

EXECUTIVE SUMMARY

At the request of the U.S. Environmental Protection Agency, the Texas Water Development Board and the New Mexico Water Resources Research Institute undertook this study to characterize binational aquifers in parts of far west Texas, south central New Mexico, and northeastern Chihuahua, Mexico. The study area lies along a corridor centered at the City of El Paso\Ciudad Juarez metropolplex and extending 62 mi (100 km) on either side of the international border. Assessments were made of the Mesilla Basin ground-water aquifer system, Rio Grande aquifer (Leasburg Dam to Indian Hot Springs), Hueco-Tularosa aquifer, southeastern Hueco aquifer, and Diablo Plateau aquifer. Technical and administrative assistance and data were provided by the Comision Nacional Del Agua, Junta Municipal de Agua y Saneamiento de Ciudad Juarez, International Boundary and Water Commission, and Comision Internacional de Limites y Aguas.

Many of the surface and ground-water resources along the transboundary corridor are shared between the two nations, yet little binational study of these resources has been undertaken. A number of environmental and hydrologic problems have been identified that will require the cooperation of both nations to solve. Solutions to water-related problems can be derived only when a better understanding of transboundary water resources is attained. This study is an important step toward attaining a better understanding of these binational resources.

To complete this study, data from several sources had to be combined into one data base. GIS coverages of ground water, surface water, and land use attributes were developed from the new data base. Study results for each aquifer are as follows:

Mesilla Basin Ground-Water Aquifer System

- The Mesilla basin ground-water aquifer system (the Rio Grande Floodplain Alluvium, Mesilla Bolson, and the Jornada del Muerto Bolson) are connected hydrologically, however the connections are restricted by aquitards and/or faults and therefore described as separate aquifers. The Mesilla basin aquifer system is an extensive intermontane aquifer system which extends from southern New Mexico to northern Mexico. It is surrounded by mountains which form the boundaries.

- Productive aquifers in the Mesilla basin ground-water system occur in both late Pleistocene to Holocene-Rio Grande alluvium deposits and the upper Tertiary and Quaternary unconsolidated sedimentary deposits of the Santa Fe Group. The surface water system is comprised of the Rio Grande and its tributaries and a network of canals, laterals and drainage ditches that discharge to the river. The surface drainage of the Mesilla basin covers approximately 11,000 square miles.

- Total water use in 1990, both surface water and ground water, for all categories was about 513,841 acre-feet of which 145,663 was from ground-water sources. Depletions were 246,279 acre-feet of which 96,895 was from ground water.

- There are two major potential sources of ground-water contamination which might impact the Mesilla Bolson: agricultural activity and high density residential septic tanks. The agricultural activity can again be broadly sub-divided into two major impact categories: cropping and dairies. The cropping activities which may have a negative impact on the ground water are: fertilization practices, pesticide and herbicide use, and irrigation practices. The number of milk cows in Doña Ana County in 1994 was estimated to be 31,000 and are largely concentrated south of Las Cruces along the eastern border of the Mesilla Bolson. Of the estimated 40,000 residents of southern Doña Ana County, New

Mexico, fewer than 7% are on sewerred wastewater systems. The majority use on-site waste treatment systems.

- The Rio Grande Floodplain Alluvium, between Leasburg dam and the El Paso narrows, is not a confined aquifer and consists of alternating and interfingering layers of clay and fluvial facies. These deposits extend laterally for hundreds of feet beyond the valley slopes with a basal gravel layer about 30 to 40 feet thick. It generally runs the width of the valley and is approximately 80 feet deep. The water table is approximately 10 to 25 feet below the land surface. Ground water within the alluvium is generally unconfined and typically moves southeastward down the valley at an average gradient of about 4 to 6 feet per mile; however, the direction is somewhat influenced by nearby hydraulic structures such as the river, drains, canals, well pumpage and heavily irrigated fields. Recharge to the aquifer occurs primarily as vertical flow from the surface water system (river, canals, laterals, and drains) and irrigated cropland fields. The quality of the water generally reflects the quality of the surface water system, ranging from about 500 TDS to over 1,000 TDS. The majority of discharge from the floodplain alluvium occurs through evapotranspiration of irrigated crops, flow to drain system, irrigation pumpage, municipal pumping, and industrial pumping. Transmissivity values range from 10,000 to 30,000 ft²/day, hydraulic conductivity of 100 to 350 ft/day, and an estimated specific yield value of 0.2. The specific capacities ranges from 10 to 217 gpm/foot drawdown with an average of 69 gpm/foot drawdown.

- In the Mesilla Bolson the major source of fresh ground water is from the Quaternary-Tertiary age Santa Fe Group. The extent of the aquifer system within the Santa Fe Group is controlled by the surrounding faults which create an effective barrier to ground-water flow, although a small amount of flow may enter or leave the bolson at low barrier points. The Santa Fe Group has thick sequences of clay and silt facies that interfinger with fluvial facies, which create confined/leaky aquifer conditions in the basin fill. These facies vary in depth

from 280 feet in the northern part of the bolson to over 2,000 feet near the center of the bolson.

- Three hydrostratigraphic units are commonly referred to: upper unit, middle unit and deep unit. The upper unit is generally only saturated in the northern third of the bolson and consists of gravels with lenticular deposits of clay. This unit may be the most permeable based on larger grain sizes and less cementation. The middle hydrostratigraphic unit is less permeable than the upper unit due to a greater degree of cementation. This unit also consists of gravel and lenticular deposits of clay. The deep unit consists of a uniform fine sand and averages approximately 600 feet in thickness. In general, the basin fill deposits of the Santa Fe Group are deep under the Mesilla Valley and generally thin toward the basin edges. The maximum thickness of Santa Fe Group deposits is estimated as approximately 2,500 feet. The deep hydrostratigraphic group rests on a bedrock of limestone conglomerate which is generally considered impermeable. Hydraulic conductivity's range from 2 - 68 ft/day, 1 - 100 ft/day and 1 - 34 ft/day for upper, middle and deep hydrostratigraphic units respectively. Estimates of transmissivity range from 2,600 ft²/day for the upper intermediate unit to 4,700 ft²/day for the deep zones and storage coefficient of 0.00043 in the southern portion.

- In the West Mesa area, the transmissivity of 5,900 ft²/day was calculated for a well screened at selected intervals between 710 to 1,210 feet. In the northern section of West Mesa the transmissivity was estimated at 10,000 ft²/day and a storage coefficient of 0.00002. Based on aquifer tests, the transmissivity ranged from 10,900 ft²/day to 40,000 ft²/day throughout the bolson. The average horizontal hydraulic conductivity was 67 ft/day. These tests also provided evidence that the horizontal hydraulic conductivity apparently decreases with depth. Vertical hydraulic conductivity values were found to range from 0.21 ft/day to 3.0 ft/day for the entire thickness of the confining layer.

- The majority of recharge occurs through mountain front recharge and through vertical flow of ground water from the floodplain alluvium. The quality of the ground water varies both with depth and areally. The upper unit generally reflects the quality of the alluvium which provides the most significant portion of the recharge, however this varies due to influence of confining clay and silt facies. The middle unit is generally of better quality, but decreases from north to south. This unit is the most heavily developed providing most all of the public and private drinking water supplies. The quality of the deep unit is generally less than the middle unit especially in the southern portion. The majority of the discharge occurs as municipal and industrial pumping.

- The Jornada del Muerto Bolson is east of the Mesilla Bolson. It covers approximately 3,344 square miles and is approximately 12 miles across at its widest section. It does not have a noticeable boundary with the Mesilla Bolson. The two bolsons are separated by a subsurface Tertiary volcanic rock high bounded by normal faults.

- The Santa Fe Group in the Jornada del Muerto Bolson is composed of a fluvial facies, a clay facies, and an alluvial-fan facies. The zone of saturation is most likely in older alluvial-fan deposits or in the fine-grained units of the clay facies. The clay facies is the predominant facies in the zone of saturation in the northern and extreme southern sections of the Jornada del Muerto Bolson. The depth to the water table is between 300 to 575 feet and the thickness of the saturated sediment is between 400 to 500 feet.

- The ground water in the northern part of the bolson moves south down the valley and west at an average gradient of 150 feet per mile. Ground water from the southern part of the bolson moves north and west at an average gradient of 10 feet per mile. The specific capacities for wells in the southern section of the Jornada del Muerto Bolson is about 5 gpm/foot drawdown. Estimated transmissivity values in this area range

from 5,000 ft²/day to 15,000 ft²/day. Recharge occurs primarily from precipitation and infiltration of mountain runoff through major arroyos. Ground water in the southern section of the Jornada del Muerto Bolson is classified as fresh and water in the northern section of the bolson is classified as slightly saline.

Hueco-Tularosa Aquifer

- A surface divide near the New Mexico/Texas State line separates the Tularosa Basin (a closed basin) and the Hueco Basin (a through-flowing basin) topographically. The surface divide does not correspond to a structural or ground-water divide, and the two basins are connected by interbasin ground-water flow from New Mexico into Texas. Because of the interconnection, the Tularosa and Hueco Basins are considered in this report as one aquifer; the Hueco-Tularosa aquifer. For convenience, the Hueco-Tularosa aquifer is designated to include water bearing strata in both the flanking highlands and saturated bolson fill.

- Total surface area of the portion of the Hueco-Tularosa aquifer evaluated in this report is 4,160 mi². Approximately 67% of its land area is in New Mexico and 22% of its land area is in Texas. About 11% of its land area is in Mexico. The aquifer is the key source of water for the City of El Paso and Ciudad Juarez, and for military installations and smaller cities in New Mexico, Texas, and Mexico.

- Well yields in the New Mexico part of the Tularosa-Hueco aquifer vary greatly. Most of the wells produce water from alluvial fans that flank the mountains. Well yields of 1,400 gpm are reported at elevations high on the fans decreasing to 300 to 700 gpm at the lower edges of the fans. Well yields in the mud-rich sediments toward the center of the Tularosa Bolson are usually less than 100 gpm and sometimes less than 15 gpm. South of the New Mexico/Texas State line, well yields in the Hueco Bolson, just east of the Franklin Mountains, are as much as 1,800 gpm. Wells underlying Ciudad Juarez yield from 300 to 1,500 gpm.

- Published hydraulic conductivity values derived from 37 aquifer tests in the Tularosa Bolson vary from 1.0 to 320.0 ft/day. Most wells are installed in alluvial fans. Ranges illustrate the heterogeneity of alluvial fan sediments. Published hydraulic conductivity values derived from 73 aquifer tests in the Hueco Bolson vary from 6.4 to 98.9 ft/day. The range is smaller in the Hueco Bolson and follows a slightly skewed log probability distribution (almost log normal). Comparison of hydraulic conductivity values between the Tularosa and Hueco Bolsons suggest more homogeneous aquifer strata in the Hueco Bolson. Wells in the Hueco Bolson are installed primarily in Camp Rice deposits, a moderately sorted, mostly fluvial deposit. The alluvial fan deposits in New Mexico have a much wider range of hydraulic conductivity due to poor sorting and extreme heterogeneity. Equivalent Camp Rice deposits in the Tularosa Bolson either do not exist or are saturated with saline ground waters and are not developed.

- Depth to ground water in the Hueco-Tularosa aquifer is variable. Depth to ground water near the Cities of Tularosa and Alamogordo at the flanks of the Sacramento Mountains is between 20 and 150 ft. Drawdowns in many municipal wells, up to 100 ft, have been recorded in this area. Ground water is at or near ground surface at Alkali Flat due to evaporative discharge from a wet gypsum playa. Depth to ground water near the White Sands Missile Range Headquarters, at interior portions of the basin, is up to 400 ft. Little drawdown has been recorded there. Drawdowns in the Hueco Bolson near the New Mexico/Texas State line has been relatively small, not exceeding 30 ft. Current depth to ground water beneath the City of El Paso is usually between 250 and 400 ft at distances from the Rio Grande. Present depth to ground water beneath Ciudad Juarez varies from about 100 to 250 ft, except near the Rio Grande where depths are often less than 70 ft.

- In heavily developed parts of the Hueco-Tularosa aquifer, drawdowns since 1940 are up to 150 ft. Pumping cones of depression in municipal wellfields

are the focal points of drawdown. Most of the drawdowns near municipal wellfields vary between 50 and 100 ft. Focal points of drawdown are shown beneath El Paso and Ciudad Juarez.

- Most ground-water discharge from the Hueco Bolson is due to pumping withdrawals for municipal and military water supply. Quantities of ground water pumped from the Hueco Bolson from municipal and other sources have increased by a factor of almost 6 since 1950. Recent trends indicate that municipal pumpage in Mexico increased about 12.5% between 1990 and 1994. Municipal and military pumpage in the United States decreased 24.0% during the same time interval. Pumping trends reflect the increased dependence on ground water in Mexico, and partial conversion from ground water to surface-water use in the United States.

- Ground water north of the New Mexico/Texas State line is usually greater than 1,000 mg/L TDS except in mountains and along mountain fronts, where ground waters are dilute. Many samples along the interior of the basin at or just south of Alkali Flat have TDS greater than 10,000 mg/L. Near and extending across state line to the Rio Grande alluvium, ground waters along the Franklin Mountains are characteristically less than 700 mg/L TDS. Basinward of the recharge areas along the Franklin Mountains salinities increase to over 1,000 mg/L in many wells, reaching concentrations over 1,500 mg/L in wells along the axis of the basin. Salinities of ground water underlying the Ciudad Juarez area are generally less than 1,000 mg/L.

- Chloride and other dissolved ions have increased over time in many of the municipal wells in El Paso and Ciudad Juarez. Hydrochemical plots show a pattern of salinization of wells that have had significant long-term drawdowns. Chloride now exceeds 250 mg/L in several of the wells in the area. Mixing due to pumpage, leakage from mud interbeds and artesian confining beds, cascading waters along well casings and

screens, lateral salt water encroachment, and potential upconing have started to degrade the freshwater zone.

- The Hueco-Tularosa aquifer is moderately susceptible to contamination. The Texas portion of the aquifer has a moderate ground-water pollution potential (DRASTIC index) that ranges mostly from 80 - 109 for general, municipal, and industrial sources (Cross and Terry, 1991). The DRASTIC index is 110 - 124 along the slopes of the El Paso Valley, where older bolson material has been incised by the Rio Grande.

- Nitrate data collected between 1994 and 1995 indicate nitrate problems in some parts of El Paso County. A cluster of wells in the vicinity of the Old Mesa Well Field in southwestern El Paso County exceed the 10 mg/L $\text{NO}_3\text{-N}$ drinking water standard. Many of the samples in El Paso County tested between 5 and 10 mg/L $\text{NO}_3\text{-N}$. All of the wells in Ciudad Juarez and immediate vicinity are less than 5 mg/L $\text{NO}_3\text{-N}$.

- In the Ciudad Juarez area, residential water supplies were tested in 1987 for possible contamination of ground water by sewage. Fecal coliform was used as an indicator parameter. Forty-two samples were obtained; 30 from tap water and 12 from raw ground water. Ninety-one percent of raw ground-water samples were fecal coliform positive. Sixty percent of tap water samples were fecal coliform positive. The percentage of positive bacteria detections in these samples suggested that ground water beneath Ciudad Juarez was contaminated by sewage.

Southeastern Hueco Aquifer

- The southeastern Hueco Bolson is separated geographically from the Hueco-Tularosa Bolson at the El Paso/Hudspeth County line. A southeast trending linear aquifer, the bolson extends for 55 miles from the El Paso/Hudspeth County line to its southeastern limit at Indian Hot Springs. The bolson is bounded on the north by the Finlay, Malone, and Quitman Mountains and Diablo Plateau. The Sierra de San Ignacio, Sierra de La Amargosa, Sierra de San Jose Del Prisco, Sierra

de Las Vacas, and Sierra de Carrizalillo define its southern boundary. For convenience, the southeastern Hueco aquifer is designated to include water bearing strata in both the flanking highlands and plateaus and saturated bolson fill. The southeastern Hueco Bolson and bounding mountains and plateaus that are hydraulically connected to the bolson along ground-water divides are grouped as one aquifer, the southeastern Hueco aquifer.

- The thickness of the bolson fill of the southeastern Hueco aquifer decreases from as much as 8,500 ft at the El Paso/Hudspeth county line to an infinitesimal thickness where the bolson thins out near Indian Hot Springs. Saturated bolson fill is principally the lower basin fill series. The lower basin fill is mostly lacustrine clay, bedded gypsum, and minor sand, silt, and clay from both alluvial fans and local fluvial deposits. The upper basin fill series, a second lithologic unit, is thin and contains little water east of the El Paso/Hudspeth County line. The upper basin fill deposits were formed in alluvial fan, fluvial, and lacustrine systems and are composed of sand and gravel and minor silt and clay.

- Transmissivity values in the Cretaceous strata and bolson fill north of the Rio Grande are all relatively low. Well yields do not exceed 200 gpm usually and most well yields are less than 50 gpm. Aquifer tests performed in wells screened or open in Cretaceous strata gave transmissivity values between 0.22 and 1.50 ft^2/day . Aquifer tests in wells completed in bolson silts and sands gave transmissivity estimates between 0.43 and 94 ft^2/day . Higher transmissivity values are characteristic of a higher percentage of sand and gravel in the basin. Lower transmissivity values are characteristic of mud-rich sediments deposited in lacustrine and playa environments. Aquifer tests in basin fill indicate relatively low transmissivity values, sufficient only for livestock and domestic use.

- North of the Rio Grande, the regional potentiometric surface map shows high hydraulic heads and ground-water divides along the Diablo Plateau, Finlay

Mountains, and Quitman Mountains. Areas of high head in the mountains and plateaus define focal points of recharge in the southeastern Hueco aquifer. Hydraulic head gradients in the Cretaceous and other bedrock strata are as much as 0.07 along ground-water divides and are as little as 0.04 along mountain fronts. Hydraulic gradients in the bolson fill are about 0.008. South of the Rio Grande, the potentiometric surface slopes to the river from high topographic elevations along mountain fronts. Springs flow at high elevations from the mountains in Mexico. These probably discharge from locally perched flow systems that do not define hydraulic head in the zone of regional saturation. Data are not adequate to define regional hydraulic heads beneath these mountains. Hydraulic gradients south of the Rio Grande, from mountain fronts to the river, are about 0.01 to 0.03.

- The southeastern Hueco aquifer can almost be considered undeveloped, especially north of the Rio Grande. Low capacity domestic and livestock wells are used to satisfy the needs of the local population and livestock industry. This is partly a function of the low yield and relatively high salinities of the aquifer.

- Total dissolved solids in the southeastern Hueco aquifer are typically greater than 1,000 mg/L in the mountains, increasing to as much as 4,000 mg/L in the bolson. The hydrochemical facies of southeastern Hueco aquifer ground waters on the United States side of the study area varies from Ca-Mg-HCO_3 and Na-SO_4 along the Diablo Plateau to $\text{Na-SO}_4\text{-Cl}$ beneath the floor of the basin. In Mexico, waters vary from Ca-Mg-HCO_3 beneath the Sierra de San Ignacio, Sierra de La Amargosa, and the Sierra de San Jose Del Prisco to $\text{Ca-Mg-SO}_4\text{-Cl}$ waters beneath the basin floor. Typically these ground waters have TDS that vary between 1,000 and 3,500 TDS. Indian Hot Springs is an exception; Na-Cl water with TDS higher than 7,000 mg/L discharges from Cretaceous carbonate and clastic rocks at the hot springs.

- Bedrock units exposed in the southeastern Hueco aquifer are moderately susceptible to contamination. The Diablo Plateau has a moderate ground-water pollution potential (DRASTIC index) that ranges from 95 - 124 for agricultural sources. The DRASTIC index for general, municipal, and industrial sources is lower, ranging from 65 - 94.

- The southeastern Hueco Bolson has a higher DRASTIC index, ranging from 110 - 124 for agricultural sources and from 80 - 94 for general, municipal, and industrial sources. Some qualification of this ranking is required. Even though the potential for contaminants at land surface being carried with infiltrating precipitation to the saturated zone is possible along arroyos, the potential for contamination along areas of the basin floor that are not juxtaposed to arroyos is generally small. The relatively dry climate, specific retention of the soil, and intensity and distribution of rainfall does not provide adequate moisture for wetting fronts to reach the saturated zone except along arroyos.

Rio Grande Aquifer

- Southeast of the El Paso narrows, the Rio Grande flows across a broad alluvial floodplain that has incised the surface of the Hueco Bolson. The Rio Grande alluvial floodplain in the El Paso/Juarez Valley is underlain by a complex mosaic of braided and meandering river deposits. Formed during alternating periods of scour and fill in the late Quaternary Period, the river deposits consist of irregularly distributed gravels, sands, clay, and silt lenses and beds. Alluvial fill consists of reworked bolson fill material, eroded bedrock, and extrabasinal sediments transported by the Rio Grande from its headwaters in New Mexico and Colorado to the El Paso/Juarez Valley.

- Water level contour maps prepared with data collected in 1973 - 74 and 1994 - 1995 illustrate losing stream, underflow, and baseflow conditions on different segments of the alluvial floodplain. The condition of losing stream is apparent along the Chamizal zone where drawdown cones from municipal well fields have

reversed the hydraulic gradient between the river and the Rio Grande aquifer. Drawdowns have intensified along the Chamizal zone since 1973. Alluvial underflow predominates between the Chamizal zone and the El Paso/Hudspeth county line. Along this stretch of floodplain, ground-water flows subparallel to the direction of surface discharge, and head in the aquifer is approximately equal to the head in the river. The head elevation along this reach did not change significantly since 1973. The condition of baseflow prevails between county line and Fort Quitman. Flow is oriented subperpendicular to the direction of surface discharge and ground water clearly discharges to the Rio Grande. Hydraulic head in this part of the floodplain has increased since 1973.

- Recharge to the Rio Grande aquifer along irrigated reaches is due primarily to infiltration of surface water that has been applied to irrigable crops. Recharge also occurs to some extent by direct seepage from diversion canals and river channels, although lining of the Rio Grande channel along the Chamizal zone limits recharge by the river locally. Other sources of recharge to the Rio Grande alluvium include direct precipitation on the floodplain surface, seepage from irrigation canals and drains, infiltration of runoff along arroyos, and recharge from cross-formational flow with the Hueco Bolson. Quantification of the amounts and spatial variability of recharge to the alluvial aquifer is infeasible with available data.

- Ground water is discharged from the Rio Grande alluvium by irrigation pumping, by subsurface seepage to the Rio Grande, by leakage to drains, and by cross-formational leakage to the Hueco Bolson. Along the heavily urbanized Chamizal zone, discharge occurs primarily by cross-formational leakage from the alluvium to the Hueco Bolson where storage in the Rio Grande aquifer is depleted by heavy municipal pumping in the bolson aquifer. From Chamizal zone to the El Paso/Hudspeth County line, discharge occurs by irrigation pumping and by leakage to the many drains which help to maintain nearly constant water-levels in the

alluvial aquifer. From the county line to Fort Quitman, discharge occurs by irrigation pumping, by seepage to the Rio Grande, and by leakage to a few drains.

- Stiff diagrams indicate sodium-sulfate type groundwaters in the Rio Grande aquifer in El Paso County. Below the El Paso/Hudspeth County line, chloride increasingly becomes the dominant anion in the cation/anion pairing. Mexican ground waters follow the same general trend, but show greater scatter in the segment of the floodplain across from Hudspeth County. Ground-water samples frequently were collected in and beneath arroyo deposits that overlie earlier alluvial floodplain deposits in Mexico. Arroyos act as recharge areas after episodic precipitation events and ground-water chemistries have wide scatter due to commingling of dilute runoff waters and older alluvial ground waters.

- Total dissolved solids in the Rio Grande aquifer in El Paso County vary substantially, but fall mostly within the 1,000 to 3,000 TDS range. Total dissolved solids are higher in alluvial deposits in Hudspeth County, falling mostly within the 3,000 to 6,000 TDS range. In both regions, total dissolved solids are lower in the Mexican part of the floodplain aquifer due to mixing of dilute runoff waters with older, higher salinity waters. This is an artifact of well locations closer to arroyos on the floodplain in Mexico.

- Historical monthly water quality and streamflow data show changes in river water quality and discharge between El Paso/Ciudad Juarez and Fort Quitman. Spatial changes in sodium, sulfate, chloride, and total dissolved solids for most months indicate appreciable decline in river water quality downstream. Data indicate that water quality improves when river discharge is high during the irrigation season.

- Rio Grande waters are already contaminated above the El Paso/Ciudad Juarez metroplex. Contaminants include TDS, fecal coliforms, sulfates, and chlorides. Possible causes of these contaminants include irrigation

return flows and municipal discharges. The quality of Rio Grande water deteriorates along the El Paso/Ciudad Juarez corridor and further downstream. Contamination is deduced by fecal bacteria as an indicator parameter. Immediately below El Paso, fecal coliforms as high as 290,500 colonies per 100 mL of water have been reported in Rio Grande water.

- The Rio Grande aquifer is highly susceptible to contamination. The aquifer can be contaminated rapidly by land application of fertilizers and pesticides, by leaching from septic tanks and feedlots, and by infiltration of chemicals or hazardous waste from storage facilities or from accidental spills. Consisting mostly of permeable unconsolidated deposits, the aquifer has received a DRASTIC index greater than 154 across much of the study area.

Diablo Plateau Aquifer

- The Diablo Plateau covers all but the southern part of Hudspeth County, Texas. The plateau is juxtaposed against regional grabens that formed by Quaternary-age lateral extension and normal faulting. The Campgrande fault displaces Cretaceous strata against bolson deposits southwest of the fault, forming an escarpment of more than 400 ft. Together with Otero Mesa to the north, the Diablo Plateau is a gently eastward-sloping structure situated at an elevation of between 4,400 and 5,200 ft. It is bounded by the Hueco-Tularosa Bolson on the southwest, by the Steeruwitz Hills, Carrizo Mountains, Van Horn Mountains, and Wylie Mountains on the south and southeast, and by the Salt Basin and Otero Break on the northeast. The edge of the Sacramento Mountains define the northern boundary of the aquifer.

- In Texas the Diablo Plateau consists of two rock units: (1) the Permian carbonate and evaporite rocks of Leonardian and Guadalupian age in northern Hudspeth County and, (2) the Cretaceous carbonate and clastic rocks of the Finlay, Cox, and Campgrande Formations, which outcrop roughly south of the Dell City parallel. The primary water-bearing units over

much of the Diablo Plateau are Permian rocks with an average thickness of 1,300 ft. Ground water is encountered at depths from 200 ft to 1,500 ft. In the Dell City area the Permian aquifer is locally known as the Victorio Peak-Bone Spring aquifer. Lithologic control for this aquifer outside the Dell City area is extremely limited.

- In New Mexico, the plateau (known as the Otero Mesa) is composed almost entirely of Permian carbonate, clastic, and evaporite rocks of the Yeso, Victorio Peak, Bone Spring, and San Andres Formations. Of these, only the Victorio Peak and Bone Spring Formations comprise the main aquifer.

- Aquifer tests conducted in the Diablo Plateau aquifer suggest that permeabilities in the aquifer are solution-and-fracture controlled. Video logs run in several test holes revealed continuous vertical fractures and grapefruit-size dissolution cavities. Approximately 44 percent of wells drilled in the Dell City area are prolific; many wells produce 100 gpm or less, even when drilled near wells successfully pumping 2,000 gpm. This response is an artifact of the high transmissivity contrast which characterizes the Permian and Cretaceous carbonate rocks in the Diablo Plateau region.

- The potentiometric map for the Diablo Plateau aquifer and surrounding region indicates that ground-water flow is generally from southwest to northeast beneath the Diablo Plateau and from northwest to southeast beneath Otero Mesa. Flow from both regions converges towards Dell City and the Salt Basin along flowpaths with average hydraulic gradients of 0.0004, although gradients are as steep as 0.001. The Dell City area is encompassed by a shallow, broad cone of depression in the potentiometric surface that has formed as a result of extensive irrigation and ground-water development. A "trough" runs beneath the Sacramento River towards Dell City, its widely spaced contour lines suggesting high transmissivity along the trough. The potentiometric surface is near land surface

in the Salt Basin where ground water discharges by evaporation.

- The ground-water resources in the study region are mostly undeveloped, except in the Dell City irrigation district. Hydrographs of six wells in the Dell City area show significant changes in water levels since predevelopment. The rest of the system is almost at steady state. As pumping exceeded recharge, water levels dropped constantly until the mid-1980's at an average rate of 1.3 ft/year, totaling 25 to 45 ft of drop area-wide. Since then, irrigation pumpage diminished, and water levels have risen slightly.

- Tritium and carbon-14 (^{14}C) levels measured in wells on the Diablo Plateau indicate that most of the ground water samples contain recent water (i.e., water recharged within the last 50 years). The tritium and ^{14}C values display significant changes within short distances and no clear distribution pattern, thus emphasizing the practical importance of fracture and karstic flow. Recharge occurs over the entire plateau (approximately 2,900 mi²) as demonstrated by the areal distribution of tritium-rich samples. Most recharge probably takes place during flooding of the ephemeral creeks ("arroyos") that cross the plateau.

- Ground water in the Diablo Plateau aquifer is fresh to brackish, with total dissolved solids (TDS) concentrations as low as 500 mg/L in the Sacramento River area, to over 3,800 mg/L in central-western Otero Mesa where water-bearing strata are interbedded with the gypsiferous Yeso Formation. In the Dell City area, where return flow from irrigation leaches salts from the soils and evaporates, TDS concentrations reach 6,500 mg/L. Hydrochemical facies in the area vary from Na-Ca-HCO₃ and Na-SO₄ in the southwest to Na-SO₄, Ca-SO₄, and Na-Cl in the north and northeast. The change in chemistry from southwest to north/northeast can be attributed to the changing lithology from Cretaceous carbonates to evaporate-rich Permian rocks along flowpaths, and to ground-water evaporation and mixing.

- The Diablo Plateau aquifer is moderately susceptible to contamination. The Diablo Plateau has a moderate ground-water pollution potential (DRASTIC index) that ranges from 95 - 124 for agricultural sources, the principal activity in the region. The DRASTIC index for general, municipal, and industrial sources ranges from 80 - 124.