1. Water Supply

This section provides an overview of the water supply in the Lower Pecos Valley Water Planning Region, including climate conditions (Section 5.1), surface water and groundwater resources (Sections 5.2 and 5.3), water quality (Section 5.4), and the administrative water supply used for planning purposes in this regional water plan update (Section 5.5). Additional quantitative assessment of water supplies is included in Section 7, Identified Gaps between Supply and Demand.

The Updated Regional Water Planning Handbook (NMISC, 2013) specifies that each of the 16 regional water plans briefly summarize water supply information from the previously accepted plan and provide key new or revised information that has become available since submittal of the accepted regional water plan. The information in this section regarding surface and groundwater supply and water quality is thus drawn largely from the accepted Lower Pecos Valley Regional Water Plan (PVWUO, 2001) and where appropriate, updated with more recent information and data from a number of sources, as referenced throughout this section.

Currently some of the key water supply issues impacting the Lower Pecos Valley region are:

- The majority of the water use in the Pecos River Basin occurs in the lower basin—that is, from Sumner Dam to the lower end of the Carlsbad Irrigation District (CID) near the confluence of the Black and Pecos Rivers—and thus in the Lower Pecos Valley region. The principal constraint to use of this water is the 1948 Pecos River Compact. Over the past decade, New Mexico has made significant progress toward assuring long-term compliance with its obligations under the Compact. The New Mexico State Legislature, the NMOSE, the NMISC, and Pecos Basin water user groups continue to collaborate to address ongoing Compact and other Pecos Basin water management issues. Compact-related accomplishments include:
  - Since the U.S. Supreme Court issued its amended decree in 1988, New Mexico’s efforts, including a total taxpayer investment of more than $100 million, have resulted in continued Compact compliance.
  - The Pecos Settlement was signed in 2003 and implemented in June 2009 after New Mexico had acquired water rights associated with about 4,500 acres of land in the CID and about 7,500 acres in the Roswell Artesian UWB. Using these and other water rights, the state has constructed two well fields and pipelines designed to augment Pecos River flows according to the terms laid out in the Settlement.
  - New Mexico has amassed a Compact delivery credit of about 100,000 acre-feet, providing both protection against a net Compact delivery deficit and some flexibility for New Mexico to maximize water use in dry years.
  - As a condition of the Pecos Settlement, the adjudication of CID water rights is nearly complete.
• Drought has significantly affected the region, with 2011, 2012, and 2013 being extraordinarily dry (until September 2013), resulting in record low flows in the Pecos River. As a consequence, it was impossible to meet the supply targets for CID despite continuous augmentation pumping by NMISC, and CID demanded a priority call until September 2013 storm flows relieved the water shortage.

• Continued compliance with the USFWS’s 2006 Biological Opinion (BO) for the threatened Pecos bluntnose shiner is an ongoing challenge. New Mexico, the USBR, and Pecos Basin water user groups have collaborated to comply with the BO; however, acquisition of additional water rights is needed to ensure long-term compliance with the BO.

• Communities such as Ruidoso and Otis have historically experienced serious water supply problems during drought years. Continued drought planning is needed to design measures to ensure that essential water needs can be met.

• The net water supply impacts of physical watershed management techniques are not well documented or understood. In particular, quantification of the effectiveness of riparian vegetation removal, upland conifer thinning, and other water salvage methods needs further study to support well informed decisions.

• Water managers need to ensure continued compliance with the terms of the Pecos Settlement and the 1988 U.S. Supreme Court amended decree.

• Oil and gas development in the Capitan and Carlsbad basins raises concerns over potential impacts to the Pecos River and stress on the aquifers. Domestic, stock, and commercial wells permitted under 72-12-1.3 (underground public waters temporary use), along with new appropriations permitted under 72-12-3, are used to supply the oil and gas industry. With respect to wells permitted under 72-12-1.3, the OSE allows well owners to pump up to 9 acre-feet a year per well under three separate temporary commercial permits that are approved without advertising the change of use in the legal section of the newspaper. Well owners must reapply each year for the temporary permits.

5.1 Summary of Climate Conditions

The accepted regional water plan (PVWUO, 2001) included an analysis of historical temperature and precipitation in the region. This section provides an updated summary of temperature, precipitation, snowpack conditions, and drought indices pertinent to the region (Section 5.1.1). Studies relevant to climate change and its potential impacts to water resources in New Mexico and the Lower Pecos Valley region are discussed in Section 5.1.2.
5.1.1 Temperature, Precipitation, and Drought Indices

Table 5-1 lists the periods of record for weather stations in the Lower Pecos Valley region and identifies four stations that were used for detailed analysis of weather trends. These stations were selected based on location, how well they represented conditions in their respective counties, and completeness of their historical records. In addition to the climate stations, data were available from one snowpack telemetry (SNOTEL) station and were used to document snowfall on Sierra Blanca (Table 5-1). The locations of the climate stations for which additional data were analyzed are shown in Figure 5-1.

Long-term minimum, maximum, and average temperatures for the four climate stations are detailed in Table 5-2, and average summer and winter temperatures for each year are shown on Figure 5-2.

The average precipitation distribution across the entire region is shown on Figure 5-3, and Table 5-2 lists the minimum, maximum, and long-term average annual precipitation (rainfall and snowmelt) at the four representative stations in the planning region. Total annual precipitation for the selected climate stations is shown in Figure 5-4.

The Natural Resources Conservation Service (NRCS) operates one SNOTEL station in the planning region, the Sierra Blanca station, located in the Sacramento Mountains near Ruidoso. This station provides snow depth and snow water equivalent data (Figure 5-5) (NRCS, 2014a).

The snow water equivalent is the amount of water, reported in inches, within the snowpack, or the amount of water that would result if the snowpack were instantly melted (NRCS, 2014b). The end of season snowpack is a good indicator of the runoff that will be available to meet water supply needs. A summary of the early April (generally measured within a week of April 1) snow depth and snow water equivalent information at the Sierra Blanca station is provided on Figure 5-5.

Another way to review long-term variations in climate conditions is through drought indices. A drought index consists of a ranking system derived from the assimilation of data—including rainfall, snowpack, streamflow, and other water supply indicators—for a given region. The Palmer Drought Severity Index (PDSI) was created by W.C. Palmer (1965) to measure the variations in the moisture supply and is calculated using precipitation and temperature data as well as the available water content of the soil. Because it provides a standard measure that allows comparisons among different locations and months, the index is widely used to assess the weather during any time period relative to historical conditions. The PDSI classifications for dry to wet periods are provided in Table 5-3.

There are considerable limitations when using the PDSI, as it may not describe rainfall and runoff that varies from location to location within a climate division and may also lag in
indicating emerging droughts by several months. Also, the PDSI does not consider groundwater or reservoir storage, which can affect the availability of water supplies during drought conditions. However, even with its limitations, many states incorporate the PDSI into their drought monitoring systems, and it provides a good indication of long-term relative variations in drought conditions, as PDSI records are available for more than 100 years.

The PDSI is calculated for climate divisions throughout the United States. The Lower Pecos Valley region falls primarily within New Mexico Climate Division 7 (the Southeastern Plains Climate Division), with the western side of the region in Division 6 (the Central Highlands Climate Division) and tiny portions of the southwestern part of the region in Division 8 (the Southern Desert Climate Division) (Figure 5-1). Figure 5-6 shows the long-term PDSI for Divisions 6 and 7. Of interest are the large variations from year to year in both divisions, which are similar in pattern though not necessarily in magnitude.

The chronological history of drought, as illustrated by the PDSI, indicates that the most severe droughts in the last century occurred in the early 1900s, the 1950s, the early 2000s, and in recent years (2011 to 2013) (Figures 5-6a and 5-6b).

The likelihood of drought conditions developing in New Mexico is influenced by several weather patterns:

- **El Niño/La Niña**: El Niño and La Niña are characterized by a periodic warming and cooling, respectively, of sea surface temperatures across the central and east-central equatorial Pacific. Years in which El Niño is present are more likely to be wetter than average in New Mexico, and years with La Niña conditions are more likely to be drier than average, particularly during the cool seasons of winter and spring.

- **The Pacific Decadal Oscillation (PDO)**: The PDO is a multi-decadal pattern of climate variability caused by shifting sea surface temperatures between the eastern and western Pacific Ocean that cycle approximately every 20 to 30 years. Warm phases of the PDO (shown as positive numbers on the PDO index) correspond to El Niño-like temperature and precipitation anomalies (i.e., wetter than average), while cool phases of the PDO (shown as negative numbers on the PDO index) correspond to La Niña-like climate patterns (drier than average). It is believed that since 1999 the planning region has been in the cool phase of the PDO.

- **The Atlantic Multidecadal Oscillation (AMO)**: The AMO refers to variations in surface temperatures of the Atlantic Ocean which, similarly to the PDO, cycle on a multi-decade frequency. The pairing of a cool phase of the PDO with the warm phase of the AMO is typical of drought in the southwestern United States (McCabe et al., 2004; Stewart, 2009). The AMO has been in a warm phase since 1995. It is possible that the AMO may be shifting to a cool phase but the data are not yet conclusive.
5.1.2 Recent Climate Studies

New Mexico’s climate has historically exhibited a high range of variability. Periods of extended drought, interspersed with relatively short-term, wetter periods, are common. Historical periods of high temperature and low precipitation have resulted in high demands for irrigation water and higher open water evaporation and riparian evapotranspiration. In addition to natural climatic cycles (i.e., el Niño/la Niña, PDO, AMO [Section 5.1.1]) that affect precipitation patterns in the southwestern United States, there has been considerable recent research on potential climate change scenarios and their impact on the Southwest and New Mexico in particular.

The consensus on global climate conditions is represented internationally by the work of the Intergovernmental Panel on Climate Change (IPCC), whose Fifth Assessment Report, released in September 2013, states, “Warming of the climate system is unequivocal, and since the 1950s many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased” (IPCC, 2013). Atmospheric concentrations of greenhouse gases are rising so quickly that all current climate models project significant warming trends over continental areas in the 21st century.

In the United States, regional assessments conducted by the U.S. Global Change Research Program (USGCRP) have found that temperatures in the southwestern United States have increased and are predicted to continue to increase, and serious water supply challenges are expected. Water supplies are projected to become increasingly scarce, calling for trade-offs among competing uses and potentially leading to conflict (USGCRP, 2009). Most of the major river systems of the southwestern U.S. are expected to experience reductions in streamflow and other limitations to water availability (Garfin et al., 2013).

Although there is consensus among climate scientists that global temperatures are warming, there is considerable uncertainty regarding the specific spatial and temporal impacts that can be expected. To assess climate trends in New Mexico, the NMOSE and NMISC (2006) conducted a study of observed climate conditions over the past century and found that observed wintertime average temperatures had increased statewide by about 1.5°F since the 1950s. Predictions of annual precipitation are subject to greater uncertainty “given poor representation of the North American monsoon processes in most climate models” (NMOSE/NMISC, 2006).

A number of other studies predict temperature increases in New Mexico from 5° to 10°F by the end of the century (Forest Guild, 2008; Hurd and Coonrod, 2008; USBR, 2011). Predictions of annual precipitation are subject to greater uncertainty, particularly regarding precipitation during the summer monsoon season in the southwestern U.S.
The NMISC is currently working with the Bureau of Reclamation on a basin study to assess the predicted impacts of climate change in the Pecos Valley. This report is expected to be completed in June of 2016.

Based on these studies, the effects of climate change that are likely to occur in New Mexico and the planning region include (NMOSE/NMISC, 2006):

- Temperature is expected to continue to rise.
- Higher temperatures will result in a longer and warmer growing season, resulting in increased water demand on irrigated lands and increased evapotranspiration from riparian areas, grasslands, and forests, and thus less recharge to aquifers.
- Reservoir and other open water evaporation are expected to increase.
- Precipitation is expected to be more concentrated and intense leading to increased projected frequency and severity of flooding.
- Streamflows in major rivers across the Southwest are projected to decrease substantially during this century (e.g., Christensen et al., 2004; Hurd and Coonrod, 2008; USBR, 2011, 2013) due to a combination of diminished cold season snowpack in headwaters regions and higher evapotranspiration in the warm season. The seasonal distribution of streamflow is projected to change as well: flows could be somewhat higher than at present in late winter, but peak runoff will occur earlier and be diminished. Late spring/early summer flows are projected to be much lower than at present, given the combined effects of less snow, earlier melting, and higher evaporation rates after snowmelt.

To minimize the impact of these changes, it is imperative that New Mexico plan for dealing with variable water supplies, including focusing on drought planning and being prepared to maximize storage from extreme precipitation events while minimizing their adverse impacts.

5.2 Surface Water Resources

Surface water supplies approximately 30 percent of the water currently diverted in the Lower Pecos Valley Water Planning Region, with its primary uses being for irrigated agriculture and reservoir evaporation. The dominant waterways flowing in the region are the Pecos River and its tributaries. Major surface drainages (including both perennial and intermittent streams) and watersheds in the planning region are shown on Figure 5-7.

The Pecos River enters the Lower Pecos Basin below Sumner Dam and exits the region at the Texas state line. An important component of surface water flow in the Lower Pecos Basin is baseflow contribution to the Pecos River from groundwater between the Acme and Artesia gages.
in the Roswell Basin. The underlying aquifer system that provides the baseflow consists of the shallow alluvium in the Roswell Basin, an underlying sequence of leaky confining beds, and below that, the very highly transmissive carbonate rocks that comprise the Roswell artesian aquifer system. The exchange of water between aquifer and river is an integral part of the river’s flow system and thus a necessary consideration in any study of surface water supplies in the basin.

The Pecos River streamflow is extremely variable from year to year and over longer periods of time. The annual inflow at Fort Sumner is less than 70,000 acre-feet to more than 600,000 acre-feet. Streamflows are composed of snowmelt from the headwaters in the Sangre de Cristo Mountains, baseflow gain largely originating from the Sacramento Mountains to the west of the river, and flood runoff.

When evaluating surface water information, it is important to note that streamflow does not represent available supply, as there are also water rights and interstate compact limitations. The administrative water supply discussed in Section 5.5 is intended to represent supply considering both physical and legal limitations, but excluding potential compact limitations. The information provided in this section is intended to illustrate the variability and magnitude of streamflow, and particularly the relative magnitude of streamflow in recent years.

Deliveries of water to Texas are governed by the Pecos River Compact and the 1988 Supreme Court amended decree. The specific methodology for determining New Mexico’s annual Compact delivery requirement is contained in the Federal Pecos River Master’s Manual. New Mexico’s delivery to Texas is the combination of measurements at the Pecos River at Red Bluff, New Mexico gage, about 3.2 miles north of the state line, and at the Delaware River near Red Bluff gage (the Delaware River enters the Pecos River slightly downstream of the Pecos River at Red Bluff gage).

The flow of the Pecos River is largely controlled by the main stem dams (Santa Rosa, Sumner, Brantley, and Avalon) that collectively control delivery of water to the CID. Historically, the entire flow of the Pecos River at Lake Avalon was in many years diverted into the main CID canal for irrigation purposes. More recently, since the 1988 U.S. Supreme Court Amended Decree, there have been regular deliveries from Avalon Dam to the Texas border to help ensure New Mexico’s compliance with its Compact delivery requirements. The deliveries have been facilitated through lease agreements between CID and NMISC and, more recently, under the provisions of the 2003 Pecos Settlement Agreement.

The surface water resources of the Hondo Basin include the Hondo and Ruidoso rivers, Eagle Creek, and Rio Bonito, all tributaries to the Pecos River that are used for irrigation, livestock, fisheries, and urban areas. The Village of Ruidoso relied heavily on the surface water supplies from Alto and Grindstone reservoirs on Eagle Creek and the Rio Ruidoso, respectively, until the
Little Bear Fire and subsequent floods and debris flows damaged the watershed in 2012. Stringent water conservation measures were in place because of the Little Bear Fire’s impact on the Village's ability to deliver water to its customers until the Village started diverting water again in 2014 (Hernandez, 2015). The Village of Ruidoso added a diversion pump in Carrizo Creek after the fire and pumped water several miles up to Grindstone Reservoir (Doydan, 2015). Surface water diversions continue to be impacted with mud flows and debris during intense rainfall events, requiring the surface water systems to be shut down.

The Village does not have sufficient water rights to meet the growing demand and has applied for temporary transfers of water rights (of about 409 acre-feet) and 22 acre-feet of permanent transfers from agricultural water rights downstream on the Rio Ruidoso. These applications have been protested because the “transfer from” locations are downstream of other water rights on the Rio Ruidoso and could result in impairment of other water rights.

The Village has four wells on U.S. Forest Service land that have been the subject of controversy and protest. A settlement order in 2006 resolved the allowable water rights, but the special use permit with the Forest Service may limit when pumping can occur (Hernandez, 2015). Baseflow analysis of the North Fork of Eagle Creek was investigated by the U.S. Geological Survey (USGS) (Matherne et al., 2011) to better understand the impacts of pumping from Village of Ruidoso wells in 1988 on the streamflow. Their study showed that the 1970–80 mean annual discharge, direct runoff, and baseflow were higher than for the period from 1989–2008, and the amount of direct runoff and base flow as a percentage of measured discharge was similar for the two periods. The decrease in streamflow is likely due to a combination of pumping and reduced recharge.

Tributary flow is not monitored in every subwatershed in the planning region. However, streamflow data are collected by the USGS and various cooperating agencies at stream gage sites in the planning region. Gaged tributaries in the Lower Pecos Basin include Cottonwood Creek, Eagle Draw, Rio Hondo, Rio Felix, Rio Peñasco, Rocky Arroyo, Fourmile Draw, North Seven Rivers, South Seven Rivers, Dark Canyon, the Black River, and the Delaware River. Many smaller, ungaged tributaries also contribute flow. Table 5-4a lists the locations and periods of record for data collected at some of the stream gages in the region, as well as the drainage area and estimated irrigated acreage for surface water diversions upstream of the station. Table 5-4b provides the minimum, median, and maximum annual yield for all gages that have 10 or more years of record. In addition to the large variability in annual yield, streamflow also varies from month to month within a year, and monthly variability or short-term storms can have flooding impacts, even when annual yields are low. Table 5-5 provides monthly summary statistics for each of the stations with 10 or more years of record.

For this water planning update, eight stream gages, shown on Figure 5-7, were analyzed in more detail. These stations were chosen because of their locations in the hydrologic system,
completeness of record, and representativeness as key sources of supply. Figure 5-8 shows the minimum and median annual water yield for these gages. Figures 5-9a through 5-9d show the annual water yield from the beginning of the period of record through 2013 for the eight gages.

The northernmost gage, Pecos River above Santa Rosa Lake, is located about 12 miles upstream and outside of the planning region, but it represents the water entering the basin from snowmelt in the Sangre de Cristo Mountains. The streamflow at this gage is highly variable, providing nearly 200,000 acre-feet in years with a good snow pack, and as low as zero in 2013, which followed two very dry years.

As shown in Figure 5-8, over the period from 1950 through 2013, the Pecos River generally gained a significant baseflow from the Puerta Luna reach just north of the planning region, lost about 18,000 acre-feet of flow between Fort Sumner Dam and the gage at Acme, and gained back an equal amount between Acme and Artesia. Most notable on Figures 5-4a and 5-4b is the outlier year of 1941, when 41 inches of precipitation were recorded at Sumner Reservoir and 34 inches at Carlsbad and the resulting flows in the Pecos River (Figure 5-9b) were nearly 1.4 million acre feet at the Artesia gage (10 times the median flow) and exceeded 1.6 million (25 times the median) just above the state line at Red Bluff (Figure 5-9c). Conversely, the severe drought of 2011 through the early fall of 2013 resulted in such meager surface water supplies that no releases to the Texas border were required by the 2003 Pecos Settlement Agreement in the years 2011 and 2012.

Several lakes and reservoirs are present in the planning region (Figure 5-7). Table 5-6 summarizes the characteristics of the larger lakes and reservoirs (i.e., storage capacity greater than 5,000 acre-feet, as reported in the NMOSE *Water Use by Categories* report [Longworth et al., 2013]). Brantley Lake, with a storage capacity of nearly 1,000,000 acre-feet is the largest of the reservoirs. Brantley Dam and Avalon Dam impound water that is released primarily for the use of CID members, the principal users of surface water in the basin, and also for flood control purposes. Water primarily for CID is released from Sumner and Santa Rosa (upstream in the Mora-San Miguel-Guadalupe region) dams in blocks that are delivered to Brantley Lake. In addition to the reservoirs shown in Table 5-6, numerous smaller lakes and reservoirs are present in the region; information on these smaller reservoirs was included in the accepted plan (PVWUO, 2001).

The NMOSE conducts periodic inspections of non-federal dams in New Mexico to assess dam safety issues. Dams that equal or exceed 25 feet in height that impound 15 acre-feet of storage or dams that equal or exceed 6 feet in height and impound at least 50 acre-feet of storage are under the jurisdiction of the State Engineer. These non-federal dams are ranked as being in good, fair, poor, or unsatisfactory condition. Dams with unsatisfactory conditions are those that require immediate or remedial action. Dams identified in recent inspections as being deficient, with high or significant hazard potential, are summarized in Table 5-7.
5.3 **Groundwater Resources**

Groundwater accounted for 70 percent of all water diversions in the year 2010 (Longworth et al., 2013).

5.3.1 **Regional Hydrogeology**

The geology that controls groundwater occurrence and movement within the planning region was described in the accepted *Lower Pecos Valley Regional Water Plan* (PVWUO, 2001) for six UWBs: Fort Sumner, Roswell, Hondo, Peñasco, Carlsbad, and Capitan. A map illustrating the surface geology of the planning region, derived from a geologic map of the entire state of New Mexico by the New Mexico Bureau of Geology & Mineral Resources (2003), is included as Figure 5-10. The accepted water plan (PVWUO, 2001) provides a detailed explanation of the hydrogeology and water uses within each groundwater basin.

Two primary physiographic regions exist within the planning region. From the west to the east, these are:

- Basin and Range (Sacramento Section)
- Great Plains (Lower Pecos Valley)

The Great Plains (Llano Estacado or High Plains Subsection) is present in very small areas in the eastern edge of the planning region (Figure 5-10).

In the Lower Pecos Basin (below Sumner Dam), groundwater is readily available from productive aquifers and is heavily used, primarily for irrigation. The principal aquifers are the Roswell artesian aquifer system and the shallow alluvial aquifer in bottom lands near the Pecos River, and the smaller Capitan Reef aquifer and Carlsbad alluvial aquifer located in the Carlsbad area. These Lower Pecos Basin aquifers are described in the following subsections.

5.3.1.1 **Fort Sumner Groundwater Basin**

The stratigraphy in the Fort Sumner Groundwater Basin consists of pancake layers of geologic formations with the Santa Rosa Sandstone, topped by alluvium that provides the highest yield and best water quality. Deeper formations, such as the San Andres, Glorieta, Artesia Group, and Chinle Formations yield unknown quantities of poor-quality water due to gypsum and other salt deposits within the formations. The alluvium is up to 500 feet thick and can yield fair-quality water at pumping rates up to 1,300 gpm (PVWUO, 2001). The Santa Rosa Sandstone is up to 380 feet thick; yields vary from 15 to 1,000 gpm (PVWUO, 2001).

5.3.1.2 **Roswell Basin**

Welder (1983) prepared the most detailed assessment of the Roswell Basin aquifers, which provided the foundation of groundwater modeling for this basin. The Roswell artesian aquifer is
an extensive, highly transmissive, limestone aquifer extending from the Pecos River about 20 miles to the west. This aquifer is overlain by a shallow alluvial aquifer extending several miles west from the Pecos River. These aquifers are separated by a thick, semi-confining unit in the southern half of the basin, making the hydraulic connection between the two aquifers poor in this area. In the northern part of the basin near Roswell, the two aquifers are in better hydrologic connection due to thinning or absence of the semi-confining unit.

Estimated average natural recharge to both aquifers is about 300,000 ac-ft/yr (DBS&A, 1995). About two-thirds of the natural recharge that feeds the Roswell artesian aquifer is derived from the Sacramento Mountains to the west. Recharge to the alluvial aquifer also occurs from irrigation return flow.

After metering began in 1967, groundwater diversions from the artesian aquifer system stabilized at a level of about 250,000 ac-ft/yr. Shallow aquifer diversions were about 110,000 ac-ft/yr in the 1990s. The agricultural sector dominates groundwater diversions in the Roswell artesian aquifer (DBS&A, 1995).

Groundwater is under pressure in the Roswell artesian aquifer, and before major development of the aquifer, wells flowed freely at the surface. Groundwater development had resulted in a decline in water levels by as much as 100 feet from the 1920s through the 1950s, but then water levels stabilized and recovered in response to increased precipitation (and recharge) during the 1980s and 1990s (DBS&A, 1995). Summer water levels drop more than 100 feet below winter levels in some areas, indicating that the aquifer is heavily stressed during the summer irrigation season. The extensive development of the Roswell artesian aquifer system has also reduced the amount of water entering the Pecos River as baseflow gain, thereby reducing available surface water supplies for downstream users as compared to historical flows.

5.3.1.3 Hondo Basin

The Hondo Basin is in the headwaters of the Roswell Basin and derives most of the groundwater from the San Andres Formation and alluvium. In some areas, the Glorieta Sandstone produces water suitable for irrigation. Minor amounts of water are derived for domestic and stock uses from the Cub Mountain, Dakota Sandstone, Chinle Shale, Santa Rosa Sandstone, Artesia Group, and Permian Yeso Formation and Tertiary volcanic rocks associated with Sierra Blanca. The Village of Ruidoso has six active wells completed in the Yeso Formation and volcanic rocks (Village of Ruidoso, 2014). Demands for groundwater and surface water have increased in the upper Rio Hondo Basin due to increases in development and population. A comparison of water level data from March 2003 to water levels in 1963 (Donohoe, 2004) indicated a decline in water levels near the Rio Ruidoso.
5.3.1.4 Peñasco Basin

The Peñasco Basin is also in the headwaters of the Roswell Basin and derives most of its groundwater from the San Andres Formation and alluvium. In some areas, the Glorieta Sandstone produces water suitable for irrigation.

5.3.1.5 Capitan Basin

The Capitan Reef is a curved geologic structure, over 100 miles long, 10 to 14 miles wide, composed of limestone and dolomite in which large solution channels and caverns (such as Carlsbad Caverns) have been formed. East of the Pecos River the Capitan Reef extends from the Carlsbad UWB into the Capitan UWB and becomes progressively deeper. Within the Capitan UWB, the Santa Rosa Sandstone and alluvium are the primary sources of water.

5.3.1.6 Carlsbad Basin

The Carlsbad Basin includes the Pecos Valley Alluvium, the Capitan Reef Aquifer and the Permian Castile and Salado Formations. The Pecos Valley Alluvium extends in a narrow strip along the Pecos River from a few miles north of the City of Carlsbad to the mouth of Dark Canyon. In the vicinity of the CID, the saturated thickness of the alluvium reaches 150 feet between Otis and Loving (Bjorklund and Motts, 1959). In the far southwestern part of the aquifer, the saturated thickness is on the order of 50 feet thick (Barroll et al., 2004). The Pecos River is generally considered the eastern limit of the Pecos Valley Alluvium.

The Capitan Reef aquifer is composed of the Carlsbad and Capitan limestones and extends from the Capitan Basin in the east up to the Guadalupe Mountains in the west. The Capitan Reef aquifer is highly transmissive and of good quality west of the Pecos River. East of the Pecos River the reef is less transmissive and the salinity is much higher. Near the City of Carlsbad, a small part of the alluvial aquifer directly overlies the Capitan Reef aquifer, and the two aquifers are hydrologically connected.

West of the Pecos River, where the reef aquifer is not present, the alluvial aquifer is directly underlain by the Permian Castile and Salado formations, which together comprise up to 2,500 feet of evaporite beds. In addition to forming the basal boundary of most of the alluvial aquifer, these units form the southern and northern boundaries of the Pecos Valley Alluvium. The Permian Castile Formation is a source of water for some relatively deep wells in the western part of the basin (Barroll et al., 2004). The Castile Formation and Pecos Valley Alluvium wells are hydrologically connected in the western part of the basin (Barroll et al., 2004).

The Capitan Reef aquifer receives an estimated 10,000 to 20,000 ac-ft/yr of natural recharge from precipitation in the Guadalupe Mountains and seepage from flood flows in Dark Canyon west of Carlsbad (Barroll et al., 2004). Estimated recharge to the Pecos Valley Alluvium from local precipitation is highly variable, depending on climatic conditions; annual values range from near zero to almost 30,000 acre-feet, with an average value of 8,000 acre-feet. In addition,
Seepage of irrigation water provides about 20,000 to 50,000 ac-ft/yr (36,000 ac-ft/yr average) of recharge to the Pecos Valley Alluvium, predominantly within the CID. Leakage of Pecos River water from Lake Avalon provides about 15,000 ac-ft/yr of recharge to both the Capitan Reef and Pecos Valley Alluvium aquifers north of Carlsbad.

The major groundwater users in this area include irrigators (both CID and non-CID), the City of Carlsbad, and the potash and oil and gas industries. Within CID more than 100 active supplemental wells augment supply when surface flows are not sufficient to provide CID rights holders a full allotment of 3.697 acre-feet per acre. During the recent drought, limited surface supplies resulted in surface water deliveries of only 1.4 and 0.8 acre-feet per acre in 2011 and 2012 respectively, thereby necessitating significant reliance on groundwater supplies. By 2014, increased surface supplies were sufficient to provide a full allotment without the use of supplemental wells. Under the terms of the 2003 Settlement Agreement, when groundwater diversions combined with surface deliveries within a single calendar year exceed CID’s maximum allotment of 3.697 acre-feet per acre, CID is required to deliver that excess volume to the ISC for compact compliance purposes. In addition to supplemental groundwater rights, some CID rights holders own primary groundwater rights for irrigation purposes.

Historically, the Pecos River gained water in this area as base inflow from the Pecos Valley Alluvium and the Capitan Reef aquifer; however, groundwater pumping from the two aquifers has reduced the base inflow of groundwater to the Pecos River. When groundwater levels are drawn down sufficiently, the direction of flow can be reversed altogether, pulling water from the river into the aquifer system. Groundwater depletions in the Carlsbad area, through groundwater pumping in the Carlsbad Basin, directly impact New Mexico’s ability to comply with the Pecos River Compact and the U.S. Supreme Court’s 1988 Amended Decree. East of the Pecos River within the Carlsbad Basin, the Rustler Formation, Santa Rosa Sandstone and alluvium are the primary sources of water.

5.3.2 Aquifer Conditions

In order to evaluate changes in water levels over time, the USGS monitors groundwater wells throughout New Mexico (Figure 5-11). Hydrographs illustrating groundwater levels versus time, as compiled by the USGS (2014b), were selected for seven monitor wells with longer periods of record and are shown on Figure 5-12.

As reported in the accepted regional water plan (PVWUO, 2001), water level declines vary by location and aquifer:

- About half of the wells in the Fort Sumner UWB showed a decline while the other half of the 175 wells showed an increase over a 27-year period from 1964 to 1990. Figure 5-11 shows that most of the wells in the Fort Sumner area are declining between 1 and 10 feet over the 20 year period (between approximately 1990 and 2010). The hydrograph of a
well completed in the Santa Rosa Sandstone (Figure 5-12) shows a decline of about 4 feet over a 50-year period from 1960 to 2014.

- Wells in the Roswell UWB fluctuate seasonally due to irrigation pumping with a trend over time that responds to annual variations in total production, which ranges from 280,000 ac-ft/yr to nearly 450,000 ac-ft/yr (Grigg, 2014). Wells completed in the shallow aquifer (e.g., well 331524104245101, north of Dexter, on Figure 5-12) vary only a few feet from summer to winter (because the aquifer is unconfined and has a high storage coefficient) compared to wells completed in the artesian (confined) aquifer that fluctuate several hundred feet from summer to winter.

- Wells completed in the upland areas such as the Hondo and Peñasco UWBs showed rising water levels during the late 1980s and 1990s in response to higher precipitation during those years. A recent study of the Rio Hondo Basin (Donohoe, 2004) comparing water levels from 2003 with 1963 data from 70 wells indicated a decline in water levels near the Rio Ruidoso but a rise in water levels near the Rio Bonito. Within the Rio Hondo Basin, the rising and declining water levels were highest in the northern part of the study area. The median rise of water levels was 4.0 feet and ranged from 0.08 to 36.4 feet. The median decline of water levels was 3.5 feet and ranged from 0.6 to 162 feet. In the southern part of the basin, the median rise of water levels was 2.2 feet and ranged from 0.5 to 17.1 feet. The median decline in water levels was 1.6 feet and ranged from 0.5 to 26.1 feet. Figure 5-11 shows the variability of decline and rise in water levels over the recent period (approximately 1990 to 2010).

- Wells in the Carlsbad and Capitan UWBs respond rapidly to changes in pumping and recharge. Review of 115 wells in the basins (PVWUO, 2001) showed a decline in 45 of the alluvial wells while water rose in 35 from 1987 to 1993. Of the 31 wells in the Capitan Reef aquifer, 20 showed a decline and 8 showed an increase over the same period. Figure 5-11 shows the variability of decline and rise in water levels over the recent period (approximately 1990 to 2010). Declines are greatest around Loving and Carlsbad.

The aquifers in the planning region are generally recharged through direct infiltration of snow melt and precipitation in the outcrop areas, infiltration from lakes, streams, and canals where the elevation of the lake or stream bottom is above the water table, irrigation return flow, and seepage from septic tanks. The accepted regional water plan did not provide published estimates of recharge in the region, focusing instead on the amount of water in storage. However, recharge in the Roswell Basin has been studied extensively and has been found to vary each year depending on the amount of precipitation. Hantush (1957) studied the “dynamic equilibrium” in specific years and developed an equation for estimating recharge:
Recharge (ac-ft/yr) = 21,000 x Rainfall (3-year average in inches)

The calibration of the Carlsbad groundwater model (Barroll et al., 2004) incorporated different values for recharge each year.

Recharge estimates for the various aquifers in the planning region include:

- Roswell artesian aquifer: 231,900 to 257,000 ac-ft/yr (Summers, 1972; Hantush, 1957)
- Roswell shallow alluvial aquifer: 14,200 to 32,000 ac-ft/yr (Summers, 1972; Hantush, 1957; Morgan, 1938)
- Total recharge to the Roswell Basin: 235,000 to 578,402 ac-ft/yr (Fiedler and Nye, 1933; Hantush, 1957; Saleem and Jacob, 1971; Summer, 1972; DBS&A, 1995)
- Capitan Reef aquifer: 5,800 to 17,315 ac-ft/yr (Barroll et al., 2004)
- Pecos River Basin alluvial aquifers in the Carlsbad Basin: 3,731 to 53,074 ac-ft/yr (Barroll et al., 2004)

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

- Fort Sumner Municipal Water System (Fort Sumner)
- Ruidoso Water System (Hondo)
- Berrendo Water Users Association (WUA) (Roswell)
- Dexter Municipal Water System (Roswell)
- Hagerman Water System (Roswell)
- Roswell Municipal Water System (Roswell)
- Otis Water Co-op (Carlsbad)
- Carlsbad Municipal Water System (Carlsbad)
- Artesia Domestic Water System (Roswell)
- Artesia Rural Water Co-op (Roswell)

5.4 Water Quality Assessment

Assurance of ability to meet future water demands requires not only water in sufficient quantity, but also water that is of sufficient quality for the intended use. This section summarizes the water quality assessment that was provided in the accepted regional water plan and updates it to reflect new studies of surface and groundwater quality and current databases of contaminant
sources. The identified water quality concerns should be a consideration in the selection of potential projects, programs, and policies to address the region’s water resource issues.

Surface water quality in the Lower Pecos Valley Water Planning Region is evaluated through periodic monitoring and comparison of sample results to pertinent water quality standards. In general, the water quality is best in the upstream reaches and increases in salinity downstream, particularly beyond Malaga Bend south of Carlsbad. Water quality varies with the rate of flow, exhibiting higher salinities during drought periods. Several lakes and tributaries to the Pecos River within the Lower Pecos River Basin watershed have been listed on the 2012-2014 New Mexico 303(d) list (NMED, 2014a). This list is prepared by NMED to comply with Section 303(d) of the federal Clean Water Act, which requires each state to identify surface waters within its boundaries that are not meeting or not expected to meet water quality standards.

Section 303(d) further requires the states to prioritize their listed waters for development of total maximum daily load (TMDL) management plans, which document the amount of a pollutant a waterbody can assimilate without violating a state water quality standard and allocates that load capacity to known point sources and nonpoint sources at a given flow. Figure 5-13 shows the locations of lakes and stream reaches with impaired water quality. Table 5-8 provides details of impairment for those reaches.

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

Groundwater quality is generally good in the Fort Sumner area and on the west side of the Pecos River throughout the region. East of the Pecos River salinity is high and reaches concentrations of 35,000 parts per million (ppm) (Maddox, 1965). North of Roswell the aquifer has high salinity, particularly in the vicinity of Bitter Lakes (Welder, 1983).

Specific sources that have the potential to impact either surface or groundwater quality in the future are discussed below. Sources of contamination are considered as one of two types: (1) point sources (Section 5.4.1), if they originate from a single location, or (2) nonpoint sources (Section 5.4.2), if they originate over a more widespread or unspecified location. Information on both types of sources is provided below.

### 5.4.1 Point Sources

Point source discharges to surface water must comply with the Clean Water Act and the New Mexico Water Quality Standards (20 NMAC 6.4.1) by obtaining a National Pollutant Discharge
and Elimination System (NPDES) permit to discharge. NPDES-permitted discharges in the planning region are summarized in Table 5-9 and shown on Figure 5-14.

The NMED Ground Water Bureau regulates facilities with wastewater discharges that have a potential to impact groundwater quality. These facilities must comply with the New Mexico Water Quality Control Commission (NMWQCC) regulations (NMWQCC, 2002) and obtain approval of a discharge plan, which provides for measures needed to prevent and detect groundwater contamination. A variety of facilities fall under the discharge plan requirements, including mines, sewage dischargers, dairies, food processors, sludge and septage disposal facilities, and other industries. The NMWQCC regulations contain requirements for cleanup of any groundwater contamination detected under discharge plan monitoring requirements. Until such cleanup is complete, these facilities may impact the availability of water supplies of sufficient quality for intended uses. Details indicating the status, waste type, and treatment for individual discharge plans can be obtained from the NMED Ground Water Bureau website (http://www.nmenv.state.nm.us/gwb/). A summary list of current discharge plans in the planning region is provided in Table 5-10; their locations are shown in Figure 5-14.

The accepted regional water plan (PVWUO, 2001) identified five sites in the planning region that were listed by the U.S. EPA (2004) as Superfund sites. One of these sites, the McGaffey & Main Groundwater Plume, is the only one currently listed as a Superfund site (U.S. EPA, 2014). Information regarding this site is provided in Table 5-11.

Leaking underground storage tank (UST) sites present a potential threat to groundwater, and the NMED maintains a database of registered USTs. Many of the facilities included in the NMED UST database are not leaking, and even leaking USTs may not necessarily have resulted in groundwater contamination or water supply well impacts. These USTs could, however, potentially impact groundwater quality in and near the population centers in the future. UST sites in the Lower Pecos Valley region are identified on Figure 5-14. Many of the UST sites listed in the NMED database require no further action and are not likely to pose a water quality threat. Sites that are being investigated or cleaned up by the state or a responsible party, as identified on Table 5-12, should be monitored for their potential impact on water resources. Additional details regarding any groundwater impacts and the status of site investigation and cleanup efforts for individual sites can be obtained from the NMED database, which is accessible from their website (http://www.nmenv.state.nm.us/ust/ustbtop.html).

Landfills used for disposal of municipal and industrial solid waste can contain a variety of potential contaminants that may impact groundwater quality. Landfills operated since 1989 are regulated under the New Mexico Solid Waste Management Regulations. Many small landfills throughout New Mexico, including landfills in the planning region, closed before the 1989 regulatory enactment to avoid more stringent final closure requirements. Other landfills have
closed as new solid waste regulations became effective in 1991 and 1995. Within the planning region, there are four operating landfills and five closed landfills (Table 5-13, Figure 5-14).

The more than 19,000 active oil and gas production wells and disposal (injection wells) in the region pose a potential threat to water quality. The nation’s only nuclear waste disposal facility (Waste Isolation Pilot Plant) is located east of Carlsbad several thousand feet below the land surface in a salt dome, but it is unlikely to threaten fresh water supplies.

5.4.2 Nonpoint Sources

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

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

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

Other nonpoint sources of pollutants that are concerns for surface water quality in the planning region include fertilizer and pesticides from farms.

One approach to addressing nonpoint source pollution is through Watershed Based Planning or other watershed restoration initiatives that seek to restore riparian health and to address sources of contamination. In the Lower Pecos Valley region, the Pecos River Basin Water Salvage Project was initiated in 1967 through the Bureau of Reclamation to control salt cedar growth from Sumner Dam to the New Mexico-Texas state line. While the initial intent was to salvage water thought to be lost to evaporation, the project has support from environmental groups who seek to restore riparian areas to a more biologically diverse ecosystem. The accepted water plan (PVWUO, 2001) identified 462,000 acres in need of restoration for the purpose of reducing the risk of catastrophic wildfire and the associated nonpoint source pollution of sediment and ash.

In 2014 the Mescalero Apache Tribe Watershed Restoration Project began with the goal of treating 600 acres within the Lower Pecos Valley and Tularosa, Salt and Sacramento water planning regions. Mechanical equipment is being used to reduce overly dense fuel stands to
reduce the threat of catastrophic wildfire while promoting forest health in three critical watershed areas on tribal land.

In addition, according to EPA’s Surf Your Watershed (U.S. EPA, 2015), several citizen-based groups have been or are working on addressing watershed health:

- The Watershed Defense Association is working on restoration and conservation projects in the Arroyo Del Macho, Gallo Arroyo, and Rio Hondo watersheds in order to protect downstream water right holders and private property rights. The group is dedicated to restoring the watershed and floodplains with the goal of retaining and protecting river flows and preserving the quality and quantity of river, irrigation, wildlife, and domestic drinking water for all downstream inhabitants.

- The Sonterra Watershed Management Area Committee is working on the Rio Hondo Watershed to preserve and enhance the quality of the Upper Hondo watershed, which includes the land, water, vegetation, and general environment surrounding and including the properties of the Ranches of Sonterra. Preserving and enhancing the quality of the watershed include issues of fire safety, forest health, groundwater maintenance, invasive vegetation, and river water quality and flow, all for the benefit of the public welfare.

- The Cloudcroft Elementary Fourth Grade has monitored water quality in the Rio Peñasco since 1996.

Several entities in the region have received Collaborative Forest Restoration Program (CFRP) funding (USFS, 2015), including:


- ENMU-Ruidoso for Implementation of Forest Treatments in Mexican Spotted Owl Habitat.

5.5 Administrative Water Supply

The Updated Regional Water Planning Handbook (NMISC, 2013) describes a common technical approach (referred to there as a platform) for analyzing the water supply in all 16 water planning regions in a consistent manner. As discussed in the handbook (NMISC, 2013), many methods can be used to account for supply and demand, but some of the tools for implementing these analyses are available for only parts of New Mexico, and resources for developing them for all regions are not currently available. Therefore, the state has developed a simple method that can be used consistently across all regions to assess supply and demand for planning purposes. The
use of this consistent method will facilitate efficient development of a statewide overview of the balance between supply and demand in both normal and drought conditions, so that the state can move forward with planning and funding water projects and programs that will address the regions’ and state’s pressing water issues.

To assess the available water supply, the common technical approach considers legal and physical constraints on the supply and a range of conditions from severe drought to normal supply. The method to estimate this supply, hereafter referred to as *administrative water supply*, is based on recent diversions, which provide a measure of supply that considers both physical supply and legal restrictions (i.e., the diversion is physically available, permitted, and in compliance with water rights policies) and thus reflects the amount of water that can actually be used by a region. The recent diversion data are also corrected to reflect drought supplies, as discussed in Section 5.5.2.

### 5.5.1 2010 Administrative Water Supply

The total diversions (i.e., administrative water supply) in 2010 for the Lower Pecos Valley region, as reported by Longworth et al. (2013), were nearly 600,000 acre-feet. Of this total, 181,157 acre-feet were surface water diversions and 416,123 acre-feet were groundwater. The breakdown of these diversions among the various sectors of use detailed in the NMOSE water use report is discussed in Section 6.1.

### 5.5.2 Drought Supply

The variability in surface water supply from year to year is a better indicator of how vulnerable a planning region is to drought in any given year or multi-year period than is the use of long-term averages. As discussed in Section 5.1.1, in the Lower Pecos Valley region, 2010 was a year with average or above average precipitation and relatively high snowpack (Figure 5-5) and, according to the PDSI (Figures 5-6a and 5-6b), an above average water year overall. As discussed in Section 5.1, the PDSI is an indicator of whether drought conditions exist and if so, what the relative severity of those conditions is. For the two main climate divisions present in the Lower Pecos Valley region, the PDSI classifications for 2010 were moderately wet (Climate Division 6) and very wet (Division 7). Given that the water use data for 2010 represent a moderately to very wet year, it cannot be assumed that this supply will be available in all years; it is important that the region also consider potential water supplies during drought periods.

There is no established method or single correct way of quantifying a drought supply given the complexity associated with varying levels of drought and constantly fluctuating water supplies. For purposes of having an estimate of drought supplies for regional and statewide water planning, the state has adopted the following method for regions with stream-connected aquifers:
• The drought correction is applied only to the portion of the administrative water supply that derives from surface water, as it is assumed that groundwater supplies will be available during drought due to the relatively stable thicknesses of groundwater aquifers that are continuously recharged through their connection to streams. While individual wells may be depleted due to long-term drought, this drought correction does not include an evaluation of diminished groundwater supplies.

• The minimum annual yield for key stream gages on mainstem drainages (Table 5-4b) was compared to the 2010 yield, and the gage with the lowest ratio of minimum annual yield to 2010 yield was selected.

• The 2010 administrative surface water supply for the region was then multiplied by that lowest ratio to provide an estimate of the surface water supply corrected for the maximum drought year of record.

For the Lower Pecos Valley region, the gage with the minimum ratio of annual yield to 2010 yield is the Pecos River near Malaga, with a ratio of 0.15 for minimum annual yield (9,267 acre-feet in 1977) to 2010 yield (61,320 acre-feet) (USGS, 2014c). Based on the region’s total administrative surface water supply of 181,157 acre-feet (Section 5.5.1), the drought-corrected surface water supply is 27,173 acre-feet. With the 416,123 acre-feet of groundwater supply, the total drought supply is 443,296 acre-feet, or about 74 percent of a normal year administrative water supply.

Though the correction is based on the minimum year streamflow recorded to date, it is possible that drought supplies could be even lower in the future. Recharge to aquifers will diminish during drought and reduce the potential yield of aquifers, and that was not factored into the drought supply. Additionally, water supplies downstream of reservoirs may be mitigated by reservoir releases in early drought phases, while longer-term droughts can potentially have greater consequences. This approach also does not evaluate mitigating influences of reservoir storage in early phases of a drought when storage is available, supplemental wells or potential development of new groundwater supplies. Nonetheless, the corrected drought supply provides a rough estimate of what may be available during a severe to extreme drought year.