate poor water quality due to groundwater flow through mine workings and stormwater flow and seepage through waste rock, tailings, and slag. The Cleveland Mill site north of Silver City was previously listed as a Superfund site (Section 5.4.2.4).

5.4.2.3 Groundwater Discharge Plans

The NMED Ground Water Quality Bureau regulates facilities with wastewater discharges that have a potential to impact groundwater quality. These facilities must comply with the NMWQCC Regulations and obtain approval of a discharge plan, which provides for measures needed to prevent and detect groundwater contamination. A variety of facilities fall under the discharge plan requirements, including mines, sewage dischargers, dairies, food processors, sludge and septage disposal, and other industries. The discharge plans (NMED, 2003e) in the Southwest Region are listed in Table 5-21.

The NMWQCC Regulations require cleanup of groundwater contamination if detected under discharge plan monitoring requirements. Regardless, any contamination discharged by these facilities still affects the quantity and availability of water supplies. Details indicating the status of discharge plan, waste type, and treatment for individual permittees can be obtained from the NMED website (www.nmenv.state.nm.us/gwb/Web%20site-DPS.xls).

5.4.2.4 Superfund Sites

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund, was enacted by the U.S. Congress on December 11, 1980. This law created the Superfund program to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment. U.S. EPA (2003a) maintains a list of sites (CERCLIS database) that have been or are being considered for potential listing as “Superfund” sites on the National Priorities List (NPL). Although 11 sites in the Southwest Region are being or have been investigated as potential Superfund sites (Table 5-22), the CERCLIS database currently includes no sites in the Southwest Region on the NPL, and the Cleveland Mill site was deleted from the final NPL in 2001 with no further action planned. The status of the remaining sites is listed in Table 5-22.

Table 5-21. Groundwater Discharge Permits in the Southwest Region
Page 1 of 4

County	City	Facility Name	Waste Type	Treatment	Discharge
Catron	Glenwood	Challenge Mill Site	Milling	Metallurgical extraction	Tailing pond
	Quemado	Pueblo Largo Subdivision	Unincorporated area	Septic tank	Leach field
	Reserve	Reserve Wastewater Treatment	Municipality	Wastewater treatment plant	Land application
Grant	Bayard	Chino Mines–Ivanhoe Conc. & Pipelines	Milling	Metallurgical extraction	Tailing pond
	Bayard	Chino North Pit Leach And Main Pit	Mine water	Metallurgical extraction	Dump leach
	Bayard	Chino-Dam & Reservoir 3	Mine water	Lagoon	Evaporation lagoon
	Bayard	No. Hurley Ph 1 Sewer	Unincorporated area	Septic tank	Leach field
	Central, NM	Manhattan Apartments	Sanitation district	Constructed wetlands	Land application
	Deming	NM Highway Department–Yucca	State agency/ organization	Septic tank	Leach field
	Fierro	Continental Mine–Tailings Ponds/Wasterock/ Mills	Mine water	Metallurgical extraction	Tailing pond
	Fierro	Continental Mine-Fierro/Humbolt Leach Pads,SX/EW	Mine water	Metallurgical extraction	Heap leach
	Hanover	Chino-Lampbright Leach	Mine water	Metallurgical extraction	Dump leach
	Hanover	Chino-Whitewater Leach	Mine water	Metallurgical extraction	Dump leach
	Hanover	Chino Mines Co SX/EW	Mine water	Metallurgical extraction	Heap leach
	Hurley	Chino-Smelter, Old Tailings, Lake1, AXIFL0, WW Creek	Mine water	Metallurgical extraction	Tailing pond
	Hurley	Chino Mines–Tailings Pond #7	Milling	Metallurgical extraction	Tailing pond
	Pinos Altos	Continental Divide RV Park 1	Campground/RV park	Lagoon	Land application
	Pinos Altos	Sapillo Crossing Lodge	Lodging	Septic tank	Leach field
	Santa Rita	Sierra Corporation	Milling	Metallurgical extraction	Heap leach
	Silver City	Mimbres Christian Camp	Lodging	Septic tank	Leach field
	Silver City	Silver City (City of)–WWTP	Municipality	Wastewater treatment plant	Land application
	Silver City	Silver City West MHP	Unincorporated area	Septic tank	Leach field

Source: NMED Ground Water Quality Bureau web site (www.nmenv.state.nm.us/gwb/Web%20site-DPS.xls)

Table 5-21. Southwest New Mexico Regional Water Plan Groundwater Discharge Permits
Page 2 of 4

County	City	Facility Name	Waste Type	Treatment	Discharge
Grant	Silver City	Sedonia Development	Sanitation district	Septic tank	Land application
	Silver City	North Hurley Wetlands–Phases II and III	Sanitation district	Septic tank	Leach field
	Silver City	Peaceful Valley Trailer Park	Mobile home park	Septic tank	Land application
	Silver City	Jeff Glenn Ranch	Feedlot	Wastewater treatment plant	Land application
	Silver City	Hamilton Construction–Arenas	Vehicle/equipment wash	None	Holding tank
	Silver City	Silver City (City of)–Sludge	Sludge disposal facility	Wastewater treatment plant	Shallow trenches
	Silver City	Cyprus Pinos Altos Mine	Underground	None	Evaporation lagoon
	Silver City	Bellwood Enterprises	Unincorporated area	Constructed wetlands	Land application
	Tyrone	P-D Tyrone Mangus Valley Tailings	Milling	Metallurgical extraction	Tailing pond
	Tyrone	Tyrone Townsite Lagoons	Unincorporated area	Lagoon	Evaporation lagoon
	Tyrone	Leach Dump #1	Mine water	Metallurgical extraction	Dump leach
	Tyrone	P-D Tyrone 2 Leach Dump	Mine water	Metallurgical extraction	Dump leach
	Tyrone	Pd Tyrone No 3 Leach System	Mine water	Metallurgical extraction	Dump leach
	Tyrone	P-D Tyrone No 1a Leach Dump	Mine water	Metallurgical extraction	Dump leach
	Tyrone	P-D Tyrone 1b Leach Dump	Mine water	Metallurgical extraction	Dump leach
	Tyrone	P-D Tyrone 1c Waste Stockpile	Mine water	Metallurgical extraction	Other
	Tyrone	P-D Tyrone 2a Leach Dump	Mine water	Metallurgical extraction	Dump leach
	Tyrone	P-D Tyrone-Gettysberg Leach Dump	Mine water	Metallurgical extraction	Dump leach
	Tyrone	P-D Tyrone East Main Pit Leach Dump	Mine water	Metallurgical extraction	Dump leach
	Tyrone	P-D Tyrone Little Rock	Mine water	None	
	Tyrone	P-D Tyrone Facility Closure [a]	NA	NA	NA
	Virden	Center Mine	Milling	None	Tailing pond
Grant/Luna		Chino Mines Facility Closure [b]	NA	NA	NA

Source: NMED Ground Water Quality Bureau web site (www.nmenv.state.nm.us/gwb/Web%20site-DPS.xls)

[a] Supplemental discharge permit for closure DP-1341, issued April 8, 2003 (NMED, 2003c).

[b] Supplemental discharge permit for closure DP-1340, issued February 24, 2003 (NMED, 2003a).

NA = Information not yet posted to NMED's web site listing discharge permts.

Table 5-21. Southwest New Mexico Regional Water Plan Groundwater Discharge Permits
Page 3 of 4

County	City	Facility Name	Waste Type	Treatment	Discharge
Hidalgo	Cotton City	Santa Fe Ingredients Company	Chile plant	Other	Land application
	Lordsburg	Westar Corporation	Mine water	Metallurgical extraction	Heap leach
	Lordsburg	Lordsburg (City of)–WWTP	Unincorporated area	Wastewater treatment plant	Infiltration basin
	Lordsburg	Lordsburg (City of)–Sludge	Unincorporated area	Wastewater treatment plant	Land application
	Lordsburg	Evergreen Energy, Lordsburg Energy Facility		Lagoon	Evaporation lagoon
	Lordsburg	Hidalgo Railcar	Mining	Lagoon	Evaporation lagoon
	Playas	P-D Hidalgo Smelter	Mine water	Metallurgical extraction	Evaporation lagoon
	Playas	Playas Townsite Lagoons	Unincorporated area	Lagoon	Land application
		Pyramid Generating Facility	Generating station	None	
Luna	Cambray	Johnny's Septic Tank Liquid	Septage	Other	Land application
	Columbus	Columbus–Industrial Park	Manufacturing	Wastewater treatment plant	Evaporation lagoon
	Columbus	Sun Foundation WWTP	Unincorporated area	Lagoon	Evaporation lagoon
	Columbus	Columbus (Village of)–WWTP	Municipality	Lagoon	E/T bed
	Deming	Pueblo De Luna Trailer Park	Unincorporated area	Septic tank	Leach field
	Deming	Deming (City of)–WWTP	Municipality	Wastewater treatment plant	Land application
	Deming	Bowlin's Butterfield Station	Restaurant/bar	Other	Evaporation lagoon
	Deming	M & I Portable Toilet Rental	Septage	Other	Land application
	Deming	Sundance Chile Products	Chile plant	None	Land application
	Deming	New Mexico Chile Products	Chile plant	None	Land application
	Deming	Ledesma's Septic Tank Service	Septage disposal facility	None	Land application
	Deming	Border Foods Inc.	Chile plant	Lagoon	Land application

Source: NMED Ground Water Quality Bureau web site (www.nmenv.state.nm.us/gwb/Web%20site-DPS.xls)

[a] Supplemental discharge permit for closure DP-1341, issued April 8, 2003 (NMED, 2003c).

[b] Supplemental discharge permit for closure DP-1340, issued February 24, 2003 (NMED, 2003a).

NA = Information not yet posted to NMED's web site listing discharge permts.

Table 5-21. Southwest New Mexico Regional Water Plan Groundwater Discharge Permits
Page 4 of 4

County	City	Facility Name	Waste Type	Treatment	Discharge
Luna	Deming	Amigo's Mexican Foods Inc	Cheese, milk, or food process	Septic tank	Land application
	Deming	NM Highway Dept–Gage	State agency/ organization	Septic tank	Leach field
	Deming	American Minerals Deming	Milling	Lagoon	Tailing pond
	Deming	Luna Energy Facility–Duke	Generating station		Evaporation lagoon
	Deming	Butterfield Dairy Farm	Dairy	Lagoon	Land application
	Deming	Marshall's Septage Service	Septage disposal facility	None	Land application
	Deming	Beacon Truck Stop	Truck stop	Septic tank	Leach field
	Deming	Turley Mines		Other	Other
	Deming	Diaz Dairy	Dairy	Lagoon	Land application
	Deming	3 M Hog Farm	Holding pen	Lagoon	Land application
	Deming	Cardiff Resources Inc		Metallurgical extraction	Tailing pond
	Deming	Hughes Septic Disposal	Septage	None	Land application
	Deming	Cyprus Deming Conc	Milling	Metallurgical extraction	Tailing pond
	Deming	Williams Cattle Trailer Wash	Vehicle/equipment wash	Lagoon	Land application
	Deming	Savoy Truck Stop	Truck stop	Septic tank	Leach field
	Hatch	Turner Dairy	Dairy	Lagoon	Land application
	Hatch	S & T Dairy		None	
	Lovington	Legen Dairy Inc	Dairy	Lagoon	Land application

Source: NMED Ground Water Quality Bureau web site (www.nmenv.state.nm.us/gwb/Web%20site-DPS.xls)

Table 5-22. Sites in the Southwest Region Included in the CERCLIS Database

Facility	Location	County	EPA ID	Site Status
Cleveland Mill	Silver City, NM	Grant	NMD981155930	Deleted from final NPL
Hearst Mill	Silver City, NM	Grant	NM0000037408	NFRAP
Mammoth Mill	Pinos Altos, NM	Grant	NM0001097716	NFRAP
Phelps Dodge Tyrone, Inc.	Tyrone, NM	Grant	NMD986684264	SI ongoing
San Vincente Creek Tailings	Silver City, NM	Grant	NMD980879415	NFRAP
Summit Mine	Mule Creek, NM	Grant	NM0001412022	NFRAP
Whitewater & Hanover Creeks	Silver City, NM	Grant	NMD986682763	Status not specified
Lake Roberts Lead	Lake Roberts, NM	Grant	NM0000605411	PA start needed
Highway 549 Solvents	Deming, NM	Luna	NM0000605167	Status not specified
Peru Hill Mill	Deming, NM	Luna	NMD097119986	Referred to removal; further assessment needed
Tulip Drive Landfill	Deming, NM	Luna	NM0000605379	SI start needed

Source: U.S. EPA, 2003

CERCLIS = Comprehensive Environmental Response, Compensation, and Liability Information System
EPA ID = U.S. Environmental Protection Agency identification number
NPL = National Priorities List

NFRAP = No further remedial action planned
SI = Site inspection
PA = Preliminary assessment

5.4.2.5 Landfills

Landfills used for disposal of municipal and industrial solid waste can contain a variety of potential contaminants that may impact groundwater quality. Landfills operated since 1989 are regulated under the New Mexico Solid Waste Management Regulations. Many small landfills throughout New Mexico, including landfills in the planning region, closed before the 1989 deadline in order to avoid more stringent final closure requirements. Within the planning region, there are currently 5 operating landfills, 3 private industrial operating landfills, 1 landfill with unknown status, and 14 closed landfills (Table 5-23) (NMED, 1990, 1996, 2000).

Table 5-23. Landfills in the Southwest New Mexico Counties Planning Region

Landfill Name	County	Operating Status	Closure Date
Datil	Catron	Closed	1989, 1996
Glenwood	Catron	Active	NA
Pie Town	Catron	Active	NA
Quemado	Catron	Closed	1995
Reserve	Catron	Active	NA
Last Frontier	Catron	Closed	1993
Southwest NM Regional	Grant	Active	NA
Old Silver City	Grant	Closed	1995
Tri City	Grant	Closed	1995
Hurley Smelter	Grant	Active	NA
Santa Rita	Grant	Active	NA
Tyrone Branch	Grant	Active	NA
Gila	Grant	Closed	1994
Hachita	Grant	Closed	1994
Chino Mines Co.	Grant	Unknown	Unknown
Lordsburg	Hidalgo	Closed	1997
Animas	Hidalgo	Closed	1997
Virden North	Hidalgo	Closed	1989
Virden South	Hidalgo	Closed	1989
Rodeo	Hidalgo	Closed	1989
Cotton City	Hidalgo	Closed	1989
Deming	Luna	Active	NA
Columbus	Luna	Closed	1998

Sources: NMED, 1990, 1996, 2000.

NA = Not applicable (landfill is still operating)

5.4.2.6 *Septic Systems*

A nonpoint source water quality concern in the planning region is groundwater contamination due to septic tank densities, particularly in the Deming and Lordsburg areas. In shallow water table areas, septic system discharges can percolate rapidly to the underlying aquifer and increase concentrations of several contaminants (NMWQCC, 2002):

- Total dissolved solids (TDS)
- Iron, manganese, and sulfides (anoxic contamination)
- Nitrate
- Potentially toxic organic chemicals
- Bacteria, viruses, and parasites (microbiological contamination)

Nitrate contamination is found in Lordsburg and Deming and is associated with high densities of septic tanks, cesspools, and publicly owned sewage facilities.

Because septic systems are generally spread out over rural areas, they are considered a nonpoint source. Collectively, septic tanks and other on-site domestic wastewater disposal constitute the single largest known source of groundwater contamination in New Mexico (NMWQCC, 2002), with many of these occurrences in the shallow water table areas.

5.4.2.7 *Salinity and Brackish Water Resources*

The southwestern closed basins (Animas, Playas, and Mimbres in particular) may contain substantial quantities of brackish waters that could be desalinated for use in the future. Although current demand is insufficient in light of the high cost of desalination, future population growth may someday create a demand for brackish reserves.

The Animas, Playas, and Mimbres Basins contain up to 2,500 feet or more of basin fill materials. Because salinity in water from these materials generally increases with depth, the water supply estimates presented in Section 5.3.2 of this report were determined using only the uppermost 600 feet of these deposits. In some locations, there may be as much as 1,500 feet of brackish water. To date, very little investigation of these deeper resources has been conducted. Although use of brackish waters may never be economically feasible for agricultural use, municipalities such as Columbus, Deming, and Lordsburg might consider desalination a viable alternative for meeting future demand.

5.4.3 Summary of Water Quality by County

The following discussion summarizes the overall water quality for each of the counties in the Southwest Region, beginning with Catron County in the northern part of the region and moving generally southward (Figure 1-1). Water quality in the region is illustrated in Figures A2-9 through A2-12.

- *Catron County:* In general, the water quality is good. However, in the Zuni Salt Lake area the water is very saline (Basabilvazo, 1997). According to the NMWQCC (2002), the salinity problems have been addressed by the Interstate Stream Commission. NMWQCC (2002) reports 6 cases of point source contamination of groundwater and 20 contaminated supply wells in Catron County.

- *Grant County:* The groundwater quality is generally good except in mining areas, where water has been impacted by sulfates, metals, and TDS (Figures A2-9 and A2-10). Relatively high concentrations of nitrate, some exceeding the drinking water standard (Figure A2-11), are also observed at several locations in the county. Elevated levels of nitrate are usually attributed to sources such as fertilizer application, septic tank discharge, or surface waterbodies that receive some form of effluent. Fluoride is another naturally occurring inorganic solute that sometimes occurs at elevated or problematic concentrations in groundwater in the county. However, in the Hayes well field, fluoride levels are well below the EPA standard when mixed with water from other wells (Gordon et al., 1993). NMWQCC (2002) reports 34 cases of point source contamination of groundwater and 48 contaminated wells in Grant County.

- *Hidalgo County:* Where present, surface water is generally of good quality. The groundwater quality is also generally very good except in the Lordsburg area, where high densities of septic tanks and drain fields have raised nitrate levels locally. NMWQCC (2002) reports 6 cases of point source contamination of groundwater and

31 contaminated wells in Hidalgo County. The area north of Animas exhibits high sulfate concentrations, which have been associated with dissolution of evaporites in the area (Elston et al., 1983).

- *Luna County:* Where present, surface water is generally of good quality. However, groundwater quality concerns exist due to septic tank discharges. In addition, the area north of Deming has a moderate salinity problem, which worsens towards the southeast part of the county, where the water is too saline for some types of agriculture (Hanson et al., 1994). In Deming, industrial operations are the suspected source for groundwater contamination by chlorinated solvents. NMWQCC (2002) reports 15 cases of point source contamination of groundwater and 19 contaminated supply wells in Luna County. An inorganic constituent (arsenic) that occurs naturally in groundwater will likely be of concern to Luna County because of a reduction in the arsenic maximum contaminant level (MCL) that will become effective in January 2006. Naturally occurring regional groundwater commonly exceeds the new 10-microgram per liter (μg/L) (0.010-mg/L) MCL (Figure A2-12).