CHAPTER 2

Hydrogeologic Framework

Chapter 2

HYDROGEOLOGIC FRAMEWORK

Introduction

The quantity and quality of ground water available in the Albuquerque Basin is determined by complex relationships between the Basin's geologic framework and its surface and ground-water hydrology. Hydrogeology is the science of subsurface ground-water reservoirs or aquifer systems. The substance of this chapter is based on studies performed as part of the Assessment by John Hawley of the New Mexico Bureau of Mines and Mineral Resources (Hawley and Whitworth, 1996). The chapter has two parts. The first part is a general description of the Basin's hydrogeologic framework and the history of its evolution and development. The second part describes the major hydrogeologic features of the Basin in more specific detail.

For purposes of hydrogeologic discussions, the Basin is expressed topographically as the valley and mesa area between the Colorado Plateau (in the west) and the Sandia-Manzano-Los Pinos Mountain range (to the east) that extends southward from Cochiti Reservoir and the Jemez Mountains to the constriction of the Rio Grande Valley at San Acacia. The Basin is a series of deep structural **depressions** of the earth's crust filled by thick sedimentary deposits designated as the **Santa Fe Group**.

Recent studies clearly indicate that much of the aquifer system of the Albuquerque Basin is not as well connected with the Rio Grande and its tributaries as has been previously thought.

Recent studies (Hawley and Haase, 1992; Kernodle, McAda, and Thorn, 1995; Thorn, McAda, and Kernodle, 1993; Hawley, Haase, and Lozinski, 1995; Hansen, in press[a]; Hansen in press[b]; Gould, 1994; Pruit and Bowser, 1994; Hawley and Whitworth, 1996; and Thomas, 1995) clearly indicate that much of the aquifer system of the Basin is not as well connected with the Rio Grande and its major tributaries as has been previously thought. Recharge of the regional aquifer is not occurring at a rate that is adequate to keep pace with ever increasing withdrawal demands. The underlying structure of the Basin and the distribution and character of sedimentary fill deposits are of primary importance in determining the extent, efficiency, and effectiveness of natural and artificial aquifer recharge.

The underlying structure of the Basin and the distribution and character of sedimentary fill deposits are of primary importance in determining the extent, efficiency, and effectiveness of natural and artificial recharge.

A major objective of recent interagency study efforts was to develop a practical working concept of the Basin's hydrogeologic framework based on a synthesis of available geologic, geophysical, and geochemical data. Significant improvement in the conceptual model of the basin-fill aquifer system (Hawley and Haase, 1992; Hawley and Whitworth, 1996) and a better definition of the internal structure, composition, and physical limits of the Albuquerque Basin have resulted from these investigations. This information is useful in developing fundamental concepts for overall management of regional water resources and in constructing an up-to-date numerical computer model of the interconnected surface water and ground-water systems.

Hydrogeologic Setting of the Albuquerque Basin

A major objective of recent interagency study efforts was to develop a practical working concept of the Basin's hydrogeologic framework.

The Albuquerque Basin is in the central part of a north-south-trending series of similar deep structural depressions that, with their flanking plateau and mountain uplifts, comprise the **Rio Grande Rift** (Rift) structural province (Chapin and Cather, 1994; and other papers in Keller and Cather, 1994). Rift zones are continental scale tectonic features produced by extension of the earth's crust. They are characterized by differential uplift at their margins and subsidence of central depressions. The Rift has formed during the past 25 million years and extends through New Mexico from the San Luis Basin of south-central Colorado to the Mesilla and Hueco Bolsons in southern New Mexico and western Texas. All sedimentary and volcanic basin fill deposited in the Rift depressions prior to initial incision of the Rio Grande Valley system about 1 million years ago is included in the **Santa Fe Group**. The term "**valley fill**" refers to younger flood plain, terrace, and other alluvial deposits that partly fill the modern valleys of the mainstem Rio Grande and its tributaries.

Much of the Basin surface is a broad lowland area of stream valleys and intervalley tablelands (mesas) flanked by the high Sandia-Manzano Mountain range on the east and the Colorado Plateau and Ladron Mountain areas on the west. The inner Rio Grande Valley from Cochiti to San Acacia is a slightly channelized flood plain flanked by gently sloping terraces and mesas. The Rio Puerco Valley has a similar topographic setting, but it is characterized by a deeply incised inner channel (arroyo) cut as much as 40 feet below the historic valley floor.

If we were to peel away all the sedimentary deposits and volcanic intrusions of the past 25 million years, we would see a rugged topography with as much as 15,000 feet of local relief forming deep basins, mountain ridges, valleys, etc. To a large degree, these structural features, and the basin fill that buries and is deformed with them, determine the characteristics of the ground-water system of the Albuquerque Basin.

Basin Subsidence and Filling by the Santa Fe Group

The process that formed the Rio Grande Rift began in late Oligocene time, about 25 to 30 million years ago, and it continues to the present day. The Rift formed as the earth's crustal plates extended, sheared, and separated along preexisting zones of structural weakness. Deep structural depressions formed as great fault-bounded blocks, or grabens, gradually subsided within the Rift. Some of these blocks are significantly tilted, and the depth within individual depressions or subbasins may vary considerably from side to side or from end to end.

The Albuquerque Basin is made up of five major fault block depressions.

The Albuquerque Basin has long been described in terms of three major hydrologic and surficial geologic subbasins: the Santo Domingo, Albuquerque, and Belen Basins. The Albuquerque and Belen Basins have also been referred to as the Albuquerque-Belen or the Northern and Southern Albuquerque Basins in other reports. In terms of deep structure, however, the Basin is now known to be made up of five major fault block depressions, here designated the Cochiti-Bernalillo, Metro Area, Wind Mesa, Lunas-Bernardo, and Lower Puerco Depressions, that are separated by more slowly subsiding buried ridges and other structural "highs" such as horsts and anticlines. The major depressions can be further divided into subbasins, some of which will be referred to in later, more detailed discussions. The locations and boundaries of these five depressions and dividing features are shown in figure 2-1.

Over time, the Rio Grande and antecedent river systems have moved all over the basin floor distributing and redistributing the basin-fill sediments.

Over time, the Rio Grande and antecedent river systems have moved all over the basin floor, distributing and redistributing sediments and filling the basin depressions as they gradually subsided. Generally, these river systems have tended to follow axes of maximum basin subsidence. During the first 20 million years of fault block subsidence, an ancient southward flowing stream system carried the bulk of the lower and middle Santa Fe Group sediments into the Basin. Most of these deposits are very fine grained and include thick playa-lake sediments in central-basin areas. There is no geologic evidence that this river and lake system connected with basins south of Socorro until about 5 million years ago.

By about 5 million years ago, a through-flowing river, the ancestral Rio Grande, became well established. This river drained at least as far south as the Engle and Jornado Basins near San Marcial and the present headwaters of Elephant Butte Reservoir. Sediments carried into the basin by this through-flowing river system continued to fill the Basin for the next 4 million years. All fill deposited in the Albuquerque Basin during this time is included in the **Upper Santa Fe Group** (Hawley et al., 1969; Hawley, 1978; Lozinsky and Hawley, 1986; Chapin, 1988).

The Albuquerque Basin's best aquifers exist in the relatively thin upper layers of the Santa Fe Group deposits.

The Santa Fe Group deposits have a maximum thickness of about 15,000 feet, and they constitute the major aquifer system of the Albuquerque Basin. The qualities and attributes of the Basin aquifer are determined, to a very large degree, by the distribution and characteristics of Santa Fe Group sedimentary fill. Fine grained sedimentary deposits, because they are relatively impermeable, are poor aquifers. Better aquifers are found in coarser grained, more permeable deposits. The Albuquerque Basin's best aquifers exist in the relatively thin upper layers of the Santa Fe Group. These layers rarely exceed 1,000 feet in saturated thickness. Lower and middle parts of the Santa Fe Group form the bulk of basin fill, but these tend to be fine-grained deposits.

Figure 2-2 illustrates how relatively thin the Upper Santa Fe Group deposits are under Albuquerque, compared to the Middle Santa Fe Group. The only aquifers that appear to have potential for production of large amounts of good quality ground water from the Lower and Middle Santa Fe Group are buried dune sands and coarse-grained fan-delta deposits in the Middle Santa Fe Group beneath northern Rio Rancho and Corrales.

Several factors account for variability in the characteristics of basin fill sediments. The prevalence of finer grained sediments in the Lower and Middle Santa Fe Group is partly due to the derivation of these materials from fine-grained marine and continental sediments in the Colorado Plateau and the southern Rocky Mountains. Also, until about 10 to 15 million years ago, the surrounding relief in much of the region was relatively low. Consequently, the streams transporting sediments into the Basin had relatively low energy, and the watersheds were small. These low energy streams were not capable of transporting and distributing great quantities of larger grained sediments. Furthermore, although closed basin, lake, and playa depositional environments existed in the most rapidly subsiding areas throughout the history of Santa Fe Group deposition, they occurred more extensively in earlier stages of Basin filling. These low lying areas tended to accumulate the finest grained sediments and precipitates.

The looser, less consolidated, and coarser grained sand and gravel deposits of the Upper Santa Fe Group that form the most productive aquifers of the Albuquerque Basin were deposited during an episode of more rapid uplift and subsidence along the Rio Grande Rift. Streams bringing sediments into the Albuquerque Basin were steeper, had more energy, and were capable of transporting larger grained sediments. Channel deposits of the through-flowing ancestral Rio Grande are among the most hydraulically conductive of the regional aquifer materials.

Ridges, Highs, and Gaps

Buried ridges and highs control the movement of ground water and significantly define the character of the aquifer system.

The deep structural depressions of the Albuquerque Basin are separated by more slowly subsiding structural ridges and other buried topographic highs consisting of less permeable older basin fills and bedrock units. These features generally lie along or are bounded by major fault zones, and they were buried as the basin filled. They control the movement of ground water and significantly define the character of the aquifer system.

Gaps formed by saddles in buried ridges and structural highs are passages for movement of ground water between adjacent depressions and subbasins. These underground gaps rarely

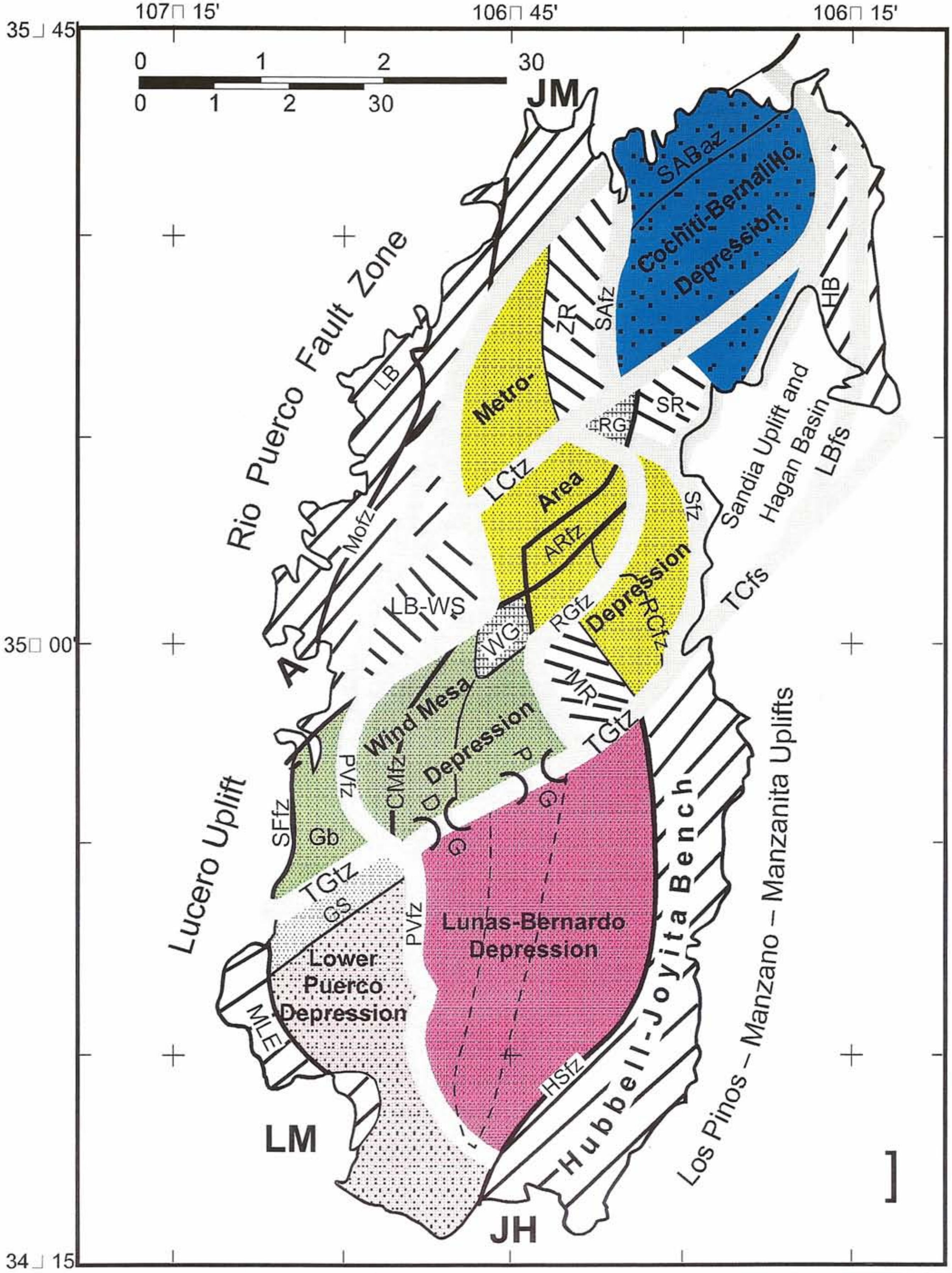

Figure 2-1.—Major intrabasin depressions, interdepression structural highs, and fault zones.

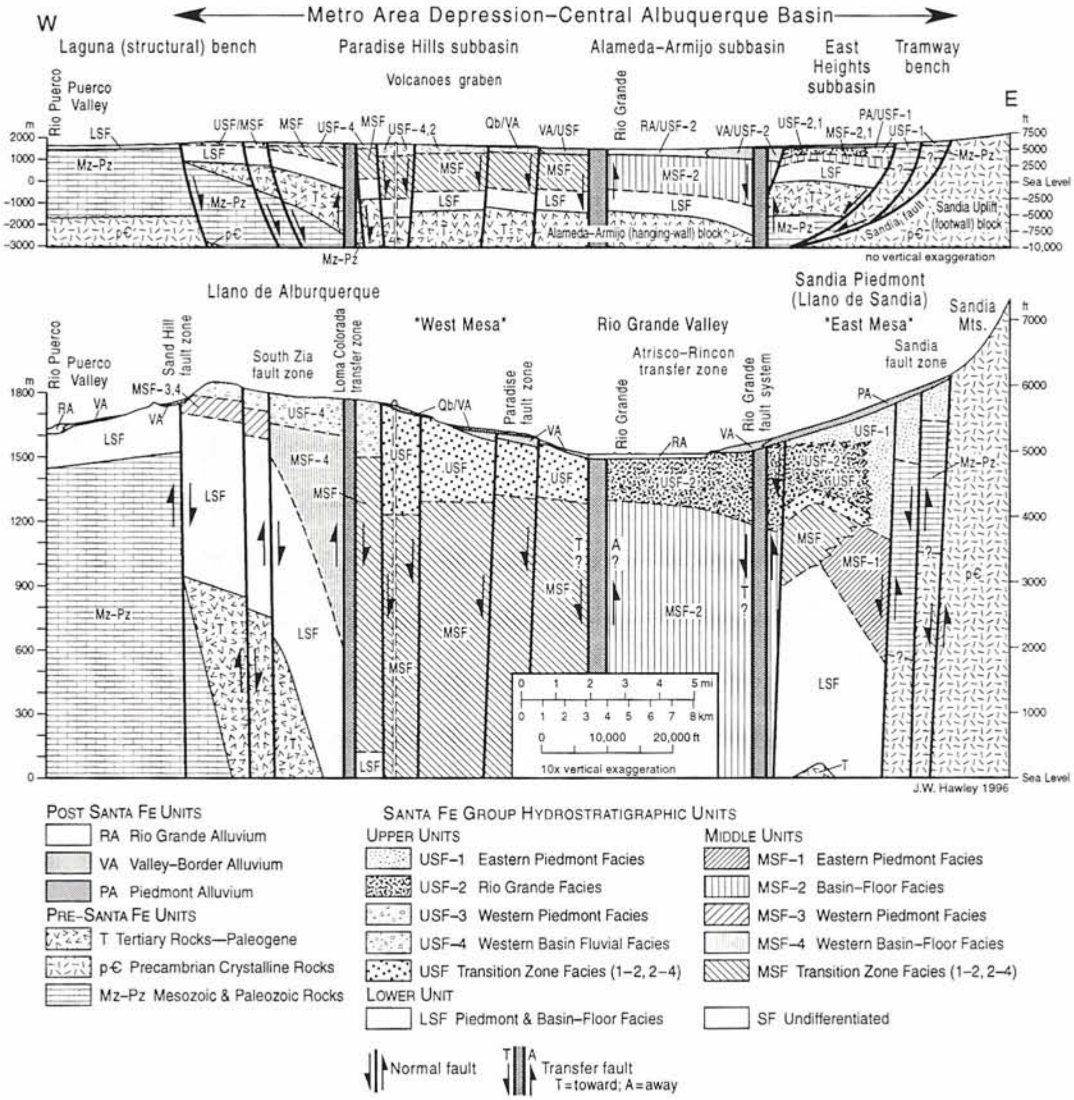

Figure 2-2.—Comparison of Metro Area Depression's hydrostratigraphic cross section with and without vertical exaggeration showing relative thinness of Upper Santa Fe Group relative to the Middle Santa Fe Group.

correspond to surface features but are evidenced by drill logs, changes in ground-water level contours, geophysical information, and geochemical data. Upstream from these gaps there is typically a convergence and flattening of ground-water flow gradients where water is forced closer to the surface, possibly even increasing surface water flow in the river or drains.

Generally, as water moves through an underground gap, the ground-water gradient can be seen to steepen. After passing into a lower basin or depression, water spreads out three dimensionally, often favoring distinct flow paths controlled by local hydrogeologic influences.

Post Santa Fe Valley Fill

About 1 million years ago, in the early part of the Quaternary (Ice-Age) Period, the Rio Grande system expanded into upstream and downstream basins and became integrated with the Gulf of Mexico drainage. These events led to rapid incision of the Rio Grande Valley system and ended Santa Fe Group deposition in the Albuquerque Basin. Post-Santa Fe Valley fill deposits include sediments that have been deposited by the Rio Grande and its tributary arroyos during subsequent cycles of valley cutting and filling. Most of these sediments have been deposited since the last major episode of valley incision that occurred during the late Pleistocene glacial interval, about 15,000 to 25,000 years ago. These deposits constitute most of the inner valley's floor and its flanking terraces. Figure 2-2 illustrates the relationship and relative quantity of Santa Fe Group and valley fill deposits.

Sand and gravel with locally extensive silt-clay layers deposited by the Rio Grande during the last cut-and-fill cycle forms a thin but extensive shallow aquifer zone beneath the Rio Grande flood plain. In the Albuquerque area, these deposits are generally about 60 to 80 feet thick. In some places, particularly upstream from Interstate 40 in the northern Albuquerque and the adjoining Santo Domingo Basins, these recent fluvial sediments directly overlie coarse-grained ancestral river deposits of older Rio Grande terraces and units of the Upper Santa Fe Group. Such contact zones are the major recharge and discharge zones for the Basin's ground water.

Aquifer Recharge Features and Mechanisms

There are identifiable paths of prevalent ground-water movement.

Ground water can and does move throughout the entire Basin. However, there are identifiable paths of preferential and prevalent ground-water movement that are created by variable influences of geologic structure, aquifer thickness, hydraulic conductiveness of aquifer materials, and driving ground-water (piezometric) gradients.

The aquifer's characteristics were created by the structural evolution of the Basin and the varying depositional environments under which the basin and valley fill materials were distributed. The resulting aquifer system is a three-dimensional labyrinth of highly conductive sands and gravels laid down as broad layers, deep pockets, and narrow axial channel deposits interwoven with less conductive deposits of silt and clay. This creates locally wide contrasts in both vertical and horizontal hydraulic conductivity ranging from near 0 foot per day for clays to several hundred feet per day for clean sands and gravels. This environment controls the direction and capacity of ground-water movement into, out of, and through the aquifer.

Planning, designing, and constructing engineering works or implementing management practices to protect or enhance aquifer recharge must be done in accordance with a clear understanding of the locations and characteristics of special recharge features.

This report will pay special attention to areas where Upper Santa Fe Group deposits are at or near the ground surface or are in contact with coarse-grained, more recent deposits connecting to surface water. These are high potential aquifer recharge zones where surface water can most easily move down into Santa Fe Group deposits. To be successful, planning, designing, and constructing engineering works or implementing management practices to protect or enhance aquifer recharge must be done in accordance with a clear understanding of the locations and characteristics of these features. Detailed identification and characterization of special recharge areas is reported in Assessment studies by Hawley and Whitworth (1996).

Recharge windows and **recharge corridors** are two types of special recharge areas discussed in this report. While recharge windows and corridors provide the most favorable conditions for surface water to move down into the deep aquifer, they are also easy routes for contaminants to reach the aquifer from the surface. The locations of identified recharge windows and corridors in the Albuquerque Basin are shown in figure 2-3.

Recharge windows and corridors provide the most favorable conditions for water to move down into the aquifer.

Recharge windows are relatively small areas where a good hydraulic connection exists between the surface and Upper Santa Fe Group deposits. While a particular window may contribute a relatively small amount of aquifer recharge, its importance may be relatively great because of location, effect on water quality, or other factors. Recharge corridors are similar but more extensive zones generally lying along the axis of the Rio Grande Valley. Corridors may connect with the river, canals, drains, or arroyos. These recharge corridors are responsible for the majority of recharge in the basin because of the large areal extent of saturated surface deposits that are in contact with the Santa Fe Group

The most significant recharge corridors are along the Rio Grande.

Generally, fault zones are barriers to ground-water flow. However, they and buried fracture zones sometimes create localized connections between the surface and the Santa Fe Group aquifer. Along the mountain front of the Sandias and Manzanos, these zones may provide routes for water coming off the mountains to reach the aquifer. Although fractures in the crystalline rock of the mountain mass are probably in direct or indirect subsurface contact with the Upper

Santa Fe Group, evidence of ground-water movement into the aquifer has not been directly observed. Therefore, their recharge contribution potential is not presently known. Middle reaches of major arroyos between the mountain front and the river valley may contain recharge windows where coarse fan deposits of the arroyo directly overlie the Upper Santa Fe Group fill.

Places where the river runs directly up against the edge of the valley are important recharge areas.

In some places at the margins of the inner Rio Grande Valley, Upper Santa Fe Group deposits are directly exposed at the surface. Exposure of the Santa Fe Group can be seen along the east side of Edith Boulevard north of Paseo del Norte and in the high steep bank west of the Rio Grande below St. Pius High School. In areas such as these, surface water in the river, drainage channels, or irrigation canals can come into direct or very close contact with the Santa Fe Group deposits, creating a direct aquifer recharge connection. Consequently, places where the river runs directly up against the edge of the valley are important recharge areas. Likewise, irrigation canals running along the edge of the valley (like the Alameda Lateral and the Corrales Main Canal) are important contributors to recharge.

There are also areas where aquifer conditions at depth are conducive to ground-water movement, but where the aquifer is not well connected to surface water. Natural recharge in these areas is slow, but artificial recharge through injection wells or other means may be practical. The important aquifer zone beneath Albuquerque's east mesa exemplifies this condition. Wells in the area tap highly conductive ancient Rio Grande channel deposits, but these deposits receive only limited recharge through a connection to the Rio Grande far to the north, from the Sandia mountain front, and from a recharge window in the South Valley. Natural recharge is inadequate to meet municipal pumping demand, but artificial recharge may be feasible to help offset the effects of overpumping.

Characteristics of the Major Hydrogeologic Features of the Albuquerque Basin

Each of the five structural depressions shown in figure 2-1 that together make up the Albuquerque Basin has different hydrogeologic characteristics.

This section of the chapter contains separate detailed descriptions of each of these depressions and the structural features that divide them. The five major depressions, subbasin units, and dividing features identified in this study are shown in figure 2-4. To orient the reader, we first present a summary listing, in generally upstream to downstream order, of the major features to be described. Map symbols and feature codes are illustrated in figure 2-5.

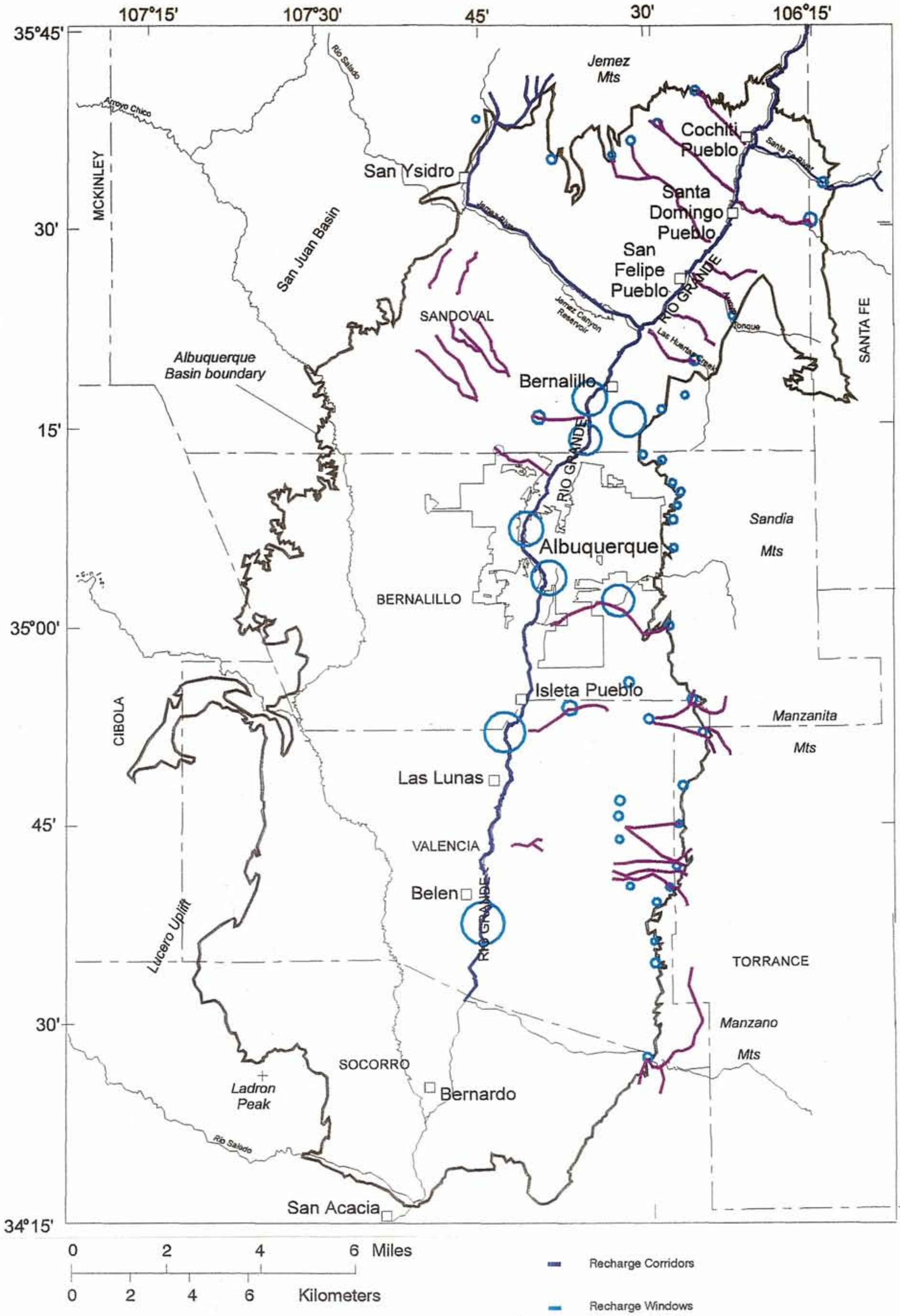

Figure 2-3.—Recharge windows and corridors within the Albuquerque Basin.

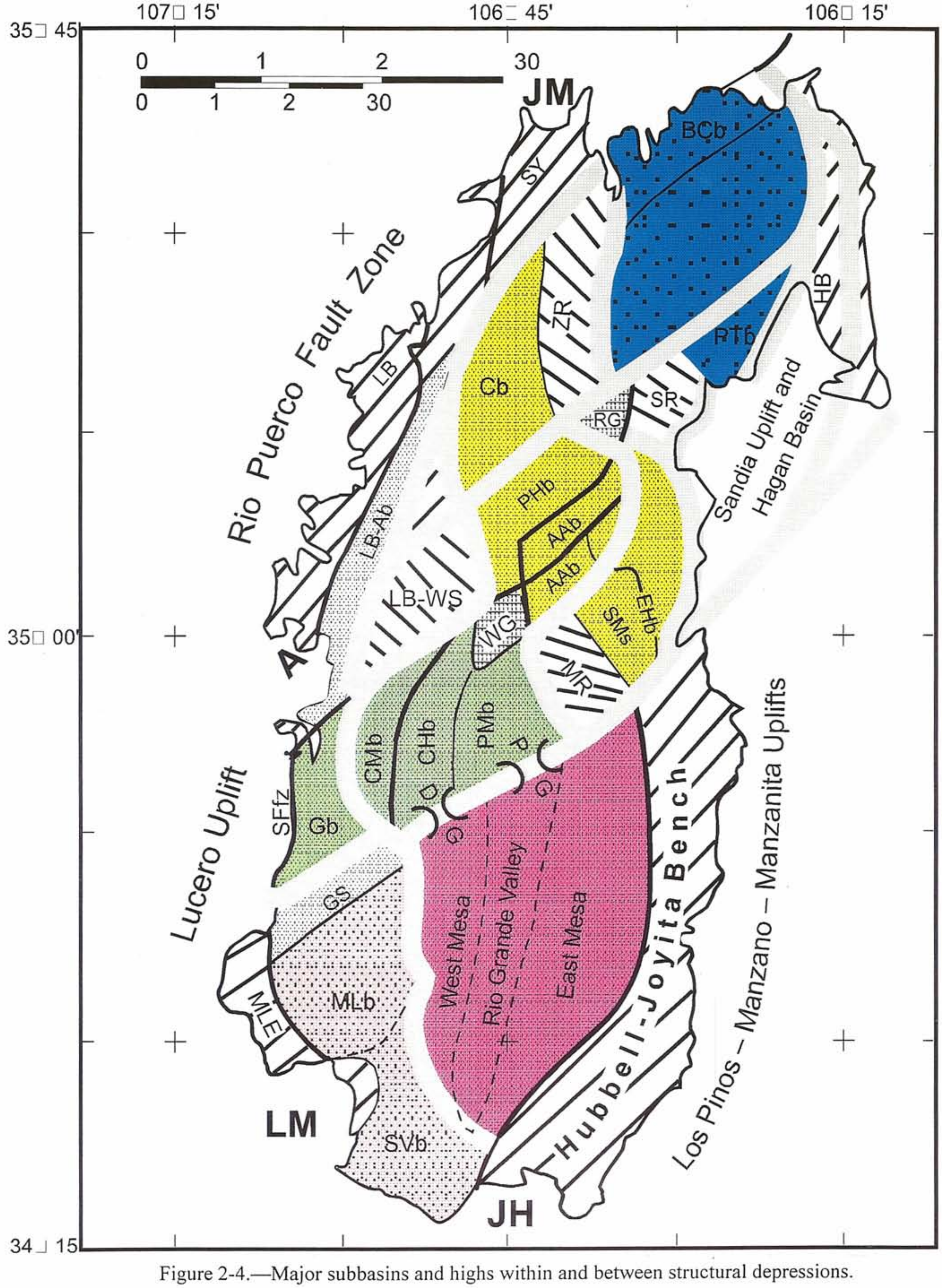

Figure 2-4.—Major subbasins and highs within and between structural depressions.

EXPLANATION

First-order structures, including major basin-margin and intrabasin faults, transfer, and accommodation zones: Tijeras-Cañoncito (TCfs); Gabaldon-Tijeras (GTaz); Loma Colorada (LCtz); La Bajada (LBfs); Rio Grande (RGfz); Puerco Valley (PVfz); and Sandia (Sfz).

Second-order structures, including significant intrabasin faults and flexures: Atrisco-Rincon (ARfz); Moquino (Mofz); Sand Hill (SHfz); and Santa Ana-Borrego (SABaz).

Third-order structures, including intrabasin transition zones, faults, and flexures: Ridgecrest (Rcfz).

Selected geomorphic boundaries.

JH — Other basin-boundary uplifts: Joyita Hills (JH); Jemez Mountains (JM); and Ladron Mountains (LM).

Major gaps in dividing ridges and other buried structural highs: Dalies (DG); Peralta (PG); River's Edge (RG); and Westgate (WG).

Structural depressions and subbasins; stipple density denotes approximate extent of selected basins.

Major structural depressions: Cochiti-Bernalillo (C-B); Metro-Area (M-A); Wind Mesa (WDM); Lunas-Bernardo (L-B); and Lower Puerco (LOP). On figures 2-1 and 2-4, C-B is blue; M-A is yellow; WDM is green; L-B is magenta; and LOP is salmon.

Subbasins (sectors): Alameda-Armijo (AAb); Apache graben (Ab); Borrego Canyon (Bb); Calabacillas (Cb); East Heights (EHb); Jemez-Zia (JZb); Placitas-Tonque (PTb); Sun Mesa sector (SMs of EHb); Paradise Hills (PHb); Cat Hills (CHb); Cat Mesa (CMb); Gabaldon (Gb); Parea Mesa (PMb); Sevilleta (SVb); and Monte Largo (MLb).

Basin margin structural bench (embayment, salient, or prong): Monte Largo (MLE); Hubbell-Joyita bench; Laguna bench (LB); San Ysidro embayment (SY); and Hagan bench and embayment (HB). Hatchure spacing denotes approximate extent of benches.

Interdepression structural highs (ridge, salient, or prong): Westland (WS); Mountainview (MR); Ziana (ZR); and Sandia Pueblo (SR).

A — Approximate location of schematic cross-section, figure 2-6.

Figure 2-5.—Explanation of map symbols and feature codes for figures 2-1 and 2-4.

Cochiti-Bernalillo Depression. Beginning at Cochiti Dam, the northernmost depression in the Albuquerque Hydrogeologic Basin. It includes the segment of the Rio Grande Valley downstream as far as Sandia Pueblo and Rio Rancho.

Ziana-Sandia Pueblo Dividing Ridge. A buried structural ridge that separates the Cochiti-Bernalillo and Metro Area Depressions. The narrow **River's Edge Gap** between Corrales and Bernalillo is the prevalent path for ground-water movement across the ridge.

Loma Colorada Transverse Fault Zone. A narrow, southwest-to-northeast-trending belt of structural deformation that extends from the Laguna bench west of the Double Eagle Airport to the Santo Domingo-La Bajada area through Rio Rancho and Bernalillo.

Metro Area Depression. A very deep central graben with flanking half-graben subbasins and structural benches that underlie much of the Albuquerque-Rio Rancho metropolitan area. At the surface, it is flanked on the east and west, respectively, by the Sandia Mountains and the Rio Puerco Valley. It is bounded on the north by the Jemez River Valley and to the south by the Interstate 40 corridor across the west mesa (Llano de Albuquerque).

Westland-Mountainview Dividing Ridge. A northwest-to-southeast-trending buried ridge separating the Metro Area Depression and the Wind Mesa Depression. The broad **Westgate Gap** beneath the Arenal-Rio Bravo area provides the primary route for water moving from the Metro Area Depression to the Wind Mesa Depression.

Wind Mesa Depression. A deep structural depression that connects northeastward with the central graben of the Metro Area Depression. The Wind Mesa Depression includes much of the transition zone between the southwestern and northwestern parts of the Central Albuquerque Basin and is bordered on the southeast by the Tijeras-Gabaldon Fault Zone.

Tijeras-Gabaldon Fault Zone. A southwest to northeast-trending belt of structural deformation that extends from the Gabaldon salient west of the Rio Puerco, through the Isleta Pueblo-Kirtland Air Force Base (AFB) area, to the upper Tijeras Canyon. The Tijeras-Gabaldon zone separates the very deep depressions of the Metro Area-Wind Mesa complex in the north-central part of the Basin from the shallower Lunas-Bernardo and Lower Puerco Depressions to the southeast. Major gaps in the Tijeras-Gabaldon Fault zone are the broad **Dalies Gap** southwest of Los Lunas, and the **Peralta Gap** under the valley between Los Lunas and Bosque Farms near the mouth of Hell's Canyon Wash.

Lunas-Bernardo Depression. A moderately deep structural depression underlying most of eastern Valencia County. It includes the Rio Grande Valley downstream from the Isleta constriction to Bernardo, the East Mesa area between the valley and the Hubbell Bench, and the west mesa (southern Llano de Albuquerque) area between the Rio Grande and Rio Puerco Valleys. The southern end of the depression is at the valley constriction between La Joya and San Acacia.

Puerco Valley Fault Zone. A fault system feature separating the Lunas-Bernardo and Lower Puerco Depressions.

Lower Puerco Depression. Furthest downstream of the major Albuquerque Basin Depressions. It includes the Rio Puerco Valley below the Highway 6 Bridge west of Los Lunas and extends westward to the Lucero and Ladron uplifts.

Cochiti-Bernalillo Depression

Cochiti-Bernalillo Depression

The Cochiti-Bernalillo Depression is the northernmost depression in the Albuquerque Basin complex. It is bounded on the north by the Santa Ana-Borrego transverse structural (accommodation) zone located west of Cochiti Dam and south of the Jemez Mountains. The depression extends southwestward to the Bernalillo area. Because of its position at the upper end of the complex of five depressions, the coarsest grained materials carried into the Basin from the north by the ancestral Rio Grande and precursor drainage systems were deposited there throughout the history of Santa Fe Group deposition. The streams coming into the Basin tended to be large, steep tributaries from high mountains. The more downstream depressions were filled with finer grained, more easily transportable materials that were carried farther down into the Basin by slower moving rivers. Coarse grained materials more recently deposited in the modern river channel and flood plain directly overlie the older coarse-grained deposits of the upper and middle Santa Fe Group. Because these coarse materials are very permeable, the surface water and ground-water systems are well connected in the entire area. However, deep ground-water movement is poorly understood in the Cochiti-Bernalillo Depression because of a lack of monitoring wells or piezometers going into the deeper zones of the aquifer.

In addition to the Rio Grande, three significant perennial tributaries, the Santa Fe River, the Jemez River, and Galisteo Creek, recharge the aquifer in the Cochiti-Bernalillo Depression. Smaller tributaries flowing to the margins of the basin include Tonque Arroyo, which drains the Ortiz Mountains, the Santo Domingo, and Borrego Canyon Arroyos draining basins in the Jemez Mountains, and Las Huertas Creek draining the eastern side of the Sandias. All of these streams become ephemeral in their lower reaches. The Rio Grande and the Santa Fe River now flow into Cochiti Reservoir where there is significant subsurface flow around and beneath the dam into the downstream ground-water system (Reclamation, 1993).

In essence, the Cochiti-Bernalillo Depression is an underground reservoir.

In essence, the Cochiti-Bernalillo Depression is an underground reservoir slowly discharging into the Metro Area Depression through the River's Edge Gap in the buried Ziana-Sandia Ridge. The gap is about a mile wide and is bounded on the northwest by the Loma Colorada transverse fault zone. It contains highly conductive aquifer zones as much as 1,500 feet thick. Flattening of the water table gradient upstream from the ridge is evidence of a ground-water constriction in the area.

The existence of a ground-water reservoir in the Cochiti-Bernalillo Depression that is well connected to the Rio Grande and other surface water features suggests that management of this system could be advantageous. In addition to potential water supply benefits, the well-known high water table conditions plaguing some areas could possibly be relieved.

Water quality considerations would be a paramount concern in managing ground water in the Cochiti-Bernalillo Depression. Except for the Santa Fe River, Las Huertas Creek, and the Rio Grande, tributaries to the Cochiti-Bernalillo Depression may contribute heavy salt and sediment loads. Salts and other dissolved constituents move through the ground-water system as well as through the surface waters. This causes water produced from many wells in the area to be of marginal to poor quality, often unfit for potable use. Streams and ground water draining from the Jemez watershed are particularly notable for high levels of arsenic and sodium sulfates, a legacy of the area's volcanism and marine shale deposits of the Colorado Plateau. The Rio Grande and the Santa Fe River drain heavily populated areas which are obvious possible sources of water pollution. Watersheds draining the Los Alamos area may pose special water quality problems.

Metro Area Depression

Albuquerque and Rio Rancho draw their water from aquifer systems in the Metro Area Depression. From the standpoint of metropolitan Albuquerque's water supply, this is an area of considerable focus. More is known about the Metro Area Depression than about any of the other Albuquerque Basin Depressions because of a relative abundance of well logs, ground-water level measurements, and other data. A fairly clear picture of the underlying geologic structure can be drawn from analyzing this information. Consequently, the hydrogeology of this section of the Basin can be discussed in more detail than is possible in the other areas.

The Metro Area Depression includes the Corrales to Isleta segment of the Rio Grande Valley and the deep structural basins extending beneath the east and west mesas. It is bounded on the east by the Sandia Mountains and on the west by the Rio Puerco Valley. Principal contributory drainages from the west mesa (Llano de Albuquerque) are the Calabacillas and Montoyas Arroyos. From the east come Sandia Wash, Juan Tabo Arroyo, and Tijeras Arroyo. The Albuquerque Metropolitan Arroyo Flood Control Authority's (AMAFCA) drainage system collects and consolidates drainage from many smaller arroyos and discharges to the Rio Grande.

The Rio Grande seeps water into the surrounding ground-water system through its bed and banks. A majority of the water lost from the river channel is picked up in the riverside drains and is returned to the river or diverted to the irrigation system. Other losses from the river are due to evaporation or transpiration by vegetation. In the Albuquerque area, only about 10 to 13 percent of the water lost from the Rio Grande makes its way down to recharge the deep aquifer (Pruitt and Bowser, 1994). The efficiency and effectiveness of this and other recharge mechanisms is of great importance to water users in Albuquerque and surrounding communities.

The Metro Area Depression can be further divided into four subbasins which are shown on a map in figure 2-4.

Calabacillas Subbasin

The Calabacillas subbasin (Cb) on the north underlies most of the Rio Rancho area north of the Loma Colorado Fault Zone including the large watersheds of Calabacillas and Montoyas Arroyos.

Paradise Hills Subbasin

The Paradise Hills subbasin (Phb) extends southwestward from Corrales and Rio Rancho beneath Paradise Hills and the Volcanos areas of western Albuquerque.

Alameda-Armijo Subbasin

The Alameda-Armijo subbasin (Aab) includes much of the inner valley of the Rio Grande and the flanking valley border areas between Coors Boulevard and Interstate 25.

East Heights Subbasin

The East Heights subbasin (EHB) lies between the river valley and the Sandia Mountains and extends south from the Pueblo of Sandia to the Sunport, Mesa del Sol, and Kirtland AFB area north of Hell's Canyon Wash.

Sun Mesa Sector

The subunit south of Gibson Boulevard, including the valley of Tijeras Arroyo below its confluence with Coyote Arroyo, is designated the Sun Mesa sector (Sms) in this study.

Except for the Calabacillas subbasin, large areas of the Metro Area Depression are underlain by thick, coarse-grained Upper Santa Fe Group sediments deposited by the ancestral Rio Grande. Beneath the inner valley and flanking mesas, saturated parts of these units constitute the major aquifer systems supplying the City with water. In the Calabacillas subbasin, another aquifer zone primarily made up of sandy middle and lower Santa Fe deposits, underlies the Rio Rancho area north of the Loma Colorada Fault Zone between Double Eagle Airport and the River's Edge subdivision. Much of this area underlies the Calabacillas and Montoyas Arroyo watersheds, and it may include some important recharge window and corridor sites.

At the upper end of the Metro Area Depression immediately downstream from the River's Edge Gap (between Bernalillo and Corrales), moving ground water spreads laterally and vertically following paths of steeper energy gradient and lower flow resistance. Recent work (Hawley and Whitworth, 1996) indicates that ground-water flow preferentially follows three major trends across the Metro Area Depression. One path tends southeastward into the East Heights subbasin between Interstate 25 and Eubank Boulevard; another follows the inner Rio Grande Valley through the Alameda-Armijo subbasin; and the third goes southwestward across the Paradise Hills subbasin. The latter path follows the north-south Albuquerque Volcanoes structural trend that is underlain by 8,000 to 16,000 feet of basin fill and is marked by a prominent "trough" in the water table. Natural troughs in the water table indicate zones of higher relative aquifer transmissivity in more permeable or thicker deposits. Ground water moves more easily in these zones than in the surrounding areas. The trough under the west mesa appears to be associated with a thick section of upper Santa Fe Group sands deposited by ancestral Rio Grande and upper Rio Puerco systems and may be influenced by flow along volcanic conduits.

A river system that once existed on the east side of the Metro Area Depression deposited the sediments that form the major aquifer in the East Heights subbasin. It flowed more or less parallel to the Sandia Mountain front in a broad zone between San Mateo and Eubank Boulevards to the area where Kirtland AFB now exists. There it encountered an alluvial fan at the mouth of Tijeras Arroyo and a structural high along the Tijeras-Gabaldon Fault Zone which forced the river back to the west as the Basin filled. The Tijeras-Gabaldon Fault Zone continues to be a barrier to southward ground-water movement. It directs water toward the Westgate Gap in the vicinity of the intersection of Isleta and Rio Bravo Boulevards near the eastern margin of the valley.

A tilted fault block creates a barrier to eastward ground-water movement from the Rio Grande toward the East Heights subbasin.

Aquifer recharge from the Rio Grande to the East Heights subbasin is largely limited to water moving through the easternmost flow path originating in the "Sandia Recharge Window" north of the City below the River's Edge Gap (see figures 2-3 and 2-4 for location). This path follows conductive aquifer zones in Upper Santa Fe Group channel deposits of the ancestral Rio Grande. As shown in the cross section sketch in figure 2-6, a tilted fault block bounded on the west by the Rio Grande Fault Zone (Hawley et al., 1995) creates a barrier to eastward ground-water movement from the Rio Grande

Schematic Cross Section: Metro-Area

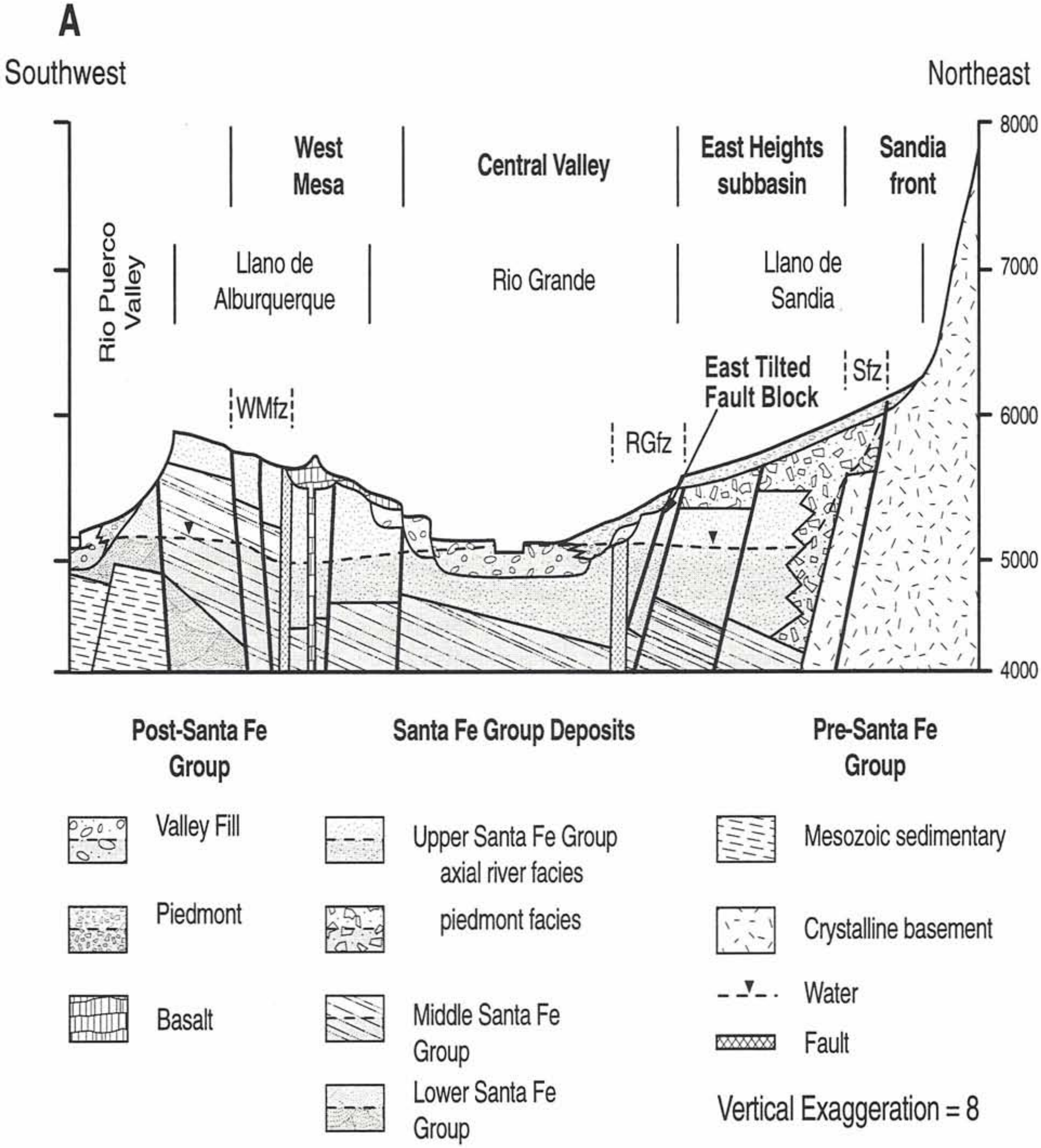

Figure 2-6.—Schematic cross section of the Metro Area.

toward the East Heights subbasin. This barrier lies roughly along Interstate 25 between Tramway Road and Interstate 40. Findings of a geochemistry study of ground water in the Albuquerque area (Logan, 1990) support this observation and conclusions.

Other recharge sources at the northeastern edge of the East Heights subbasin are windows along the Sandia Mountain front. Although we currently have no way to quantify this recharge, it is probably a relatively small contribution because of limited watershed areas. Mountain front tributaries contributing recharge to the East Heights subbasin through these windows include the small Domingo Baca, Bear-Oso, Embudo, and Embudito Arroyo systems. The large Tijeras Canyon drainage system (including Coyote Canyon) is the major contributor to ground-water recharge on the east side of the Basin. The Tijeras mountain front recharge window is located in the East Heights subbasin downstream from the Four Hills Boulevard crossing.

There is an important recharge window along the middle reach of the Tijeras Arroyo on Kirtland AFB. Low levels of the suspected carcinogen TCE have recently been discovered in the ground water in this area.

There is another important upland recharge window in the southern East Heights subbasin's Sun Mesa sector along the middle reach of the Tijeras Arroyo on Kirtland AFB just below the confluence of Tijeras and Coyote Arroyos between lines projected southward from Juan Tabo and Eubank Boulevards. In the window area, coarse-grained arroyo deposits are directly in contact with underlying Upper Santa Fe Group basin fill. Upstream along the arroyo from the window, the coarse arroyo deposits lie on less permeable, older Santa Fe sediments; downstream, the arroyo has deposited less permeable fine-grained materials creating less favorable recharge conditions. Low levels of the suspected carcinogen trichloroethylene (TCE) have recently been discovered in the ground water in this area.

Large areas of the Rio Grande flood plain in the Alameda-Armijo subbasin function as a recharge corridor. However, over time, engineering and management changes have reduced the efficiency and effectiveness of recharge in the inner valley. Reduction of the areal extent of the river channel, installation of the riverside drains, heavy ground-water withdrawals by the City, and reduction of irrigated acreage in the valley have all contributed to a reduction of recharge. More detailed discussion of these changes and their effects will be presented in later chapters of this report.

An important recharge window within the Alameda-Armijo subbasin is along the Rio Grande upstream from Interstate 40 where the river runs along the high bluff on the west side. This window has been designated the "Oxbow Window" for the oxbow feature that exists at the upper end of the reach. Here, the river comes into direct contact with Upper Santa Fe Group and older valley fill deposits. This window contributes water to the ground-water trough which has already been described in connection with one of the flow paths originating below the Rivers Edge Gap. This trough is a path for ground-water movement beneath the west mesa that can be traced southward all the way to Belen via the central Wind Mesa and northwestern Lunas-Bernardo Depressions.

A potential recharge area exists along the upper reach of Calabacillas Arroyo on the far west side of the Calabacillas subbasin. However, the most important recharge area along the Calabacillas is the lower reach between Unser Boulevard and the river where the arroyo's coarse-grained channel deposits are in contact with both the saturated alluvium of the Rio Grande and the Upper Santa Fe Group. Evidence exists (Bitner, Halloran, and Minchak, 1996) that TCE ground-water contamination associated with the Sparton Technology facility on Coors Road is being drawn into the aquifer through this recharge window. The window connects saturated Rio Grande Valley fill alluvium to the ground-water trough under the west mesa. This circumstance may cause a rapid migration of this contaminant plume into and through the aquifer.

The ground-water gradient out of the East Heights subbasin has been reversed. Wells in the East Heights, Sunport, and Mesa del Sol areas could eventually be affected by contamination that has caused the shutdown of the San Jose Well Field in the South Valley.

Another recharge window at the southeastern edge of the Alameda-Armijo subbasin is in the San Jose area on the east side of the river between Bridge Street and Rio Bravo Boulevard. Subsurface flow in this area is influenced by the aquifer conditions and ground-water development in adjacent parts of the East Heights subbasin. In the past, the San Jose Recharge Window was probably a ground-water discharge area. Ground water originating in Tijeras Arroyo or moving southward from the East Heights subbasin would have discharged to the river in the San Jose area through springs, seeps, or directly through the river's bed and banks. However, heavy pumping from the Upper Santa Fe aquifer system to the east and northeast has produced an elongate depression in ground-water levels under much of eastern Albuquerque. This drawdown trough is deepening and expanding. Consequently, the southwestward and westward ground-water gradient out of the southern East Heights subbasin that once existed has now reversed. This reversal of gradient will increasingly bring water into the East Heights area from the Alameda-Armijo subbasin, through the San Jose Recharge Window. Wells in the East Heights, Sunport, and Mesa del Sol areas could eventually be affected by contamination that has caused the shutdown of the San Jose Well Field in the South Valley. Migration of nitrates from the south valley is another possible source of contamination for aquifers in the southeast part of the Metro Area Depression. Northward expansion of ground-water drawdown will cause gradients into the subbasin from the north to steepen and result in an increased movement of water from the Sandia and mountain front recharge windows.

The Westland-Mountainview ridge separates the Metro Area Depression from the Wind Mesa Depression. A broad gap between buried structural highs extending beneath the valley from the east (Mountain View Prong) and west (Mountainview Ridge and Westlands salient of the Laguna Bench beneath Nine-Mile Hill) is the main path for southward movement of ground water between the two depressions. This gap is about 6 miles wide and is designated the Westgate Gap. The upper saturated zone within the gap is in moderately permeable Upper Santa Fe sediments and forms an aquifer that is about 500 feet thick. Based on evidence of ground-water gradients that have been measured in piezometer nests along Rio Bravo Boulevard, water appears to be forced upward as it moves through this gap.

Wind Mesa Depression

Wind Mesa Depression

The hydrogeologic framework of the Wind Mesa Depression can only be described in a very general sense because subsurface data is limited. The geologic data that is available comes from relatively shallow stock water wells, a few very deep exploratory oil and gas wells, and reconnaissance geophysical surveys. Most of the information used to form the conceptual model is from earlier studies by Bjorklund and Maxwell (1961) and by Titus (1963), hydrocarbon resource investigations (Keller and Cather, 1994), and ongoing studies by the New Mexico Bureau of Mines and Mineral Resources.

The deepest part of the Albuquerque Basin with the thickest, well-documented Santa Fe Group basin fill (about 16,000 feet) lies within the Wind Mesa Depression. The area includes the large Cat Hills basalt field which includes a line of volcanic vents, like the Albuquerque volcanoes, that formed along a deep fracture zone near the western margin of the Rio Grande Rift. There are four other volcanic centers in this depression: Isleta-Paria Mesa, Wind Mesa, Cat Mesa, and Los Lunas. The andesitic Los Lunas Volcano (Cerro de Los Lunas) is located along the Tijeras-Gabaldon transverse fault system which forms the southeastern border of the Wind Mesa Depression.

Two ground-water flow systems having general north-to-south trends are located in the Wind Mesa Depression. The most prominent of these flow systems is manifest as a natural ground-water trough in the western part of the Wind Mesa Depression beneath the Cat Hills volcanic field. This is a continuation of the ground-water trough in the Paradise Hills subbasin of the Metro Area Depression that has been previously described. It passes across the Tijeras-Gabaldon Fault Zone through the Dalies Gap southwest of Los Lunas and continues into the Lunas-Bernardo Depression and across the Rio Grande Valley near Belen. The other area of preferential ground-water flow in the Wind Mesa Depression is beneath the Peralta area of the river valley between lower Hells Canyon Wash near Isleta and Los Lunas.

The western border of the Wind Mesa Depression, along the Rio Puerco, is a zone of structural transition between the deep central part of the Albuquerque Basin and the Lucero uplift which forms the eastern boundary of the Colorado Plateau. Santa Fe Group basin fill is very thick there, but the deposits are fine grained and, for the most part, represent playa-lake and piedmont alluvial sediments deposited in early and middle Santa Fe time (Lozinsky and Tedford, 1991). Because of the fine-grained nature of these deposits, this area does not offer significant ground-water development potential.

Natural recharge contributions in the Wind Mesa Depression are very limited. Volcanic centers have an adverse effect on water quality.

Natural recharge contributions in the Wind Mesa Depression are very limited. Artificial recharge through injection wells in the Isleta area may be feasible, but water quality problems could limit the practicality of this kind of project. As in the western part of the Metro Area Basin, ground-water quality and surface water quality is adversely affected by the Colorado Plateau borderland drainage basins formed in marine shales to the west. These drainages contribute high concentrations of dissolved solids and suspended sediments. The young volcanic centers existing in both the Wind Mesa and Metro Area Depressions also appear to have an adverse effect on water quality. Arsenic occurring naturally in ground water in Santa Fe Group aquifers (Chapin and Dunbar, 1995) is a particular problem that appears to be exacerbated by the elevated temperatures of geothermal systems at and near these volcanic centers.

Tijeras-Gabaldon Fault Zone

The Tijeras-Gabaldon Fault Zone is a major belt of structural deformation as much as 4 miles wide that extends diagonally across the central part of the Albuquerque Basin complex. From the mouth of Tijeras Canyon, it extends southwestward across the Rio Grande between Bosque Farms and Los Lunas, then southwest to the Gabaldon-Mohinas Bench west of the Rio Puerco Valley. The Tijeras-Gabaldon Fault Zone is a demarcation that separates northern and southern depressions of the Albuquerque Basin. Depressions to the north of this zone have distinctly different aquifer characteristics compared with those to the south.

The Tijeras-Gabaldon and Sandia Faults, acting in concert, have caused the subsiding fault blocks that formed the Metro Area Depression to the north to tilt eastward. This tilting caused the river system to tend toward the eastern side of the basin where it deposited thick and productive Upper Santa Fe group aquifer materials in the East Heights subbasin. South of the Tijeras-Gabaldon Fault Zone, the deepest subsidence has been along the western edge of the basin in the Lower Puerco Depression adjacent to the Ladron-Lucero Uplift. Subsidence in the more eastern Lunas-Bernardo Depression appears to have been less pronounced.

The Tijeras-Gabaldon Fault Zone also created a hydraulic control and backwater effect on surface flow that, in conjunction with the basin constriction at Isleta, caused generally coarser sediments to be deposited to the north and finer sediments to the south.

The combination of these effects on the depositional environment during the emplacement of Upper Santa Fe Group fills was an important factor in causing the occurrence of an excellent aquifer under northeast Albuquerque, while poorer aquifer conditions were created in the Lunas-Bernardo and, particularly, the Lower Puerco Depressions.

Lunas-Bernardo Depression


Lunas-Bernardo Depression

The Lunas-Bernardo Depression includes the Isleta to Bernardo segment of the Rio Grande Valley and the structural subbasins which extend east and west of the valley under the mesas. The depression is bounded on the east by the Hubbell Bench west of the Manzano Mountains, on the west by the Rio Puerco Valley, on the north by the Tijeras-Gabaldon Fault Zone, and on the south by the Becker Embayment and Black Butte Salient of the Joyita Bench east of Bernardo. There are no significant contributing drainages from the west mesa in this area. The only significant drainages crossing the Llano de Manzano east of the valley are the Hell's Canyon Wash at the northern end of the reach and the Abo Arroyo which heads in Abo Pass between the Manzano and Los Pinos Mountains and flows into the Rio Grande near Veguita.

Los Lunas, Belen, Rio Communities, and other fast developing Valencia County areas draw water from aquifers in the Lunas-Bernardo Depression. This is an area where heavy future ground-water development can be anticipated. To date, no major multiagency study efforts, such as those undertaken to characterize the ground-water system in the Albuquerque metropolitan area, have been initiated here. A ground-water study by Titus (1963), some detailed seismic investigations by the Consortium for Continental Reflection Profiling (Russel and Snelson, 1994b), and reconnaissance study by Hawley and Whitworth (1996) provide the basis for characterizing the hydrogeologic framework of the Lunas-Bernardo Depression.

Large areas of the east mesa or Llano de Manzano between the Rio Grande Valley and the Hubbell Springs Fault zone appear to be underlain by coarse-grained Upper Santa Fe Group materials that were deposited by the ancestral Rio Grande. These deposits appear to extend beneath the inner valley uninterrupted by less pervious structures as they are in the Metro Area Depression. They also extend westward an unknown distance toward the Rio Puerco Valley but are not known to be present west of the Llano de Albuquerque. These Upper Santa Fe Group deposits constitute the aquifers used by Belen, Los Lunas, and neighboring communities.

The recharge corridor along the Rio Grande riparian zone is the primary recharge feature for the Lunas-Bernardo Depression.

The recharge corridor along the Rio Grande riparian zone is the primary recharge feature for the Lunas-Bernardo Depression. In addition, this reach of the Rio Grande has two identified recharge windows. The Isleta Recharge Window is located at the point where the river channel is close to the west bluff of the valley near the Bernalillo-Valencia County line. This window exerts influence on the ground-water trough under the west mesa and may also contribute some recharge to the Wind Mesa Depression. The second window is along the east bank of the river between the Highway 6 bridge at Belen and the Jarales pipeline crossings. Here, the river runs directly against or near the eastern valley margin. The segment of this reach below the Belen railway bridge is the most important because it has so far been least impacted by development.

Mountain front sources provide a relatively minor contribution to recharge in the Lunas-Bernardo Depression. Mountain front recharge windows are associated with springs discharging along the Hubbell Springs Fault Zone west of the Manzano Mountain front. These include Maes Spring, Carrizo Spring, and several other smaller springs at the lower end of Arroyo del Cuervo and Arroyo del Trigo. These springs are fed by higher perennial stream and spring systems discharging along the base of the Manzano Mountains. Recharge windows in mid- and lower reaches of the large Abo and Hell's Canyon Wash Arroyos may have favorable conditions for artificial recharge basins. Because the Abo Arroyo drainage includes large areas of gypsum bedrock, water quality problems could pose significant difficulties there.

Lower Puerco Depression


Lower Puerco Depression

The boundary between the Lunas-Bernardo and Lower Puerco Depressions has not yet been clearly defined. It appears to follow the eastern edge of the Rio Puerco near the base of the Ceja del Rio Puerco escarpment that forms the western edge of the Llano de Albuquerque. The depression terminates to the north with the Gabaldon salient at the southwest end of the Tijeras-Gabaldon Fault Zone, and it transitions southward into the Socorro and La Jencia Basins between the Joyita Hills and Ladron Mountains. The western boundary is well defined by sediments of the Ladron and Lucero uplifts. The Lower Puerco Depression also includes a short segment of the Rio Grande Valley between Bernardo and the mouth of the Rio Salado just above San Acacia. The San Acacia constriction is the boundary between the Albuquerque and Socorro Basins. Two subbasins of the Lower Puerco Depression are separated by a salient or buried ridge extending northeast from the Sierra Ladron.

Aquifer quality in the Lower Puerco Depression is poor.

Aquifer quality in the Lower Puerco Depression is poor because it is located farthest downstream in the Basin and because it tended to be the most rapidly subsiding during the time when the Basin filled. The ancestral Rio Grande did not flow through the Lower Puerco Depression as it did in the other Basin depressions. Until development of a through-flowing river about 5 million years ago, this area served as the sump for much of the ancestral Rio Grande, Rio Puerco, San Jose, and Salado drainage systems. Consequently, the finest-grained lake and playa sediments tended to accumulate in this part of the Basin. Playa-lake systems also produced high levels of alkalinity and salinity. There are local evaporite deposits, primarily sulfates. Few, if any, areas are underlain by thick Upper Santa Fe river deposits.

Because of poor aquifer conditions and poor surface water quality, due to both dissolved and suspended loads, there is probably little potential for recharge enhancement in this area. However, a short recharge corridor may exist from Veguita (southern Lunas-Bernardo Depression) to La Joya along the river. Good quality water from large springs along the Sierra Lucero at the northwest edge of the depression that is associated with travertine deposits is not a significant recharge source.

Concluding Remarks

This chapter has described the geologic processes that formed the Albuquerque Basin and its aquifer systems. Influences of climate and human activities have also had roles in shaping the contemporary hydrologic system of the Basin. The next chapter will describe some of the changes that have resulted from intensive human management of the land and water along the Rio Grande over the past century. Further discussions in this report describe some elements of management that are needed to meet the resource demands of the future.