The Hueco Bolson—An aquifer at the crossroads

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Chapter 6

The Hueco Bolson: An Aquifer at the Crossroads

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Introduction

The Hueco Bolson is a thick pocket of sediments derived from nearby mountains that extends from New Mexico, through Texas, and into Mexico in the El Paso and Ciudad Juarez area. Over time, these sediments filled with water and became the Hueco Bolson aquifer: an oasis of plentiful water in the northern part of the Chihuahuan Desert. El Paso and Ciudad Juarez have relied on the Hueco Bolson aquifer as a primary source of drinking water for several decades (Sayre and Penn, 1945; White and others, 1997). Ciudad Juarez, several communities in New Mexico, and the Fort Bliss Military Reservation currently depend on the Hueco Bolson aquifer as their sole source of drinking water (Sheng and others, 2001). Because of the desert climate and the local geology, the aquifer is not easily replenished, and recharge is low. Low recharge and high pumping rates have caused large water-level declines and large decreases in fresh-water volumes in the aquifer.

The aquifer and the El Paso-Ciudad Juarez area are at the crossroads. With current trends, groundwater models predict that El Paso will pump the last of its fresh water by 2025, and Ciudad Juarez will pump the last of its fresh water by 2005 (Sheng and others, 2001). The El Paso Water Utilities/Public Service Board (EPWU) has recognized the nature of limited groundwater resources in the area and has investigated and invested in several strategies to increase the longevity and usefulness of the aquifer. The purpose of this paper is to briefly summarize the hydrogeology of the Hueco Bolson aquifer and discuss several of the management strategies to protect and responsibly use the aquifer.

Hydrogeology

The Hueco Bolson aquifer is coincident with the Hueco Bolson, a long, sediment-filled trough that lies between the Franklin, Organ, and San Andres Mountain ranges and the Quitman, Malone, Finlay, Hueco, and Sacramento Mountain ranges (fig. 6-1). Hill (1900) defined the Hueco Bolson as including the Tularosa Basin (as shown in fig. 6-1).

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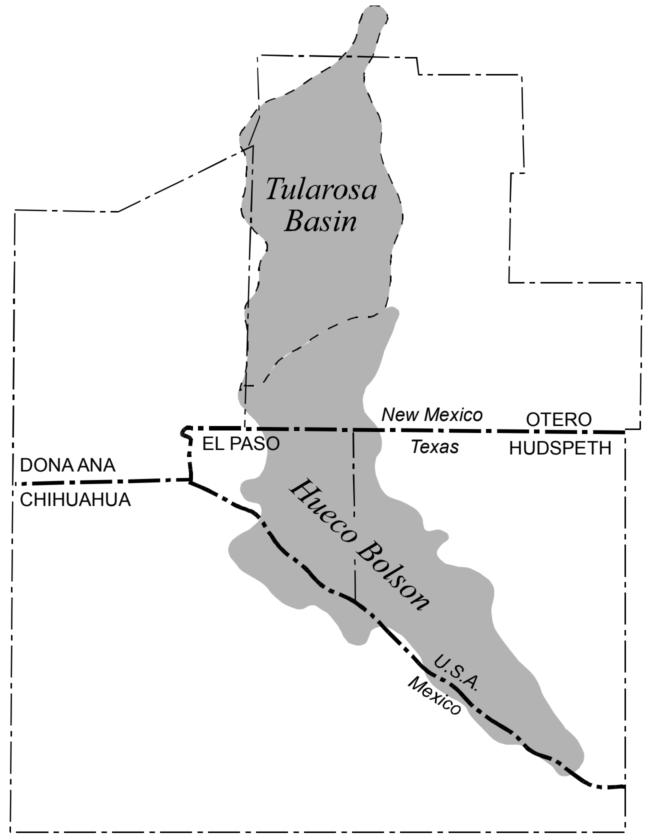

Figure 6-1: Location of the Hueco Bolson aquifer in Texas, New Mexico, and Mexico.

However, Richardson (1909) divided the bolson into two parts: the Tularosa Basin to the north and the Hueco Bolson to the south. The topographic divide between these two basins is about 7 mi north of the Texas–New Mexico border. However, the Hueco Bolson and the Tularosa Basin are hydraulically connected to each other (Wilkins, 1986) and have been combined into the Hueco-Tularosa aquifer (Hibbs and others, 1997).

The Hueco Bolson is about 200 mi long and 25 mi wide. The Hueco Bolson aquifer consists of unconsolidated to slightly consolidated deposits composed of fine- to medium-grained sand with interbedded lenses of clay, silt, gravel, and caliche. Sediments in the bolson are fluvial, evaporitic, alluvial fan, and aeolian in origin and have a maximum thickness of 9,000 ft (Mattick, 1967; Cliett, 1969; Abeyta and Thomas, 1996). The bottom part of the Hueco Bolson is primarily clay and silt. Therefore, only the top several hundred feet produce good-quality water.

Recharge

The Hueco Bolson aquifer is recharged by mountain-front recharge; seepage from the Rio Grande, canals, and agricultural drains; and deep-well injection (Knorr and Cliett, 1985;

Land and Armstrong, 1985; White and others, 1997). Mountain-front recharge is the seepage of surface run-off after rainfalls into the aquifer where the bolson laps up against bordering mountains. Before the aquifer was heavily pumped, water in the aquifer naturally discharged to the Rio Grande. After pumping caused water levels to decline, the Rio Grande began to lose water into the aquifer, so much so that a part of the river through El Paso-Ciudad Juarez has been lined with concrete to minimize leakage. Unlined irrigation canals and drains also leak water into the aquifer, although the water is usually of poor quality. EPWU has taken treated wastewater and injected it up-gradient of one of El Paso's well fields to increase recharge to the aquifer.

Meyer (1976) estimated that mountain-front recharge (from the Organ and Franklin Mountains in New Mexico and Texas and the Sierra de Juarez in Mexico) to the aquifer in El Paso County is 5,640 acre-ft/yr. White (1987) estimated that about 33,000 acre-ft/yr of water is recharged into the Rio Grande alluvium overlying the bolson aquifer. Recharge from the Rio Grande was reduced significantly when the bottom of the Rio Grande was lined in 1973 and 1998 in the El Paso-Ciudad Juarez area (Hibbs and others, 1997; Heywood and Yager, in review).

Treated wastewater is injected at the Fred Harvey Wastewater Treatment Plant in El Paso and provided about 3,800 acre-ft of water per year in 1995 (USEPA, 1995) and about 1,800 acre-ft in 1999 (Sheng and others, 2001).

Well Yields

Well yields in the Texas part of the Hueco Bolson aquifer are as much as 1,800 gpm (Hibbs and others, 1997). In New Mexico, yields are higher in alluvial fans that flank the basin (~1,400 gpm) and lower in the interior of the basin (300 to 700 gpm) (Hibbs and others, 1997). In the well field for Ciudad Juarez in Mexico, yields range between 300 and 1,500 gpm (Hibbs and others, 1997). Hydraulic conductivity in the Hueco Bolson, as determined with 73 aquifer tests, varies from 6.4 to 98.9 ft/day (Hibbs and others, 1997).

Pumping

The Hueco Bolson aquifer is pumped at a much greater rate than the aquifer is recharged. Groundwater withdrawals from the aquifer in Texas amounted to about 69,000 acre-ft in 1999 (Sheng and others, 2001): about nine times greater than the amount of recharge in El Paso County. Over the past 20 yr, pumping from the Hueco and Mesilla Bolsons in Texas has ranged from 96,000 to 138,000 acre-ft/yr (Mace, this volume).

Water Quality

Water quality in the Hueco Bolson varies depending on location and depth. Water quality in the Texas part of the Hueco Bolson tends to be better to the west than to the east, although there are pockets of good-quality water in the eastern part of the bolson (Gates and others, 1980). North of the Texas-New Mexico border, water tends to have total dissolved solids (TDS) greater than 1,000 mg/L except near mountain fronts where there is active recharge (Hibbs and others, 1997). The upper part of the aquifer tends to be fresher with TDS ranging between 500 and 1,500 mg/L, with an average of about 640 mg/L (Ashworth and Hopkins, 1995). Water quality has been affected by the large water-level declines in the aquifer, which have induced flow of poor-quality water into areas of fresh water. Water quality in the shallow part of the aquifer along the Rio Grande in the alluvium has degraded because of leakage of poor-quality irrigation return-flow into the aquifer (Sheng and others, 2001). Water quality beneath Ciudad Juarez is generally less than 1,000 mg/L TDS (Hibbs and others, 1997), however, water-quality deterioration has been observed in wells along the border and in the downtown area.

Water Levels and Groundwater Flow

Depth to water in the Hueco Bolson aquifer ranges from very shallow to very deep. Depth to groundwater near the Cities of Tularosa and Alamogordo is between 20 and 150 ft, whereas depth to water below El Paso ranges from 250 to 400 ft in depth, and depth to water below Ciudad Juarez ranges between 100 and 250 ft (Hibbs and others, 1997). Depth to water below the Rio Grande is less than 70 ft. Groundwater flows from the Tularosa Basin southward into the Hueco Bolson and into Texas (Hibbs and others, 1997, their fig. 3.8). Little drawdown has been recorded in the northern part of the aquifer. The drawdown in Hueco Bolson along the Texas-New Mexico border has been relatively small, not exceeding 30 ft (Hibbs and other 1997). In heavily developed parts of the Hueco Bolson aquifer, drawdowns since predevelopment in 1903 are up to 170 ft. Focal points of drawdown are beneath the City of El Paso and Ciudad Juarez (Hibbs and others, 1997).

The model by Heywood and Yager (in review) suggests that about 6,000 acre-ft/yr of groundwater flowed in the Hueco Bolson aquifer from New Mexico into Texas before large-scale pumping by El Paso in the 1960’s. Since then, the amount of flow has increased to about 18,000 acre-ft/yr. In the El Paso-Ciudad Juarez area, groundwater flows toward cones of depression. Between 1910 and 1960, groundwater flowed from Mexico into Texas toward pumping centers in El Paso (Sheng and others, 2001). Since 1960, groundwater, generally of poor quality, has flowed from Texas into Mexico (Sheng and others, 2001).

Groundwater Models

Several groundwater flow models have been constructed for the Hueco Bolson aquifer system. These models include an early electric-analog model of the El Paso area (Leggat and Davis, 1966) and three numerical models developed by the U.S. Geological Survey, including (1) Meyer and Gordon (1973) and Meyer (1975, 1976) (later updated by Knowles and Alvarez, 1979), (2) Groschen (1994), and (3) an as yet unpublished model (Heywood and Yager, in review). Mullican and Senger (1990, 1992) developed a model of the southeastern part of the Hueco Bolson. Mexico has also developed a groundwater flow model for part of the area. Wilson and others (1986) used a preexisting model to predict water resources through 2060.

Models by Groschen (1994) and Heywood and Yager (in review) simulate potential water-level declines, as well as changes in water quality due to pumping. Groschen (1994) showed that water quality in the bolson is most likely affected by horizontal movement of saline water in response to pumping.

The integrated flow and water-quality model by Heywood and Yager (in review) represents the cooperation of EPWU, the USGS, the International Boundary and Water Commission (IBWC), Fort Bliss Military Reservation, JMAS (Junta Municipal de Agua y Saneamiento de Ciudad Juarez), and CILA (Comision Internacional de Limites y Aguas). Binational coordination has included the exchange of aquifer information and comparison of water-resource management plans. The model is being used to assess (1) water storage in the aquifer, (2) the optimization of pumping for fresh and brackish water, (3) the location of new production wells, (4) the control of brackish-water intrusion, (5) the design of an aquifer storage and recovery program, and (6) the planning of water resources among Texas, New Mexico, and Mexico (Sheng and others, 2001).

Groundwater Availability

Groundwater availability represents the amount of water that can be used from an aquifer. Groundwater availability can be defined in many different ways depending on the local socioeconomic needs (Mace and others, 2001). In the El Paso area, groundwater availability has been defined using a systematic depletion approach, where the total amount of recoverable water is considered the amount of water available for use. In general, groundwater availability is assessed for the fresh-water part of the aquifer. However, as water resources become scarcer in the state, more and more areas, including El Paso, are also evaluating the usable amounts of slightly saline water for ongoing or potential desalination projects.

Fresh Water

The approximate volume of recoverable freshwater in the entire Hueco Bolson aquifer is about 7.5 million acre-ft, with 3 million acre-ft in Texas, 3.9 million acre-ft in New Mexico, and 600,000 acre-ft in Mexico (Sheng and others, 2001, on the basis of a review of USGS publications). The Far West Texas Planning Group estimated that there were about 3 million acre-ft of fresh water in the Hueco Bolson and 2.5 million acre-ft of slightly saline water for desalination (FWTPG, 2001). Recoverable fresh water accounts for economic and geologic constraints and does not represent all of the fresh water in the aquifer.

Other studies have suggested differing volumes of fresh water. Knowles and Kennedy (1956) estimated that the Hueco Bolson in Texas had about 7.4 million acre-ft of recoverable water, with less than 250 mg/L chloride (~750 mg/L TDS). Meyer (1976) estimated the recoverable amount of fresh water in the Texas part of the Hueco Bolson to hold 10.64 million acre-ft. White (1987) estimated that the Hueco Bolson aquifer in Texas holds about 9.95 million acre-ft of recoverable fresh water. The TWDB (1997) estimated that there was about 9 million acre-feet of fresh water in the Texas part of the Hueco Bolson.

Slightly Saline Water

Slightly saline water may be a large potential water resource in the El Paso area. There is an estimated 20 million acre-ft of slightly saline water (TDS between 1,000 and 3,000 mg/L) in the Hueco Bolson aquifer in El Paso County (Sheng and others, 2001). Similar volumes of slightly saline water may also exist in New Mexico and Mexico (Sheng and others, 2001). Sheng and others (2001) recommended additional studies to quantify a more exact volume of poor-quality water in the aquifer.

Strategies to Increase Groundwater Availability

Although recent modeling work suggests that the Hueco Bolson in the El Paso area will run out of fresh water by 2025, it is not a forgone conclusion. For prediction purposes, the model assumes that current trends and practices will remain the same. However, the life of the fresh groundwater resource can be extended by implementing strategies to increase the availability of groundwater.

Increase Surface-Water Use

By increasing the use of surface water, groundwater use can be minimized, thus extending the useful life of the fresh-water part of the aquifer. In this case, surface water is relied upon when plentiful, and groundwater is relied upon when surface water is not plentiful. Regional water providers are pursuing this strategy by the implementation of the Regional Sustainable Water Project (IBWC and EPWU, 2000). The Far West Texas Planning Group also identifies the pursuit of additional surface-water supplies as a recommended water management strategy for the area (FWTPG, 2001). However, the planning group noted that El Paso cannot rely on the Rio Grande for water during times of severe drought (FWTPG, 2001).

Hydraulic Control and Desalination

To reduce the degradation of groundwater quality due to laterally flowing poorer quality water, wells can be installed to hydraulically control the migration of poorer quality water by capturing the poorer quality water before it mixes with fresher water. The produced water can then be desalinated. EPWU and the Department of Defense at the Fort Bliss Military Reservation are investigating this approach in existing wells in the Airport/Montana well field (Sheng and others, 2001). To maximize the water supply, the desalinated water (~200 mg/L TDS) can then be blended with slightly saline water (~1,500 mg/L TDS) to produce a water with a TDS of about 900 mg/L TDS. Hydraulic control and desalination extend the life of the fresh-water part of the aquifer by protecting existing fresh-water resources from further intrusions of poor-quality water and decreasing the reliance on the fresh-water part of the aquifer. Hydraulic control and desalination are also being considered in other El Paso wellfields (Sheng and others, 2001).

Pumping Optimization

Pumping of wells can be optimized to minimize the migration of poor-quality water and the depth of cones of depression around pumping centers. Pumping of water-supply wells should be optimized aquiferwide to minimize the effects of pumping on the migration of poor-quality water into areas of fresh water. An operational priority list for the Hueco well fields has been developed and used in well-field operation for over a year (Sheng and others, 2001). Results of the optimization program will be evaluated to further improve operation of the well fields. Pumping optimization extends the life of the fresh-water resource by minimizing the impacts of poor-quality water intrusions.

Aquifer Storage and Recovery

Aquifer Storage and Recovery (ASR) is when treated surface water is injected into an aquifer when it is plentiful and demand is low, and then recovered the stored water from the aquifer when demand is high or during times of drought. ASR extends the life of the aquifer by maximizing the use of surface water and recharging the aquifer. In addition, it will also prevent brackish water intrusion if injection wells are located along the transition zone of marginal quality groundwater.

Blending high-grade water with poor-quality water

Using the best quality water first has often been the preferred method of groundwater production. However, by blending good quality water with poorer quality water up to the Safe Drinking Water Act standards for TDS, chloride, and sulfate secondary maximum contamination levels, water providers can enhance their production capacity. The blending method extends the life of the aquifer by maximizing the use of the freshwater resource. When combined with hydraulic control, existing freshwater resources can also be additionally protected.

Conclusions

The Hueco Bolson aquifer and the El Paso-Ciudad Juarez area are at the crossroads. Several scientific studies and recent modeling projects suggest that, under current trends, fresh water from the Hueco Bolson aquifer in Texas will be depleted by 2025. However, using groundwater more strategically can extend the longevity of fresh-water resources in the aquifer. EPWU and FWTPG are actively researching and implementing a number of strategies to do just this, including increased surface-water use, hydraulic control and desalination, pumping optimization, aquifer storage and recovery, and blending to increase freshwater supplies. The area will need to continue to follow this path to ensure that future water needs of El Paso are met.

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References

Abeyta, C., and Thomas, C. L., 1996, Hydrogeology and groundwater quality of the chromic acid pit site, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas: U.S. Geological Survey Water Resource Investigations Report 96-4035.

Ashworth, J. B., and Hopkins, J., 1995, Aquifers of Texas: Texas Water Development Board Report 345, 69 p.

Cliett, T. E., 1969, Groundwater occurrence of the El Paso area and its related geology: *in* New Mexico Geological Society, Border Region, Chihuahua, Mexico, and United States, Guidebook, 20th Field Conference, p. 209-214.

FWTPG, 2001, Far West Texas Regional Water Plan: Far West Texas Planning Group, report submitted to the Texas Water Development Board, variously paginated.

Gates, J. S., White, D. E., Stanley, W. D., and Ackermann, H. D., 1980, Availability of fresh and slightly saline groundwater in the basins of westernmost Texas: Texas Department of Water Resources Report 256, 108 p.

Groschen, G. E., 1994, Simulation of ground-water flow and the movement of saline water in the Hueco Bolson aquifer, El Paso, Texas, and adjacent areas: U.S. Geological Survey Open-File Report 92-171.

Heywood, C. E., and Yager, R. M., in review, Ground-water flow and chloride-transport simulation of the Hueco Basin, El Paso, Texas, and adjacent areas: U.S. Geological Survey.

Hibbs, B. J., Ashworth, J. B., Boghici, R. N., Hayes, M. E., Creel, B. J., Hanson, A. T., Samani, B. A., and Kennedy, J. F., 1997, Trans-boundary aquifers of the El Paso/Ciudad Juarez/Las Cruces region: report prepared by the Texas Water Development Board and New Mexico Water Resources Research Institute for the U.S. Environmental Protection Agency, Region VI, under contract X 996343-01-0 and X 996350-01-0, 156 p.

Hill, R. T., 1900, Physical geography of the Texas region: U.S. Geological Survey Topographic Atlas, Folio No. 3.

IBWC (International Boundary and Water Commission) and EPWU, 2000, Draft environmental impact statement, El Paso–Las Cruces regional sustainable water project, volume I.

Knorr, D. and Cliett, T., 1985, Proposed groundwater recharge at El Paso, Texas: *in* Asano, T., ed., Artificial recharge of groundwater Butterworth Publishers, p. 425-480.

Knowles, D. B., and Kennedy, R. A., 1956, Groundwater resources of the Hueco Bolson, northeast of El Paso, Texas: Texas Board of Water Engineers Bulletin 5615, 265 p.

Knowles, T. R., and Alvarez, H. J., 1979, Simulated effects of ground-water pumping in portions of the Hueco Bolson in Texas and Mexico during the period 1973 through 2029: Texas Department of Water Resources Report LP-104.

Land, L. F., and Armstrong, C. A., 1985, A preliminary assessment of land-surface subsidence in the El Paso area, Texas: U.S. Geological Survey Water Resource Investigations Report 85-4155.

Leggat, E. R., and Davis, M. E., 1966, Analog model study of the Hueco bolson near El Paso, Texas: Texas Water Development Board, 26 p.

Mace, R. E., Mullican, W. F., III, and Way, T. (S.-C.), 2001, Estimating groundwater availability in Texas: *in* the proceedings of the 1st annual Texas Rural Water Association and Texas Water Conservation Association Water Law Seminar: Water Allocation in Texas: The Legal Issues. Austin, Texas, January 25-26, 2001. Section 1, 16 p.

Mattick, R. E., 1967, A seismic and gravity profile across the Hueco Bolson, Texas: *in* U.S. Geological Survey Professional Paper 575-D, p. 85-91

Meyer, W. R., 1975, Digital model studies of the hydrology of the Hueco Bolson, El Paso area, Texas: *in* Hills, J. M., ed., Exploration from the mountains to the basin, p. 141.

Meyer, W. R., 1976, Digital model for simulated effects of ground water pumping in the Hueco Bolson, El Paso area, Texas, New Mexico, and Mexico: U.S. Geological Survey Water-Resources Investigations Report 58-75.

Meyer, W. R., and Gordon, J. D., 1973, Water-budget studies of lower Mesilla Valley and El Paso Valley, El Paso County, Texas: U.S. Geological Survey, Open-File Report OF 73-0185, 41 p.

Mullican, W. F., III, and Senger, R. K., 1990, Saturated-zone hydrology of south-central Hudspeth County, Texas, *in* Hydrogeology of Trans-Pecos Texas: Kreitler, C.W., and Sharp, J. .M., Jr., eds., The University of Texas at Austin, Bureau of Economic Geology Guidebook 25, p. 37-42.

Mullican, W. F., III, and Senger, R. K., 1992, Hydrogeologic investigations of deep ground-water flow in the Chihuahuan Desert, Texas: The University of Texas at Austin, Bureau of Economic Geology, Report of Investigations 205, 60 p.

Richardson, G. B., 1909, Geological atlas, U.S. Geological Survey, El Paso Folio (No. 166).

Sayre, A. N., and Penn, L., 1945, Groundwater resources of the El Paso area, Texas: U.S. Geological Survey Water Supply Paper 919.

Sheng, Z., Fahy, M. P., and Devere, J., 2001, Management strategies for the Hueco Bolson in the El Paso, Texas, USA, and Ciudad Juarez, Mexico, region: *in* Bridging the gap–Proceedings of the World Water and Environmental Resources Congress, Orlando, Florida, May 20–24, CD ROM, ASCE.

TWDB, 1997, Water for Texas: Texas Water Development Board, Document No. GP-6-2, variously paginated.

USEPA , 1995, Hueco Bolson ground water recharge demonstration project, El Paso Texas, Part II, Water quality analysis: U.S. Environmental Protection Agency.

White, D. E., 1987, Summary of hydrologic information in the El Paso, Texas, area, with emphasis on ground-water studies, 1908-1980: Texas Water Development Board Report 300, 75 p.

White, D. E., Baker, E. T., and Sperka, R., 1997, Hydrology of the shallow aquifer and uppermost semi-confined aquifer near El Paso, Texas: U.S. Geological Survey, Water-Resources Investigations Report 97-4263.

Wilkins, D. W., 1986, Geohydrology of the southwest alluvial basins regional aquifer-systems analysis, parts of Colorado, New Mexico, and Texas: U.S. Geological Survey.

Wilson, L., and Associates, 1986, Technical Report for the Hueco Bolson Hearing, Prepared for El Paso Water Utilities/Public Service Board.