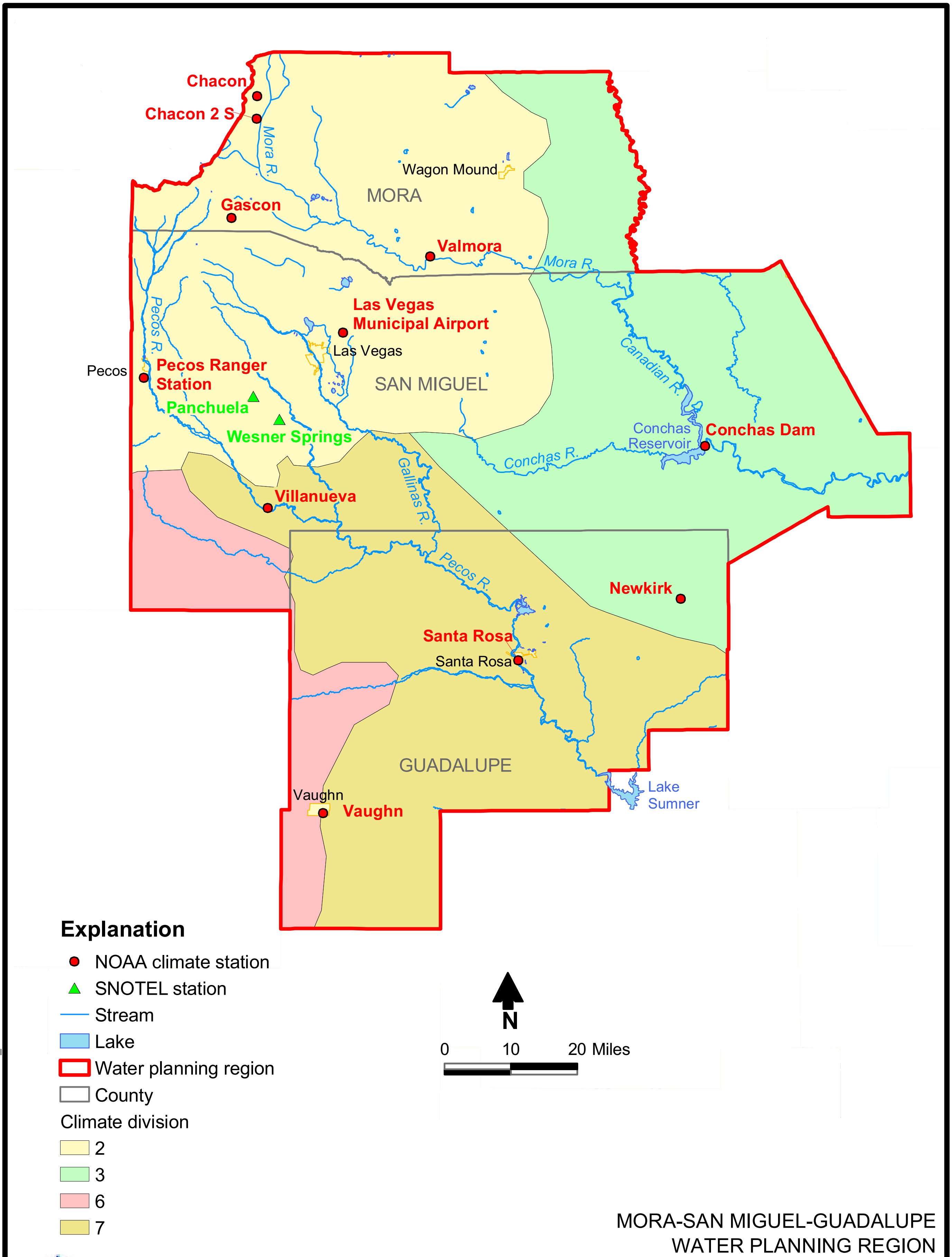
5. Water Supply

This section provides an overview of the water supply in the Mora-San Miguel-Guadalupe Water Planning 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 A. 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 Summary of Climate Conditions

The varied terrain of the Mora-San Miguel-Guadalupe Water Planning Region, which ranges from the Rocky Mountains to the High Plains, 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.

A number of climate data collection stations are located in Mora, San Miguel, and Guadalupe Counties, 11 of which (Figure 5-1) were selected for more detailed analysis. Table 5-1 lists the periods of record for all the weather stations in the three counties and identifies the 11 stations analyzed in more detail. These 11 stations were selected based on location, how well they represented conditions in their respective counties, and completeness of their historical records. In addition to the climate stations, data were available from two snowpack telemetry (SNOTEL) stations and were used to document snowfall in the Sangre de Cristo Mountains. Information on the SNOTEL stations is also provided in Table 5-1.



MORA-SAN MIGUEL-GUADALUPE
WATER PLANNING REGION
Climate Stations

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Figure 5-1

Table 5-1. Mora-San Miguel-Guadalupe Climate Stations
Page 1 of 2

Climate Stations [a]	Data Start	Data End	Latitude	Longitude	Elevation	Source
Mora County						
Chacon	07/01/1946	09/19/1985	36°10'N	105°23'W	8499.8	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Chacon 2 S	09/19/1985	12/31/1997	36°07'N	105°23'W	8051.1	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Gascon	11/01/1953	Present	35°54'N	105°27'W	8247.9	www.wrcc.dri.edu/summary/climsmnm.html
La Cueva	07/01/1947	09/30/1950	35°56'N	105°13'W	7022.2	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Levy	07/01/1946	01/31/1962	36°05'N	104°41'W	6251.4	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Ocate 1 N	08/01/1960	Present	36°11'N	105°04'W	7652.9	www.wrcc.dri.edu/summary/climsmnm.html
Optimo	01/01/1941	01/06/1959	35°54'N	104°43'W	6402.2	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Valmora	03/01/1917	Present	35°49'N	104°55'W	6310.4	www.wrcc.dri.edu/summary/climsmnm.html
San Miguel County						
Bell Ranch	07/01/1946	Present	35°32'N	104°06'W	4498.8	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Conchas Dam	07/01/1946	Present	35°24'N	104°11'W	4243.0	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Cowles	06/01/1954	11/09/1964	35°49'N	105°40'W	8104.9	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Cowles	10/01/1949	07/31/1952	35°49'N	105°39'W	8803.8	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Las Vegas 1 ENE	07/01/1946	10/31/1971	35°36'N	105°13'W	6442.2	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Las Vegas 2 NW	10/01/1971	06/16/1983	35°37'N	105°16'W	6602.3	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Las Vegas 4 NW	05/01/1967	06/30/1969	35°38'N	105°16'W	6704.3	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Las Vegas Exp Plot	05/01/1938	02/28/1945	35°35'N	105°11'W	6504.2	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Las Vegas Municipal Airport	08/01/1932	Present	35°39'N	105°09'W	6864.4	www.wrcc.dri.edu/summary/climsmnm.html
Las Vegas Sewage Plant	06/17/1983	Present	35°34'N	105°13'W	6347.5	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Montezuma 8 NW	08/01/1971	10/01/1973	35°41'N	105°23'W	7242.2	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Onava	01/01/1931	12/31/1942	35°42'N	105°07'W	6704.3	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Pecos 11 SE	07/01/1996	09/01/2001	35°26'N	105°34'W	6798.1	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Pecos Ranger Station	01/01/1916	Present	35°33'N	105°41'W	6876.2	www.wrcc.dri.edu/summary/climsmnm.html
Rencona	07/01/1946	01/10/1972	35°17'N	105°36'W	7003.1	www.ncdc.noaa.gov/oa/climate/stationlocator.html

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

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Table 5-1. Mora-San Miguel-Guadalupe Climate Stations
Page 2 of 2

Climate Stations [a]	Data Start	Data End	Latitude	Longitude	Elevation	Source
San Miguel County (continued)						
Ribera	03/01/1950	04/15/1965	35°22'N	105°27'W	6104.4	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Sanchez	07/01/1946	09/30/1976	35°37'N	104°26'W	4903.6	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Serafina 6 WNW	01/01/1949	03/31/1950	35°25'N	105°25'W	6504.2	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Tererro	07/01/1946	08/31/1961	35°46'N	105°40'W	7505.0	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Trujillo	07/01/1946	04/30/1957	35°32'N	104°42'W	6461.3	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Villanueva	07/01/1947	Present	35°16'N	105°21'W	5763.6	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Guadalupe County						
Cuervo	12/01/1932	05/31/1952	35°02'N	104°25'W	4843.0	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Dilia 1 SSE	07/01/1946	Present	35°11'N	105°03'W	5150.0	www.wrcc.dri.edu/summary/climsmnm.html
Gennetti Ranch	01/01/1953	01/31/1974	34°41'N	104°39'W	5003.0	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Newkirk	07/01/1946	Present	35°04'N	104°15'W	4564.0	www.wrcc.dri.edu/summary/climsmnm.html
Pastura	07/01/1946	04/30/1956	34°47'N	104°57'W	5292.0	www.wrcc.dri.edu/summary/climsmnm.html
Pastura 6SSE	04/01/1956	03/31/1957	34°42'N	104°55'W	5413.0	www.wrcc.dri.edu/summary/climsmnm.html
Santa Rosa	07/01/1946	Present	34°56'N	104°41'W	4610.0	www.wrcc.dri.edu/summary/climsmnm.html
Santa Rosa 12 SE	08/01/1963	01/26/1967	34°48'N	104°33'W	4603.0	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Santa Rosa 17 SE	05/01/1967	08/14/1967	34°46'N	104°29'W	4482.0	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Santa Rosa Highway 66	07/01/1947	03/31/1975	34°56'N	104°41'W	4534.0	www.ncdc.noaa.gov/oa/climate/stationlocator.html
Vaughn	07/01/1946	09/11/1981	34°36'N	105°12'W	5974.0	www.wrcc.dri.edu/summary/climsmnm.html
SNOTEL Stations						
Wesner Springs	06/23/1939	Present	35°46'N	105°32'W	11120.0	http://www.wrcc.dri.edu/inventory/snotelNM.html
Panchuela	12/21/1991	Present	35°51'N	105°39'W	8300.0	http://www.wrcc.dri.edu/inventory/snotelNM.html

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

5.1.1 Temperature

Appendix E1 includes graphs of the long-term monthly average, minimum, and maximum temperatures at the eight climate stations for which temperature data are available (temperature data are not available for the Chacon, Chacon 2 S, and Villanueva stations), and Table 5-2 presents minimum, maximum, and average annual temperatures for these stations. As shown in Table 5-2, the average temperature at the eight stations with available data for 1950 through 2002 was mainly dependent on geographic region, with temperatures at higher elevations in Mora and western San Miguel Counties ranging from about 44°F to 49°F and temperatures at lower elevations in Guadalupe County and eastern San Miguel County ranging from 53°F to 59°F. No long-term increasing or decreasing trend in average annual temperatures is apparent at these locations during the last 50 years (Appendix E1).

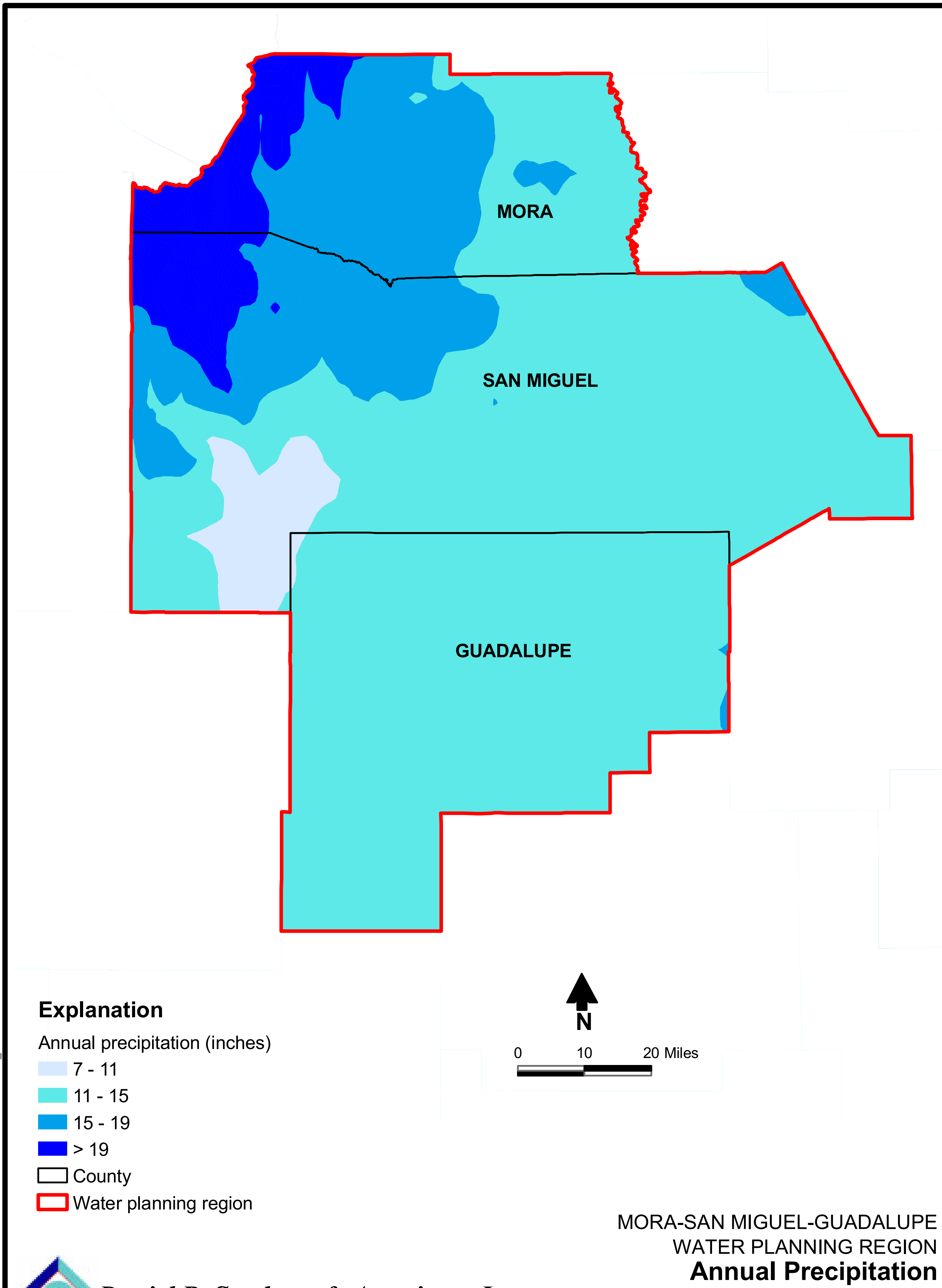
5.1.2 Precipitation

Precipitation varies considerably across the planning 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), or southwest (Gulf of Mexico), and the particular mix of temperatures and moisture varies depending on the origin of the system. Table 5-2 shows the maximum, minimum, and long-term average annual precipitation (rainfall and snowmelt) at the 11 representative stations in the planning region, and Appendix E1 contains graphs showing the long-term annual and average monthly precipitation amounts at these stations. Average annual precipitation, including both snowmelt and rainfall, ranges from about 12 to 24 inches (Table 5-2). Contoured precipitation throughout the planning region is illustrated in Figure 5-2 and in Figure B-5.

Annual precipitation amounts for the 11 representative stations vary substantially by location and year (Appendix E1). As indicated by Figure 5-3, which shows the average annual precipitation (for the period studied) at each station in relation to its elevation, there is a general trend toward increasing precipitation with increasing elevation within the planning region.

Table 5-2. Temperature and Precipitation for Representative Climate Stations
Mora-San Miguel-Guadalupe Planning Region

Station Name	Elevation (feet msl)	Precipitation				Temperature			
		Annual Average	Annual Minimum	Annual Maximum	% of Possible Observations	Annual Average	Average Minimum	Average Maximum	% of Possible Observations
Chacon/Chacon 2S	8275	24.06	9.11	35.14	87	NA	NA	NA	NA
Gascon	8247	23.91	9.77	32.94	100	44.0	28.6	59.4	100
Valmora	6310	16.87	6.56	27.22	94	49.3	32.4	66.2	87
Conchas Dam	4244	14.27	6.35	29.56	100	59.1	56.5	62.2	84
Las Vegas Municipal Airport	6864	16.64	5.41	27.79	100	49.7	35.2	64.2	93
Pecos Ranger Station	6876	16.10	9.82	25.34	81	49.0	32.6	65.3	56
Villanueva	5763	12.17	0.91	24.88	70	NA	NA	NA	NA
Newkirk	4564	14.75	4.76	37.46	92	57.7	56.1	59.6	55
Santa Rosa	4610	14.55	6.63	34.97	99	58.0	54.3	60.6	84
Vaughn	5974	12.87	5.1	29.95	87	53.2	51.3	55.2	45



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MORA-SAN MIGUEL-GUADALUPE
WATER PLANNING REGION
Annual Precipitation

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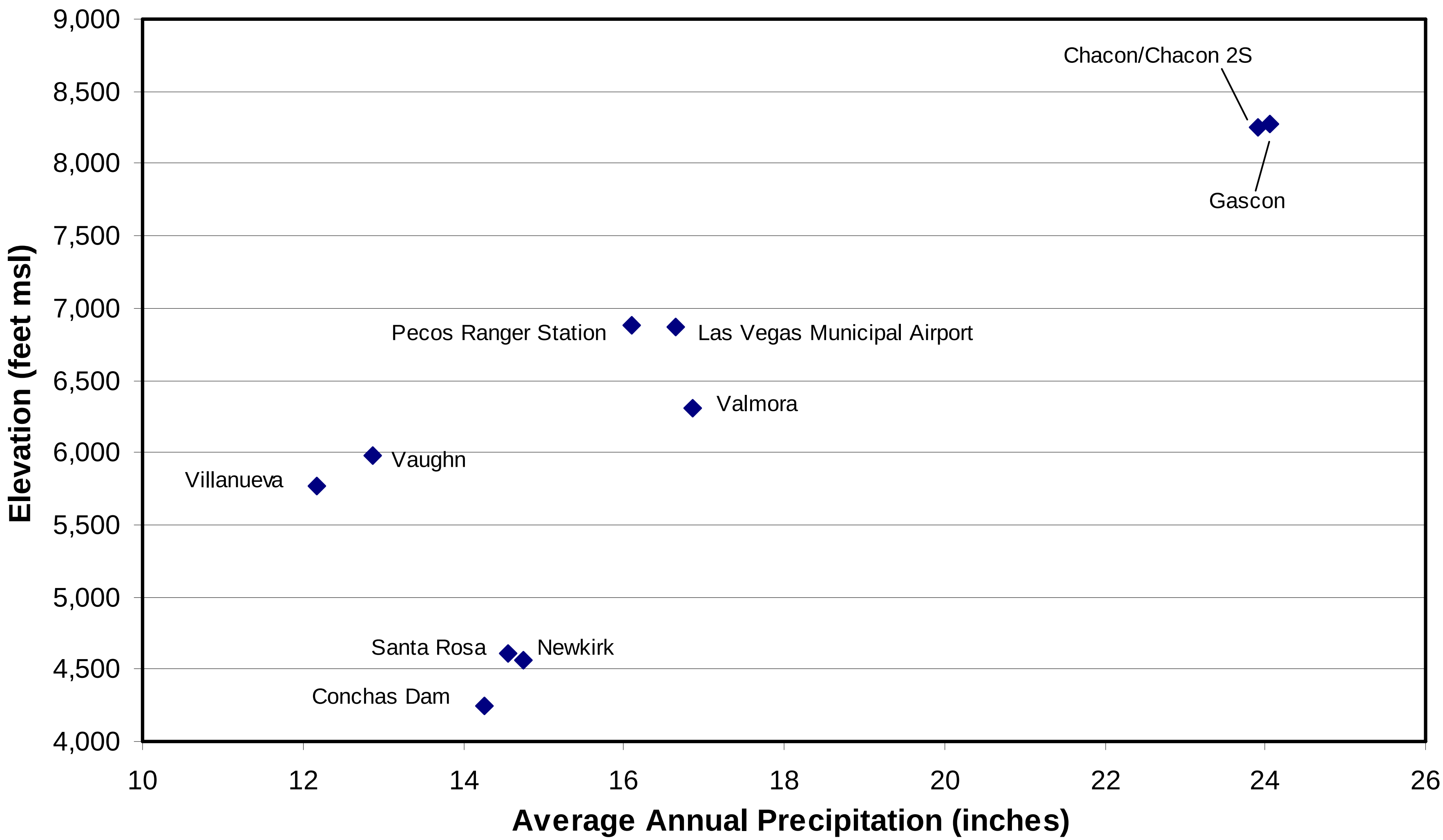
Figure 5-2



MORA-SAN MIGUEL-GUADALUPE WATER PLANNING REGION

Precipitation as a Function of Elevation

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7/1/05

Figure 5-3

5.1.2.1 Snowpack Monitoring

Two SNOTEL stations are located within Mora and San Miguel Counties, both of which provide both rainfall and snow water equivalent (SWE) data (Table 5-1). The Wesner Springs SNOTEL site, located at 11,120 feet above mean sea level (ft msl) on the eastern flank of the Sangre de Cristo Mountains, measures snowpack above the headwaters of the Canadian River. The Panchuela SNOTEL site is located at 8,400 ft msl near the headwaters of the Pecos River, just north of Cowles, New Mexico. Both stations have been active only since 1990. Appendix E1 contains graphs of the daily SWE for the two stations over the past decade. SWEs at Wesner Springs have been relatively consistent over this period of time, while SWEs at Panchuela have fluctuated considerably.

5.1.2.2 The Palmer Drought Severity Index

Consulting drought indices can aid in water supply and agricultural planning and decision making. 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. The PDSI was created by W.C. Palmer (1965) to measure the variations in the moisture supply and is based upon the supply-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 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 an assessment of the weather during any time period relative to historical conditions. The PDSI classifications for dry to wet periods are provided in Table 5-3.

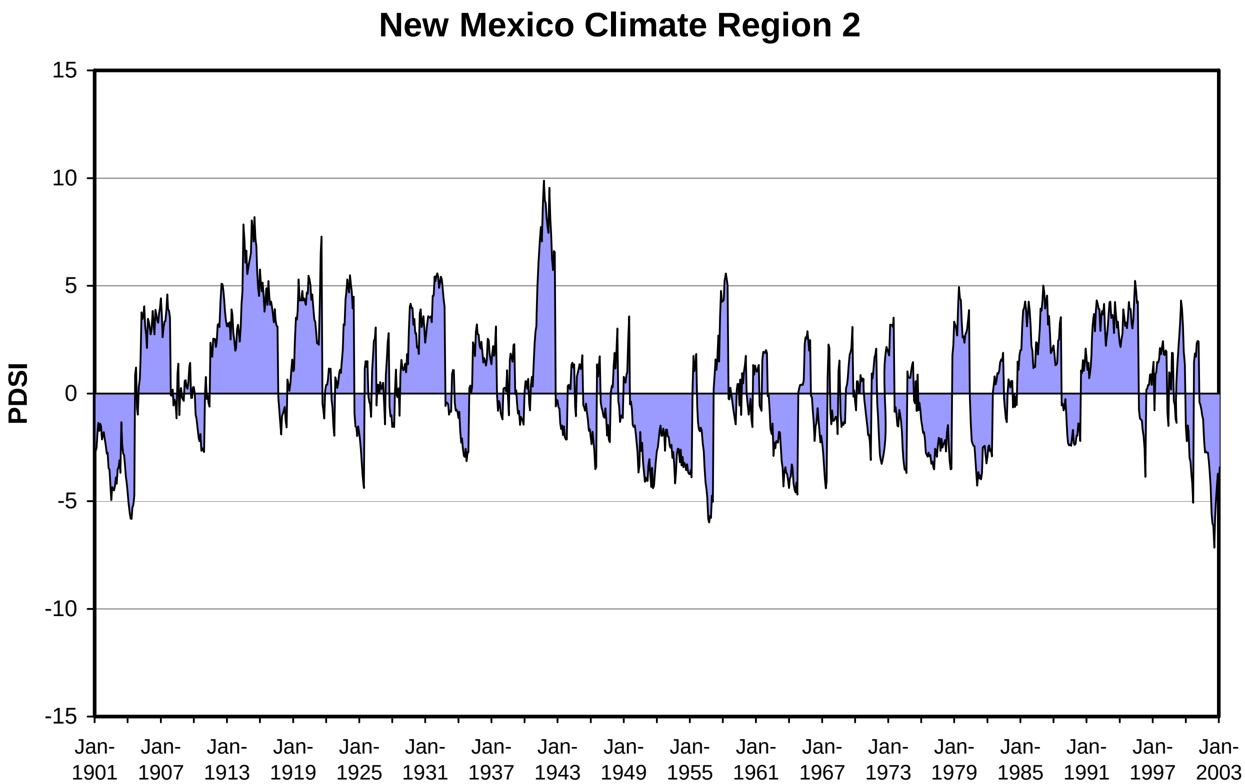
There are considerable limitations when using the PDSI, as described by Alley (1984) and Karl and Knight (1985). One drawback of the PDSI is that it does not adequately represent conditions in regions that have extremely variable rainfall, runoff, or elevation (Smith et al., 1993). The PDSI may also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

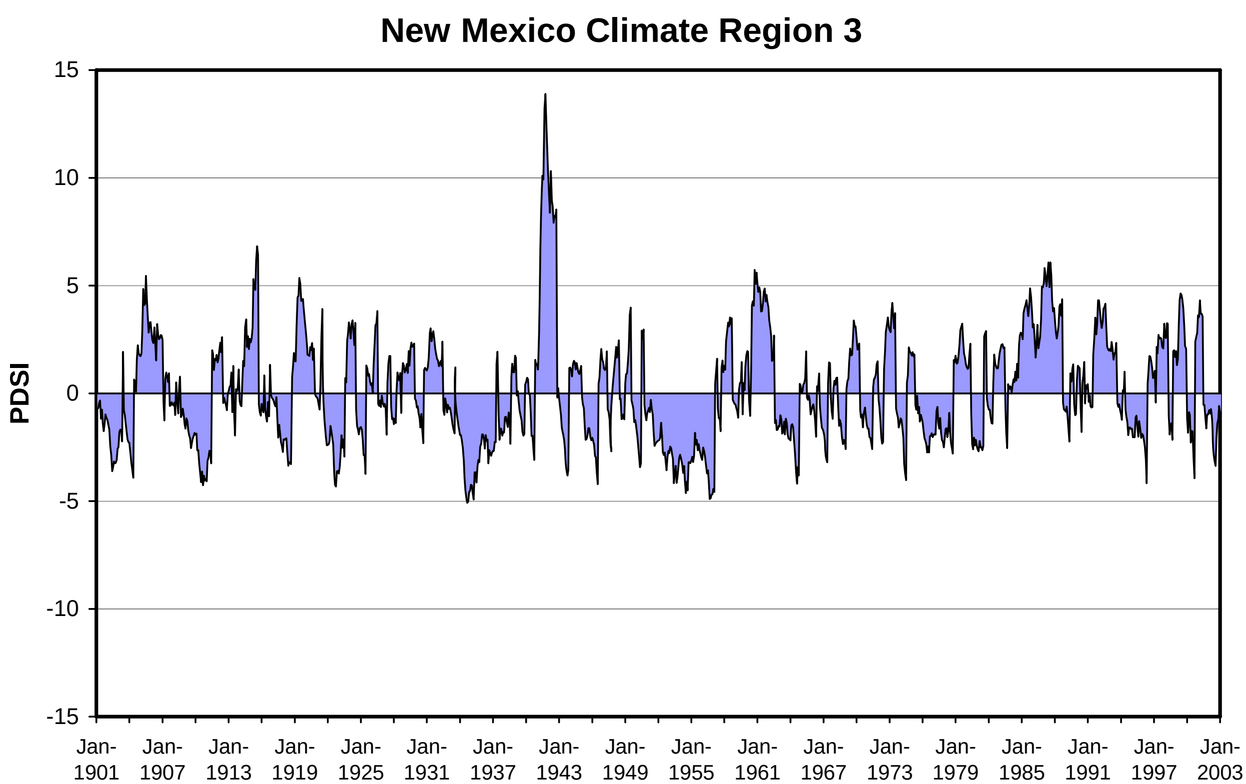
Table 5-3. Palmer Drought Severity Index Classifications

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

The PDSI is calculated for climate divisions throughout the United States. Mora County falls entirely within New Mexico Climate Region 2, the Northern Mountains Climate Region (Figure 5-1), and San Miguel County falls mainly within Region 2 and the Northeastern Plateau Climate Regions (Region 3). Figure 5-4a shows the long-term PDSI for these two regions. Guadalupe County and parts of San Miguel County fall within New Mexico Climate Regions 6 and 7; graphs of the PDSI for these regions are shown in Figure 5-4b. Of interest are the large variations from year to year in all four divisions, which are similar in pattern though not necessarily in magnitude. Three important aspects noticeable in Figures 5-4a and 5-4b are the lack of a distinct trend in recent times, the pronounced variability, and lowest PDSI seen in Climate Region 2 in 2002.

The chronological history of drought, as illustrated on Figures 5-4a and 5-4b, indicates that the most severe droughts in the last century occurred in the early 1900s, the 1950s, and the early 2000s. In addition to the shortage of water for human use, drought is responsible for or contributes to catastrophic wildfires, plant and wildlife mortality (Gutzler, 2003; Betancourt, 2003; Shorey, 2005), failed crops and idled croplands, loss of rangeland and agricultural land (Chambers, 1935; U.S. Water News Online, 1996; American Farmland Trust; 2005), and it heightens battles over endangered species protections and interstate water agreements (Holmes, 2002; Bell; 2004). In the extreme, drought is thought to have contributed to the collapse of prehistoric civilizations (Gutzler, 2003).





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MORA-SAN MIGUEL-GUADALUPE WATER PLANNING REGION

Palmer Drought Severity Index
New Mexico Climate Divisions 2 and 3

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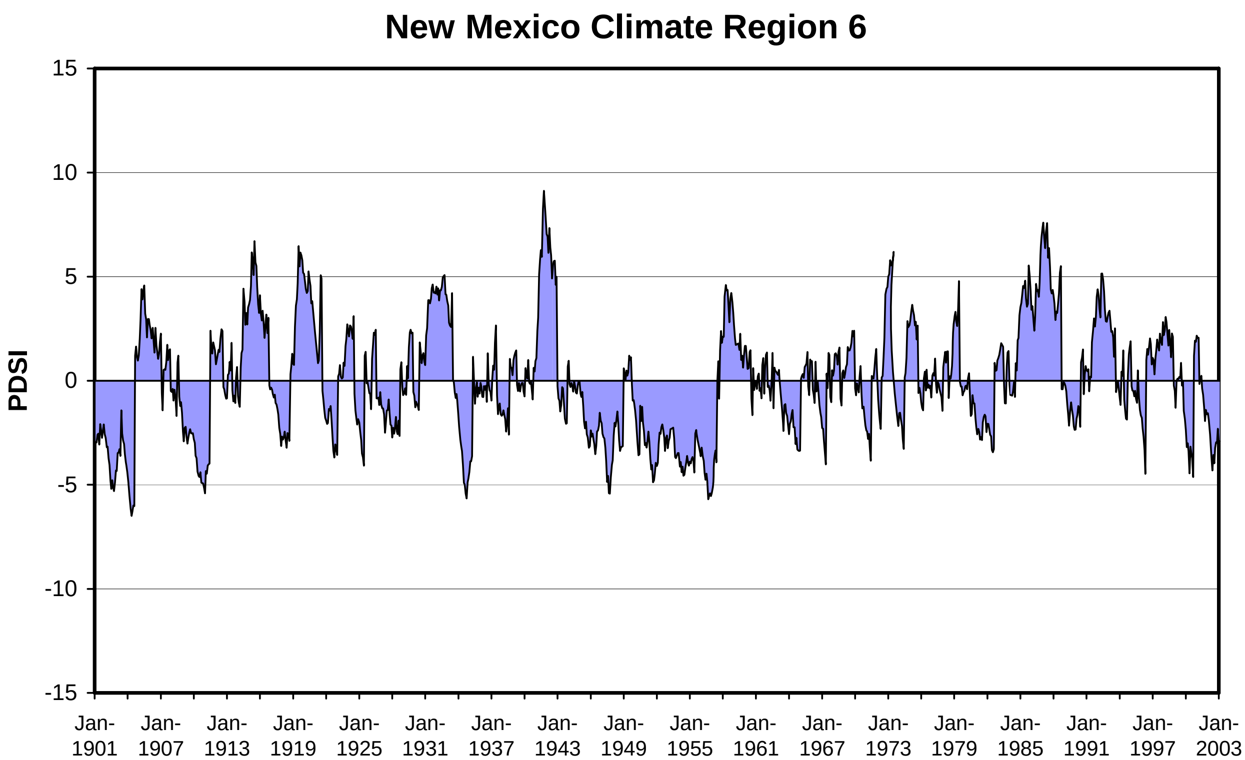
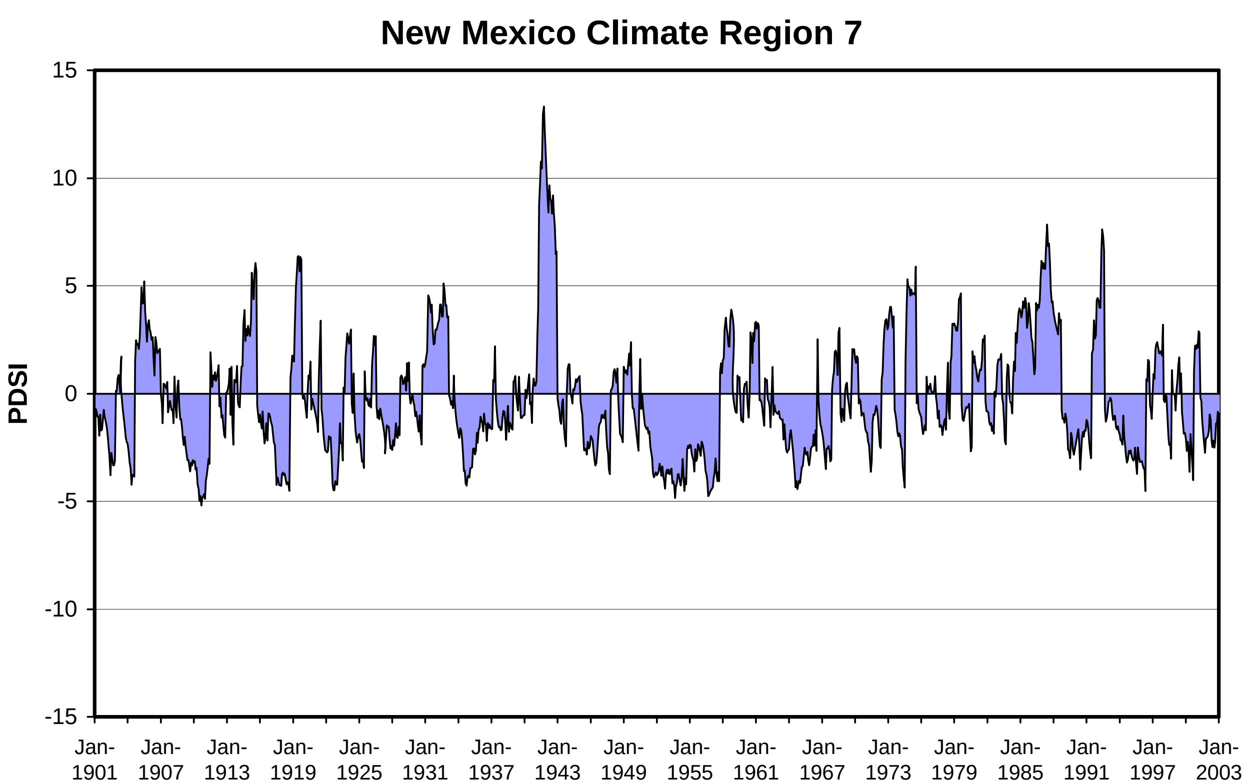
Figure 5-4a





MORA-SAN MIGUEL-GUADALUPE WATER PLANNING REGION

Palmer Drought Severity Index
New Mexico Climate Regions 6 and 7

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7/1/05

Figure 5-4b

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5.1.2.3 Pacific Decadal Oscillation Index

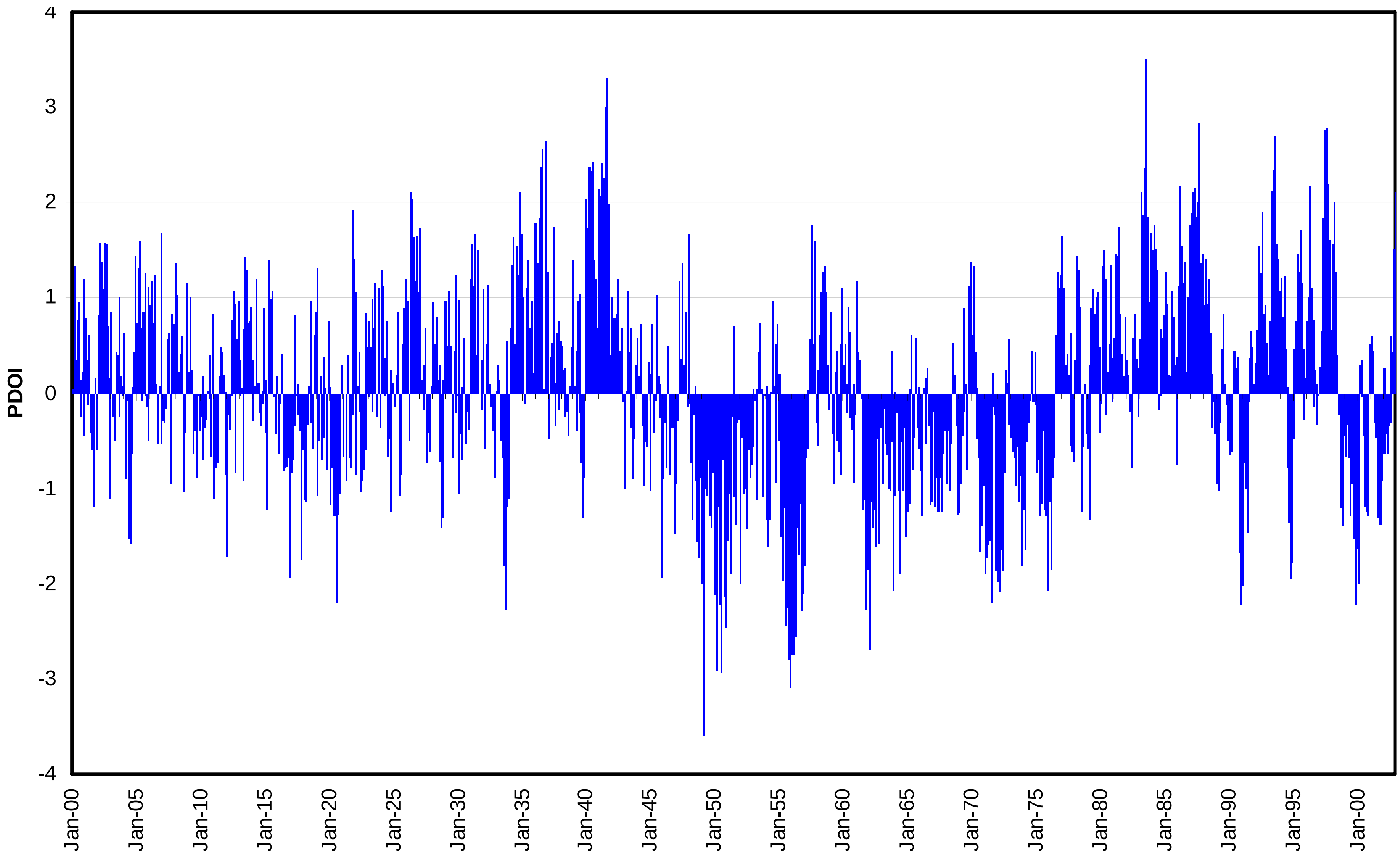
The Pacific Decadal Oscillation (PDO) is a long-lived El Niño-like pattern of climate variability due to fluctuation of the Pacific Ocean that waxes and wanes approximately every 20 to 30 years. Fisheries scientist Steven Hare coined the term in 1996 while researching connections between Alaska salmon production cycles and Pacific climate (Mantua, 2000). Much like the PDSI, the Pacific Decadal Oscillation Index (PDOI) serves as an indicator of climatic trends that can help predict long-term precipitation amounts. Figure 5-5 presents the PDOI over the past century.

The climate anomalies associated with the PDO are broadly similar to those associated with El Niño and La Niña, although they're generally not as extreme (Latif and Barnett, 1994; Trenberth and Hurrell, 1994; Latif and Barnett, 1996; Zhang et al., 1997; Mantua et al., 1997, as cited by Mantua, 2002). Warm phases of the PDO (shown as positive numbers on the PDOI) correspond to El Niño-like temperature and precipitation anomalies, while cool phases of the PDO (shown as negative numbers on the PDOI) correspond to La Niña-like climate patterns. PDO variability appears to influence regional snowpack and streamflow anomalies, especially in the western U.S. (Cayan, 1996; Mantua et al., 1997; Bitz and Battisti, 1999; Hamlet and Lettenmeier, 1999, as cited by Mantua, 2002), and may also influence summer rainfall and drought (Nigam et al., 1999, as cited by Mantua, 2002).

There is a strong relationship between the PDO and precipitation in New Mexico. During the last cool phase of the cycle (1947 through 1976), dry years outnumbered wet years nearly four to one (55 to 15 percent of the years), while during the last warm phase of the cycle (1977 through 1997), wet years outnumbered dry ones three to one (43 to 14 percent). The state's average precipitation was roughly 114 percent of normal during positive (warm-phase) PDO years.

5.1.2.4 Interpretation and Relevancy of PDSI and PDOI to Water Resources

As discussed in Section 5.1.2.2, the PDSI shows that large variations in precipitation are common, and in 2002, the PDSI in climate division 2, which covers the headwaters of the Pecos and Canadian Rivers, dipped to its lowest index value in more than 100 years. Tree ring



MORA-SAN MIGUEL-GUADALUPE WATER PLANNING REGION

Pacific Decadal Oscillation Index

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Figure 5-5

analyses conducted in various locations in the southwest have indicated that current moisture conditions in many areas are higher than the longer-term (500- to 1,000-year) record.

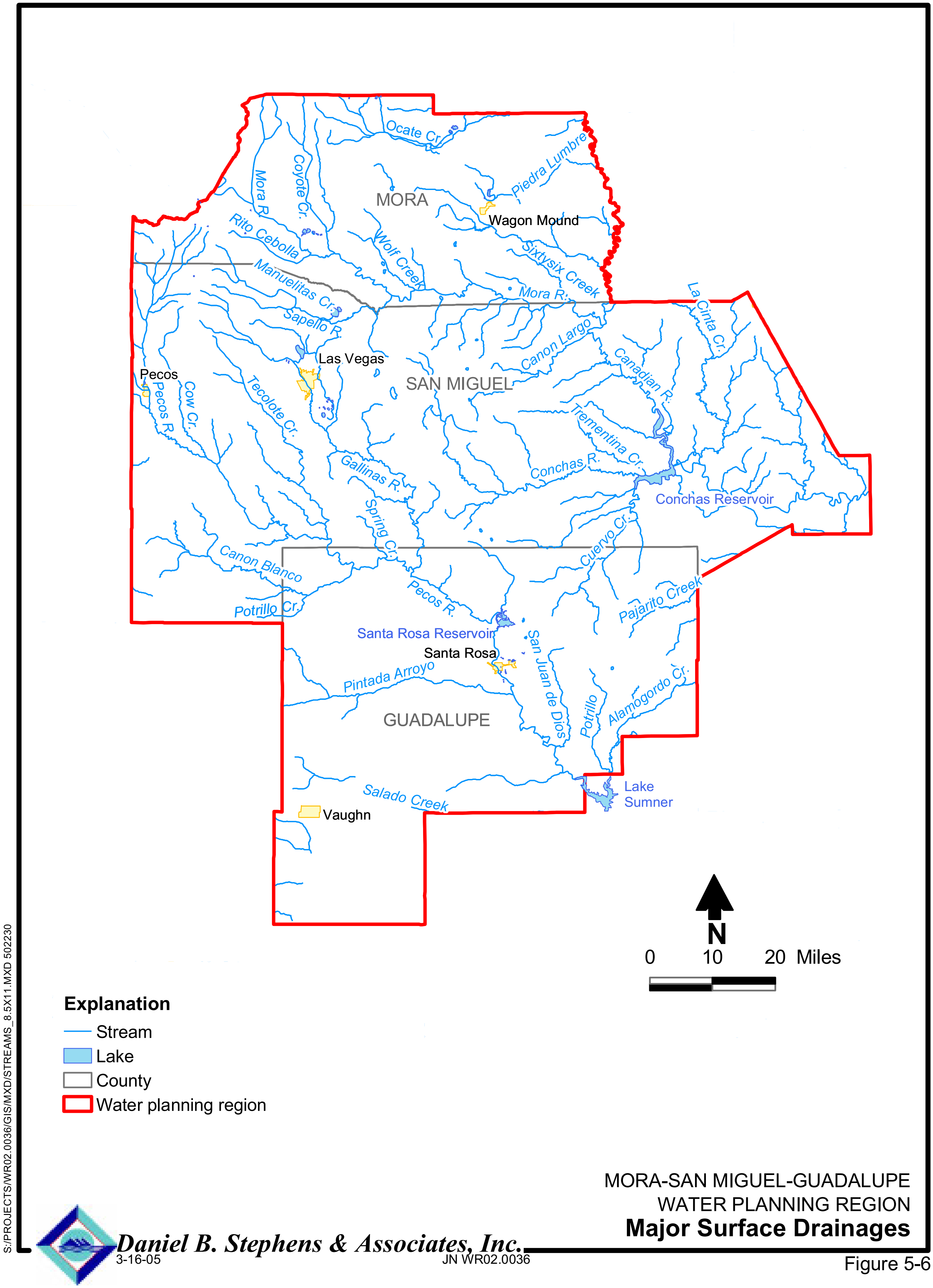
It is believed that since 1999 the planning region has been in the cool phase of the PDO, as indicated by the presence of a wedge of lower than normal sea-surface heights and ocean temperatures in the eastern equatorial Pacific and a pattern of higher than normal sea-surface heights connecting the northern, western, and southern Pacific. In the warm or positive phase, which appears to have existed from 1977 through 1997, the western Pacific Ocean becomes cool and the wedge in the east warms. Recently, McCabe et al. (2004) suggested that variations in surface temperatures of the Atlantic Ocean, called the Atlantic Multidecadal Oscillation (AMO), in combination with the PDO, account for 52 percent of drought frequency over the continental U.S. In particular, the pairing of a cool phase of the PDO with the warm phase of the AMO is typical of long-term drought.

5.2 Surface Water Supply

Surface water supplies approximately 97 percent of the water currently diverted in the Mora-San Miguel-Guadalupe Water Planning Region, with its primary uses being for irrigated agriculture and reservoir evaporation. The dominant waterways flowing in the region are the Canadian and Pecos Rivers and their tributaries. Surface water availability varies greatly from year to year, with the highest-flow years supplying many times more water than the drier years. Therefore, an understanding of the frequency of flows of various magnitudes is essential in evaluating the available water supply in 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.

5.2.1 Streams and Rivers

Major surface drainages (including both perennial and intermittent streams) and watersheds in the planning region are shown on Figures 5-6 and B-6 (in Appendix B). Surface waters in the planning region lie primarily within the Canadian and Pecos River Basins; a small portion along



MORA-SAN MIGUEL-GUADALUPE
WATER PLANNING REGION
Major Surface Drainages

Figure 5-6

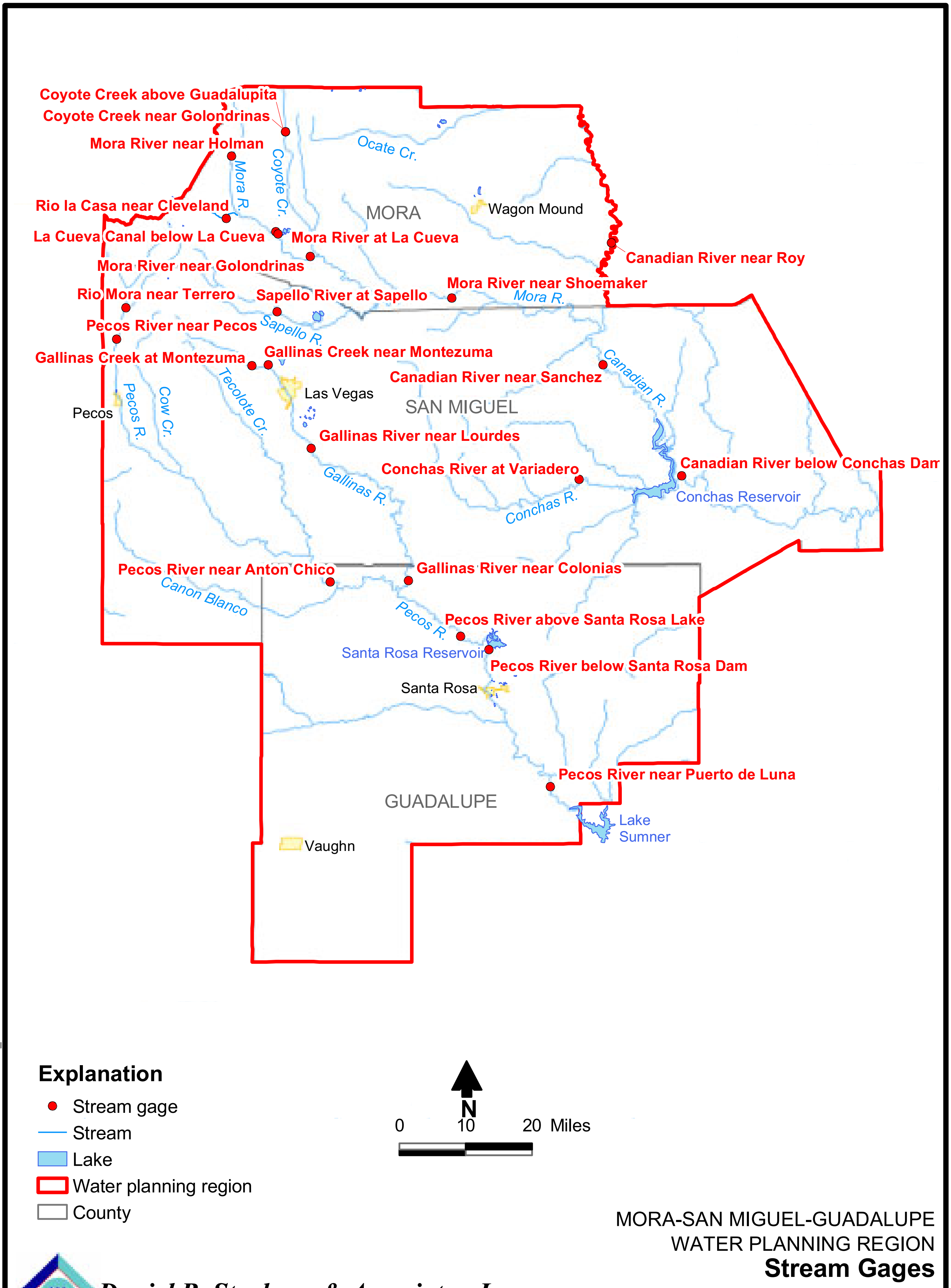
the western edge of the planning region is within the Rio Grande Basin. Each of these basins contains multiple sub-basins:

- Within the planning area, the Canadian River Basin, which is technically a part of the Arkansas-White-Red River Basin, contains five sub-basins (Figure B-4):
  - Upper Canadian
  - Mora
  - Conchas
  - Upper Canadian Ute Reservoir
  - Ute

- The portion of the Pecos River Basin within the planning area is drained by the Pecos and Gallinas Rivers and contains two sub-basins (Figure B-4):
  - Pecos Headwaters
  - Pintada Arroyo

- The small portion of the Rio Grande Basin within the planning region contains very small parts of three sub-basins (Figure B-4):
  - Upper Rio Grande
  - Rio Grande-Santa Fe
  - Western Estancia

Tributary flow is not monitored in every sub-basin in the planning region. However, streamflow data are collected by the USGS at several gage sites in the planning region plus one just upstream of the planning region in Colfax County, and a reasonable estimate of the region's surface water supply can be made from those records. A detailed table listing all active and inactive USGS gage sites is contained in Appendix E2. Figure 5-7 shows the locations of USGS gage stations with 10 or more years of record, and Table 5-4 lists the locations, periods of record, and types of records collected at these stream gages, as well as the drainage area and estimated irrigated acreage for surface water diversions upstream of the station, as reported in USGS publications.



MORA-SAN MIGUEL-GUADALUPE
WATER PLANNING REGION
Stream Gages

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Figure 5-7

Table 5-4. USGS Stream Gage Information for Stations with 10 or More Years of Record
Page 1 of 3

USGS Site Name [a]	USGS Site Number	Elevation (ft msl)	Drainage Area (acres)	Irrigated Land Upstream of Gage (acres)	Type of Record	Start Date	End Date
Colfax County							
Canadian River near Taylor Springs	07211500	5,635	1,824,000	30,000	Daily streamflow	10/01/1939	09/30/2002
					Peak streamflow	09/29/2004	05/03/1999
					Water quality samples	06/27/1966	06/04/1975
Mora County							
Canadian River near Roy	07214000	4,892.55	2,533,760	NA	Daily streamflow	04/01/1936	09/30/1965
					Peak streamflow	06/12/1936	06/18/1965
Mora River near Holman	07214500	7,845	36,480	NA	Daily streamflow	01/01/1953	01/14/1974
					Peak streamflow	05/28/1953	08/04/1973
Rio la Casa near Cleveland	07214800	7,635	14,720	NA	Daily streamflow	06/01/1956	09/30/1970
					Peak streamflow	08/05/1957	07/22/1970
Mora River at La Cueva	07215500	7,000	110,720	7,000	Daily streamflow	05/01/1906	09/30/2002
					Peak streamflow	05/02/1931	04/30/1999
					Water quality samples	02/23/1981	08/16/1995
Mora River near Golondrinas	07216500	6,750	170,880	12,000	Daily streamflow	04/01/1915	09/30/2002
					Peak streamflow	08/01/1916	04/30/1999
					Water quality samples	11/12/1980	01/30/1981
Coyote Creek above Guadalupita	07217100	7,605	45,440	NA	Daily streamflow	06/01/1956	01/07/1974
					Peak streamflow	05/11/1957	05/14/1973
Coyote Creek near Golondrinas	07218000	6,785	137,600	4,000	Daily streamflow	10/01/1929	09/30/2002
					Peak streamflow	09/22/1929	08/06/1999
					Water quality samples	07/22/1975	07/22/1975
Mora River near Shoemaker	07221000	6,145	661,120	26,000	Daily streamflow	10/01/1919	09/30/1996
					Peak streamflow	04/16/1915	07/11/1996
					Water quality samples	10/27/1966	06/19/1969

[a] **Bold** indicates key stream gaging stations.

USGS = U.S. Geological Survey

ft msl = Feet above mean sea level

NA = Not available

Table 5-4. USGS Stream Gage Information for Stations with 10 or More Years of Record
Page 2 of 3

USGS Site Name [a]	USGS Site Number	Elevation (ft msl)	Drainage Area (acres)	Irrigated Land Upstream of Gage (acres)	Type of Record	Start Date	End Date
San Miguel County							
Sapello River at Sapello	07220000	6,910	84,480	NA	Daily streamflow	01/01/1917	12/31/1973
					Peak streamflow	08/04/1957	04/14/1973
Canadian River near Sanchez	07221500	4,495	3,655,680	56,000	Daily streamflow	10/01/1912	09/30/2002
					Peak streamflow	06/12/1913	08/08/1999
					Water quality samples	09/14/1966	01/23/1997
Conchas River at Variadero	07222500	4,430	251,520	300	Daily streamflow	10/01/1936	09/30/1996
					Peak streamflow	06/03/1937	07/10/1996
Canadian River below Conchas Dam	07224500	4,022	4,469,760	NA	Daily streamflow	05/01/1936	09/30/1972
					Peak streamflow	07/12/1936	08/31/1972
					Water quality samples	04/15/1963	08/03/1964
Rio Mora near Terrero	08377900	7,890	34,048	0	Daily streamflow	10/01/1963	09/30/2002
					Peak streamflow	05/22/1964	05/24/1999
					Water quality samples	11/06/1962	09/11/2002
Pecos River near Pecos	08378500	7,502	120,960	75	Daily streamflow	10/01/1919	09/30/2002
					Peak streamflow	05/24/1920	05/24/1999
					Water quality samples	05/15/1963	09/09/1973
Gallinas Creek near Montezuma	08380500	6,875	53,760	80	Daily streamflow	09/01/1926	09/30/2002
					Peak streamflow	07/27/1915	10/31/1998
					Water quality samples	01/11/1964	10/02/1990
Gallinas Creek at Montezuma	08381000	6,675	55,680	NA	Daily streamflow	10/23/1904	12/31/1966
					Peak streamflow	09/30/1904	08/21/1966
					Water quality samples	09/25/1963	07/27/1964
Gallinas River near Lourdes	08382000	5,928	200,320	NA	Daily streamflow	07/01/1951	12/31/1963
					Peak streamflow	08/04/1952	08/25/1963

[a] **Bold** indicates key stream gaging stations.
USGS = U.S. Geological Survey
ft msl = Feet above mean sea level
NA = Not available

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Table 5-4. USGS Stream Gage Information for Stations with 10 or More Years of Record

USGS Site Name [a]	USGS Site Number	Elevation (ft msl)	Drainage Area (acres)	Irrigated Land Upstream of Gage (acres)	Type of Record	Start Date	End Date
Guadalupe County							
Pecos River near Anton Chico	08379500	5,130	672,000	4,900	Daily streamflow	10/01/1910	09/30/2002
					Peak streamflow	09/29/1904	08/06/1999
					Water quality samples	08/31/1959	06/20/1977
Gallinas River near Colonias	08382500	4,944	5,270,400	7,000	Daily streamflow	01/01/1951	09/30/2002
					Peak streamflow	06/01/1937	09/16/1999
					Water quality samples	08/31/1959	09/22/1976
Pecos River above Santa Rosa Lake	08382650	NA	1,497,600	11,800	Daily streamflow	02/28/1976	09/30/2002
					Peak streamflow	08/03/1976	08/31/1999
					Water quality samples	02/27/1976	08/22/2002
Pecos River below Santa Rosa Dam	08382830	NA	1,555,200	12,000	Daily streamflow	01/17/1980	09/30/2002
					Peak streamflow	08/10/1981	08/05/1999
Pecos River near Puerto de Luna	08383500	4,311	2,540,800	10,280	Daily streamflow	05/01/1938	09/30/2002
					Peak streamflow	09/06/1938	04/30/1999
					Water quality samples	09/16/1959	08/23/2002

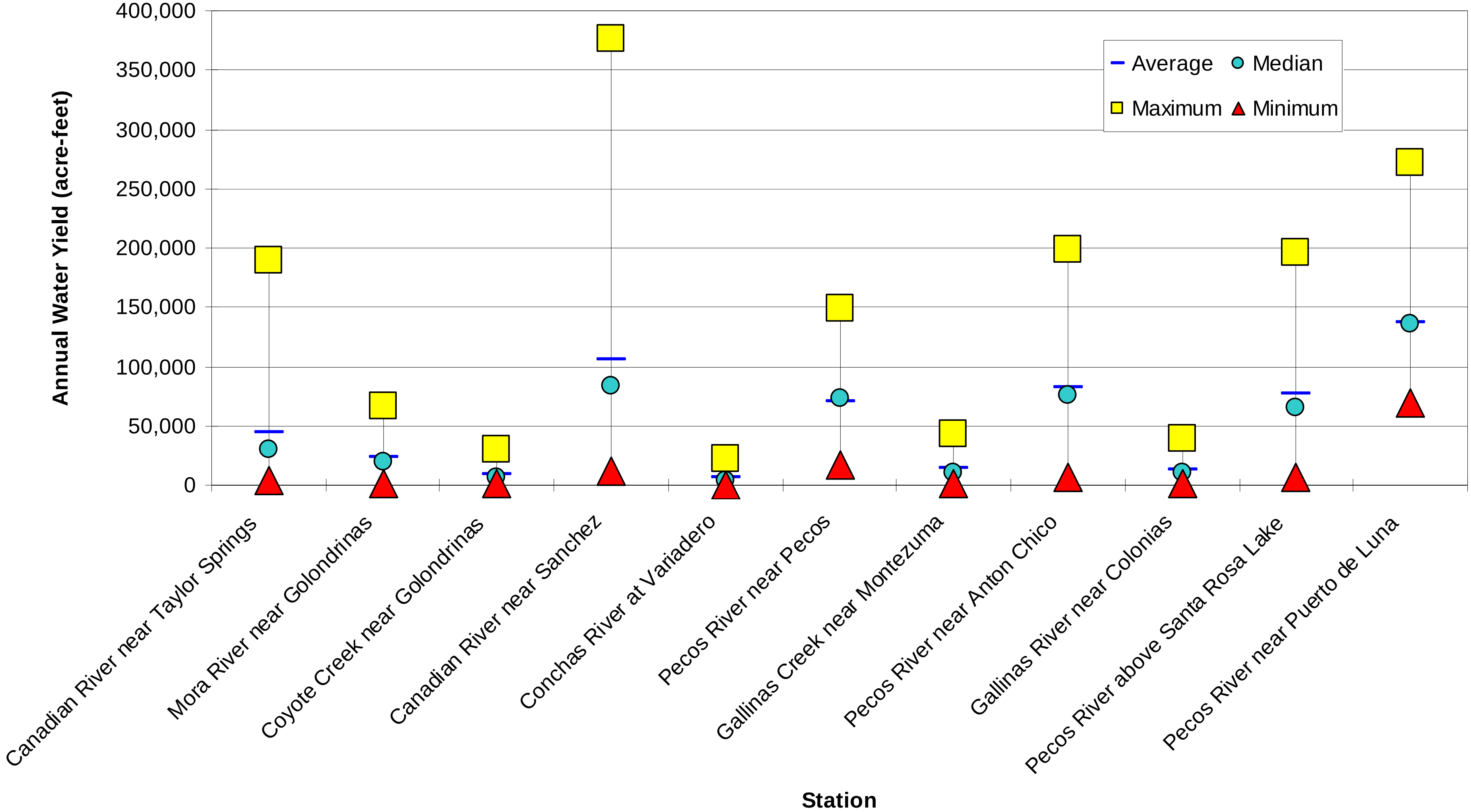
[a] **Bold** indicates key stream gaging stations. USGS = U.S. Geological Survey ft msl = Feet above mean sea level NA = Not available

For this water planning study, the 11 stream gages that have the longest and most complete period of record of daily streamflow measurements were selected for analysis as key stations. These stations were chosen because of their locations in the hydrologic system, completeness of record, and representativeness as key sources of supply. To develop a comparison between the stations for a consistent period of record, water yield data from these stations for calendar years 1950 through 2002 were analyzed. Figure 5-8 shows descriptive statistics for annual water yield at these stations for the period of analysis, and Table 5-5 provides summary statistics for each of the key stations.

When comparisons are made among watersheds, it is useful to base those comparisons on some type of standardized value. The most common and convenient standardization is to divide the parameter being measured by the area of the watershed. This is commonly done for runoff volume by dividing the total runoff, expressed in acre-feet, by the watershed area, in acres. The resulting value is expressed as inches of runoff, allowing comparison not only among different watersheds but also to the depth of precipitation that contributes to runoff. Figure 5-9 shows standardized annual yield statistics for the key stations for the selected period of analysis (calendar years 1950 through 2002).

Graphs illustrating annual streamflow for the key stations, including the monthly distribution of streamflow over a year, are presented in Appendix E2. For some of the key stations, streamflow data were missing for discrete time periods when the stream gage was not operational. Data for these time periods were estimated on a monthly or annual basis by developing relationships with nearby stations that recorded streamflow data during the missing period. The specific stations and time periods that were used to estimate missing data are noted on the graphs in Appendix E2.

In addition, some daily data were missing from the periods of record of several gage stations due to the river icing over or equipment malfunctions. In cases where these gaps were due to ice cover at the gage site, a daily value of zero was assumed. In cases where these gaps were caused by equipment malfunctioning, daily values during the data gap period were estimated as the average of the daily discharges on either side of the data gap.



MORA-SAN MIGUEL-GUADALUPE WATER PLANNING REGION

Annual Water Yield, 1950 through 2002

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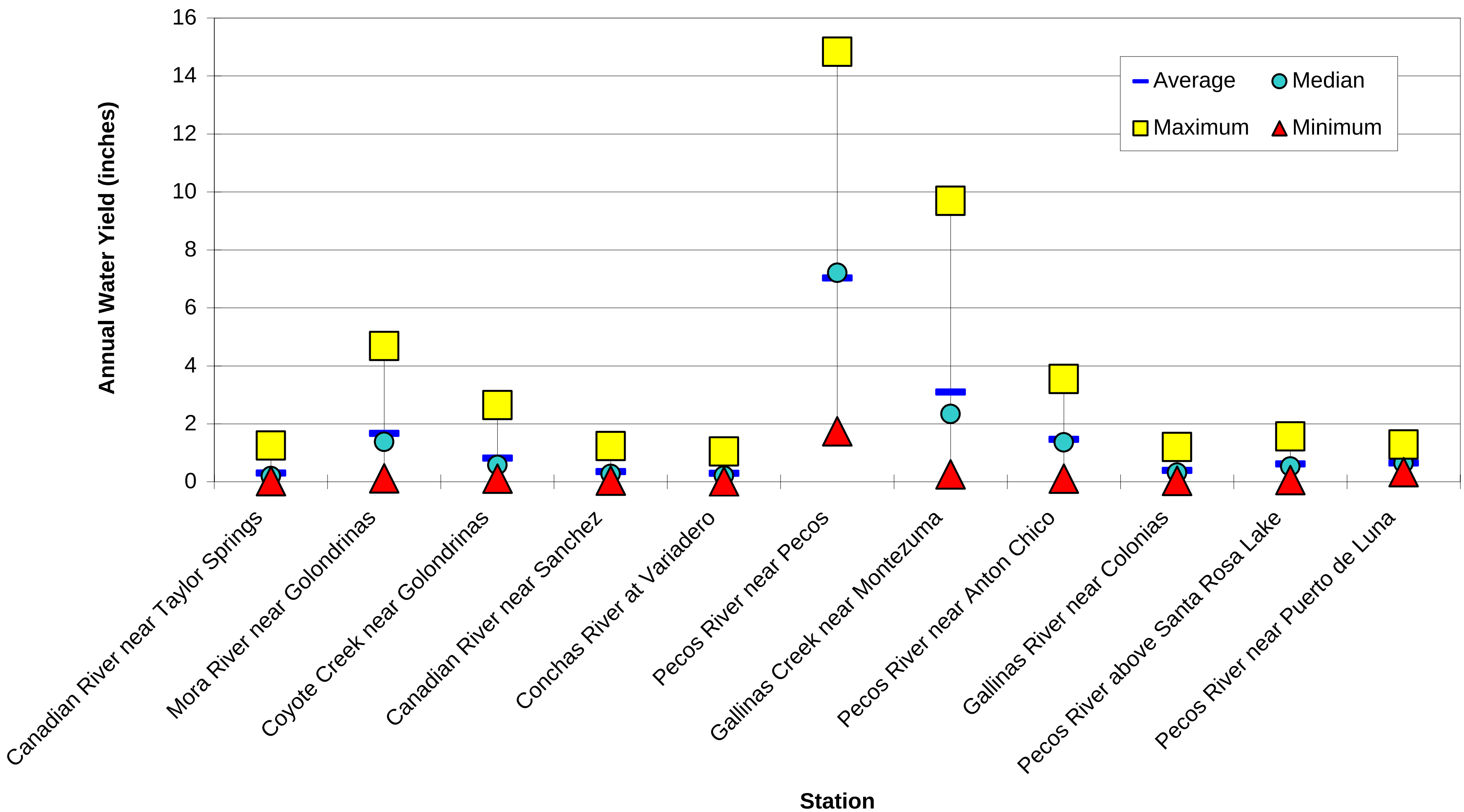
Table 5-5. Summary of Annual Water Yield and Flow Distribution Statistics for Key Stream Gaging Stations from 1950 to 2002

USGS Site Name	Average Daily Streamflow (cfs)	Annual Water 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]
Canadian River near Taylor Springs [f]	62	4,396	29,558	44,722	189,922	42,897	8,894	17,335	29,558	48,627	116,414
Mora River near Golondrinas [f]	33	1,667	19,593	23,684	66,708	18,267	4,306	8,596	19,593	36,935	55,235
Coyote Creek near Golondrinas [f]	13	1,305	6,664	9,386	30,318	7,852	2,408	3,743	6,664	12,068	22,032
Canadian River near Sanchez	145	11,660	83,945	105,257	376,746	82,137	25,041	45,491	83,945	136,585	234,153
Conchas River at Variadero [f]	8	131	4,509	6,021	21,829	4,661	1,499	2,722	4,509	8,773	12,892
Pecos River near Pecos [f]	98	17,610	72,672	70,843	149,574	34,001	32,461	43,543	72,672	92,423	122,277
Gallinas Creek near Montezuma [f]	19	1,157	10,463	13,875	43,430	9,483	4,403	8,629	10,463	15,967	27,054
Pecos River near Anton Chico	113	5,977	76,064	81,890	198,717	49,587	25,938	44,667	76,064	105,663	161,624
Gallinas River near Colonias [f]	18	1,111	10,139	12,697	38,914	9,312	3,365	6,552	10,139	16,799	27,537
Pecos River above Santa Rosa Lake [f]	106	7,182	65,956	76,627	195,454	48,065	24,594	40,115	65,956	98,498	145,773
Pecos River near Puerto de Luna	190	69,908	135,626	137,675	271,264	44,294	87,888	107,233	135,626	164,989	198,017

[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.
[f] A few days to several years of water yields were estimated by various techniques in order to have a comparable record length for these key sites. Details of the estimations are presented in Section 5.2.1 and Appendix E2.

USGS = U.S. Geological Survey
cfs = Cubic feet per second
ac-ft = Acre-feet



MORA-SAN MIGUEL-GUADALUPE WATER PLANNING REGION

Standardized Annual Water Yield, 1950 through 2002

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Figure 5-9

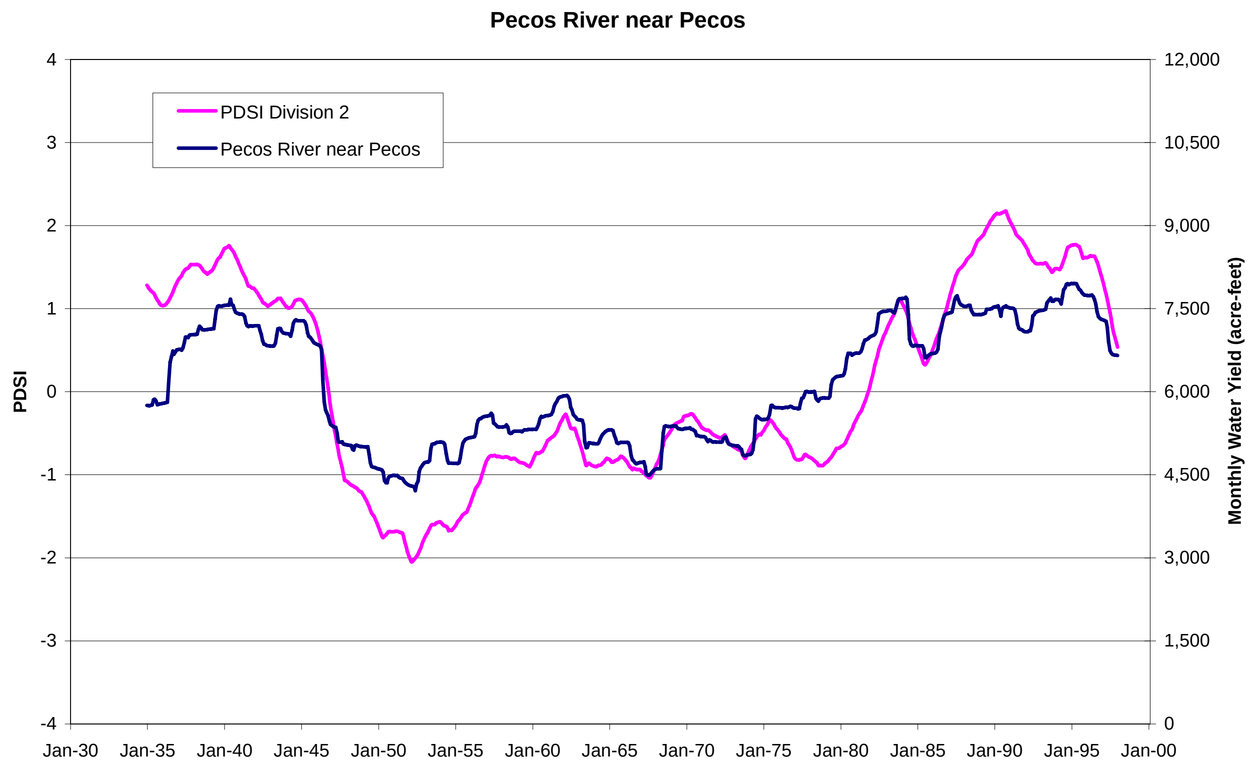
The graphs illustrating annual streamflow for the key stations (Appendix E2) show large variability of annual flows. Streamflow also varies from month to month within a year (Appendix E2), and monthly variability or short-term storms can have flooding impacts, even when annual yields are low. For the key stations analyzed, average flows tend to peak first in April through June due to spring runoff and again to a lesser extent in August or September due to runoff from monsoon rains. After these runoff peaks, a period of low or base flows occurs, primarily during October through March.

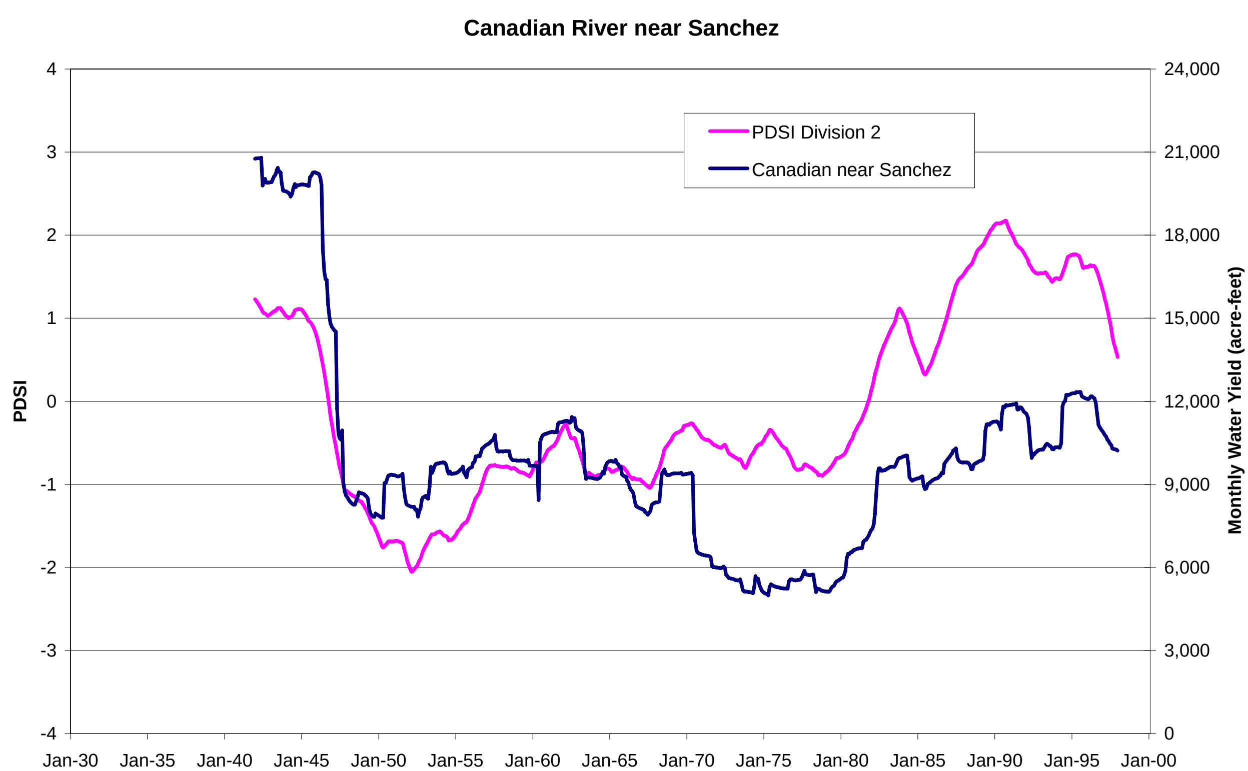
5.2.1.1 Drought Effects on Streamflow

The variability in streamflow from year to year is an important factor in long-term planning, as the use of long-term average streamflow does not provide adequate information to understand the vulnerability of the planning region to drought. Consequently, the summary statistics presented in Table 5-5 also show the 10th percentile flows, or the streamflows where 10 percent of flows are less than that amount and 90 percent are greater.

Figure 5-10 illustrates the relationship between PDSI (Section 5.1.2.2) and streamflow in the planning region. This figure shows a 10-year (120-month) moving average that compares the monthly PDSI for New Mexico Climate Division 2 (the headwaters portion of the planning region) with the monthly water yields for the Pecos River near Pecos and Canadian River near Sanchez gaging stations. 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 Pecos River near Pecos and Canadian River at Sanchez gaging stations to the monthly PDO (Section 5.1.2.3) using a 10-year (120-month) moving average. In general, the streamflow follows the sinusoidal pattern of the PDO, 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.





MORA-SAN MIGUEL-GUADALUPE WATER PLANNING REGION

Monthly Streamflow vs. PDSI

10-Year (120-Month) Moving Average

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Figure 5-10

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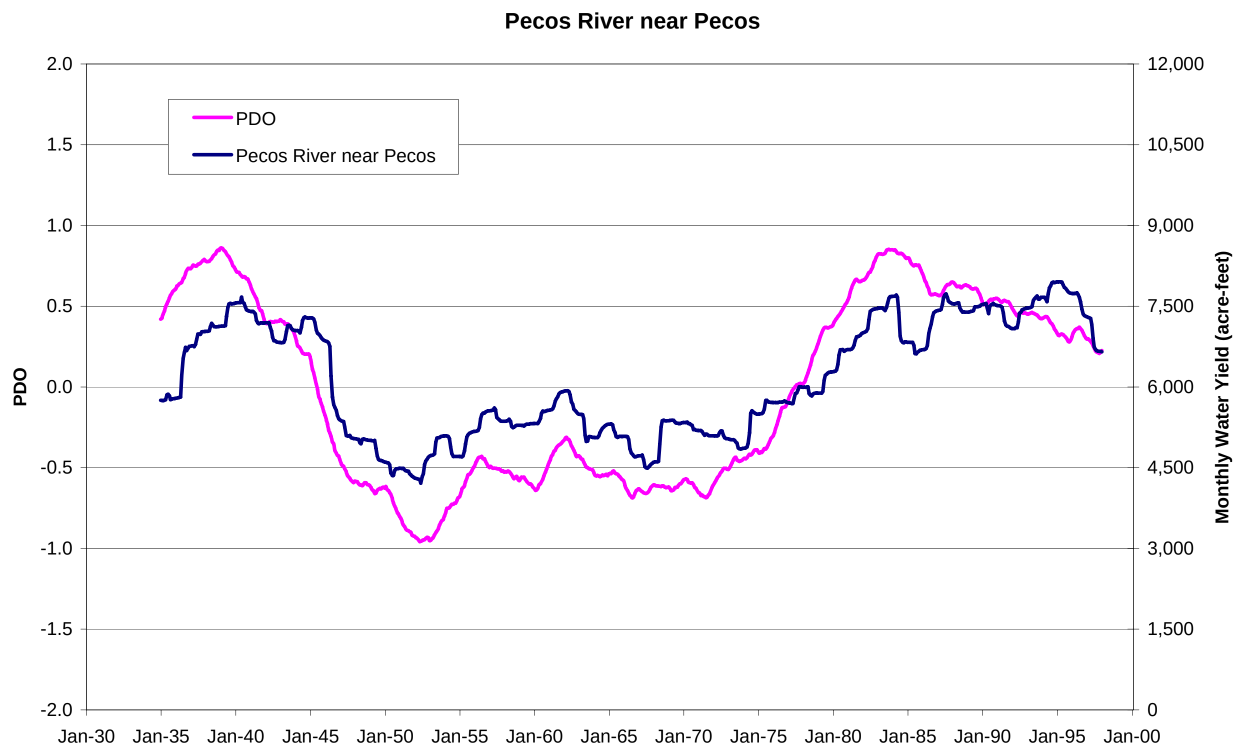

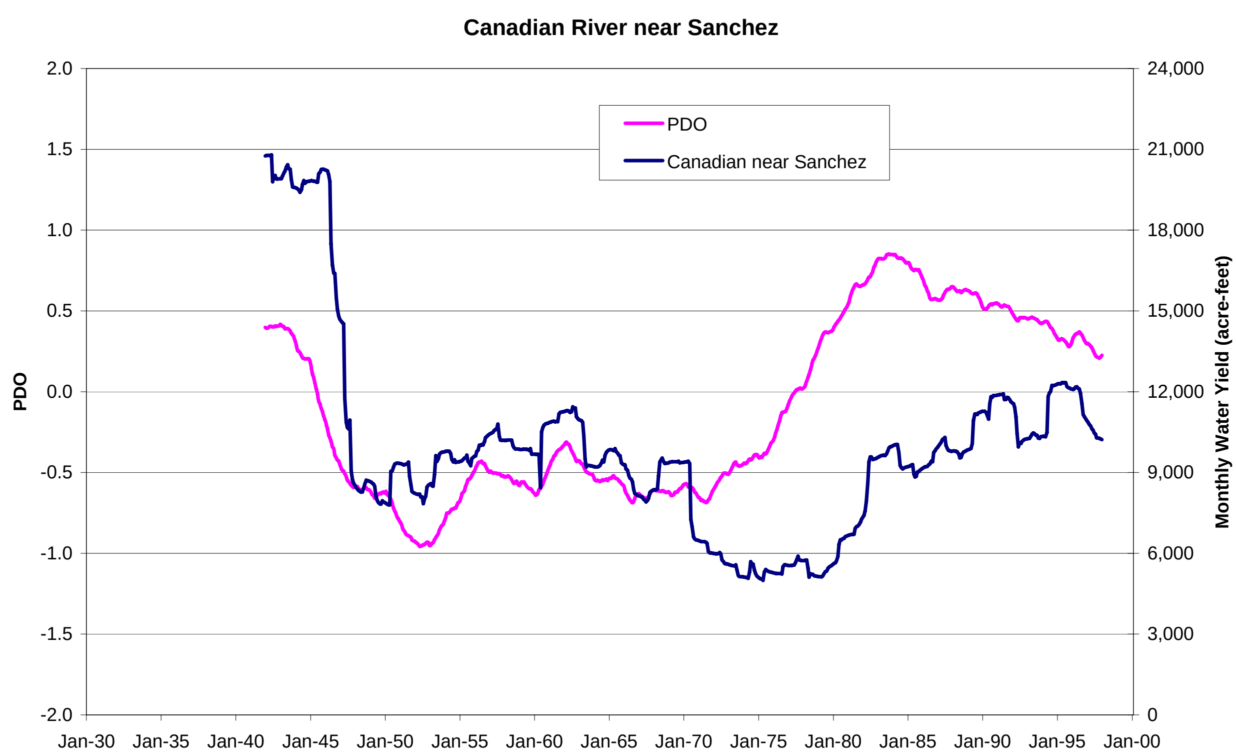

MORA-SAN MIGUEL-GUADALUPE WATER PLANNING REGION

Monthly Streamflow vs. PDO
10-Year (120-Month) Moving Average

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Figure 5-11

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5.2.1.2 Seepage Measurements on Gallinas River

In 1977 the USGS conducted two seepage studies on the Gallinas River. Seepage studies are conducted to determine where the stream is gaining or losing and involve a series of measurements at different locations on a stream, including the diversions and inflows to the stream, over a short period of time. The seepage studies conducted on the Gallinas took place over two 2-day periods, one in July and one in September. Whereas ideally, no precipitation event that alters flow should occur over the course of a seepage study, a storm event on the second day of the July investigation impacted the seepage study at the downstream reach.

The results of the seepage investigations, summarized in Table 5-6 and Appendix E3, show that the Gallinas appears to be gaining and losing throughout the river. Figures E3-1 and E3-2 show the calculated gains and losses on the stream due to groundwater and surface water inflow, diversions, or seepage losses to the groundwater. Figures E3-3 and E3-4 show the measured flow in the stream. The streamflow during the July 1977 investigation is greatest at the downstream reach due to runoff from a storm event.

Examination of the long-term streamflow records between the Montezuma (upper reach) and Colonias (near the confluence with the Pecos River) gages suggests that the river is gaining significantly. Figure E3-5 (Appendix E3) shows the historical record of flow for the two gages from 1950 through 2001. The median flow measured near Montezuma is 10,800 ac-ft/yr (15 cubic feet per second [cfs]), and the median flow measured downstream at the Colonias gage is10,100 ac-ft/yr (14 cfs), after an average of more than 17,000 ac-ft/yr depletions for public supply, irrigation, and evaporation. The average flow in the year that the seepage study was conducted was about half of the median flow, which may result in a low estimate of stream gains.

5.2.2 Reservoirs and Lakes

Several lakes and reservoirs are present in the planning region (Figure 5-12). Appendix E4 summarizes characteristics of these lakes and reservoirs. Information contained in this appendix was compiled primarily by Brian Wilson of the OSE with some information gathered during previous water planning efforts and directly from reservoir managers. As indicated in Appendix E4, the two largest reservoirs in the planning region are Santa Rosa and Conchas

Table 5-6. Results of USGS Seepage Studies on the Gallinas River
Page 1 of 3

Location	River Mile	July 26 and 27, 1977						September 20 and 21, 1977					
		Time	Flow (cfs)					Time	Flow (cfs)				
			Main Stream	Tributary or Inflow	Gain or Loss		Diversions		Main Stream	Tributary or Inflow	Gain or Loss		Diversions
					USGS Calculation	Including Tributary Inflow					USGS Calculation	Including Tributary Inflow	
Gallinas Creek	74.4	1030	6.49	---	---	---	---	1005	2.22	---	---	---	---
Gallinas Creek	72.4	1130	1.59	---	–4.9	–4.9	---	1030	0.11	---	–2.11	–2.11	---
Seepage	71.1	1100	---	0.4	---	---	---	1150	---	0.31	---	---	---
Storrie Lake Feeder	71	1000	---	–2.06	---	---	–2.06	110	---	–0.23	---	---	–0.23
Gallinas Creek, below Storrie Lake Feeder	71	1030	0.96	---	1.03	1.43	---	1130	0.97	---	0.78	1.09	---
Diversion near Camp Luna	68.6	1250	---	–1.34	---	---	–1.34	1300	---	–1.13	---	---	–1.13
Gallinas Creek near Camp Luna	68.2	1225	0.15	---	0.53	0.53	---	1250	0.15	---	0.31	0.31	---
Diversion near Athletic Field, Las Vegas	66.1	1230	---	–0.7	---	---	–0.7	900	---	0	---	---	0
Gallinas Creek below Athletic Field	66.1	1245	0	---	0.55	0.55	---	940	0.95	---	0.8	0.8	---
Diversion at Hwy 85 in Las Vegas	64.9	1325	---	–0.13	---	---	–0.13	1100	---	–1.09	---	---	–1.09

Source: USGS, 1978
Shading indicates storm flow impacted seepage study.

cfs = Cubic feet per second
USGS = U.S. Geological Survey

--- = Not applicable
WWTP = Wastewater treatment plant

Table 5-6. Results of USGS Seepage Studies on the Gallinas River

		July 26 and 27, 1977						September 20 and 21, 1977					
			Flow (cfs)						Flow (cfs)				
					Gain or Loss						Gain or Loss		
Location	River Mile	Time	Main Stream	Tributary or Inflow	USGS Calculation	Including Tributary Inflow	Diversions	Time	Main Stream	Tributary or Inflow	USGS Calculation	Including Tributary Inflow	Diversions
Gallinas Creek below Hwy 85 Diversion	64.9	1335	0	---	0.13	0.13	---	1030	0	---	0.14	0.14	---
Gallinas Creek above Arroyo Pecos, below Las Vegas WWTP Outfall	63.1	1410	1.78	---	1.78	1.78	---	1240	2.46	---	2.46	2.46	---
Arroyo Pecos	63.1	1445	---	2.45	---	---	---	1315	---	2.11	---	---	---
Gallinas River	56.3	1555	5.19	---	0.96	3.41	---	1615	3.2	---	–1.37	0.74	---
Smith Canyon	56.3	1545	---	0.06	---	---	---	1545	---	0.04	---	---	---
Gallinas River near Lourdes Gage	51.5	840	4.63	---	---	–0.56	---	1510	3.46	---	0.22	0.26	---
Gallinas River near Lourdes Gage	51.5	---	---	---	---	---	---	1000	3.74	---	---	---	---
San Augustin Ditch	50.8	840	---	–2.85	---	---	–2.85	1035	---	–0.27	---	---	–0.27
Gallinas River below San Augustin Ditch	50.7	910	1.43	---	---	–0.35	---	1100	4.52	---	1.05	1.05	---

Source: USGS, 1978
Shading indicates storm flow impacted seepage study.

cfs = Cubic feet per second
USGS = U.S. Geological Survey

--- = Not applicable
WWTP = Wastewater treatment plant

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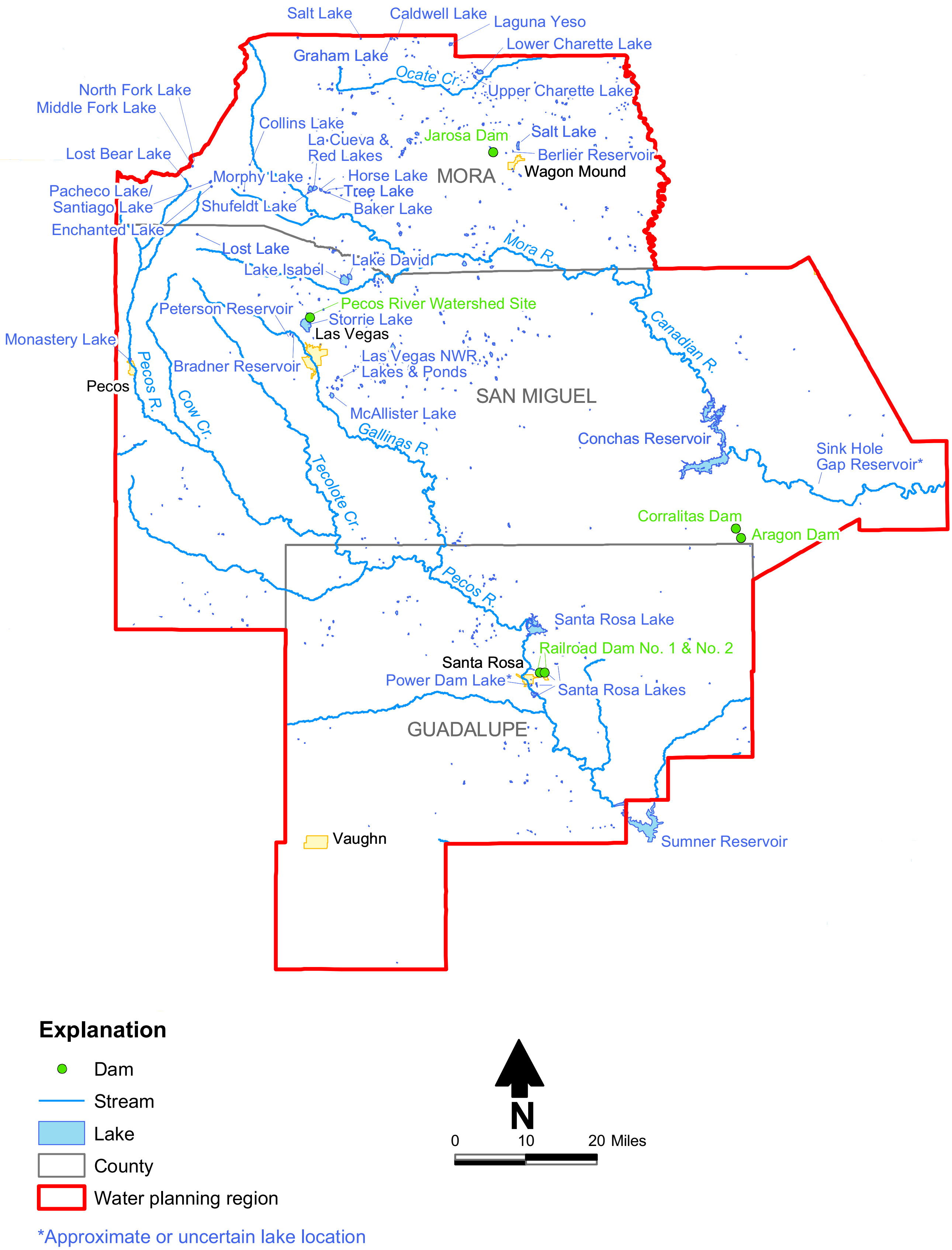
Table 5-6. Results of USGS Seepage Studies on the Gallinas River
Page 3 of 3

Location	River Mile	July 26 and 27, 1977 Time	July 26 and 27, 1977 Flow (cfs) Main Stream	Tributary or Inflow	Gain or Loss: USGS Calculation	Gain or Loss: Including Tributary Inflow	Diversions	September 20 and 21, 1977 Time	September 20 and 21, 1977 Flow (cfs) Main Stream	Tributary or Inflow	Gain or Loss: USGS Calculation	Gain or Loss: Including Tributary Inflow	Diversions
Gallinas River near Concepcion	46.4	940	3.31	---	---	1.88	---	1135	3.21	---	–1.31	–1.31	---
Gallinas River at La Liendre	40.5	1030	2.03	---	---	–1.28	---	1230	3.96	---	0.75	0.75	---
Gallinas Upstream from Chaperito	30.5	1150	2.20	---	---	0.17	---	1330	3.50	---	–0.46	–0.46	---
Gallinas above Agua Azul	22.6	1210	2.08	---	---	–0.12	---	1430	3.05	---	–0.45	–0.45	---
Gallinas near Park Springs Ranch	13.2	1345	4.06	---	---	1.98	---	1515	3.37	---	0.32	0.32	---
Gallinas at San Miguel Guadalupe Co. Line	6.3	1525	12.6	---	---	8.54	---	1600	1.15	---	–2.22	–2.22	---
Gallinas at Gage near Colonias	2.4	1605	0	---	---	–12.6	---	1650	0.45	---	–0.7	–0.7	---

Source: USGS, 1978
Shading indicates storm flow impacted seepage study.

cfs = Cubic feet per second
USGS = U.S. Geological Survey
--- = Not applicable
WWTP = Wastewater treatment plant



MORA-SAN MIGUEL-GUADALUPE
WATER PLANNING REGION
Lakes

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Figure 5-12

Reservoirs. While these reservoirs provide important recreational and associated economic benefits to the region, the actual water stored is held primarily for users outside of the planning region. Storrie Lake stores water for irrigators along the Gallinas River, the USFWS, and the City of Las Vegas, and Las Vegas also has storage capacity in Bradner and Petersen Reservoirs. Lake Isabella stores water from the Sapello River. Many of the other lakes and reservoirs in the planning region are either small or privately held and do not provide opportunities for storage for most water users in the region.

5.3 Groundwater Supply

Groundwater, which within the planning region is used primarily for municipal and domestic household use, accounted for only about 4 percent of all water depletions in the year 2000 (Wilson et al., 2003). Though this is a small percentage of the total use in the planning region, groundwater provides the sole source of drinking water for most communities. In fact, with the exception of Las Vegas, New Mexico (which depends on surface water with some supplemental groundwater), Big Mesa Water Co-op, Conchas Dam, and Pendaries Water System, almost all of the region's drinking water comes from groundwater. This section summarizes the groundwater supplies in the planning region.

The following sections include an overview of the regional hydrology by physiographic province (Section 5.3.1), a description of the geologic formations in the planning region (5.3.2), quantitative hydraulic parameters for each of the major hydrogeologic aquifers (5.3.3), estimates of natural recharge (5.3.4), and descriptions of key well fields located within the planning region (5.3.5). Section 5.3.6 presents estimates of sustainable yields in the areas of highest water consumption.

5.3.1 Regional Hydrogeology

This section presents a general overview of the geology that controls groundwater occurrence and movement within the planning region. A map illustrating the surface geology of the entire planning region is included as Figure 5-13. Cross sections illustrating the subsurface geology in the vicinity of the Las Vegas Taylor well field, the Gallinas Creek area, and the Santa Rosa area are shown as Figures 5-14 through 5-16.

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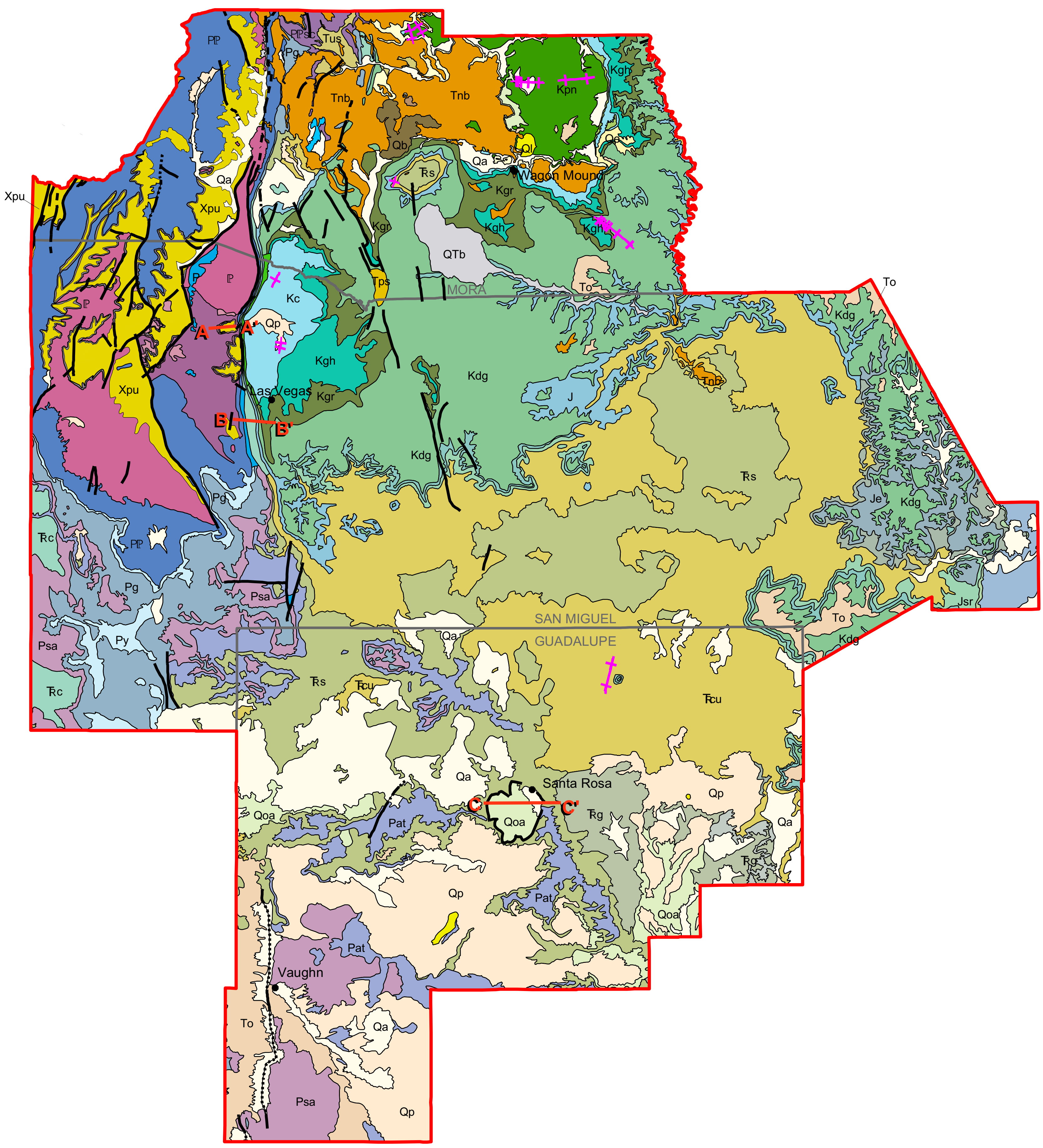

Explanation

- Water planning region
- County
- Fault (dashed where approximately located, dotted where concealed)
- Dike
- A—A' Cross section location
- City

N

0 7 14 Miles

Source: Green and Jones, 1997

MORA-SAN MIGUEL-GUADALUPE
WATER PLANNING REGION
Geology

Figure 5-13

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JN WR02.0036

Geologic Units

- Qa - Alluvium; upper and middle Quaternary
- Qb - Basalt and andesite flows and locally vent deposits
- Qe - Eolian deposits
- Ql - Landslide deposits and colluvium
- Qp - Piedmont alluvial deposits: upper and middle Quaternary
- Qpl - Lacustrine and playa-lake deposits
- Qv - Basaltic volcanics; tuff rings, cinders, and proximal lavas
- Qoa - Older alluvial deposits of upland plains and piedmont areas, and calcic soils and eolian cover sediments of High Plains region
- QTb - Basaltic and andesitic volcanics interbedded with Pleistocene and Pliocene sedimentary units
- Tnb - Basalt and andesite flows; Neogene; includes flows interbedded with Santa Fe and Gila Groups
- To - Ogallala Formation, alluvial and eolian deposits, and petrocalcic soils of the southern High Plains
- Tps - Paleogene sedimentary units
- Tus - Upper Tertiary sedimentary units
- Ku - Upper Cretaceous, undivided
- Kpn - Pierre Shale and Niobrara Formation
- Knf - Fort Hays Limestone Member of Niobrara Formation
- Kc - Carlile Shale
- Kgg - Graneros Shale and Greenhorn Formation
- Kgh - Greenhorn Formation
- Kgr - Graneros Shale
- Kdg - Dakota Group
- J - Jurassic rocks, Middle and Upper, undivided
- Jm - Morrison Formation; Upper Jurassic nonmarine rocks present only in northern one-third of state
- Jmsu - Morrison Formation and upper San Rafael Group
- Jsr - San Rafael Group; consists of Entrada Sandstone, Todilto and Summerville Formations
- Je - Entrada Sandstone, Middle Jurassic; Callovian
- ŦRcu - Upper Chinle Group, Garita Creek through Redonda Formations, undivided
- ŦRc - Chinle Group; Upper Triassic; includes Moenkopi Formation (Middle Triassic) at base in many areas
- ŦRr - Redonda Formation
- ŦRb - Bull Canyon Formation; Norian
- ŦRt - Trujillo Formation; Norian
- ŦRg - Garita Creek Formation; Carnian
- ŦRs - Santa Rosa Formation; Carnian; includes Moenkopi Formation (Middle Triassic) at base in most areas
- P - Permian rocks, undivided
- Pat - Artesia Group; shelf facies forming broad south-southeast trending outcrop
- Psa - San Andres Formation; limestone and dolomite with minor shale
- Pg - Glorieta Sandstone; texturally and mineralogically mature, high-silica quartz sandstone
- Psg - San Andres Limestone and Glorieta Sandstone; Guadalupian and Leonardian
- Py - Yeso Formation; sandstones, siltstones, anhydrite, gypsum, halite, and dolomite; Leonardian
- PIP - Permian and Pennsylvanian rocks
- PIPsc - Sangre de Cristo Formation, in Sangre de Cristo Mountains
- IP - Pennsylvanian rocks, undivided
- IPm - Madera Formation (Limestone or Group)
- IPs - Sandia Formation; predominantly clastic unit (commonly arkosic) with minor black shales and limestone in lower part
- M - Arroyo Penasco Group, undivided
- Xpu - Proterozoic metamorphic, metasedimentary, and plutonic rocks, undivided

MORA-SAN MIGUEL-GUADALUPE
WATER PLANNING REGION
Geology

Figure 5-13

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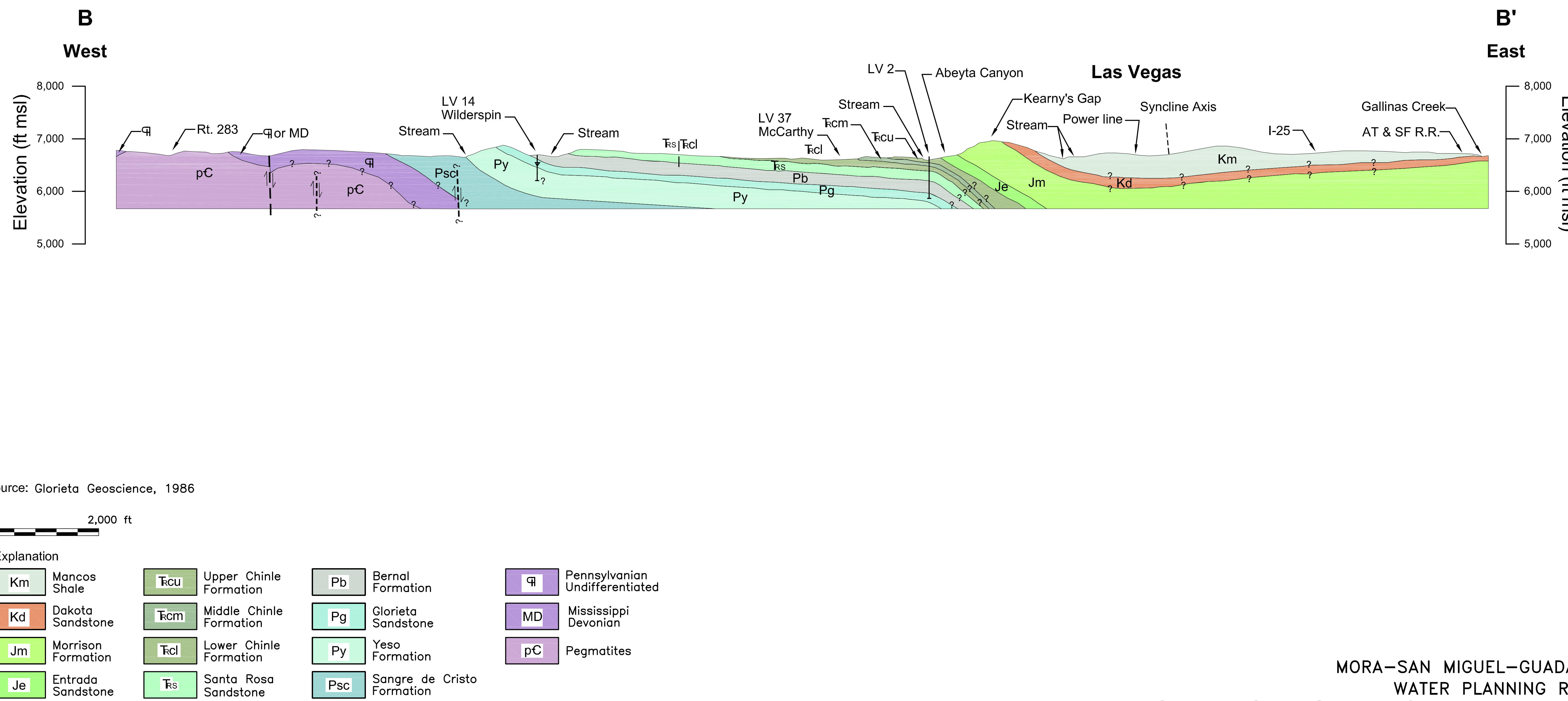

MORA–SAN MIGUEL–GUADALUPE
WATER PLANNING REGION

Geologic Cross Section of the Taylor Well Field
Las Vegas, New Mexico

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3-21-05 JN WR02.0036

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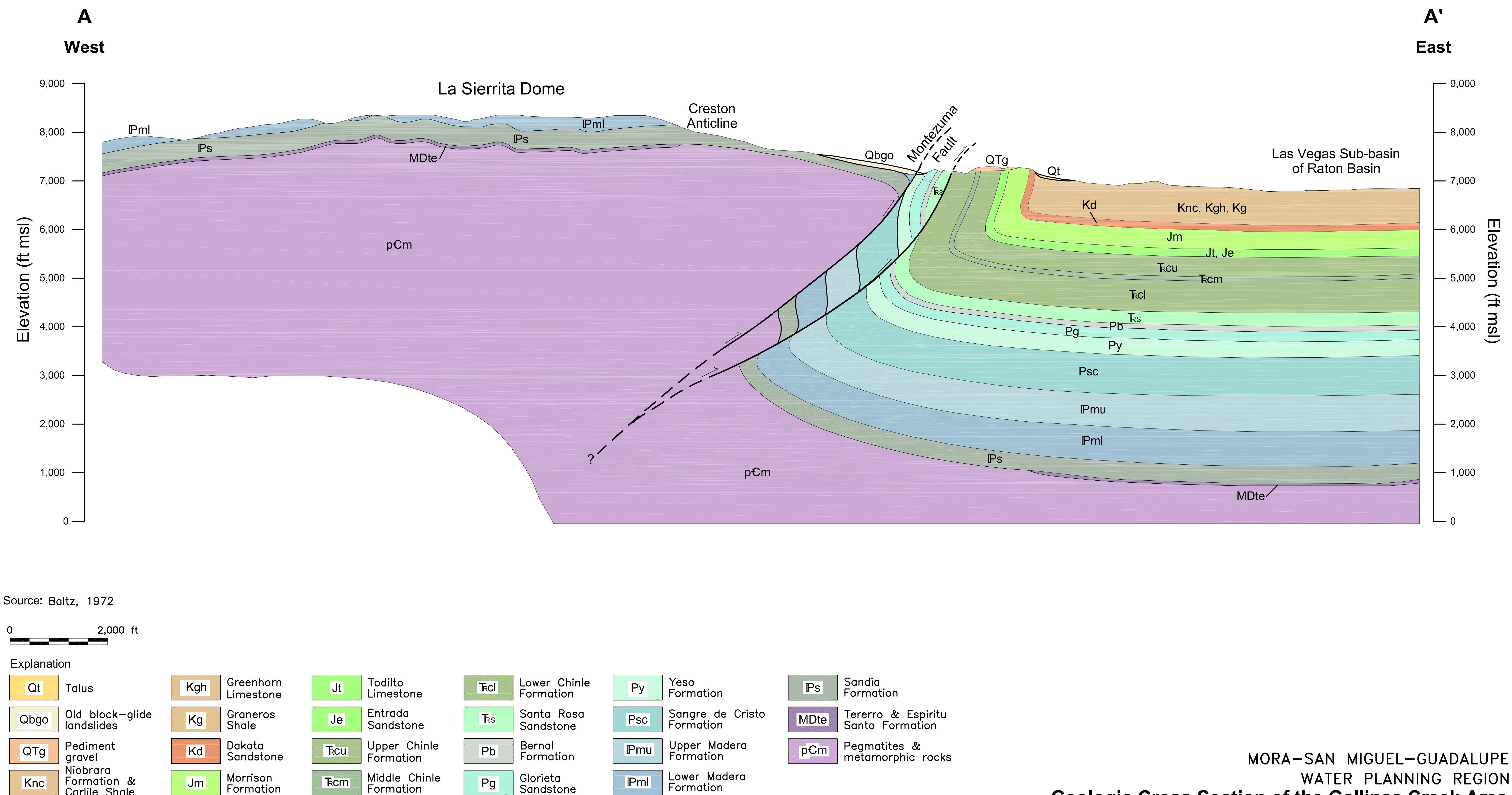
Figure 5-14



MORA–SAN MIGUEL–GUADALUPE
WATER PLANNING REGION

Geologic Cross Section of the Gallinas Creek Area
San Miguel County, New Mexico

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Figure 5-15

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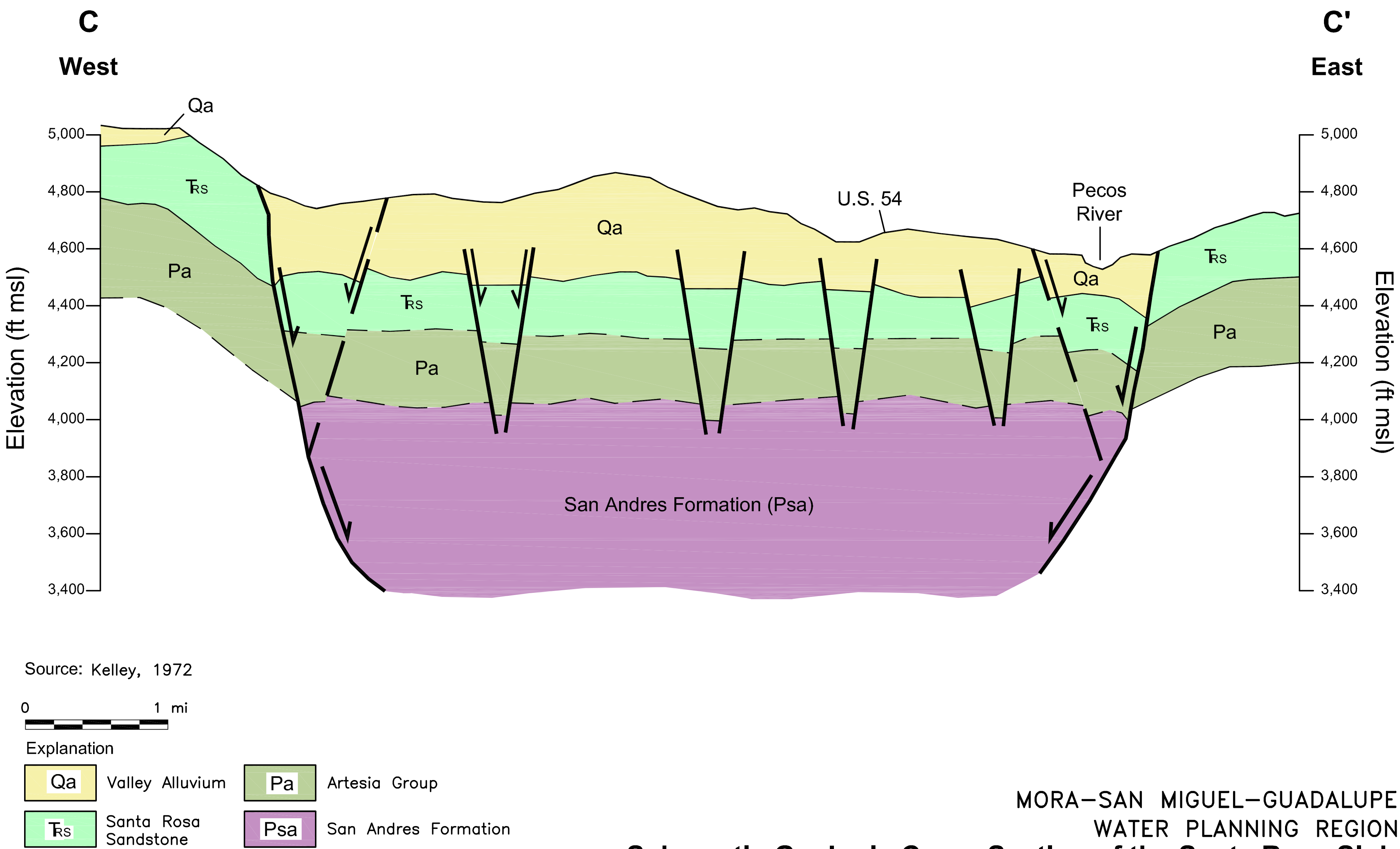

MORA–SAN MIGUEL–GUADALUPE
WATER PLANNING REGION

Schematic Geologic Cross Section of the Santa Rosa Sink
Santa Rosa, New Mexico

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3-17-05
JN WR02.0036

Figure 5-16

The information in this section is drawn from several sources:

- Griggs and Hendrickson (1951) described the hydrogeology of San Miguel County in detail and compiled a geologic map of the county.

- Mercer and Lapalla (1970, 1972) reported the hydrogeology and water quality of western Mora County and conducted well pump tests in the region.

- Further south, Baltz (1972) mapped the geology and produced geologic cross sections of the Gallinas Creek region in San Miguel County.

- Trauger (1972), Kelley (1972), Dinwiddie and Clebsch (1973), and Risser (1987) provided detailed descriptions of the geology and groundwater resources of Guadalupe County.

- Risser (1987) also explained aquifer properties, groundwater flow and groundwater-surface water interaction and provided water level and water quality data for the aquifers and wells in northwest Guadalupe County.

These and other existing sources of information, such as USGS monitor well data and plans and reports from municipalities and others in the region, were used to help characterize the groundwater supply in the planning region. A bibliography of all information used in this plan is provided in Appendix A.

5.3.1.1 Physiographic Regions

Four physiographic regions exist within the planning region (Griggs and Hendrickson, 1951). From the west to the east, these are:

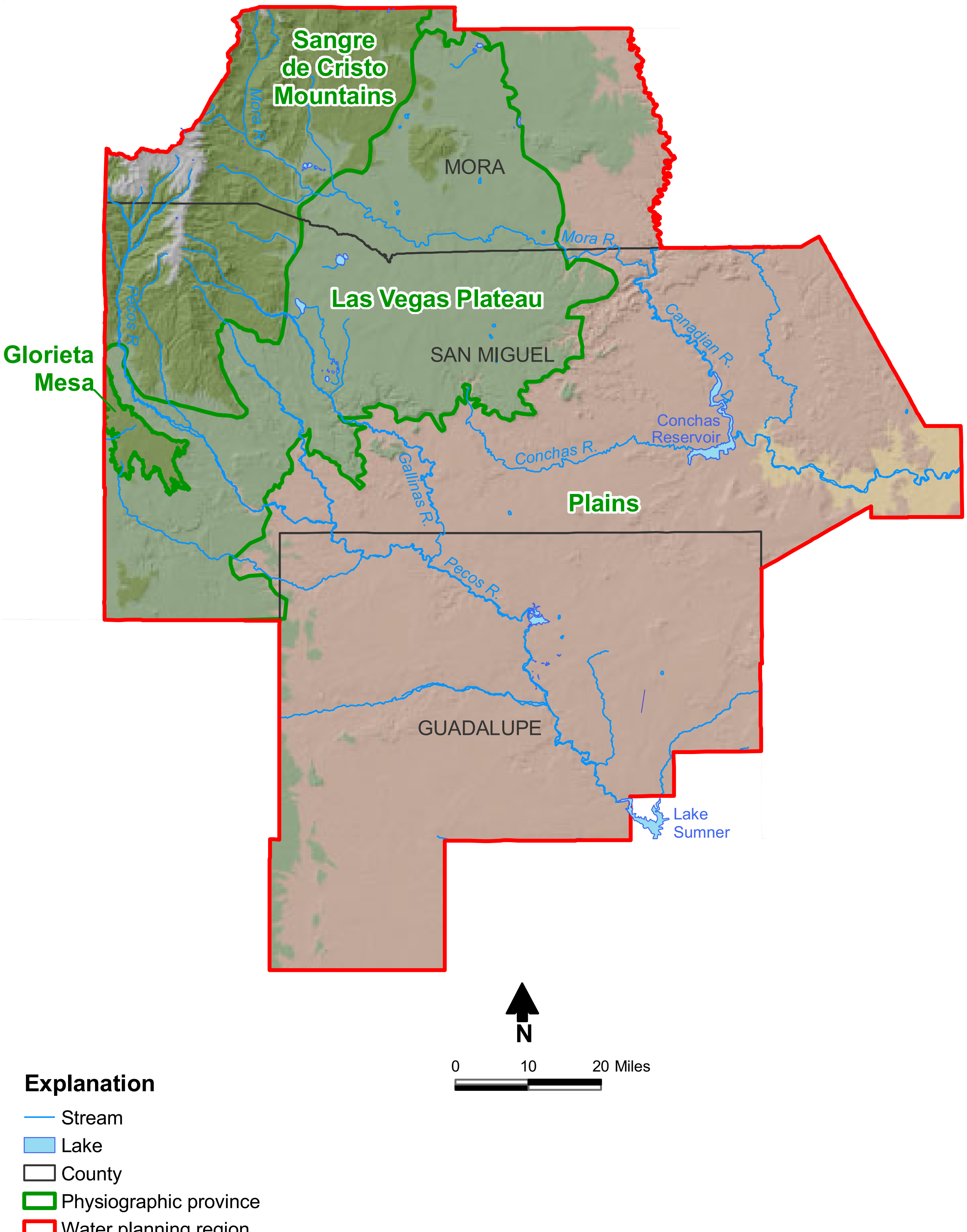
- Sangre de Cristo Mountains
- Glorieta Mesa
- Las Vegas Plateau
- The Plains

Figure 5-17 shows the approximate extents of these areas, as well as the OSE-declared basins present within the planning region. The four areas have distinct geologies that to a large extent control groundwater quantity, depth, quality, and recharge rates.

5.3.1.1.1 Sangre de Cristo Mountains. The mountain province constitutes the western portion of the planning region where elevations extend from approximately 6,000 to 11,600 ft msl. The greatest complexity of structure in the planning region occurs within these mountains. Precambrian rock extends through younger strata, which thicken away from the mountains. Strata near the Precambrian outcrops dip from 3 degrees to as much as 30 degrees in a downward direction away from the mountains.

Within the mountain areas, limited groundwater can generally be found within small streamside alluvial deposits and near-surface (within 10 feet below ground surface [bgs]), fractured portions of the Precambrian rocks (Griggs and Hendrickson, 1951). More reliable groundwater can be found in the Sandia Formation, Madera Limestone, and Sangre de Cristo Formation at depths up to 200 feet bgs. The strongest wells within the mountainous area are completed in the Sandia Formation and the Madera Limestone at depths of approximately 1,000 feet bgs, where strong artesian conditions exist (Griggs and Hendrickson, 1951). In western Mora County, unconsolidated alluvial, colluvial, and lacustrine deposits are present in the mountain valleys. The thickness and extent of these deposits is variable, but in many cases is sufficient to support domestic, livestock, or small-scale irrigation uses (Mercer and Lapalla, 1970, 1972).

5.3.1.1.2 Glorieta Mesa. Glorieta Mesa lies south of the mountains and comprises the southwestern corner of San Miguel County, where elevations range between about 6,000 and 8,000 ft msl. The sedimentary beds of Glorieta Mesa are uplifted in a broad, nearly flat-topped arch, and the beds are slightly warped. Depths of wells in the Glorieta Mesa area range from 200 to 1,100 feet; the average well depth is approximately 300 feet, although the depth to water is as much as 500 feet in some places (Griggs and Hendrickson, 1951). Most of the wells on the Glorieta Mesa are completed in the Yeso Formation, although some are completed in the deeper Sangre de Cristo Formation, and some shallower wells are completed in the Glorieta Sandstone and the Santa Rosa Sandstone.



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MORA-SAN MIGUEL-GUADALUPE
WATER PLANNING REGION
Physiographic Provinces

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3-18-05 JN WR02.0036

Figure 5-17

5.3.1.1.3 Las Vegas Plateau. The Las Vegas Plateau covers much of Mora County and the north-central portion of San Miguel County. Elevations in this area are between approximately 4,500 and 6,800 ft msl. The geology of the Las Vegas Plateau is not very complex; most of the rocks are horizontal, with minor amounts of gentle folding and low displacement faulting.

Most of the Las Vegas Plateau is capped by the Dakota Sandstone (Figure 5-13), which is the primary aquifer over much of this part of the planning region. The Dakota and Purgatoire formations generally contain water within 250 feet of ground surface (Griggs and Hendrickson, 1951), and the strongest wells generally penetrate the entire thickness of these two units. Water has sometimes been obtained from wells completed in the Morrison Formation, Graneros Shale, Greenhorn Limestone, and Carlile Formation, where they are present, but these wells are usually weak (Griggs and Hendrickson, 1951).

5.3.1.1.4 Plains. The plains lie in the south and southeastern portion of San Miguel and Guadalupe Counties, between approximately 4,000 and 6,000 ft msl. Over most of the plains area, water sufficient for domestic wells and livestock can be obtained from the Chinle Group. In the eastern part of the area, the Entrada and Morrison formations also produce water. The depths of wells in this part of the planning region are usually between 100 and 300 feet (Griggs and Hendrickson, 1951). In Guadalupe County, significant sources of water are present in the Santa Rosa and San Andres formations (Risser, 1987). Groundwater is also produced from surficial alluvial deposits in all three counties.

5.3.2 Major Geologic Units

Figure 5-13 shows the geology of the planning region, as derived from a geologic map of the entire state of New Mexico by Green and Jones (1997). A description of each of geologic units present in the planning region follows.

5.3.2.1.1 Precambrian Rocks. The oldest rocks found in the planning region are the Precambrian igneous and metamorphic rocks that form the core of the Sangre de Cristo Mountains and underlie sedimentary rocks throughout the remainder of the region. These rocks consist of gneiss, schist, quartzite, granite, and pegmatite (Griggs and Hendrickson, 1951).

Precambrian rocks crop out at the surface along the western part of the planning region and in certain places within the Pecos Valley. The Precambrian rocks contain little available water. Flow occurs within fractures, generally within 100 feet of ground surface, with most of the fracturing and associated groundwater flow occurring in the upper 10 feet (Griggs and Hendrickson, 1951).

5.3.2.1.2 Magdalena Group. The Magdalena Group (Pennsylvanian) unconformably overlies the Precambrian rocks in the mountainous western part of the planning region. This unit is known to reach thicknesses of more than 2,000 feet (Griggs and Hendrickson, 1951) and crops out over an area of approximately 500 square miles. The Magdalena Group is comprised of sedimentary layers of sandstone, shale, and limestone and has been subdivided into two formations: the Sandia Formation and the Madera Limestone.

The Sandia Formation is the older of the two formations and, where present, ranges in thickness from 100 to 400 feet (Griggs and Hendrickson, 1951). It is comprised primarily of gray limestone with low permeability. The Sandia Formation is locally fractured, and its sandstone beds are known to contain modest amounts of water. This water is highly mineralized, however, and few wells are completed in this unit outside of the mountainous area where outcrops are present.

The Madera Limestone, which comprises most of the Magdalena Group, overlies the Sandia Formation. It ranges from 300 to 3,000 feet thick. Two members of the Madera Limestone have been identified: the lower member, which is as much as 800 feet thick, and the upper member, which if present, may be more than 1,000 feet thick (Griggs and Hendrickson, 1951). Groundwater within the Lower Madera Limestone flows through small fractures that form along bedding planes and can supply water to small-capacity wells. The Upper Madera Limestone contains interbedded arkosic sandstone, and groundwater occurs in interstitial pore spaces within the sandstone layers, as well as along fractures that form along bedding planes (Griggs and Hendrickson, 1951).

5.3.2.1.3 Sangre de Cristo Formation. The Sangre de Cristo Formation (Pennsylvanian) conformably overlies the Madera Limestone throughout most of the planning region and is comprised mainly of dark pink and maroon-colored feldspathic sandstone. The formation crops out near the edges of the mountains and in places on the Glorieta Mesa. It ranges in thickness from 600 to 1,000 feet. Arkosic sandstone layers 25 to 50 feet thick contain most of the water found in this unit. Most of the wells completed within the Sangre de Cristo Formation occur near the outcrop areas and offer modest yields for livestock and domestic well use.

5.3.2.1.4 Yeso Formation. The Yeso Formation (Permian) overlies the Sangre de Cristo Formation. It consists primarily of light-red or orange-red siltstone (Griggs and Hendrickson, 1951). The Yeso ranges from approximately 300 to 1,000 feet thick and crops out on the east side of the mountains and within Glorieta Mesa. Although some stock and domestic wells in San Miguel County are completed in the Yeso, wells are almost always drilled through the Yeso into the Sangre de Cristo Formation. In the western part of Guadalupe County, the Yeso Formation yields small amounts to domestic and stock wells. The formation does not provide groundwater in the eastern part of the County because it is overlain by units that produce larger yields of better quality (Dinwiddie and Clebsch, 1973).

5.3.2.1.5 Glorieta Sandstone. The Glorieta Sandstone (Permian) is comprised of light gray quartzitic sandstone with thin interbedded layers of yellow to red clay and silt. It ranges from 150 to more than 200 feet thick in San Miguel County and from 400 to 500 feet thick near Santa Rosa. The Glorieta Sandstone forms most of the caprock found on the surface of the Glorieta Mesa, and it is also found in some locations on the east slope of the mountains. Several wells within San Miguel County are completed in the Glorieta, and it is thought that the water in these wells is supplied by fractures along bedding planes. The Glorieta Sandstone generally yields small amounts of water to stock and domestic wells in Guadalupe County (Dinwiddie and Clebsch, 1973).

5.3.2.1.6 San Andres Formation. The San Andres Formation is a Permian limestone that overlies the Glorieta Sandstone, although outcrops are sparse. It is a fine-grained, gray limestone with layers of anhydrite, dolomite, and shale, grading into beds of anhydrite, gypsum, and salt in eastern Guadalupe County. Whereas it has a maximum thickness of approximately 30 feet in San Miguel County, its thickness ranges from 90 to 300 feet in Guadalupe County.

The San Andres Limestone does not contain significant amounts of water in San Miguel County, but in western Guadalupe County, Permian dissolution and subsequent collapse of the evaporite beds of the San Andres Limestone have resulted in a cavernous aquifer that provides as much as 2,500 gpm (Trauger, 1972). These collapse features manifest themselves at the surface as numerous small lakes and sinkholes, the most obvious of these being the Santa Rosa Sink, which is about 6 miles in diameter and is home to the City of Santa Rosa. A geologic cross section for the Santa Rosa area is presented in Figure 5-16. The San Andres Limestone (in combination with the Glorieta Sandstone) is the principal aquifer for the City of Santa Rosa (Risser, 1987).

5.3.2.1.7 Bernal Formation. The Bernal Formation (Permian) conformably overlies the San Andres Limestone and crops out in San Miguel and Guadalupe Counties, especially along the reach of the Pecos River there. The Bernal Formation is 50 to 250 feet thick and consists of orange-red to gray shale and siltstone, fine-grained sandstone, dolomite, and gypsum. The Bernal Formation generally yields small amounts of water to domestic and stock wells and to a few small irrigation wells in central and western Guadalupe County (Dinwiddie and Clebsch, 1973). Permian rocks above the San Andres Limestone, where units are not well defined, have been labeled the Artesia Formation; however, the Bernal Formation is well defined in much of the planning area and so the Bernal terminology is used here.

5.3.2.1.8 Santa Rosa Sandstone. The Santa Rosa Sandstone (Late Triassic) unconformably overlies the Bernal Formation and, along with the Chinle Formation, is in the Dockum Group. The Santa Rosa is a silty, fine-grained, gray sandstone and contains some thin beds of conglomerate and shale. Its thickness ranges from 250 to 350 feet. The Santa Rosa is exposed in portions of the Las Vegas Plateau and the Glorieta Mesa; it crops out extensively in Guadalupe County and is relatively shallow within the rest of the plains area of the planning region, with water levels within 25 feet of ground surface. The permeability of the Santa Rosa is variable. In the plains region of western and central Guadalupe County, the Santa Rosa is a weak aquifer (Trauger, 1972); however, near Las Vegas where it is approximately 2,000 feet bgs, it is the primary aquifer for the Taylor well field, which supplies the city with approximately 6 percent of its domestic water.

5.3.2.1.9 Chinle Formation. The Chinle Formation (Late Triassic) conformably overlies the Santa Rosa Sandstone and is part of the Dockum Group. The formation is approximately 800 feet thick and consists of red, brown, and purple shale and siltstone, gray, brown, and red fine-grained sandstone, and lenses of limestone conglomerate (Dinwiddie and Clebsch, 1973). The Chinle generally yields small quantities of water, although more flow can be yielded in places where the sandstone is fractured. Because of the generally small yield, however, water from the Chinle Formation has not been used extensively as a source of groundwater.

5.3.2.1.10 Entrada Sandstone. The Entrada Sandstone (Late Jurassic) conformably overlies the Chinle Formation. It is a fine- to medium-grained, poorly cemented, pink sandstone that crops out mostly along the Canadian escarpment and in limited areas of southeast San Miguel County and northeast Guadalupe County. The Entrada ranges in thickness from 35 to 85 feet in western to eastern San Miguel County and may be thicker in Guadalupe County. It contains little bedding except for a thin bed that occurs along the top and bottom of the unit at certain locations. The Entrada Sandstone is generally not used as an aquifer on the Las Vegas Plateau because it is not areally extensive and is overlain by the Morrison Formation, a shale unit that prevents much recharge to the Entrada. The Entrada is most productive along the Canadian River, where it receives recharge from the streambed.

5.3.2.1.11 Summerville Formation. The Summerville Formation was formerly termed Bell Ranch Formation in this region (Lucas and Woodward, 2001), and is Late Jurassic in age. It is present mostly in northeastern Guadalupe County, cropping out in that area, and it conformably overlies the Entrada Sandstone, where present. This formation consists of alternating beds of light gray sandstone and brownish red siltstone, dark gray thinly bedded limestone, and gypsum up to a thickness of 65 feet (Dinwiddie and Clebsch, 1973). This Summerville Formation is not used as an aquifer due to its limited presence in the planning region.

5.3.2.1.12 Morrison Formation. The Morrison Formation (Late Jurassic) conformably overlies the Summerville Formation in Guadalupe County and the Entrada Sandstone in other areas. The Morrison consists of variegated shale and gray to buff, fine- to medium-grained sandstone up to 200 feet thick. The Morrison Formation is for the most part a poor producer of groundwater, and the few wells that are completed in it supply water of poor quality. The exception occurs in wells south of Mosquero, where the formation is exposed over a large area and interbedded sandstone layers provide adequate water for livestock (Griggs and Hendrickson, 1951).

5.3.2.1.13 Dakota Group. The Dakota Sandstone and underlying Purgatoire Formation (Lower Cretaceous) are present on parts of the Las Vegas Plateau in San Miguel County, but are absent in Guadalupe and Mora Counties. These formations consist of quartzitic sandstone, with some interbedded shale, and form the resistant cap over most of the Las Vegas Plateau. The Dakota Group provides the best available source of groundwater for a large part of western San Miguel County. Over the main body of the Las Vegas Plateau, water can be obtained from this unit within 200 feet of ground surface. The most productive areas are within the closed depressions that occur on the Las Vegas Plateau, which may also be structural basins.

5.3.2.1.14 Graneros Shale. The Graneros Shale (Lower Cretaceous) overlies the Dakota Group in places on the Las Vegas Plateau. It is a dark to medium gray shale, with thin beds of argillaceous limestone, and can be as much as 200 feet thick (Griggs and Hendrickson, 1951 [citing Northrop, 1946]). The shale is relatively impermeable, but it is known to supply small quantities of water to some wells completed in the bottom of the unit. The quality of water from this unit is poor; much of it has the odor of hydrogen sulfide and all of it has a disagreeable taste (Griggs and Hendrickson, 1951 [citing Northrop, 1946]).

5.3.2.1.15 Greenhorn Limestone. The Greenhorn Limestone (Upper Cretaceous) consists of thin beds of dark gray limestone and interbedded dark gray shale that are collectively approximately 45 feet thick. It occurs only on the Las Vegas Plateau, above the Graneros Shale. In most places where this unit occurs it is above the water table. Water to the few wells completed in the Greenhorn Limestone comes from fractures in the rock, but the overall permeability is low. Additionally, the quality of this water is poor, similar to that found in the Graneros Shale.

5.3.2.1.16 Carlile Shale. The Carlile Shale (Upper Cretaceous) unconformably overlies the Greenhorn Limestone in San Miguel County. It is a dark gray shale with low permeability, and while a few wells are completed in this unit, most are considered weak or inadequate (Griggs and Hendrickson, 1951 [citing Northrop, 1946]).

5.3.2.1.17 Niobrara Formation. The Niobrara Formation (Upper Cretaceous) is a gray clay shale and calcareous shale on the eastern edge of the Sangre de Cristo Mountains (Baltz and Myers, 1999). It contains a few thin beds of gray limestone and is 700 feet thick near Storrie Lake. It crops out extensively along with the overlying Pierre Shale in northeastern Mora County (Green and Jones, 1997).

5.3.2.1.18 Ogallala Formation. The Ogallala Formation (Tertiary) exists in portions of the Las Vegas Plateau in the southeast corner of the planning region, as well as sparsely within the Glorieta Mesa portion of the region. The formation is up to 100 feet thick and consists of poorly sorted sandstone, siltstone, and conglomerate capped by caliche. It yields small amounts of water to a few domestic and stock wells, but is not widely used within the planning region because of its limited extent in the region.

5.3.2.1.19 Quaternary Alluvium. Alluvial deposits consist of unconsolidated silt, sand, and gravel, generally yielding small amounts of water to domestic and stock wells. Because they are relatively thin, alluvial deposits are not known to yield large amounts of water within the planning area. The most significant deposits lie alongside streams, the most developed of which are along the Canadian River (Griggs and Hendrickson, 1951 [citing Northrop, 1946]). The only other significant deposits occur in some of the larger valleys in the Sangre de Cristo Mountains and in a broad valley between Lower Rociada and the San Miguel County line. The water quality in the alluvium ranges from good to poor; high total dissolved solids (TDS) resulting from calcium and carbonate may cause the poor water quality (Griggs and Hendrickson, 1951 [citing Northrop, 1946]).

5.3.3 Aquifer Characteristics

An inventory of quantitative data on aquifer properties was compiled by reviewing available information found in the documents listed in the bibliography (Appendix A). The inventory is shown in Appendix E5 and is organized by declared basin, with all the aquifers that occur within each basin listed separately. Much of the information contained in the table is used by hydrologists to quantify well performance and water availability. The following list of terms is included to help the reader who may not be familiar with their exact meaning:

- *Hydraulic conductivity.* A constant of proportionality 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 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 the properties of the liquid and the properties and 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.

As indicated by the gaps in Appendix E5, aquifer performance in the parts of San Miguel County and in Guadalupe County along the Pecos River has been fairly well characterized, but the aquifers of Mora County and southern and eastern Guadalupe County are less well understood.

In addition to the aquifer characteristics shown in Appendix E5, groundwater levels are important in evaluating aquifer characteristics. Water levels in the planning region are shown in Figures B-7 and B-8. In most of the aquifers in the planning region, the groundwater flow direction is to the east or southeast, from the mountains in the west toward the plains.

In order to evaluate changes in water levels over time, hydrographs for representative wells, illustrating groundwater levels versus time for each well, have been compiled (Appendix E6). Most of the hydrographs were obtained from the USGS website, but it contained information only for wells in Guadalupe County. Hydrographs for two additional wells in San Miguel County were developed by obtaining data from USGS annual reports (USGS, 2000, 2001, 2002a, and

2003). Though the number of years of available data is limited, groundwater levels in these two counties appear to be declining slightly in many of the wells.

Although the USGS has no long-term monitor wells in Mora County and no USGS monitor well data are therefore available for the county, the USGS evaluated water level trends in Mora County between 1982 and 1987 (Cruz, 1988). The investigation indicated that water levels fluctuated very little, with some wells showing slight increases in water levels and one well showing a slight decline (Cruz, 1988).

The amount of subsurface characterization (i.e., well logs) within the planning region is not adequate to allow highly accurate determination of groundwater properties or to develop accurate storage estimates. In addition, the quality of water varies throughout the planning 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. In addition to the water quality issue, legal (water right) issues or the economics of development in remote areas further restrict groundwater development in the area, as discussed in Section 8.7.

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, 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 planning region occurs through direct rainfall and mountain front recharge. Localized recharge also occurs along portions of the Pecos, Gallinas, and Canadian Rivers, which recharge the underlying alluvial aquifers.

5.3.4.1 Published Recharge Estimates

Recharge data for the planning region are sparse. In the mountain foothill region near Las Vegas, recharge to the Taylor well field aquifers has been estimated to range from 0.2 to 2 inches per year (in/yr), or 1 to 12 percent of total rainfall (Molzen-Corbin and Lee Wilson, 1985). Risser (1987) estimated recharge of 0.18 to 0.3 in/yr near Santa Rosa. No estimates of recharge for the rest of the planning region are available in the published literature.

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) indicating 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. Based on 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 in a groundwater basin encompassed between two iso-precipitation contours

$R_i = r_i P_i$

where: i = Precipitation contour

R_i = Recharge rate 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 percentage 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 regressions. Table 5-7 summarizes the results of their analysis.

Table 5-7. Maxey-Eakin Recharge Percentages for Precipitation Ranges

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

Many hydrogeologic and climatic similarities can be found between the planning region and most of the basins studied by Maxey and Eakin in Nevada, which share semiarid climatic regimes. Given the similarities, the Maxey-Eakin recharge model was chosen to estimate basin recharge in the planning region through direct use of equations (1) and (2). This model was used in conjunction with a contoured precipitation map of the planning region (Figure B-4 in

Appendix B) to estimate recharge within the selected groundwater basins in the planning region. Precipitation ranges were adjusted to correspond to the contours of the precipitation map available from WRRI (Table 5-8).

Table 5-8. Precipitation Ranges and Recharge Percentages Used

Precipitation Range (inches)	Percentage of Precipitation that Becomes Recharge	
	Maxey-Eakin Calculation	Alternate Calculation
<11	3	1
11 to 15	7	1.5
15 to 19	15	2
>19	25	10

Using these precipitation ranges results in a slightly higher estimate of recharge than estimates resulting from the original Maxey-Eakin ranges.

Using the same precipitation ranges and the same areas used for the Maxey-Eakin approach, DBS&A also developed an alternative estimate of recharge for each declared basin in the planning region, based on previous investigations (Molzen-Corbin and Lee Wilson, 1985) indicating that the percentage of recharge in the region is lower than the Maxey-Eakin estimates. The recharge rates used to develop the alternate estimate are shown in Table 5-8, and the calculated recharge is shown in Table 5-9. The alternative estimate is a more conservative recharge estimate and is therefore more appropriate for planning purposes.

Table 5-9. Calculated Recharge to OSE-Declared Groundwater Basins

	Annual Recharge			
	Maxey-Eakin		Alternate Estimate	
Basin	ac-ft	%	ac-ft	%
Canadian River Basin	290,198	14	65,539	3
Ft. Sumner Basin	55,903	7	11,882	2
Not declared	87,888	8	17,865	2
Roswell Basin	11,560	7	2,477	2
Tucumcari Basin	55,926	7	11,517	2
Upper Pecos Basin	255,922	11	66,523	3

The differences among the estimates in Table 5-9 underscore the uncertainty associated with recharge estimates and the need for local field and modeling studies to more accurately estimate recharge.

The total groundwater withdrawals in the planning region during 2000 were 3,910 acre-feet (Section 6.1), well below the recharge estimates shown in Table 5-9. Even if it is assumed that the recharge rate in the planning region is only 1.5 percent of total precipitation, recharge is more than 110,000 ac-ft/yr, which still far exceeds the groundwater withdrawals in the area. However, because the best aquifers in the planning region are often overlain by geologic units that add unwanted chemical constituents to recharging water (such as hardness and sulfate), this relatively large volume of recharge does not necessarily translate into good-quality, usable groundwater. Additionally, the region-wide recharge estimate does not necessarily indicate that recharge water will be available to localized pumping centers; for example, in locations where pumping is concentrated, declining water levels indicate that withdrawals are exceeding recharge. And while groundwater may be available in remote areas throughout the planning region, it is not economically viable to pump water from those areas to the population centers. Furthermore, legal restrictions on surface-connected groundwater (Section 4) further restrict the ability of the planning region to use available groundwater supplies.

5.3.5 Major Well Fields

The major well fields in the planning region, along with the basins they draw from, are:

- Taylor well field of the City of Las Vegas (Upper Pecos Basin)
- Colonias well field of the City of Santa Rosa (Upper Pecos and Ft. Sumner Basins)
- Negra well field of Vaughn (Upper Pecos and Ft. Sumner Basins, outside the planning region)

The City of Las Vegas receives its primary surface supply from the Gallinas River. The Taylor well field was developed during the severe drought of the 1950s to augment Las Vegas's dependence upon surface water supplies (Romero, 1994) and is used by the City only when surface water supplies are insufficient to meet the needs of the community. It is located in a valley southwest of Las Vegas and west of the Creston, a north-south trending ridge developed on the resistant Dakota Sandstone (Molzen-Corbin and Lee Wilson Associates, 1985). The Santa Rosa Sandstone is the primary aquifer for the well field.

Numerous domestic wells are located in the Romerville area near the Taylor well field, and the domestic well owners have had considerable concern regarding the potential for longer-term pumping of the Taylor well field to impact domestic wells. An analysis produced by a hydrologist for the citizen's group indicated that drawdown in some domestic wells could be expected if the Taylor wells are pumped for a long period of time (Brinkman, 2004).

The City of Santa Rosa receives all of its supply from two production wells in the Colonias well field, which is located about 15 miles northwest of Santa Rosa. Both wells are completed in the San Andres Limestone to total depths of 620 and 635 feet bgs (ASCG, 2004). The wells were drilled in 1956 and 1963 and originally produced 425 gallons per minute (gpm) each (Molzen-Corbin, 1992). Currently, one of the wells produces 410 gpm and the other produces 405 gpm (ASCG, 2004). The water obtained from these wells is of good quality, with TDS concentrations of about 300 milligrams per liter (mg/L) (ASCG, 2004).

The Town of Vaughn receives its water supply from the four wells in the Negra well field (Town of Vaughn, 2004), which also supplies water to the communities of Encino and Duran and to local ranchers. The well field is located in Torrance County, 19 miles northwest of Vaughn and about 5.5 miles northwest of Encino. Two of the wells draw from the Upper Pecos Basin and the other two from the Ft. Sumner Basin. A fifth well in the Ft. Sumner Basin is not currently in use. The four operating wells produce 105, 90, 170, and 150 gpm and are capable of collectively producing about 831 ac-ft/yr. In the year 2002, the city (population 575, including Duran) depended mainly on three of the four operating wells, and only about 170 acre-feet were produced.

In addition to these well fields, numerous domestic and stock wells are located throughout the Upper Pecos and Canadian River Basins. Further information regarding sustainable yields and production in the major well fields in the planning 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 development to an amount that can be maintained over a long time period or that will not be detrimental to other resources. Commonly accepted requirements for maintaining a "sustainable water supply" (Shomaker, 2001) include:

- For surface water, limiting water use to the net surface supply in any given year

- For groundwater, limiting the amount of water that can be withdrawn to an amount that has no unacceptable effects on drawdown or streamflows

Although there is no single universally accepted definition of sustainable yield in groundwater management, a useful one was provided by a recent study completed in Arizona, which defined it 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.

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 needs (Sophocleous, 1998). 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.

No quantitative estimates of sustainable yields have been developed specifically for any groundwater basins in the planning region, and currently available data are insufficient to evaluate sustainable yields. Additional field studies and modeling efforts would be required to develop quantitative estimates of sustainable yields for all the basins in the planning region. Current indications of the sustainability of aquifers in the planning region include:

- Based on available data, water levels appear to be declining slightly in the Las Vegas area and in Guadalupe County wells, possibly indicating that groundwater mining is occurring. However, the declining water levels could also be at least partially due to decreased precipitation. Due to concerns over the capacity and long-term sustainability of the well field, the Taylor well field is used only when surface water supplies do not meet demand.

- The Village of Pecos, which relies completely on groundwater for its domestic and municipal supplies, experiences periodic water shortages, particularly in the summer months, because existing wells cannot produce enough.

- The Village of Wagon Mound receives all of its domestic water from a spring that is estimated to be capable of serving a community of seven or eight thousand people (Romero, 1994), which greatly exceeds its actual population of approximately 400. However, since there are no reliable long-term measurements of spring flow (Smith, 2005), the long-term sustainability of the spring is uncertain.

5.4 Water Quality Assessment

Assurance of availability to meet future water demands requires not only water in sufficient quantities, 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 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 supplies must also be of sufficient quality for these uses or expensive treatment will be required.

Water quality in the Mora-San Miguel-Guadalupe Water Planning Region was assessed through review of 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 not meeting or not expected to meet water quality standards (NMED, 2003d) and (2) *Water Quality and Water Pollution Control in New Mexico, 2002,* a report prepared by the NMWQCC for submission to the United States Congress (NMWQCC, 2002). Information regarding groundwater quality was obtained primarily through the NMWQCC document, and information on specific sites and facilities that may pose a potential for surface water or groundwater quality impacts was obtained from various NMED and EPA databases.

5.4.1 Potential Sources of Contamination

Sources of contamination are considered as one of two types: (1) point sources, if they originate from a single location, or (2) nonpoint sources, if they originate over a more widespread or unspecified location.

5.4.1.1 Permitted Point Source Discharges

Potential point source discharges to surface water must comply with the Clean Water Act and the New Mexico Water Quality Standards (20 NMAC 6.4.1) by obtaining an NPDES permit to discharge. A summary of NPDES permitted discharges in the planning region is included in Table 5-10.

Table 5-10. Municipal and Industrial NPDES Permittees in the Mora-San Miguel-Guadalupe Water Planning Region

Permit No.	Municipality/Industry	Status	County
Municipalities			
NM0024996	Mora Mutual Domestic Water & Sanitation	---	Mora
NM0028827	Las Vegas	Major	San Miguel
NM0029041	Pecos	---	San Miguel
NM0028363	San Miguel County-Operation Breakthrough	---	San Miguel
NM0024988	Santa Rosa	---	Guadalupe
Industries			
NM0030031	Mora National Fish Hatchery	---	Mora
NM0030341	Las Vegas Water Treatment Plant	---	San Miguel
NM0030121	Lisboa Springs Fish Hatchery	---	San Miguel
NM0029289	Native American Preparatory School	---	San Miguel
NM0030155	Rock Lake Fish Hatchery	---	Guadalupe

Source: NMED, 2004b --- = No status given

5.4.1.2 Groundwater Discharge Plans

The NMED Groundwater Bureau regulates facilities with wastewater discharges that have a potential to impact groundwater quality. These facilities must comply with the NMWQCC regulations (NMWQCC, 2002) 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 facilities, and other industries. A summary list of the discharge plans (NMED, 2003c) in the planning region is provided in Table 5-11.

The NMWQCC regulations contain requirements for cleanup of groundwater contamination if detected under discharge plan monitoring requirements. However, these facilities still carry a potential for causing groundwater contaminant impacts that may affect the quantity and availability of water supplies. Details indicating the status, waste type, and treatment for individual discharge plans can be obtained from the NMED Ground Water Bureau website (http://www.nmenv.state.nm.us/gwb/gwqbhome.html).

5.4.1.3 Superfund Sites

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 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, including surface water or groundwater supplies. Three sites in the planning region are listed by the U.S. EPA (2004) as Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) sites (Table 5-12). Two of these sites are associated with early 20th century lead and zinc mining and ore processing at the Terrero Mine and El Molino Mill on the Upper Pecos River and are currently undergoing remediation. A third site (East Pecos) has not yet undergone a preliminary investigation.

Though mining was discontinued in 1939, natural leaching of waste rock piles containing elevated amounts of heavy metals has resulted in local vegetation die-off and is a concern for the Lisboa Fish Hatchery 12 miles downstream (Johnson and Deeds, 1995). None of the sites are currently listed on the Superfund National Priorities List (NPL), which identifies the top priority hazardous waste sites, though the U.S. EPA has funded state-led stabilization and

Table 5-11. Groundwater Discharge Plans in the Mora-San Miguel-Guadalupe Water Planning Region
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County	Municipality	Facility Name	Facility Type	Permitted Discharge Amount (gpd)
Guadalupe	Santa Rosa	U.S. Army Corps Engsanta Rosa Lake	AMU-Campground/RV Park	10,000
	Santa Rosa	Rio Pecos Villa Mda	UNINCORP-Wastewater	3,375
	Santa Rosa	Santa Rosa (City of) - Wastewater Treatment Plant	MUNI-Wastewater	445,000
	Santa Rosa	Santa Rosa Roping Arena	AMU-Campground/RV Park	3,500
	Santa Rosa	New Mexico (State of) - Santa Rosa Petroleum Yard	Hydrocarbon Remediation of Ground Water	28,800
	Vaughn	Vaughn (Town of) - Wastewater Treatment Plant	MUNI-Wastewater	150,000
Mora	Mora	Mora (Village of) - Wastewater Treatment Plant	MUNI-Wastewater	53,000
	Wagon Mound	Wagon Mound (Village of) - Wastewater Treatment Plant	MUNI-Wastewater	27,000
San Miguel	South San Ysidro	Native American Prep Sch	Lodging	9,500
	Pecos	El Molino Operable Unit	Mining-Mill Facility	11,000
	Las Vegas	Las Vegas (City of) - Sludge Disposal Facility	Septage Disposal Facility	15,900
	Las Vegas	Johnny's 66	Hydrocarbon Remediation of Ground Water	7,200
	Las Vegas	El Porviner Christian Camp	Lodging	6,100
	Las Vegas	Las Vegas (City of) - Effluent Reuse Project	MUNI-Wastewater	500,000
	Las Vegas	New Mexico Highway and Transportation Dept - District4 Service Center	State Agency/Organization	NA
	Las Vegas	Lakeside MHP Las Vegas	Mobile Home Park/Subdivision	11,500
	Las Vegas	Country Acres Subdivision	Mobile Home Park/Subdivision	45,150
	Las Vegas	Blue Haven Youth Camp	Lodging	8,600

Source: NMED, 2004b

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

[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 permits.

gpd = Gallons per day

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Table 5-11. Groundwater Discharge Plans in the Mora-San Miguel-Guadalupe Water Planning Region
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County	Municipality	Facility Name	Facility Type	Permitted Discharge Amount (gpd)
San Miguel (continued)	Las Vegas	BTU Block and Concrete Inc	Manufacturing	1,000
	Montezuma	Armand Hammer United World College	Educational Institution	48,750
	Montezuma	Las Vegas Water Treatment Facility	MUNI-Wastewater	20,000
	Pecos	Pecos Benedictine Monastery	Educational Institution	8,000
	Pecos	Salazar's Mobile Home Park	UNINCORP-Wastewater	2,000
	Pecos	Pecos (Village of) - Wastewater Treatment Plant	MUNI-Wastewater	142,000
	Pecos	Inn of Pecos	Lodging	2,685
	Ribera	Valley Mid.& Elem. School	Educational Institution	9,200
	Rociada	Pendaries Park At Rociada	AMU-Campground/RV Park	1,500

Source: NMED, 2004b
[a] Supplemental discharge permit for closure DP-1341, issued April 8, 2003 (NMED, 2003b).
[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 permits.
gpd = Gallons per day

asphalt capping of roads and campgrounds near Terrero Mine where waste rock was used to build U.S. Forest Service roads in the 1970s before the risk of heavy metal contamination was realized.

Leachate from mine waste is a concern to both surface and groundwater supplies. Until reclamation at the mine site occurred, the Pecos River was vulnerable to heavy metal runoff and acid mine drainage, especially during times of heavy stormwater flows. Several wells downgradient from the Terrero Mine and El Molino Mill have sulfate concentrations above the NMWQCC drinking water standard of 600 mg/L. The NMED, New Mexico Game and Fish, and Phelps Dodge are working together to evaluate groundwater and surface water impacts and to monitor and replace impacted domestic wells near the mill.

Table 5-12. CERCLA Superfund Sites in the Mora-San Miguel-Guadalupe Water Planning Region

Facility	City	County	EPA ID	Site Status
East Pecos	East Pecos	San Miguel	NM0000605422	PA start needed
El Molino Mill	Pecos	San Miguel	NMD981057292	Status not specified
Terrero Mine	Terrero	San Miguel	NMD986668820	State-led cleanup

Source: U.S. EPA, 2004

EPA ID = U.S. Environmental Protection Agency identification number
PA = Preliminary assessment

5.4.1.4 Mining

Mining is not a major concern to water quality in most of 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) and are listed in the publication *Mines, Mills and Quarries in New Mexico* (NMEMNRD, 2001). Appendix E7 lists general information about the mines and mills currently operating in the planning region (one in Mora County, four in San Miguel County, and none in Guadalupe County), all of which are exclusively sand and gravel quarries. Such quarries are not generally considered potential contaminant sources.

The major threats to surface water and groundwater quality by mining in the planning region are from the abandoned Terrero Mine and associated El Molino Mill near the Village of Pecos.

These two locations are classified as Superfund (CERCLA) sites and are under remediation efforts as described in Section 5.4.1.3.

5.4.1.5 Underground Storage Tanks

Leaking USTs are one of the most significant point source contaminant threats, particularly to groundwater. As of April 2004, the NMED (2004a) had reported 2,412 leaking UST cases in New Mexico, 81 of which are active in the planning region (Table 5-13). These leaking USTs represent releases of oil, gasoline, diesel, and aviation fuel containing petroleum constituents that are common groundwater contaminants, such as benzene, toluene, ethylbenzene, and xylenes (BTEX), and methyl tertiary-butyl ether (MTBE). Because the facilities that use USTs (e.g., gas stations) are necessarily near population centers, the majority of leaking UST sites are concentrated around municipal and industrial areas.

The leaking UST sites do not necessarily signify that groundwater contamination or water supply well impacts have actually occurred. Currently, 20 sites have contributed unknown impacts to the water supply and the remaining sites have not affected it (Table 5-13). Additional 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, which is accessible from their website (www.nmenv.state.nm.us/ust/ldocs/reports/relcity.txt). Many additional facilities with registered USTs that are not leaking are also included in the NMED UST database. These USTs could potentially impact groundwater quality in and near the population centers in the planning region.

5.4.1.6 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. Other landfills have closed as new solid waste regulations became effective in 1991 and 1995. Within the planning region, there are currently 3 operating landfills and 20 closed landfills (Table 5-14). The Santa Rosa Landfill is scheduled to close when a newly constructed waste transfer station at the site begins operation.

Table 5-13. Leaking Underground Storage Tank Sites in the Mora-San Miguel-Guadalupe Planning Region
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County	City	Name	Facility ID	Physical Address	Water Supply Impacts [a]
Mora	Mora	Allsups 270 A	26517	Main St	N
		Gandert's Servi	28250	General Delivery	N
	Wagon Mound	NMSHTD Wagon Mound	29874	I 25 Frontage Rd At Mile Post 386	N
		Sav-O-Mat TC	30495	State Rd 120 Off Of I 25 Old Hwy 85	N
		Texaco Levis	1995	US Hwy 85	N
	Watrous	Moberg's Garage	29439	Hwy 161	N
		Texaco Station	1869	Hwy 161	N
		Watrous Service Stat	31558	Hwy 85	N
San Miguel	Las Vegas	Allsups 255	26513	Seventh And Dalby	U
		Allsups 255 (Atex 38)	26513	Seventh And Dalby	N
		Allsups 259	26515	2603 Hot Springs Blvd	N
		Allsups 271	26518	113 Grand Avenue	N
		Atex 394(Allsup	26519	615 Grand Avenue	N
		Atex/Allsups 271 (39)	26518	113 Grand Avenue	N
		Bell Gas #188	957	1032 Grand	N
		Bob Dalton	27624	1625 S Pacific	U
		Cactus Hall Sto	1989	Village Of Villanueva	N
		Cactus Hall Store	1989	Village Of Villanueva	U
		Charlies Conoco	31317	310 S Pacific St	N
		County Rd Dept	30416	Rte 1	N
		Eusebio Bustos	27177	317 Grand	N
		FAA Moon Ranch	26611	6 Miles N Of I 40 On Us	N
		Franken O&D Crp	1268	503 Twelfth St	N
		Freds Lumber	28166	400 S Grand	N
		Giant StopNGo 54A	1151	405 Grand St	N
		Johnnys 66	1500	102 S Grand	N
		Junior's Shamrock	28801	2201 Seventh St	N
		Las Vegas Shamrock	29052	17 Grand Ave	N
		Martinez Gas Co	1509	300 S Grand Ave	N
		Medical Centr Physic	29960	3695 Hot Springs Blvd	U
		NM Highlands Ph	29602	Eleventh And San Francisco	N
		NM Highlands Phys Pl	29638	Mills Ave	N
		NM State Police	27686	301 Mills Ave	U

Source: NMED, 2004a

[a] U = Impacts of unknown extent and severity
N = No impacts

Table 5-13. Leaking Underground Storage Tank Sites in the Mora-San Miguel-Guadalupe Planning Region
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County	City	Name	Facility ID	Physical Address	Water Supply Impacts [a]
San Miguel (continued)	Las Vegas (continued)	NMSHTD Dist 4 Svc Ct	30534	W Frontage Rd	N
		NMSHTD Patrol Yard L	29867	W Frontage Rd	N
		Performance 66	1583	1339 N Grand Ave	N
		Pino Fina	29980	701 Grand Ave	N
		Pino's Fina	28026	905 Grand Ave	N
		Pino's Truck Stop	29981	1901 N Grand Ave	N
		Ralphs Trk Stp	30132	100 S Grand	N
		Retirement Ctr	1717	722 Douglas Ave	N
		Ross Texaco	1866	700 Grand Ave And University	N
		Sav-O-Mat #11	30491	502 University Ave	N
		Small Engines	30637	107 E Washington	N
		Superstop Shell	1851	Seventh And Legion Dr	N
		Target Gas Station	1860	225 Mills Ave	N
		Thunderbird Con	1861	S Hwy 85	N
		Warehouse, City	1462	1700 N Grand Ave	N
	Pecos	Forked Lgtng Rc	28082	PO Box 459	N
		Inn Of Pecos	28663	Rte 1	N
		It's Food And Gas	28677	Main St	U
		Ortiz Gulf	29813	NM Hwy 63	N
		Pecos 66	29844	State Rd 63 50	U
		Target Gas Station	1859	Glorieta Hwy	U
	Ribera	Sunshine Service Sta	30829	Hwy 3	U
	Rowe	NMSHTD Rowe	29876	State Rd 63 At Mile Post 3	N
	Sapello	Midway Chevron	29408	State Rd 3	N
Guadalupe	Anton Chico	Abercrombie Store	26375	State Rd 119	U
	Santa Rosa	Allsups 1152	875	1485 Will Rogers	N
		Bar F 10	27734	1190 Will Rogers	N
		Bobs Chevron	27000	108 Coronado	N
		Exxon/Conway #8	1782	I 40 And Willrogers Dr	N
		Flying C Ranch	986	40 Miles W Of Santa Rosa	U
		Grandview Texaco	27163	1415 Will Rogers Dr	U
		Hilltop Conoco	28542	3229 E Will Rogers Dr	N
		Jims Automotive	28760	85 Parker Avenue	N

Source: NMED, 2004a

[a] U = Impacts of unknown extent and severity
N = No impacts

Table 5-13. Leaking Underground Storage Tank Sites in the Mora-San Miguel-Guadalupe Planning Region
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County	City	Name	Facility ID	Physical Address	Water Supply Impacts [a]
Guadalupe (continued)	Santa Rosa (continued)	Martinez Gulf	26352	W Parker Ave	N
		NMSHTD Santa Ro	29868	601 Black St	N
		Rio Pecos Statn	30250	240 Coronado	N
		Santa Rosa Chevron	1781	3630 Will Rogers Dr	U
		Santa Rosa City Of	30474	141 S Fifth St	N
		Santa Rosa Cons	30475	344 4th St	N
		Silver Moon Texaco	30621	3527 Will Rogers Dr	U
		T/A BP Oil	31215	I 40 And Us 66	N
		Truckstops Of America	31215	I 40 And Us 66	U
	Vaughn	Allsups 124	886	Hwy 285 N	U
		AT&SF Duoro	26688	10 Miles S Us Hwy 60	U
		AT&SF Railroad Ea Of	26682	15 Miles E Of Vaughn	U
		Gilbert's Hardware	28337	PO Box 125	U
		NMSHTD Vaughn	29681	US 285	U
		Vaughn Depot	26688	10 Miles S Us Hwy 60	N

Source: NMED, 2004a

[a] U = Impacts of unknown extent and severity
N = No impacts

Table 5-14. Landfills in the Mora-San Miguel-Guadalupe Water Planning Region

County	Landfill Name	Operating Status	Closure Date	Location [a]
Mora	Northeast New Mexico Regional	Operating	NA	---
	Holman	Closed	1989	---
	Mora	Closed	1994	---
	Rainsville	Closed	1997	---
	Wagon Mound	Closed	1997	T21N, R21E, Sec. 35
San Miguel	Big Mesa Coop	Closed	1989	---
	Blue Haven Camp	Closed	1993	---
	Conchas	Closed	---	---
	Las Vegas	Closed	1999	T16N, R16E, Sec. 16
	Pecos	Closed	1995	T16N, R12E
	Rowe	Closed	1995	T15N, R12E, Sec. 33
	San Miguel	Closed	1994	T13N, R14E, Sec. 15
	Villanueva	Closed	1998	T25N, R15E, Sec. 16
Guadalupe	Santa Rosa	Operating	NA	T09N, R21 E, Sec. 36
	Vaughn	Operating	NA	T04N, R16E, Sec. 03
	Anton Chico	Closed	1989	Lat. 35.11, Long. 105.08
	Colonias	Closed	1994	T09N, R20E
	Cuervo	Closed	1999	T09N, R24E, Sec. 08
	Delia	Closed	1993	---
	La Loma	Closed	1993	---
	Newkirk	Closed	1989	---
	Pastura	Closed	1988	---
	Puerto de Luna	Closed	1989	---

Sources: NMED, 1990, 1996, 2000, 2002

[a] Location information based on records available with New Mexico Environment Department (NMED). For landfills without location information, additional research with local officials will be needed to obtain records.

NA = Not applicable
--- = Information not available

5.4.1.7 Septic Systems

A primary water quality concern in the planning region is groundwater contamination due to septic tanks. In areas with shallow water tables or in karst terrain, septic system discharges can percolate rapidly to the underlying aquifer and increase concentrations of (NMWQCC, 2002):

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

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 systems 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. Additional information regarding septic tanks in the planning region is provided in Section 8.6.

5.4.2 Existing Surface Water Quality

The Mora-San Miguel-Guadalupe Water Planning Region is mostly drained by the Upper Pecos River, the Upper Canadian River, and their tributaries. Water quality is generally very good throughout the planning region with some exceptions. Nonpoint sources of pollutants that are concerns for surface water quality in the planning region include grazing, agriculture, recreation, hydromodification, removal of riparian vegetation, road and highway maintenance, silvicultural activities, land disposal, resource extraction, road runoff, and natural and unknown sources. Specific pollutants or threats to surface water quality resulting from these nonpoint sources are turbidity, stream bottom deposits, metals, undesirable pH, dissolved oxygen, temperature extremes, pathogens, plant nutrients, streambank destabilization, and conductivity (NMWQCC, 2002). The point sources described in Sections 5.4.1.1 through 5.4.1.6 also pose threats to surface water quality such as total ammonia, pathogens, and metals.

The common pollutants in the planning region and their probable sources include:

- *Aluminum:* Resource extraction, range grazing, off-road vehicles, mill tailings, agriculture, and natural sources

- *Mercury in fish tissue:* Atmospheric deposition from sources outside the planning region
- *Temperature:* Recreation, habitat modification, and natural sources
- *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
- *Stream bottom deposits:* Removal of riparian vegetation, range grazing, highway maintenance and runoff, habitat modification, and streambank destabilization/ modification
- *Total ammonia:* Septic tanks and domestic and municipal point sources.
- *Pathogens:* Septic tanks and domestic and municipal point sources

Several reaches of rivers within the Upper Canadian and Upper Pecos watersheds have been listed on the 2002-2004 New Mexico 303(d) list (NMED, 2003d). 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 not expected to meet water quality standards. Table 5-15 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 5-18.

Section 303(d) further requires the states to prioritize their listed waters for development of TMDL management plans. A TMDL documents the amount of a pollutant 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 Table 5-15, no TMDL management plans have yet been developed for streams in the planning region and no watersheds in the planning region have been listed as high-priority (NMED, 2003d). However, management plans are scheduled to be completed for several reaches in the planning region:

Table 5-15. Total Maximum Daily Load Status of Streams in the Mora-San Miguel-Guadalupe Water Planning Region

Waterbody Name (Basin, Segment) Support Status Assessment Unit ID	Affected Reach (mi or ac)	Probable Sources of Pollutant	TMDL Due Date	Specific Pollutant	NPDES Permits on the Reach	Uses Not Fully Supported	Acute Public Health Concern	IR Category [a]
Canadian Basin								
Charette Lake (Lower) Not supported NM-2305.5_10	300	Atmospheric deposition of toxics, unknown sources	12/31/2017	Mercury in fish tissue	0	CWF, WWF	No	5/5A
Conchas Reservoir Not supported NM-2304_00	4,218.17	Atmospheric deposition of toxics, loss of riparian habitat, rangeland grazing, unknown sources, stream-bank modification/ destabilization	12/31/2017	Plant nutrients, mercury in fish tissue	0	WWF	No	5/5A
Manueles Creek (Ocate Creek to headwaters) Partially supported NM-2306.A_090	8.91	Unknown sources	12/31/2017	Unknown	0		No	1
Ocate Creek (Ocate to Wheaton Creek) Partially supported NM-2306.A_070	14.49	Low-flow alterations	12/31/2017	Unknown	0	HQCWF	No	4C
Coyote Creek (Mora River to Black Lake) Partially supported NM-2306.A_020	37.5	Natural sources, rangeland grazing	12/31/2008	Specific conductance, temperature	0	HQCWF	No	5/5B

Sources: NMWQCC, 2005a and 2005b

[a] Impairment (IR) category definitions are attached as the last page of this table.

mi = Miles (for streams and rivers)
ac = Acres (for lakes)
TMDL = Total maximum daily load

NPDES = National Pollutant Discharge Elimination System
CWF = Cold water fishery
WWF = Warm water fishery

HQCWF = High quality cold water fishery
LWWF = Limited warm water fishery
MCWF = Marginal cold water fishery

Table 5-15. Total Maximum Daily Load Status of Streams in the Mora-San Miguel-Guadalupe Water Planning Region
Page 2 of 7

Waterbody Name (Basin, Segment) Support Status Assessment Unit ID	Affected Reach (mi or ac)	Probable Sources of Pollutant	TMDL Due Date	Specific Pollutant	NPDES Permits on the Reach	Uses Not Fully Supported	Acute Public Health Concern	IR Category [a]
Mora River (Canadian River to USGS gages east of Shoemaker) Partially supported NM-2305.A_020	50.14	Rangeland grazing, unknown sources	12/31/2008	Dissolved oxygen	0	LWWF	No	5/5C
Mora River (Rio la Casa to headwaters) Not supported NM-2306.A_000	32.87	Silviculture, range grazing-riparian and/or upland, grazing-related sources, agriculture	12/31/2017	Turbidity, stream bottom deposits	0	HQCWF	No	Not found
Morphy (Murphy) Lake Not supported NM-2305.3.B_30	50	Silviculture, recreation and tourism activities (other than boating), range grazing-riparian and/or upland, grazing-related sources, agriculture	12/31/2017	pH, plant nutrients, dissolved oxygen, sedimentation/ siltation	0	MCWF, WWF	No	5/5A
Rio la Casa (Mora River to confluence of North and South Forks) Partially supported NM-2306.A_030	6.08	Unknown sources	12/31/2017	Unknown	0		No	2
Sapello River (Mora River to Manuelitas Creek) Partially supported NM-2305.3.A_20	27.39	Unknown sources	12/31/2017	Unknown	0		No	1

Sources: NMWQCC, 2005a and 2005b

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Table 5-15. Total Maximum Daily Load Status of Streams in the Mora-San Miguel-Guadalupe Water Planning Region
Page 3 of 7

Waterbody Name (Basin, Segment) Support Status Assessment Unit ID	Affected Reach (mi or ac)	Probable Sources of Pollutant	TMDL Due Date	Specific Pollutant	NPDES Permits on the Reach	Uses Not Fully Supported	Acute Public Health Concern	IR Category [a]
Pecos Basin								
Beaver Creek (Porvenir Creek to headwaters) Partially supported NM-2212_04	5.86	Loss of riparian habitat, other recreational pollution sources, silviculture harvesting	12/31/2004 Monitoring schedule, 2009	Sedimentation/ siltation	0	HQCWF	No	5/5A
Cow Creek (Pecos River to Bull Creek) Partially supported NM-2214.A_090	15.6	Highway/road/bridge runoff (non-construction related), loss of riparian habitat, rangeland grazing, streambank modification/ destabilization, watershed runoff following forest fire	12/31/2004	Sedimentation/ siltation, temperature, water turbidity	0	HQCWF	No	5/5A
Gallinas River (Las Vegas Diversion to headwaters) Not supported NM-2212_00	24.21	Highway/road/bridge runoff (non-construction related), livestock (grazing or feeding operations), loss of riparian habitat, rangeland grazing, streambank modification/ destabilization	12/31/2004	Sedimentation/ siltation, temperature, water	0	HQCWF	No	5/5A
Gallinas River (San Augustin to Las Vegas Diversion) Not supported NM-2213_21	16.44	Flow alterations from water diversions, municipal point source discharges, on-site treatment systems (septic systems and similar decentralized systems), unknown sources	12/31/2005	Ammonia (unionized) - toxin, benthic-macro-invertebrate bioassessments (streams), fecal coliform, sediment bioassays-chronic toxicity freshwater	0	MCWF	No	5/5C

Sources: NMWQCC, 2005a and 2005b

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Table 5-15. Total Maximum Daily Load Status of Streams in the Mora-San Miguel-Guadalupe Water Planning Region
Page 4 of 7

Waterbody Name (Basin, Segment) Support Status Assessment Unit ID	Affected Reach (mi or ac)	Probable Sources of Pollutant	TMDL Due Date	Specific Pollutant	NPDES Permits on the Reach	Uses Not Fully Supported	Acute Public Health Concern	IR Category [a]
Holy Ghost Creek (Pecos River to headwaters) Partially supported NM-2214.A_020	6.92	Unknown sources	12/31/2017		0		No	2
Pecos River (Alamitos Canyon to Willow Creek) Partially supported NM-2214.A_002	16.17	Aquaculture (permitted), highway/ road/bridge runoff (non-construction related), natural sources, other recreational pollution sources, reclamation of inactive mining	12/31/2004	Turbidity	0	HQCWF	No	5/5B
Pecos River (Canon del Oso to Alamitos Canyon) Partially supported NM-2213_00	66.54	Removal of riparian vegetation, recreation and tourism activities (other than boating), range grazing, riparian and/or upland, municipal point sources, habitat modification (other than hydromod-ification), grazing-related sources, bank or shoreline modifica-tion/destabilization, agriculture	12/31/2017	Stream bottom deposits	2	MCWF	No	
Pecos River (Sumner Reservoir to Santa Rosa Reservoir) Partially supported NM-2211.A_00	42.5	Flow alterations from water diversions, rangeland grazing	12/31/2004	Sedimentation/ siltation	0	LWWF	No	5/5A

Sources: NMWQCC, 2005a and 2005b

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Table 5-15. Total Maximum Daily Load Status of Streams in the Mora-San Miguel-Guadalupe Water Planning Region

Waterbody Name (Basin, Segment) Support Status Assessment Unit ID	Affected Reach (mi or ac)	Probable Sources of Pollutant	TMDL Due Date	Specific Pollutant	NPDES Permits on the Reach	Uses Not Fully Supported	Acute Public Health Concern	IR Category [a]
Rio Mora (Pecos River to headwaters) Partially supported NM-2214.A_040	17.95		12/31/2017		0		No	2
Santa Rosa Reservoir Not supported NM-2211.B_00	1,500	Atmospheric deposition of toxics, highway/road/bridge runoff (non-construction related), impervious surface/parking lot runoff, rangeland grazing, unknown sources	12/31/2017	Mercury in fish tissue, nutrient/ eutrophication biological indicators, sedimentation/ siltation	0	LWWF	No	5/5A
Sumner Reservoir Not supported NM-2210_00	4,277.79	Atmospheric deposition of toxics, loss of riparian habitat, other recreational pollution sources, unknown sources	12/31/2017	Mercury in fish tissue, nutrient/ eutrophication biological indicators, sedimentation/ siltation	0	WWF	No	5/5A
Tecolote Creek (I-25 to Blue Creek) Not supported NM-2212_10	21.3	Flow alterations from water diversions, highway/road/bridge runoff (non-construction related), loss of riparian habitat, rangeland grazing, site clearance (land development and redevelopment), streambank modification/ destabilization	12/31/2004	Specific conductance, temperature, water	0	HQCWF	No	5/5B

Sources: NMWQCC, 2005a and 2005b

[a] Impairment (IR) category definitions are attached as the last page of this table.

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Table 5-15. Total Maximum Daily Load Status of Streams in the Mora-San Miguel-Guadalupe Water Planning Region
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Waterbody Name (Basin, Segment) Support Status Assessment Unit ID	Affected Reach (mi or ac)	Probable Sources of Pollutant	TMDL Due Date	Specific Pollutant	NPDES Permits on the Reach	Uses Not Fully Supported	Acute Public Health Concern	IR Category [a]
Willow Creek (Pecos River to headwaters) Partially supported NM-2214.A_030	5.76	Habitat modification (other than hydromodification), highway/road/ bridge runoff (non-construction related), mine tailings, unknown sources, streambank modification/ destabilization	12/31/2017	Zinc-chronic, zinc-acute, turbidity, stream bottom deposits, conductivity, cadmium-chronic	0	HQCWF	Yes	5/5C
Wright Canyon Creek (Tecolote Creek to headwaters) Partially supported NM-2212_18	2.05	Highway/road/bridge runoff (non-construction related), other recreational pollution sources, rangeland grazing	12/31/2004	Sedimentation/ siltation	0	HQCWF	No	5/5A

Sources: NMWQCC, 2005a and 2005b

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Table 5-15. Total Maximum Daily Load Status of Streams in the Mora-San Miguel-Guadalupe Water Planning Region

Impairment (IR) categories are determined for each assessment unit (AU) by combining individual designated use support decisions. The unique assessment categories for New Mexico are described as follows:

Category 1: Attaining the water quality standards for all designated and existing uses. AUs are listed in this category if there are data and information that meet all requirements of the assessment and listing methodology and support a determination that the water quality criteria are attained.

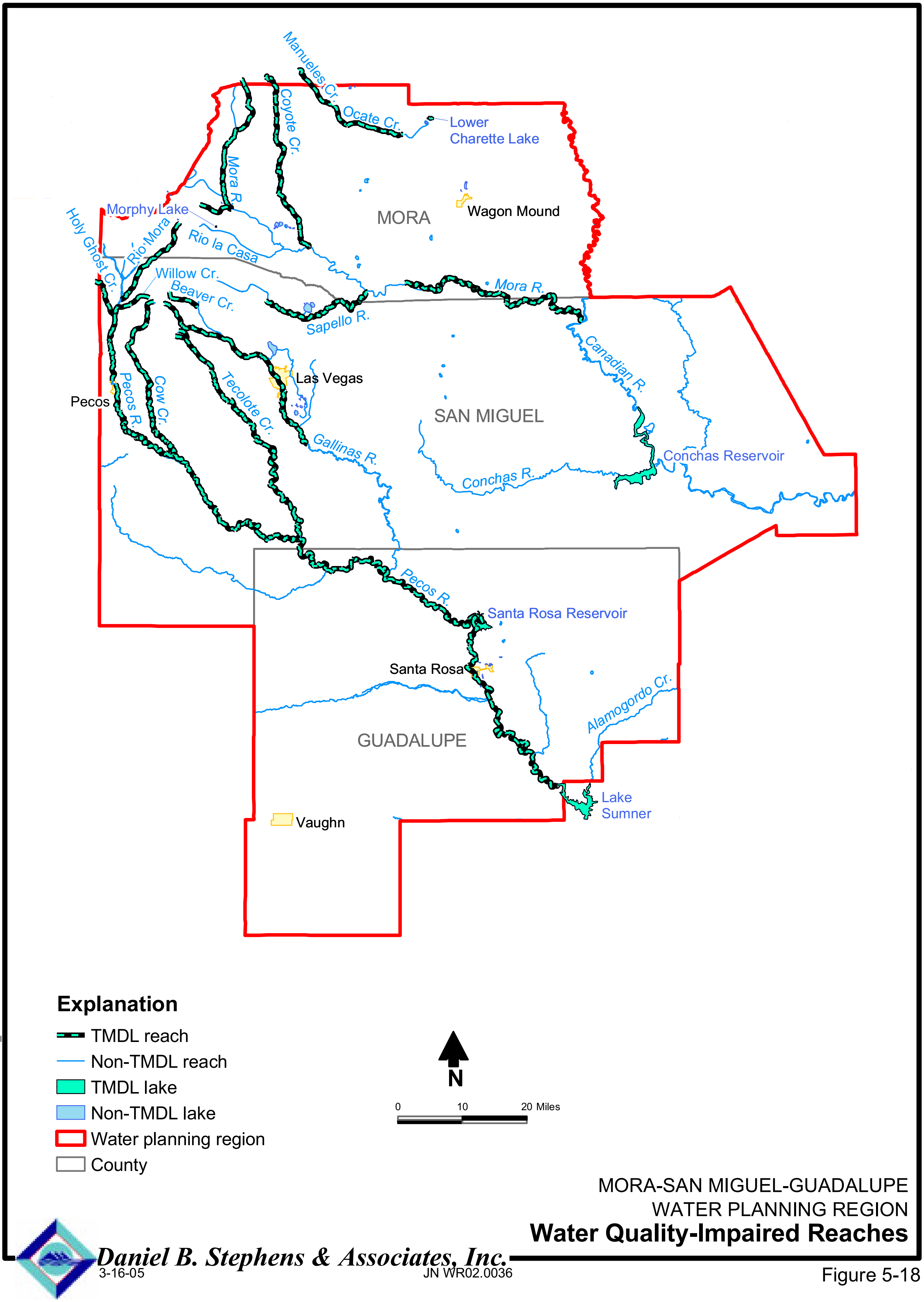
Category 2: Attaining some of the designated or existing uses based on numeric and narrative parameters that were tested, and no reliable monitored data are available to determine if the remaining uses are attained or threatened. AUs are listed in this category if there are data and information that meet requirements of the assessment and listing methodology to support a determination that some, but not all, uses are attained based on numeric and narrative water quality criteria that were tested. Attainment status of the remaining uses is unknown because there are no reliable monitored data with which to make a determination.

Category 4C: Impaired for one or more designated uses, but does not require development of a TMDL because impairment is not caused by a pollutant. AUs are listed in this subcategory if a pollutant does not cause the impairment. For example, the U.S. Environmental Protection Agency (EPA) considers flow alteration to be “pollution” vs. a “pollutant.”

Category 5A: Impaired for one or more designated or existing uses and a TMDL is underway or scheduled. AUs are listed in this category if the AU is impaired for one or more designated uses by a pollutant. Where more than one pollutant is associated with the impairment of a single AU, the AU remains in Category 5A until TMDLs for all pollutants have been completed and approved by U.S. EPA.

Category 5B: Impaired for one or more designated or existing uses and a review of the water quality standard will be conducted. AUs are listed in this category when it is possible that water quality standards are not being met because one or more current designated uses are inappropriate. After a review of the water quality standard is conducted, a use attainability analysis (UAA) will be developed and submitted to U.S. EPA for consideration, or the AU will be moved to Category 5A and a TMDL will be scheduled.

Category 5C: Impaired for one or more designated or existing uses and additional data will be collected before a TMDL is scheduled. AUs are listed in this category if there are not enough data to determine the pollutant of concern or there are not adequate data to develop a TMDL. For example, AUs with biological impairment will be listed in this category until further research can determine the particular pollutant(s) of concern. When the pollutant(s) are determined, the AU will be moved to Category 5A and a TMDL will be scheduled. If it is determined that the current designated uses are inappropriate, it will be moved to Category 5B and a UAA will be developed. If it is determined that “pollution” is causing the impairment (vs. a “pollutant”), the AU will be moved to Category 4C.



MORA-SAN MIGUEL-GUADALUPE
WATER PLANNING REGION
Water Quality-Impaired Reaches

Daniel B. Stephens & Associates, Inc.
3-16-05
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Figure 5-18

- Management plans are due by December 31, 2017 for listed streams in the Upper Canadian River watershed, including Manueles Creek and Ocate Creek, the Mora River and its tributaries Coyote Creek, Rio la Casa and the Sapello River, and Lower Charette Lake and Conchas Reservoir. TMDL plans are needed mainly to address nonpoint pollutant sources such as road/parking lot runoff, silviculture, highway maintenance and runoff, removal of riparian vegetation, range grazing (riparian or upland), flow regulation/modification, construction, hydromodification, habitat modification other than hydromodification, grazing-related sources, bank or shoreline modification/ destabilization, atmospheric deposition, and agriculture. No NPDES permitted dischargers are present in the listed reaches of the Upper Canadian and Mora River watersheds.

- Several reaches in the Upper Pecos River watershed are also designated for TMDL management plan completion, including the Pecos River and listed tributaries such as Beaver Creek, Cow Creek, the Gallinas River, Holy Ghost Creek, Rio Mora, Tecolote Creek, Willow Creek, and Wright Canyon Creek and lakes including Morphy (Murphy) Lake, Santa Rosa Reservoir, and Sumner Reservoir. Plans are necessary to address water quality impacts resulting from the same nonpoint sources affecting the Upper Canadian and Mora basins, as well as point sources including mine tailings, mill tailings, hazardous waste, and land disposal. Two NPDES permitted dischargers are present in the Upper Pecos watershed for municipal and industrial activities in Las Vegas, New Mexico.

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.

In addition to the 303(d) listings, the State of New Mexico has listed Brantley Reservoir, the Charette Lakes, Conchas Reservoir, McAllister Lake, Santa Rosa Reservoir, Storrie Lake, and Sumner Reservoir on the impaired lakes list and has issued fish consumption advisories (NMWQCC, 2002). The fish advisories were issued because mercury has been found in some fish at concentrations that could lead to significant adverse human health effects. The main threat is from the very low concentration of elemental mercury found in bottom sediments that is passed through the food chain progressively from smaller to larger fish, resulting in elevated levels in the larger fish. The source of the mercury is most likely atmospheric deposition outside of the planning region.

5.4.3 Existing Groundwater Quality

Groundwater in the planning region is generally uncontaminated. It is suitable for agriculture and for private domestic consumption, and it can be treated for public water supply systems. However, groundwater contamination has already occurred in some areas of the planning region from both point and nonpoint sources. Existing facilities that may have the potential to impact groundwater quality are described in Section 5.4.1. The NMWQCC (2002) reports that the majority of groundwater concerns in the planning region are from leaking USTs, nitrates from septic tanks, metals from mineral leaching operations, and TDS, metals, and sulfates from mining operations.

5.4.4 Summary of Water Quality by County

The following discussion summarizes the overall water quality for each of the counties in the Mora-San Miguel-Guadalupe water planning region.

- *Mora County:* In general, the water quality is good. The Petroleum Tank Storage Bureau (NMED, 2004a) reported leaking underground storage tanks near Mora, Wagon Mound, and Watrous, but they are not affecting groundwater quality at this time. Elevated nitrate levels are reported near and in Wagon Mound (NMWQCC, 2002). Elevated levels of nitrate are usually attributed to sources such as fertilizer application, septic tank discharge, or surface water bodies that receive some form of effluent. Naturally occurring high fluoride, high hardness, and other dissolved solids exist in groundwater in the Upper Canadian River Basin (Mercer and Lappala, 1972). Though little monitoring data exist, the high concentration of septic tanks in the Mora Valley indicates a potential water quality concern. No Superfund sites exist in Mora County.

- *San Miguel County:* The groundwater quality is generally good, though hard (Griggs and Hendrickson, 1951). The major exception is the abandoned Terrero mining area where sulfate and metals contaminate the domestic wells and surface water (Johnson and Deeds, 1995; Koch and Barkmann, 1995). In fact, the Terrero Mine, El Molino Mill, and a site in East Pecos are included on the CERCLIS list, but are not listed as Superfund NPL sites. Aside from mining activities, leaking USTs are present near and in Las Vegas, Pecos, Ribera, Rowe, and Sapello, though very few, if any, of these tanks affect groundwater quality. Additionally, nitrate contamination of groundwater has been reported in Las Vegas and Ribera (NMWQCC, 2002), and naturally occurring fluoride and other dissolved solids exist at elevated or problematic concentrations in groundwater in some places in the county (Griggs and Hendrickson, 1951). Though little monitoring data exist, the high concentration of septic tanks in the Romerville area indicates a potential water quality concern.

- *Guadalupe County:* The water quality is generally good, though hardness is high. The Petroleum Tank Storage Bureau (NMED, 2004a) reported leaking USTs near Anton Chico, Santa Rosa, and Vaughn, but it is not substantiated that any of them affect groundwater quality. No Superfund sites exist in Guadalupe County.