5. Water Resources

This section provides an overview of the water supply in the Socorro-Sierra water planning region, including both surface and groundwater supplies and water quality, in order to address the first water planning question: what is the region's available water supply? The ISC has funded and evaluated surface water supplies in the region separately from the Socorro-Sierra regional water plan. Consequently, this plan focuses in greater detail on groundwater supplies that are not hydraulically well connected with the surface water in the Rio Grande Valley. Summary information on the surface water supply of the region is discussed in Section 5.1 and is primarily based on work by ISC's consultant, SSPA (Appendix E1). Summary information on the water supply of the region relative to the demands for water use is provided in Section 7.

Other studies that have also addressed the water supply in portions of the Socorro-Sierra planning region include:

- The Middle Rio Grande water supply study, jointly funded by the ISC and the Army Corps of Engineers (COE) (S.S. Papadopulos & Associates, Inc. [SSPA], 2000; 2003 [the latter study is included in Appendix E1]), covers the area from Cochiti to Elephant Butte Reservoirs and addresses primarily surface flow in the Rio Grande and, to a lesser degree, groundwater connected to the Rio Grande. The southern portion of the area covered by the Middle Rio Grande study is located in the Socorro-Sierra planning region.

- Studies of the Lower Rio Grande planning area, including the Lower Rio Grande hydrographic survey, address a small portion of southern Sierra County.

- The Rio Grande and La Jencia Basins groundwater resources study, funded by the Interstate Stream Commission (SSPA, 2002a, included in Appendix E2), characterizes groundwater supplies in the La Jencia Basin and in the Rio Grande Basin from the Socorro-Valencia County line to Elephant Butte Reservoir. A copy of this report is provided in Appendix E2, and the work is summarized in Sections 5.9 and 5.10.

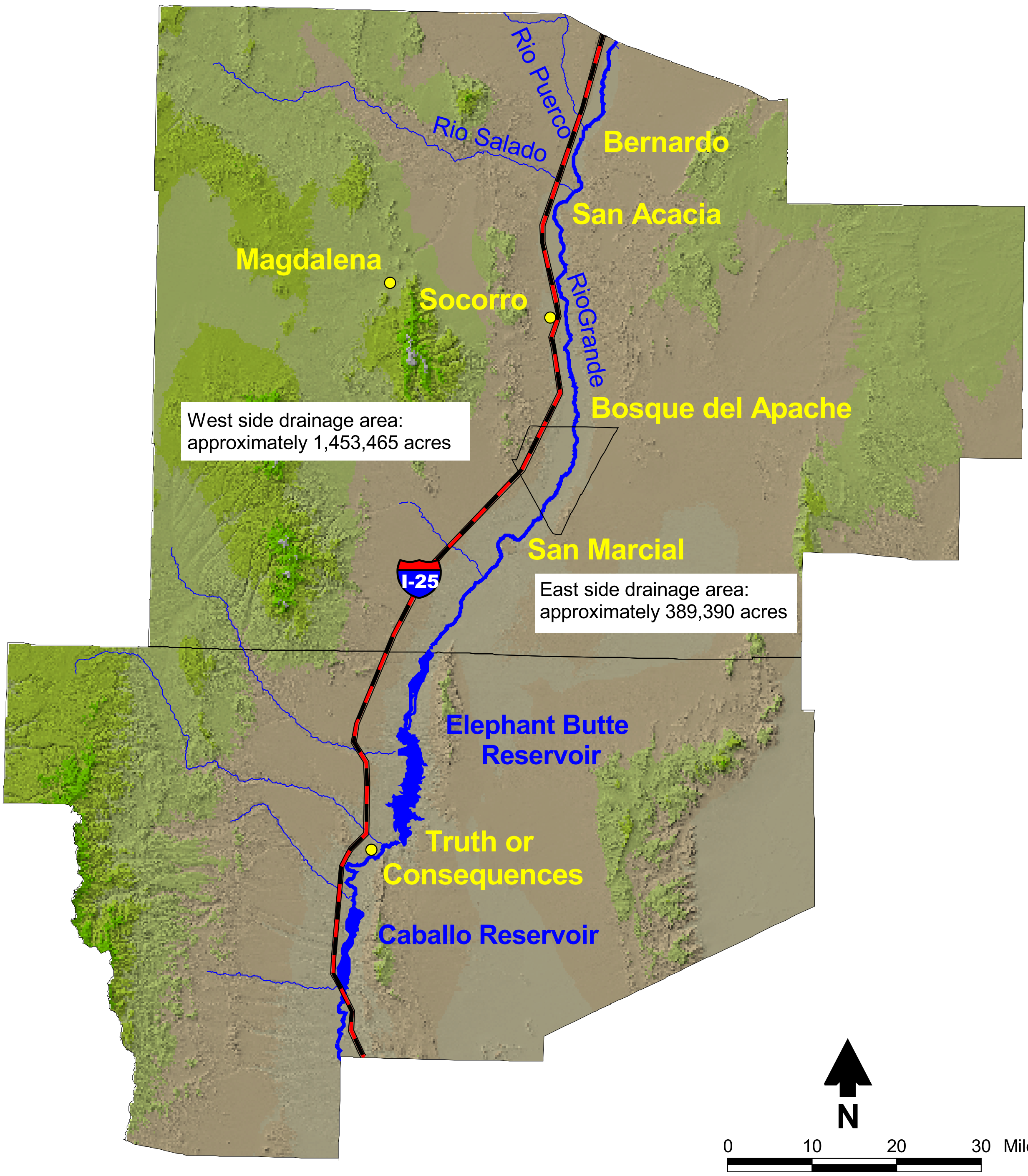
- The ISC is in the process of developing and calibrating a surface water/groundwater model of the Rio Grande from San Acacia to Elephant Butte Reservoir. The purpose of the model is to evaluate potential system-wide depletions that may result from changes in operation of the Low Flow Conveyance Channel (LFCC), riparian vegetation restoration projects, and river bed aggradation. The USGS program MODBRANCH is being used to simulate the Rio Grande channel, the LFCC, main irrigation canals and drains, and the alluvial and Santa Fe Group aquifers. The model is being calibrated against surface water flow measurements and groundwater levels and is being used to investigate different scenarios to optimize surface water depletion (Shafike et al., 2002).

In addition to the surface water discussion in Section 5.1, an overview of the region's groundwater supplies is included in Section 5.2, and descriptions of the water resources of individual groundwater basins in the Socorro-Sierra water planning region are presented in Sections 5.3 through 5.10. Estimates of recharge to and storage in these basins are included in Section 5.11. Information regarding background water quality in each groundwater basin is included in Sections 5.3 through 5.10, with a more detailed assessment of the quality, including potential contaminant sources, of both surface water and groundwater supplies in the region provided in Section 5.12.

5.1 Surface Water Supply

The primary surface water supply in the Socorro-Sierra Region is the Rio Grande and its tributaries (Figure 5-1). Prior to development of the Socorro-Sierra regional water plan, the ISC retained SSPA to evaluate surface water and stream-connected groundwater resources of the Rio Grande from Cochiti Reservoir to Elephant Butte Reservoir. The ISC directed the Socorro-Sierra Region to use the information from the SSPA study rather than conducting its own evaluation of its surface water resources, and consequently did not include funding for surface water evaluations in the contract with the region. Hence, information in this section on the climate and surface water supply of the region has been extracted from SSPA studies.

SSPA completed an initial model of the Middle Rio Grande water supply in 2000 (SSPA, 2000). The SSPA study area extended from Cochiti Reservoir to Elephant Butte Reservoir, an area



Base Map Source: ESRI Data & Maps, 1999
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Surface Water Drainage Areas

Figure 5-1

that was referred to as the Middle Rio Grande Region. The SSPA study area encompassed portions of both the Middle Rio Grande and the Socorro-Sierra planning regions. In 2003, SSPA conducted additional analyses of the water supply and evaluated some of the Socorro-Sierra region alternatives for their impact on the Rio Grande water supply. This work, which is currently an interim draft under review by the ISC, is presented in Appendix E1. Additional discussion of the alternatives analysis portion of the SSPA work is provided in Section 8. Summary information on the climate and surface water supply was extracted from the SSPA draft (Appendix E1) and is provided in Sections 5.1.1 through 5.1.3.

5.1.1 Summary of Climatic Conditions

The varied terrain of Socorro and Sierra Counties, which ranges from mountains to foothills to plains and valleys, results in significant climate variations. For example, temperatures range from lows that are well below 0 degrees Fahrenheit (°F) in the mountains to highs in excess of 100°F in the valley. The average temperature in the planning region ranges between 50 and 60°F.

Precipitation also varies across the planning region, influenced by location and somewhat by elevation. Weather systems may enter the planning region from the west (Pacific), northeast (Arctic air masses from the plains), and southwest (Gulf of Mexico), and systems from each point of origin bring unique sets of temperatures and moisture to the planning region. Average precipitation, including both snowmelt and rainfall, ranges from about 8 to 18 inches. The majority of the precipitation occurs as monsoons during the months of July through September. Maps showing average annual precipitation and average annual free water surface evaporation were prepared by WRRI and are included in Appendix B, as Figures B-6 and B-7, respectively.

As part of the surface water study, SSPA evaluated the climatic conditions in the region. The surface water period of record used in the SSPA study (1950 to 2002) was chosen because of the availability of data and because it is representative of current development conditions. Concern was raised as to whether this period would be representative of both future and long-term average climatic conditions. To address this issue, climate reconstruction using tree rings and the effects of Pacific Decadal Oscillation (PDO) in the Middle Rio Grande Basin were examined (Appendix E1).

Climate reconstruction from 622 to 1992 was based on tree ring records at three locations: El Malpais (southwest of Grants), Magdalena Mountains, and Sandia Mountains (Grissino-Mayer et al., 2002, as cited in SSPA, 2003). The resulting analysis, based on events 5 or more years in length, identified 60 occurrences of either extreme drought or wetness in the 1,371-year period.

The PDO serves as an indicator of climatic trends that can help predict long-term precipitation amounts. The PDO is a long-lived El Niño-like pattern of Pacific climate variability—specifically, a long-term fluctuation of the Pacific Ocean—that waxes and wanes approximately every 20 to 30 years. The PDO is defined as the leading principal component of north Pacific monthly sea surface temperature variability (Mantua, 2000).

The North American climate anomalies associated with PDO are broadly similar to those connected with El Niño and La Niña, although in general not as extreme (Latif and Barnett, 1994, as cited in Mantua, 2002). Warm phases of the PDO are correlated with El Niño-like North American temperature and precipitation anomalies, while cool phases of the PDO are correlated with La Niña-like climate patterns. A strong correlation exists between the PDO cool phase and regional droughts in New Mexico. Since 1650 all six periods of extended drought coincided with cool PDO phases (SSPA, 2003).

The following conclusions regarding the climate in this area of the Rio Grande Basin were drawn in the SSPA report (Appendix E1):

- The 1950s drought was the third worst drought in the past 1,371 years.
- The 1978 to 1992 period was the third wettest multi-year period in the past 1,371 years.
- The 1950 to 2002 climate period includes extremes (dry and wet), and thus provides a good representation of long-term conditions.

- Correlations between PDO and local climate conditions suggest that extended drought conditions are returning to New Mexico, based on the apparent switch in 1998 of the PDO from a warm to a cool phase.

5.1.2 General Hydrologic Setting

Surface waters in the planning region lie mostly within the Rio Grande Basin or are closed basins, but a small portion (northwest corner of Sierra County) is in the Lower Colorado River Basin. The region contains portions of 11 surface water sub-basins as defined by the USGS (Figure B-8):

- Rio Salado
- Rio Puerco
- Rio Grande Albuquerque
- Jornada del Muerto
- Tularosa Valley
- Plains of San Agustin
- Elephant Butte Reservoir
- Caballo
- Jornada Draw
- El Paso Las Cruces
- Mimbres

Elephant Butte Reservoir serves as the dividing line between the Middle and Lower Rio Grande Basins. The Plains of San Agustin, Mimbres, Jornada del Muerto, Tularosa Valley, and Jornada Draw sub-basins are closed surface water basins and do not contribute surface flow to the Rio Grande. The small portion of the planning area that falls within the Lower Colorado River Basin contains the headwaters of the Upper Gila sub-basin (Figure B-8).

5.1.3 Summary of Streamflow Data

Numerous ephemeral tributaries flow to the Rio Grande, which at times is intermittent depending on diversions into irrigation ditches. Several small streams have perennial reaches in their headwaters, but none flow continuously to the Rio Grande. Surface inflow components to the Middle Rio Grande in the Socorro-Sierra planning region include flow from the Rio Puerco, Rio Salado, and ungaged tributaries east and west of the Rio Grande. The Rio Puerco and Rio Salado are ephemeral streams that join the Rio Grande just south of Bernardo and just north of San Acacia, respectively. Ungaged tributaries contributing storm flow to the Middle Rio Grande and Elephant Butte Reservoir on the west side include Tiffany Canyon, Milligan Gulch, Alamosa Creek, and many smaller drainages. On the east side, Abo Arroyo, arroyos of the Los Pinos Mountains (including Palo Doro Canyon), and many small arroyos contribute ungaged inflow to the Middle Rio Grande. Because these tributaries are not gaged (except for a temporary gaging station in Abo Arroyo), no information is available regarding their flows.

Streamflow data are collected by the USGS at several gage sites in the planning region. Table 5-1 summarizes the minimum, median, average, maximum, and standard deviation of annual water yields for the Rio Grande, Rio Puerco, and Rio Salado based on data available from the USGS for the entire period of record for each of these stations. As shown on this table, surface water availability varies greatly from year to year, with the years when flow is highest 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 Socorro-Sierra planning region.

The variability of the surface water flows in the region is also illustrated by modeling work completed by SSPA. This work, including a summary of the modeled water budget, is further discussed in Section 7 and Appendix E1. Estimates of flows to the Middle Rio Grande within the planning region from the SSPA Phase 3 report (Appendix E1) are contained in Table 5-2. Rio Puerco and Rio Salado flows are based on available streamflow data. Flows for Abo Arroyo and arroyos of the Los Pinos Mountains (east side-north) are based on available data from the temporary gaging station. Flows for the remaining ungaged east and west side tributaries are estimated based on a relationship developed between watershed area and gaged Rio Salado flows (SSPA, 2003 [Appendix E1]).

Table 5-1. Water Yield Statistics for Selected Stream Gaging Stations in the Socorro-Sierra Region

USGS Site Name	USGS Site Number	Period of Record	Water Yield [a] (acre-feet)				
			Minimum	Median	Average	Maximum	Standard Deviation
Rio Puerco near Bernardo	08353000	1940 to 2001	3,722	22,123	30,087	159,315	26,851
Rio Salado near San Acacia	08354000	1948 to 1983	109	8,292	10,414	81,106	13,614
Rio Grande at San Marcial	08358500	1899 to 1902 1905 to 1907 1910 1912 1914 1917 to 1919 1925 to 1963	114,417	738,281	866,416	2,832,190	613,496

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

Table 5-2. Estimated Surface Inflow to the Middle Rio Grande in the Planning Region

Tributary	Surface Inflow (ac-ft/yr)		
	Minimum	Mean	Maximum
Rio Puerco	913	25,645	220,113
Rio Salado	93	10,393	159,293
West side inflow [a]	219	17,090	262,398
East side inflow-north [b]	35	6,381	95,135
East side inflow-south [c]	25	4,602	68,622

[a] Inflow from ungaged west side tributaries below Rio Salado to Elephant Butte Reservoir
[b] Inflow from ungaged east side tributaries from Socorro County line to San Acacia (includes Abo Arroyo and arroyos of the Los Pinos Mountains)
[c] Inflow from ungaged east side tributaries from San Acacia to Elephant Butte Reservoir

In the Lower Rio Grande Basin within the planning region, ungaged tributaries that contribute storm flows to the Rio Grande and Caballo Reservoir on the west side include Palomas Creek, Seco Creek, Las Animas Creek, Percha Creek, Tierra Creek, and many small arroyos. On the east side, ungaged tributaries that contribute storm flow to the Lower Rio Grande include Palomas Gap Creek and numerous unnamed drainages. Flow estimates for these ungaged tributaries have not been calculated at this time. Based on EBID records from 1930 to 1995, the average annual flow in the Rio Grande at Caballo Dam was 693,000 ac-ft/yr (ISC, 2003).

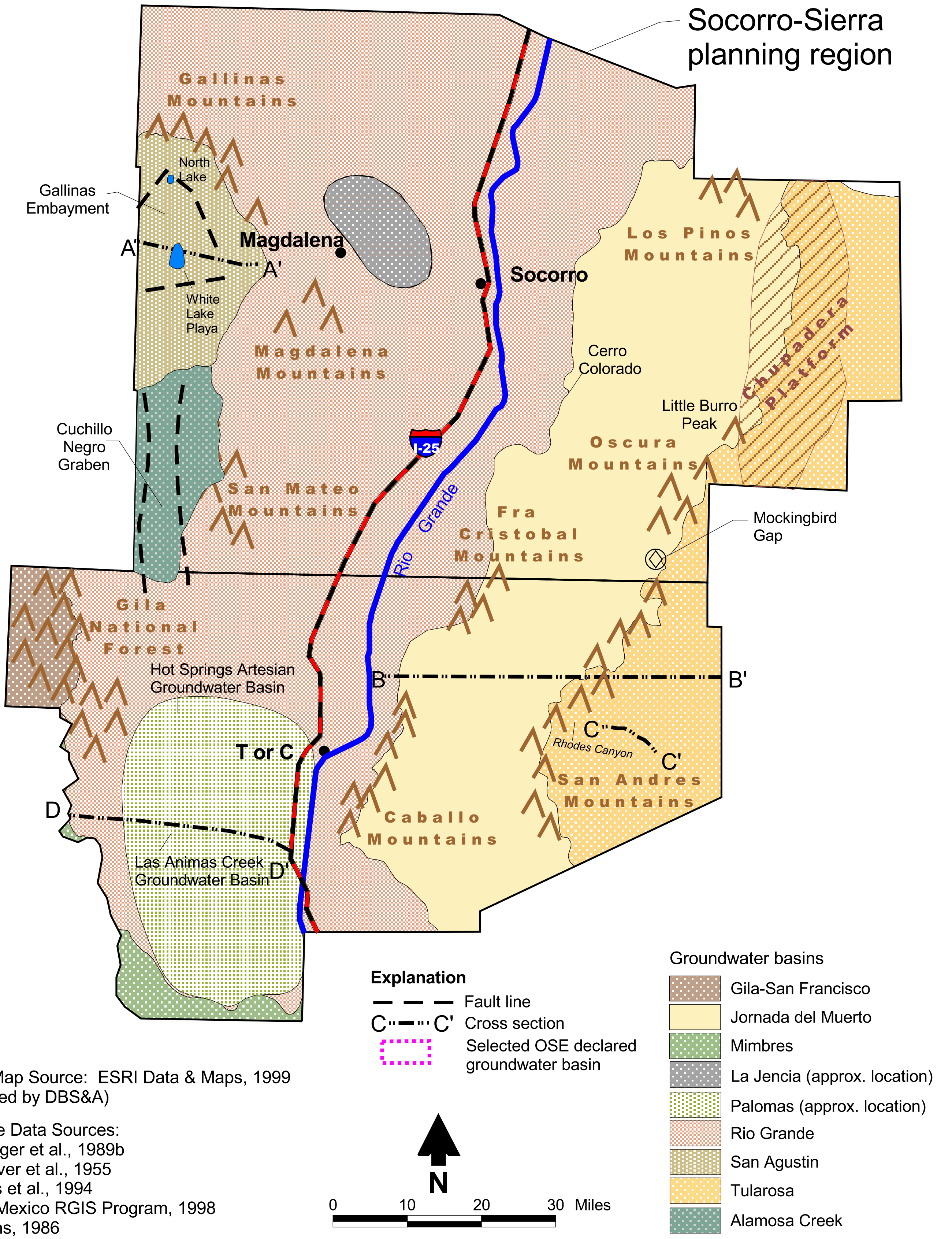
5.2 Overview of Groundwater Supplies in the Socorro-Sierra Water Planning Region

The Socorro-Sierra planning region is located in central New Mexico (Figure 1-1). Groundwater basins in the region that have been declared by the Office of the State Engineer (OSE) for the purpose of active management (and thus requiring OSE approval for withdrawals) are delineated in Figure 4-1. Figure 5-2 shows the geologically distinct groundwater basins based on physical boundaries defined by the U.S. Geological Survey (USGS) and others.

As shown on Figure 4-1, portions of eight declared groundwater basins fall within the planning area, and a small portion of the northeast corner of the region is part of an undeclared groundwater basin. The degree to which these basins are discussed in this section is outlined below:

- The Nutt-Hockett, Gila-San Francisco, Lower Rio Grande, and Mimbres Valley declared groundwater basins are not discussed because the portions of these basins within the planning region are small relative to their total areas. Additionally, the Nutt-Hockett and Lower Rio Grande Basins are being evaluated as part of Lower Rio Grande planning activities, and the ISC therefore requested that the region not direct funds toward evaluation of stream-connected resources in these basins.

- As discussed in Sections 5.3 through 5.6, a detailed characterization was completed for four USGS-defined groundwater basins (San Agustin, Alamosa Creek, Jornada del Muerto, all of which are within the Rio Grande declared basin, and the Tularosa Basin) within the planning region (Figure 5-2). These basins were chosen for more detailed investigation because of their separation from the Rio Grande. The Jornada del Muerto



Base Map Source: ESRI Data & Maps, 1999 (modified by DBS&A)

Feature Data Sources:
Bedinger et al., 1989b
Conover et al., 1955
Myers et al., 1994
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SOCORRO-SIERRA REGIONAL WATER PLAN

Major USGS-Defined Groundwater Basins in Planning Region

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Figure 5-2

and Alamosa Creek Basins may have some hydraulic connection with the Rio Grande Valley basins; however, they are located at a greater distance from the Rio Grande Valley and do not appear to overlap the study area of the other ISC investigations.

- Since the ISC surface water evaluation (Appendix E1) extends only to Elephant Butte Reservoir, the stream-connected resources of the Hot Springs Artesian and Las Animas Creek Basins below Elephant Butte were evaluated for the Socorro-Sierra regional water plan by ISC. Their evaluation is presented in Sections 5.7 and 5.8.

- Although La Jencia Basin is hydraulically connected to groundwater in the Rio Grande Valley, it represents a potentially significant source of groundwater in the planning region, and an investigation of the basin was therefore completed by SSPA (Appendix E2). A brief description of this basin and summary of the SSPA groundwater resources study regarding this basin are provided in Section 5.9.

- The Rio Grande Basin comprises a significant portion of the planning region, and a detailed investigation of the basin was completed by SSPA (Appendix E2). A brief description of this basin and summary of the SSPA groundwater resources study regarding this basin are provided in Section 5.10.

DBS&A's evaluation of groundwater supplies in the Socorro-Sierra planning region included the following:

- A bibliography of water resources publications for the Socorro-Sierra planning region was developed and is included as Appendix A1. An annotated bibliography of the most relevant publications is also included, in Appendix A2.

- Geologic, stratigraphic, and hydrostratigraphic information and figures from existing literature were reviewed. Geologic cross sections from existing reports were selected and modified to depict hydrostratigraphic relationships, if possible, and to show very generalized water quality information. A map of surficial geologic features was prepared by the New Mexico Water Resources Research Institute (WRRI) and is included in Appendix B (Figure B-9).

- Water level elevation and well completion data for Socorro and Sierra Counties were obtained from the USGS Ground Water Sites Inventory (GWSI) database in June 2000 (a summary of well completion information and water level data from the GWSI database is contained in Appendix F1). The data were compiled using ARC-VIEW geographic information system (GIS) software, separated by basins, and compared to tabulated data from reports. The most recent water level elevation data of sufficient sample size were posted and, when feasible, contoured.

- Available information regarding aquifer properties for the non-stream-connected aquifers evaluated by DBS&A in the planning region was synthesized and is included in Appendix F2.

The above information was used to characterize the physiography, geology, and hydrogeology of the San Agustin, Alamosa Creek, Jornada del Muerto, Tularosa, Las Animas Creek, and Hot Springs Artesian Basins, as summarized in Sections Section 5.3 through 5.8, respectively. For each of the six basins, two additional analyses were performed: estimation of volumetric average annual recharge and computation of volume of groundwater stored in place. Results of these analyses are included in Section 5.11.

5.3 San Agustin Basin

The San Agustin Basin is a topographically closed basin (or bolson) located in Socorro and Catron Counties (Figure 5-2). Approximately 460 square miles of its 2,000-square-mile area are located within the planning region. From the following analysis and discussion of the geologic and hydrologic features of the San Agustin basin (Sections 5.3.1 through 5.3.3), it is evident that the basin contains a potentially significant supply of potable water. However, the ability to develop and use this water is constrained legally, as discussed in Section 4.

5.3.1 Physiography

The basin's northern boundary is along the Mangas and Datil Mountains. To the east the basin is bounded by the Gallinas Mountains. To the southeast the basin is bounded by an unnamed sill at approximately 7,000 feet above mean sea level (ft msl) (Hawley, 1993), which separates the San Agustin Basin from the Alamosa Creek Basin. To the south and west the basin is bounded by the Continental Divide in Catron County (Myers et al., 1994).

The basin's valley floor is known as the Plains of San Agustin (Plains). Elevations of the Plains range from about 6,800 to 7,500 ft msl (Hawley, 1993). The elevation of the surrounding mountains exceeds 10,000 ft msl (Myers et al., 1994). Average annual precipitation in the area is 13.25 inches (Myers et al., 1994).

The basin contains no perennial streams; however, intermittent streams flow from the basin's margins toward playas that are remnants of a large lake that covered portions of the Plains during the Pleistocene Age (Myers et al., 1994; Wilkins, 1986). In Socorro County, North Lake and White Lake occupy low areas within the remnant lake bed.

5.3.2 Geology

Myers et al. (1994) describe the San Agustin Basin as a filled graben. By definition, a graben is a deep downthrown block lying between parallel or subparallel faults. The San Agustin Graben is structurally complex at depth. Using geophysical methods, Myers et al. (1994) determined the location of a north-trending subsurface block described as a buried ridge or saddle. This buried ridge transects the San Agustin Basin slightly west of and parallel to the Socorro-Catron County line (Myers et al., 1994). Myers et al. (1994) call the area to the northeast of this buried ridge the Gallinas Embayment (Figure 5-2).

The top elevation of the buried ridge is mapped at approximately 6,800 ft msl (Myers et al., 1994). Below that elevation, the Gallinas Embayment is structurally distinct from the San Agustin Graben, while above it, the embayment is an extension of the graben. The Gallinas Embayment lies north of the Cuchillo Negro Graben, which underlies the adjacent Alamosa

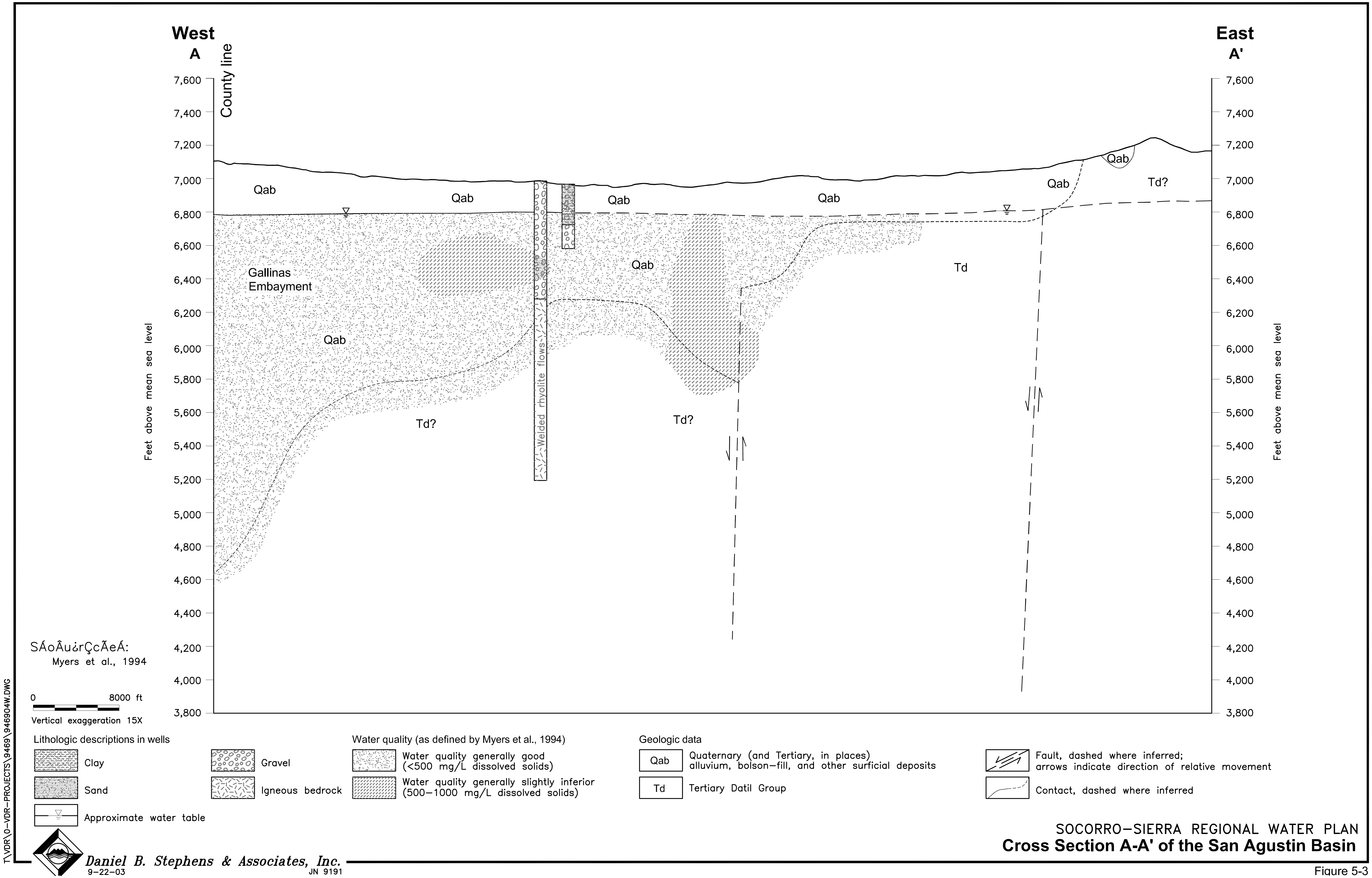
Creek Basin. These structural basins have been linked to Tertiary Rio Grande rifting (Myers et al., 1994; Chapin, 1971).

The Gallinas Embayment generally corresponds with the area described by Myers et al. as the "eastern elliptical area" (Myers et al., 1994). Because the county line happens to be located very near the buried ridge, the Gallinas Embayment portion of the San Agustin Plains contains the groundwater supplies of interest to the planning region and is the focus of the geologic and hydrogeologic descriptions that follow.

Surficial geology is illustrated on the geologic map of the planning region included in Appendix B (Figure B-9). The youngest formation in the Gallinas Embayment is unconsolidated Quaternary alluvium, derived from the erosion of the basin's highland areas. The Quaternary alluvium overlies older Tertiary Santa Fe Group sediments. (Tertiary sediments formerly described as Gila Conglomerate are called Tertiary Santa Fe Group if located east of the continental divide. This naming convention is used herein and follows a naming change, which occurred after Myers et al. published in 1994 [Hawley, 2000]). In combination, these Quaternary/Tertiary sediments, called bolson-fill by Myers et al. (1994), contain the primary aquifer of the Gallinas Embayment. Most of the bolson-fill in the San Agustin Plains area correlates with Pliocene and Miocene deposits in Rio Grande rift basins to the east (Hawley, 1978, Chart 1; Chapin and Cather, 1994). In places the Tertiary Santa Fe Group unconformably overlies and in other places is interbedded with an older unnamed Tertiary volcanic flow, which in turn overlies the upper layer of the Tertiary Datil Group.

The Tertiary Datil Group (Osburn and Chapin, 1983) consists of volcanoclastic rocks with interlayered ash-flow tuffs and lava flows. This unit is up to 5,000 feet thick, yields some water to wells, and is the dominant outcrop of the basin's surrounding highland areas. The Tertiary Datil Group is a significant source of the material that makes up the bolson-fill.

Cross section A-A' (Figure 5-3, location shown in Figure 5-2) shows the stratigraphic relationships between the Quaternary/Tertiary bolson-fill and the Tertiary Datil Group. Myers et al. (1994) assert that other Tertiary volcanic formations underlie rocks of the Datil Group and may yield small quantities of water to wells in the planning region.



SOCORRO–SIERRA REGIONAL WATER PLAN
Cross Section A-A' of the San Agustin Basin

Figure 5-3

Cretaceous and Triassic sedimentary rocks likely underlie Tertiary rocks, since they are present at the surface along the basin margins. These rocks are not known to yield groundwater to wells in the San Agustin Basin although they sometimes provide water (often of poor quality) elsewhere in New Mexico.

Carbonate rocks of the Permian system underlie the Triassic rocks. Again, these rocks are not known to yield water to wells in the San Agustin Basin

Underlying the Permian system are the Pennsylvanian Madera Limestone and Sandia Formation. Neither of these carbonate formations are known to yield water to wells in the San Agustin Basin in the planning region (Myers et al., 1994).

5.3.3 Hydrogeology

Aquifers in the San Agustin Basin are recharged by infiltration of rain water and snowmelt along the basin margins, by infiltration from intermittent streams, or through seepage between the bolson-fill and the Datil Aquifers. Groundwater discharge occurs as pumpage, evapotranspiration, outflow to active playa lakes, or seepage to portions of the basin outside the planning region (Blodgett and Titus, 1973).

Groundwater of the San Agustin Basin grades from fresh to saline in a westerly direction toward Catron County. As shown in Figure 5-3, there are isolated areas of inferior water quality as defined by elevated total dissolved solids (TDS)/salinity in some wells in the planning region (Myers et al., 1994, Figure 10).

Myers et al. (1994) identify three aquifers in the portion of the San Agustin Basin that is located in Socorro County: (1) the shallow upland aquifer, (2) the Quaternary/Tertiary bolson-fill aquifer (hereafter bolson-fill aquifer), and (3) the Datil Aquifer. The Datil Aquifer underlies the bolson-fill aquifer of this basin and also underlies the Alamosa Creek shallow aquifer to the southeast. (The Alamosa Creek aquifers are discussed in Section 5-4.)

5.3.3.1 Shallow Upland Aquifer

The shallow upland aquifer is located within Quaternary alluvial material deposited along upland stream courses of the San Agustin Basin and, where present, is unconfined. Wells generally penetrate 50 feet or less of Quaternary alluvium and are completed into the underlying Datil Aquifer, producing water from both the Quaternary alluvium and rocks of the Datil Group. Yields are generally less than 10 gallons per minute (gpm) (Myers et al., 1994). Due to its limited areal extent, this is not considered a primary aquifer of the basin, so water level elevation data from this aquifer were not contoured for this report.

5.3.3.2 Bolson-Fill Aquifer and Datil Aquifer

In general, the bolson-fill and Datil aquifers are unconfined, although local conditions of confinement may occur (Blodgett and Titus, 1973). The bolson-fill and Datil aquifers are estimated to cover approximately 290 and 305 square miles, respectively, of the Gallinas Embayment. Cross section A-A' (Figure 5-3) shows the configuration of these two aquifer units in the Gallinas Embayment from the eastern basin margin to the Socorro-Catron County line. According to Myers et al. (1994), the 1979 to 1980 hydraulic gradient in the bolson-fill aquifer above the ridge area (just west of the county line) was steeper than the gradient in the fill of the Gallinas Embayment, reflecting the change in aquifer saturated thickness. The potentiometric surface of the underlying Datil Aquifer appears to be unaffected by the presence of the buried ridge (Myers et al., 1994).

Myers et al. (1994) conducted pump tests in the bolson-fill aquifer near North Lake, to assess the transmissivity of the aquifer. (Transmissivity is a parameter describing the rate of groundwater flow through a vertical section of aquifer of unit width under a unit gradient.) Estimates of transmissivity obtained from Myers et al. ranged from 2,300 square feet per day (ft^2/d) to 48,400 ft^2/d (1994). Wells completed in the bolson-fill aquifer yield from 1 gpm to 2,700 gpm (Roybal, 1991).

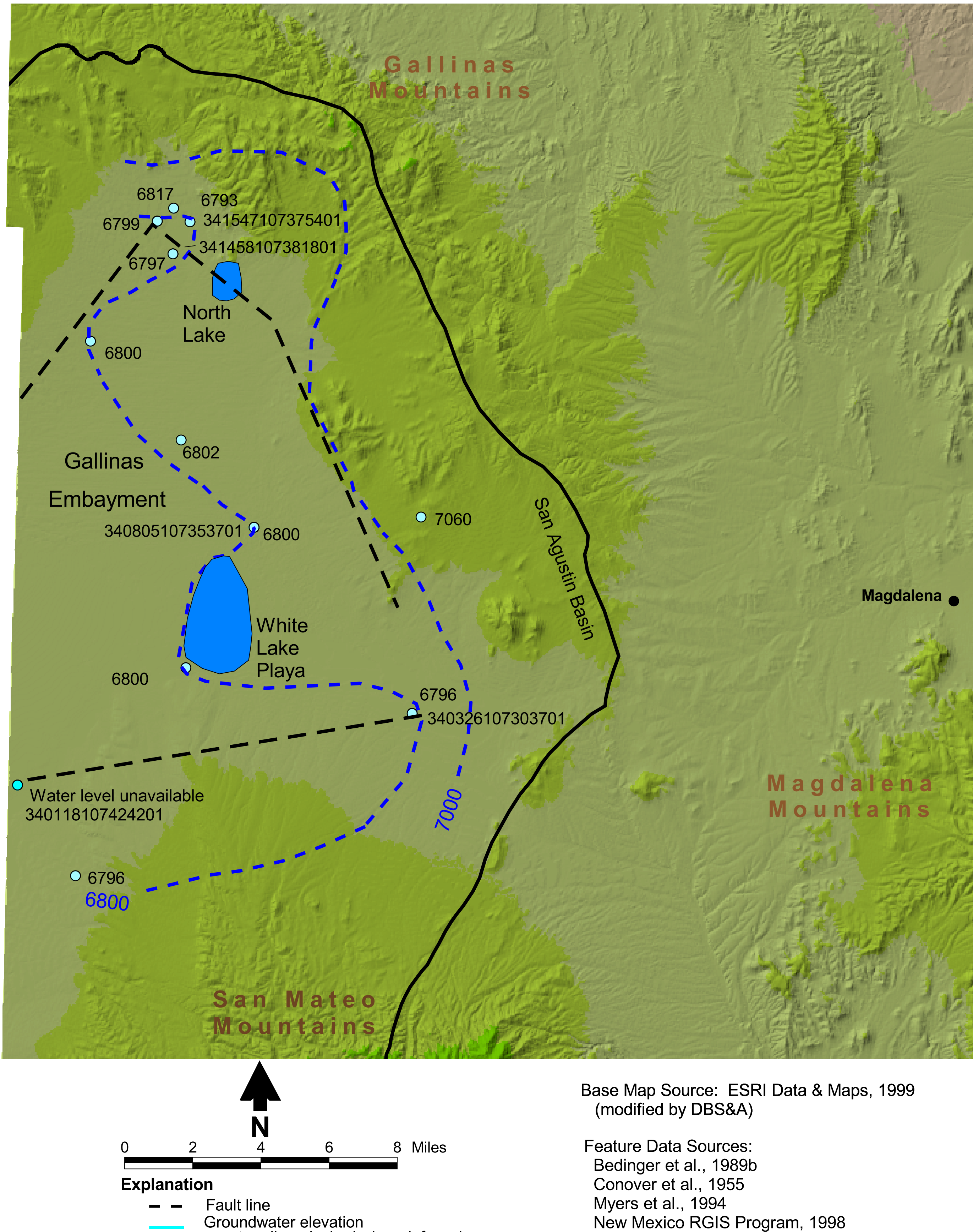
In the Gallinas Embayment, the bolson-fill aquifer's hydraulic gradient is less than 5 feet per mile and the flow direction ranges from south to southwest (Myers et al., 1994). Groundwater is usually between 150 and 300 feet below ground surface (ft bgs), and the estimated average saturated thickness is 277 to 477 feet. Groundwater elevations measured in 1991 are shown in

Figure 5-4. In general, the contoured surface plotted by DBS&A agrees well with the 1979 to 1980 potentiometric surface contoured by Myers et al. (1994). Maps from both periods indicate that groundwater of the bolson-fill aquifer flows from the basin's margins toward the playa lakes on the basin floor and toward the west.

Hydrographs plotted for a subset of wells of the bolson-fill aquifer are provided in Appendix F1. Hydrographs for the area near North Lake show that water levels have fluctuated about 7 feet between the mid-1970s and the late 1990s, and a hydrograph for a well located between the playa lakes indicates a fluctuation of slightly more than 4 feet during the same period. A hydrograph for a well in the southeastern quadrant of the Gallinas Embayment shows fluctuations of more than 30 feet, and a hydrograph from a well just outside the county line but within the Gallinas Embayment shows fluctuations of about 12 feet for the same period.

These hydrographs indicate that water levels in the Gallinas Embayment increase in stability with proximity to the playas on the basin floor and increase in their range of fluctuation near the basin's margins. The larger fluctuations near the basin margins may reflect changes due to recharge and/or pumping. None of the hydrographs show a significant and consistent decline in water levels, indicating that the basin is not exhibiting steady depletion as is seen in many locations in New Mexico.

Myers et al. (1994) show that groundwater within the Datil Aquifer flows generally from the basin margins southward toward the Alamosa Creek Basin, westward toward Catron County, and southwestward toward the Gila Basin. Well yields in this aquifer are usually less than 30 gpm (Roybal, 1991). Roybal (1991) also reports that depth to water in the Datil Aquifer is usually less than 300 feet bgs; however, this finding may reflect the fact that most wells completed in the Datil Formation are located near the basin margins. The estimated saturated thickness of the Datil Aquifer is 225 to 425 feet, based on examination of well data compiled by Roybal (1991). There is hydraulic evidence that the bolson-fill aquifer and the Datil Aquifer are hydraulically connected near the basin's northern and southern margins. Wells completed in the Datil Group or in fill material eroded from it tend to yield good-quality water.



Note: *Water level elevations measured in February 1991*

Base Map Source: ESRI Data & Maps, 1999
(modified by DBS&A)

Feature Data Sources:
Bedinger et al., 1989b
Conover et al., 1955
Myers et al., 1994
New Mexico RGIS Program, 1998

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SOCORRO-SIERRA REGIONAL WATER PLAN

Water Level Elevations in Gallinas Embayment Bolson-Fill Aquifer

Figure 5-4

5.4 Alamosa Creek Basin

The Alamosa Creek Basin is located in the west-central portion of the planning region (Figure 5-2). Approximately 300 square miles of the Alamosa Creek Basin's 400 square miles lie within Socorro County, and approximately 5 square miles lie in Sierra County. Its remaining area lies in Catron County. From the following analysis and discussion of the geologic and hydrologic features of the Alamosa Creek Basin, it is evident that the relatively small basin may provide a minor supplemental supply of potable water. Legal constraints regarding the use of this supply are discussed in Section 4.

5.4.1 Physiography

The basin is bounded on the northeast by the San Mateo Mountains and on the northwest by unnamed topographically high areas between this basin and the Gallinas Embayment extension of the San Agustin Basin. The southwestern boundary is along the Continental Divide. To the southeast, this basin is bounded by the Monticello Box.

Elevations of the valley floor range from about 6,200 to 7,000 ft msl; the highest elevation of the surrounding mountains exceeds 10,000 ft msl. Average annual precipitation in the area is 13.95 inches (Myers et al., 1994).

Surface water and groundwater flows toward Alamosa Creek and emerge at the Monticello Box. Alamosa Creek flows from the Monticello Box as a tributary to the Rio Grande. Flow from the Monticello Box averages 8.3 cubic feet per second (cfs) annually (Myers et al., 1994). Alamosa Creek surface water and its shallow groundwater are hydraulically connected to basins of the Rio Grande Valley. Available data are insufficient to determine if deeper groundwater is also hydraulically connected to the Rio Grande basins.

5.4.2 Geology

The basin's major subsurface structural feature is the Cuchillo Negro Graben (Figure 5-1). The graben extends toward the south and is bordered by the Tertiary Santa Fe Group, Tertiary igneous rocks, and Cretaceous and older sedimentary rocks. The formation of this structural basin is linked to Tertiary Rio Grande rifting (Myers et al., 1994; Chapin and Cather, 1994).

Quaternary alluvial fill deposits of unconsolidated gravel, sand, silt, and clay are usually less than 50 feet thick in the Alamosa Creek Basin. These fill deposits were produced by erosion of upland areas; hence they were derived from the sedimentary or volcanic formations that have cropped out above the basin floor since its formation in Tertiary times (Myers et al., 1994). Surficial geology is illustrated on the geologic map of the planning region included in Appendix B (Figure B-9).

Quaternary alluvium overlies older Tertiary Santa Fe Group sediments. In combination, these Quaternary/Tertiary sediments yield water to wells. The Santa Fe Group sediments in places unconformably overlie and in other places are interbedded with an unnamed unit described by Myers et al. (1994) as a basalt to basaltic-andesite flow, which may yield water to wells.

The unnamed basaltic unit unconformably overlies the upper layer of the Tertiary Datil Group, which consists of volcanoclastic rocks with interlayered ash-flow tuffs and lava flows. The Datil Group yields small quantities of water to wells.

In the Cuchillo Negro Graben, the Rubio Peak Formation unconformably underlies the Datil Group (Myers et al., 1994). The Rubio Peak Formation consists of andesite and intermediate volcanoclastic rocks, is up to 700 feet thick, and in places yields small quantities of water to wells (Myers et al., 1994). However, in most places this unit is a major aquitard or aquiclude and does not yield water to wells.

Undifferentiated Cretaceous sedimentary rocks unconformably underlie the Rubio Peak Formation and crop out on the east side of the Cuchillo Negro Graben (Dane and Bachman, 1965, as cited by Myers et al., 1994). Triassic sedimentary rocks underlie either the Tertiary Datil Group or Cretaceous rocks and crop out in nearby areas. These Mesozoic rocks are not known to yield water to wells in the area, although they do yield water elsewhere in New Mexico (Myers et al., 1994; Roybal, 1991, Plate 2).

Permian carbonate rocks underlie Triassic rocks and crop out at the eastern margin of the southern Cuchillo Negro Graben.

The Pennsylvanian Madera Limestone and Sandia Formations underlie Permian rocks and crop out on the east margin of the southern Cuchillo Negro Graben. While no wells are known to be screened within the Paleozoic rocks in this basin, they are known to yield water to wells elsewhere in New Mexico (Myers et al., 1994; Roybal, 1991, Plate 2).

5.4.3 Hydrogeology

Myers et al. (1994) identified three aquifers of the Alamosa Creek Basin, portions of which are located in Socorro County. These include (1) the shallow upland aquifer in the higher parts of the study area, (2) the Alamosa Creek shallow aquifer, and (3) the deeper Tertiary Datil Aquifer. In general, these aquifers are unconfined although local conditions of confinement may occur (Wilkins, 1986). The Datil Aquifer, which underlies the Quaternary alluvial aquifer of this basin, extends northwesterly and also underlies the bolson-fill aquifer of the Gallinas Embayment (Section 5-3).

The aquifers in this area are recharged diffusively by infiltration of rain water and snowmelt runoff and perhaps by subsurface inflow of groundwater from the adjacent San Agustin Basin. Groundwater also infiltrates to aquifers from Alamosa Creek. Discharge occurs through evapotranspiration, pumpage, spring flow, and outflow to Alamosa Creek (Myers et al., 1994).

5.4.3.1 Shallow Upland Aquifer

The shallow upland aquifer lies within Quaternary alluvial material deposited in channelized upland areas of the Alamosa Creek Basin. Wells generally penetrate 50 feet or less of Quaternary alluvium and are completed into either the underlying Santa Fe Group sediments or the Datil Aquifer, producing water from both the Quaternary alluvium and rocks of the Datil Group. Yields are generally less than 10 gpm (Myers et al., 1994).

5.4.3.2 Alamosa Creek Shallow and Datil Aquifers

The Alamosa Creek shallow aquifer is located in Quaternary alluvium overlying Tertiary Santa Fe Group sediments and covers 118 square miles of the total area of the basin. The Datil Aquifer underlies and rings the shallow aquifer and covers 167 square miles of the total area of the basin. The Alamosa Creek shallow aquifer contains most of the groundwater of the area and generally yields between 2 and 100 gpm of water to wells (Myers et al., 1994). Well completion depths are generally less than 150 feet, and depth to water is less than 90 feet bgs. Hydraulic conductivity estimates have not been published, although literature values for the alluvial basin-fill deposits (which comprise the shallow aquifer) range between 0.1 and 30 feet per day. The hydraulic gradient ranges from 140 to 400 feet per mile at the basin's margins to about 40 to 80 feet per mile in the lower basin.

The only water level data available in the GWSI database were those used by Myers et al. (1994). The groundwater elevation map prepared by Myers et al. (1994, p. 27) indicates that shallow groundwater flows from the basin's margins toward and into Alamosa Creek, which then discharges to the Monticello Box area, approximating the direction of surface drainage (Myers et al., 1994). A groundwater elevation map for this aquifer was not prepared as part of this study due to lack of more recent data than those used by Myers et al. (1994).

The degree of hydraulic interconnectivity between the Alamosa Creek shallow aquifer and the Datil Aquifer is unknown due to a lack of lithologic information. Myers et al. (1994) estimate that the hydraulic head difference between the two aquifers ranges between 460 feet and 510 feet, indicating a poor hydraulic connection between the two aquifers.

The groundwater elevation map prepared by Myers et al. (1994) shows that groundwater in the Datil Aquifer also flows in a path that roughly approximates surface drainage. The areal extent and thickness of the Datil Aquifer in this region of Alamosa Creek are unknown.

5.5 Jornada del Muerto Basin

The Jornada del Muerto Basin is a north-south trending basin lying east of and parallel to the Rio Grande Valley in the eastern portions of Socorro and Sierra Counties (Figure 5-1). It is more than 120 miles long and ranges in width from 12 to 30 miles; its area is about 2,700 square miles (Conover et al., 1955; Herrick and Davis, 1965). The basin is referred to as a bolson, indicating that it is topographically closed (Herrick and Davis, 1965; Roybal, 1991); however, Bedinger et al. (1989b) show that the basin is open to the southwest to basins that include (or drain to) the Rio Grande Valley.

From the following analysis and discussion, it is evident that the Jornada del Muerto Basin contains significant quantities of groundwater; however, much of the groundwater would require treatment to be suitable for most uses. Legal constraints regarding the use of this water are discussed in Section 4.

5.5.1 Physiography

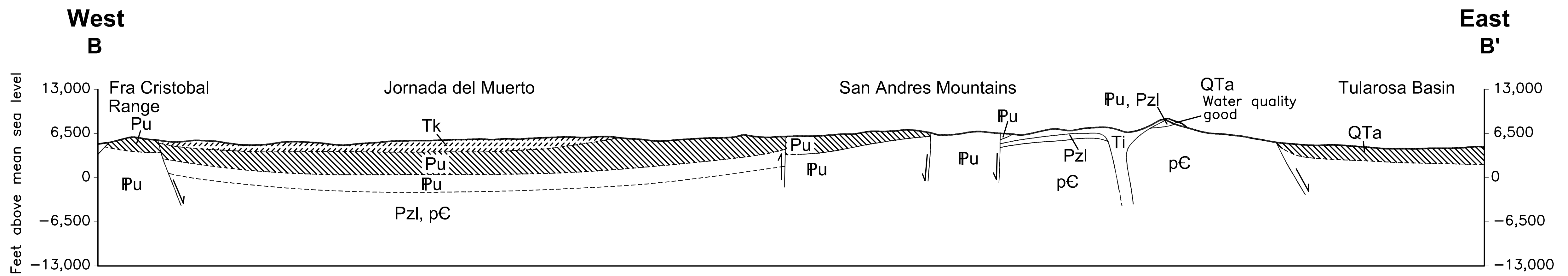
The Jornada del Muerto is bounded to the west by the Fra Cristobal and Caballos Mountains, to the north by the Los Pinos Mountains and the Chupadera Platform, to the east by the Sierra Oscura and the San Andres and Organ Mountains, and to the south by the Doña Ana Mountains (Seager et al., 1987).

Land surface elevations of the basin floor range from 5,250 ft msl in the north to 4,100 ft msl in the south (Bowers, 1990). Annual precipitation is about 7 to 9 inches (Conover et al., 1955).

No perennial fresh surface water bodies exist in the Jornada del Muerto, although Herrick and Davis (1965) report that springs yielding water of poor quality emerge in upland areas, and many playas occupy the basin floor.

5.5.2 Geology

Structurally, the Jornada del Muerto is complex (Dane and Bachman, 1965; Lozinsky, 1987; Seager et al., 1982; Seager et al., 1987). It includes shallow syncline segments, as shown in Cross Section B-B' (Figure 5-5, location shown on Figure 5-2), as well as graben and half-graben structures. Strata of the surrounding fault-block mountains dip into the Jornada del Muerto Basin, except for those of the Oscura Mountains and Little Burro Peak, which dip away



Sources: Seager et al., 1989b, Plate 2
Conover et al., 1955
Herrick and Davis, 1965

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Water quality *

- Water quality generally good (<250 mg/L chloride or sulfate)
- Water quality generally inferior (between 250 and 500 mg/L chloride or sulfate; <750 mg/L of both)
- Water quality generally very inferior, impotable (>500 mg/L chloride or sulfate; >750 mg/L chloride and sulfate)

* Water quality descriptions from Herrick and Davis, 1965. Descriptions applied in accordance with Conover et al., 1955, p. 115.

Geologic data

QTa	Late Tertiary to Quaternary basin fill; alluvium
Tk	Kneeling Nun tuff
Pu	Permian rocks, undifferentiated
₽u	Pennsylvanian rocks, undifferentiated
Pzl	Lower Paleozoic rocks, undifferentiated
p€	Precambrian rocks, undifferentiated
Ti	Tertiary intrusive rocks

- Fault, dashed where inferred; arrows indicate direction of relative movement
- Contact, dashed where inferred

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Cross Section B-B' of the Jornada del Muerto and Tularosa Basins

Figure 5-5

(Bachman, 1968). Surficial geology is illustrated on the geologic map of the planning region included in Appendix B (Figure B-9). Kelley and Silver (1952) note that outcrops of Cretaceous and older formations occur erratically in the center of the Jornada del Muerto, opposite the Caballo and Fra Cristobal Mountains, suggesting that complicated folding and faulting features are hidden by bolson-fill deposits. Bedinger et al. (1989b) note that the maximum thickness of the bolson-fill in the Jornada del Muerto ranges between 650 and 1000 feet.

Surficial alluvial and lacustrine deposits at least 400 feet thick, composed of erosional products of upland areas, cover about 1,600 square miles of the valley floor. These Quaternary deposits include unconsolidated dune sand, gypsiferous silt and sand, and impure gypsum (calcium-sulfate salts) (Conover et al., 1955; Neal et al., 1983).

The bolson-fill primarily consists of unconsolidated to partly indurated sands, silts, and gravel of the Quaternary/Tertiary Santa Fe Group and overlying post-Santa Fe deposits. The upper part of the group includes deposits of the ancestral Rio Grande, which is believed to have altered its course in response to tectonic deformation and damming by basalt flows (Hawley et al., 1976; Hawley, 1975, 1978; Johnson et al., 1989). The Santa Fe Group crops out in the northwestern part of the basin, and a vertical section more than 1,100 feet thick is exposed just south of the Sierra County line, but the formation is mostly covered by younger sediments in the north-central part of the Jornada del Muerto, (Osburn, 1984; Johnson et al., 1989).

Volcanic rocks of the Tertiary Datil Group crop out in the northwest part of the Jornada del Muerto (Osburn, 1984) and yield water to one well within Socorro County (Roybal, 1991).

The basin's northern highlands are dominated by rocks of the Permian system, which yield water of poor quality to wells (Roybal, 1991). A general stratigraphic representation of the central Jornada del Muerto is shown in Figure 5-5. This cross section does not intersect all of the geologic units present in the basin.

Roybal (1991) indicates that Cretaceous, Triassic, and Permian rocks crop out in the northern Jornada del Muerto. Conover et al. (1955) reported that in the northeast part of the basin rocks underlying the bolson-fill are Permian, and elsewhere they are Cretaceous (Conover et al., 1955).

5.5.3 Hydrogeology

The primary aquifer of the Jornada del Muerto is contained within the Quaternary/Tertiary bolson-fill. Recharge occurs by infiltration of rain or runoff along ephemeral channels on the basin's floor or in alluvial fans along the basin's margins. According to Conover et al. (1955), Jornada del Muerto groundwater discharges to the Socorro and Mesilla Basins of the Rio Grande Valley. Groundwater is also discharged by pumpage and by evapotranspiration.

DBS&A used Bedinger et al.'s (1989a, 1989b) estimated parameters for basin fill of the Jornada del Muerto and an assumed aquifer saturated thickness of 325 feet to calculate transmissivity values ranging between 7800 ft^2/d to 23,400 ft^2/d. The Bedinger et al. parameters include a range of effective porosity values between 0.12 and 0.36 (1989a, 1989b) and an aquifer gradient of approximately 16 feet per mile (Bedinger et al. 1989b, citing Brady et al., 1984). According to Brady et al. (1984), groundwater flows from the margins of the basin toward its center and discharges from the basin to the Rio Grande in Socorro County and also in areas to the south, outside the planning region. However, the sparsity of wells and water level data makes accurate evaluation of hydraulic connections difficult.

The groundwater of Jornada del Muerto is generally of poor quality. In 1955, Conover et al. wrote that potable water was collected as rain or runoff or was hauled into the basin. These researchers did note that wells completed in alluvial fan deposits or in the bolson-fill near recharge areas may yield potable water. However, the groundwater from the Quaternary/Tertiary bolson-fill deposits is generally of poor quality, although suitable for watering stock. Higher production irrigation wells in the area, which yield water of even poorer quality, are completed at greater depths in either Cretaceous or Permian rocks (Conover et al., 1955).

Herrick and Davis (1965) report that groundwater is abundant in the Jornada del Muerto, but much of it is of very poor quality. This poor groundwater quality is directly related to the chemical composition of the aquifer matrix. The Quaternary alluvial fill contains gypsiferous sediments, and recharging groundwater in contact with these sediments dissolves calcium-sulfate salts, causing rapid degradation of water quality (Conover et al., 1955; Herrick and Davis, 1965; Roybal, 1991). Hence, wells completed in Quaternary or Tertiary volcanic rocks yield water of quality that varies from good to very poor as a function of proximity to their recharge areas (Conover et al., 1955; Roybal, 1991, Plate 2). While saline groundwater of the Jornada del Muerto could potentially be treated to improve its usefulness, the untreated water has limited potential for addressing water supply needs of the region. Figure 5-5 depicts the poor water quality expected to occur throughout the Jornada del Muerto.

Other potential sources of water in the Jornada del Muerto are the two Permian formations, which yield groundwater of varying quality. Water from the Permian San Andres Formation is of very poor quality, while the Permian Glorieta Sandstone yields potable water (Conover et al., 1955; Doty, 1968). Artesian flow was obtained from a Jornada del Muerto well completed in the Permian San Andres Formation at a depth of greater than 1,300 feet bgs (Conover et al., 1955). Doty (1968) describes a well that was completed in a downfaulted block of Permian Glorieta Sandstone in the area of Mockingbird Gap, a pass joining the Jornada del Muerto with the Tularosa Basin to the east.

Herrick and Davis (1965) report that both potable groundwater and groundwater of poor quality have been located in the vicinity of Mockingbird Gap. They also report the presence of potable groundwater at the southwest flank of the Cerro Colorado east of the Bosque del Apache (Figure 5-2) and on the western flank of the San Andres Mountains in the vicinity of Rhodes Canyon, at Township 12 South, Range 2 East (T12S, R2E), in Sierra County.

Due to decreasing well yields, a drilling program was conducted during 1965; results indicated that the supply of good-quality groundwater was locally limited (Doty, 1968). Wells completed in Permian rocks near Chupadera Platform typically yield less than 56 gpm of water (Roybal, 1991).

The depth to water within the Jornada del Muerto is variable. Roybal (1991) reported that depths to water commonly range from 50 to 300 feet bgs in the Jornada del Muerto in Socorro

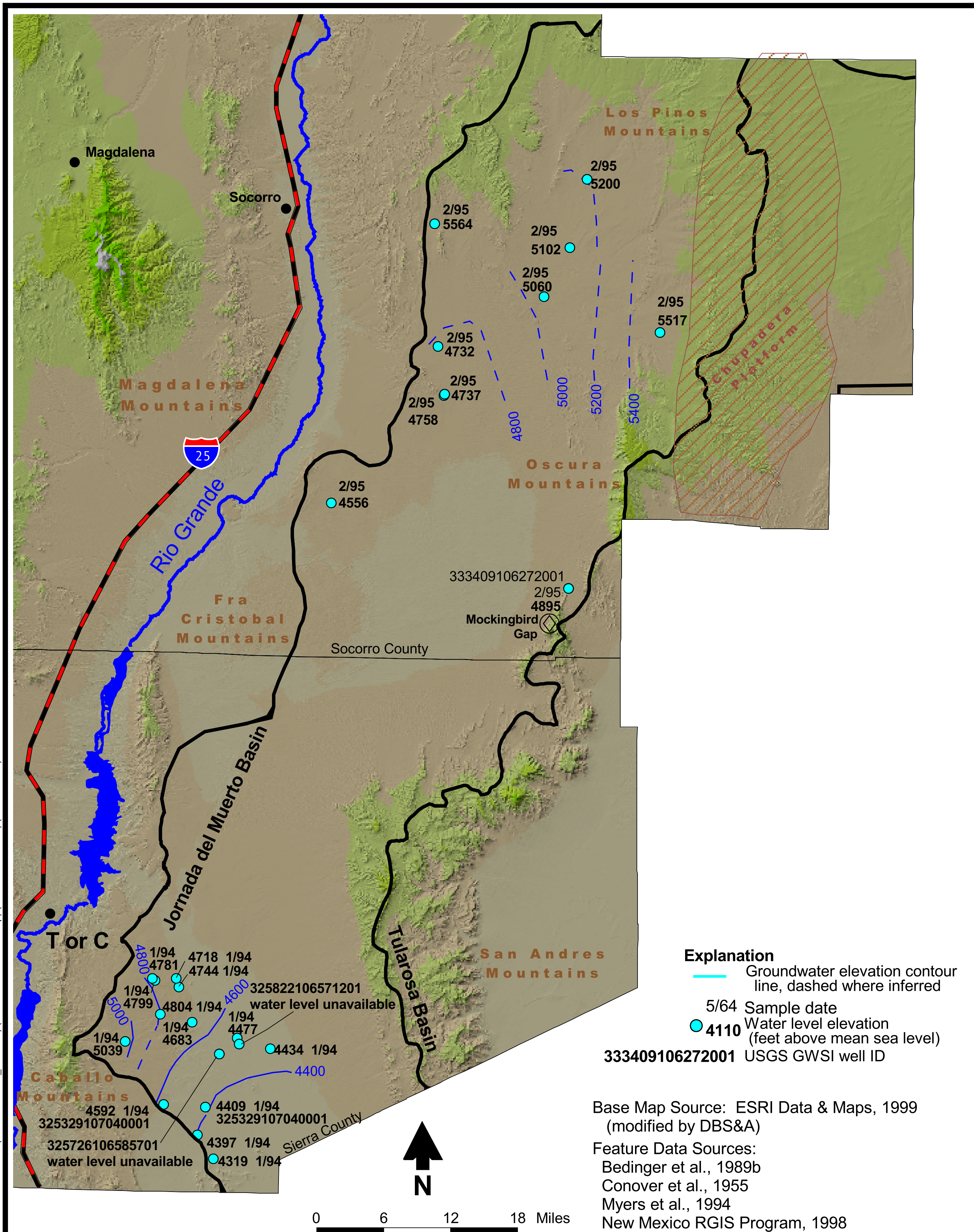
County. Near the Cerro Colorado, depths to water in the bolson-fill aquifer range from 30 to 400 feet bgs (Conover et al., 1955). Conover et al. (1955) reported that confined groundwater occurred in one well completed in the Cretaceous Dakota Sandstone in the northern part of the basin. They described that “water from the Dakota reportedly flowed at 200 gallons a minute . . .” and that “. . . during a pump test the well yielded 300 gpm with 180 feet of draw down” (p. 115). A hydrograph of well 333409106272001, located at Mockingbird Gap and completed in Permian Rocks (Appendix F1), shows that water level elevations at this well have slightly increased between 1965 and 1995.

The groundwater elevation map prepared by Brady et al. (1984) agrees in general with groundwater elevation data collected during the early 1990s. The 1990s data have been plotted and contoured and are shown in Figure 5-6. These data indicate that groundwater flows from topographically high areas near the basin margins toward the basin’s center and then southward.

Water level elevations were plotted for four Jornada del Muerto wells with the longest periods of record (Appendix F1). These wells are located in the Sierra County portion of the basin (Figure 5-6). Although these wells are all located in the same general area, their hydrographs showed two types of responses over time. One set of wells exhibited water level elevation fluctuations of between 3 and 8 feet over the period of record, while the other set exhibited fluctuations of between 50 and 60 feet over the same period of record. Though the sparsity of data makes the water level fluctuations difficult to interpret, the high fluctuations likely result from recharge and discharge variability or variations in aquifer permeability.

5.6 Tularosa Basin

The Tularosa Basin trends north-south and lies parallel to and east of the Jornada del Muerto (Figure 5-2). Orr and Myers (1986) report that the basin’s total area is 6,500 square miles; however, only two quadrants of the northern portion of the basin, about 950 square miles of total area, lie within the Socorro-Sierra planning region. Sierra County contains approximately 500 square miles of the basin, and Socorro County contains about 450 square miles of the basin’s



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SOCORRO-SIERRA REGIONAL WATER PLAN

Water Level Elevations in Jornada del Muerto Basin

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Figure 5-6

Chupadera Platform highlands. The Tularosa Basin is topographically closed and is referred to interchangeably as a “basin” or a “bolson” in the documents reviewed for this report.

From the following analysis and discussion, it is evident that the Tularosa Basin does contain small amounts of fresh water, primarily in alluvial fans located in the southern part of the basin.

5.6.1 Physiography

Within the planning region, the Tularosa Basin is bounded to the west by the San Andres and Oscura Mountains and on the northwest by the Chupadera Platform (Conover et al., 1955; Meinzer and Hare, 1915; Bedinger et al., 1989b). The Chupadera Platform is continuous with the Mesa Jumanes, which marks the northern terminus of the basin (Meinzer and Hare, 1915; Conover et al., 1955). Mockingbird Gap, a low-elevation pass at the northern end of the San Andres Mountains, connects the Tularosa Basin with the Jornada del Muerto.

Within the planning region, the Mesa Jumanes section of the Chupadera Platform is approximately 7,000 ft msl (Meinzer and Hare, 1915). Land surface elevations of the basin’s floor range from about 4,400 ft msl to 4,000 ft msl (Herrick and Davis, 1965). The average annual precipitation at the valley floor is less than 10 inches and in the highland areas of the basin’s margins exceeds 25 inches (Herrick and Davis, 1965).

Conover et al. (1955) note that only five perennial streams naturally flow to the basin’s interior. Of these, three are diverted before reaching the Quaternary/Tertiary bolson-fill. Springs emerge on the Chupadera Platform (Meinzer and Hare, 1915), and salt marshes, playas, and alkali flats appear on the basin’s floor (Conover et al., 1955; McLean, 1970; Meinzer and Hare, 1915).

5.6.2 Geology

Although the majority of the Tularosa Basin is located outside of the planning region, the geologic description provided in this section addresses the entire basin to provide context for the hydrogeologic description that follows. A very generalized depiction of Tularosa Basin stratigraphy within the planning region is shown in Figure 5-5. Surficial geology of the portion of the basin that is located within the planning region is shown on the geologic map included in Appendix B (Figure B-9).

The Tularosa Basin is a graben, bounded by tilted fault-block mountains on the east and west (Johnson et al., 1989; Seager et al., 1987; Bachman, 1968; Orr and Myers, 1986; Sandeen, 1954). Conover et al. (1955, p. 118) note that "older valley fill probably has been tilted and deformed slightly" and that bedding of the bolson-fill exhibits a "predominant downward slope from east to west" and "faulting of alluvial fans at the mouths of canyons." Both Sandeen (1954) and Bachman and Harbour (1970) describe other extremely complex structural features, but a discussion of them is beyond the scope of this report.

Quaternary and Tertiary alluvial fill deposits of the basin's floor include gravel, sand, and clay (Johnson et al., 1989). These deposits have a total thickness as great as 5,000 feet in the southern part of the basin and thin from south to north (Conover et al., 1955). The fill has been described as consisting of lacustrine alluvium and evaporite deposits (Orr and Myers, 1986) and as fanglomerates, conglomerates, sandstone, caliche, shale, and gypsum (calcium sulfate salts) (Sandeen, 1954). Halite beds (of sodium chloride salt) occur within the planning region (McLean, 1970). Conover et al. (1955, p. 110) report that "the sulfate salts in the Tularosa Basin's fill and deeper strata degrade well-water quality in the alluvial fill aquifer." They go on to say that "water contributed to the fill from older rocks and from perennial stream flow is already mineralized. Within a short distance from the mountains, groundwater moving through the fill has dissolved enough mineral matter to render it unfit for domestic consumption, and after moving a few miles farther it is unfit for agricultural purposes" (Conover et al., 1955, p. 118).

Along the basin's margins, alluvial deposits fan out from the highland source areas. The particles comprising these alluvial fan deposits typically become finer with increasing distance from their source areas until they merge with the bolson-fill sediments of the valley floor.

The Tularosa Basin floor, the Chupadera Platform, and the flanks of the surrounding highland areas contain Holocene Malpais basaltic flows (Meinzer and Hare, 1915; Conover et al., 1955; Hawley, 1983).

Cretaceous rocks, consisting of the sequence (younger to older) of Mesa Verde Formation, Mancos Shale, and Dakota Sandstone, parallel and/or crop out on the west front of the San Andres and Oscura Mountains, according to Sandeen (1954), who suggests that these rocks may underlie much of the alluvial fill of the Tularosa Basin. Triassic rocks of the Dockum Group crop out near the Oscura Mountains and in areas northwest of the Tularosa Basin (Sandeen, 1954).

In the Tularosa Basin, Permian rocks underlie Triassic rocks and crop out at the basin's margins. Roybal (1991, Plate 1) indicates that Permian rocks dominate the surface geology of the Chupadera Platform at the northern margin of the basin. From younger to older (and stratigraphically from higher to lower), the Permian sequence includes the San Andres Limestone, the Glorieta Sandstone, the Hueco Limestone, and the Yeso, Abo, and Bursum Formations (Roybal, 1991). In general, the Permian system is comprised of interbedded arkose, sandstone, siltstone, shale, carbonate rocks, and evaporite deposits. The Permian Yeso Formation is 4,260 feet thick in the northern part of the Tularosa Basin, with beds of halite as thick as 800 feet (McLean, 1970). Roybal (1991, Plate 2) indicates that the Yeso, Abo and Bursum Formations yield water ranging from good to very poor quality to wells in this basin within the planning region.

McLean (1970) notes the exposure of 5,000 feet of Paleozoic sedimentary rocks in the San Andres Mountains. Meinzer and Hare (1915) and Sandeen (1954) also describe the presence of Paleozoic rocks in the San Andres, Sacramento, and Caballo Mountains. Roybal (1991, Plate 2) indicates that undifferentiated Pennsylvanian rocks yield water of good quality to wells and springs along the flank of the Oscura Mountains within the planning region.

Precambrian granitic and metamorphic rocks crop out along the margins of the Organ and San Andres Mountains, at Mockingbird Gap, and at the Sierra Oscura (McLean, 1970; Sandeen, 1954).

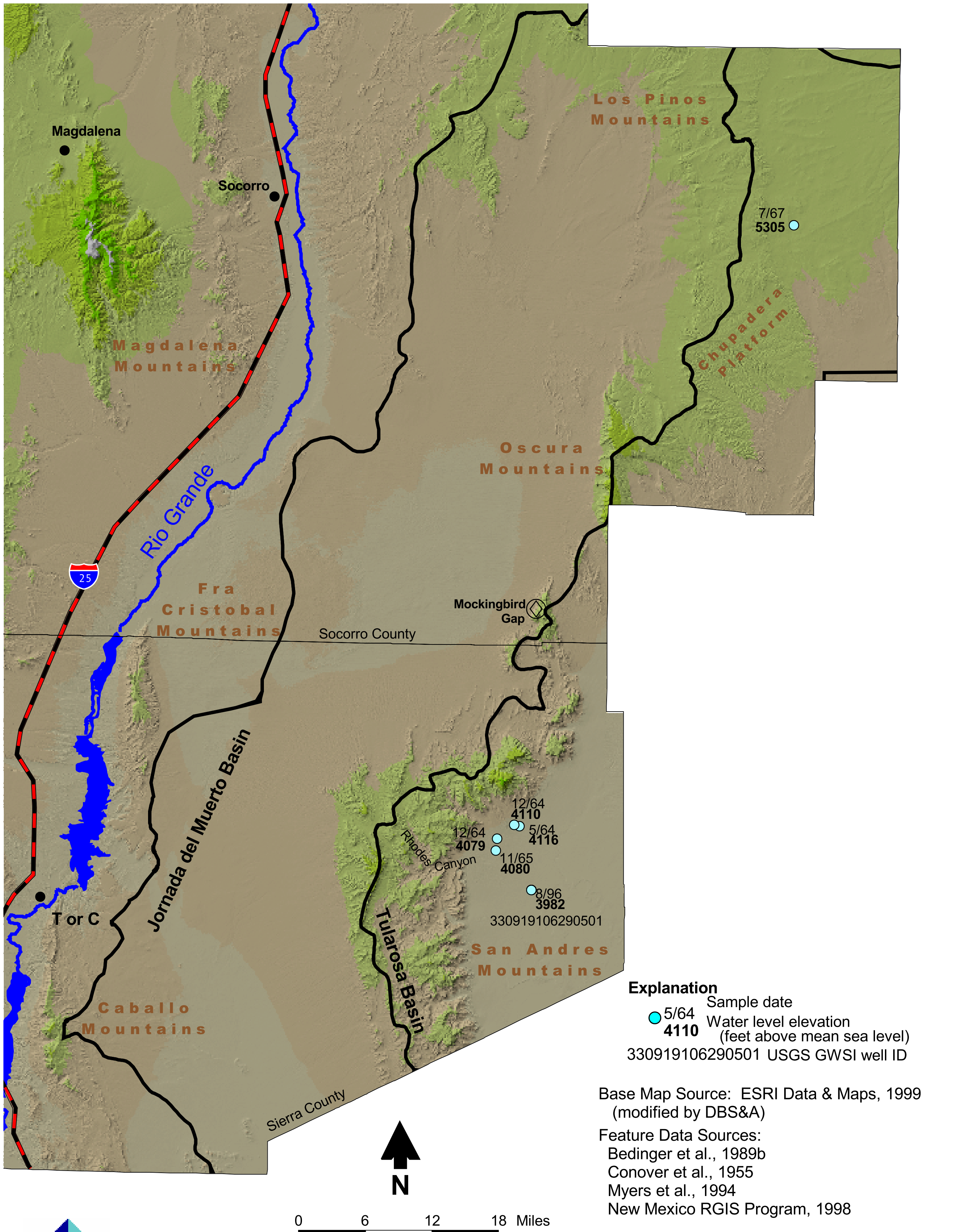
5.6.3 Hydrogeology

As with the neighboring Jornada del Muerto Basin, the principal hydrogeologic characteristic of the Tularosa Basin is its scarcity of potable water sources. This basin's most important aquifer, in terms of water quantity, is its bolson-fill, which yields water ranging from good to poor quality. The best-quality groundwater (potable to slightly inferior quality) in this aquifer is limited to a relatively narrow zone near the basin's highland areas (Conover et al., 1955; Orr and Myers, 1986). An associated source of potable groundwater in the Tularosa Basin is found in locally occurring aquifers within alluvial fan sediments at the bases of the highland margins of the basin. At depth, these alluvial fan sediments lie in interfingered relationship with the bolson-fill sediments. These two sources of potable groundwater are clearly related, as groundwater from the alluvial fans provides recharge to the bolson-fill. The bolson-fill deposits are depositionally heterogeneous, generally grading from coarser piedmont deposits along the margins, to medium-grained stream deposits, to finer playa and evaporite deposits in the center.

Conover et al. (1955) state that recharge to the Tularosa Basin is limited to infiltration of runoff waters following intense summer thunderstorms; most of the light precipitation that falls in the basin evaporates before it has a chance to infiltrate. The material of the alluvial fans is relatively coarse, which promotes recharge, and the bolson-fill aquifer is recharged where the alluvial fans meet the valley fill (Conover et al., 1955). Throughout the basin, groundwater discharges to playas, evapotranspiration, and groundwater pumpage at Tularosa, Alamogordo, and the White Sands Missile Range (Wilkins, 1986).

5.6.3.1 Bolson-Fill Aquifer

Herrick and Davis (1965) report that groundwater of inferior to very inferior quality is abundant in the Tularosa Basin. In the planning region, groundwater flows from the basin's margins toward its center and then generally to the south (Bedinger et al., 1989b; Conover et al., 1955). Depth to groundwater at the basin's floor ranges from several inches to several hundred feet below ground surface (Conover et al., 1955). Figure 5-7 shows water level elevations from data collected primarily in the 1960s (the latest time frame for which basin-wide data were available from the GWSI database) for wells located within the planning region; these water level



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Water Level Elevations in Tularosa Basin

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Figure 5-7

elevations agree relatively well with the 1955 groundwater elevation map provided by Conover et al. (1955, p. 109).

To assess more recent water level elevation behavior in the bolson-fill aquifer, a hydrograph of well 330919106290501 located in southeast Sierra County was plotted and is presented in Appendix F1. The hydrograph shows that water level elevations at this well were relatively constant between 1970 and 1990, but began to increase after 1990. Hydrographs of water level elevation data collected from monitor wells near Tularosa, nearby but outside the planning region, also exhibited marked increases in their water levels between 1986 and 1991, indicating that the increasing water level elevations shown in Appendix F1 may have been part of a local trend (Wilkins and Garcia, 1995). Elsewhere in the Tularosa Basin water level elevations declined during the same period (Wilkins and Garcia, 1995), so it is not possible to infer a regional or basin-wide trend from the data currently available.

5.6.3.2 Locally Occurring Freshwater Aquifers in Alluvial Fans

In the course of their study of Tularosa Basin groundwater resources, Orr and Myers (1986) investigated the occurrence of fresh to slightly saline groundwater at the bases of alluvial fans on the east flank of the San Andres Mountains. They found that the freshwater zone in the alluvial fan at Rhodes Canyon in eastern Sierra County (Figure 5-2) may be as thick as 1,500 feet in deposits at the margin and thins outward toward the distal edge of the fan. The estimated average saturated thickness in the fans is 600 to 800 feet. Figure 5-8 shows a cross section of the Rhodes Canyon fan, modified from Orr and Myers (1986), which represents potential groundwater conditions in the locally occurring alluvial fan aquifers of the planning region.

Though little transmissivity data exist for the Rhodes Canyon alluvial fan aquifer, Orr and Myers (1986) estimated that the transmissivity may range from less than 30 to 2,200 ft^2/d. Results of a bailing test conducted at a well completed in the Rhodes Canyon alluvial aquifer were used to estimate a transmissivity value of less than 20 ft^2/d (Orr and Myers, 1986; Appendix F2).

While Orr and Myers caution that groundwater elevation data from their Rhodes Canyon study area were limited, they estimated a hydraulic gradient of about 25 feet per mile existed within

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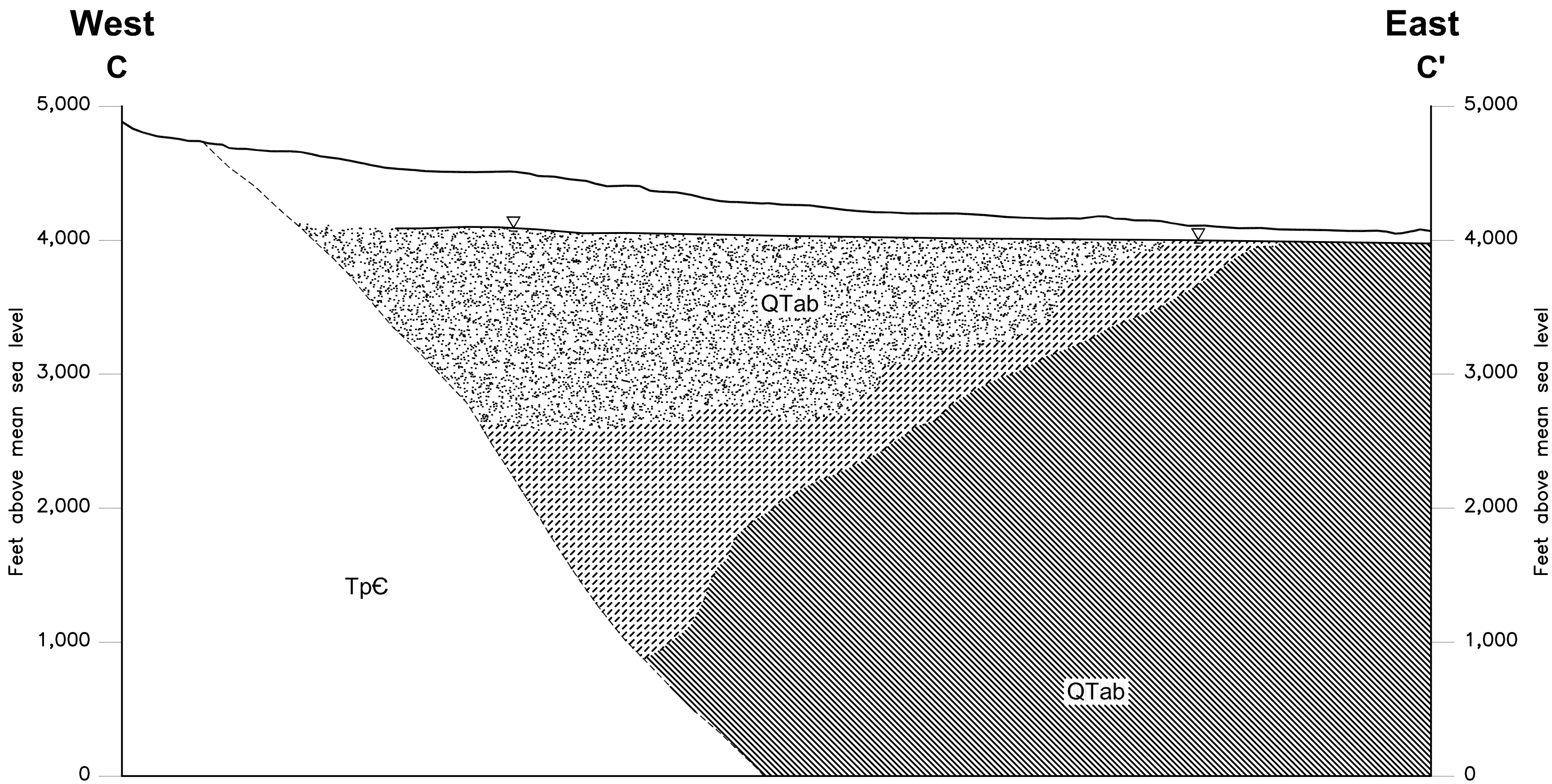

Source: Orr and Myers, 1986

0 1 Mi

Vertical exaggeration 4X

Explanation

Approximate water table

Water quality data

Water quality generally good (<1000 mg/L dissolved solids)

Water quality generally inferior (1000–3000 mg/L dissolved solids)

Water quality generally very inferior (>3000 mg/L dissolved solids)

Geologic data

QTab — Bolson deposits, Pleistocene to middle Miocene basin–fill deposit composed of clay, silt, sand, and gravel

TpЄ — Consolidated bedrock, Tertiary to Precambrian rocks consisting of sedimentary, metamorphic, and igneous rocks. Includes undifferentiated volcanic and intrusive rocks

Contact, dashed where inferred

SOCORRO–SIERRA REGIONAL WATER PLAN

Cross Section C-C' of Representative Alluvial Fan (at Rhodes Canyon) in the Tularosa Basin

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Figure 5-8

the Rhodes Canyon alluvial fan aquifer. Groundwater flow directions are expected to follow local topography, and depth to the freshwater/saline water interface is expected to be variable in these alluvial fan aquifers (Orr and Myers, 1986). McLean (1970) reported yields of 1,400 gpm from wells completed in alluvial fans, with yields decreasing as fines increase toward the base of the fans. Long-term data for plotting hydrographs are unavailable for wells identified as being completed in these aquifer(s).

5.6.3.3 Other Potable Water Sources

Herrick and Davis (1965) report that both potable groundwater and groundwater of poor quality have been located in the vicinity of Mockingbird Gap and that potable groundwater has been located on the southeastern flank of North Oscura Peak, of the Sierra Oscura. The extent of these sources is unknown.

5.7 Las Animas Creek Basin

Las Animas Creek Basin is an east-west trending basin centered approximately on Las Animas Creek and located in the west-central portion of Sierra County (Figure 4-1). Las Animas Creek is a tributary of the Rio Grande, but its surface waters presently flow to Caballo Reservoir. The basin is approximately 32 miles long and ranges in width from 1 to 7 miles; its area is about 150 square miles (Davie and Spiegel, 1967).

While the Las Animas Creek Basin has been declared a groundwater basin by the OSE for the purposes of administering rights to the groundwater, it is also part of a larger structural basin known as the Palomas Basin (Figure 5-1) (Wilkins, 1986; Keller and Cather, 1994) and might more appropriately be called a sub-basin of the larger Palomas structural groundwater basin. However, because it contains significant quantities of water and is administered as a separate basin by the OSE, for the purposes of this report the Las Animas Creek Basin will be addressed as a separate groundwater basin.

5.7.1 Physiography

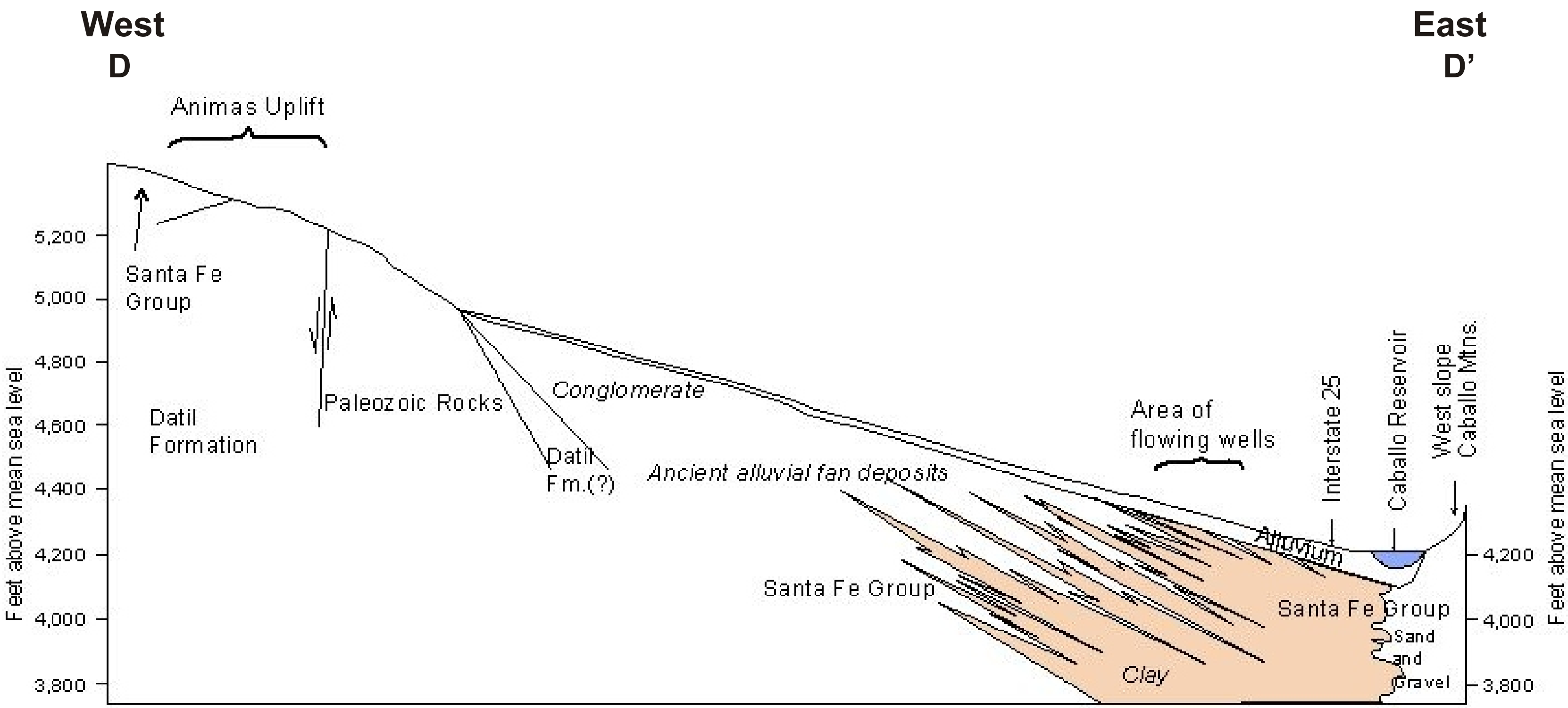
According to Davie and Spiegel (1967), Las Animas Creek Basin is the catchment of Las Animas Creek, a tributary of the Rio Grande; surface waters of Las Animas Creek presently flow to Caballo Reservoir. The basin is contained in an area of about 135 square miles in the western half of Sierra County. Las Animas Creek Basin is bounded on the west by the Black Range and on the east by Caballo Reservoir on the Rio Grande (prior to 1939, when the Caballo Reservoir dam was completed, the basin was bounded on the east by the Rio Grande). The basin is bounded to the north by the Seco Creek drainage and to the south by the Percha Creek drainage, both of which are part of the Lower Rio Grande underground basin (Figure 4-1).

Land surface elevations range from about 4,200 ft msl in the valley at the Caballo Reservoir boundary to 9,800 ft msl in the Black Range. Average annual precipitation ranges from about 8 inches per year in the Rio Grande Valley at the eastern edge of the basin to 25 inches per year in the highlands on the western edge of the basin (OSU, 2000-2002.

5.7.2 Geology

Las Animas Creek is one of a number of streams that are entrenched in an east-sloping plain that has formed across rocks filling the Rio Grande structural depression. Across this plain in the Socorro-Sierra water planning region are two principal north-trending fault blocks, both tilted to the east in late Cenozoic time. The western block was raised on the west to form the Black Range, and the eastern block was similarly raised on the west to form a range of hills known as the Animas uplift (Kelley, 1952) (Figure 5-9). A sequence of rocks from Precambrian to Permian and from early Tertiary to Recent occurs in the Las Animas Creek area. Surficial geology is illustrated on the geologic map of the planning region included in Appendix B (Figure B-9).

Precambrian rocks crop out in a small area near the head of Animas Gulch near the western boundary of the basin. Paleozoic rocks crop out in the gorge where Las Animas Creek crosses the Animas Uplift near Sections 34 and 35 of T14S, R7W. Paleozoic rock units in the area



Explanation

Alluvium: Late Quaternary age. Alluvium underlies the inner valley of the Rio Grande and Las Animas Creek, and consists of unconsolidated gravel, sand, silt, and clay.

Santa Fe Group: Quaternary-Tertiary age. Consolidated and unconsolidated brown, red, and gray gravel, sand, silt, and clay.

Datil formation: Tertiary age. Consolidated and unconsolidated fine to coarse pyroclastics, including pumice, tuff, and breccia, and lesser amounts of alluvial sediments with localized interbedded lava.

Paleozoic rocks: Undifferentiated limestones and shales of Silurian to Pennsylvanian ages.

Source: Davie and Spiegel, 1967

Horizontal scale
1 inch = approximately 2 miles

SOCORRO - SIERRA REGIONAL WATER PLAN

Cross Section D-D' of the Las Animas Creek Basin

Figure 5-9

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include, from oldest to youngest, Fusselman dolomite, Percha shale, Lake Valley formation, and Magdalena formation.

A thick sequence of lava flows, tuffs, intrusives, and associated volcanic-derived sediments, equivalent to the Datil Group, was deposited on top of the Precambrian and Paleozoic rocks. The Datil Group is deeply buried by the Santa Fe Group in most of the basin, but is locally exposed by erosion in the Animas Uplift (Davie and Spiegel, 1967).

The Santa Fe Group is a thick sequence of sediments that was deposited in a broad north-trending structural depression along the entire length of New Mexico. In the Las Animas Creek area the Santa Fe Group consists of three facies: (1) alluvial fan deposits derived from the Datil Group form the westernmost facies and interfinger eastward with (2) clays, which in turn interfinger eastward with (3) a river facies of well sorted sand and gravel (Figure 5-9).

Quaternary alluvium fills the Rio Grande Valley along the eastern edge of the Las Animas Creek Basin. Davie and Spiegel (1967) report that the depth of alluvial fill in the Rio Grande Valley in southern New Mexico averages 63 to 75 feet below the normal river bed. This depth is greater than would be expected as the result of flood scouring; therefore, it is assumed that the river has aggraded, or filled in its own channel.

5.7.3 Hydrogeology

The basin’s primary aquifers are located in the Quaternary alluvium along Las Animas Creek, in the Quaternary/Tertiary Santa Fe Group, which was deposited by the ancestral Rio Grande, and in underlying Paleozoic rocks. Davie and Spiegel (1967) found that groundwater is recharged to Paleozoic rocks and the Santa Fe Group by rainfall and resulting runoff on the drainage areas of the basin of Las Animas Creek and Seco Creek, and groundwater generally flows in an easterly direction, following the surface water flow direction. The groundwater discharges to the valley of Las Animas Creek and Caballo Reservoir. The main surface drainage for the basin, Las Animas Creek, is an intermittent stream for most of its length, but flows perennially below about 4,500 feet elevation (Davie and Spiegel, 1967), indicating that the upper part of the creek is a losing reach and the lower part is a gaining reach. The authors did not provide estimates of stored groundwater in this basin.

Davie and Spiegel (1967) observe that the construction of diversion ditches, wells, and Caballo Dam has modified the hydrologic cycle considerably. For instance, groundwater levels at the lower end of the basin fluctuate in response to stage changes at Caballo Reservoir. While a query of the GWSI database found some water level data, the database did not contain enough recent data to prepare a groundwater elevation map, nor were the periods of record long enough to graph water level trends.

5.7.3.1 Alluvial Aquifer

The total area of the alluvial aquifer in Las Animas Creek Basin is small (approximately 5 square miles), and its high transmissivity permits rapid natural drainage. Seasonal runoff (snowmelt in the spring and storm runoff in the summer) causes large seasonal water level fluctuations in the alluvium. In most of the eastern edge of the basin the transmissivity of the alluvium is high enough to convey the entire flow of Las Animas Creek, but springs emerge in the stream channel in areas where the alluvium cannot convey all of the underflow. Both underflow and surface flow discharge to springs and wells in the alluvium or into Caballo Reservoir.

5.7.3.2 Santa Fe Group Aquifer

As mentioned in Section 5.7.2, the Santa Fe Group in the area of Las Animas Creek consists of three facies. The alluvial fan facies generally has a low transmissivity, and well yields in this facies are sufficient for stock and domestic use but not for irrigation. The clay facies contains thin sand layers interbedded with clay and in some areas yields water to wells in amounts sufficient for irrigation use. The river facies of the Santa Fe Group consists of well sorted sand and gravel with relatively high transmissivity.

A study by the State Engineer Office (SEO, now called the OSE) and the USGS in the early 1940s (Murray and Theis, 1946) indicated that artesian conditions were present in the Santa Fe Group aquifer near the eastern edge of the Las Animas Basin and that water discharged to the surface by upward percolation through semiconfining beds. The study also indicated that several wells developed along a 3-mile stretch of Las Animas Creek yielded natural artesian flows ranging from a few gpm up to 75 gpm. Estimates of transmissivity and storage coefficient for the Santa Fe Group aquifer were on the order of 7,000 to 14,000 gallons per day per foot (gpd/ft) and 0.0004 to 0.002, respectively.

Development of artesian wells in the 1930s resulted in large quantities of water being released from storage because few of the wells were equipped with valves. Construction of nearby Caballo Dam in 1936 partially masked the effects of pumping as the filling of the reservoir caused a rise in groundwater levels (Davie and Spiegel, 1967). Long-term water level data are not available to determine the overall effect.

5.7.3.3 Paleozoic Aquifer

The Paleozoic Aquifer mainly occurs in the western portion of the Las Animas Basin. The Percha shale in the western part of the Animas Uplift is presumed to form a nearly impermeable barrier to groundwater movement (Davie and Spiegel, 1967). Therefore, all groundwater in the region west of the Animas Uplift emerges in the valley of upper Las Animas Creek. Other groundwater from Pennsylvanian rocks discharges at springs in the eastern part of the Animas Uplift.

5.8 Hot Springs Artesian Basin

The Hot Springs Artesian Basin is located in central Sierra County, bordering the modern bed of the Rio Grande and the Caballo Reservoir (Figure 4-1). While the Hot Springs Artesian Basin has been declared a groundwater basin by the OSE for the purposes of administering rights to the groundwater, it is also part of the Palomas Basin (Figure 5-1) (Wilkins, 1986; Keller and Cather, 1994) and might more appropriately be called a sub-basin of the larger Palomas structural groundwater basin. However, because it contains significant quantities of water and is administered separately by the OSE, for the purposes of this report the Hot Springs Artesian Basin is addressed as a separate groundwater basin.

The Hot Springs Artesian Basin is an east-west trending basin centered approximately on Palomas Creek. The basin is approximately 32 miles long and 9 miles wide with a total area of about 275 square miles.

As its name describes, the basin contains flowing wells that are completed in rocks of the Quaternary/Tertiary Santa Fe Group, which contains the most important aquifers of the basin. According to Murray (1959) groundwater enters the artesian aquifer from the west and "is discharged indirectly to the river by upward percolation through imperfectly confining beds to the overlying, shallow-water aquifers and thence to the river." Murray also reports that heads exceeded 45 feet above land surface in two wells completed in the artesian aquifer in 1945; these two wells yielded 7 gpm per foot of drawdown.

5.8.1 Physiography

The Hot Springs Artesian Basin is bounded on the west by the Black Range and on the east by Caballo Reservoir and the modern Rio Grande (prior to 1939, when the Caballo Reservoir dam was completed, the eastern boundary of the basin was the Rio Grande). The basin is bounded to the north by the Rio Grande Basin and to the south by the Lower Rio Grande Basin (Figure 4-1).

Land surface elevations range from about 4,200 ft msl at the Rio Grande boundary to 9,600 ft msl at the Black Range. Average annual precipitation ranges from about 8 inches per year in the Rio Grande Valley at the eastern edge of the basin to 22 inches per year in the highlands on the western edge of the basin (OSU, 2000-2002).

5.8.2 Geology

The main structural features of the Hot Springs Artesian Basin are the Black Range on the western edge of the basin, the east-west trending tributary streams flowing to the Rio Grande, the Mud Springs Mountains near the east edge of the basin, and the Rio Grande Valley, which forms the eastern edge of the basin. Faulting in late Cenozoic time formed the Black Range, the raised western block of a north-trending fault block. Subsequent normal faulting resulted in the Rio Grande depression, a broad north-trending structural depression along the entire length of New Mexico. Drainage from the higher western mountains toward the Rio Grande depression formed the entrenched streams and arroyos that cross the east-sloping plain, including Palomas Creek. Transverse faulting created a northward tilted fault block that forms the Mud Springs Mountains, a northwest-trending mountain range near the eastern edge of the basin (Murray, 1959).

A sequence of rocks from Precambrian to Permian and from Cretaceous to Recent occurs in the Hot Springs Artesian Basin area. Coarse, red granite is the most common Precambrian rock in the area. This red granite is exposed in a low terrace south of Truth or Consequences and at the south end of the Mud Springs Mountains (Murray, 1959).

Paleozoic strata consist of a sequence of sedimentary sandstones, shales, and limestones, including (from oldest to youngest) Bliss sandstone, El Paso limestone, Montoya limestone, Fuselman limestone, Percha shale, Lake Valley limestone, Sandia formation, Madera limestone, Abo Formation, and the Yeso and San Andres Formations. Paleozoic strata crop out mainly in the mountainous regions of the Hot Springs Artesian Basin, including on the east flank of the Black Range and in the Mud Springs Mountains near Truth or Consequences. These strata probably underlie much of the basin, beneath the valley fill (Murray, 1959).

Tertiary and Quaternary strata in the area include both sedimentary and igneous rocks. The valley fill deposits that occupy the Rio Grande depression are the most prevalent sedimentary rocks in the area and are the most important in terms of storing and conveying groundwater. These deposits make up the Santa Fe Group, a thick sequence of sediments that was deposited in a broad north-trending structural depression along the entire length of New Mexico. In the Hot Springs Artesian Basin, the Santa Fe Group is exposed along nearly the full length of Palomas Creek, as well as along other smaller drainages and the Rio Grande. The Santa Fe Group consists of unconsolidated to partly consolidated sand, gravel, and clay. The clay beds are more prevalent closer to the Rio Grande and disappear toward the upland areas to the west. It is believed that the clay layers act as confining layers and are responsible for the artesian conditions found in the eastern part of the basin, near the Rio Grande (Murray, 1959).

Tertiary and Quaternary igneous rocks are exposed in the upland areas of the Hot Springs Artesian Basin. Rhyolite that was extruded in the late Tertiary age is especially prevalent in the Black Range, while newer patches of Quaternary basalt are extruded onto the surface in numerous areas of the basin. The igneous rocks in the basin have too low a storage capacity to be important as aquifers, but they do act to funnel infiltrated precipitation into the sedimentary units of the basin (Murray, 1959).

5.8.3 Hydrogeology

Groundwater in the Hot Springs Artesian Basin occurs as thermal and non-thermal waters, both under free-flowing artesian conditions and static conditions. The main aquifers of the basin are the Quaternary/Tertiary Santa Fe Group and the underlying Paleozoic rocks. The non-thermal water is stored in the Santa Fe Group aquifer and thermal water emerges from the underlying Paleozoic aquifer. Murray (1959) studied the non-thermal artesian conditions near Truth or Consequences, and Summers (1976) includes sections on the thermal groundwater conditions near Truth or Consequences.

According to Murray (1959, p. 1), groundwater enters the artesian aquifer from the west and "is discharged indirectly to the river by upward percolation through imperfectly confining beds to the overlying, shallow-water aquifers and thence to the river." Murray (1959) reports that artesian heads exceeded 45 feet above land surface in two wells completed in the artesian aquifer in 1945; these two wells yielded 7 gpm per foot of drawdown.

Little or no data are available on the non-thermal and non-artesian groundwater conditions that exist away from the Truth or Consequences area. Though some water level data were found in the GWSI database, not enough recent data were available to prepare a groundwater elevation map, nor were the periods of record long enough to graph water level trends.

Recharge to the basin occurs through direct rainfall and snowmelt on the upland areas to the west, with infiltration into the outcropping edges of the Santa Fe Group rocks along the sides of streams and arroyos. Groundwater flow is generally eastward, coinciding with the direction of surface water flow. Because of their relatively low permeability, the Tertiary igneous rocks help to direct and funnel groundwater flow into the adjacent valley fill. Groundwater discharges as artesian flow farther to the east, in the lower portions of Palomas Creek and Mud Springs Draw, near Truth or Consequences.

5.8.3.1 Santa Fe Group Aquifer

The SEO/USGS study (Murray and Theis, 1946) indicated that artesian conditions were present in the Santa Fe Group aquifer near the eastern edge of the Hot Springs Artesian Basin. Water discharges to the surface by upward percolation through semiconfining beds. It is believed that the well-developed clay layers within the Santa Fe Group near the Rio Grande act as confining layers. The SEO/USGS study indicated that artesian wells were developed on the west side of the Rio Grande from Truth or Consequences (then known as Hot Springs) to Arrey, about 17 miles south. Prior to 1945, artesian wells in Mud Springs Draw furnished the municipal water supply for the town of Hot Springs. Aquifer testing in the Mud Springs Draw area determined transmissivities ranging from 7,100 to 13,000 gpd/ft (Murray, 1959).

Water from the artesian wells is of fair quality and varies from well to well (Murray, 1959). Sodium, calcium, chloride, and bicarbonate are the most abundant cations and anions in the water. Dissolved solids and hardness average 550 and 225 parts per million, respectively.

5.8.3.2 Paleozoic Aquifer

Thermal water, highly mineralized artesian and non-artesian water occurring in the Pennsylvanian limestones of the Magdalena group, has been used in the Truth or Consequences area for therapeutic and recreational uses since the early 1900s (hence the former name of the town, Hot Springs). The heat of the water is a result of faulting, which provides conduits for thermal waters to rise to the surface (Summers, 1976). Although the mineralized hot springs are not considered a significant source of water supply, the thermal waters remain a major tourist draw for the town of Truth or Consequences and are therefore important to the economy of the area (some mineral bath spas currently operate within the town).

5.9 La Jencia Basin

La Jencia Basin was not extensively reviewed by DBS&A because its groundwaters and surface waters are hydraulically connected with basins of the Rio Grande Valley. However, SSPA conducted a study of this basin (SSPA, 2002a), which is summarized here to enable a more thorough overview of groundwater supplies in the planning region. The entire SSPA study, including maps and recharge and storage estimates of La Jencia Basin, is provided in Appendix E2.

La Jencia Basin is a partially closed basin that encompasses approximately 200 square miles west of the Rio Grande Basin in central Socorro County. The basin is bounded on the south and west by the Magdalena Mountains, on the west by the Bear Mountains, and on the north by the Ladron Mountains and the Colorado Plateau (Anderholm, 1987, as referenced by SSPA, 2002a). Elevations range from 6,400 feet along the mountain ranges to the west to about 5,000 feet near the Rio Salado in the northeast part of the basin. Average annual precipitation in the basin is 11.7 inches as measured in Magdalena (Roybal, 1991, as referenced by SSPA, 2002a). The basin is drained by three ephemeral streams: Bear Springs Canyon and La Jencia Creek, which flow north into the Rio Salado, and Water Canyon, which flows east toward the Rio Grande (Anderholm, 1983, as referenced by SSPA, 2002a).

A sequence of rocks from Paleozoic to Quaternary age occurs in the basin. The Santa Fe Group is primarily composed of conglomerate, sandstone, and playa deposits of the Popotosa Formation, alluvial fan and playa deposits of the Sierra Ladrones Formation, and Quaternary deposits. Underlying this group is the Tertiary Socorro volcanics, which in turn overly the Datil Group and Baca Formation. Mesozoic and Paleozoic rocks are found below these formations. The basin floor is shaped by asymmetrically grouped, tilted fault blocks that underlie the basin fill sediments (SSPA, 2002a).

The primary aquifer in this basin is composed of the Sierra Ladrones and Popotosa Formations of the Santa Fe Group (Anderholm, 1987, as referenced by SSPA, 2002a). In general, regional groundwater flow is northward. Some wells have been drilled into minor aquifers within the Tertiary volcanics of the Datil Group, Baca Formation, and the underlying Mesozoic and Paleozoic rocks that are located in the highlands at the edge of the basin (Anderholm, 1987, as referenced by SSPA, 2002a). Groundwater within the basin is primarily used for domestic and livestock purposes.

Aquifer test results from the Sierra Ladrones Formation are not available, but an analysis of aquifer test data from wells in the Quaternary deposits and the Upper Santa Fe Group, adjacent to the Socorro Basin, indicate an average hydraulic conductivity between 41 feet per day (ft/d) and 60 ft/d and a storativity ranging from 0.0002 to 0.23 (Hantush, 1961; USGS, 1979; Waldron, 1956, as cited by SSPA, 2002a). Calculations of transmissivity ranged from 3,700 to 27,000 ft^2/d (Hantush, 1961; Theis, 1938; Waldron, 1956, as cited by SSPA, 2002a). Aquifer tests conducted in the Tertiary volcanic rocks indicate transmissivities of 160 ft^2/d (Bishop, 1975) and 5,000 ft^2/d (Summers, 1975).

Little data exist on well yields in the La Jencia Basin. Roybal (1991) reported one measured flow of 0.5 gpm. The yields of wells completed into the Upper Santa Fe Group in the adjacent Rio Grande Basin are commonly less that 50 gpm. Depth to water ranges from 10 feet to nearly 500 feet. In most locations the water table is more than 100 feet deep.

Groundwater recharge occurs through infiltration of direct precipitation and runoff from upgradient areas and through seepage from ephemeral streams. Water quality is good within the primary aquifers of the basin, having a TDS concentration generally below 300 mg/L (Anderholm, 1987, as referenced by SSPA, 2002a).

5.10 Rio Grande Basin

The Rio Grande Basin hydrogeology was reviewed by SSPA as part of its investigation because its groundwaters and surface waters are hydraulically connected with basins of the Rio Grande Valley. SSPA studied this basin (SSPA, 2002a) from the Valencia-Socorro county line to the Elephant Butte Reservoir, and their findings are summarized here to enable a more thorough overview of groundwater supplies in the planning region. The entire SSPA study, including maps and recharge and storage estimates for this portion of the Rio Grande Basin, is provided in Appendix E2.

The Rio Grande Basin trends north-south, and the portion included within the Socorro-Sierra water planning region contains the southern portion of the Albuquerque-Belen Basin, the Socorro Basin, the San Marcial Basin, and the Engle Basin (SSPA, 2002a). On the west, the Rio Grande Basin is bound by the Ladron, Lemitar, Magdalena, and San Mateo Mountains and the Cuchillo Range. The eastern boundary is formed by the Los Pinos Mountains, the Joyita

Hills, the Lomas de las Canas Uplift, Cerro Colorado, Little Pasqual Mountain, and the Fra Cristobal Range (SSPA, 2002a). Elevations range from 6,000 to 10,000 feet in the nearby mountains to between 4,450 and 4,700 feet along the valley floor. Mean annual precipitation is 9.35 inches.

The basin is drained by the Rio Grande and its tributaries: the Rio Puerco, Rio Salado, Nogal Canyon Creek, Milligan Gulch, and Alamosa Creek (SSPA, 2002a). In addition, various infrastructures associated with irrigated agriculture occur in the Rio Grande Valley.

A sequence of rocks from Paleozoic to Quaternary overlying Precambrian basement rocks occurs in the basin. In general, the Quaternary alluvial and fluvial deposits are less than 50 feet thick (Spiegel, 1955, as referenced by SSPA, 2002a) and overlie the Santa Fe Group. The Santa Fe Group is composed primarily of the Quaternary-Tertiary Sierra Ladrones Formation and the Tertiary Popotosa Formation. Underlying this group is the Tertiary Socorro volcanics, which in turn overlie in some locations the Datil Group and Baca Formation (Osburn and Chapin, 1983, as referenced by SSPA, 2002a). Where present, Mesozoic and Paleozoic strata are found below these formations.

The primary aquifers include the Upper Santa Fe Group and Quaternary deposits, which together form the shallow aquifer, and the lower part of the Popotosa Formation (Anderholm, 1987, as referenced by SSPA, 2002a). In general, regional groundwater flow is from the upland areas toward the river and from north to south along the Rio Grande Valley. The majority of supply wells are screened in the Quaternary alluvium or in the Santa Fe Group (SSPA, 2002a). To a limited extent, minor aquifers are found in the Tertiary volcanics and other bedrock formations (SSPA, 2002a).

Transmissivity of the Santa Fe Group has been estimated (USGS, 1979) to range from approximately 7,000 to 21,000 ft^2/d with an average hydraulic conductivity of approximately 60 ft/d and storage coefficient ranging from 0.0002 to 0.0006. Anderholm (1987) presented estimates of hydraulic properties of the Upper Santa Fe Group based upon information from Hantush (1961) and Theis (1938). The estimates included transmissivity ranging from 6,700 to 27,000 ft^2/d, hydraulic conductivity of approximately 41 ft/d, and a specific yield of 0.23.

Waldron (1956) reported aquifer test results indicating a transmissivity range from 3,700 to 26,000 ft^2/d and storage coefficient between 0.0084 and 0.05.

Yields range from 0.5 to 2,700 gpm (Roybal, 1991, as cited by SSPA, 2002a), although nearly 70 percent of reported yields are less than 50 gpm. Yields for municipal water supply wells for the City of Socorro are consistently between 540 and 850 gpm. Based upon well records provided by the USGS, groundwater elevations along basin margins and in the inner valley in the Rio Grande Basin do not show a consistent increasing or decreasing trend in water levels for the last 20-year period (Appendix E2). However, water levels within the inner valley have decreased due to the development of irrigation infrastructure.

Groundwater recharge occurs through infiltration of direct precipitation and of runoff from upgradient areas, through seepage from streams and irrigation works, and through inflow from adjacent groundwater basins (SSPA, 2002a). Water quality is highly variable within the basin, with average chloride concentrations ranging from 50 mg/L near Socorro to 600 mg/L in the northern part of the basin (Anderholm, 1987, as referenced by SSPA, 2002a).

5.11 Groundwater Recharge and Storage

Each basin was analyzed to estimate the volumetric average annual recharge and to compute the volume of groundwater stored in place. The estimates for La Jencia and Rio Grande Basins were developed by SSPA as part of their evaluation of these basins under a separate contract to the ISC and are included in Appendix E2. Four of the other six basins were analyzed by Hydrosphere and DBS&A, while ISC estimated recharge and storage for the Hot Springs Artesian and Las Animas Creek Basins. Results of the recharge and groundwater storage tasks for the six basins are discussed in Sections 5.11.1 and 5.11.2.

When using these estimates for planning purposes, water planners should take into account that use of stored water is affected by legal and water rights constraints and that development of stored groundwater, particularly at greater depths, may not be economically feasible. In particular, the necessity of meeting Rio Grande Compact obligations means that any new groundwater withdrawals that will affect surface water flows can only be accomplished by transferring existing surface water or stream-connected groundwater rights.

5.11.1 Recharge Estimates

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 migration into aquifers at the base of a mountain.

Recharge rates in the Socorro-Sierra Region have not been well characterized and documented in existing literature; therefore, recharge was estimated using methods accepted by the scientific community to help provide data where needed. Numerous authors have investigated natural areal groundwater recharge in arid and semiarid environments similar to New Mexico (e.g., Maxey and Eakin, 1949; Gee and Hillel, 1988; Lerner et al., 1990; Allison et al., 1994; Phillips, 1994; Stephens, 1994), and the results of those studies were used to help develop accurate estimation methods.

The Maxey-Eakin approach was used to estimate both areal and mountain front recharge in the Socorro-Sierra planning region. Additionally, another set of estimates was developed using a modification of the Maxey-Eakin method with an adaptation of their approach that incorporates directly measured recharge values from New Mexico; the methods and results of that analysis are included in Appendix F3.

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 estimates 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; that is, the higher the annual precipitation, the higher the annual recharge. This hypothesis was supported by the observation, based on basin water balance studies, 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 (Maxey and Eakin, 1949). Upon this premise and using a contoured precipitation map of the state of Nevada, they defined average annual recharge to a groundwater basin in Nevada as:

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

where: A_i = the land surface area (L^2) in a groundwater basin encompassed between two iso-precipitation contours and

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

where: i = precipitation contour

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

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

P_i = the average annual precipitation in zone i

Given the pre-existence of the contoured precipitation map of the state (Harman, 1936), from which areas could be determined, the only set of unknowns in this recharge model were the percent recharge values (r_i). To estimate r_i, Maxey and Eakin (1949) used independent water balance results from 21 groundwater basins in the state of Nevada. These studies provided $\text{Volume}_{\textit{recharge}}$ for those 21 basins, and the contoured precipitation map (Harman, 1936) provided the required A_i. Using these two known quantities, Maxey and Eakin (1949) solved for the r_i values using multiple regression. Table 5-3 summarizes the results of their analysis.

Table 5-3. 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 Socorro-Sierra water planning region and most of the basins studied by Maxey and Eakin (1949) in Nevada. Both lie within the Basin and Range Province and are characterized by block faulted mountain ranges separated by broad valleys underlain by thick sequences of alluvial bolson-fill materials. Furthermore, much of Nevada and the planning region share semiarid to arid climatic regimes, although Nevada tends to get a larger fraction of its annual precipitation in the winter season.

Given the similarities, the Maxey-Eakin recharge model can be used to estimate basin recharge in the Socorro-Sierra planning region through direct use of equations (1) and (2) parameterized by the percentage recharge constants taken from Table 5-3. Accordingly, this model was used in conjunction with a contoured precipitation map of the planning region (a copy of which is included as Figure B-6 in Appendix B) to estimate recharge within the selected groundwater basins in the planning region. The results are presented in Table 5-4.

To check the accuracy of the calculations, recharge to the Alamosa Creek Basin was compared to field-measured data. At the hydrologic outlet to the basin, the total flow into the Monticello Box from Alamosa Creek and the Apache Warm Springs ranges between 6 and 8 cfs (Myers et al., 1994; Jeffrie, 2000), or from 4,344 to 5,791 acre feet per year (ac-ft/yr). The average annual recharge to the basin computed using the Maxey-Eakin model is on the same order of magnitude (roughly half [Table 5-3]) as the observed basin discharge. This is a reasonably close agreement given the approximation techniques used. However, the Maxey-Eakin method provides only an approximation, and planners should recognize that actual recharge rates may vary. Particularly in lower-elevation areas with less precipitation and without significant recharge from stream losses, recharge values could be lower than those estimated. More accurate recharge estimates would require local field studies.

Table 5-4. Calculated Recharge to Groundwater Basins Outside the Rio Grande Valley in the Socorro-Sierra Water Planning Region

Basin	Area [a] (acres)	Volumetric Annual Recharge (ac-ft/yr)	
		Total	Mountain Front
San Agustin	240,100	7,620	201
Alamosa Creek	163,109	2,331	325
Jornada del Muerto	1,188,800	47,121	3,858
Tularosa	780,000	21,805	526
Las Animas Creek	75,100	17,200	NC
Hot Springs Artesian	178,545	17,040	NC
Rio Grande Basin	NA	63,800 [b]	NC
La Jencia Basin	91,069	20,000 [b]	NC

NC = Not calculated
NA = Not available
[a] Portion of the basin that falls within the planning region
[b] SSPA (2002a) estimate

5.11.1.1 Mountain Front versus Areal Recharge Rates

The precipitation that falls in the highlands around the basin perimeters that ends up recharging the basin aquifers is considered mountain front recharge. The increasing r_i values in the Maxey-Eakin model (Table 5-4) suggest that highland areas have enhanced recharge, per unit area, compared to basin floors. The 12-inch precipitation contour roughly parallels topographic breaks, and the higher-precipitation component (>12 inches of precipitation) of the Maxey-Eakin equation was used to infer the percentage of the total recharge contributed by the highlands, or the mountain front recharge (Table 5-4).

Hearne and Dewey (1988) developed an independent approach for computing mountain front recharge based on winter precipitation, basin area, and channel slope. Roybal (1991) applied the Hearne and Dewey approach to Socorro County and projected significantly higher values of mountain front recharge than those obtained using the modified Maxey-Eakin approach.

5.11.2 Groundwater Resources in Storage

Groundwater resources stored in aquifers in the four basins considered were computed by multiplying estimated saturated aquifer volumes by specific yield (Sy), which can be considered to equal the amount of water that would be drained from a unit volume of saturated rock under gravity. Table 5-5 summarizes estimated aquifer thicknesses and specific yields for the six basins. In addition, the aquifer areas were estimated using the following sources of information:

- The areas of the alluvial basin-fill aquifers in the San Agustin and Alamosa Creek Basins were obtained from the areas of the Qab deposits as presented in Myers et al. (1994, Figure 4).

- The area of the alluvial basin-fill in the Jornada del Muerto Basin was derived from Plate 4 of Bedinger et al. (1985).

- The area of the Datil Group Aquifer in the Alamosa Creek Basin was determined from Figure 11 of Myers et al. (1994) less 140 square miles for the higher elevation portions of the basin in the San Mateo Mountains.

- The area of the saturated portions of the Datil Group Aquifer in the San Agustin Basin was calculated as the basin area above the 6,800-foot-msl water table altitude less 25 square miles in the San Mateo Mountains (as determined from Figure 11 of Myers et al. [1994]).

- The area of the saturated alluvial fans in the planning region portion of the Tularosa Basin was obtained from Figure 17 of Orr and Myers (1986).

- The area of the Santa Fe Group in the Hot Springs Artesian Aquifer was obtained from Lund and Witcher (2002).

Table 5-5. Estimates of Groundwater Resources Stored Outside the Rio Grande Valley in Socorro-Sierra Water Planning Region

Basin	Estimated Area (square miles)	Estimated Area (acres)	Estimated Minimum Average Thickness (feet)	Estimated Minimum Aquifer Volume (acre-feet)	Estimated Maximum Average Thickness (feet)	Estimated Maximum Aquifer Volume (acre-feet)	Specific Yield[a] (%) Minimum	Specific Yield[a] (%) Maximum	Groundwater Stored (acre-feet) Minimum	Groundwater Stored (acre-feet) Maximum
San Agustin										
Bolson-Fill Aquifer[b]	291[c]	186,240	277[d]	51,605,194	477[d]	88,853,194	5.0	20.0	2,580,260	17,770,639
Datil Group	305[e]	195,200	225[f]	43,920,000	425[f]	82,960,000	0.5	5.0	219,600	4,148,000
Alamosa Creek										
Basin fill	118[g]	75,520	30[h]	2,265,600	50[h]	3,776,000	15.0	20.0	339,840	755,200
Datil Group	167[i]	106,880	225[j]	24,048,000	425[j]	45,424,000	0.5	5.0	120,240	2,271,200
Las Animas Creek										
Stream Alluvium	5[k]	3,200	63[k]	201,600	75[k]	240,000	15.0	20.0	30,240	48,000
Santa Fe Group	150[k]	95,999	---	---	---	---	0.5	5.0	---	---
Hot Springs Artesian										
Santa Fe Group	275	176,000	---	---	---	---	0.5	5.0	---	---
Paleozoic Rocks	275	176,000	---	---	---	---	---	---	---	---
Jornada del Muerto[l]										
Bolson fill	1600[m]	1,024,000	225[n]	230,400,000	425[n]	435,200,000	5.0	20.0	11,520,000	87,040,000
Tularosa[l]										
Alluvial fans[o]	126[p]	80,640	600[q]	48,384,000	800[q]	64,512,000	5.0	20.0	2,419,200	12,902,400

Note: Estimates of groundwater stored do not necessarily indicate how much can economically be recovered without detrimental impacts

[a] Estimated from values published by Dunne and Leopold (1978) and Freeze and Cherry (1979) and compared to values in Myers et al. (1994); lower values were used as minimums for deeper aquifers, where yields are typically lower.

[b] In Gallinas Embayment.

[c] Area in planning region of Qab from Figure 4 of Myers et al. (1994)

[d] Obtained by trapezoidal integration of section presented in Figure 4 (assuming "cupping" to north and south as well), ± 100 feet

[e] Area in planning region above 6,800 water table altitude, less 25 square mile in San Mateo Mountains as determined from Figure 11 of Myers et al. (1994)

[f] Based on existing well depths in accessible portions of the basin, as shown in Roybal (1991) (± 100 feet for minimum and maximum)

[g] Area in planning region of Qab from Figure 4 of Myers et al. (1994)

[h] According to Myers et al. (1994, p. 26), "the shallow aquifer in the Alamosa Creek Basin . . . usually consists of less than 50 feet of quaternary alluvium and underlying Gila conglomerate;" therefore, the assumed range is 30 to 50 feet.

[i] Area of basin in planning region, less 140 square miles in San Mateo Mountains as determined from Figure 11 of Myers et al. (1994)

[j] Based on existing well depths in accessible portions of the basin, as shown in Roybal (1991) (± 100 feet for minimum and maximum)

[k] Davie and Spiegel, 1967

[l] Much of the groundwater resources in the Jornada del Muerto and Tularosa Basins are of marginal quality (Sections 5 and 6).

[m] Derived from Plate 4 of Bedinger et al. (1985)

[n] Based on Bedinger et al. (1985) estimate of thickness and Roybal (1991) estimate of depth to groundwater (± 100 feet for minimum and maximum)

[o] In planning region only.

[p] Estimated from Figure 17 of Orr and Myers (1986)

[q] Estimated from Orr & Myers (1986) (± 100 feet for minimum and maximum)

- The area of the Santa Fe Group in the Las Animas Creek Aquifer was obtained from Davie and Spiegel (1967).

SSPA (2002a) provided estimates of aquifer area for the Rio Grande and La Jencia Basins (Appendix E2). However, because the method SSPA used for estimating total water in storage was different than the method used by DBS&A, reference to SSPA's 2002 report is required before comparing the values for these basins to those in Table 5-5 for the other basins.

Specific yields for the types of materials in each aquifer were estimated based on values reported in the literature (Dunne and Leopold, 1978; Freeze and Cherry, 1979). The values used (Table 5-5) are consistent with site-specific values reported in Myers et al. (1994), except that, in order to provide a conservative estimate, lower values of specific yield were used for the minimum calculations at greater depths.

To account for uncertainty in the various components that comprise a volume-in-storage calculation, ranges for the thickness and specific yield were used to bound the storage estimates. The thickness ranges were inferred based on reported values in the literature (Myers et al., 1994; Bedinger et al., 1985; Orr and Myers, 1986), and the specific yield ranges were based on the values summarized in Dunne and Leopold (1978, Figure 7-7 and Table 7-1).

Integrating the area, thickness, and specific yield information allowed estimation of expected ranges of groundwater in storage. These estimates (Table 5-5) compare with values published in the literature as follows:

- Myers et al. (1994) estimate that 34.3 million acre-feet of freshwater are stored in the Gallinas Embayment (one of the four sub-basins within the San Agustin Basin). This is nearly two times higher than the maximum estimate of stored groundwater presented in Table 5-5.

- Herrick and Davis (1965) estimate that the northern part of the Jornada del Muerto contains 11 million acre-feet of non-potable groundwater in the bolson-fill. This estimate is similar to the minimum groundwater storage estimate presented in Table 5-5, but the Herrick and Davis estimate is for a smaller area.

Although the quantity of the water in storage is abundant (Table 5-5), the quality of much of that water limits its usability. Most of the potable groundwater in the planning region is found in the alluvial bolson-fill deposits that underlie the surface of all six basins considered. For the Alamosa Creek and eastern San Agustin (Gallinas Embayment) basins, the alluvial aquifer groundwater quality is generally good. To a certain extent in the Jornada del Muerto and to a much larger degree in the Tularosa Basin, however, the shallow groundwater may exhibit relatively high TDS/salinity, as discussed in more detail in Sections 5.5 and 5.6, respectively. Within the Tularosa Basin, alluvial fans on the eastern flanks of the San Andres Mountains may contain significant freshwater resources of much higher quality.

In addition to the water quality issues, use of groundwater is constrained by water rights, as discussed in Section 4. In addition, not all of the water in storage can be economically withdrawn, and if withdrawal rates are too high, ground subsidence might occur.

5.12 Water Quality Assessment

Assurance of availability to meet future water demands requires not only a sufficient *quantity* of water, but also water that is of sufficient *quality* for the intended use. In order to meet drinking water quality standards, surface water supplies and some groundwater supplies in the planning region already require treatment. Water may be of insufficient quality to meet intended uses due either to background conditions or to man-induced sources of contamination. The possibility of contaminants further impacting surface water or groundwater quality may place additional limits on the use of available water resources, and significant degradation of water quality will require the provision of more aggressive and costly treatment or the identification of alternative water supplies. This problem of is particular concern regarding the drinking water supply, but can also affect other uses for which standards are generally not as high (i.e., irrigation and livestock uses), but which still require a certain level of water quality.

Water quality for Socorro and Sierra Counties was assessed using existing documents and databases:

- An overview of water quality in New Mexico is provided in *Water Quality and Water Pollution Control in New Mexico, 2002,* a report prepared by the State of New Mexico pursuant to Section 305(b) of the Federal Clean Water Act (CWA) for submission to the United States Congress (NMWQCC, 2002).

- Surface water quality has been assessed by the New Mexico Environment Department (NMED) in compliance with Section 303(d) of the CWA; the results are provided in reports on NMED's Stream Reach Ranking System (NMED, 2002b).

- Information regarding regional groundwater quality was obtained primarily through the USGS database (Section 1.2)

- Information on specific sites and facilities that may pose a potential for groundwater quality impacts was obtained from various NMED databases (e.g., lists of discharge permit holders [http://www.nmenv.state.nm.us/gwb/Web%20Site-DPs.xls] and registered underground storage tanks [http://www.nmenv.state.nm.us/ust/leakcity.html]).

5.12.1 Surface Water

Measured impacts to surface waterbodies and potential sources of contamination are described in Sections 5.12.1.1 and 5.12.1.2, respectively. The quality of both surface water and groundwater that enters the region from upstream is discussed in Section 5.12.3.

5.12.1.1 Existing Surface Water Quality

The Rio Grande Basin within the planning region is dominated by Elephant Butte and Caballo Reservoirs, which store the entire surface flow in this section of the Rio Grande Basin. Numerous ephemeral tributaries flow to the Rio Grande, which at times is intermittent depending on diversions into irrigation ditches. Several small streams have perennial reaches in their headwaters, but none flow continuously to the Rio Grande. Surface water quality in the region is suitable for recreational uses and for irrigation of agricultural land in the valley.

The NMED has implemented a State Water Quality Planning Strategy (NMED, 2002b) to comply with Section 303(d) of the CWA, which requires each state to identify surface waters within its boundaries that are not meeting or not expected to meet water quality standards. Part of this program is a Stream Reach Ranking System that targets resources on priority rivers and streams for development of total maximum daily load (TMDL) management plans. As discussed in Section 4.2.1.2, a TMDL documents the amount of a pollutant a waterbody can assimilate without violating a state water quality standard; that is, a TMDL allocates the load capacity to known point sources and nonpoint sources at given flows. In addition to pollutant concentration levels, TMDLs can be triggered by threatened and endangered aquatic species or threats to public health as overriding priorities.

Water quality in the area is generally good; however, Alamosa and Percha Creeks have been listed on the 2002-2004 New Mexico 303(d) list (NMED, 2003a) for stream bottom deposits (Table 5-6). 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 indicates that degradation can occur in the water supply.

Table 5-6. Assessed Stream and River Reaches in the Socorro-Sierra Planning Region State of New Mexico 2002-2004, CWA§303(d) List

Water Body Name	Total Size Affected (mi)	Probable Source(s) of Pollutant	Specific Pollutant	TMDL Due	Uses not Fully Supported [a]
Alamosa Creek (perennial reaches above Monticello diversion)	13.4	Source unknown Road directly in stream	Stream bottom deposits	12/31/2017	WWF MCWF
Percha Creek (perennial reaches from Caballo Reservoir to Middle Fork)	18.41	Source unknown	Stream bottom deposits	12/31/2017	MCWF WWF

Source: NMED, 2003a
mi = miles

[a] MCWF = Marginal coldwater fishery
WWF = Warmwater fishery

Although the Rio Grande meets applicable surface water quality standards, the NMED (2003a) has issued guidelines for consumption of fish from Elephant Butte and Caballo Reservoirs (Table 5-7). These advisories were issued because mercury has been found in some fish at concentrations that could lead to significant adverse human health effects. Although the levels of mercury in waters of these lakes are insignificant and are far below water quality standards, very low levels of elemental mercury found in bottom sediments are passed through the food chain progressively from smaller to larger fish, resulting in elevated levels in the larger fish.

The advisories are guidelines only, and no associated legal restrictions on catching or eating fish from these lakes have been issued. The NMED continues to recommend fishing and camping at these lakes, but urges those who fish and their families to make an informed decision as to what fish they can safely eat. While the occasional consumer of fish from these lakes is at little risk, repeated ingestion of mercury at levels found in some of these fish over a long period could result in serious health problems.

Table 5-7. Waters with Fish Consumption Guidelines Included on the 2002-2004 CWA§303(d) List

Water Body Name	Total Size Affected [a] (acres)	Probable Source(s) of Pollutant/Threat	Probable Cause of Impairment	Impaired Designated Use [b]
Caballo Reservoir	3,020	Source unknown Recreation Range grazing Atmospheric deposition Agriculture	Mercury in fish tissue	WWF
Elephant Butte Reservoir	6,517	Source unknown Range grazing Atmospheric deposition Agriculture	Mercury in fish tissue	WWF

Source: NMED, 2003.

[a] Acres within the State of New Mexico's jurisdiction.
[b] WWF = Warmwater fishery

As demonstrated by this example, it is important to consider the nature of any water quality impairment and its effect on potential use when evaluating surface water quality for the regional water planning process. As in this case, problems that do not necessarily make the water unusable for some purposes may preclude its use in other applications, sometimes even those with generally less stringent water quality standards. Long-range protection of water quality is of importance not only for drinking water purposes, but also for agricultural and recreational uses, which are mainstays of the economic well-being of Socorro and Sierra Counties.

5.12.1.2 Potential Sources of Contamination

Sources of contamination are classified as two types: (1) point sources, originating from a single location or (2) nonpoint sources, originating over a more widespread or unspecified location. Dischargers of potential point sources must comply with the Clean Water Act and the NMWQCC Regulations by obtaining a permit to discharge, referred to as National Pollutant Discharge Elimination System (NPDES) permits. NPDES permitted discharges in the planning region are summarized in Table 5-8, and their approximate discharge locations are shown on Figure B-14.

Table 5-8. Municipal and Industrial NPDES Permittees in Socorro and Sierra Counties

Permit No.	Municipality/Industry
Municipalities:	
NM0028835	Socorro
NM0020681	Truth or Consequences
Industries:	
NM0024937	New Mexico State Parks - Elephant Butte
NM0029050	St. Cloud Mining Company
NM0029726	State Fire Training Academy

Source: NMED, 2002a

In addition to NPDES dischargers in the planning region, several NPDES permittees discharge to the Rio Grande upstream of the planning region, thereby potentially affecting water quality in the planning region, as discussed in Section 5.12.3.

Probable nonpoint sources of surface water pollutants include agriculture, mine runoff, recreation, hydromodification (which includes channel modifications, dams, and streambank erosion), 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, plant nutrients, metals, pathogens, temperature extremes, total ammonia, elevated conductivity, and pH problems (NMWQCC, 2002).

5.12.2 Groundwater

The vulnerability of groundwater in the planning region to water quality impacts is shown in Figure B-13 (Appendix B). As shown on this figure, groundwater along the Rio Puerco and Rio Grande valleys is extremely vulnerable to contamination. Figure B-14 shows the approximate locations of sites with potential water quality concerns, such as discharge permit locations, landfills, mine sites, and areas with leaking underground storage tanks. In addition, the various dominant chemical groundwater types and groundwater salinity are shown on Figures B-15 and B-16, respectively. Background water quality is discussed in Section 5.12.2.1, while Section 5.12.2.2 presents sources of groundwater contamination.

5.12.2.1 Background Water Quality

Sections 5.3 through 5.10 discuss the background water quality in the groundwater basins in the planning region. To summarize:

- The *San Agustin Basin* contains isolated areas of elevated TDS concentrations and high-salinity water (Section 5.3). In general, groundwater in this basin grades from fresh to saline in a westerly direction (Section 5.3.3).

- Groundwater in the *Alamosa Creek Basin* contains water of either the calcium magnesium bicarbonate or sodium bicarbonate type, except for a small portion of the basin in the northwest corner that has a sulfate type (Figure B-15). TDS are generally less than 500 mg/L, but increase to 3,000 in the same northwest portion that has the sulfate water type (Figure B-16).

- Groundwater of the *Jornada del Muerto Basin* is generally of poor quality, primarily due to high salinity. Limited quantities of potable water are available from the Glorieta Sandstone and in the vicinity of Mockingbird Gap (Section 5.5.3).

- Potable water sources are also scarce in the *Tularosa Basin.* Isolated pockets of potable to slightly degraded quality water have been found are in a narrow zone of the bolson-fill near the basin's highland areas, in locally occurring aquifers within alluvial fan sediments at the bases of the highland margins of the basin, in the vicinity of Mockingbird Gap, and on the southeastern flank of North Oscura Peak (Section 5.6.3).

- Groundwater in the Las Animas Creek Basin contains water of the calcium magnesium bicarbonate type, transitioning to either a chloride or sodium bicarbonate type near Caballo Reservoir (Figure B-15). TDS is generally less than 500 mg/L, increasing to 1,000 near Caballo Reservoir (Figure B-16).

- Water quality in the non-thermal Santa Fe Group Aquifer of the *Hot Springs Artesian Basin* is of fair quality, with elevated sodium, calcium, chloride, bicarbonate, TDS, and hardness. The thermal waters of the Paleozoic aquifer are highly mineralized (Section 5.8.3).

- Water in the primary aquifers of *La Jencia Basin* is of good quality, having a TDS concentration generally below 300 mg/L (Section 5.9.3).

- Water quality in the *Rio Grande Basin* is highly variable; for example, average chloride concentrations range from 50 mg/L near Socorro to 600 mg/L in the northern part of the basin (Section 5.10.3).

5.12.2.2 Sources of Groundwater Contamination

Groundwater contamination can occur from both point sources and nonpoint sources of contaminants. Records of existing facilities that may have the potential to impact groundwater quality were examined through review of NMED records. Within New Mexico, NMWQCC (2002) reports the following frequency of point source groundwater impacts from various contaminant sources:

- Underground (fuel) storage tanks (USTs) 58.5%
- Oil and gas 13.7%

• Miscellaneous industry	10.1%
• Centralized sewage works	4.5%
• Mining	3.7%
• Aboveground (fuel) storage tanks/pipelines	3.4%
• Dairies and meat packing	2.8%
• Landfills	0.8%
• Unknown/other	2.5%

NMWQCC (2002) reports 27 cases of point source contamination of groundwater and 45 contaminated supply wells in Socorro County and 13 cases of point source contamination of groundwater and 12 contaminated supply wells in Sierra County. The locations of key potential sources of groundwater contamination are shown in Figure B-14 in Appendix B.

Leaking USTs are one of the most significant point source contaminant threats. As of August 2003, NMED (2003d) had reported 62 leaking UST cases in Socorro and Sierra Counties (Table 5-9, 33 of which are active (active cases include those in the pre-investigation, investigation, cleanup, and monitoring phases). These leaking USTs represent releases of oil, gasoline, diesel, and aviation fuel, all of which contain one or more petroleum constituents that are common groundwater contaminants, such as benzene, toluene, ethylbenzene, xylenes, and methyl tertiary-butyl ether (MTBE). The fact that these USTs are leaking, however, does not necessarily mean that groundwater or water supply wells have actually been contaminated. Table 5-9 includes details from NMED's database indicating whether groundwater has been impacted and the status of site investigation and cleanup efforts, and Figure B-14 shows their approximate locations.

The majority of leaking UST sites are concentrated around the larger municipalities in the region and are frequently close to the water supply sources serving these communities. Many additional facilities with registered USTs that are not leaking are also included in the NMED UST database. These USTs present a potential for groundwater quality impacts that could affect available water resources in and near the population centers in the region.

Table 5-9. Leaking Underground Storage Tank Sites in Socorro and Sierra Counties
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Site Name	Facility No.	Address	City	Water Supply Impact	Leak Status [a]
Price-Black Dairy	30050	1 Mile West of NM 187	Arrey	No	M
Bosque Trading Post	27022	1006B Old Highway 85	Bosque	No	I
Didios	27739	16559B Highway 60	Bosque	Yes	C
Caballo Lake Trading	27193	Star Route, Box 162	Caballo	Unknown	I
Old Cuchillo Bar & Grill	29741	NM 52 & Cuchillo	Cuchillo	No	NFA
Anton's Marine	26613	100 Anton Drive	Elephant Butte	Unknown	NFA
Basils Shamrock	28694	NM 52	Elephant Butte	No	NFA
J & S Shamrock	28694	NM 52	Elephant Butte	Unknown	PI
Pat's Bermuda Triangle	29877	1006 NM 195	Elephant Butte	Unknown	PI
NMSHTD Hillsboro	29657	NM 90	Hillsboro	No	NFA
Vergeer Property	31476	1059 Highway 304	Las Nutrias	No	I
Chavez Grocery/Atex	27318	11 Chambon Road	Lemitar	Yes	I
Orlando's Truck Stop	29800	I-25, Exit 156	Lemitar	No	NFA
Adobe Ranch	26399	HC 64, Box 30	Magdalena	No	NFA
Guins Texaco	28424	Highway 60 & Oak	Magdalena	No	NFA
Magdalena Airport	47932	P.O. Box 145	Magdalena	Unknown	NFA
Magdalena Dormitory	29230	South Poplar Street	Magdalena	Unknown	NFA
Magdalena School	29231	High school gym	Magdalena	No	NFA
Magdalena Shell	29232	Highway 60	Magdalena	No	NFA
National Radio Observatory	31479	25 miles west of Magdalena	Magdalena	No	NFA
National Radio Observatory/VLA	31479	25 miles west of Magdalena	Magdalena	Unknown	NFA
Sevillita National Wildlife Refuge	31383	Sevillita National Wildlife Refuge	San Acacia	No	NFA

Source: NMED, 2003d.

NMSHTD = New Mexico State Highway and Transportation Department
--- = Not available
VLA = Very Large Array
T or C = Truth or Consequences

[a] Status Key:
C = Cleanup
I = Investigation
PI = Pre-investigation
M = Monitoring
NFA = No further action

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Table 5-9. Leaking Underground Storage Tank Sites in Socorro and Sierra Counties
Page 2 of 2

Site Name	Facility No.	Address	City	Water Supply Impact	Leak Status [a]
Bar F 31 Socorro	27619	907N California	Socorro	No	M
Bureau of Reclamation Field Office Yard	27162	P.O. Box VV	Socorro	Unknown	NFA
Chevron 75865 Socorro	27329	1101 California	Socorro	No	C
Chevron South	26296	I-25 & Highway 85	Socorro	No	NFA
Circle K 290	1081	805 California	Socorro	No	C
Circle W	27381	1104 California	Socorro	No	I
Coronado Village	26393	500 6th Street	Socorro	No	NFA
Diamond Shamrock 129	27619	907 California	Socorro	No	I
Electric Co-op	30665	215 Manzanares NE	Socorro	No	M
Jennings Prop.	27825	900 California	Socorro	No	C
Mike's Texaco	31068	1105 California	Socorro	No	I
MRGCD Socorro	29506	703 Manzanares	Socorro	No	I
NMSHTD Socorro	29676	I-25 Frontage	Socorro	Unknown	NFA
Phillips 66 Socorro	28401	401 California	Socorro	No	C
San Marcial Yard	27162	Unknown	Socorro	No	NFA
Socorro Auto Cl.	30659	210 California	Socorro	Unknown	NFA
Socorro Shell	26357	408 California NW	Socorro	No	I
Sonny's Pump n Save	30671	210 California NE	Socorro	No	I
State Police	27683	110 Manzanarez Avenue	Socorro	No	NFA
Texaco Mini-Mart	30574	924 South Highway 85	Socorro	Unknown	NFA
Vagabond Prop./F	31434	1015 California NW	Socorro	No	C
Vagabond/Lube N	31433	1013 California	Socorro	No	C

Source: NMED, 2003d.

NMSHTD = New Mexico State Highway and Transportation Department
--- = Not available
VLA = Very Large Array
T or C = Truth or Consequences

[a] Status Key:
C = Cleanup
I = Investigation
PI = Pre-investigation
M = Monitoring
NFA = No further action

Table 5-9. Leaking Underground Storage Tank Sites in Socorro and Sierra Counties
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Site Name	Facility No.	Address	City	Water Supply Impact	Leak Status [a]
Chevron 76135	26299	I-25 Interchange	T or C	No	I
Circle K 515	1098	918 Date Street	T or C	No	I
Bell Gas T or C	1830	Broadway & Pershing	T or C	No	M
City Warehouse	27405	400 East Riverside	T or C	No	NFA
Elephant Butte	30041	Box 312	T or C	No	M
Elephant Butte Dam	30041	Elephant Butte Reservoir	T or C	Unknown	NFA
Farm & Ranch Supply	27962	417 Date Street	T or C	No	I
John Berry Station	31138	2201 South Broadway	T or C	No	NFA
Sierra County Road	30600	300 Date Street	T or C	No	NFA
T or C	47988	---	T or C	Unknown	PI
Texaco Broadway	27051	901 Broadway	T or C	No	I
Triangle Conoco	31195	727 Broadway	T or C	No	M
Chevron 75842	2025	704 West Broadway	Williamsburg	Unknown	NFA
NMSHTD Williamsburg	29682	Highway 51	Williamsburg	Yes	C
Shell Food Mart	30572	601 Broadway	Williamsburg	No	C
Shell Truck Terminal	30572	601 Broadway	Williamsburg	No	NFA
Williamsburg Chevron	2025	704 West Broadway	Williamsburg	Unknown	I
Winston Patrol Yard	29683	NM 52	Winston	No	NFA

Source: NMED, 2003d.

NMSHTD = New Mexico State Highway and Transportation Department
--- = Not available
VLA = Very Large Array
T or C = Truth or Consequences

[a] Status Key:
C = Cleanup
I = Investigation
PI = Pre-investigation
M = Monitoring
NFA = No further action

The prevalence of hard rock mining in Socorro and Sierra Counties is also an important consideration for groundwater quality protection in the planning region. Active mining operations are registered with the Mining and Minerals Division (MMD) of the New Mexico Energy, Minerals and Natural Resources Department (NMEMNRD). An excerpt from the publication *Mines, Mills and Quarries in New Mexico* (NMEMNRD, 2001) that includes general information on the mines and mills operating in Socorro and Sierra Counties, is provided in Appendix F4. (Quarries for sand and gravel extraction are not generally considered potential contaminant sources but are included for informational purposes.) The locations of the registered mines in the planning region are shown in Figure B-14 (Appendix B).

In addition to the active mining operations, many more abandoned mining operations are scattered throughout the mining districts of the planning region. These mines present a potential threat to groundwater quality because of the toxic compounds used in mineral extraction such as mercury and cyanide. Abandoned mines can also generate poor water quality due to groundwater flow through mine workings and stormwater flow and seepage through waste rock, tailings, and slag.

The NMED Ground Water Bureau regulates facilities with wastewater discharges that have a potential to impact groundwater quality. These facilities must comply with the NMWQCC Regulations and obtain approval of a discharge plan that 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 operations, and other industries. Although the NMWQCC Regulations contain requirements for cleanup of groundwater contamination if detected under discharge plan monitoring requirements, these facilities still have the potential to cause groundwater contaminant impacts that may affect the quantity and availability of water supplies. A list of the approved discharge plans (NMED, 2003b) in Socorro and Sierra Counties is provided in Table 5-10, and their approximate locations are shown on Figure B-14 in Appendix B.

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund, was enacted by the U.S. Congress on December 11, 1980. This law created the Superfund program to respond directly to releases or threatened releases

Table 5-10. Groundwater Discharge Permits in the Socorro-Sierra Water Planning Region

County	Closecity	Facility Name	Waste Type	Treatment	Discharge
Sierra	Arrey	Barrera Dairy	Dairy	Lagoon	Land Application
Sierra	Arrey	Caballo Dairy LLC	Dairy	Lagoon	Land Application
Sierra	Arrey	AA Chile	Chile Plant	None	Land Application
Sierra	Arrey	Ma & Sons Chile	Chile Plant	None	Land Application
Sierra	Caballo	Caballo Lake State Park	Campground/RV Park	Package Plant	Leachfield
Sierra	Caballo	Grubstake Mine	Milling	Metalurgical Extraction	Tailing Pond
Sierra	Elephant Butte	Oasis Subdivision 10 &11	Unincorporated Area	Package Plant	Leachfield
Sierra	Elephant Butte	Charities Boat And Car Wash	Vehicle/Equipment Wash	Oil-Water Separator	Leachfield
Sierra	Elephant Butte	Crossman RV Park	Campground/RV Park	Septic Tank	Leachfield
Sierra	Elephant Butte	Inn At The Butte	Lodging	Septic Tank	Leachfield
Sierra	Elephant Butte	Cedar Cove MHP	Campground/RV Park	Septic Tank	Leachfield
Sierra	Elephant Butte	Narrow RV Resort	Campground/RV Park	Septic Tank	Leachfield
Sierra	Elephant Butte	Cozy Cove RV Park	Campground/RV Park	Septic Tank	Leachfield
Sierra	Elephant Butte	Cedar Heights RV Park	Campground/RV Park	Sand Filter	Land Application
Sierra	Hillsboro	Copper Flat Mine	Open Pit	Metalurgical Extraction	Tailing Pond
Sierra	Hillsboro	Copper Flat Leaching	Open Pit	Metalurgical Extraction	Tailing Pond
Sierra	Monitcello	Montecello Canyon Water Assoc	Sanitation District	Septic Tank	Leachfield
Sierra	T or C	Elephant Butte State Park	Campground/RV Park	Septic Tank	Leachfield
Sierra	T or C	Monticello R.V. Park	Campground/RV Park	Septic Tank	Leachfield
Sierra	T or C	Truth or Consequences (Town of) - Sludge	Sludge Disposal Facility	Other	Landfill
Sierra	T or C	Sierra Linda Sewer Assoc	Unincorporated Area	Septic Tank	Leachfield
Sierra	T or C	Sierra (County of) - LWDS	Septage	Lagoon	Evaporation Lagoon
Sierra	T or C	Elephant Butte State PK	Campground/RV Park	Constructed Wetlands	Evaporation Lagoon
Sierra	T or C	Truth or Consequences (Town of) - WWTP	Municipality	WWTP	Land Application
Sierra	T or C	Elephant Butte Estates	Unincorporated Area	Septic Tank	Leachfield
Sierra	Winston	St. Cloud Mining Company	Milling	Metalurgical Extraction	Tailing Pond

Table 5-10. Groundwater Discharge Permits in the Socorro-Sierra Water Planning Region
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County	Closecity	Facility Name	Waste Type	Treatment	Discharge
Sierra	Winston	Chem Tech-Emporia Mine	Milling	None	Tailing Pond
Socorro	Belen	Genesis Dairy	Dairy	Lagoon	Evaporation Lagoon
Socorro	Belen	Othart Dairy 2	Dairy	Lagoon	Evaporation Lagoon
Socorro	Belen	La Promesa Elementary School	School/Educational Facili	Constructed Wetlands	Infiltration Basin
Socorro	Bernardo	Jose Yguado Dairy	Dairy	Lagoon	Land Application
Socorro	Bingham	Ozark Mahoney Mine		Other	Tailing Pond
Socorro	Las Nutrias	Merrill Dairy-Alexander	Dairy	Lagoon	Land Application
Socorro	Lemitar	Roadrunner Travel Center	Truck Stop	Septic Tank	Leachfield
Socorro	Lemitar	Cal-West Metals-Batteries	Other	Lagoon	Other
Socorro	Magdalena	Magdalena (Village of) - WWTP	Municipality	Lagoon	Land Application
Socorro	San Antonio	Permanent High Explosives Test Site	Doe/Dod	Septic Tank	Leachfield
Socorro	Socorro	Energetic Materials Research	Manufacturing	Lagoon	Evaporation Lagoon
Socorro	Socorro	Nm State Fire Training Acad	State Agency/Organization	Lagoon	Evaporation Lagoon
Socorro	Socorro	Black And White Dairy	Dairy	Lagoon	Evaporation Lagoon
Socorro	Socorro	Handley Dairy	Dairy	Lagoon	Land Application
Socorro	Socorro	Socorro (City Of) - Sludge	Sludge Disposal Facility	WWTP	Land Application
Socorro	Socorro	Socorro Livestock Market	Feedlot	None	Evaporation Lagoon
Socorro	Socorro	Ruben's Custom Meats	Meat Packing		
Socorro	Socorro	Eagle-Picher Industries Inc	Manufacturing	Lagoon	Evaporation Lagoon
Socorro	Socorro	Eagle Picher Plant	Manufacturing	Septic Tank	Leachfield
Socorro	Turn	Merrill Dairy-Alexander 2	Dairy	Lagoon	Evaporation Lagoon
Socorro	Veguita	Heraa Dairy	Dairy	Lagoon	Evaporation Lagoon
Socorro	Veguita	Abo Dairy	Dairy	Lagoon	Evaporation Lagoon
Socorro	Veguita	A&M Dairy	Dairy	Lagoon	Evaporation Lagoon
Socorro	Veguita	Pareo Dairy	Dairy	Lagoon	Land Application
Socorro	Veguita	Glenn's Septic Pumping	Septage	Lagoon	Land Application

of hazardous substances that may endanger public health or the environment. U.S. EPA (2003a) lists five sites in Socorro County and one site in Sierra County as Superfund hazardous waste sites (Table 5 11), but none are currently included on the Superfund National Priorities List (NPL). The Cal West Metals site was deleted from the final NPL in 1996, and no further action is planned for the Hop Canyon Mill site. The status of the remaining sites is listed in Table 5-11.

Table 5-11. CERCLA Superfund Sites in Socorro and Sierra Counties

Facility	Location	County	EPA ID	Site Status
Cal West Metals	Lemitar	Socorro	NMD097060272	Deleted from the Final NPL
Cobb Resources Corporation	Magdalena, Cibola National Forest	Socorro	NM5122307551	Status not specified
Hop Canyon Mill	Magdalena	Socorro	NMD981600455	NFRAP
Olson Well	Socorro	Socorro	NM0000605186	SI start needed
Southwest Tire Processors Plant	Socorro	Socorro	NM0000605301	Removal only site (no site assessment work needed)
North Broadway Groundwater Plume	Truth or Consequences	Sierra	NM0000605458	PA start needed

Source: U.S. EPA, 2003a
NPL = National Priorities List
NFRAP = No further remedial action planned
SI = Site inspection
PA = Preliminary assessment

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 Socorro and Sierra Counties, closed before the 1989 deadline in order to avoid the more stringent final closure requirements. Within the planning region, there are currently 4 operating landfills and 16 closed landfills, as listed in Table 5-12 (NMED, 2000, 1996, 1990). The approximate locations of these landfills are shown in Figure B-14 in Appendix B.

Table 5-12. Landfills in Socorro and Sierra Counties

Landfill Name	County	Operating Status	Closure Date (if applicable)
Socorro	Socorro	Operating	NA
White Sands (Stallion Range)	Socorro	Operating	NA
San Antonio	Socorro	Closed	1995
La Joya	Socorro	Closed	1995
Magdalena	Socorro	Closed	1995
Lemitar	Socorro	Closed	1988
Veguita	Socorro	Closed	1995
Ft. Craig	Socorro	Closed	1990
Truth or Consequences	Sierra	Operating	NA
Sierra County	Sierra	Operating	NA
Winston	Sierra	Closed	1990 - 1994
Arrey	Sierra	Closed	1989
Hillsboro	Sierra	Closed	1989
Cuchillo	Sierra	Closed	1989
Truth or Consequences #2	Sierra	Closed	1985
Las Palomas	Sierra	Closed	1989
Monticello	Sierra	Closed	1989
Elephant Butte	Sierra	Closed	1987
Derry	Sierra	Closed	1989
Placitas	Sierra	Closed	1988

Sources: NMED, 2000
NMED, 1996
NMED, 1990

NA = Not applicable

A primary water quality concern in the Socorro-Sierra planning region is shallow groundwater contamination due to domestic wastewater disposal through septic systems. In areas where the water table is shallow, septic system discharges can percolate rapidly to the underlying aquifer and increase concentrations of (NMWQCC, 2002):

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

Because septic systems are generally spread out over rural areas, they are considered a nonpoint source. Collectively, septic tanks and other on-site domestic wastewater disposal constitute the single largest known source of groundwater contamination in New Mexico (NMWQCC, 2002), with many of these occurrences in the shallow water table areas along the Rio Grande Valley. Protection of shallow groundwater quality in the populous valley areas in Socorro and Sierra Counties plays an important role in maintaining the available water resources in these areas.

5.12.3 Quality of Water Entering the Planning Region

In addition to point and nonpoint sources of contamination within the planning region, the quality of the surface water entering the region from the north is another concern in the region. Section 5.12.3.1 presents the results of water quality monitoring near the northern planning region boundary, and Section 5.12.3.2 discusses the major NPDES dischargers upstream of the planning region that may impact the quality of water that enters the planning region.

5.12.3.1 USGS Water Quality Monitoring

Water quality is routinely monitored at two USGS stream gaging stations in the northern portion of the region, near Bernardo, New Mexico. These stations are on the Rio Grande Floodway (08332010) and the Rio Puerco (08353000), just downstream of the northern Socorro County border with Valencia County and have been sampled since 1960 and 1947, respectively (USGS, 2003).

The water quality at the Rio Grande Floodway monitoring station is generally good. In recent years, the pH has been typically between 7 and 9, and the specific conductance between 300 and 500 microsiemens per centimeter (μS/cm), corrected to 25°C. The amount of suspended sediment varies greatly between 10 and 31,000 mg/L due to the effects of storm runoff. Dissolved arsenic has been between 3 to 6 μg/L, which is below the new U.S. EPA 10-μg/L standard and well below the 100-μg/L State irrigation standard set for this reach. Only three one-time exceedances of water quality standards were noted at this monitoring station (Table 5-13).

Table 5-13. Standard Exceedances at USGS Stream Water Quality Monitoring Stations

Parameter	Standard	Units	Number of Exceedances	Date Range	Value Range
Rio Grande Floodway near Bernardo, NM (08332010)					
pH	6.6 to 9.0	su	1	07/17/80	10
Sulfate	500	mg/L	1	08/04/66	674
Temperature	32.2	°C	1	07/30/01	33
Rio Puerco near Bernardo, NM (08353000)					
Boron	750	µg/L	4	07/09/63 to 07/08/99	940 to 2,570
Chloride	250	mg/L	28	07/10/61 to 07/08/99	260 to 1,800
Mercury	0.77	µg/L	3	02/17/95 to 07/19/95	1 to 3
Sulfate	500	mg/L	302	10/19/60 to 08/15/01	510 to 4,100
TDS [a]	1,500	mg/L	135	03/10/66 to 05/23/86	1,510 to 9,060

Source: USGS, 2003
[a] TDS has not been sampled for since 1995.

su = Standard units
mg/L = Milligrams per liter
°C = Degrees Celsius
µg/L = Micrograms per liter
TDS = Total dissolved solids

The water quality at the Rio Puerco monitoring station is generally not as good as that at the Rio Grande Floodway station. The pH varies between 7 and 9 but is typically around 8, and the specific conductance is between 1,000 and 6,000 µS/cm, corrected to 25°C. Similar to the Rio Grande Floodway, the amount of suspended sediment varies greatly between 100 and 300,000 mg/L due to the effects of storm runoff. Dissolved arsenic usually is not detected above the laboratory limit and has not been measured above 2 µg/L. As shown in Table 5-13, numerous exceedances of sulfate and TDS standards have been detected at this monitoring station.

5.12.3.2 Major Upstream NPDES Dischargers

Several major municipal and two industrial NPDES permit holders, considered to be major dischargers, discharge to the Rio Grande or its tributaries upstream of the planning region, thereby potentially affecting water quality in the planning region. Table 5-14 contains a list of these major dischargers by county.

Table 5-14. Major Municipal and Industrial NPDES Permittees Upstream of the Socorro-Sierra Planning Region

County	Municipality/Industry (major dischargers only)	Permit No.
Municipalities		
Bernalillo	Albuquerque	NM0022250
Los Alamos	Los Alamos County	NM0020141
Rio Arriba	Espanola	NM0029351
Sandoval	Rio Rancho # 2	NM0027987
Santa Fe	Santa Fe	NM0022292
Valencia	Belen	NM0020150
Industries		
Sandoval	Uranium King, Rio Puerco Mine	NM0028169
Federal Facilities		
Los Alamos	U.S. DOE/University of California Los Alamos National Laboratories (LANL) [a]	NM0028355

Source: NMED, 2003c
[a] Single permit covering all LANL discharges, both industrial effluent and domestic sewage.

According to reports available from the EPA web site (EPA, 2003b), periodic violations of permit standards have been noted in the recent past for all of these dischargers (except for the mine in Sandoval County, for which a report was not available). Past numeric violations include:

- Biochemical oxygen demand (Rio Rancho, Los Alamos County, Albuquerque)
- Total suspended solids (Rio Rancho, LANL)
- Fecal coliform (Rio Rancho, Belen, Albuquerque, Española)
- Total residual chlorine (LANL, Albuquerque)
- Selenium (LANL)
- Total ammonia (Santa Fe, Albuquerque)
- Dissolved oxygen (Albuquerque)
- Total aluminum (Albuquerque)

A recent report prepared for the City of Albuquerque (Thomson and Chwirka, 2002), summarizes the City's wastewater treatment plant (WWTP) effluent compared to NPDES permit conditions for 2001 and 2002. Table 5-15 contains the water quality information provided in the report.

Table 5-15. City of Albuquerque Wastewater Treatment Plant Effluent Quality, 2001 and 2002

Parameter	Units	NPDES Permit Condition (30 day average)	Monthly Effluent Quality	
			Average	Maximum
Flow	mgd	76	51.7	52.7
Aluminum [a]	µg/L	60 to 87	61.0	240
Arsenic	µg/L	13.7	6.4	7.7
Total cyanide	µg/L	monitor	<4.0	24.3
Carbonaceous BOD	mg/L	10	3.01	4.0
Total suspended solid	mg/L	30	9.99	19.0
Fecal coliform bacteria	cfu/100 mL	100	13.6	56
Silver	µg/L	3.75	<2	<2
Minimum dissolved oxygen [a]	mg/L	2 to 4	4.84	4.09
Total ammonia [a]	mg/L	1 to 3	0.85	2.12
Nitrate [a]	mg/L	8 to 26	7.96	13.5

Source: Thomson and Chwirka, 2002
[a] Permit condition is dependent on river flow; the most stringent criteria apply during low flow conditions.

mgd = million gallons per day
µg/L = micrograms per liter
BOD = Biochemical oxygen demand
mg/L = milligrams per liter
cfu/100 mL = colony forming units per 100 milliliters

The report acknowledges that the City has exceeded permit conditions a few times in the past, but they are currently meeting standards for all regulated parameters with a comfortable margin of safety. The switch in the City's source of water in the future, from groundwater to surface water, should have no effect on the quantity of water discharged from the WWTP. After the switch, the WWTP discharge may contain lower TDS and arsenic concentrations because these constituents are typically lower in surface water than in current groundwater supplies (Thomson and Chwirka, 2002).