Chapter 10

Bone Spring-Victorio Peak Aquifer of the Dell Valley Region of Texas

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Introduction

The Bone Spring-Victorio Peak aquifer produces groundwater in an irrigated region commonly referred to as Dell Valley. Because of its importance to the local agricultural economy, the Texas Water Development Board (TWDB) has designated the Bone Spring-Victorio Peak as a minor aquifer and has delineated its extent in Texas on the basis of its occurrence underlying irrigable land. This paper, which is a modification and update of TWDB Report 344 by the same author, describes the groundwater resource underlying the valley in terms of its geological and hydrological characteristics, quantity, quality, historical use, and changing conditions.

Location

Dell Valley is located 75 mi east of El Paso and 20 mi west of the Guadalupe Mountains in northeastern Hudspeth County (fig. 10-1). Dell City, with a population of approximately 500, is located in the center of the irrigation district. The valley consists of approximately 40,000 acres of irrigable land in Texas and extends northward into Otero County, New Mexico, where it is referred to as Crow Flats. Low rainfall, averaging 8 to 10 inches annually, and a high rate of evaporation, which averages nine times the precipitation rate, characterize the arid climate in the region.

Dell Valley is a broad, alluvial, outwash plain that is bordered on the east by the Salt Basin and gently rises to the west and south to limestone uplands of the Diablo Plateau. The land-surface elevation of the valley rises gradually from approximately 3,640 ft above sea level on the eastern edge to approximately 4,200 ft on the western edge.

Although infrequent, a major problem in the watershed is its susceptibility to flooding. Surface drainage originates in the Cornudas Mountains, Sixteen Mountains, and the Sierra Tinaja Pinta in the far western extent of the watershed. Floodwaters intermittently traverse from the highlands onto the Dell Valley alluvial plain through Eightmile, Hitson, C&L, and Washburn draws in Texas, and Cornudas and North draws in New Mexico (fig. 10-2). Total watershed area is approximately 600 mi^2. Runoff from a storm in 1966 resulted in the largest flood in Dell Valley's recorded history and caused approximately

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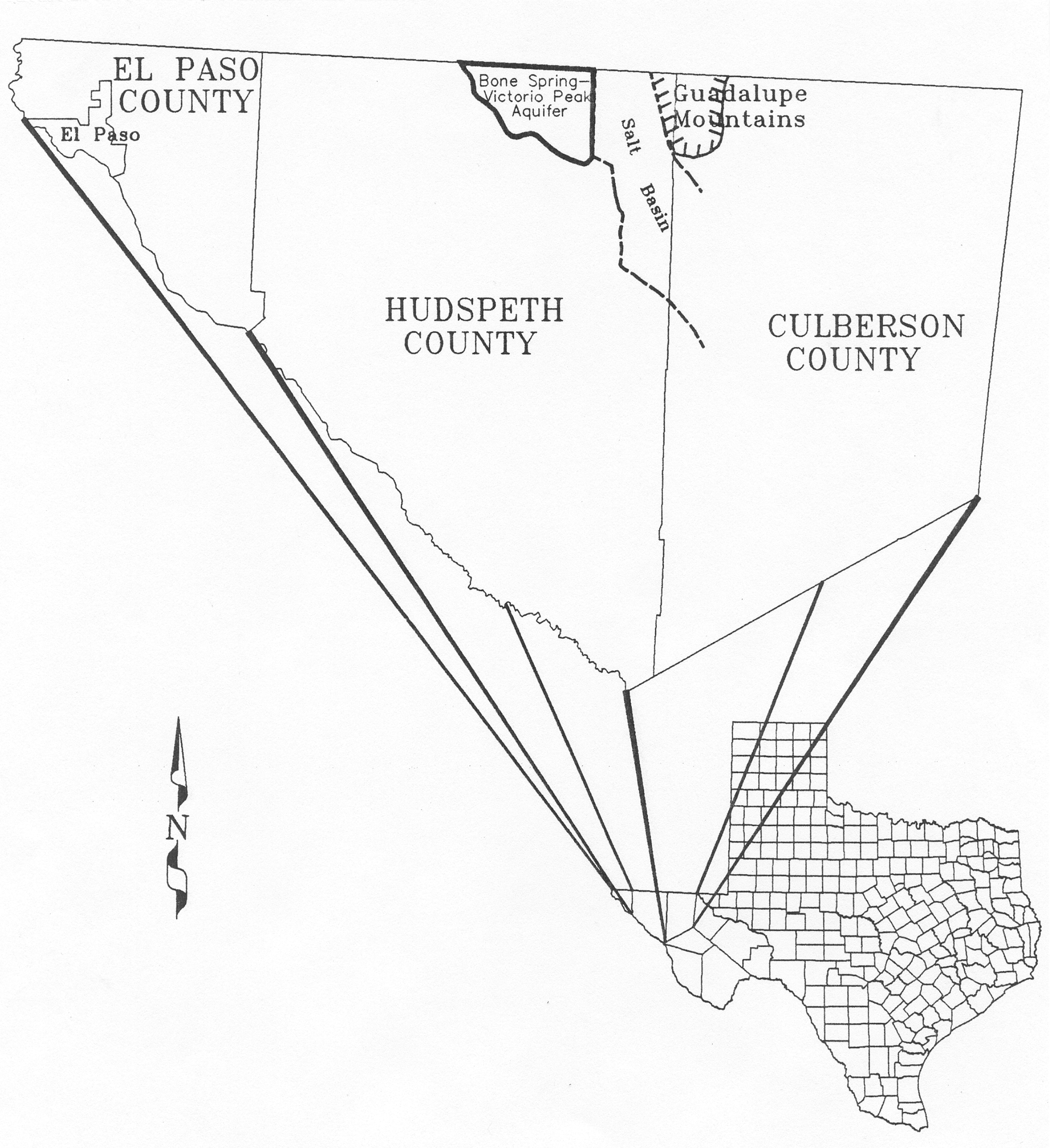


Figure 10-1: Location of the Bone Spring-Victorio Peak aquifer.

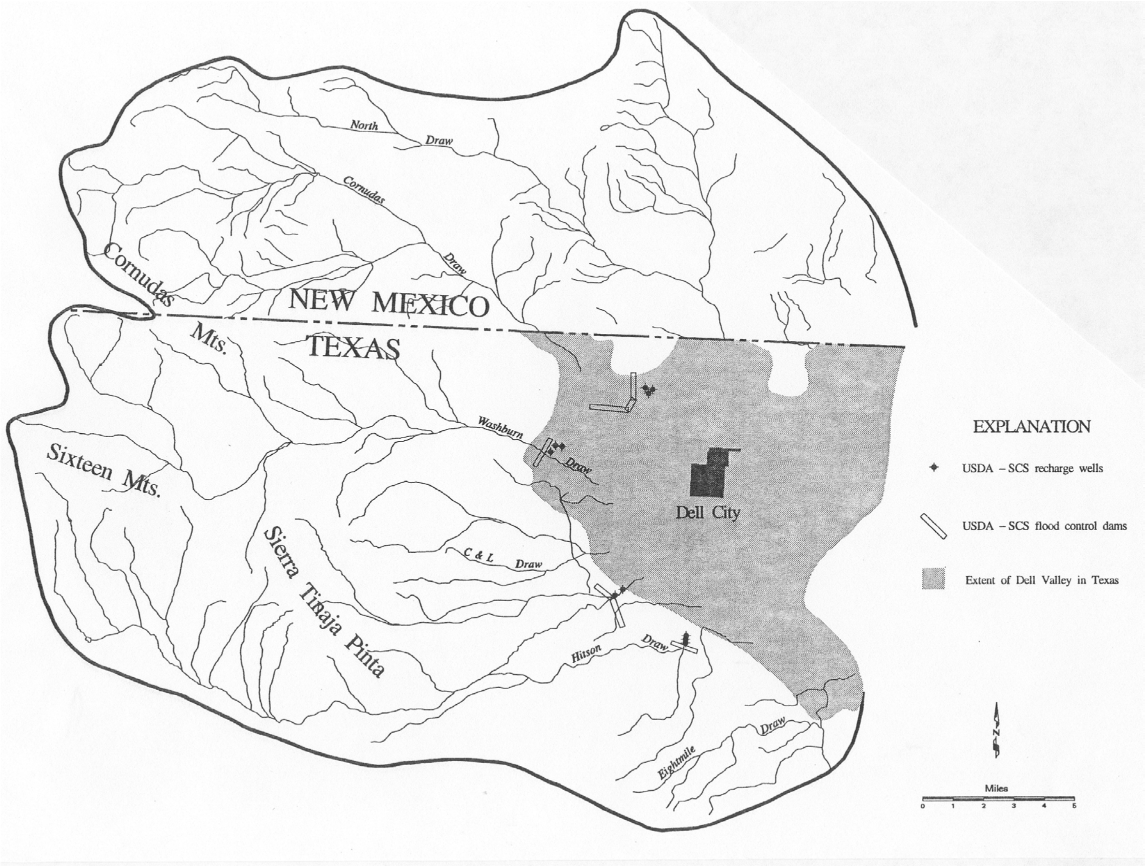


Figure 10-2: Watersheds contributing to Dell Valley.

$3 million in damages (El Paso-Hudspeth Soil and Water Conservation District and others, 1969).

Floodwaters reaching the valley floor typically fan out in an overland or sheet-type flow causing extensive damage. However, the U.S. Department of Agriculture, Soil Conservation Service, has constructed four flood-control structures on the west side of the valley (fig. 10-2) to capture floodwaters draining through Cornudas, Hitson, C&L, and Washburn draws.

History of Water Use

Springs

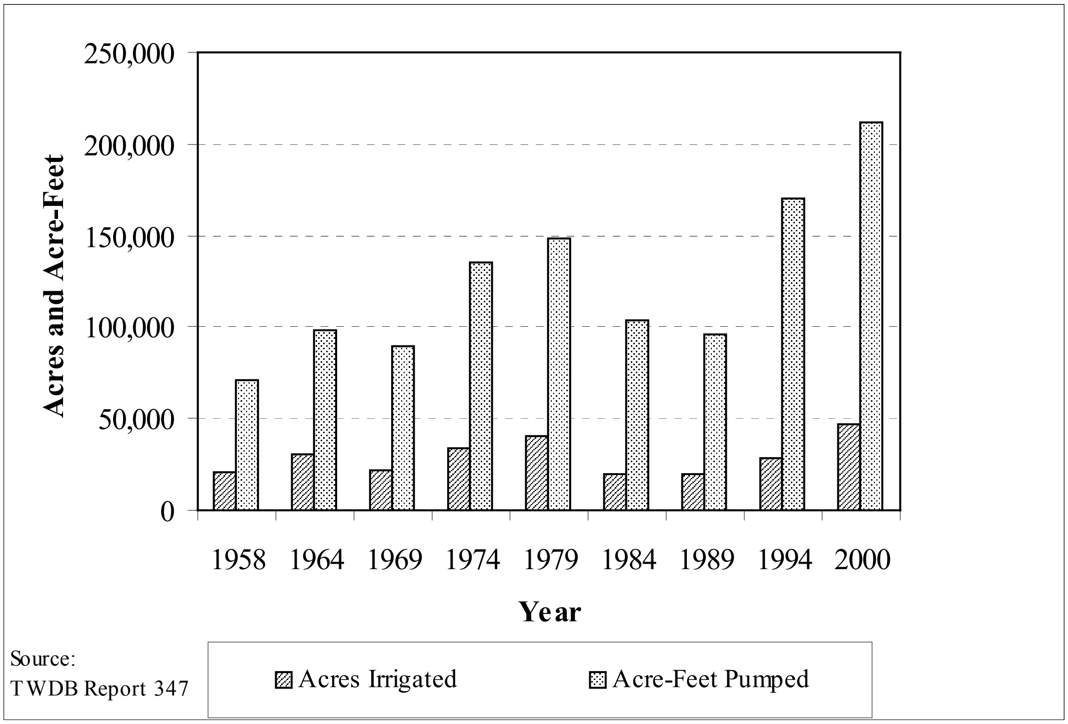
The first mention of water supplies in the area is recorded in scientific journals and military travel logs from the middle 1800's (e.g., Marcy, 1851; Pope, 1954). Travelers involved in exploration and survey trips, wagon trains, and military expeditions frequently stopped at Crow Springs (also known as Ojos del Cuervo) to replenish their water supplies (Brune, 1981). The springs were also a stage stop on an early Butterfield Overland mail route. Located northeast of Dell City and near the State line, Crow Springs issued brackish water that had a strong sulfur odor and filled two shallow lakes that covered 4 or 5 acres. Shallow wells dug in the vicinity of the springs provided more potable water. As late as 1948, the springs still trickled approximately 3 gallons per minute (gpm). However, by 1950, pumping of irrigation wells drilled near the springs lowered the water table and brought an end to the discharge.

Irrigation

Prior to the introduction of the first irrigation wells in 1947, Dell Valley was primarily the site of cattle ranching, and the only use of groundwater was for domestic and livestock needs (Scalapino, 1950). By 1949, 78 wells had been drilled; however, only 32 wells had sufficient yields to be used for irrigation purposes. About 2,500 acres were irrigated in 1948. A year later, about 6,000 acres of feed crops and cotton were irrigated with approximately 18,000 acre-ft of groundwater.

Across the State line in the Crow Flats area of New Mexico, a few wells were completed with windmills for domestic and livestock use as early as 1905 and 1906 (Bjorklund, 1957). The first irrigation wells were drilled in 1949 shortly following their introduction in Dell Valley. In 1956, 17 out of 23 wells drilled to supply water for irrigation in Crow Flats were in use to irrigate approximately 3,000 acres of cotton and alfalfa. In the combined Dell Valley–Crow Flats region, 228 irrigation wells were in use in 1956 to irrigate approximately 32,000 acres.

Irrigated agriculture in the valley continued to expand through the late 1970's as approximately 39,000 acres of cropland were irrigated with 144,000 acre-ft of groundwater (TWDB, 1996). Irrigation diminished through the 1980's as a result of declining market conditions, increased labor expense, and government conservation programs. Irrigation in the 1990's once again increased. A 1994 survey indicated approximately 28,000 acres was irrigated with 165,000 acre-ft of groundwater. Figure 10-3 shows the amount of water pumped for irrigation use and the corresponding number of acres irrigated for specified time periods.



Source:
TWDB Report 347

Figure 10-3: Irrigation pumpage and acres irrigated.

Public Supply

With a population of more than 500, Dell City became incorporated in 1961 and began plans for a public water-supply system (Young, 1975, 1976). Domestic water supply had previously been provided by several private water companies; however, by 1964, it was evident that the area groundwater supply was becoming increasingly saline and a water treatment system would be necessary.

In 1967, the city installed an electrodialysis treatment plant with a capacity of 50,000 gallons per day (gpd). The plant was designed to mitigate as much as 2,450 parts per million (ppm) dissolved solids to potable standards. Water was supplied from a single well (North Well, 48-07-522). Dell City was the first community in the United States to incorporate saline water conversion equipment in a system financed by the Farmers Home Administration, U.S. Department of Agriculture. The plant was increased to 69,000 gpd in 1968 in order to treat enough water to satisfy peak demands. Also, an additional well (Elias or South Well, 48-07-523) was brought into the system.

By 1974, the plant had become ineffective. Chemical quality of the source water from the aquifer had deteriorated beyond the design specifications for the plant. In addition, the plant system had not been adequately maintained. The old plant was replaced in 1976 with a modern, reverse-polarity-type electrodialysis plant with a 100,000-gpd capacity. The plant is currently in use and operates at a rate of 50,000 to 70,000 gpd.

In 1986, the Prather Well (48-07-219), located 3 mi north of town, was drilled to provide the primary source of water to the plant. The North Well is still connected to the system as a backup but is rarely used for that purpose.

The city also operates a separate water delivery system for irrigation use. Water for this purpose is pumped from the North Well and is supplemented with the by-product water from the electrodialysis treatment plant. The plant by-product water is actually of better quality than the water from the North Well. The Elias Well is used occasionally as a backup or supplement to the irrigation system.

Geology

The principal water-bearing rocks that underlie Dell Valley are limestones and dolomites of Permian age. These rocks of marine origin were deposited in the early development of the Delaware Basin. The Victorio Peak Limestone occupies much of the surface area immediately west of the Salt Basin on the Diablo Plateau and, along with the underlying Bone Spring Limestone, is prominently exposed on the eastern escarpment of the Sierra Diablo south of Dell Valley (King, 1965). The Bone Spring Limestone is predominantly a black to dark-gray, cherty limestone with thin interbedded black or brown layers of siliceous shale. The Bone Spring grades upward into the Victorio Peak Limestone, a light-gray, thick-bedded, mainly calcitic but slightly dolomitic limestone.

Two significant faults are of particular interest in the Dell Valley area. A north-south-trending fault is the west boundary of the Salt Basin and represents the approximate eastern extent of the aquifer. Displacement along the fault has not been precisely determined; however, sediments on the eastern side of the fault have probably dropped several hundred feet (King, 1948; Gates and others, 1980; Goetz, 1977). A second fault, trending northwest-southeast, forms the southern topographic edge of the valley and is also the designated aquifer boundary. Downward displacement of approximately 100 ft occurs on the north side of the fault.

An igneous (volcanic) intrusive body of Tertiary age, known locally as Round Mountain, crops out 3 mi east of Dell City and rises about 175 ft above the valley floor (fig. 10-4). Other prominent igneous peaks comprise the Sierra Pinta and Cornudas Mountains approximately 10 to 15 mi west of Dell City.

Overlying much of the Permian limestone formations in the delineated aquifer area is a mantle of up to 150 ft of Quaternary and recent alluvial sediments ranging in size from boulders to silt and clay. The sediments were eroded from highlands to the west and northwest, transported by flooded streams, and deposited on the relatively flat valley floor. Surface soils overlying the alluvium are largely gray silts and silt loams, underlain at depths of 1 to 3 ft by a soft marl or caliche. The high natural salinity of the soil suggests that at one time, the salt lake that currently exists in the Salt Basin to the east

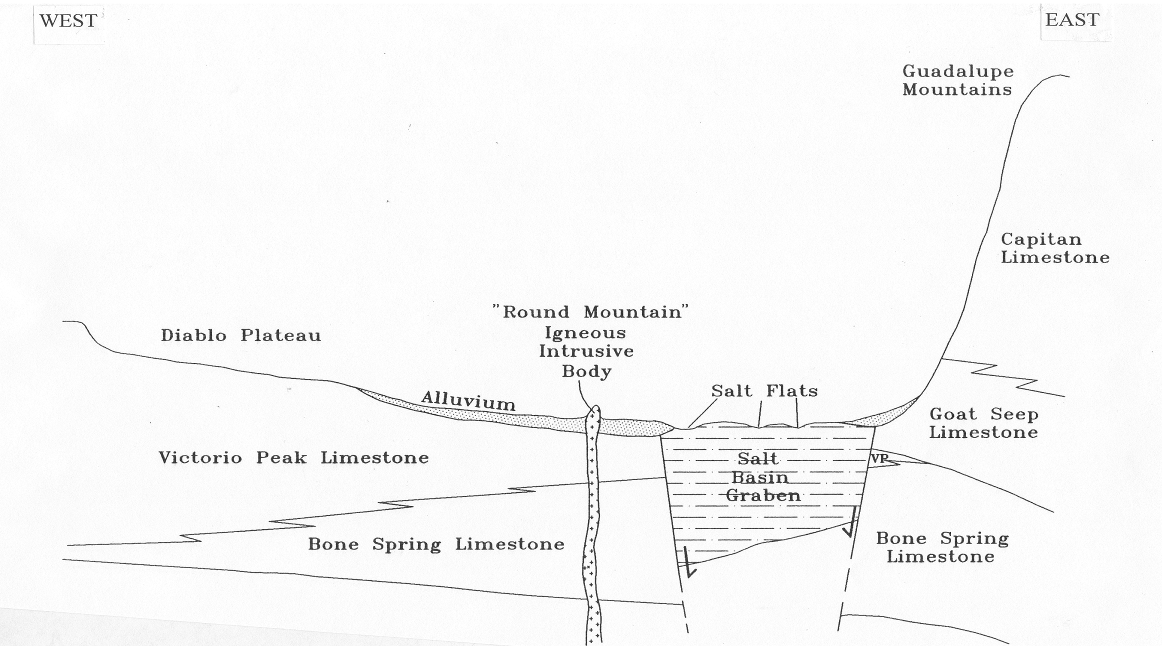


Figure 10-4: Generalized geologic section across Dell Valley and the Salt Basin.

may have covered the entire valley. Years of irrigation water application have actually improved the chemical condition of the soil by lowering the pH and total salt and sodium content (Longenecker and Lyerly, 1959). Unfortunately, these minerals have not been eliminated but, instead, have been transported downward to the underlying aquifer.

Hydrology

Occurrence

Groundwater occurs in the Permian limestones throughout the Diablo Plateau region. However, unlike elsewhere on the plateau, the aquifer in the Dell Valley area has been developed because of the relatively shallow water table and the presence of soils capable of growing crops. Groundwater in the aquifer is concentrated in interconnected solution cavities that have developed in joints, fractures, and bedding planes that vary in size and dimension. Water-bearing zones have been encountered in wells drilled in excess of 2,000 ft. Well production is thus linked to the number and size of cavities intercepted by the well bore.

Recharge

Recharge to the regional Diablo Plateau aquifer system is derived from the infiltration of precipitation on the entire plateau area of approximately 2,900 mi^2 and the downward seepage of water in the Sacramento River. Recharge on the Diablo Plateau primarily occurs as infiltration of runoff in beds of ephemeral streams, or arroyos, during occasional flash floods. Only during intense rainstorms is the rate of precipitation greater than evaporation. Much of the groundwater in Dell Valley originates as precipitation that infiltrates into the regional aquifer system within the drainage area (fig. 10-2). Karst features, such as vertical fractures and sinkholes, permit rapid access of infiltrating surface water. The presence of tritium in most well samples collected from the plateau aquifer indicates recent recharge (Kreitler and others, 1987).

The Sacramento River, which drains the Sacramento Mountains in New Mexico, is a major source of recharge in the northern segment of the plateau (Scalapino, 1950; Mayer, 1995). Water drains rapidly into the subsurface as the river leaves higher elevations and encounters the flatter surface of the plateau. Mayer (1995) showed that groundwater in the northern part of the plateau is chemically similar to the water in the river but differs from groundwater elsewhere in the plateau. Mayer speculates that the river source may influence the quality of the aquifer in the northern and eastern parts of Dell Valley, where fresher conditions occur.

A change in the chemical quality of groundwater in the valley over time is a possible indication that some water pumped for irrigation use has returned to the aquifer. Logan (1984) suggested that 35 percent of groundwater pumped returns to the aquifer. Davis and Gordon (1970) estimated a return-flow of as much as 50 percent.

A continuous water-level record in well 48-07-516 and annual irrigation pumpage in the valley for specified years are compared in figure 10-5. Since 1984, irrigation pumpage has varied from approximately 40,000 to 100,000 acre-ft annually. At the lower range of annual pumpage (40,000 to 60,000), water levels have risen, while at a higher range of pumpage (90,000 to 100,000), water levels have remained relatively constant. Therefore, 90,000 to 100,000 acre-ft appears to be a reasonable estimate of total annual recharge to the aquifer, which includes both lateral inflow and irrigation return-flow.

Construction of four flood-control structures on the western side of Dell Valley is capable of providing as much as 3,300 acre-ft of recharge annually by seepage through the highly permeable pool area (El Paso-Hudspeth Soil and Water Conservation District and others, 1969). However, there has not been enough significant rainfall to fill the reservoirs since the completion of the dams. Included in the project are 11 wells for recharging water captured by the dams (fig. 10-2). Each well is designed with the intention of recharging water by gravitational flow at a rate of at least 2,000 gpm (Logan, 1984).

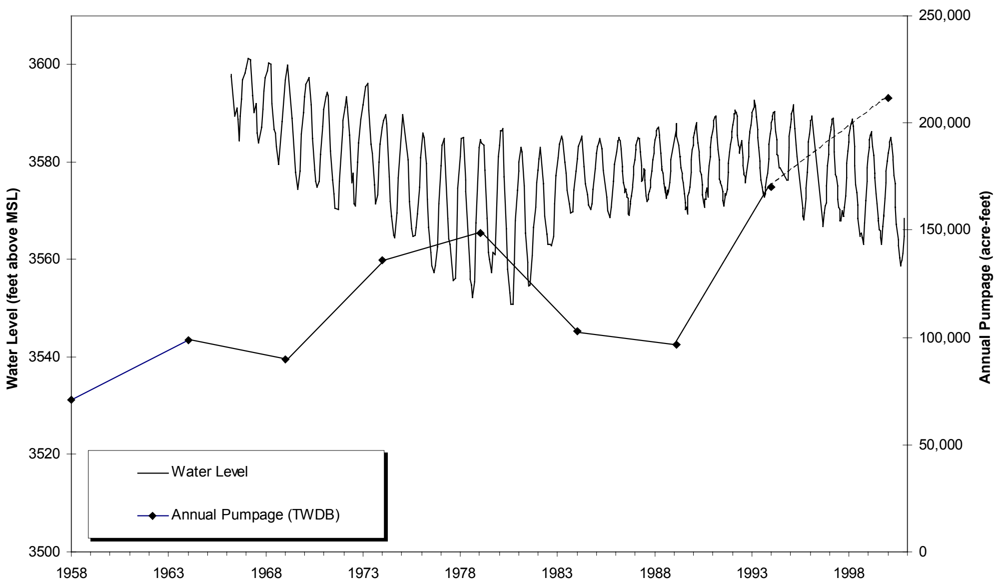


Figure 10-5: Hydrograph of water level in well 48-07-516 and annual pumpage during designated years.

Movement

Regionally, groundwater moves in an east-to-northeasterly direction from the Diablo Plateau in Texas toward the Salt Basin, where it discharges naturally by evaporation from the salt flats. Across the State line in New Mexico, groundwater flow moves in a southeasterly direction toward the basin (Mayer, 1995). A regional potentiometric surface map prepared by Kreitler and others (1987) illustrates a relatively low hydraulic gradient of 2.5 to 5 ft/mi. Within the Salt Basin, groundwater percolates upward to the surface, drawn by evaporation through the capillary fringe in the flats (Boyd and Kreitler, 1986).

The orientation and concentration of solution cavities developed along prominent fractures and bedding planes control water movement on a local scale. During the irrigation season, movement is altered in the direction of pumping wells.

Declining water levels caused by pumpage may reverse the groundwater flow direction on the eastern side of the valley and allow highly saline water to move westward into the irrigated region. Current water-level elevations in the central part of Dell Valley are, in fact, lower than levels in the adjacent Salt Basin, which suggests that the potential for such movement does exist. However, chemical-quality analyses of water samples from wells located along the eastern side of the valley do not indicate a significant influx of saline water. The less-permeable sediments that fill the Salt Basin may hinder rapid migration of the saline water.

Discharge

Large quantities of water are discharged from the aquifer annually. Discharge occurs naturally through springs, seeps, and evaporation from the salt flats and artificially by pumpage.

Natural Discharge

Eastward migrating groundwater underlying the Diablo Plateau moves into the Salt Basin, where it partially discharges by evaporation, especially from the salt flats where the water table is 3 to 10 ft below the surface (Boyd and Kreitler, 1986). Prior to irrigation development, the aquifer was at a quasi-steady state, and the amount of water discharged through evaporation from the salt flats was approximately equal to the recharge to the Bone Spring-Victorio Peak aquifer in the Dell Valley and Crow Flats areas.

Bjorklund (1957) estimated that less than 100,000 acre-ft annually were originally discharged by way of evaporation. Davis and Leggat (1965) estimated that approximately 40,000 acre-ft evaporate annually in the Texas portion of the Salt Basin. Boyd and Kreitler (1986) suggested that evaporation rates on the salt flats could theoretically range from 15.7 to 78.7 inches/yr or more. At this rate 49,000 to 243,000 acre-ft of groundwater could evaporate annually.

Pumpage

With the advent of irrigated agriculture in the 1940's, pumpage has become the principal means of discharge from the aquifer. Except for a scattering of wells throughout the Diablo Plateau, almost all of the pumpage occurs in the Dell Valley and Crow Flats areas. Pumpage in the Dell Valley area reached a peak in the late 1970,s, with more than 140,000 acre-ft being pumped annually. Annual withdrawals for irrigation use since 1984 range from approximately 40,000 to 100,000 acre-ft. During the 1970's, pumpage exceeded recharge, resulting in a decline in the elevation of the water table. The historical development of groundwater use in this area is discussed more thoroughly in the section titled "History of Water Use."

Regionally, the aquifer is highly transmissive. However, at any particular location, well yields can vary significantly. Highly productive wells, producing up to 3,000 gpm, are those that intersect numerous fractures and solution zones. Fractures are not, however, equally distributed throughout the aquifer, as is evidenced by the number of lower capacity wells (e.g., 300 gpm) that have been drilled in the near vicinity of highly productive wells.

Water Levels

Water Table

Depth to water was measured in 72 wells in February 1994 at a time when the aquifer water level should have reached its maximum recovery just prior to the start of the spring pumping season. Altitude of the water table above mean sea level was calculated and contoured as shown on figure 10-6. Ninety-three percent of the measurements vary between altitudes of 3,587 and 3,602 ft and average 3,594 ft. The lowest water levels occur near the center of the valley in the vicinity of Dell City and north of town near the location of the primary municipal supply well. The fault that forms the southern boundary of the valley does not appear to affect water levels in its vicinity. South of the delineated valley, low water levels occur in the vicinity of Highway 62-180.

The relative flatness (low gradient) of the water table results in a westerly increase in depth to water as the land surface altitude increases. Depth to water ranges from a few feet below the surface in the salt flats to more than 800 ft in higher elevations of the Diablo Plateau (Kreitler and others, 1987). Within the irrigated region of the valley, depths to water range from 33 ft along the eastern side to 323 ft on the west.

Seasonal Fluctuation

Water levels in the valley exhibit a seasonal fluctuation. During the irrigation season, the large quantity of water pumped from the aquifer results in a depressed water-table surface as more water is being withdrawn than can be immediately replaced. However, during the winter (nonpumping) season, the water table rebounds as additional water recharges the aquifer system, and cones of depression recover. The seasonal water-level fluctuation can be observed on the hydrograph of well 48-07-516 (fig. 10-5). The hydrograph shows that the aquifer response is in the range of 15 to 35 ft, depending on the amount of annual pumpage.

Water-Level Change

Drawdown on the aquifer occurred immediately after irrigation wells began pumping in the late 1940's. The water level dropped at an average rate of 1.3 ft/yr for the next 30 yr as pumpage exceeded recharge to the aquifer. By the late 1970's, water-level declines of 25 to 45 ft had occurred throughout the valley. During the 1980's irrigation pumpage diminished somewhat, and water levels remained relatively constant or, in some locations, rose slightly. Since the mid-1990's, water levels once again are on a downward trend, averaging 1 to 2 ft of decline per year.

Water Quality

Chemical Quality Characteristics

The groundwater underlying Dell Valley is generally brackish, very hard, and dominated by elevated levels of calcium, sodium, sulfate, and chloride. Water in the Dell Valley area can be classified as slightly to moderately saline, with TDS ranging from approximately 1,000 to more than 6,500 milligrams per liter (mg/L, and averaging about 3,500 mg/L (fig. 10-7). TDS is greatest along a north-south strip east to southeast of Dell City, where concentrations exceed 5,000 mg/L.

The prominence of calcium, sodium, sulfate, and chloride minerals in the groundwater can be traced to two dominant processes: (1) water flowing through the aquifer system and dissolving minerals along the flow path and (2) irrigation water percolating downward through the soil zone. Calcium and sulfate minerals are readily dissolved by groundwater that comes in contact with evaporite deposits in the Bone Spring and Victorio Peak Limestones. The very high hardness (as $CaCO_3$) value is also indicative of groundwater in a limestone/dolomite environment.

Irrigation water percolates with relative ease through the naturally saline soils and underlying gypsiferous caliche of the valley. However, some of the water applied to the land surface is partially evaporated, which leaves behind a slightly more concentrated dissolved mineral solution. In order to leach salt minerals from the root zone of crops, relatively large amounts of water are applied annually to the porous land surface. Thus, each application of water delivers additional dissolved minerals, especially sulfates and chlorides, downward to the aquifer.

1992 Quality Survey

A water-quality survey was conducted in 1992 in which samples were collected from 30 wells and were analyzed for primary and trace inorganic minerals, nutrients, pesticides, and radionuclides. Sulfate was found to be the most prominent constituent, with concentrations ranging from 631 to 2,448 mg/L. Calcium, sodium, and chloride also attain high levels of concentration.

Water samples were analyzed for the following minor or trace inorganic constituents: arsenic, barium, copper, iodide, iron, manganese, selenium, and zinc. Concentrations were below detection limits in all samples except for one iron and five zinc analyses. However, even these did not exceed Federal Safe Drinking Water Standards.

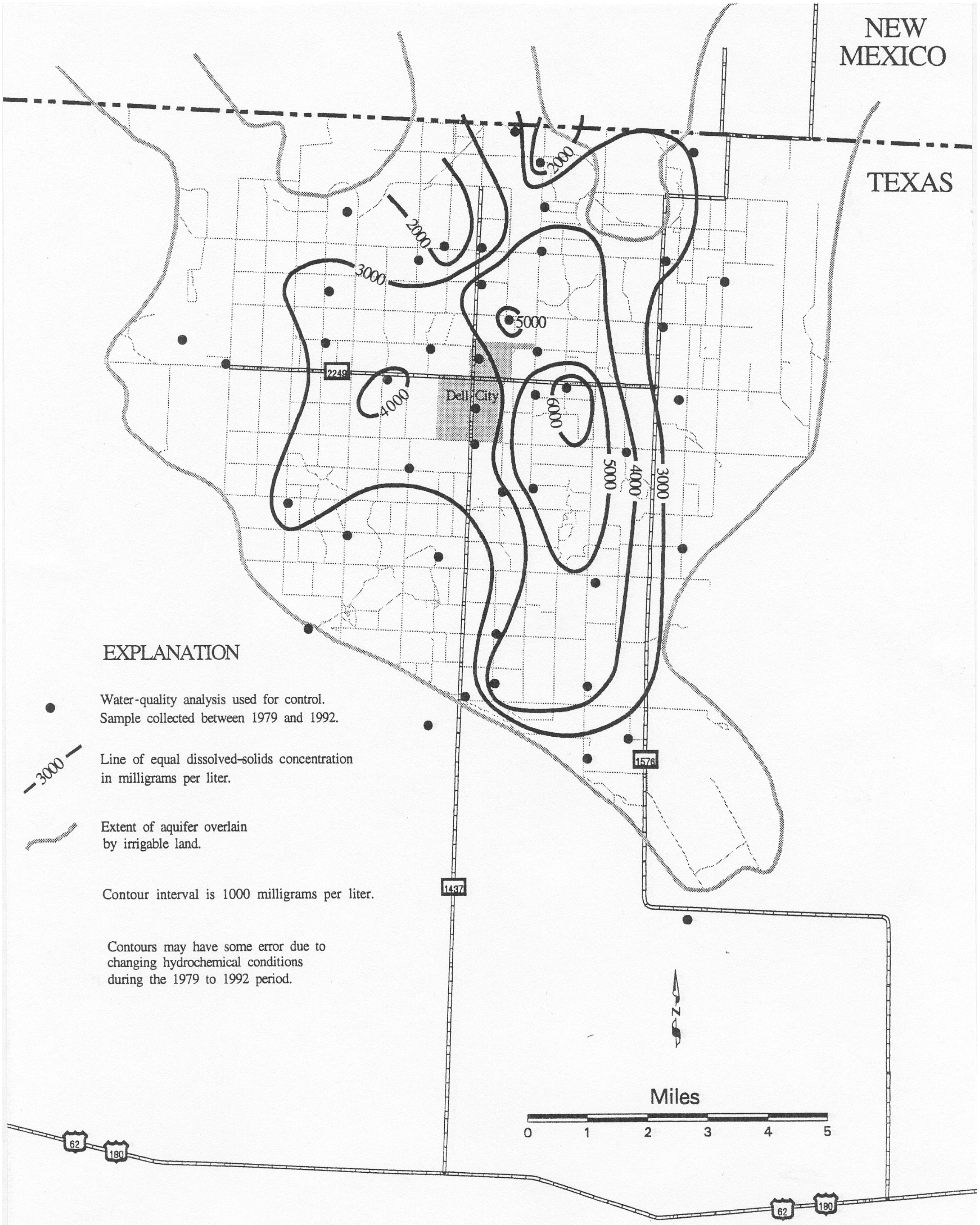


Figure 10-7: Dissolved-solids content, 1979 through 1992.

Nutrients in groundwater are various derivatives of nitrogen. When found dissolved in groundwater, nutrients are an indicator of contamination from, most commonly, decaying organic matter, human and animal waste, and fertilizers. Samples from the 30 wells were analyzed for ammonia, nitrite, nitrate, and Kjeldahl nitrogen. All ammonia and nitrite analyses were below detection limits, and Kjeldahl nitrogen values ranged from 0.2 to 1.0 mg/L. Eight of the samples had nitrate (as NO_3) concentrations in excess of the recommended limit for drinking water of 44.3 mg/L. The elevated nitrate concentrations are most likely derived from fertilizers transported rapidly by irrigation water return-flow.

Dissolved radionuclide activity above recommended safe levels was detected in sampled water. Fourteen of thirty well samples had measured gross alpha activity in excess of the recommended maximum safe level of 15 picocuries per liter (piC/L). Only two samples exceeded the recommended safe level for gross beta activity of 50 piC/L. Radioactive particles, or radionuclides, are found as trace elements in most rocks and soils. The source of most of the radioactive elements in the groundwater underlying Dell Valley is probably derived from the disintegration of volcanic rocks that occur in the near vicinity.

Because of the high permeability of the unsaturated zone above the aquifer, it is reasonable to expect contaminants from the surface to travel rapidly downward to the water table. Potential contaminants to the aquifer that pose a health hazard include various pesticides used in agriculture. A pesticide scan analysis, which included 48 organic compounds, was run on 5 well samples. No organic compounds were found above detection limits in any of the 5 wells.

Suitability for Drinking Water

The quality of water for human consumption is always of concern. In 1974, the Federal Safe Drinking Water Act was adopted, and standards were set for drinking-water quality. Twenty-four of thirty chloride samples and all of the thirty sulfate samples from the 1992 water-quality survey exceeded set limits. Also, all 30 samples exceed set limits for total dissolved solids. Other constituents and quality characteristics that exceeded recommended standards in a lesser percentage of the samples include nitrate, gross alpha and beta, fluoride, and pH. Groundwater in Dell Valley is, therefore, not recommended for human drinking purposes without prior treatment, such as the desalination process now employed for the Dell City community system.

Suitability for Irrigation

The suitability of groundwater for irrigation purposes is largely dependent on the chemical composition of the water. The extent to which the chemical quality will affect the growth of crops is determined in part by the climate, soil, management practices, crops grown, drainage, and quantity of water applied. Primary characteristics that determine the suitability of groundwater for irrigation are total concentration of soluble salts, relative proportion of sodium to other cations (calcium and magnesium), and concentration of boron or other toxic elements. These are termed the salinity hazard (specific conductance), sodium hazard (SAR), and boron hazard, respectively.

The specific conductance of water is used as an index of its salinity hazard. Specific conductance measured in 1992 in samples from 22 wells ranged from 1,438 to 8,810 micromhos per centimeter and averaged 4,720. All samples but one fell within the category of having a very high salinity hazard. Dissolved solids are approximately 78 percent of specific conductance.

High concentrations of sodium relative to calcium and magnesium in irrigation water adversely affect soil structure by forming a hard, impermeable crust that results in cultivation and drainage problems. An index used for predicting the sodium hazard is the sodium-adsorption ratio (SAR). SAR values computed from the analyses of the 30 well samples range from 0.3 to 7.9 and average 4.2.

Boron is necessary for good plant growth but rapidly becomes toxic at higher concentrations. Permissible limits of boron for various crops range from 0.67 to 3.00 mg/L. The concentration of boron in 30 well samples collected in 1992 range from 0.12 to 2.36 mg/L, and average 0.81 mg/L. Nineteen of the thirty samples exceed the lower limit; however, none exceed the upper limit. Water from the aquifer, therefore, appears to be acceptable for the irrigation of most semi-boron-tolerant crops.

Although the water is high in salinity, irrigated agriculture has been successful in Dell Valley owing to the high permeability of the soil, the balance of the dissolved minerals, and the low sodium percent. A study by Longenecker and Lyerly (1959) shows that 6 to 8 yr of water application definitely improved the chemical conditions in the irrigated soils versus uncultivated soils. With the application of sufficient quantities of water, resident salts in the soil profile are easily leached downward beyond the root zone of crops. Soil salinity, however, cannot be reduced below the salinity of the water used for leaching. Although the leaching process has been beneficial to crop growth, it has unfortunately caused a degradation of the quality of the groundwater because of irrigation return-flow.

Water-Quality Change

Groundwater quality changes have been occurring since the 1940’s, when return-flow of water from the first irrigation wells began altering the natural chemical composition of the aquifer. Water applied to agricultural land has percolated down to the water table, leaching additional minerals on its way. Also, the drilling and open completion of hundreds of wells in the valley has created a condition in which zones containing poor-quality water can mix with all other water-bearing zones.

Over time, the concentration of individual dissolved constituents in the groundwater has increased. Typical water-quality change in the valley is illustrated in figure 10-8, which shows the increasing concentration of sulfate, chloride, sodium, and dissolved solids in samples collected from well 48-07-205 between 1948 and 1992. During this period, dissolved solids increased from 1,119 mg/L to 4,395 mg/L. The increase in sulfate

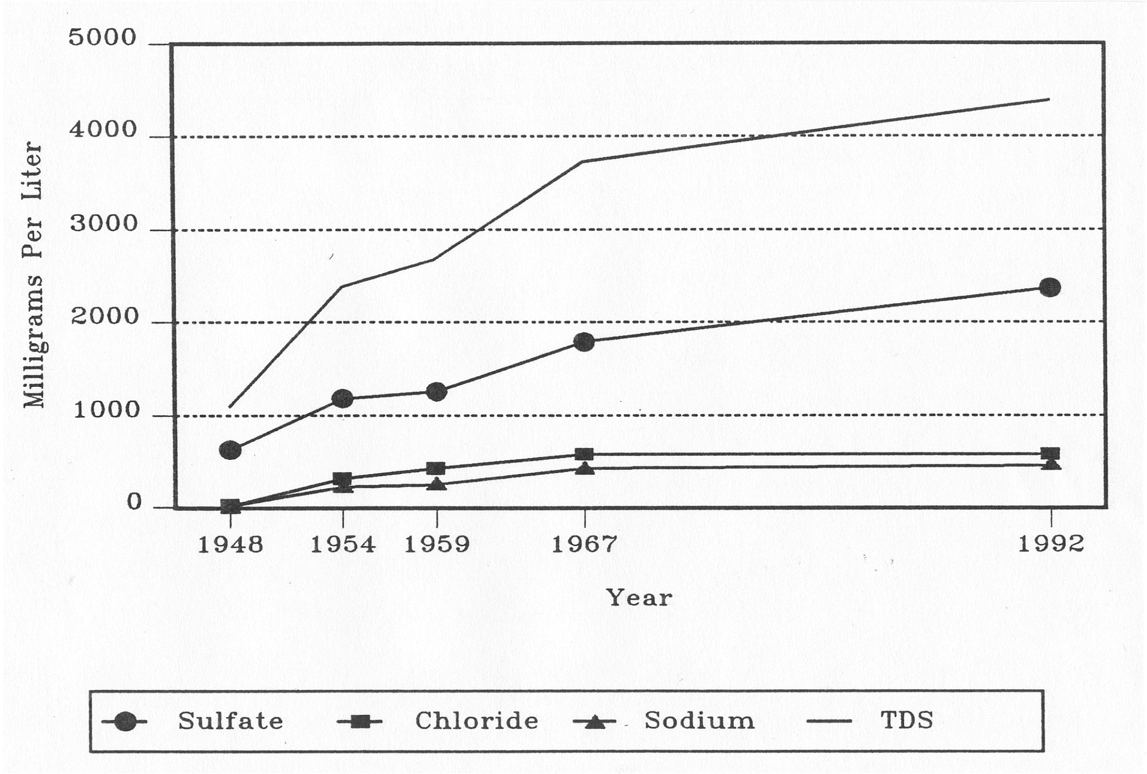


Figure 10-8: Water-quality change in well 48-07-205 from 1948 through 1992.

concentration alone represents approximately half of the total increase. The disproportionate increase in sulfate is primarily the result of dissolution of gypsum as irrigation return-flow water percolates downward through the soil zone.

Conclusions

The amount of groundwater annually available on a sustainable basis in the Dell Valley region is contingent on rates of water-level decline and water-quality deterioration. A comparison of water-level and pumpage trends indicates that an annual pumpage of approximately 90,000 to 100,000 acre-feet can be maintained without continuously lowering the water table. At this rate, the seasonal water-level fluctuation remains at about 15 ft. An increase in annual pumpage to approximately 140,000 acre-ft, such as was common in the late 1970's and early 1980's, results in a noticeably declining water level and increases the seasonal water-level fluctuation to about 30 ft. The significance of a greater seasonal water-level fluctuation is that it steepens the hydraulic gradient, which increases the likelihood of the migration of highly saline water from the salt flats to the east.

The economy of the Dell Valley region is supported almost entirely by the agricultural industry, which in turn is dependent on the availability of groundwater. Today, the Bone Spring-Victorio Peak aquifer displays the effects of almost a half-century of intense use. A continuous 5 yr of water-level declines in the valley indicate that the groundwater resource is being depleted at a rate in excess of recharge. Local management decisions that will impact the viability of this aquifer and those that depend on it are currently being debated.

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