Chapter 16

The Aquifers of Red Light Draw, Green River Valley, and Eagle Flat

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Introduction

The water-planning studies conducted as part of Senate Bill 1 for the Far West Texas Regional Water Planning Group have generated much interest in the groundwater resources of the westernmost counties of Texas. This paper is intended to provide a basic description of Red Light Draw, Green River Valley, and Eagle Flat—all of which are part of the complex of West Texas bolsons. As such, the paper is based principally on (1) a study of the fresh and slightly saline groundwaters of westernmost Texas (Gates and others, 1980), (2) an evaluation of the suitability of the Eagle Flat Basin to be the location for a repository for low-level radioactive waste (Darling and others, 1994), and (3) a Ph.D. dissertation on the hydrogeology of the basins (Darling, 1997).

Location and Physiographic Setting

Eagle Flat, Red Light Draw, and Green River Valley (fig. 16-1) are located approximately 100 mi east of the City of El Paso. The only settlements in the area are the unincorporated villages of Sierra Blanca and Allamoore.

The Diablo Plateau is a low-relief upland that slopes toward the north from an escarpment that forms the southern boundary of the extensive tableland and the northernmost extent of the region described in this paper. Three topographic basins lie south of the plateau.

Eagle Flat covers an area of approximately 560 mi^2. The northwestern area of Eagle Flat is a closed topographic depression (the Blanca Draw Watershed), which drains through Blanca Draw, an ephemeral stream, into a playa known as Grayton Lake. Water accumulates in Grayton Lake only after periods of heavy rainfall. Eagle Flat Draw drains the southeastern area of the larger Eagle Flat Basin. This drainage area is referred to later as the Southeast Eagle Flat Watershed. Toward the north-northeast, the watershed is bounded by the Carrizo Mountains. The Blanca Draw Watershed is bordered along the southwest by the rugged sandstone and limestone spines of Devil Ridge and by the Eagle

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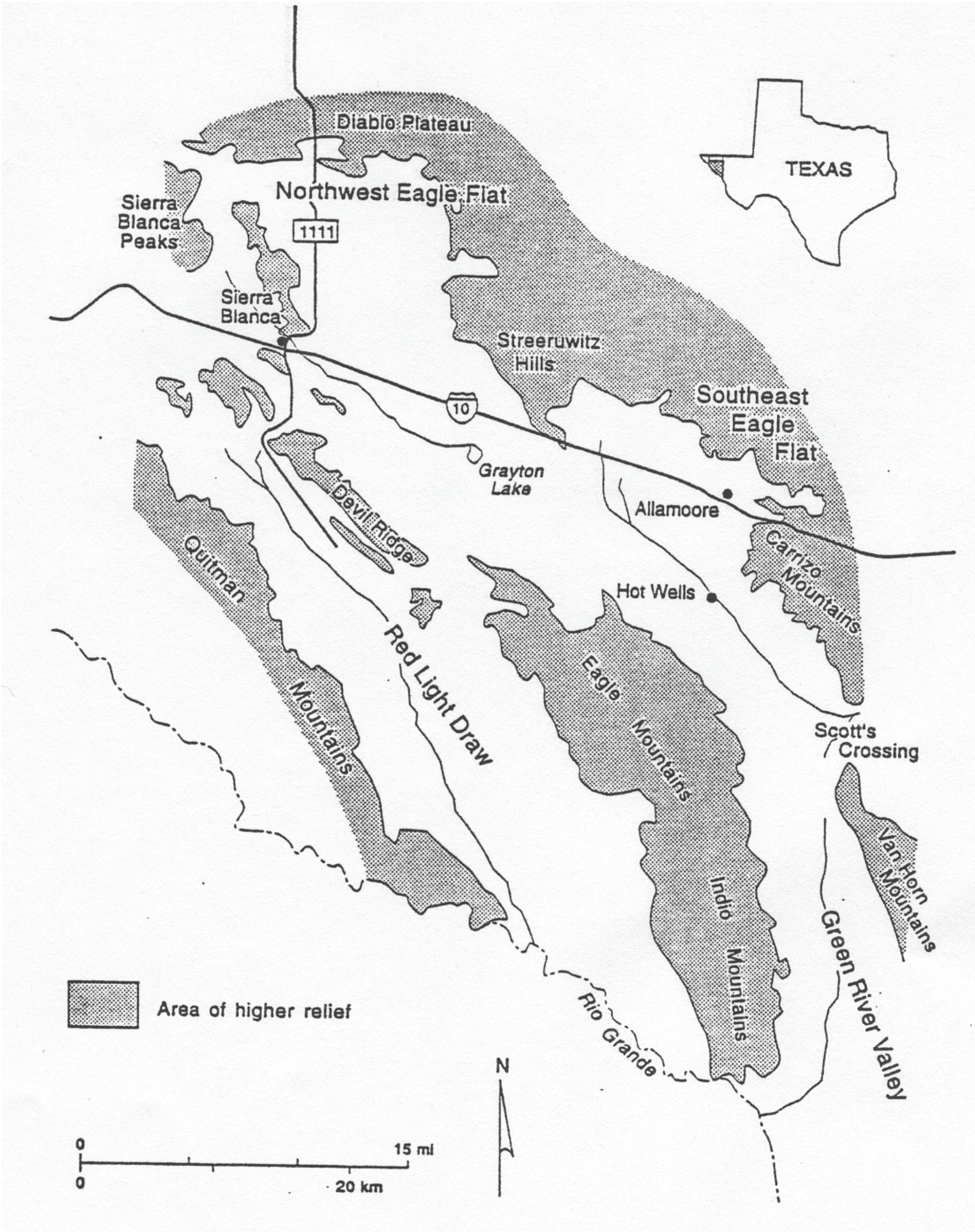

Figure 16-1: Location and major physiographic features.

Mountains. The Southeast Eagle Flat Watershed is bordered along the southwest by the Eagle Mountains.

Red Light Draw is flanked along the northeast by the Indio Mountains, the Eagle Mountains, Love Hogback, and Devil Ridge. The Rio Grande forms the southern boundary of the basin. Red Light Draw encompasses an area of approximately 370 mi^2. This watershed is drained by a Red Light Arroyo, an ephemeral tributary of the Rio Grande. The basin is bounded along the southwest by the Quitman Mountains. The Rio Grande is the only perennial stream in the area.

Green River Valley lies in parts of Hudspeth, Culberson, Jeff Davis, and Presidio Counties. This basin, which lies between the Indio Mountains on the west and the Van Horn Mountains on the east, is drained by the Green River, an ephemeral tributary of the Rio Grande. The surface area of the watershed is approximately 160 mi^2.

Elevations

The Eagle Mountains form the highest topographic point in the area, reaching an elevation of 7,484 ft above mean sea level (msl). Sierra Blanca Peak rises to an altitude of 6,800 ft above msl. The Carrizo and Van Horn Mountains are more than 5,200 ft above msl, and the highest elevation of the Quitman Mountains is approximately 6,200 ft above msl. The villages of Sierra Blanca and Allamoore are at 4,500 ft above msl, and the center of the Grayton Lake playa of Northwest Eagle Flat lies at an elevation of 4,270 ft above msl, the lowest point in the Blanca Draw Watershed. Over a distance of more than 25 mi, the floor of Red Light Draw decreases from nearly 4,500 ft above msl in the northernmost reaches of the watershed to between 3,200 and 3,100 ft above msl along the Rio Grande. The floor of Green River Valley decreases from approximately 4,250 ft above msl in the northernmost area of the basin to around 3,100 ft above msl along the Rio Grande.

Climate

The mean annual temperature is 65°F. The average annual low temperature is 48°F, and the average high is 81°F. Sierra Blanca receives approximately 10 to 12 inches of precipitation each year. Mean annual evaporation is 84 inches. Precipitation decreases to between 7 and 8 inches at El Paso, where evaporation is approximately the same as at Sierra Blanca. Hudspeth County and neighboring counties usually record the lowest annual precipitation of reporting stations in Texas. Low rainfall and high evaporation combine to create drought conditions during all or part of most years (Larkin and Bomar, 1983).

Most precipitation occurs during the months of July through October as widely scattered thunderstorms (Larkin and Bomar, 1983; Nativ and Riggio, 1989, 1990). Most winter rainfall is associated with widespread frontal systems that originate over the Pacific Ocean (Elliot, 1949; Nativ and Riggio, 1989, 1990). Winter storms account for less than one-third of the region’s total precipitation.

Aquifers

Red Light Draw, Green River Valley, and Eagle Flat are part of the complex of West Texas bolsons (Ashworth and Hopkins, 1995). It is generally understood by hydrogeologists that each bolson encompasses a separate aquifer; however, the degree to which adjacent basins are hydrogeologically integrated is not well understood because there has been little research that would allow such inferences to be made with certainty.

Red Light Draw Aquifer

Wells in Red Light Draw produce groundwater from Cretaceous rocks, Cenozoic basin fill, Tertiary igneous rocks, and Quaternary river alluvium. Cretaceous limestones and sandstones predominate in the northernmost areas of the draw, giving way to basin fill in the central and southern areas of the basin. Wells within the Rio Grande floodplain produce groundwater from coarse- to fine-grained sand and silt of the Rio Grande alluvium. Although the Texas Water Development Board (TWDB) considers the Rio Grande alluvium of the Hueco Bolson to be separate from the Hueco Bolson aquifer (Hibbs and others, 1997), we regard the alluvium and the basin fill of Red Light Draw to be part of the larger Red Light Draw aquifer. The thickness of the basin fill ranges from less than 400 ft in the northernmost reaches of Red Light Draw to between 1,000 and 2,000 ft in the central area of the basin, and to more than 3,000 ft in the vicinity of the Rio Grande (Gates and others, 1980). The base of the saturated section of the formations that underlie the basin fill is unknown. The depth to the potentiometric surface is 200 ft or less in the mountainous areas that surround the basin (fig. 16-2) and as much as 400 ft beneath the northern and central areas of Red Light Draw. (The potentiometric surface is the level to which groundwater rises in a well.) The depth to the potentiometric surface decreases to less than 25 ft within the Rio Grande floodplain.

The Red Light Draw aquifer is not a source of water for municipal supply. All current production is either for domestic use or for the watering of livestock and wild game. Large-capacity wells completed in the Rio Grande alluvium supplied water to irrigate cotton fields during the 1950’s and 1960’s. The farms in this area of Red Light Draw were abandoned in the 1970’s, and the irrigation wells are no longer in use.

Green River Valley Aquifer

The Green River Valley aquifer consists of limestone, sandstone, conglomerate and siltstone of Cretaceous age, and Tertiary volcanics. The maximum thickness of the basin-fill deposits ranges from 1,700 to 2,000 ft. The basin fill includes thick sequences of coarse-grained volcanic material eroded from the surrounding mountains. Near the Rio Grande, the thickness of the basin fill is more than 2,000 ft. In this area, the basin fill consists predominantly of clay, silt, and possibly altered tuff (Gates and others, 1980). The depth to the potentiometric surface ranges from less than 200 ft in the mountains that bound the basin to as much as 400 ft within the central area of the basin (fig. 16-2). The depth decreases to less than 25 ft within 1 mi of the Rio Grande. A few windmills and wells equipped with submersible pumps supply water to the ranches in Green River

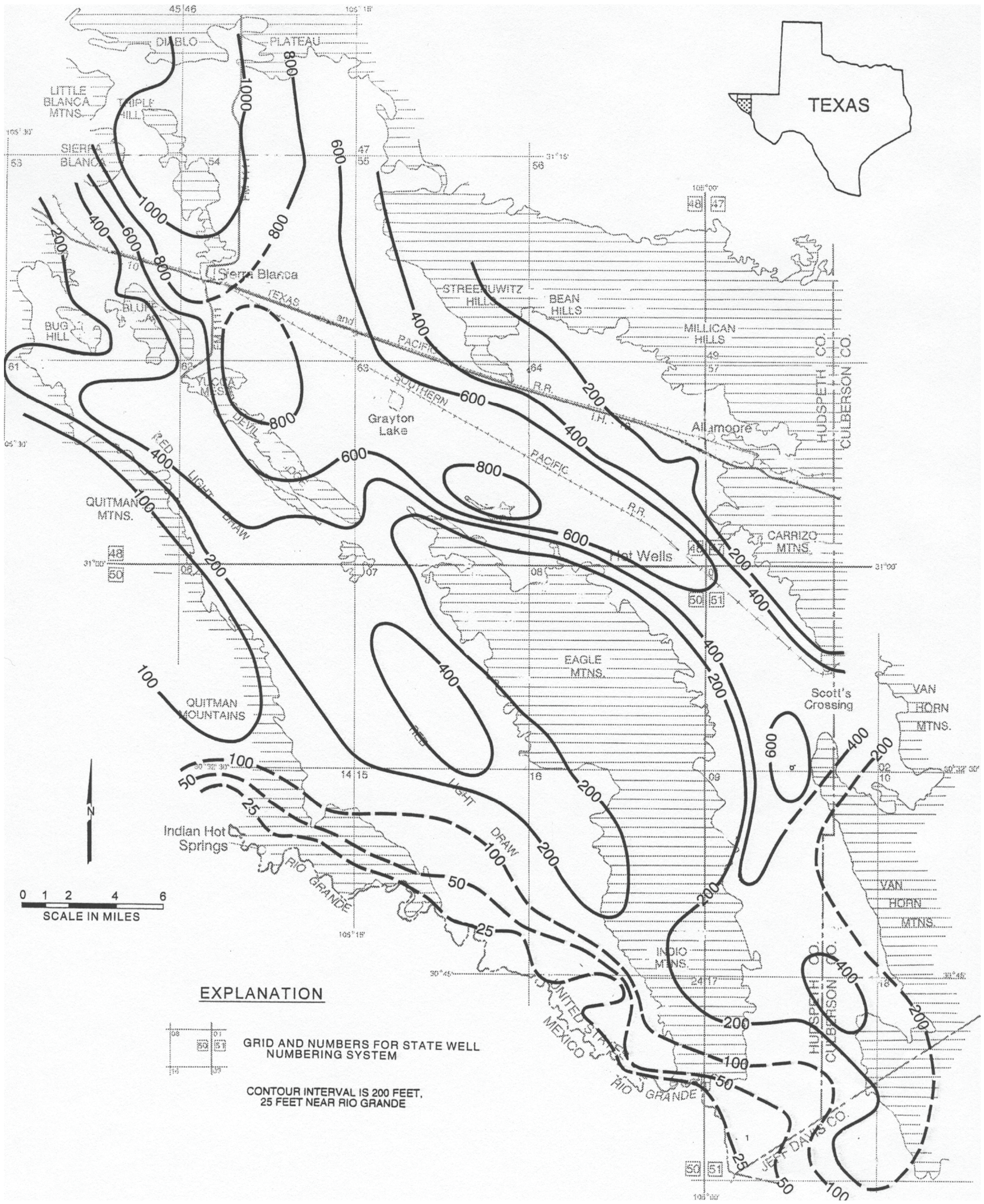

Figure 16-2: Depth to the potentiometric surface (adapted from Darling, 1997).

Valley, one of the most remote and rugged of the bolsons of West Texas. The depth of most water wells is less than 200 ft, and well yields vary widely, from less than 25 gpm in shallow wells along the margins of the basin to more than 100 gpm in irrigation wells (now abandoned) along the Rio Grande. All groundwater production is for the watering of livestock or wild game.

Eagle Flat Aquifer

Metamorphosed rocks of Precambrian age make up the Eagle Flat aquifer between the Streeruwitz Hills and the Carrizo Mountains of Southeast Eagle Flat. Wells in this area of the basin are either windmills or small-diameter boreholes equipped with submersible pumps. These wells, most of which are 100 to 200 ft deep, are sufficiently productive to provide water for domestic use and for watering of livestock. The depth to the potentiometric surface is generally 200 ft or less in the area between the Streeruwitz Hills and the Carrizo Mountains (fig. 16-2).

Farther to the south and southeast, the Eagle Flat aquifer consists of interbedded sequences of sand, silt, and clay. In the 1970's, the U.S. Geological Survey (USGS) drilled four test wells to assess availability of the fresh –to –slightly saline groundwater resources of westernmost Texas (Gates and White, 1976). (A concise summary of the drilling program in the Red Light Draw/Eagle Flat area is Gates and Smith, 1975). The USGS drilled one of the four wells midway between Scott's Crossing and Hot Wells (locations marked on figs. 16-1 and 16-2). This well penetrated 2,100 ft of sand, silt, and clay without encountering bedrock. At Hot Wells, two wells drilled in the early 1900's to supply water for steam locomotives produced groundwater from coarse-grained alluvial-fan material shed from the Eagle Mountains. Each well was 1,000 ft deep, and each was fitted with 10-inch (internal diameter), slotted steel casing (Gates and others, 1980). The wells are reported to have been capable of producing several hundreds of gallons of water per minute. The wells, which lie within the right-of-way of the Union Pacific Railroad, are no longer in service. The depth to the potentiometric surface of the Allamoore System ranges from 400 to 600 ft (fig. 16-2). In the middle to upper sections of the alluvial fan that borders the northwest face of the Eagle Mountains, the depth to the potentiometric surface is 200 ft or less. Scattered windmills and small-diameter wells equipped with submersible pumps produce water for domestic use and for watering of livestock and wild game in this area.

Limestone and sandstone formations of Cretaceous age make up the aquifer beneath Northwest Eagle Flat. The Cenozoic basin fill, which is as much as 500 to 700 ft thick in the central area of Northwest Eagle Flat, is not known to be a source of groundwater in this area of the basin (Gates and others, 1980). The saturated thickness of the Cretaceous formations that lie beneath the basin fill is unknown. Wells drilled to evaluate the suitability of Northwest Eagle Flat to be the location of a repository for low-level radioactive waste did not fully penetrate the Cretaceous bedrock (Darling and others, 1994). Pumping tests conducted in conjunction with the investigation indicate that the transmissivity of the Cretaceous bedrock formations is highly variable. In many cases, drawdowns of 100 ft or more were recorded at pumping rates that ranged from 10 to 15 gpm (Darling and others, 1994). A smaller number of wells appeared to be capable of substantially larger yields (Gates and others, 1980; Darling and others, 1994; Darling, 1997). The wide variability of well yields is probably related to fault-induced fracturing of the bedrock. The wells with higher yields may be located within zones of denser fracturing. Wells with lower yields may be completed in blocks that have not been highly fractured. The depth to the potentiometric surface ranges from 600 ft along the margins of the basin to between 800 and 1,000 ft beneath the floor of the basin (fig. 16-2).

The Cretaceous formations used to be the only source of drinking water for the unincorporated village of Sierra Blanca (population ~700). In the early 1970's, a newly developed municipal well field 5 mi to the west-southwest of Sierra Blanca was abandoned when water levels fell precipitously after 1 yr of operation (Gates and others, 1980). The rapidly falling water levels were probably related to stresses caused by pumpage from rocks of relatively low permeability and low groundwater storage capacity. Sierra Blanca now gets its water from a well field at the Van Horn municipal airport in Culberson County, 35 mi to the east.

Potentiometric Map

A map of the potentiometric surface (fig. 16-3) delineates four major groundwater divides in the area. A groundwater divide is a naturally occurring hydrologic boundary between adjacent basins or within a basin represented by a high in the potentiometric surface. A groundwater divide is a hydraulic barrier to the direct lateral flow of groundwater. The first divide, which is roughly parallel to the rim of the Diablo Plateau, separates the groundwaters of the Diablo Plateau aquifer to the north from those of the Eagle Flat aquifer to the south. This hydrologic barrier is the *Plateau groundwater divide*.

The second divide lies between the Carrizo Mountains and the Eagle Mountains, forming a narrow saddle beneath the valley between both mountain ranges. This is the *Eagle Flat groundwater divide*. Groundwaters flowing northward from the Eagle Mountains and southward from the Carrizo Mountains converge beneath the floor of Southeast Eagle Flat to form the Eagle Flat groundwater divide. This divide creates two separate flow systems within the Eagle Flat aquifer. The system east of the divide is referred to as the *Allamoore flow system*, and the component west of the divide is the *Sierra Blanca flow system* (Darling, 1997). The potentiometric surface of the Allamoore system is broad and flat, and the 3,800-ft contour is open toward the east in the vicinity of Scott's Crossing, indicating flow toward the east (that is, toward the Lobo Valley aquifer). The potentiometric surface of the Sierra Blanca system is broad and flat, and the 3,600-ft contours in the center of the system are closed. The closed contours representing the surface of the Sierra Blanca system indicate no direct pathway for flow out of the basin.

The third divide extends northwestward from the Eagle Mountains and extends beneath Love Hogback and Devil Ridge. This barrier, referred to as the *Devil Ridge groundwater divide*, lies between the Red Light Draw aquifer and the Sierra Blanca flow system of the Eagle Flat aquifer. The Red Light Draw aquifer originates in the mountains and uplands surrounding Red Light Draw. The potentiometric surface of the Red Light Draw aquifer

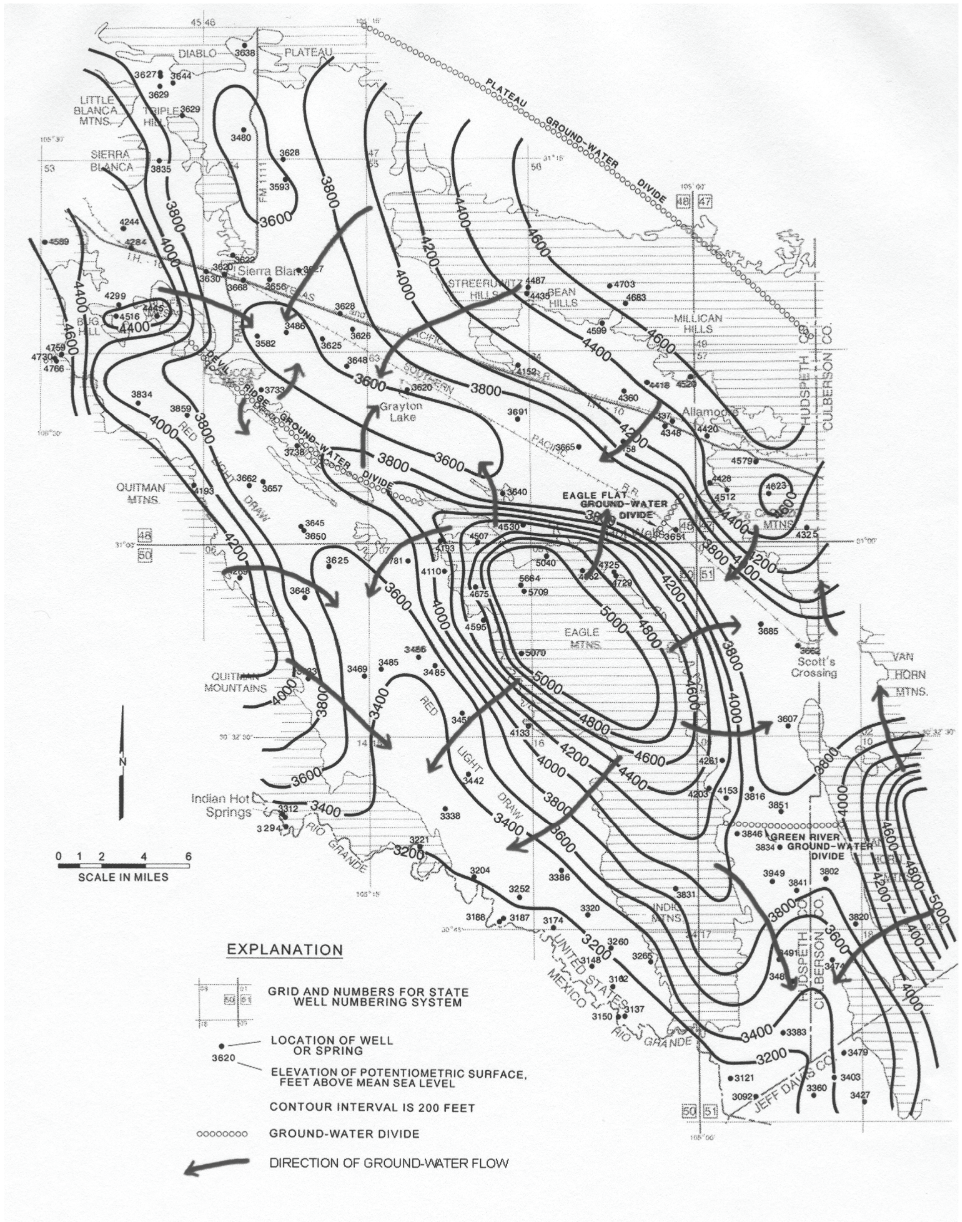

Figure 16-3: Map of the potentiometric surface (adapted from Darling, 1997).

slopes toward the Rio Grande, decreasing from approximately 3,600 ft above msl beneath the northernmost part of the draw to between 3,200 and 3,100 ft above msl in areas adjacent to the river.

The fourth divide extends from beneath the Eagle Mountains eastward to the Van Horn Mountains, forming a broad potentiometric high beneath the topographic high that establishes the boundary between Southeast Eagle Flat and Green River Valley. This is the *Green River groundwater divide*. This divide separates flow in the Green River Valley aquifer from the groundwaters of the Allamoore flow system. Over a distance of approximately 10 mi, the elevation of the potentiometric surface of the Green River Valley aquifer decreases from around 3,900 ft along the highest point of the groundwater divide to between 3,200 and 3,100 ft along the Rio Grande.

Generalized Groundwater Flow Paths

The map of the potentiometric surface (fig. 16-3) provides a basis for delineating flow paths in each of these aquifers.

Red Light Draw and Green River Valley Aquifers

The Red Light Draw and Green River Valley aquifers originate in the mountains that bound the basins. Groundwaters of these basins converge beneath the floors of their respective watersheds. The direction of flow is southward toward the Rio Grande, which lies within the discharge zone of each aquifer. This pattern of flow toward the Rio Grande is characteristic of all other West Texas bolsons that are dissected by the river (Hueco, Presidio, Redford Bolsons).

Eagle Flat Aquifer

Lying to the north of both Red Light Draw and Green River Valley, Eagle Flat is not dissected by a major through-flowing stream such as the Rio Grande or by a smaller stream that drains to the Rio Grande. The floor of the basin lies at a higher elevation than that of the floors of Red Light Draw and Green River Valley, and, with the exception of minor springs in the middle to upper elevations of the Eagle Mountains, there is no area within Eagle Flat where groundwater discharges to the surface. The incision of bolsons by the Rio Grande 2 million yr ago initiated a set of conditions that have allowed for the flow of groundwater from these basins toward the river. The groundwater flow regimes of Eagle Flat and of other basins that have not been dissected by the Rio Grande (e.g., Ryan Flat, Lobo Valley, Wildhorse Flat, and Michigan Flat) are unlike those of Red Light Draw and Green River Valley (as well as the Hueco Bolson and the Presidio and Redford Bolsons). A few researchers have suggested that these aquifers might be linked to a deep regional flow system that transports groundwater toward the east (Nielson and Sharp, 1985; Sharp, 1989). Eagle Flat is the westernmost of the bolsons that are not bordered by the Rio Grande. The degree to which this basin is hydrogeologically integrated with others is not well understood. The following two sections of this paper present a set of hypotheses regarding possible directions of flow from this aquifer.

Allamoore Flow System

Flow lines indicate that the direction of flow from the Allamoore system is toward the east (fig. 16-3). This interpretation is based partly on consideration of water-level measurements from Lobo Valley (Gates and others, 1980; Darling and others, 1994; LBG-Guyton Associates, 1999), where the potentiometric surface manifests a northward-directed gradient at elevations ranging from approximately 3,700 to 3,600 ft above msl immediately east of Scott's Crossing (Gates and others, 1980; LBG-Guyton Associates, 1999). If bedrock formations are sufficiently permeable to permit the flow of groundwater from the Allamoore system to the Lobo Valley aquifer, then the lower hydraulic potential east of the Scott's Crossing basin boundary should allow for the possibility of flow from the Allamoore system to the Lobo Valley aquifer. The lower hydraulic head of the Green River Valley aquifer (between 3,200 and 3,100 ft along the Rio Grande) cannot be ignored because the elevations along the river also suggest the potential for flow toward the south beneath the Green River groundwater divide from deeper sections of the Allamoore system. However, the few data in this area do not permit the partitioning of flow between eastward and southward components from the Allamoore system at this time. The best that can be argued is that the lower hydraulic head in basins to the east and to the south of Southeastern Eagle Flat underscore only the potential for flow in one or both directions.

Sierra Blanca Flow System

Both the Eagle Flat and the Devil Ridge groundwater divides appear to limit direct lateral flow from the Sierra Blanca system to the Allamoore system and to Red Light Draw. The most likely avenue for the transfer of groundwater from the Sierra Blanca system is along vertical pathways to more porous and permeable rocks that underlie the Cretaceous bedrock. The depth to the static water level (fig. 16-2) and the relatively flat potentiometric surface (fig. 16-3) suggests the influence of a drain that permits flow downward to an intermediate or a regional flow system.

At least one well offers support for the occurrence of higher porosity and permeability in bedrock formations of the Eagle Flat Basin. In 1965, Texaco, Inc., drilled a 1,700-ft core test (Capitan Drilling Co., No. 1 Espy Ranch) approximately 5 mi to the west of the Eagle Flat groundwater divide. The surface elevation at the well was reported to be 4,368 ft above msl. The drilling record on file at the TWDB shows that the borehole penetrated 240 ft of basin fill before encountering limestone. The record also reports lost circulation in bedrock between depths of 1,590 ft and 1,700 ft. The drillers were unable to regain circulation, and the well was plugged and abandoned at a depth of 1,700 ft.

This core test was one of the deepest recorded penetrations of bedrock in Eagle Flat. The loss of circulation reported for this test occurred at an elevation of 2,778 ft above msl, or nearly 1,000 ft below the potentiometric surface in this part of the Sierra Blanca flow system. The loss of circulation in the well suggests that higher permeability pathways in bedrock formations might provide a deep bypass of local groundwater divides. Similar pathways for flow beyond basin boundaries in the Great Basin of southern Nevada have been described by the USGS (Winograd, 1962).

Two possible directions of flow from the Sierra Blanca system are postulated. The first is toward the east, beneath the Allamoore system. The second is toward the south, beneath the Red Light Draw aquifer. The lowest elevations of the potentiometric surface of the Sierra Blanca system are approximately 3,600 ft above msl; and within the Allamoore system, the lowest elevations are approximately 3,700 ft above msl in the vicinity of Scott's Crossing (fig. 16-3). Along the Rio Grande, however, the elevations are between

3,200 and 3,100 ft above msl. The river, therefore, establishes the zone of lowest hydraulic potential in the study area.

The higher hydraulic head of the Allamoore system may limit the potential for the eastward flow of groundwater from the Sierra Blanca system. However, the nearly 400-ft difference in head between the lowest areas of the Sierra Blanca system and the Red Light Draw aquifer indicates that groundwater of the Sierra Blanca system might flow southward, beneath the Devil Ridge groundwater divide—first along vertical flow paths and then southward in deeply buried Cretaceous formations and Tertiary igneous rocks. Gates and others (1980) also observed that “the available water-level data are not sufficient to trace the movement of ground water in northwestern Eagle Flat, but the data suggest that the water may discharge through the Cretaceous rocks in the subsurface, probably toward the Rio Grande to the south.”

Recharge of the Aquifers

Researchers with the USGS have surmised that the aquifers of West Texas are recharged by infiltration along the foothills of mountains and plateaus and locally along the channels of ephemeral streams in the basins (Gates and others, 1980). Their recharge estimates, however, are based on the assumption that 1 percent of average annual precipitation of 12 inches distributed uniformly across the area is available to recharge the aquifers of Red Light Draw, Green River Valley, and Eagle Flat. Proceeding from this assumption, the USGS (Gates and others, 1980) estimated that average annual recharge attributable to precipitation might be as much as 2,000 acre-ft in Red Light Draw, 1,000 acre-ft in Green River Valley, and 3,000 acre-ft in Eagle Flat (an acre-ft is equal to 325,851 gallons.)

Darling (1997), on the basis of his research using analyses of the radioactive isotopes carbon-14 and tritium to delineate recharge areas of Red Light Draw and Eagle Flat and also on a cross-sectional numerical flow model through Red Light Draw (Hibbs and Darling, 1995), concluded that recharge in Red Light Draw occurs only along the higher elevations of the mountain fronts and not within the middle to lower elevations of alluvial fans or along the floors of the basins. He estimated that total recharge might be as little as 14 percent (or 280 acre-ft) of the average annual estimates by Gates and others (1980). If this is typical of other areas, then recharge in Eagle Flat and Green River Valley might be as low as 430 and 120 acre-ft, respectively.

More recently, LBG-Guyton Associates and others (2001) used a modification of the approach by Gates and others (1980) to derive estimates of recharge for each of the bolsons of West Texas. The aquifer outlines as shown on maps published by the TWDB (Ashworth and Hopkins, 1995) were regarded as “storage” areas, and only the highlands that form the boundaries of the aquifers were considered to be primary recharge areas. One percent of average annual rainfall over the highlands was assumed to be available as recharge. All precipitation and runoff over the storage zones were assumed to be removed by evaporation and transpiration. (In Red Light Draw and Green River Valley, runoff to the Rio Grande also accounts for a pathway to remove surface water from the basins.)

Using this approach, LBG-Guyton Associates and others (2001) estimated that recharge might be 700 acre-ft/yr in Red Light Draw and Green River Valley and approximately 1,000 acre-ft/yr in Southeastern Eagle Flat. The lower estimates of recharge derived by Darling (1997) and by LBG-Guyton Associates and others (2001) should be interpreted to indicate only that a reasonable basis exists for inferring that the aquifers of this area might receive a much smaller amount of recharge than estimates based on an assumed relationship between annual precipitation and the entire surface area of a basin.

Water Quality

The quality of water varies widely, not only between but also within the basins (fig. 16-4). Chloride concentrations in the central area of the Sierra Blanca flow system range from 5 to 20 millimoles/liter (180 to 710 milligrams/liter [mg/L]). The highest concentrations occur within the central areas of the flow system. In the Allamoore system and the Green River Valley aquifer, chloride concentrations are typically less than 35 mg/L. In the Red Light Draw aquifer, the concentration of chloride ranges from 35 to 70 mg/L except in areas along the river where concentrations increase to between 700 and 5,000 mg/L. The higher concentrations of chloride associated with the Rio Grande alluvium are attributed principally to the flushing of salts that accumulated over long periods of time from the evaporation of water used to irrigate crops and to the infiltration of salty irrigation-return water from the Rio Grande. The elevated concentrations of chloride are typically accompanied by sulfate concentrations that range from 300 to as much as 2,000 mg/L. The secondary drinking-water standards promulgated by the U.S. Environmental Protection Agency specify 250 mg/L as the maximum concentration of chloride and of sulfate. Although most high-chloride/high-sulfate waters are not regarded as suitable for consumption by humans, they are typically acceptable for watering of livestock.

Potential for Development

The development potential of the Red Light Draw, Green River Valley, and Eagle Flat aquifers has not been fully examined. Research programs conducted by the USGS (Gates and others, 1980) and The University of Texas at Austin, Bureau of Economic Geology (BEG) (Darling and others, 1994) have not explicitly addressed this important issue. The disappointing performance of the municipal well field developed for Sierra Blanca (Gates and others, 1980) and the results of aquifer tests conducted in Eagle Flat by the Bureau of Economic Geology (Darling and others, 1994) could cause skepticism regarding the large-scale development potential of Northwestern Eagle Flat. Without significantly more detailed hydrogeologic investigations in other areas, nothing can be stated with certainty regarding the development potential of Southeastern Eagle Flat, Red Light Draw, or Green River Valley. Further comment on this matter would be little more than speculation.

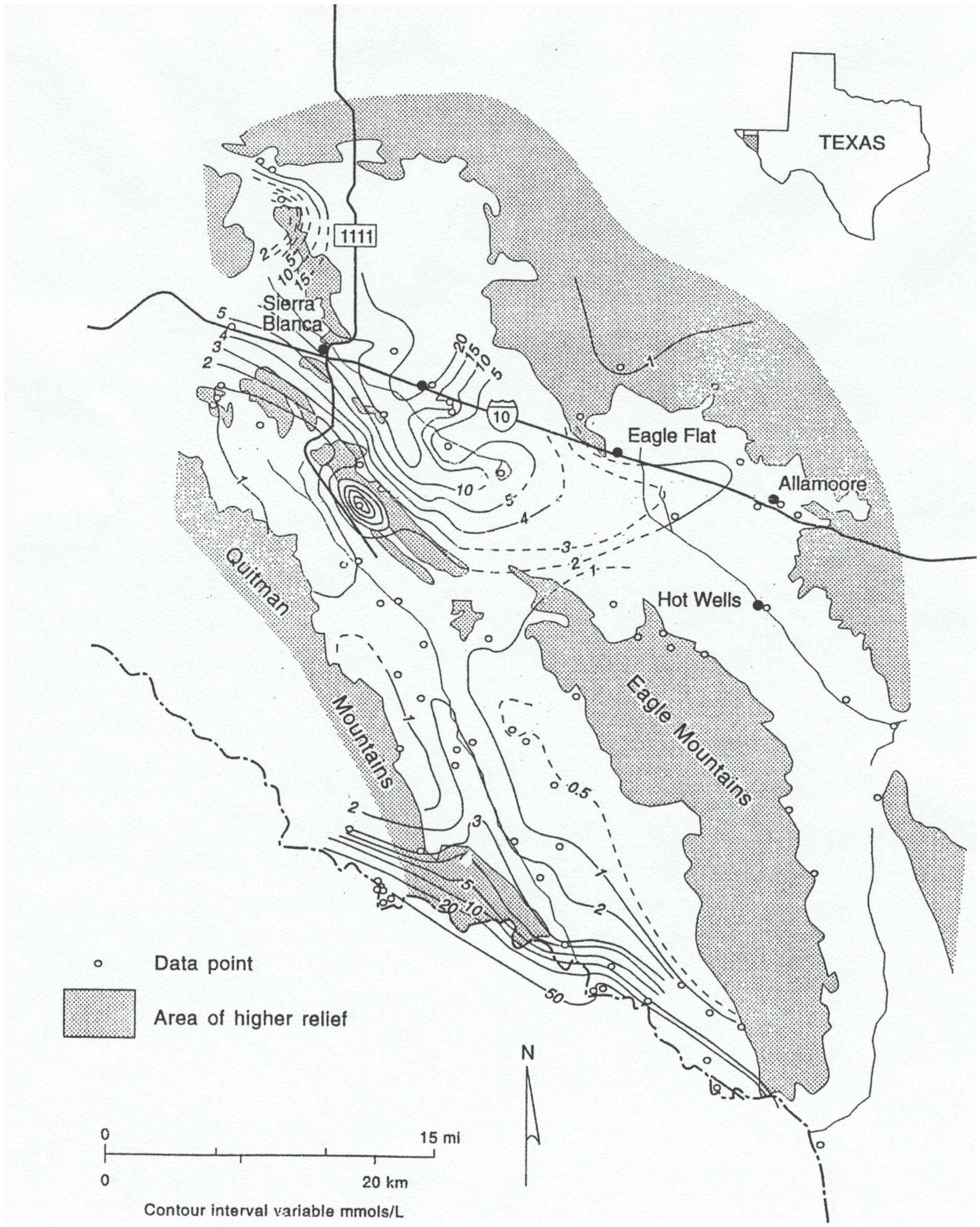

Figure 16-4: Chloride concentrations in groundwater (adapted from Darling, 1997).

Conclusions

The aquifers of Red Light Draw, Green River Valley, and Eagle Flat present an interesting set of problems with regard to our understanding the hydrogeologic integration of the bolsons of West Texas. Groundwaters of Red Light Draw and Green River Valley, for example, flow toward the Rio Grande—in a manner consistent with all other bolsons down-cut by the river. The flow of groundwater from Eagle Flat, however, is not clearly apparent. Located north of Red Light Draw and Green River Valley, Eagle Flat appears to have more in common with other bolsons that are not bordered by the Rio Grande. There are insufficient data to allow flow paths from the Allamoore and Sierra Blanca systems to be delineated with certainty. At least two pathways from each system are possible, and a substantial amount of hydrogeologic research will be required to determine where the groundwaters of these systems flow.

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