Chapter 2: The Middle Rio Grande Basin

Physical characteristics

The Middle Rio Grande Basin covers approximately 3,060 square miles in central New Mexico, encompassing parts of Santa Fe, Sandoval, Bernalillo, Valencia, Socorro, Torrance, and Cibola Counties (fig. 2.1). In this report, “Middle Rio Grande Basin” refers to the geologic basin defined by the extent of deposits of Cenozoic age along the Rio Grande from about Cochiti Dam to about San Acacia. This basin lies almost entirely within the Rio Grande Valley and is equivalent to the Albuquerque Basin of Thorn, McAda, and Kernodle (1993) and Kernodle, McAda, and Thorn (1995). The extent of the Middle Rio Grande Basin has been defined many different ways in different reports; no standard or convention seems to apply.

Alluvial fans are the open-fan or cone-shaped masses of sediment deposited by streams at canyon mouths along a mountain front. *Terraces* are the step-like benches that parallel a stream and represent different climatic and geologic episodes in the stream’s history. *Sand dunes* are mounds of loose windblown sediment ranging in height from inches to hundreds of feet. They are heavily influenced by climate, and their movement can be slowed or stopped by the growth of vegetation on their surfaces (Jackson, 1997).

The Middle Rio Grande Basin lies in an asymmetric, elongated valley along the Rio Grande. The basin encompasses the inner valley, or flood plain, of the Rio Grande and the surrounding terrain that slopes from surface-drainage divides toward the river. The eastern boundary of the basin is largely mountainous, with merging alluvial fans and stream terraces leading downslope to the Rio Grande. The basin surface west of the Rio Grande has only isolated mountains and volcanoes and generally slopes up to a rolling divide to the Rio Puerco (this surface is known as the Llano de Albuquerque). Both active and vegetated sand dunes and dune fields are found throughout the basin.

The Rio Grande inner valley is the area adjacent to the Rio Grande underlain by alluvium of Quaternary age of the most recent cut-and-fill episode of the river. In the basin, the inner valley ranges from approximately 0.5 to 5 miles wide and is incised into older Quaternary alluvium and Santa Fe Group sediments. The inner valley corresponds to the flood plain of the pre-flood-control era (1971).

Alluvium is a general term for sediment deposited by a stream or other running water. Typically, a late Cenozoic age is implied (Jackson, 1997).

Elevation in the Middle Rio Grande Basin ranges from about 4,650 feet above sea level on the Rio Grande at San Acacia to about 8,000 feet on the flanks of the Manzano and Sandia Mountains. However, peaks in the adjacent Jemez, Sandia, and Manzano Mountains are greater than 10,000 feet above sea level, with the highest being Redondo Peak in the Jemez Mountains at 11,254 feet.

Climate

One of the definitions scientists use to define a desert is “a region with a mean annual precipitation of 10 inches or less, and so devoid of vegetation as to be incapable of supporting any considerable population” (Jackson, 1997). By using this definition, much of the Middle Rio Grande Basin may be classified as a desert.

Precipitation generally increases with elevation, and because the elevations of the basin and surrounding mountains span nearly 7,000 feet, Scientists currently understand the Earth to be about 4.7 billion years old. To facilitate the study of rocks and their features, geologists have divided this *geologic time* into a hierarchical system of units characterized by distinct assemblages of rock types and fossils. The time prior to most of the fossil record is known as the Precambrian era, which encompasses the period from 4,700 to 570 million years before the present (Ma). The remaining time until the present is divided into three eras: the Paleozoic (approximately 570 to approximately 240 Ma), Mesozoic (approximately 240 to 66 Ma), and Cenozoic (66 Ma to present) (Press and Siever, 1986; Hansen, 1991; Jackson, 1997).

Era	**Period**	**Epoch**	**Age estimates, in millions of years**
Cenozoic	Quaternary	Holocene	Present – 0.010
		Pleistocene	0.010 – 1.6
	Tertiary	Pliocene	1.6 – 5
		Miocene	5 – 24
		Oligocene	24 – 38
		Eocene	38 – 55
		Paleocene	55 – 66
Mesozoic	Cretaceous		66 – 138
	Jurassic		138 – 205
	Triassic		205 – 240
Paleozoic	Permian		240 – 290
	Pennsylvanian		290 – 330
	Mississippian		330 – 360
	Devonian		360 – 410
	Silurian		410 – 435
	Ordovician		435 – 500
	Cambrian		500 – 570

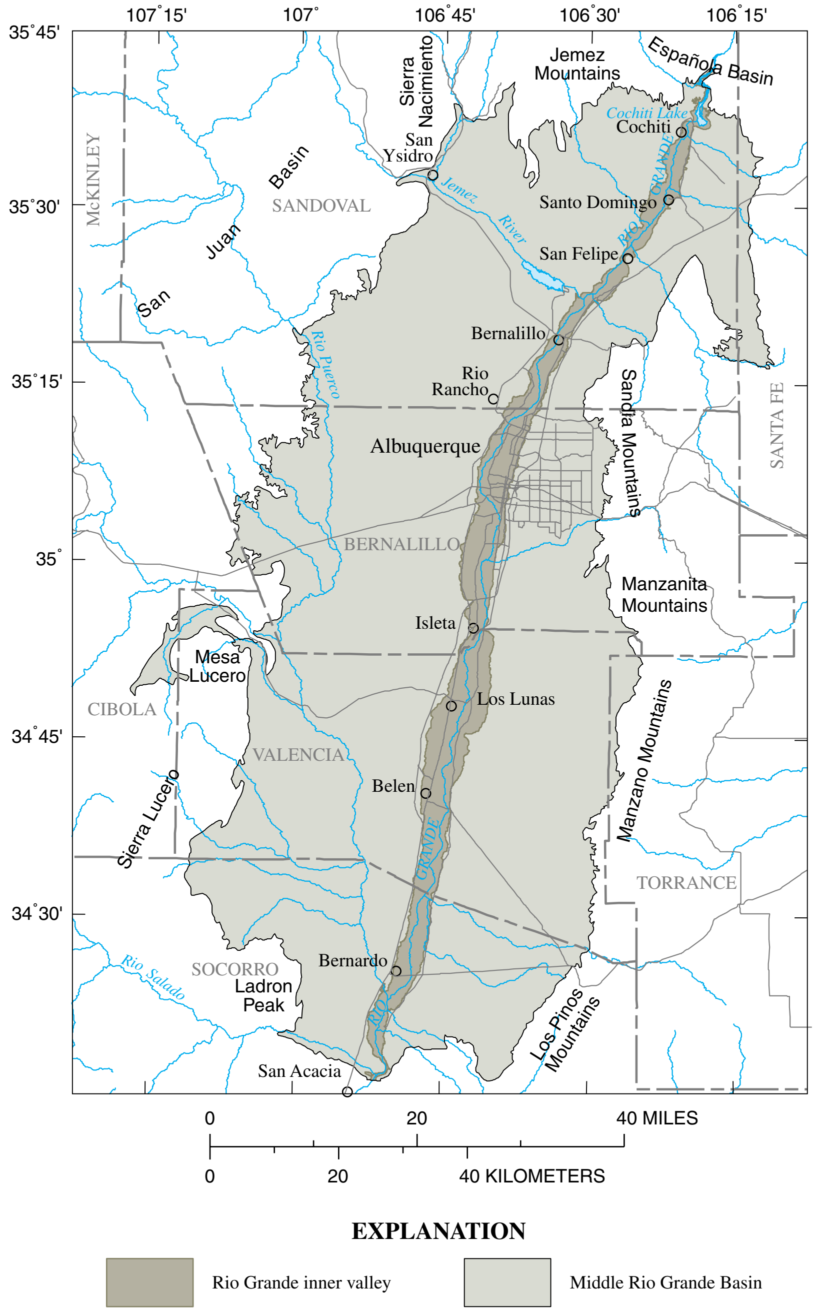


Figure 2.1.—*Major physiographic features of the Middle Rio Grande Basin.*

climate in the basin ranges from arid to humid, though climate over most of the basin is semiarid (based on modified Thornwaite climate types by Tuan, Everard, and Widdison [1969]). The climate is characterized by sunshine and low humidity: Albuquerque receives 77 percent of the possible annual sunshine, and its average annual relative humidity at 5:30 p.m. is 32 percent (Tuan, Everard, and Widdison, 1969).

The National Weather Service has seven weather stations in the Middle Rio Grande Basin with at least 10 years of record (table 2.1). The Sandia Crest station has also been included as representative of conditions in the mountains surrounding the basin. Locations of the weather stations are shown in figures 2.2 and 2.3.

Average annual temperatures at weather stations in the basin range from 54.0° F at the Corrales station to 56.5° F at the Belen station. At the Sandia Crest station, the average annual temperature is 37.6° F. The coldest month in the basin is January, with average temperatures ranging from 33.5° F at the Cochiti Dam station to 35.1° F at the Albuquerque WSFO station. The warmest month is July, with average temperatures ranging from 74.4° F at the Corrales station to 78.5° F at the Belen station. January and July average monthly temperatures are 20.0 and 56.9° F, respectively, at the Sandia Crest station. Average monthly temperatures for the seven weather stations in the basin and Sandia Crest are shown in figure 2.2 (National Weather Service, 2002).

Moisture in storms is derived mainly from the Gulf of Mexico (Tuan, Everard, and Widdison, 1969). July and August are typically the wettest months, though the rainy season may be considered to extend from July through October; 45 to 62 percent of annual precipitation falls during these 4 months (National Weather Service, 2002). Average annual precipitation ranges from 7.6 inches at Belen to about 23.0 inches at Sandia Crest. Average monthly precipitation is shown in figure 2.3. Precipitation in the

Many different formal climate classification systems have been developed, each with its own terminology and basis of classification. However, the two most commonly used classification systems are Thornwaite climate types (based on a ratio of precipitation to evaporation) and Köppen climate types (based on temperature and precipitation). Various authors have modified these two classification systems to meet local, more specific conditions (Gates, 1972).

Table 2.1.—National Weather Service weather stations in the Middle Rio Grande Basin and Sandia Crest station

[National Weather Service (2002). WSFO, Weather Service Field Office; —, still in operation]

Station name	Station number	Latitude	Longitude	Elevation (feet above sea level)	Dates in operation	
					Starting date	Ending date
Albuquerque WSFO	290234	35° 03'N	106° 36'W	5,310	01/01/14	—
Belen	290846	34° 40'N	106° 46'W	4,800	11/01/41	05/31/76
Bernalillo 1 NNE, new	290903	34° 26'N	106° 49'W	5,045	02/01/24	08/31/82
Bernardo	290915	34° 25'N	106° 50'W	4,735	08/01/33	—
Cochiti Dam	291982	35° 38'N	106° 20'W	5,560	02/01/75	—
Corrales	292100	35° 14'N	106° 36'W	5,015	10/06/82	—
Los Lunas 3 SSW	295150	34° 46'N	106° 45'W	4,840	07/01/23	—
Sandia Crest	298015	35° 13'N	106° 27'W	10,680	02/16/53	04/30/79

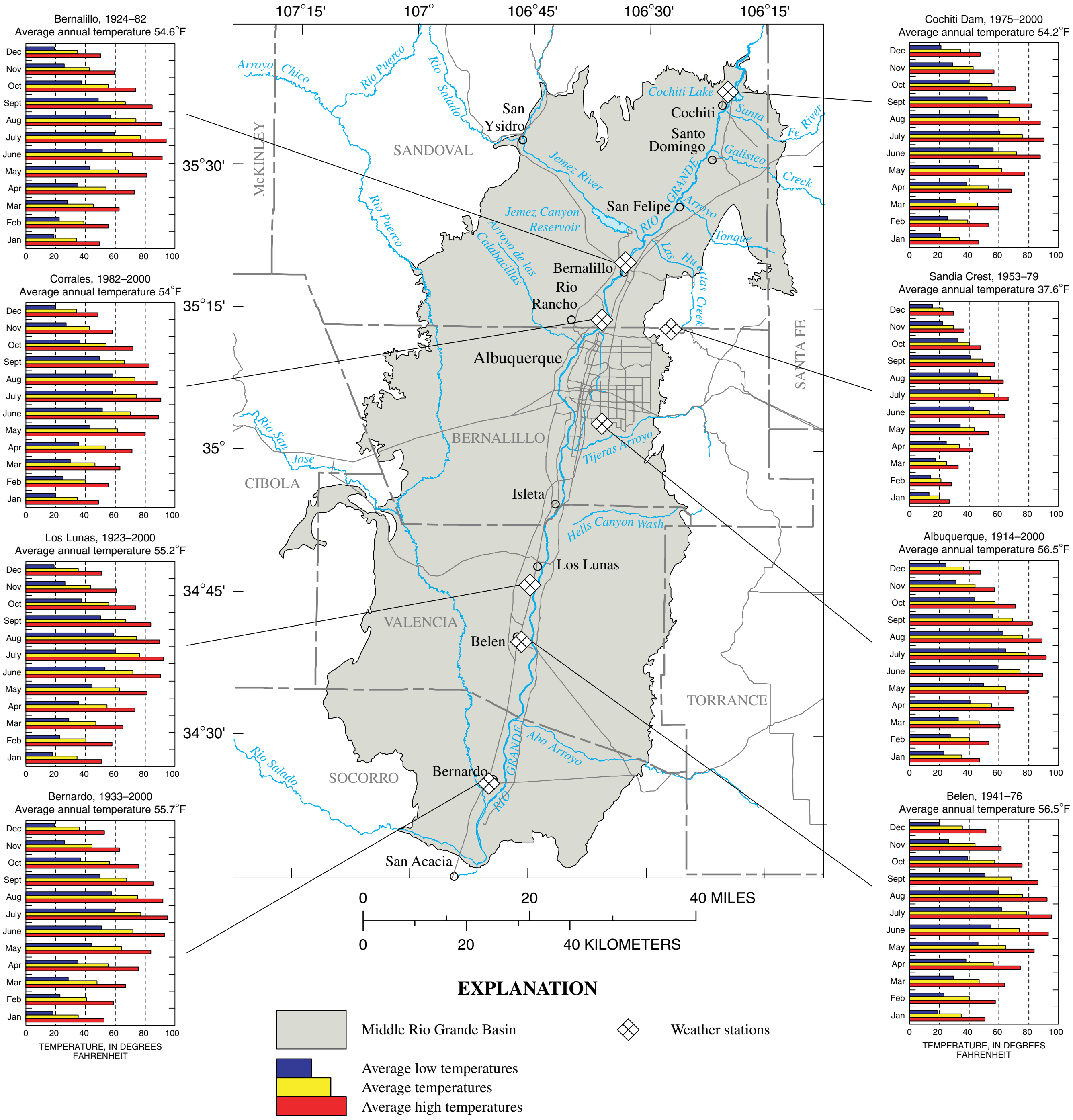


Figure 2.2.*—Average monthly temperatures for selected National Weather Service stations in and near the Middle Rio Grande Basin.*

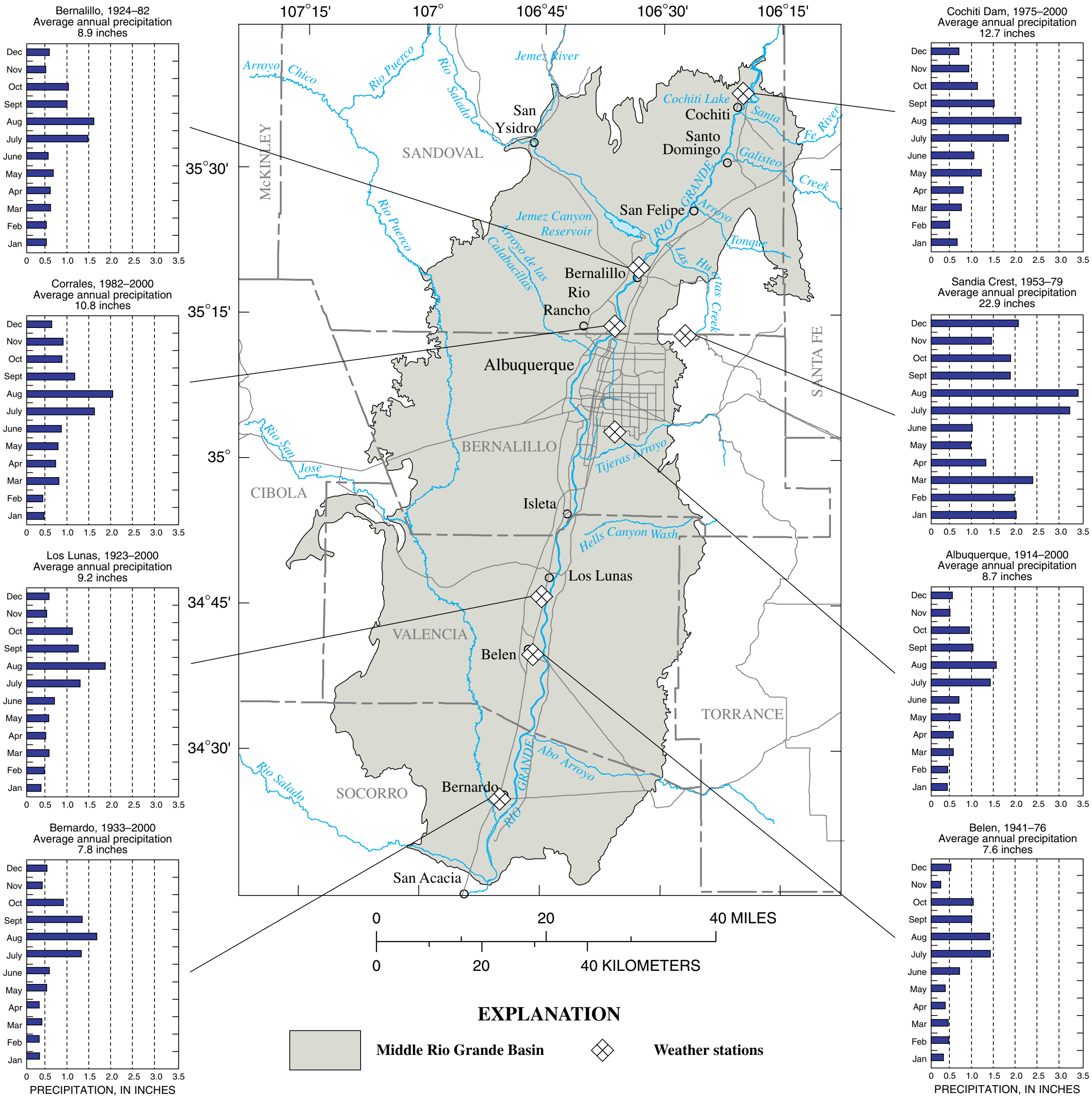


Figure 2.3.—Average monthly precipitation for selected National Weather Service stations in and near the Middle Rio Grande Basin.

The Rio Grande bosque at Paseo del Norte in northern Albuquerque. The tree in the left foreground is a Russian olive and the tallest trees on the opposite bank are cottonwoods.

basin comes from local thunderstorms due to orographic or convective uplift in the summer months and from frontal storms due to the interaction of large masses of air in the winter months (Bullard and Wells, 1992). Because thunderstorms can be localized and short lived, precipitation in the basin can be extremely variable from year to year and place to place.

Evaporation occurs from open water and moist soil; transpiration occurs from plants. Because open bodies of water generally compose a fairly small percentage of the area of continental interiors, hydrologists usually group the combined water loss from evaporation and transpiration into evapotranspiration. Many factors influence evapotranspiration rates, including temperature, windspeed, amount of solar radiation, and humidity. Annual potential evapotranspiration was estimated by Gabin and Lesperance (1977) to be 41.19 inches at Bernalillo, 47.58 inches at Albuquerque, 42.29 inches at Los Lunas, 45.25 inches at Belen, and 39.97 inches at Bernardo. At all these sites, annual potential evapotranspiration is at least four times greater than annual precipitation.

As documented by tree ring and other data, drought has repeatedly occurred in the Southwestern United States at irregular intervals during the past several thousand years, though the complex climatic interactions responsible for triggering and sustaining drought remain poorly understood (National Drought Mitigation Center, 1995). The two most recent major droughts in the Southwest were during 1942–56 and 1976–77 (Thomas and others, 1963; Matthai, 1979). Though the effects of drought on surface-water supplies are usually immediate and obvious, effects on ground-water supplies may not be. In addition to reducing recharge to ground water, drought often forces surface-water users to replace or augment their supplies by pumping from wells.

Periodic water-temperature fluctuations in the eastern equatorial Pacific Ocean, termed El Niño and La Niña, can influence episodes of drought in the Southwestern United States (Conlan and Service, 2000). El Niño conditions are characterized by warmer ocean temperatures and tend to cause an increase in moisture in the Southwest. La Niña conditions are characterized by cooler ocean temperatures and tend to cause drier conditions in the Southwest. Research into these phenomena has increased since the mid-1970's; however, understanding remains incomplete, and patterns and effects cannot yet be predicted with much certainty. For additional information on the climate of the Middle Rio Grande Basin, the reader is referred to Tuan, Everard, and Widdison (1969), Gabin and Lesperance (1977), Scurlock (1998), Scurlock and Johnson (2001), and the National Weather Service (2002).

Major vegetation types

For the present-day Middle Rio Grande Basin and surrounding mountains, Scurlock (1998) defined eight main plant communities, listed in a progression from near the Rio Grande to the mountaintops: riparian, desert grassland, plains-mesa grassland, scrublands, juniper savanna, pinyon-juniper woodlands, ponderosa pine, and subalpine and mixed coniferous forest. Dick-Peddie (1993) further divided the scrubland in the basin into three separate plant communities: Great Basin desert scrub, plains-mesa sand scrub, and montane scrub. Martin (1986) used still another classification system.

The riparian woodland (or bosque) is highly prized for recreation and is protected as the Rio Grande State Park through much of the Albuquerque area. Today, the bosque consists of native species of cottonwood (*Populus deltoids* ssp. *wislizeni*) and willow (*Salix* sp.), as well as introduced exotic species, mainly Russian olive (*Elaeaganus angustifolia*) and tamarisk or salt cedar (*Tamarix pentandra* and *Tamarix chinensis*). Currently (2002) the bosque covers the flood plain of the river between the levees; when the Spanish arrived in the 16th century, however, the flood plain supported scattered stands of predominantly cottonwood and willow (Bogan, 1998; Scurlock, 1998). The construction of flood-control projects since 1925 has stabilized the channel of the Rio Grande and eliminated the periodic flooding now considered necessary for cottonwood reproduction (Finch and others, 1995). Though reduced cottonwood reproduction is an issue, the largest factor in the change in composition of the bosque was the introduction of the exotic species prior to 1900 (Campbell and Dick-Peddie, 1964).

The bosque assumed its present character fairly recently, as can be seen in the photographs shown in figure 2.4. In the past 60 to 70 years, the bosque has developed in an area that was formerly semi-barren flood plain. A similar change can be seen in two oblique aerial photographs in a report by Ground-Water Science, Inc. (1995).

From a water-resources perspective, the bosque is of importance because it is composed largely of phreatophytes. Along the Rio Grande, the amount of riparian vegetation has increased (Ground-Water Science, Inc., 1995); therefore, it is probable that more water is required to maintain the dense vegetation of the bosque today than was required for the scattered stands of cottonwood and willow that existed in the past. Ground-Water Science, Inc. (1995) estimated that evapotranspiration from riparian vegetation and evaporation from open water account for about two-thirds of surface-water consumptive use in the basin.

The remaining plant communities in the Middle Rio Grande Basin are of less interest from a hydrologic standpoint. Most have been altered by human activities such as grazing, fire suppression, and logging, as well as natural factors such as climatic variation (Scurlock, 1998). Detailed descriptions of these plant communities are in Dick-Peddie (1993) and Scurlock (1998).

Phreatophytes are plants that extend their roots to the water table. A phreatophyte acts as a pump by transporting ground water (in the Middle Rio Grande Basin, the source often is ultimately the river) upwards to be transpired from leaf surfaces. Tamarisk, willows, Russian olive, and cottonwood are all phreatophytes. In the past, phreatophyte-control projects were conducted along streams such as the Pecos River to enhance streamflow (Welder, 1988). The mixed success of these efforts, changing esthetic values, and threatened and (or) endangered-species issues have curtailed such efforts.

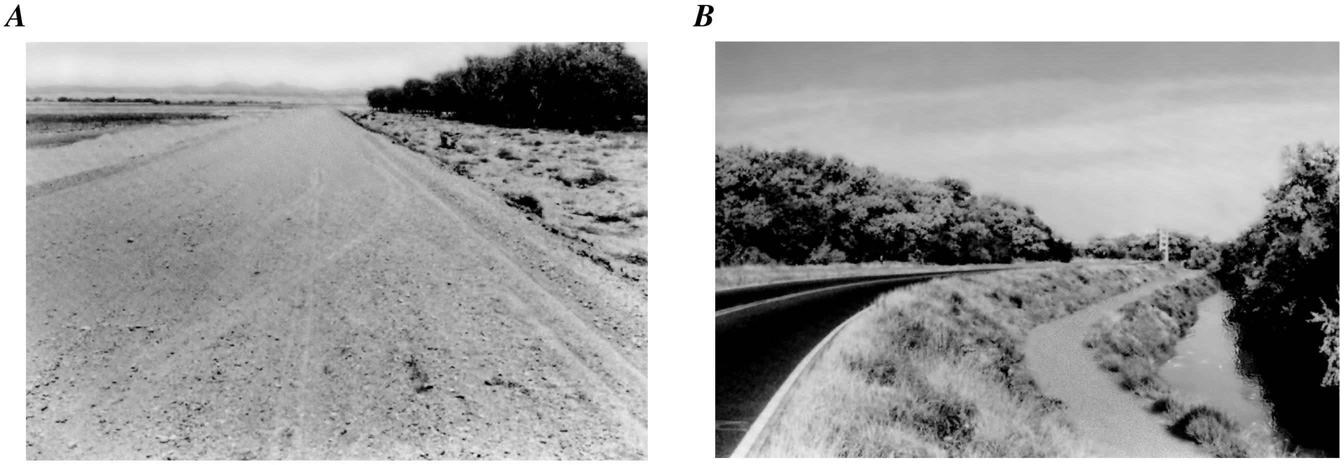


Figure 2.4.*—Photographs looking west across the Rio Grande toward the Albuquerque volcanoes. Photograph (A) was taken in the early 1930’s (courtesy of the Middle Rio Grande Conservancy District). Photograph (B) was taken in 1994 at the same location (courtesy of Gary Daves, City of Albuquerque Public Works Department).*

Farming in the Middle Rio Grande Basin is important for several reasons. Water use by irrigated agriculture in the basin is several times that of urban use, and because irrigated agriculture predates substantial urban growth in the basin, most senior water rights are held by irrigators. As part of its Middle Rio Grande Basin Water Assessment study, the Bureau of Reclamation developed crop-acreage estimates and cropping patterns for the basin, by county, from June 1992 aerial photography (Kinkel, 1995). These estimates were then compared to New Mexico Office of the State Engineer and New Mexico State University estimates. The Bureau of Reclamation estimates indicate that nine main crop types were being cultivated in the basin, including pasture. The most abundant crop type was alfalfa, composing 42 to 62 percent of the cultivated area in each county. The remaining crop types each covered less than 30 percent of the total crop area (Kinkel, 1995).

Another irrigated "crop" is turf grass in residential yards, parks, golf courses, and other urban land. In 1992, turf grasses in urban areas were the second most abundant crop (in terms of planted acreage) in Bernalillo County, after alfalfa. In Sandoval, Socorro, and Valencia Counties, turf-grass acreage composed a very minor percentage of total irrigated acreage (Kinkel, 1995). Nevertheless, Ground-Water Science, Inc. (1995) estimated that turf grasses in the Middle Rio Grande Basin transpired about 12,000 acre-feet of water in 1990.

In 1992, turf grasses in urban areas, such as this golf course, were the second most abundant crop (in terms of planted acreage) in Bernalillo County, after alfalfa.

Human activities and water resources

Water-resource managers and scientists use the term *acre-feet* to describe a particular volume of water. One acre-foot is the amount of water it takes to cover 1 acre 1 foot deep in water. Though the term had its origins in describing irrigation diversions, it is used in referring to any large volume of water. One acre-foot is equivalent to 43,560 cubic feet or about 325,829 gallons.

More than 10,000 years of human settlement along the Rio Grande has been documented (Ware, 1984). By the 10th century, primitive irrigation systems had been developed in parts of New Mexico (Bullard and Wells, 1992), and by the early to mid-1300's, most of the "major, historic" pueblos in the Rio Grande drainage had been founded (Scurlock, 1998). As the pueblos developed the water resources along the Rio Grande, populations began to abandon smaller villages and consolidate into the larger pueblos. The habitation of these pueblos was largely dependent on water, and they were often abandoned permanently or temporarily during drought (Scurlock, 1998).

Spanish settlement in New Mexico began in 1598 with a settlement at San Juan Pueblo and spread into the Middle Rio Grande Basin as far south as Isleta Pueblo by the 1620's. Bernalillo was founded in 1700, Albuquerque in 1706, and Tomé (between Los Lunas and Belen) in 1739. The Spanish began development of the current irrigation system, patterned after the community irrigation ditches (or acequias) of the pueblos (Wozniak, 1987). This acequia system was a successful means of assuring access to irrigation water and replenishing topsoil and nutrients depleted by farming. The Spanish continued to develop the irrigation system along the Rio Grande throughout the colonial period (Scurlock, 1998). Early settlers dug shallow wells in unconsolidated river alluvium for domestic use (Kelly, 1982).

Acequia is the Spanish word for irrigation ditch. It can also refer to a community-owned or maintained irrigation system, which is maintained by an acequia association.

Most of New Mexico passed into the possession of the United States in 1848 with the Treaty of Guadalupe-Hidalgo. In the 1850's, farms increased in number, size, and value in the Middle Rio Grande Basin as a result of the increasing number of Anglo farmers who introduced new crops, farming techniques, and equipment, including barbed wire and the steel plow. The arrival of the Santa Fe Railroad and other rail lines around

1880 accelerated the influx of Anglo settlers. Albuquerque's population was 1,307 in 1880 (Ground-Water Science, Inc., 1995). Territorial legislation was enacted to protect existing irrigation systems, farms, and irrigation rights; subsequent Federal legislation stimulated irrigation development in the region. Irrigated acreage probably peaked sometime in the early 1890's, after which "droughts, sedimentation, aggradation of the main channel, salinization, seepage, and waterlogging" caused total acreage to decline (Wozniak, 1996). By 1889, the Rio Grande did not flow downstream from Albuquerque for 4 months of the year (Wozniak, 1996). Increased irrigation diversion of the Rio Grande upstream in the San Luis Valley of Colorado was responsible for at least some of these problems (Wozniak, 1996). During this period, most of the water for domestic use came from hand-dug wells (Scurlock, 1998).

The municipal water-supply system for Albuquerque started as a private utility with a few shallow wells around the time the city incorporated in 1885 (Daves, 1994; Ground-Water Science, Inc., 1995). Daves stated that the first municipal-supply well for Albuquerque was completed in 1875. By 1904, there were several wells more than 200 feet deep (the deepest well was 710 feet deep) and one 65-foot-diameter dug well (Lee, 1907). The public sewage system began discharging untreated effluent into the Rio Grande in 1891–92; rudimentary treatment of the effluent began in 1919 (Ground-Water Science, Inc., 1995).

Prior to the First World War, Albuquerque became a regional trade and railway center serving the largely agricultural economy in the Middle Rio Grande Basin. By 1910, the city had a population of 11,200 (Ground-Water Science, Inc., 1995). Following the First World War, further development of the automobile and the opening of U.S. Route 66 in 1926 reinforced Albuquerque's status as a regional trade and tourism center (Reeve, 1961). Bernalillo, Los Lunas, and Belen also experienced growth around their railroad depots, though at a slower rate than Albuquerque (Ground-Water Science, Inc., 1995).

The Albuquerque area began to grow significantly during the Second World War, and postwar growth led to a population increase in Albuquerque from about 35,000 to about 200,000 people between 1940 and 1960 (Reeve, 1961). After an infrastructure redesign in 1948, an expanding network of municipal-supply wells supported the water needs of this growing population (Ground-Water Science, Inc., 1995), though little thought was given to monitoring or characterizing the ground-water resources of the basin. In about 1950, several Albuquerque municipal-supply wells were pumped dry, leading one of the major figures in the science of hydrogeology, C.V. Theis, to make the rather pointed remark, "What happened was that the city got a notice from its bank that its account was overdrawn and when it complained that no one could have foreseen this, only said in effect that it had no bookkeeping system" (Theis, 1953). These and other ground-water-supply problems led to the first efforts to understand the hydrogeology of the Middle Rio Grande Basin. Nevertheless, most people in the basin continued to believe that the aquifer beneath Albuquerque contained a volume of freshwater equivalent to one of the Great Lakes (Niemi and McGuckin, 1997).

Scientific studies completed in the early 1990's (such as Hawley and Haase, 1992; Thorn, McAda, and Kernodle, 1993; and Kernodle, McAda, and Thorn, 1995) provided a much more comprehensive understanding of the ground-water system of the Middle Rio Grande Basin and showed conclusively that Albuquerque was withdrawing water from the aquifer faster than the water was being replenished (City of Albuquerque

The Albuquerque skyline from the west. (Courtesy of R.A. Durall, USGS.)

Name a great American city on a large body of water: Albuquerque.
Each year the Rio Grande Basin, an underground lake larger than Lake Superior, yields over 30 billion gallons to the City's wells serving 109,000 residential and commercial Albuquerque customers. At the projected rate of growth, the City's present water rights holdings will allow Albuquerque to tap this vast underground lake well into the twenty-first century.
—Paid advertisement, *Albuquerque Living* magazine, October 1984.

Public Works Department, 1997b). This led the City of Albuquerque to revise its water-use strategy and actively encourage water-use conservation and move toward the direct use of native Rio Grande water and San Juan-Chama Project water diverted into the Rio Grande upstream from the city (Brown and others, 1996; City of Albuquerque Public Works Department, 1997b; Niemi and McGuckin, 1997). (The San Juan-Chama Project is discussed on page 67.)

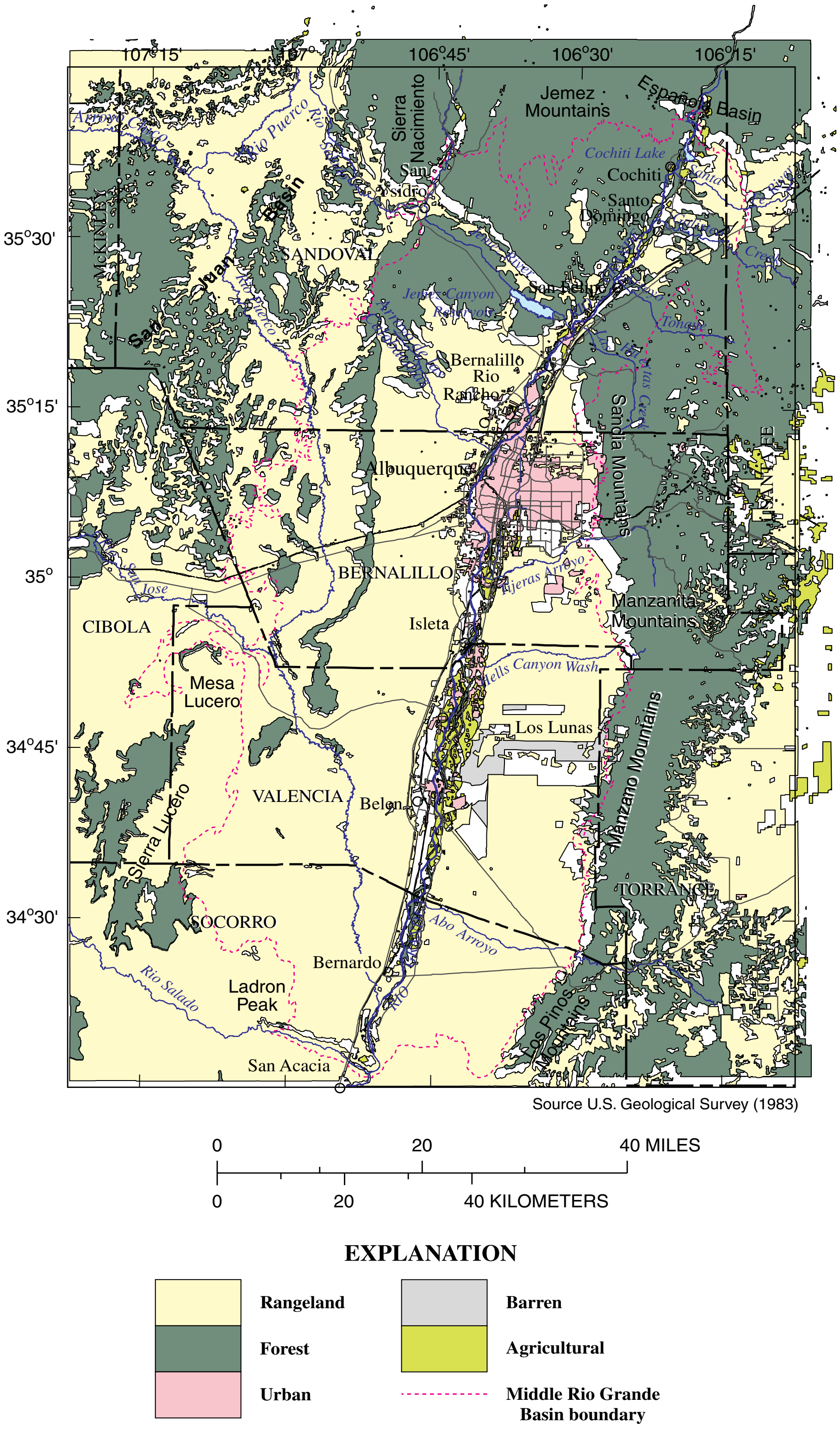
In 2000, the population of the Middle Rio Grande Basin was about 690,000 or about 38 percent of the population of New Mexico. The steady population increase in New Mexico, Albuquerque, and the Middle Rio Grande Basin since 1900 is listed in table 2.2. Other than the growth of Albuquerque as a percentage of the population of New Mexico, the most interesting aspect of these data is the decrease in 2000 of Albuquerque's population as a percentage of the population in the Middle Rio Grande Basin.

The population increase in the Middle Rio Grande Basin has led to the urbanization of irrigated agricultural land in the inner valley of the Rio Grande, as well as an increase in population in other communities in the basin including Rio Rancho, Los Lunas, Belen, Corrales, and Bernalillo. Currently (2002), residential development in response to economic growth in the Middle Rio Grande Basin is occurring primarily west and northwest of Albuquerque, in and east of the Los Lunas-Belen area, and outside the basin in the east mountain area (east of the Sandia, Manzanita, and Manzano Mountains). Secondary residential development is occurring on the north and south margins of Albuquerque, as well as on plots of vacant land within the Albuquerque city limits. A land-use and land-cover map of the Middle Rio Grande Basin in the early 1980's is shown in figure 2.5.

Table 2.2.—Population in New Mexico, Albuquerque, and the Middle Rio Grande Basin, 1900–2000

[Data from Thorn, McAda, and Kernodle, 1993; Ground-Water Science, Inc., 1995; Famighetti, 1997; U.S. Census Bureau, 2001a, 2001b; --, no data]

Year	Population			Percentage of population		
	New Mexico	Albuquerque	Middle Rio Grande Basin	Middle Rio Grande Basin/ New Mexico	Albuquerque/ Middle Rio Grande Basin	Albuquerque/ New Mexico
1900	195,310	6,238	--	--	--	3.2
1910	327,301	11,200	--	--	--	3.4
1920	360,350	15,160	--	--	--	4.2
1930	423,317	26,570	--	--	--	6.3
1940	531,818	35,400	--	--	--	6.7
1950	681,187	96,800	--	--	--	14
1960	951,023	201,200	--	--	--	21
1970	1,017,055	244,500	314,900	31	78	24
1980	1,303,302	332,900	419,000	32	80	26
1990	1,515,069	384,600	563,600	37	68	25
2000	1,819,046	448,600	690,000	38	65	25



Source U.S. Geological Survey (1983)

Figure 2.5.—*Generalized land use and land cover in the Middle Rio Grande Basin in the early 1980's. This is currently (2002) the most recent land-use and land-cover map of the entire basin.*

A

Landscape change modeling

David J. Hester[1] and Mark R. Feller[1]

The landscape changes that result from the growth of metropolitan areas are one subject of the USGS Land Cover Characterization Program. By using historical maps, aerial photography, and satellite imagery, scientists construct databases showing how urban land use has changed over several decades. These databases are then used to analyze how urbanization has affected the landscape as well as to model urban growth and land-use change to project future growth patterns and changes under different scenarios (U.S. Geological Survey, 1999).

The extent and characteristics of an urban area and its infrastructure are the result of differing social, economic, and environmental conditions. Understanding the factors that have contributed to shaping an urban area is essential for gaining an insight into the processes that will influence its growth and change in the future. Such an understanding can then be used to construct computer simulations (models) for projecting urban-landscape change in the future.

In the Albuquerque area, human-induced land changes were characterized by mapping the shape and extent of Albuquerque's urban area as it evolved over time (table A.1 and figs. *A.1* and *A.2*). Although Albuquerque has grown both on vacant land within developed areas (infill development) and on the fringes of developed areas (new development), the long-term trend was greater dispersed development, leading to an increase in the size of the urban area (urban expansion).

Table A.1.—Urban growth in Albuquerque, 1935–2050. Projections for 2050 are based on SLEUTH model output

[--, not applicable]

Year	Urban area (acres)	Percent growth	
		Cumulative, since 1935	Since previous period
1935	4,372.2	--	--
1951	15,397.9	252	252
1973	49,746.1	1,038	223
1991	84,889.3	1,842	71
2050	124,608.5	2,750	47

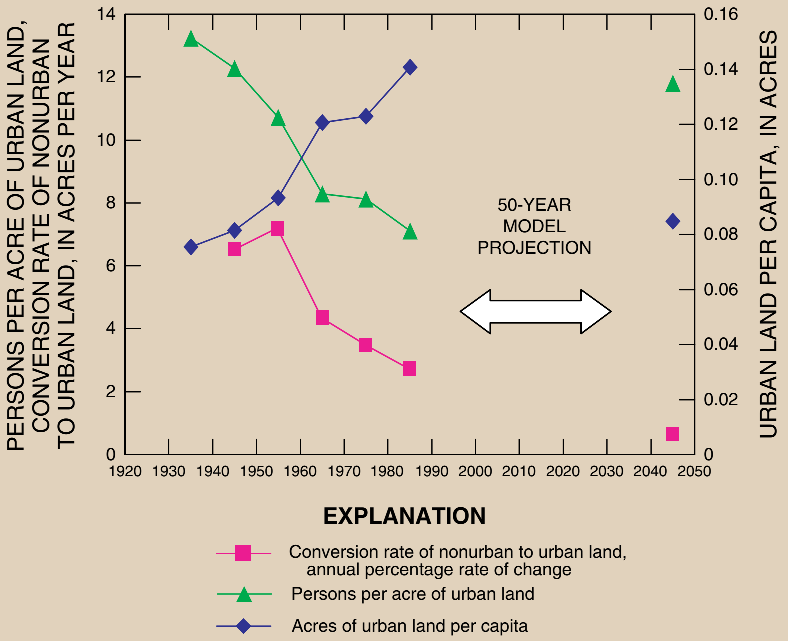


Figure A.1.—*Changes in urban characteristics for Albuquerque, 1935–2050. Projections for 2050 are based on University of New Mexico Bureau of Business and Economic Research population estimates.*

---

[1] U.S. Geological Survey, Denver, Colorado.

Assuming that redevelopment (the transition of an existing or prior land use into another land use category) did not contribute to the total urban area, the amount of urban land in the Albuquerque area per person (shown as acres of land per capita in fig. *A.1*) approximately doubled from 1940 to 1990.

As part of the Middle Rio Grande Basin Study, the USGS modeled the Albuquerque area using the **S**lope, **L**and Use, **E**xclusions, **U**rban, **T**ransportation, and **H**illshade (SLEUTH) urban-growth model developed by the University of California-Santa Barbara (U.S. Geological Survey, U.S. Environmental Protection Agency, and University of California-Santa Barbara, 2001). The SLEUTH model is used to estimate the probability of an area becoming urbanized by using a database of contemporary land-surface characteristics (such as the current extent of urban lands, land-surface slopes likely to develop, lands excluded from development, and probable effects of the existing road network on future land-use patterns). For the Albuquerque area, simulations projected the urbanized area extent in 2050. This 50-year projection was chosen to correspond with the FOCUS 2050 Regional Plan of the Middle Rio Grande Council of Governments (Middle Rio Grande Council of Governments, 2000).

Because conditions in 1935 and 1991 are known (fig. *A.2, A* and *B*), model runs simulating the period 1935–91 were used to adjust model parameters in order to match the known conditions in 1991 (model calibration). Once a composite score indicated the “best” combination of variables, a projection between 1991 and 2050 was run. The resulting projection is shown in figure *A.2, C*. If the trend of dispersed development in the Albuquerque area continues until 2050, approximately 125,000 acres of the Middle Rio Grande Basin landscape will be urbanized, with a resulting population density of 11.8 persons per urban acre (fig. *A.1*).

The goal of landscape-change modeling is to provide accurate scientific information such as basic data (such as historical and contemporary landscape characteristics), projections (such as the 2050 simulated urban landscape that was forecast using SLEUTH), and perspectives (such as “land-surface characterization” analyses calculated from historical, contemporary, and future landscapes that can be used to analyze urbanization trends, rates, patterns, and densities) to help managers form sound policies for guiding sustainable growth. Because the Albuquerque area is surrounded by numerous boundaries with Federal and pueblo lands and because the availability of water may ultimately be limited, decisions on growth can only be improved by realistic projections of growth patterns and changes based on scientific methods.

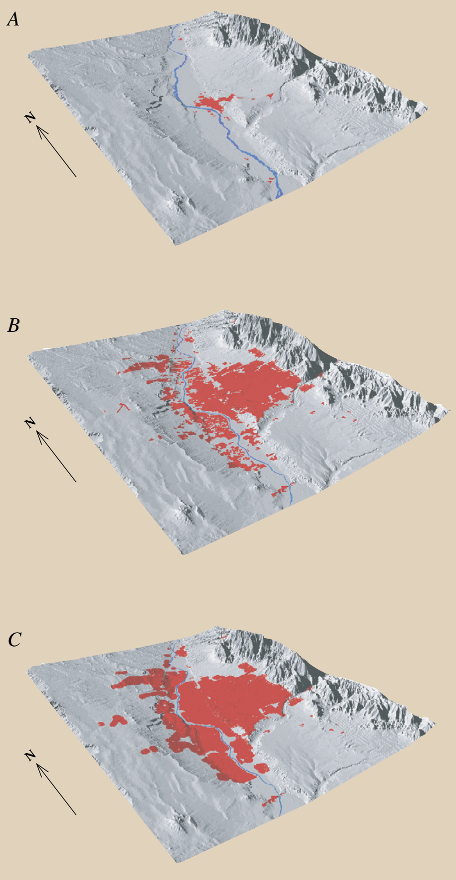


Figure A.2.—*Urban area in the vicinity of Albuquerque in (A) 1935, (B) 1991, and (C) 2050 projected using the SLEUTH model.*