Report 300

Summary of Hydrologic Information in the El Paso, Texas, Area, With Emphasis on Ground-Water Studies, 1903-80

August 1987

Texas Water Development Board

316684

TEXAS WATER DEVELOPMENT BOARD

REPORT 300

SUMMARY OF HYDROLOGIC INFORMATION IN THE EL PASO, TEXAS, AREA, WITH EMPHASIS ON GROUND-WATER STUDIES, 1903-80

By

D. E. White
U.S. Geological Survey

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TEXAS WATER DEVELOPMENT BOARD

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ABSTRACT

Significant development of ground water in the El Paso area started in the early 1900's; pumping gradually increased to the early 1950's and has since accelerated commensurate with the area's rapid population growth. In 1980, withdrawals of ground water for municipal, industrial, and military supplies totaled 164,354 acre-feet within the El Paso, Fort Bliss, and Ciudad Juarez, Mexico metropolitan area, and adjacent areas in Texas and New Mexico. Most of the water, 132,652 acre-feet, was pumped from the Hueco bolson, the principal aquifer. The Mesilla bolson and Rio Grande alluvium in the lower Mesilla Valley supplied 27,461 and 4,241 acre-feet respectively.

The cumulative 1906 through 1980 withdrawals of ground water from the Hueco bolson metro area total 3.0 million acre-feet—about 2.2 million acre-feet has been pumped in the United States and 0.8 million acre-feet in the Republic of Mexico. These withdrawals have caused water levels to decline about 130 feet in the downtown sections of El Paso and Ciudad Juarez. In January 1980 the theoretically recoverable volume of freshwater in storage within the Texas part of the Hueco bolson metro area was estimated at 10.0 million acre-feet. Dissolved-solids concentrations in recent samples from Hueco bolson wells averaged 642 milligrams per liter in the Texas part of the metropolitan area and 736 milligrams per liter in Ciudad Juarez. Concentrations are increasing at an average-annual rate of about 10 milligrams per liter in Texas and 30 milligrams per liter in Juarez.

Ground water in the lower Mesilla Valley is pumped for municipal and industrial supply and also for supplemental crop irrigation during years of inadequate surface-water supply in the Rio Grande. The 1979-80 withdrawals in the valley averaged about 31,000 acre-feet per year. Most of the water, about 21,000 to 22,000 acre-feet per year, was pumped from shallow, medium depth, and deep wells in the Canutillo field. Dissolved-solids concentrations from recent samples from Canutillo wells ranged from 252 to 1,854 milligrams per liter.

Flow in the Rio Grande is diverted for crop irrigation in the United States and the Republic of Mexico, and for limited municipal supply in El Paso. The flow is regulated by releases from reservoirs in New Mexico and varies widely in both quantity and quality (dissolved-solids concentrations). During 1943-80, the flow at El Paso ranged from 57,481 acre-feet in 1956 to 631,800 acre-feet in 1943 and averaged about 317,000 acre-feet per year.

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SUMMARY OF HYDROLOGIC INFORMATION IN THE EL PASO, TEXAS, AREA, WITH EMPHASIS ON GROUND-WATER STUDIES, 1903-80

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INTRODUCTION

The availability of water in the city of El Paso and Ciudad Juarez to meet the rapidly growing demands for industrial use and municipal supply concerns not only the residents, but also the State and Federal governments. The future of the international community and the Fort Bliss and Biggs Air Base military installations is likely to be dependent upon the use of ground water pumped in the area. Because of the limits of the freshwater resources of the area and their importance, the U.S. Geological Survey has been monitoring and investigating the water resources in the area in cooperation with the city of El Paso Public Service Board and the Texas Water Development Board, or predecessor agencies, since the 1930's.

Located in the far western tip of Texas, the study area includes most of El Paso County and adjacent areas in New Mexico and Ciudad Juarez in Mexico. The location of the study area and regional physiography is shown in Figure 1. In this report the designated study area is frequently abbreviated as the El Paso area.

The climate of the El Paso area is typical of the arid to semiarid region of the southwestern United States and northern Mexico. The days are warm and the nights are cool. In late winter and early spring, high winds and blowing sand are common. The humidity is low and the evaporation rate is high, with the gross annual lake surface evaporation totaling about 80 inches.

The rate of evaporation in El Paso greatly exceeds the average annual rainfall of about 8.0 inches. Figure 2 shows the annual precipitation in El Paso for 1856 through 1980. During the period of continuous record starting in 1879, annual rainfall ranged from a low of 2.22 inches in 1891 to a high of 18.29 inches in 1884. During the 100-year period (1881-1980) rainfall averaged 8.43 inches.

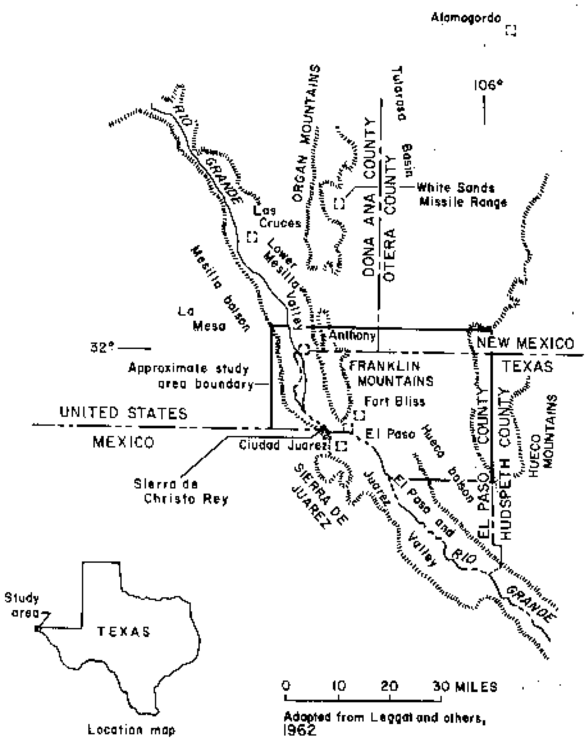

Figure 1.—Location and Physiographic Map of El Paso Area

Purpose and Scope

The purpose of this report is to summarize the development of the water resources of the El Paso area, centering on the use of ground water for municipal, military, and industrial supply within the city of El Paso-Fort Bliss Military Reservation and Ciudad Juarez metropolitan complex. Included are estimates of current withdrawals and reserves of fresh ground water and recent projections of future conditions. Due to availability of published reports that contain detailed aquifer descriptions and tabulations of data, no effort is made to duplicate the information in these publications.

Previous Investigations

Numerous studies have been made on the water resources of the El Paso area. Early studies were by Slichter (1905), Richardson (1909), and Lippencott (1921). The geology and ground-water resources have been adequately described by Sayre and Livingston (1945), Knowles and Kennedy (1956), Leggat, Lowry, and Hood (1962), and more recent studies, which include Meyer and Gordon (1972), U.S. Bureau of Reclamation (1973), Bluntzer (1975), Gates and others (1978), Alvarez and Buckner (1980), and C. A. Wilson and others (1981).

Ground-water digital-model studies were made by Meyer (1976) and Knowles and Alvarez (1979) for the Hueco bolson, the principal aquifer. Muller and Price (1979) included the El Paso area in their Statewide projections of ground-water availability through 2030. The U.S. Water and Power Resources Service (1980) examined the water resources of the Elephant Butte Reservoir-Fort Quitman project which includes the El Paso area and projected future population growth and water use using several scenarios of ground- and surface-water allocation. Garza and others (1980) studied the potential for injection-well recharge with treated sewage effluent. Lee Wilson and Associates (1981) studied El Paso's water supply, projected water demand and potential supplies to the year 2080, and proposed alternatives for alleviating future shortages.

Alvarez and Buckner (1980) compiled records on wells, water levels, and water quality in the Texas part of the study area, and C. A. Wilson and others (1981) compiled records for the New Mexico part. Bluntzer (1975) compiled well data and pumpage records for Ciudad Juarez. These records and more current data are on file in the El Paso office of the Texas Water Development Board and in the Geological Survey field offices in El Paso, Texas, and Las Cruces, New Mexico.

A Geological Survey Regional Aquifer System Analysis (RASA) study of the southwest alluvial basins, including the Rio Grande in the El Paso area, is currently in progress (1983). During this investigation much of the data that has been collected in the area will be compiled and

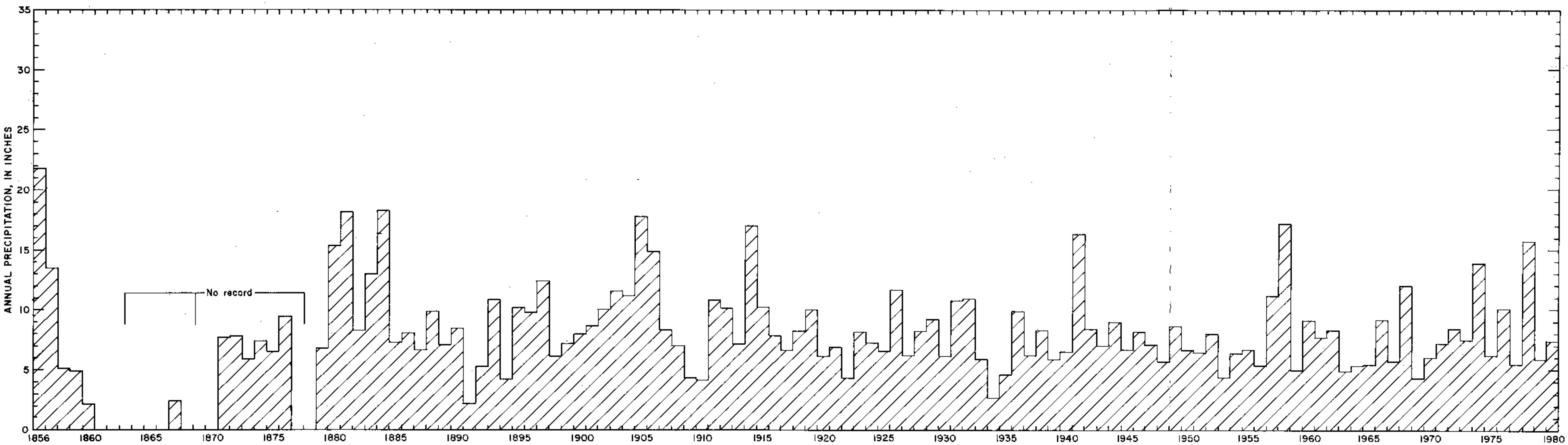

Figure 2
Annual Precipitation in El Paso, 1856 to 1980

a digital model of the regional ground-water flow system in the Mesilla basin will be developed. The Geological Survey, in cooperation with the city of El Paso Public Service Board, Texas Water Development Board, and the Department of the Army (Fort Bliss), is also currently conducting a three-dimensional solute transport modeling project in the Hueco Bolson. This project is designed to understand better the potential for saline water encroachment into the freshwater part of the aquifer.

Metric Conversions

Factors for converting inch-pound units of measurement to metric equivalents are given in the following table:

From	Multiply by	To obtain
inch	25.4	millimeter (mm)
foot	0.3048	meter (m)
mile	1.609	kilometer (km)
square mile	2.590	square kilometer (km^2)
acre	4,047	square meter (m^2)
	0.4047	hectare (ha)
gallon	3.785	liter (L)
acre-foot	1,233	cubic meter (m^3)
	0.001233	cubic hectometer (hm^3)
million acre-feet	1.23	cubic kilometer (km^3)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (million gal/d)	0.04381	cubic meter per second (m^3/s)
ton, short	0.9072	megagram (Mg)
ton per acre-foot	736	milligrams per liter (mg/L)

DEVELOPMENT OF WATER RESOURCES

There are no records on the first well to be dug or drilled in the El Paso area. Irrigated farming was introduced by the Spaniards in 1659 when Fray Garcia de San Francisco y Zuniga founded "Our Lady of Guadalupe of El Paso" Mission in what is now downtown Ciudad Juarez. Water was diverted from the Rio Grande to irrigate crops and sustain the community, which grew up around the mission (U.S. Bureau of Reclamation, 1973). Shallow wells probably were dug to augment the supply during periods of little or no flow in the river. The available records indicate use of ground water in the El Paso area was negligible until there was a significant growth in population, starting in about 1900. For purposes of this report, the significant ground-water development began during 1903, although records on withdrawals are not available until 1906.

The 10-year census population for the city of El Paso from 1910-80 is summarized below. During that time, El Paso's population increased more than tenfold and the per capita use of water nearly tripled from 76 gallons per day to more than 200 gallons per day. Currently (1980), most of the water used for municipal and industrial supply in the El Paso area is pumped from deep wells in the Hueco bolson east of the Franklin and Sierra de Juarez (Juarez Mountains). Additional supplies are pumped from wells completed in the Mesilla bolson west of the mountains and from shallow wells in the Mesilla and El Paso-Juarez Valleys. Only a limited amount of surface water is used by the city of El Paso for municipal purposes. Flow in the Rio Grande is diverted primarily for irrigation of crops in the valleys. During years of inadequate surface-water supply, shallow wells in the Rio Grande alluvium are pumped to augment the diversions.

Year	Population	Year	Population
1910	39,300	1950	130,000
1920	77,500	1960	279,000
1930	102,400	1970	322,500
1940	96,800	1980	425,100

Table 1 shows the source and use of ground water pumped in the El Paso area during 1965-80. The table does not include pumpage from privately owned domestic and irrigation wells in the Mesilla and El Paso Valleys. The location of the well fields in the lower Mesilla Valley and their estimated pumpage for 1979 are shown in Figure 3. Locations of well fields in the Hueco bolson area and their estimated pumpage for the same year are shown in Figure 4.

The total annual surface-water diversions from the Rio Grande for El Paso municipal supply are shown in Figure 5. The diversions started in 1943, and the rates of diversions in succeeding years have ranged from a low of 1,058 acre-feet during 1956, a year of extreme drought, to 20,057 acre-feet during 1980, a year of full surface-water allotments. The general increase since 1943 in the annual diversions reflects the acquisition by the El Paso Water Utilities of additional surface-water allotments.

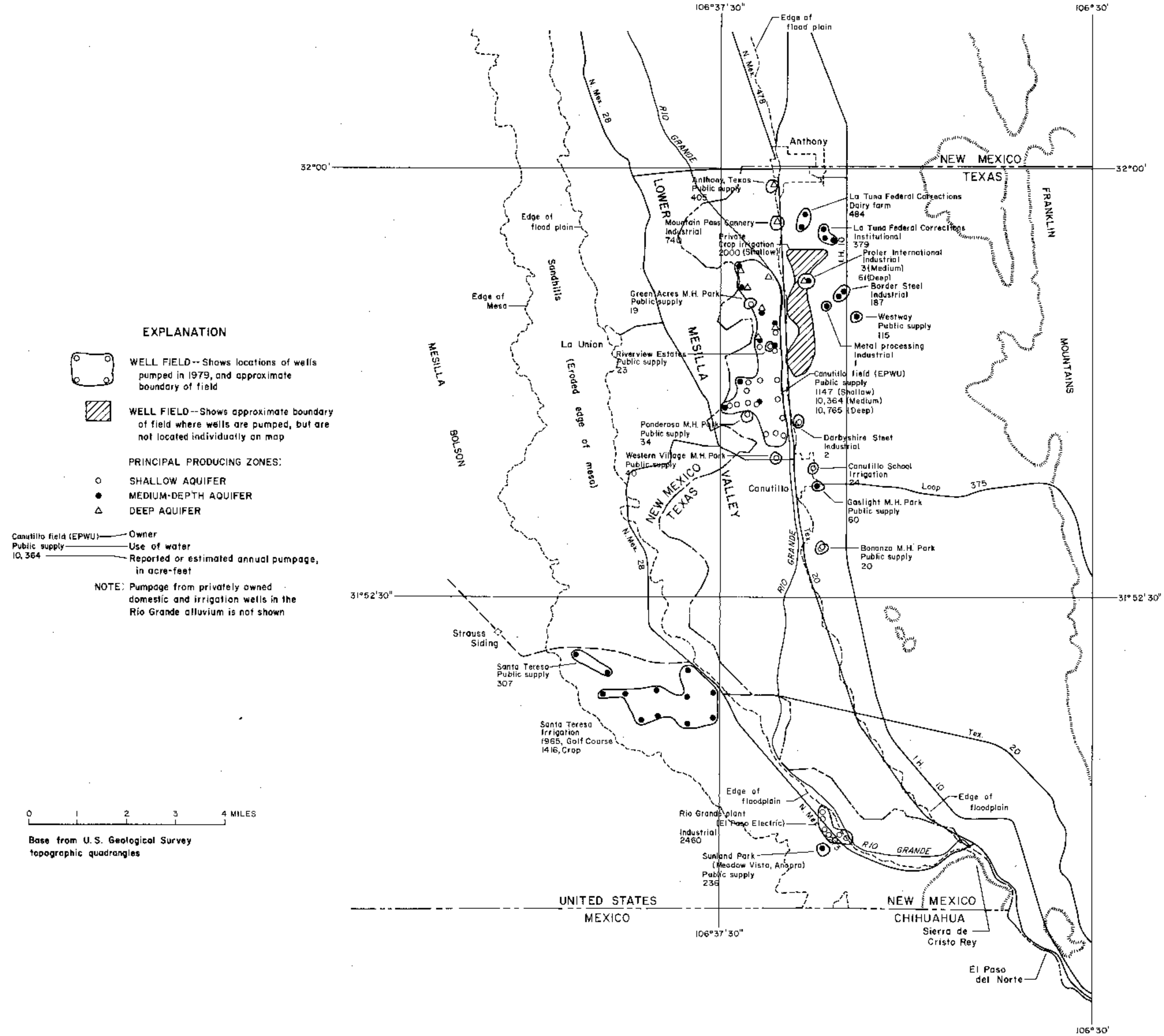

Figure 3
Well-Field Areas and Ground-Water Withdrawals, Lower Mesilla Valley, 1979

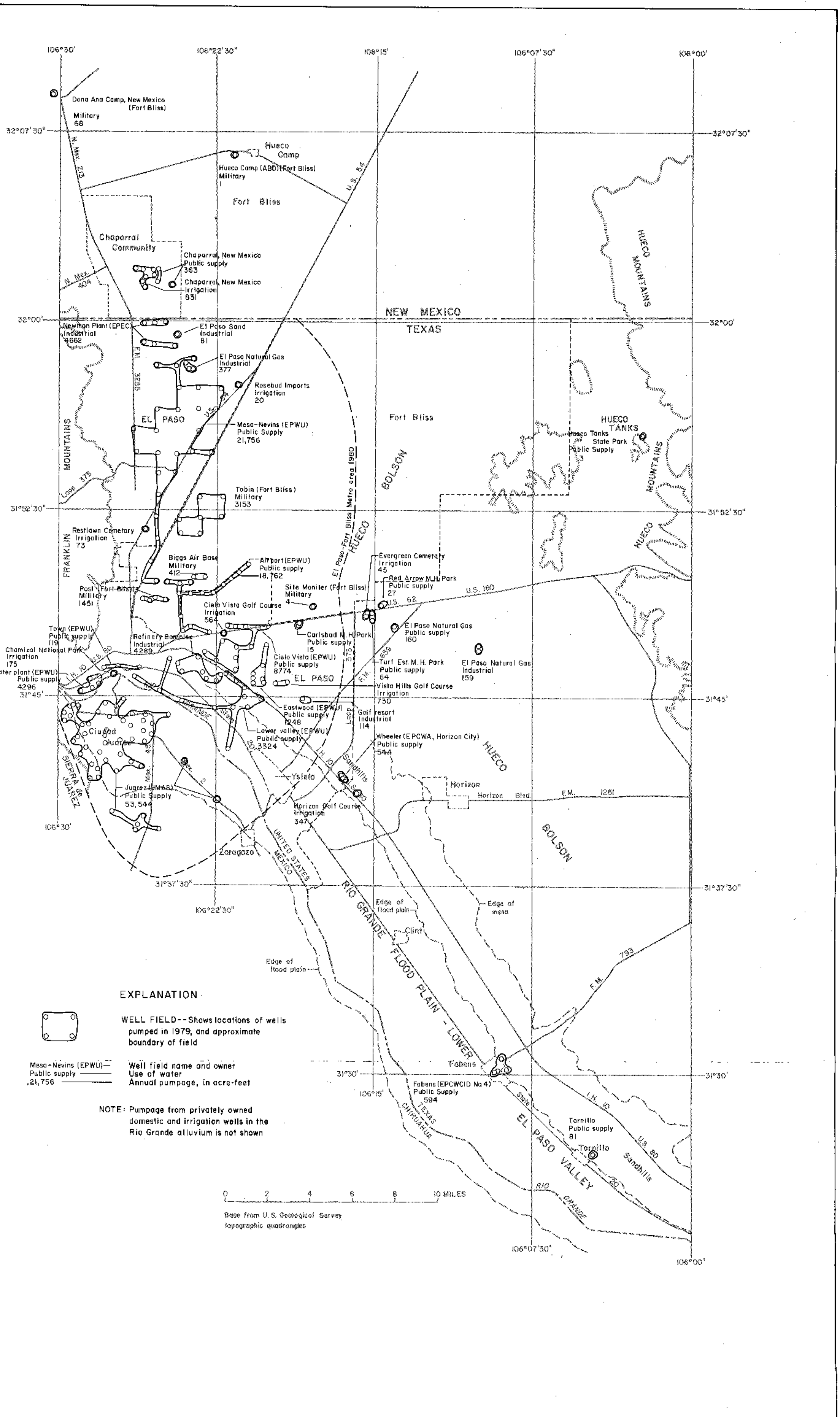

Figure 4
Well-Field Areas and Ground-Water Withdrawals, Hueco Bolson, 1979

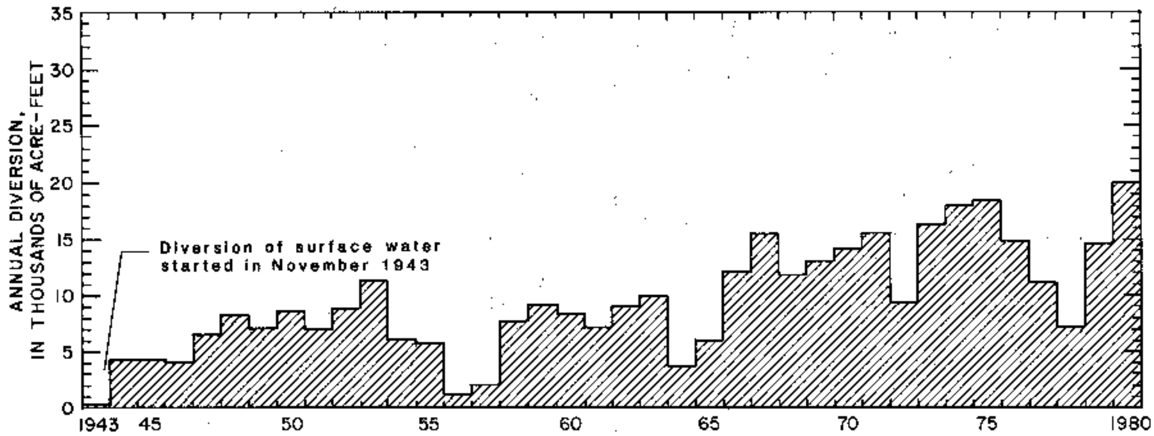

Figure 5.—Annual Surface-Water Diversions From the Rio Grande for the City of El Paso Municipal Use, 1943-80

LOWER MESILLA VALLEY AND MESILLA BOLSON

The geology and ground-water resources of the lower Mesilla Valley and Mesilla bolson have been studied by Leggat, Lowry, and Hood (1962), Gates and others (1978), Alvarez and Buckner (1980), and C. A. Wilson and others (1981). The latter two reports include data on wells in the Texas and New Mexico parts of the valley, respectively. The following discussion draws liberally on these reports.

The Mesilla Valley of the Rio Grande crosses the east side of the Mesilla bolson and west of the Franklin and Organ Mountains. The lower Mesilla Valley extends south from the New Mexico-Texas stateline at Anthony to "El Paso del Norte," the gap between the Franklin Mountains and Sierra de Cristo Rey at the northern tip of the Sierra de Juarez (Figure 1). The eastern part of the valley is in Texas and the western part is in New Mexico with the area about equally divided between the two states.

The Franklin Mountains to the east of the valley are composed of Precambrian rocks and Paleozoic and Cretaceous limestone, dolomite, and sandstone. Tertiary intrusives flanked by Cretaceous rocks form the Sierra de Cristo Rey and hills southeast of Cristo Rey or the east side of the Rio Grande. The Sierra de Juarez consists entirely of Cretaceous sedimentary rocks intruded by Eocene dikes and sills.

The west side of the valley is bordered by La Mesa which is also called the West Mesa in New Mexico. La Mesa is the undissected surface of the Mesilla bolson that is underlain by basin fill of late Tertiary and Quaternary age.

Most of the Mesilla Valley and La Mesa is underlain by thick sections of alluvial basin fill probably underlain by thick sections of volcanic rocks. The basin fill of the Mesilla bolson is composed of clay, silt, sand, and gravel and includes equivalents of the Santa Fe Group of Miocene to Pleistocene age and the Rio Grande alluvium of Holocene age.

Ground water in the lower Mesilla Valley is stored in the unconsolidated Rio Grande alluvium and bolson fill deposits. These deposits are in hydraulic connection. Previous investigators have

Table 1.—Ground-Water Withdrawals, El Paso County, Texas and Adjacent Areas in New Mexico and Mexico, 1965-80

USE OF WATER (acre-feet)

Year	El Paso County, Texas						Dona Ana County, New Mexico					Total U.S.	Mexico		Grand total region1/
	Public	Military	Industrial	Recreation	Crop irrigation	Subtotal	Public and military	Industrial	Recreation	Crop irrigation	Subtotal		Ciudad Juarez	Other	
1965	59,883	5,493	10,277	569	8,933	85,155	2/85	2,441	0	2/412	2,938	88,093	16,822	Data	104,915
1966	51,082	5,765	10,413	569	8,209	76,038	97	2,121	0	560	2,778	78,816	16,806	not	95,622
1967	59,432	5,931	10,530	1,058	7,876	84,827	109	2,348	0	560	3,017	87,844	18,087	avail-	105,931
1968	58,530	6,052	10,005	1,058	7,084	82,729	121	2,359	0	560	3,040	85,769	19,709	able.	105,478
1969	62,650	5,748	10,664	1,139	6,445	86,646	145	2,573	0	560	3,278	89,924	22,151		112,075
1970	60,760	5,236	10,182	1,125	8,141	85,444	169	2,368	0	560	3,097	88,531	23,985		112,516
1971	70,903	5,313	11,015	1,125	7,880	96,236	194	2,273	0	560	3,027	99,263	29,473		128,736
1972	77,037	5,058	10,313	1,797	7,132	101,337	230	3,304	0	560	4,094	105,431	32,412		137,843
1973	75,725	5,100	10,721	3,042	6,907	101,495	266	3,399	2/1,965	571	6,201	107,696	35,636		143,332
1974	73,659	5,103	10,503	2,469	6,968	98,702	307	3,356	1,965	571	6,199	104,901	37,294		142,195
1975	76,179	5,370	10,497	2,789	1,936	96,771	343	3,457	1,965	674	6,439	103,210	39,529		142,739
1976	75,905	5,298	10,320	2,439	377	94,339	442	3,016	1,965	827	6,250	100,589	42,111		142,700
1977	90,357	5,488	10,572	3,071	1,307	110,795	569	2,363	1,965	2,243	7,140	117,935	45,170		163,105
1978	95,781	5,190	10,176	2,675	20	113,842	614	2,768	1,965	2,247	7,594	121,436	49,175		170,611
1979	82,986	5,020	10,718	2,492	504	101,720	975	2,460	1,965	2,247	7,647	109,367	53,544		162,911
1980	81,823	5,013	9,894	2,439	880	100,049	1,071	3,078	1,965	2,381	8,496	108,545	55,808		164,353

SOURCE OF WATER (acre-feet)

Year	Hueco bolson						Mesilla bolson			Rio Grande alluvium				Total region	Grand total region
	Metro area 3/		Total metro	New Mexico	El Paso Valley	Total region	Texas	New Mexico	Total region	Mesilla Valley		El Paso Valley			
	Texas	Mexico								Texas	New Mexico	Texas	Mexico		
1965	60,718	16,822	77,540	2/497	817	78,854	18,547	0	18,547	4,767	2,441	306	Data	7,514	104,915
1966	52,236	16,806	69,042	657	713	70,412	19,355	0	19,355	3,427	2,121	306	not	5,854	95,621
1967	55,621	18,087	73,708	669	753	75,130	16,798	0	16,798	11,099	2,348	556	avail-	14,003	105,931
1968	61,771	19,709	81,480	711	1,124	83,315	14,754	0	14,754	4,518	2,359	562	able.	7,439	105,508
1969	67,777	22,151	89,928	705	1,432	92,065	14,222	0	14,222	2,643	2,573	571		5,787	112,074
1970	60,997	23,985	84,982	729	1,927	87,638	16,491	0	16,491	5,467	2,368	562		8,397	112,526
1971	64,964	29,473	94,437	754	2,283	97,474	18,083	0	18,083	10,345	2,273	562		13,180	128,737
1972	72,494	32,412	104,906	790	1,973	107,669	17,819	0	17,819	8,448	3,304	603		12,355	137,843
1973	75,896	35,636	111,532	837	2,214	114,583	15,917	2/1,965	17,882	7,014	3,399	455		10,868	143,333
1974	75,440	37,294	112,734	878	2,556	116,168	15,406	1,965	17,371	4,911	3,356	389		8,656	142,195
1975	72,040	39,529	111,569	1,017	2,695	115,281	16,664	1,965	18,629	5,010	3,457	362		8,829	142,739
1976	70,991	42,111	113,102	1,192	2,983	117,277	18,799	2,042	20,841	1,209	3,016	358		4,583	142,701
1977	79,005	45,170	124,175	1,243	2,322	127,740	23,318	3,534	26,852	5,774	2,364	376		8,514	163,106
1978	81,696	49,175	130,871	1,272	2,203	134,346	24,368	3,554	27,922	5,077	2,768	498		8,343	170,611
1979	74,464	53,544	128,008	1,263	1,973	131,244	23,563	3,924	27,487	1,324	2,460	398		4,182	162,913
1980	73,423	55,808	129,231	1,264	2,157	132,652	23,308	4,153	27,461	767	3,079	395		4,241	164,354

1/ Withdrawals from domestic and irrigation wells in Rio Grande alluvium are unaccounted.
2/ Estimated.
3/ Hueco bolson metro area is arbitrarily defined as having large-scale ground-water development and a freshwater section generally exceeding 100 feet in thickness in 1980.

separated the alluvium and bolson deposits into three aquifers based on differences in lithology, water levels, and water quality. These are the shallow aquifer, the medium-depth or intermediate aquifer, and the deep aquifer. This terminology was first applied to wells in the El Paso Water Utilities Canutillo field. There the shallow production wells are completed to depths of 200 feet or less. The medium-depth production wells have screens starting at 168-356 feet and extending to depths of 278-550 feet. The deep production wells are screened starting at depths of 512-650 feet and extending to depths of 900-1,200 feet.

Ground water in the lower Mesilla Valley is pumped for municipal and industrial supply and irrigation of crop land. Pumpage for irrigation is supplemental to diversions of flow from the Rio Grande; therefore, the rate of pumpage varies inversely with surface-water availability. Leggat and others (1962) reported that the amount of water pumped from wells in the lower Mesilla Valley was small before 1951 because most of the irrigated land had surface-water rights, and the supply released from storage in Elephant Butte Reservoir was adequate. In 1946, only two large-capacity wells were used. From 1946-50, the number of irrigation wells increased to 16, and by the end of 1954, about 250 wells had been drilled. These wells pumped an estimated 40,000 acre-feet of water to irrigate 15,000 acres of cotton and alfalfa.

The estimated annual withdrawal of ground water in the lower Mesilla Valley and Mesilla bolson from 1945 through 1980 is shown in Figure 6. The pumpage is separated by source and use of water. The amounts of ground water pumped in 1979 for municipal and industrial supply, and the locations of well fields and selected wells were shown earlier in Figure 3. The municipal and industrial pumpage for 1965-80 was also included in Table 1. Farmers in the lower Mesilla Valley received full surface-water allotments in both 1979 and 1980 so ground-water withdrawals went mainly for municipal and industrial supply and averaged about 31,000 acre-feet. Most of the withdrawals, about 21,000-22,000 acre-feet, came from wells in the El Paso Water Utilities Canutillo field.

The annual withdrawals from the three aquifers in the Canutillo well field during 1952-80, and hydrographs of observation wells are shown in Figures 7a-c. The shallow wells in the Canutillo field discharge into the Rio Grande. These wells are pumped during periods of release of irrigation water from Elephant Butte and Caballo Reservoirs in New Mexico. The well water, less transportation losses, is diverted along with the El Paso Water Utilities surface-water allotments at the Roberson-Umbenhauer treatment plant near downtown El Paso. The intermediate and deep wells, which pump better-quality water, are connected directly to the storage-distribution system.

Ground-Water Hydrology

Depths to water in wells in the lower Mesilla Valley vary both seasonally and annually. Water levels also vary at a particular location depending upon how deep a well is screened. Water levels in shallow wells on the valley floor generally are 5-15 feet below land surface and a few feet above water levels in nearby drains. During periods of inadequate surface-water supply and heavy withdrawals for irrigation such as in the mid 1950's, water levels may decline as much as 10-15 feet.

Hydrographs of annual high and low measurements for 10 U.S. Bureau of Reclamation shallow observation wells in the valley are given in Figure 8. Figure 9 shows the location of the

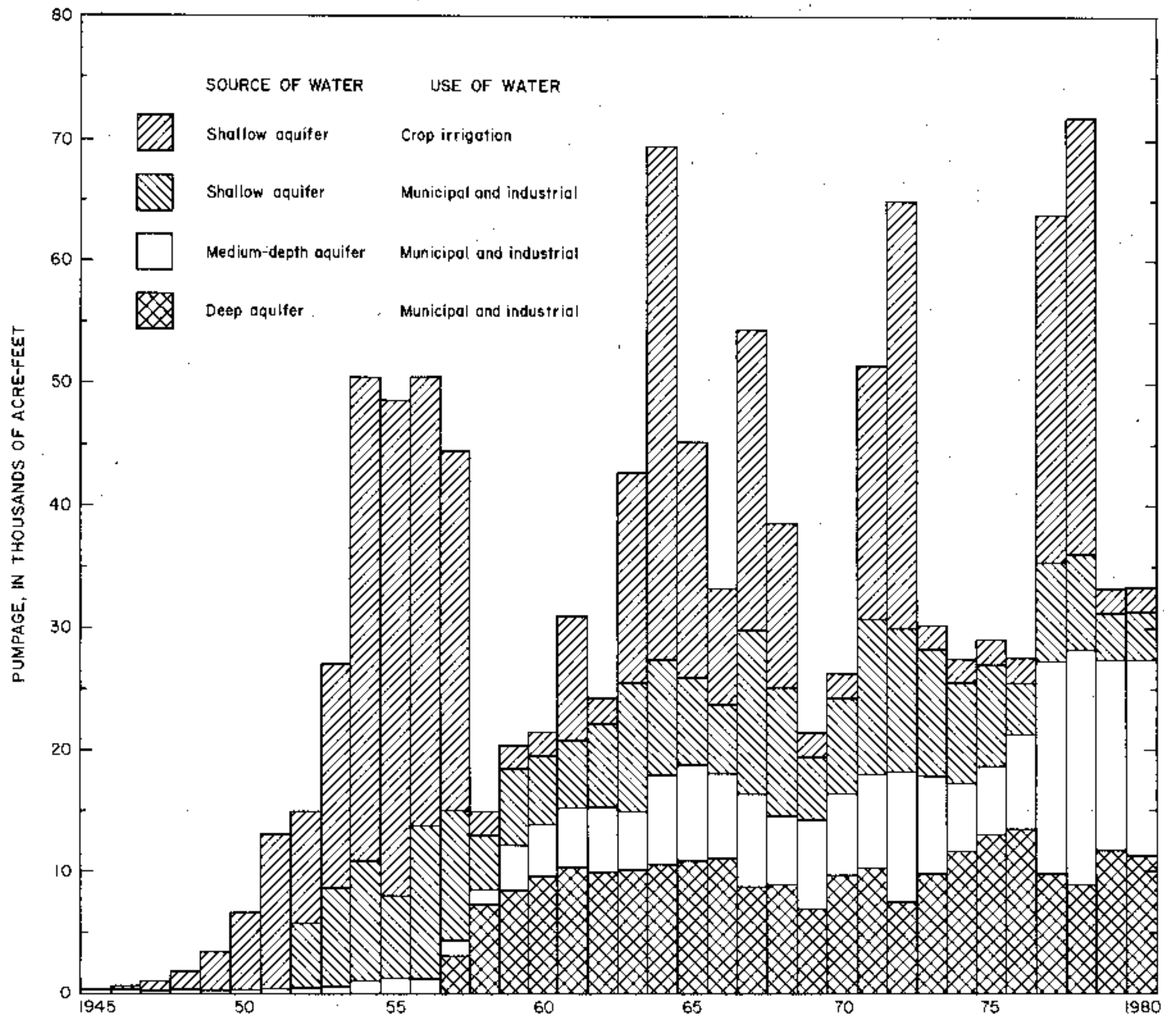

Figure 6.—Estimated Withdrawals and Use of Ground Water in the Lower Mesilla Valley, Texas and New Mexico, 1945-80

Bureau of Reclamation shallow observation wells and selected Geological Survey shallow, intermediate, and deep observation wells in the lower Mesilla Valley.

Hydrographs of observation wells in the heavily-pumped northern part of the lower Mesilla Valley show the greatest fluctuations in water levels. The hydrographs are essentially flat for wells in the southern part of the valley where the ground water is brackish and developed comparatively little. Substantial urbanization of formerly irrigated cropland in the southern part of the valley has reduced the amount of recharge from applied surface water.

The hydrographs of shallow wells in the lower Mesilla Valley do not show any appreciable long-term rise or decline in the water table. This stability indicates that recharge to and discharge from the aquifer are in general equilibrium.

The altitude of the water table in the lower Mesilla Valley and adjacent areas is mapped by contours in Figure 10. The water table contours show approximation of predevelopment conditions and were drawn using historic to recent (late 1930's to early 1970's) water-level data. The contours show the general ground-water flow direction from the uplands toward the valley and

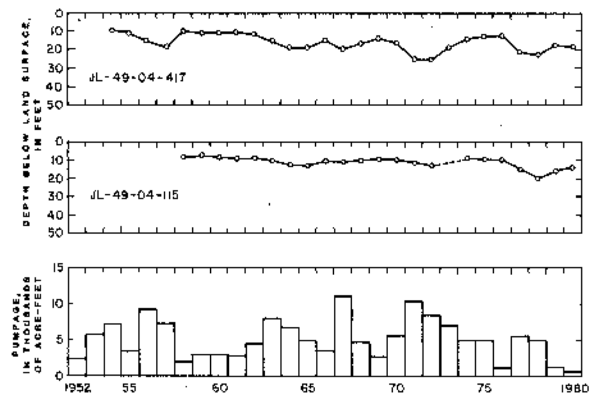

Figure 7a.—Withdrawals of Ground Water From the Canutillo Well Field and Hydrographs of Observation Wells, 1952-80, Shallow Wells

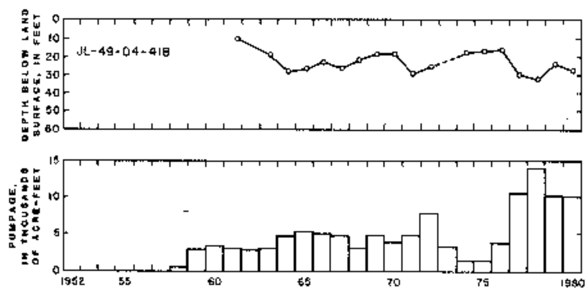

Figure 7b.—Withdrawals of Ground Water From the Canutillo Well Field and Hydrographs of Observation Wells, 1952-80, Intermediate Wells

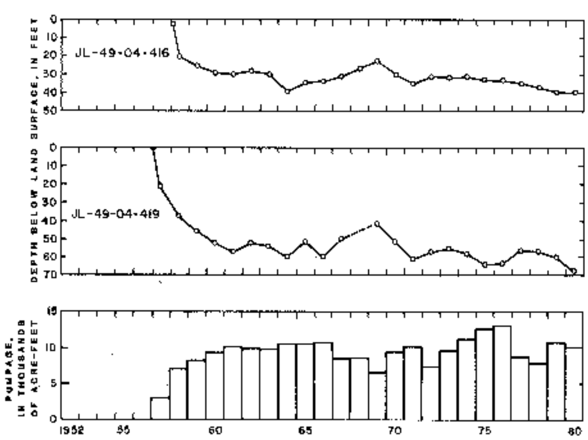

Figure 7c.—Withdrawals of Ground Water From the Canutillo Well Field and Hydrographs of Observation Wells, 1952-80, Deep Wells

north to south down the valley. The water-table map also shows that the flood plain of the Rio Grande has been an area of ground-water discharge and the uplands have been areas of recharge. Leggat and others (1962) estimated the ground-water inflow to the three aquifers of the lower Mesilla Valley to be about 18,000 acre-feet per year. The inflow comes from La Mesa to the west, the Franklin Mountains to the east, and from the Mesilla Valley north of Anthony.

Before major ground-water development in the lower Mesilla Valley (1956), water levels in wells in the deep aquifer were a few feet to as much as 10 feet higher than levels in the shallow aquifer, indicating upward movement of ground water from the deep to the shallow aquifer. These conditions still exist in the southern end of the valley where subsurface flow is constricted by bedrock barriers, and well development has been inhibited by high salinity in the ground water.

The upward movement of ground water has been reversed in the Canutillo well field and along the eastern edge of the valley from the town of Anthony south to the community of Canutillo (Figures 7a, b, c, and 11). This is an area of concentrated withdrawals for municipal and industrial supply which in 1979 totaled about 24,000 acre-feet. These withdrawals, together with an estimated 2,000 acre-feet pumped annually to irrigate cropland above the canals have caused water levels to decline about 10-30 feet in the Anthony-Canutillo area since the early 1950's. Ground water originally flowed laterally and vertically toward the Rio Grande or the valley drains. The water-level declines reversed this original gradient and direction of flow.

Mapping the static water levels of the three aquifers in the Canutillo well field is essentially impossible because several of the wells are operating at any given time. Since all of the wells normally are shut down only during periods of emergencies, water-level maps for other than predevelopment conditions have not been drawn.

On January 26, 1976, a break in the Canutillo main required all of the production wells to be shut down for 53½ hours. The recovery of water levels was measured in the three deep observation wells in the field (JL-49-04-419, JL-49-04-416, and JL-49-04-111), and hydrographs of the recovery levels were prepared (Figure 11). A partial and finally a complete shutdown of production wells also occurred during December 1977-February 1978. During early December 1977, only one or two wells were pumped and on December 27, all pumping stopped. Production from the field did not resume until February 21, 1978. Monthly measurements made during the shutdown showed recovery of water levels in the deep observation wells as follows:

(Water levels below land surface, feet)

Date	Well number (altitude, feet) JL-49-04-416 (3,768.5)	JL-49-04-419 (3,772.5)	JL-49-04-111 (3,775.8)
Dec. 19, 1977	25.97	37.23	45.25
Jan. 20, 1978	18.58	22.13	22.16
Feb. 20, 1978	17.97	21.50	21.15

The recovery measurements made in deep observation wells in the Canutillo field indicate that the artesian head is currently (1980) about 20 feet below land surface, or about 20 feet below the 1956 predevelopment levels. This decline is comparable to the 10- to 30-foot decline in the water table in the Anthony-Canutillo strip east of the well field and the Rio Grande flood plain and the two may be related.

Water Quality

Water quality in wells and test holes in the lower Mesilla Valley ranges from very fresh to saline (dissolved-solids concentrations range from less than 300 mg/L to more than 10,000 mg/L). In general, the salinity in ground water increases from north to south, which is also generally true for flow in the Rio Grande and in the valley drains. However, for any particular section across the valley, the quality of water varies both vertically and laterally and may change with time.

Variations in water quality in the shallow wells in the Canutillo field are given in Table 2. The dissolved-solids concentrations in recent samples from 16 shallow production wells ranged from 683 to 1,854 mg/L and averaged 1,019 mg/L. A comparison of these values with those determined in earlier samples shows a general increase in salinity, averaging about 11 mg/L per year.

Table 2 also shows distances between the shallow wells and the lines of recharge in the Rio Grande or Canutillo lateral (Figure 10). Concentrations of dissolved solids in recent samples from six wells located about 0.1 mile west of the river ranged from 766 to 913 mg/L and averaged 853

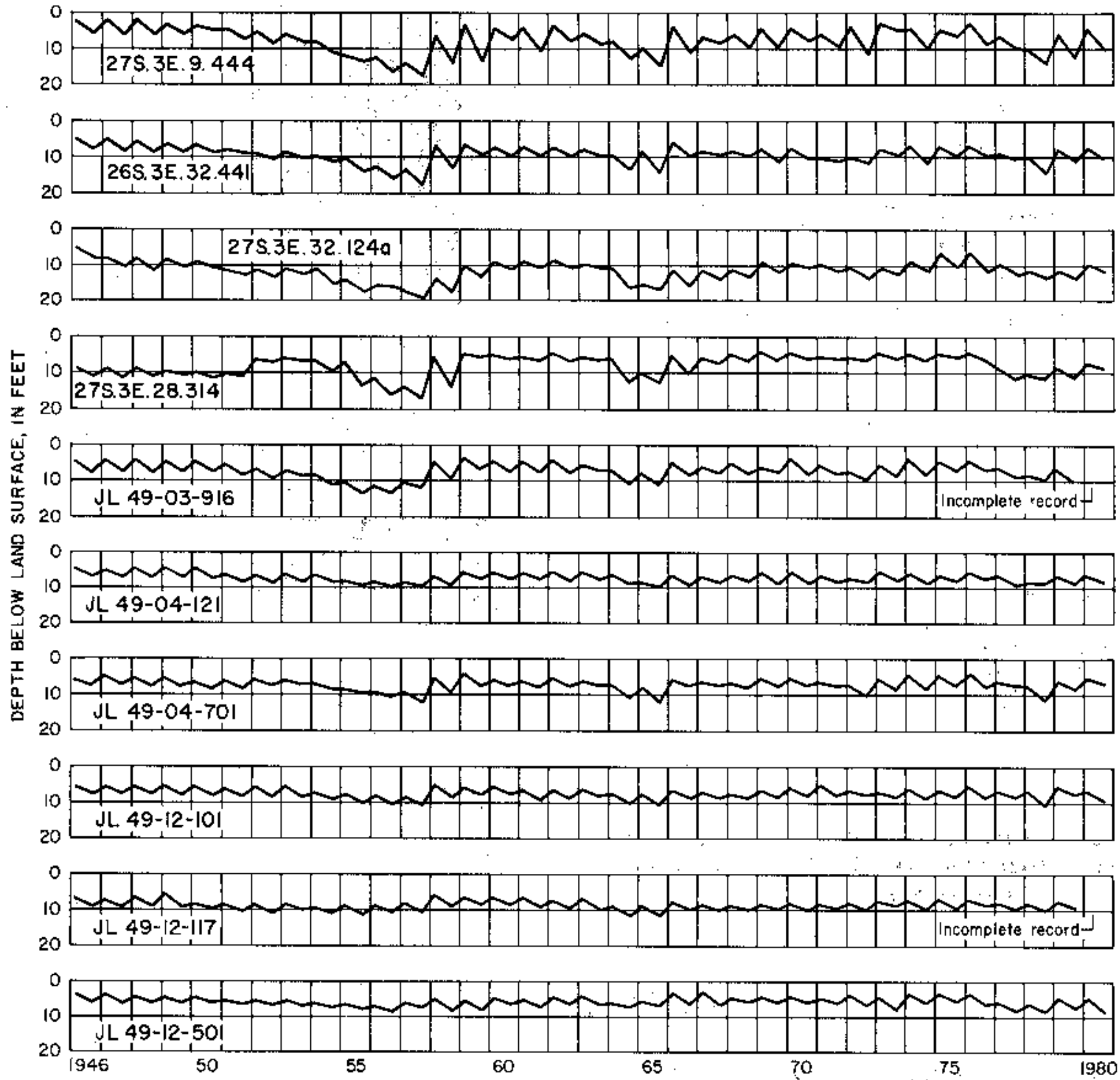

Figure 8.—Hydrographs of Ten Shallow Observation Wells in the Lower Mesilla Valley

mg/L. Dissolved-solids concentrations ranged from 683 to 881 mg/L in samples from four wells drilled along the Canutillo lateral. The dissolved-solids concentrations from five wells located 0.25 to 0.5 mile from the river or canals ranged from 1,145 to 1,854 mg/L. Two samples collected from the Nemexas drain on the west side of the well field contained dissolved-solids concentrations of 1,606 and 1,683 mg/L in February 1981.

Dissolved-solids concentrations in recent samples from nine intermediate production wells ranged from 328 to 741 mg/L and averaged 489 mg/L as shown in Table 3. The dissolved-solids concentrations have increased in the intermediate wells at an average rate of about 9 mg/L per year. Most, if not all, of the increase can be attributed to leakage of inferior-quality water from the shallow zone (0 to 200 feet) into screens that are set at too shallow (200 feet or above) a depth.

The water from the six deep production wells in the Canutillo field is exceptionally low in dissolved-solids concentrations as shown in Table 4. The dissolved solids in samples collected

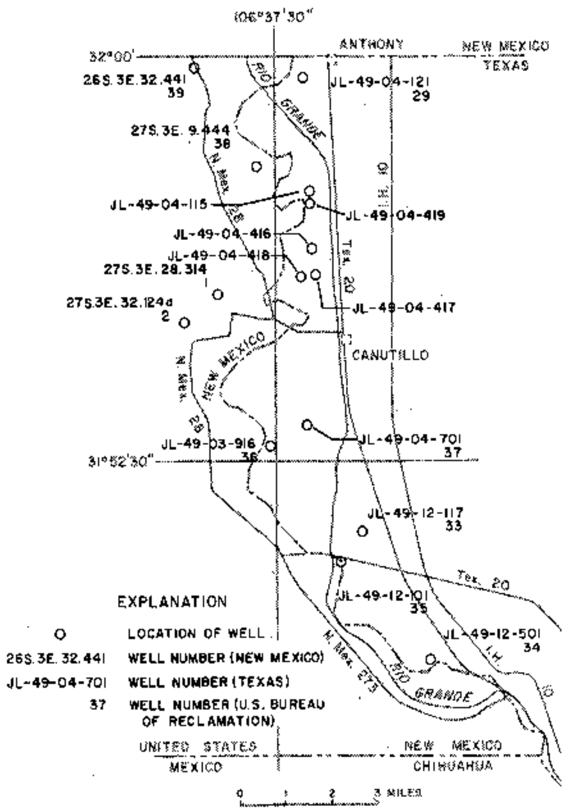

Figure 9.—Location of 15 Water-Level Observation Wells in the Lower Mesilla Valley With Hydrographs Shown in Figures 7a-c and 8

during 1980-81 ranged from 252 to 340 mg/L and averaged 278 mg/L. No pronounced changes in water quality have been observed in wells screened in the deep aquifer except for observation well JL-49-04-416 (CR-3). The sands containing freshwater in the deep aquifer decrease in thickness north to south. Well CR-3 was screened opposite both fresh and brackish water zones in the aquifer at a location 0.7 mile south of the nearest deep production well, JL-49-04-402 (city well 201). Periodic jetting of well CR-3 for water samples may have developed the lower part of the screened section opposite sands containing brackish water. The electric log and interval samples collected when the well was drilled indicate the base of the zone containing fresh water (top of brackish water) is at about 920 feet which is about 140 feet above the bottom of the screened section. Recent analyses of water from city well 201 have shown an increase in dissolved-solids concentration, which may reflect northward migration of the freshwater-brackish water interface.

Ground-Water Availability

According to Gates and others (1978, p. 108) about 0.8 million acre-feet of fresh ground water is stored under the Texas part of the lower Mesilla Valley and the adjacent mesa area to the east. About 4.7 million acre-feet is stored under the New Mexico part of the valley and the adjacent mesa area to the west. In addition to the freshwater, about 0.3 million acre-feet of slightly saline water is stored in the Rio Grande alluvium under the Texas part of the valley. These estimates were made using a specific yield of 10 percent for the total thickness of sediments containing fresh or slightly saline water. The volumes estimated to be in storage and theoretically recoverable may be substantially greater than can be practically recovered.

Figure 12 shows the approximate thickness of sediments containing freshwater in the lower Mesilla Valley and adjacent area. The map was prepared by using electric-log and water-sample data from wells and test holes, supplemented by interpretation of electrical-sounding data. The map delineates areas underlain by more than 1,000 feet, 500-1,000 feet, 100-500 feet, and less than 100 feet of freshwater-bearing sediments.

The map shows the thickest section containing fresh ground water, more than 1,000 feet, is in the northwest part of the valley. C. A. Wilson and others (1981, plate 15) show the freshwater section thickening to the north and west in New Mexico to as much as 2,400 feet in the vicinity of the community of Mesquite and the city of Las Cruces. The C. A. Wilson and others study (1981, p.

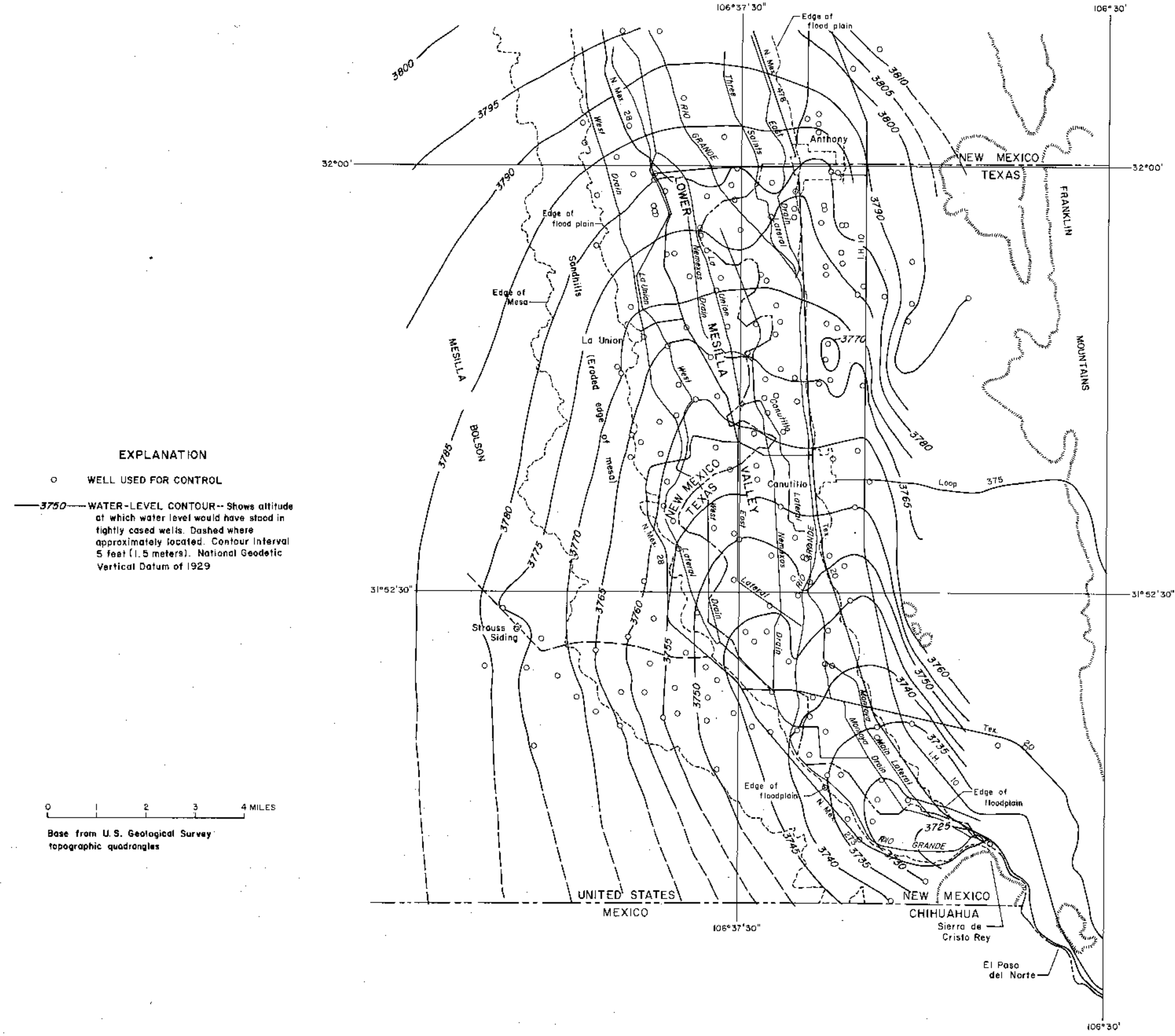

Figure 10
Estimated Predevelopment Altitude of the Water Table in the Lower Mesilla Valley

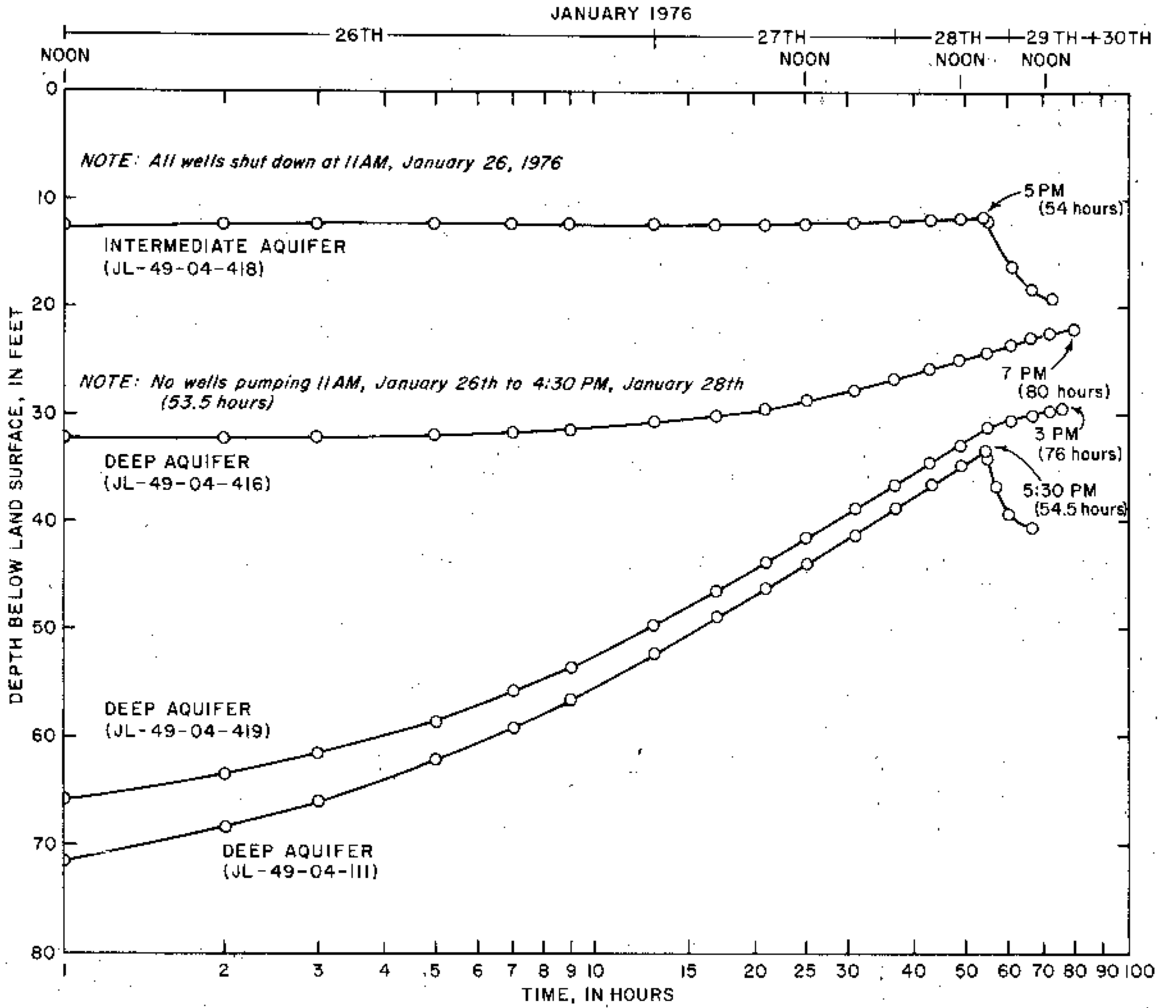

Figure 11.—Recovery of Water Levels in Response to Shutdown of Pumping in the Canutillo Well Field, January 1976

84) estimated that 20 million acre-feet of freshwater and 2.7 million acre-feet of slightly saline water are theoretically available to wells in the upper Mesilla Valley north of the State line at Anthony. On the West Mesa, or La Mesa part of the Mesilla bolson, the study showed 34 million acre-feet of freshwater theoretically available to wells. These estimates were made using specific yields of 9.3 percent in the Mesilla Valley and 9.5 percent on the Mesilla bolson.

HUECO BOLSON-EL PASO VALLEY

The Hueco bolson is the principal aquifer supplying fresh ground water for municipal, military, and industrial supply in the El Paso area. Many geologic and hydrologic studies have been made of the Hueco bolson including those by Sayre and Livingston (1937), Knowles and Kennedy (1958), Alvarez and Buckner (1980), Meyer (1976), and Gates and others (1978). The latter report summarized the availability of fresh and slightly saline ground water in the basins of westernmost Texas including the El Paso area.

The following discussion on the geology and water-bearing characteristics of the Hueco bolson is condensed from the Gates (1978) report with only minor additions or deletions. The

Table 2.—Dissolved-Solids Concentrations in Water From Shallow Wells in the City of El Paso Canutillo Well Field, Lower Mesilla Valley, Texas

State well number	Local number	Slotted interval (feet)	Distance to centerline of Rio Grande (RG) or Canutillo lateral (CL) (feet)	Early analysis: Dissolved solids (mg/L)	Early analysis: Date	Recent analysis: Dissolved solids (mg/L)	Recent analysis: Date	Rate of change, in dissolved solids (± mg/L/year)
				Production Wells				
JL-49-04-403	104	76-155	2,350 CL	583 1,006	1952 1957	1,854	1980	+45.4 +39.9
405	110	53-170	2,180 RG	859 1,269	1955 1957	1,675 1,702	1980 1981	+32.6 +18.0
406	103	63-150	450 RG	284 935	1952 1955	913	1980	+22.5 -.9
407	112	62-200	330 CL	546	1956	817	1980	+11.3
408	111	61-200	210 CL	755	1956	738	1980	-1.5
409	109	37-156	1,400 CL	946	1955	1,324	1980	+15.1
411	108	60-194	1,300 CL	704 972	1955 1957	1,145	1981	+17.0 +6.7
412	102	59-121, 140-160	450 RG	455 716	1952 1957	855	1981	+13.8 +5.8
413	106	76-155	200 CL	615 689	1952 1957	881	1979	+9.9 +8.7
414	107	62-200	1,100 CL	809 722	1955 1957	782	1980	-1.1 +2.6
415	101	52-62, 72-122	460 RG	590 683	1951 1957	854	1980	+9.1 +7.4
420	105	73-150	330 CL	447 346	1952 1957	683	1980	+8.4 +14.6
423	115	100-200	420 RG	659	1964	890	1979	+15.4
424	116	100-200	460 RG	593	1964	796	1979	+13.5
426	117	100-200	2,350 RG	1,363	1967	1,276	1980	-6.7
428	118	100-200	640 RG	876	1966	810	1980	-4.7
				Nonproduction Wells				
JL-49-04-115	CR-4	102-202	2,560 RG	640	1957	--	--	--
417	CR-1	100-200	1,600 RG	1,520	1966	--	--	--
430	OW#27	20-50	100 RG	1,386	1968	--	--	--
431	OW#28	20-50	110 RG	781	1968	--	--	--

Table 3.—Dissolved-Solids Concentrations in Water From Medium-Depth Wells in the City of El Paso Canutillo Well Field, Lower Mesilla Valley, Texas

State well number	Local number	Slotted interval (feet)	Early analysis: Dissolved solids (mg/L)	Early analysis: Date	Recent analysis: Dissolved solids (mg/L)	Recent analysis: Date	Rate of change, in dissolved solids (± mg/L/year)
Production Wells							
JL-49-04-107	301	285-550	345	1957	450	1980	+4.6
					426	1981	+3.4
110	309	209-506	614	1967	707	1980	+7.2
					664	1981	+3.6
116	308	168-278	274	1969	686	1980	+37.5
					741	1981	+38.9
404	305	220-404	294	1969	399	1980	+9.5
410	302	275-444	294	1964	457	1980	+10.2
					503	1981	+12.3
421	303	356-550	274	1964	268	1980	-.4
					286	1981	+.7
422	304	198-390	375	1964	495	1979	+8.0
					637	1980	+16
425	307	242-440	308	1964	328	1980	+1.2
427	306	230-461	445	1969	465	1980	+1.8
Nonproduction Well							
JL-49-04-418	CR-5	355-545	266	1963	349	1979	+5.2

ground-water reservoir known as the Hueco bolson includes areas in Texas, New Mexico, and Mexico. The northern part of the bolson, in Texas and New Mexico, lies between the southern Organ Mountains and the Franklin Mountains on the west and the Hueco Mountains on the east. The southeastern part of the bolson, in Texas and Mexico, lies between several mountain ridges in Mexico on the west and the Diablo Plateau and the Finley, Maline, and Quitman Mountains on the east. Along the Rio Grande, alluvium is entrenched about 200 to 250 feet into the Hueco bolson sediments and locally called the El Paso-Juarez Valley.

The primary water-bearing material of the Hueco bolson and the Rio Grande alluvium is the unconsolidated basin fill (Knowles and Kennedy, 1958, p. 19-20; and Alvarez and Buckner, 1980). In the northern part of the bolson, Davis and Leggat (1967) reported that the thickest section of

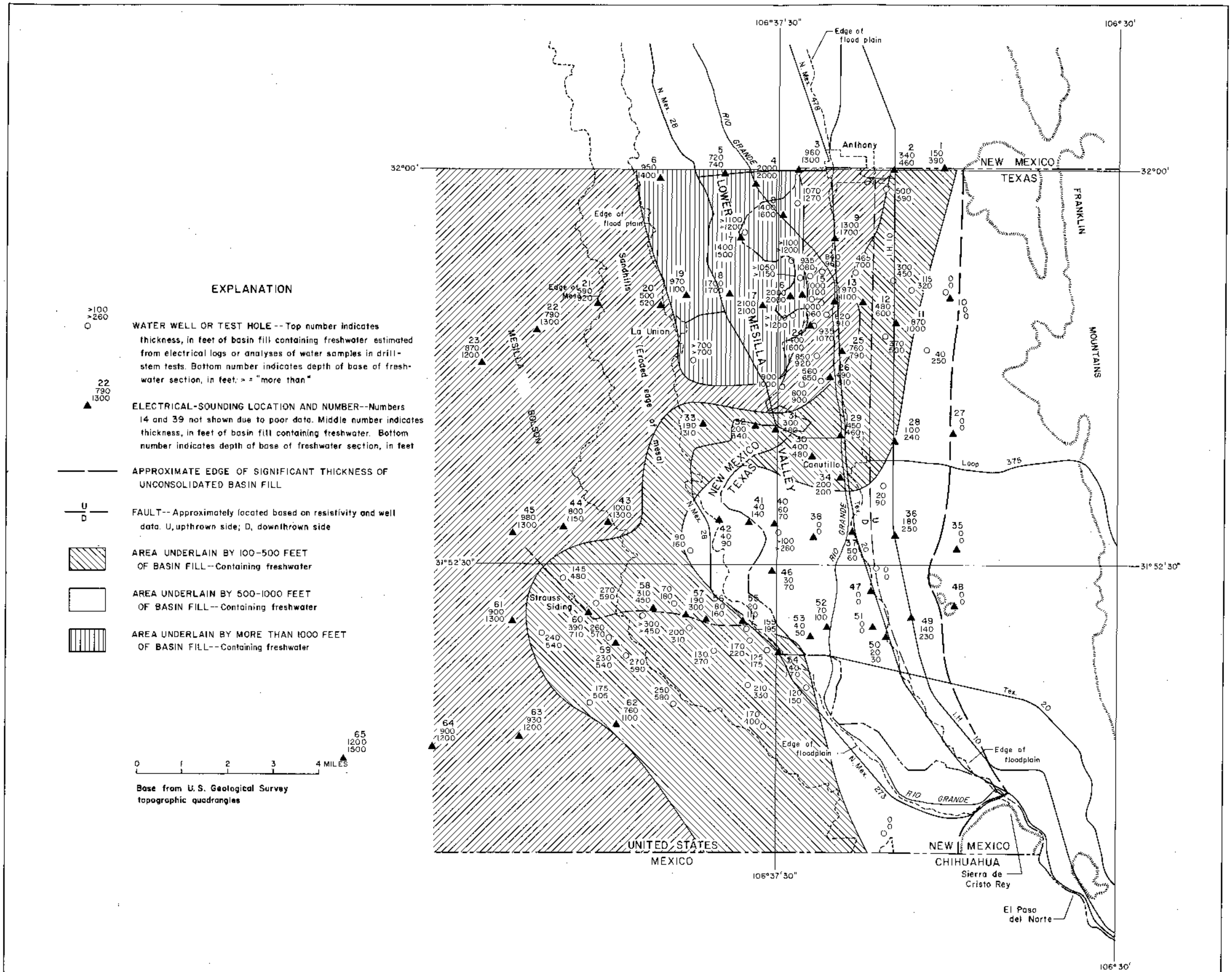

Figure 12
Estimated Thickness of Sediments Containing Freshwater
in the Lower Mesilla Valley

Table 4.—Dissolved-Solids Concentrations in Water From Deep Wells in the City of El Paso Canutillo Well Field, Lower Mesilla Valley, Texas

State well number	Local number	Slotted interval (feet)	Early analysis: Dissolved solids (mg/L)	Early analysis: Date	Recent analysis: Dissolved solids (mg/L)	Recent analysis: Date	Rate of change, in dissolved solids (± mg/L/year)
			Production Wells				
JL-49-04-104	203	650-1,150	250	1957	258	1980	+0.3
					271	1981	+.9
105	204	544-950	260	1959	271	1980	+.5
					294	1981	+1.5
106	202	544-1,090	271	1957	252	1980	-.8
					262	1981	-.4
113	206	635-1,200	281	1965	268	1980	-.9
					269	1981	-.8
401	205	510-900	265	1958	269	1980	+.2
					283	1981	+.8
402	201	586-1,060	283	1957	302	1980	+.8
					340	1981	+2.4
			Nonproduction Wells				
JL-49-04-111	CR-6	768-863, 963-1,063	257	1966	281	1981	+1.6
419	CR-2	585-1,050	269	1966	304	1980	+2.5
416	CR-3	528-1,013	510	1957	1,666	1980	+50
			895	1966			+55

basin fill occurs as a trough-shaped body adjacent and parallel to the Franklin Mountains. The total thickness of this section may be as much as 9,000 feet. In the southeastern part of the bolson between El Paso and Clint, the basin fill is from 1,000- to 3,000-feet thick (Davis and Leggat, 1967).

Recharge to the Hueco bolson occurs along the mountains bordering the bolson, and at times locally along the Rio Grande. Before the Rio Grande drained the Hueco bolson, ground water probably flowed to depressions or lakes in the lowest parts of the bolson where it discharged to evapotransporation. After the river cut through the bolson, the floodplain served as the discharge zone. Meyer (1976, p. 18) estimated, from digital-model studies, that the annual recharge around the perimeter of the northern end of the bolson, including areas in New Mexico and around Ciudad Juarez in Mexico, was about 6,000 acre-feet.

Large-scale development of ground water in the Hueco bolson started in the early 1900's when deep wells were drilled in the Old Mesa well field to supply residents of El Paso and Fort Bliss (Lippencott, 1921, and Sayre and Livingston, 1945). The Old Mesa field was located in what is now the Fort Bliss sump and the El Paso Water Utilities Mesa plant yard northeast of the intersection of Railroad Drive and Fred Wilson Road which is shown later in Figure 20. The field was first developed in 1904. The production wells were equipped with 8- to 14-inch diameter casing and pumped from a central air-lift plant. The Old Mesa wells were gradually abandoned because of their low operating efficiency and were replaced by large-diameter wells with turbine pumps. The well field produced a total of 68,000 acre-feet through 1926 when it was shut down and the wells were abandoned.

Some of the early large-capacity wells in the Hueco bolson included Fort Bliss No. 1 (JL-49-13-509) drilled in 1913 at the main base pumping plant, city of El Paso No. 1 (JL-49-13-817) drilled in 1918 near the intersection of Madison (now Radford) and Montana Streets, and Ciudad Juarez No. 1 drilled in 1925 at the corner of Mariscal and Avenida 16 de Septiembre. All of these wells have been abandoned because of failure of casing seals and screens, and deterioration of water quality. The locations of the early wells and selected water-level observation wells are later shown in Figure 16.

Figure 13 includes a bar graph showing the estimated pumpage from the Hueco bolson metropolitan area (hereafter called the metro area), during 1906-80. The area was shown earlier in Figure 4. The Hueco bolson metro area is arbitrarily defined in this report as having large-scale ground-water development and a freshwater section generally exceeding 100 feet in thickness in 1980. The pumpage in the metro area is separated according to use in the United States and Mexico. Prior to the early 1950's, the metro pumpage was less than 30,000 acre-feet per year. Since 1953, the annual withdrawals have increased at an average rate of about 3,600 acre-feet per year and in 1970, totaled 84,982 acre-feet (Table 1). During that year, the city of El Paso (El Paso Water Utilities or EPWU) pumped 39,949 acre-feet from 60 wells and Ciudad Juarez (Junta Municipal de Aquas y Saneamiento or JMAS) pumped 23,985 acre-feet from 23 wells. By 1980, pumpage in the metro area had increased to 129,231 acre-feet; the EPWU pumped 58,213 acre-feet from 81 wells, and the JMAS pumped 55,808 acre-feet from 52 wells.

The cumulative pumpage from the Hueco bolson metro area during 1906-80 totals about 3.0 million acre-feet. About 73 percent of the water (about 2.2 million acre-feet) has been pumped in the United States and about 27 percent (about 0.8 million acre-feet) has been pumped in Ciudad Juarez.

Ground-Water Hydrology

Ground water in the Hueco bolson flows from areas of recharge to points of discharge. The rate of movement is slow, normally less than 1.0 foot per day or a few hundred feet per year, and is controlled by the ability of the aquifer to transmit water (hydraulic conductivity) and the slope (gradient) of the water table.

Figure 14 shows the estimated 1903 and January 1980 water-level contours in the central part of the Hueco bolson which includes the El Paso, Fort Bliss, and Ciudad Juarez metropolitan areas. The 1903 (predevelopment) contours were drawn from early water-level measurements in

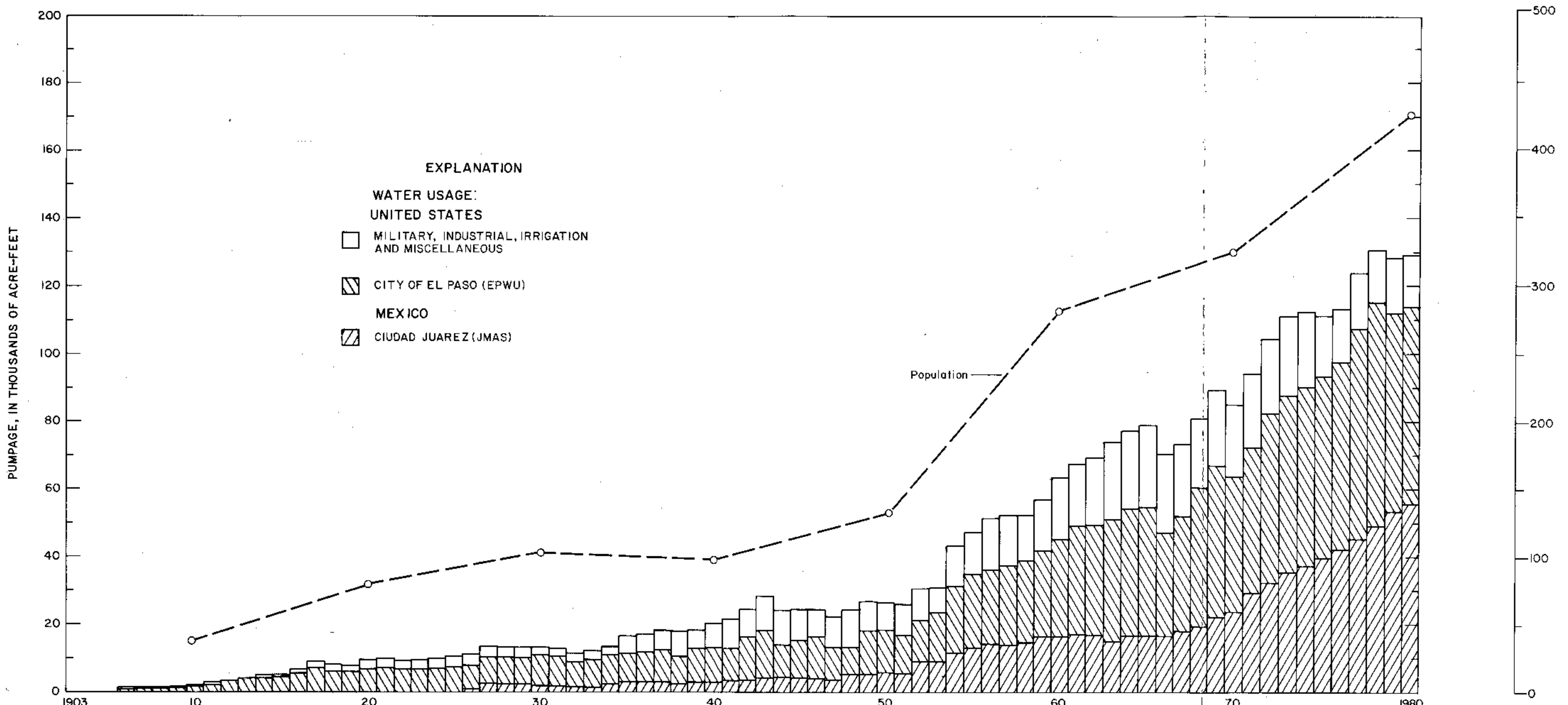

Figure 13

Withdrawals of Ground Water From the Hueco Bolson Metro Area, 1906-80, and 10-year Census Population for the City of El Paso

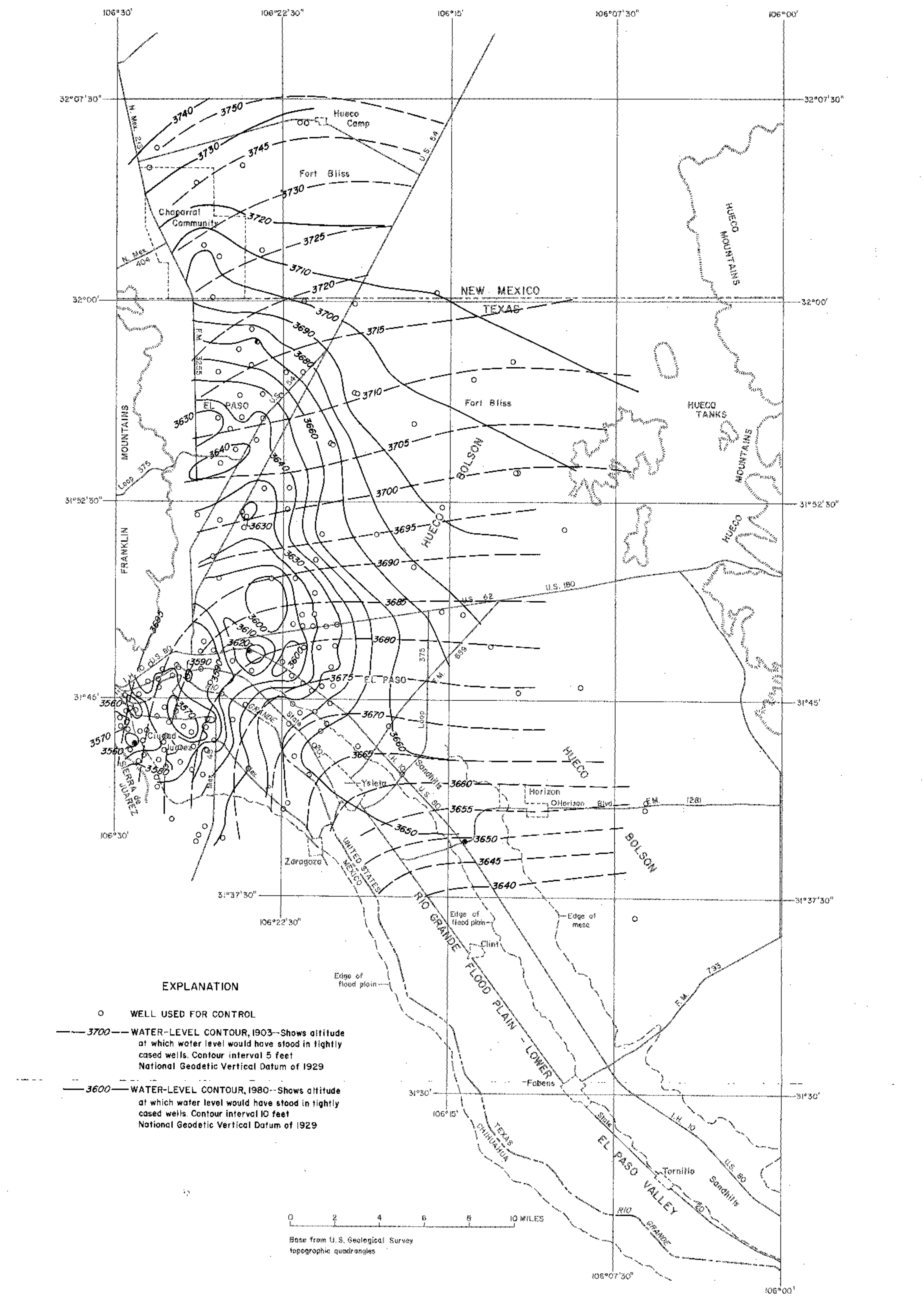

Figure 14
Approximate Altitude of Water Levels in the Hueco Bolson, 1903 and January 1980

wells which were adjusted for the estimated declines prior to the date of measurement, and from steady-state digital model simulations by Meyer (1976).

Prior to, and during the early 1900's ground water in the Hueco bolson flowed south from the Texas-New Mexico line, and east to southeast from the Sierra de Juarez. The general direction of movement was toward the valley of the Rio Grande. There, the water moved upward through the shallow alluvium and discharged as seepage or through evapotranspiration.

The historical (1906-80) withdrawals of ground water from the Hueco bolson metro area, totalling about 3 million acre-feet, have caused major water-level declines. These declines have significantly changed the direction and rate of flow and in 1980, most of the flow is toward centers of pumping.

Figure 15 shows hydrographs for 13 observation wells in the Texas part of the metro area, and Figure 16 is a map showing locations of the wells. The rates of water-level declines shown on the hydrographs are considered representative of those in the metro area, and range from less than 0.5 foot per year near the eastern boundary to more than 5 feet per year in centers of pumping.

The historical (1903-80) water-level declines can be estimated by subtracting the altitude of the 1980 water levels from the 1903 water levels at any particular location on Figure 14. Accordingly, the greatest declines (deepest cones of depression) of 130 feet are in the downtown areas of El Paso and Ciudad Juarez. The downtown areas have had long-term, large-scale ground-water withdrawals from well fields located near relatively impermeable bedrock boundaries along the Franklin and Juarez Mountain fronts.

The historical declines in the Hueco bolson decrease with distance from the centers of pumping and are minimum, about 10 feet, along the eastern and southeastern boundaries of the metro area. The average 1903-80 decline in water levels over the 223 square miles in the Texas part of the metro area is about 53 feet.

The direction and rate of flow in the shallow alluvial aquifer has also changed significantly since the early 1900's. Figure 17 shows the contours of the water-table altitudes in the shallow aquifer in April 1936, July 1967, and December 1979-January 1980 from downtown El Paso southeast to Ysleta. During 1936, movement of ground water was generally down the valley but also toward wells and irrigation drains. Depths to water were generally a few feet (5 to 10) below land surface. At that time sump pumps were used to drain some of the basements in downtown El Paso.

Water levels in the shallow aquifer declined as much as 20 feet from 1936 to 1967. The declines are attributed to urbanization of the valley, which paved over much of the formerly irrigated fields and drainage areas, and to the increased pumping and declining heads in the underlying bolson deposits inducing downward leakage from the alluvium.

The rates of declines accelerated after the river was lined from downtown El Paso through the Chamizal Zone in 1968. However, part of the increase in the rate of decline can be attributed to a general increase in bolson pumpage in El Paso and a marked increase in Ciudad Juarez. During July 1967 to January 1980, the water levels in shallow wells declined about 20 to 30 feet near the downstream end of the lined section of the river and from 70 feet to more than 80 feet in downtown El Paso. In the downtown area, the water level in an observation well declined from about 25 feet below land surface in September 1968 to 51 feet in December 1971, when it went dry. The water level in a 150-foot deep replacement well drilled in 1975 declined from about 76 feet below land surface in September 1975 to 110 feet in January 1980. In parts of downtown El Paso and probably in Ciudad Juarez, the Rio Grande alluvium has been drained and the shallow water table has declined to the uppermost section of bolson fill.

The January 1980 water-level contours in Figure 17 show that ground water in the shallow aquifer in southeast El Paso is moving northeast away from the river. Movement near the downstream end of the lined section is to the north and west toward centers of pumping from bolson wells. In those areas, the Rio Grande is now a major source of recharge to the shallow aquifer rather than one of discharge.

Digital-model studies of the Hueco bolson indicated that the Rio Grande supplied substantial quantities of seepage to the alluvium since the mid 1930's (Meyer, 1976, Table 1). The average annual seepage to or from the Rio Grande and leakage between the shallow aquifer and bolson fill for 1903-73 estimated in the model studies was as follows:

Period	Average seepage (acre-feet per year) to/from Rio Grande (+ to river, -from river)	Average leakage between aquifers (acre-feet per year) (+ out of bolson, -into bolson)
1903-20	+ 6,864	+ 4,677
1920-36	+ 353	- 3,423
1936-48	- 4,588	- 7,975
1948-53	- 7,625	-11,780
1953-58	-13,466	-19,698
1958-63	-18,767	-24,609
1963-68	-19,183	-23,549
1968-73	-12,765	-33,278

Water Quality

The dissolved-solids concentrations in water from wells in the Hueco bolson metro area are shown in Figure 18, and the average annual change in dissolved solids is shown in Figure 19. Most of the dissolved-solids concentrations used to delineate quality areas shown in Figure 18 were determined from samples collected during 1979-81. Early samples used to calculate rates of

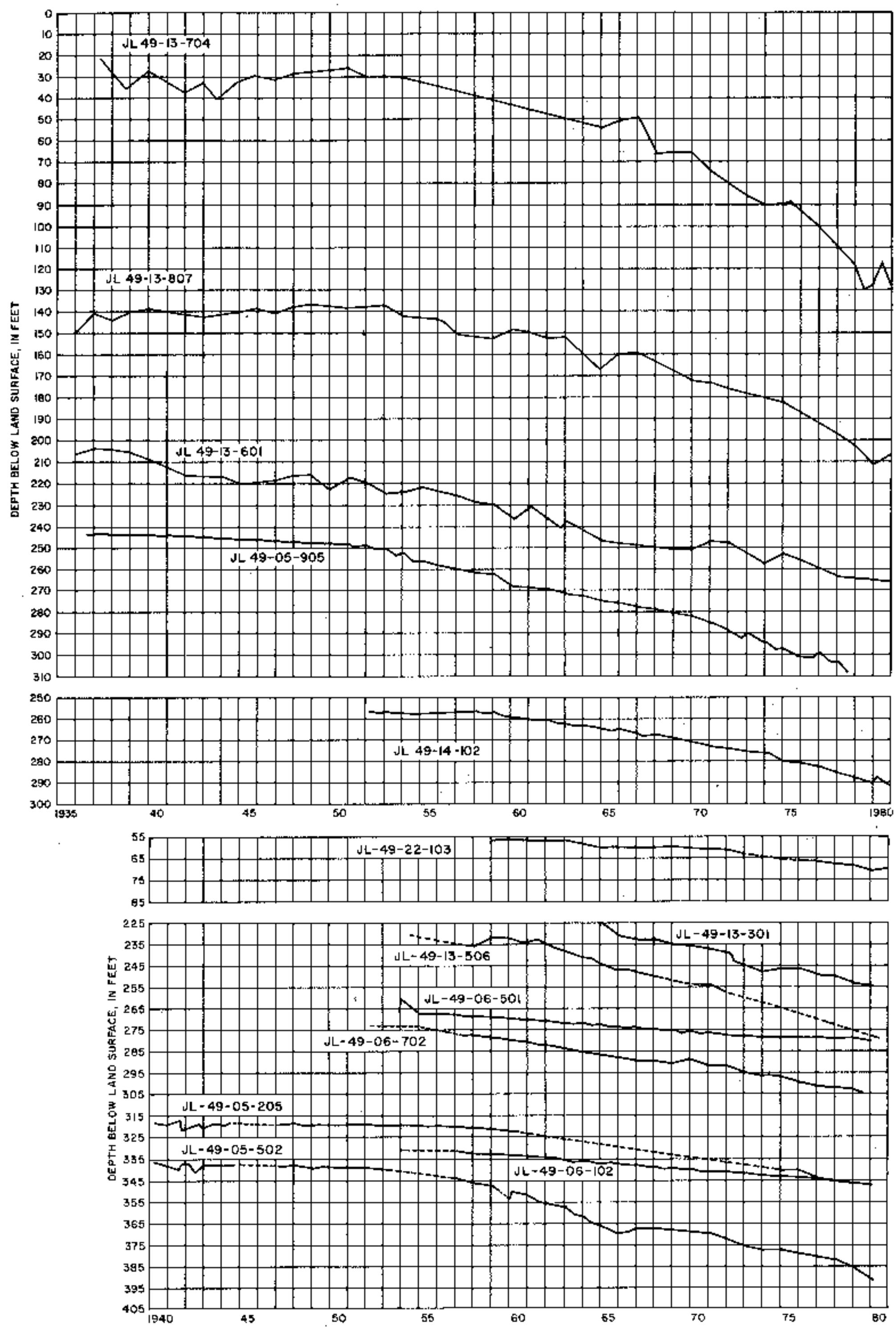

Figure 15
Hydrographs of 13 Wells in the Hueco Bolson

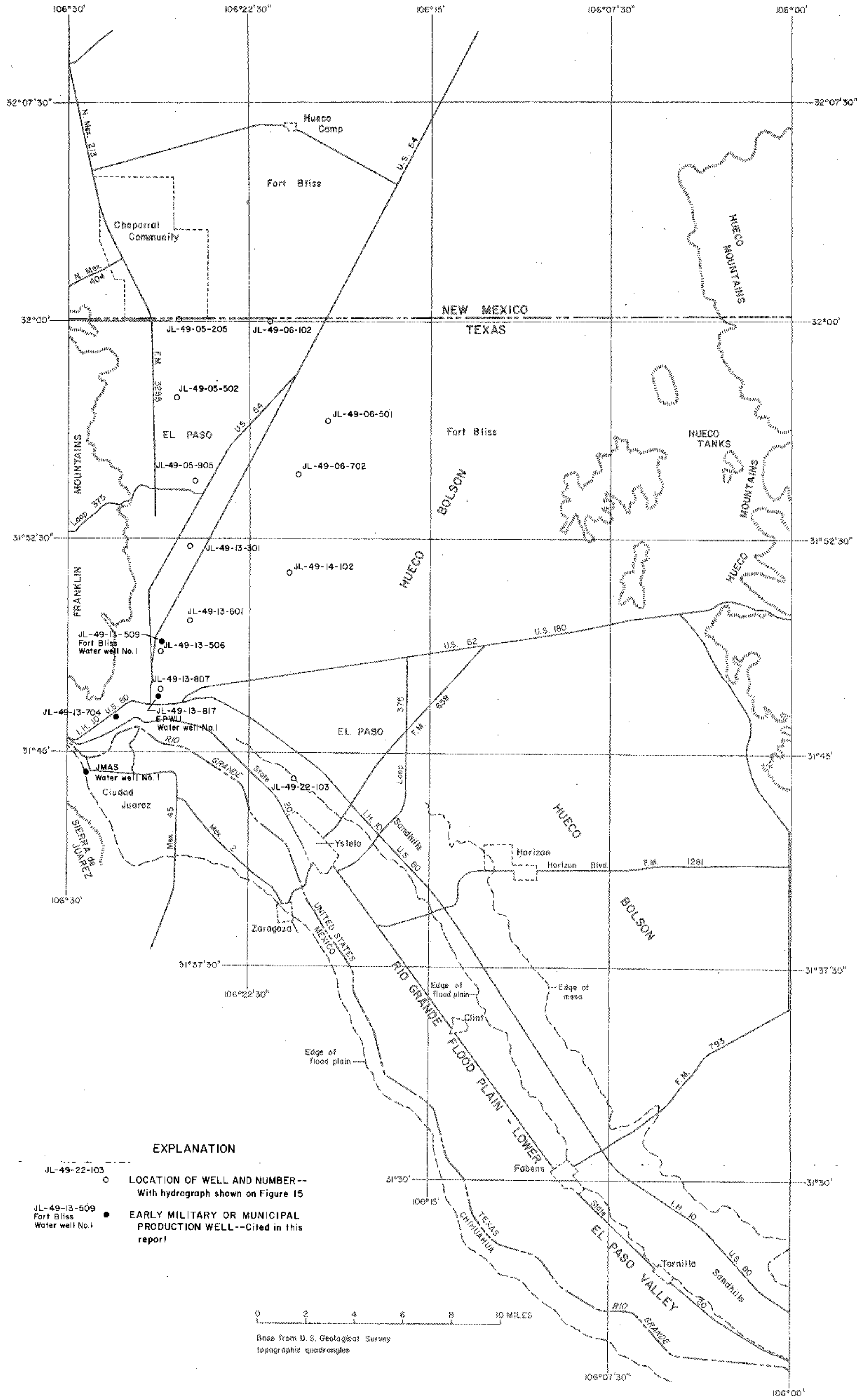

Figure 16

Location of 13 Water-Level Observation Wells and 3 Early Municipal and Military Production Wells in the Hueco Bolson

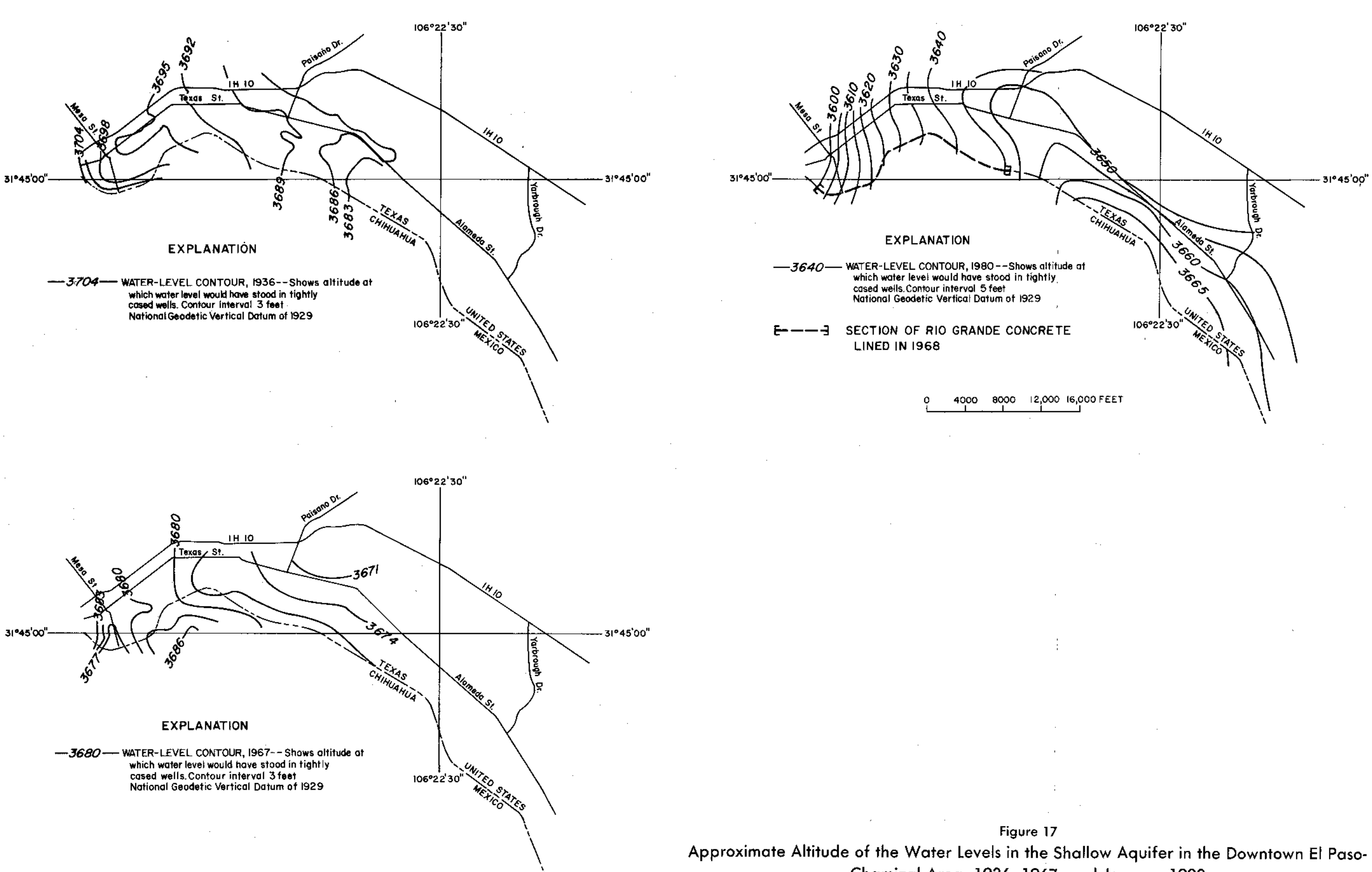

Figure 17

Approximate Altitude of the Water Levels in the Shallow Aquifer in the Downtown El Paso-Chamizal Area, 1936, 1967, and January 1980

change in dissolved solids (Figure 19) were collected in the 1950's and 1960's in the El Paso-Fort Bliss part of the metro area and during the early 1970's in Ciudad Juarez. With only a few exceptions, the analyses of water from El Paso were by the EPWU laboratory. All analyses in Ciudad Juarez were by the JMAS laboratory. Dissolved-solids concentrations in samples collected from 148 wells in the United States part ranged from about 270 to 1,500 mg/L and averaged 642 mg/L. Dissolved-solids concentrations in recent samples from 45 wells in Ciudad Juarez ranged from about 370 to 1,500 mg/L and averaged 736 mg/L. The annual rate of change in dissolved solids averaged about +10 mg/L per year in the United States and about +30 mg/L per year in Ciudad Juarez.

The dissolved-solids concentrations in samples from wells in the vicinity of the Fort Bliss Tobin well field have decreased slightly in recent years (the well field is shown in Figure 4, and the area of quality improvement, average annual change of -1.6 mg/L per year is outlined in Figure 19). There has been a general and locally pronounced deterioration in water quality in other parts of the metro area.

In parts of downtown El Paso and Juarez, the dissolved-solids concentrations in water from bolson wells have increased at rates of 40 to 100 mg/L per year and this increase is attributed mainly to downward leakage of brackish water from the shallow aquifer and possible upconing of brackish water from below. The downtown area also has the largest declines in water levels in both the bolson and shallow aquifers (Figures 14, 15, and 17). Some of the older wells in the area are screened in both the alluvial and bolson deposits and are existing or potential conduits for vertical (downward) movement of brackish water.

Dissolved-solids concentrations have increased as much as 40 to 60 mg/L per year in wells along Montana Street (U.S. Highway 180-62) near the eastern edge of El Paso. These wells were drilled near the fresh-brackish water interface in the eastern part of the bolson. The increases may reflect intrusion of brackish water from the east or upconing of brackish water from below.

According to Alvarez and Buckner (1980), water in the shallow aquifer in the El Paso Valley within the Hueco bolson metro area ranges from fresh to moderately saline (less than 1,000 to greater than 3,000 mg/L dissolved-solids concentrations). Because of the wide range in dissolved-solids concentrations in the shallow aquifer, leakage of water from the aquifer to the underlying bolson deposits may be beneficial locally, but in other places may be detrimental. Most of the freshwater in the shallow aquifer is stored downstream from the end of the lined section of the Rio Grande and near the river indicating that leakage of freshwater out of the river is recharging the aquifer. Upstream from the downstream end of the section, freshwater generally occurs in the deeper Hueco bolson deposits and slightly saline water occurs in the overlying shallow aquifer.

Old Mesa Well Field

Recent (1979-81) analyses of water from wells along Fred Wilson Road in northeast El Paso show a general increase in dissolved solids and a marked increase in nitrate concentrations above background levels. The data indicate an abnormally high nitrate concentration of 43 mg/L in a sample pumped from El Paso's city well no. 39 (JL-49-13-511) in July 1980. Samples collected from 10 nearby El Paso Water Utilities (EPWU) and Fort Bliss production wells during 1980-81

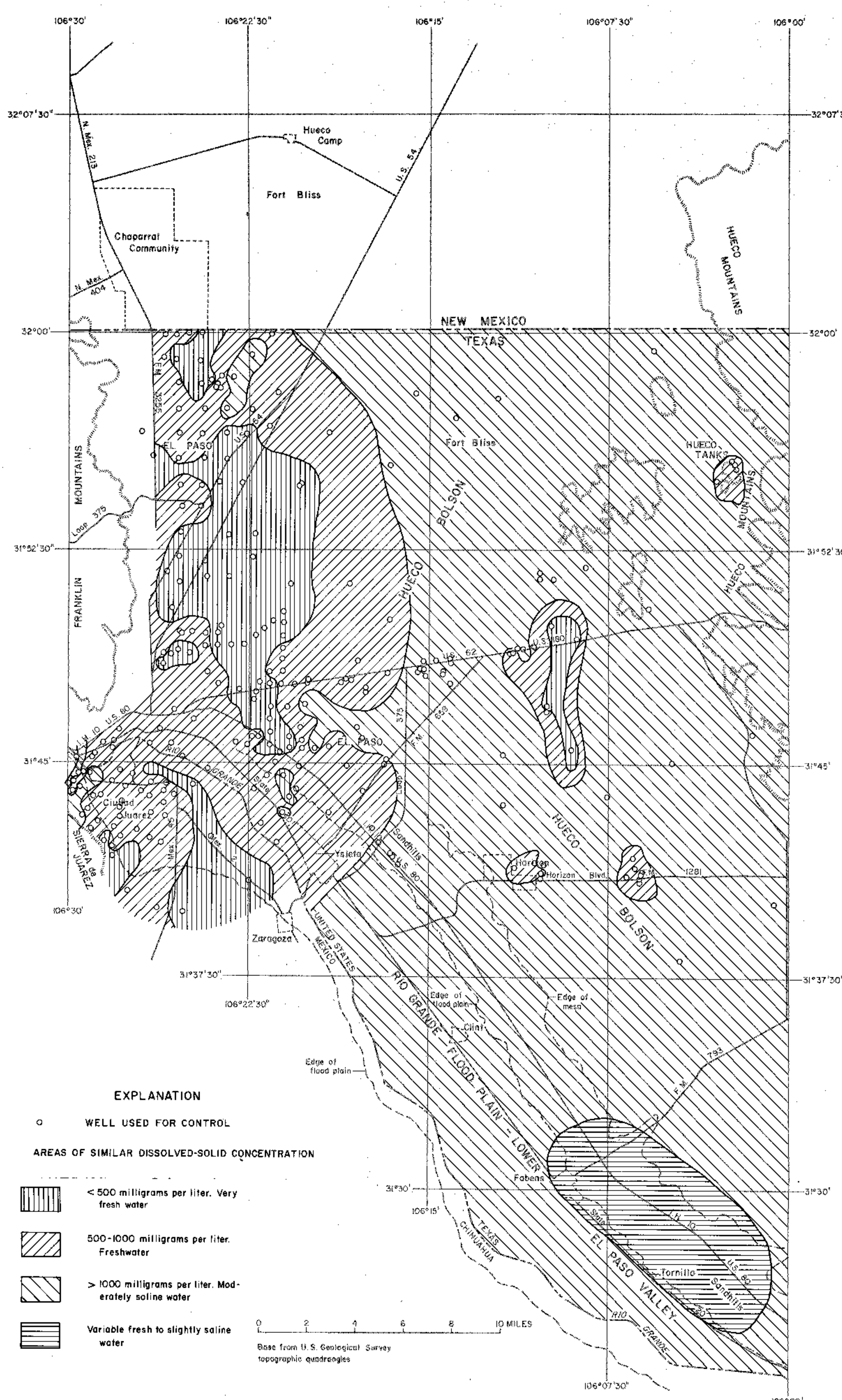

Figure 18
Areas of Similar Dissolved-Solids Concentrations in Samples From Wells in the Hueco Bolson, 1979-81

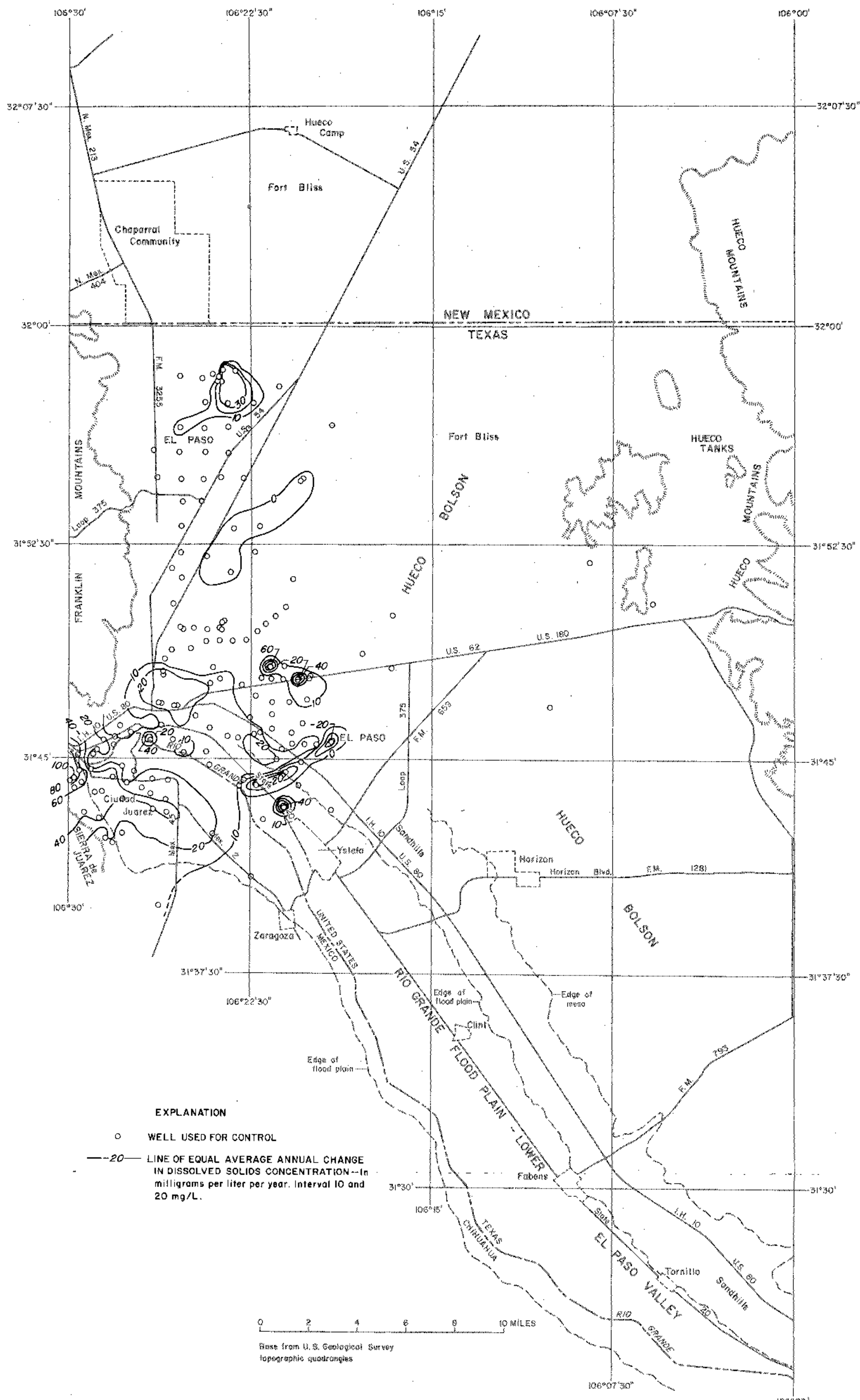

Figure 19

Average Annual Change in Dissolved-Solids Concentrations in Samples From Wells in the Hueco Bolson Metro Area

had nitrate concentrations ranging from 6.6 to 17 mg/L. Six samples had nitrate concentrations exceeding the Hueco bolson background level of less than 10 mg/L. Figure 20 shows the locations of the sampled production wells, and Table 5 shows the cross reference of local and State numbers of wells in the vicinity of the Old Mesa field which was abandoned in 1926. The locations of the Old Mesa wells are shown in Figure 21.

A field investigation was made in 1980-81 to determine the possible sources of the high nitrate concentrations noted above. The investigation centered on the area in and around the EPWU Mesa plant and the Fort Bliss drainage sump (Figure 20). The drainage sump was constructed in the early 1950's and currently (1980-81) collects runoff from about 25 square miles in northeast El Paso and Fort Bliss. The Mesa plant and active city wells 8, 11, and 39 (JL-49-13-512, 502, and 511, respectively) are located on a strip of land south of the sump, north of Fred Wilson Road, and near the center of a north-south trending topographic low. This is also the site of the Old Mesa well field (Figure 21).

According to Sayre and Livingston (1945) and historical records, the Old Mesa well field was developed in 1904 by the International Water Company to supply the city of El Paso and Fort Bliss. In 1910 the city of El Paso acquired the property and drilled additional wells. By 1917 a total of 43 wells and test holes had been drilled to depths ranging from 425 to 2,285 feet. The production wells were equipped with 8- to 14-inch-diameter casings and pumped from a central air-lift plant. The Old Mesa wells were gradually abandoned because of their low operating efficiency and replaced by large-diameter wells with turbine-equipped pumps. The well field produced a total of about 68,000 acre-feet through 1926 when production was shut down. Most of the wells were subsequently destroyed by construction of the Fort Bliss sump, a railroad spur, and the widening of Fred Wilson Road. Only nine Old Mesa wells could be located in 1980-81 (see Figure 21).

During the field investigation, four of the nine abandoned Old Mesa wells, which were located, had shallow ground water seeping into them. Samples of seepage water were collected from these wells by either catching the cascading water or bailing just below the water surface. These included Old Mesa wells 112, 114, 115, and 116 which are also numbered JL-49-13-501, 521, 522, and 523, respectively. Samples were also bailed from city wells 12 and 15 (JL-49-13-601 and 605), which were out of production and had the pumps pulled.

Figures 22-25 show the dissolved-solids and nitrate concentrations in water sampled from wells in and near the Old Mesa well field during the investigation. Where accessible, the water levels were measured in wells. The abandoned wells were measured when sampled and the production wells were measured at the end of the pumping season. Figure 26 shows the depths and altitudes of water levels measured in selected wells including levels in abandoned Old Mesa wells JL-49-13-501 and 521. The levels in the abandoned wells are perched about 10 to 35 feet higher than the regional ground-water levels. Figures 22 and 24 show the dissolved-solids and total nitrogen as nitrate concentrations in pumped samples. These data are considered to be representative of water currently withdrawn from the major producing zone of the Hueco bolson aquifer within the area of the investigation. Figures 23 and 25 show the same chemical constituents except that all of the samples were bailed from wells.

Figure 27 shows the concentration of dissolved solids as recorded in historic records. In addition to these data, records of the Old Mesa well field stated that wells 81, 96, and 97 (Figure 21) had dissolved-solids concentrations of 292, 335, and 306 mg/L, respectively, in samples collected during the early 1900's. These values and those shown in Figure 27 can be compared with recent data given in Figure 22 to determine the change in dissolved-solids concentrations.

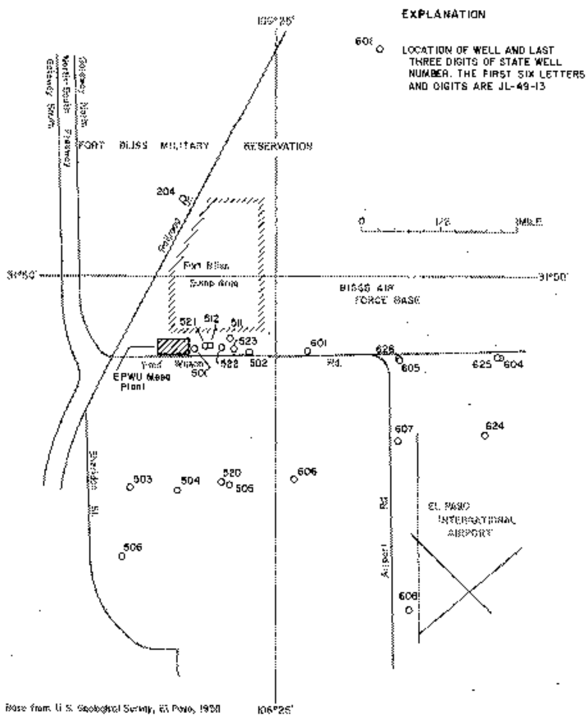

Figure 20.—Location of Selected Wells in the Vicinity of the Old Mesa Well Field

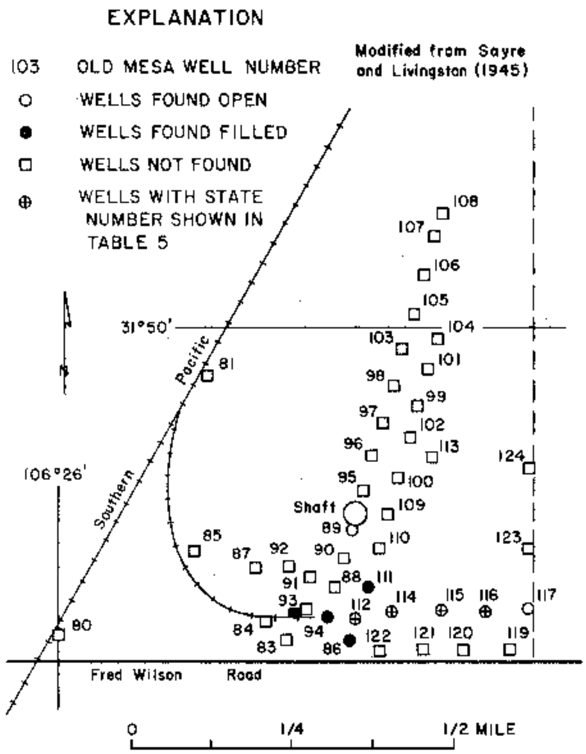

Figure 21.—Location of Abandoned Wells in the Old Mesa Well Field

The comparison of total dissolved-solids concentration data in Figures 22, 23, and 27, which represent recent aquifer conditions, recent seepage from shallow ground-water formations, and historic aquifer conditions, indicates that the highest concentrations occur in the seepage. These concentrations ranged from 460 to 1,522 mg/L and averaged 849 mg/L. For the recent aquifer samples, the average was about 500 mg/L and the maximum was 693 mg/L. Also a comparison of Figures 22 and 27 shows that 9 of 10 wells had increases. The historic and recent values averaged 413 and 512 mg/L indicating a gradual deterioration of water quality.

The comparison of total nitrogen as nitrate concentrations in Figures 24 and 25, which represent recent aquifer conditions and recent seepage from shallow ground-water formations, indicates that the seepage concentrations of nitrate are considerably higher than the aquifer concentrations. More specifically, the recent aquifer samples ranged from 6.6 to 43 mg/L and the seepage concentrations ranged from 8.4 to 133 mg/L and averaged almost 60 mg/L. The background nitrate concentrations in water pumped from bolson wells are less than 10 mg/L.

The available data indicate that a substantial amount of inferior-quality water is being recharged to the Hueco bolson aquifer by shallow ground-water seepage into abandoned wells in and near the Old Mesa well field. The seepage originates mostly as impounded urban runoff and possibly by deep percolation of lawn irrigation water which may be slightly saline. The nitrogen concentrations of water from the aquifer in the Old Mesa well field are above background levels and are assumed to be caused by the seepage mentioned previously. The high nitrogen concentrations in the seepage support this assumption. Unplugged abandoned wells provide a mechanism (conduit) for channeling the inferior-quality recharge water directly into the aquifer, and substantial quantities of recharge water are available. This well leakage could account for most of the increase in total dissolved-solids concentrations. The release of slightly saline water from clay beds caused by a decrease in hydrostatic pressure may also contribute to the increase in dissolved solids in this and other heavily pumped areas in the Hueco bolson.

Table 5.—Cross Reference of State and Local Numbers of Wells in the Vicinity of the Old Mesa Well Field

State well number	Owner well number
JL-49-13-204	City well 20
501	Old Mesa well 112
502	City well 11
503	Fort Bliss well 9
504	Fort Bliss well 5
505	Fort Bliss well 6
506	V33 Observation well
511	City well 39
512	City well 8
520	Fort Bliss well 6A
521	Old Mesa well 114
522	Old Mesa well 115
523	Old Mesa well 116
601	City well 12
604	City well 16
605	Old Mesa well 15
606	Fort Bliss well 7
607	City well 19
608	City well 37
624	City well 77
625	City well 16A
626	City well 15A

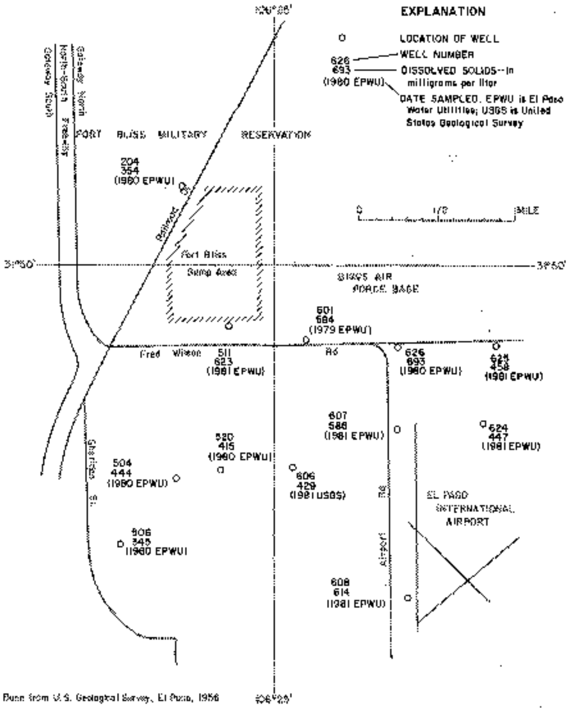

Figure 22.—Dissolved-Solids Concentrations in Samples Pumped From Wells in the Vicinity of the Old Mesa Well Field, 1979-81

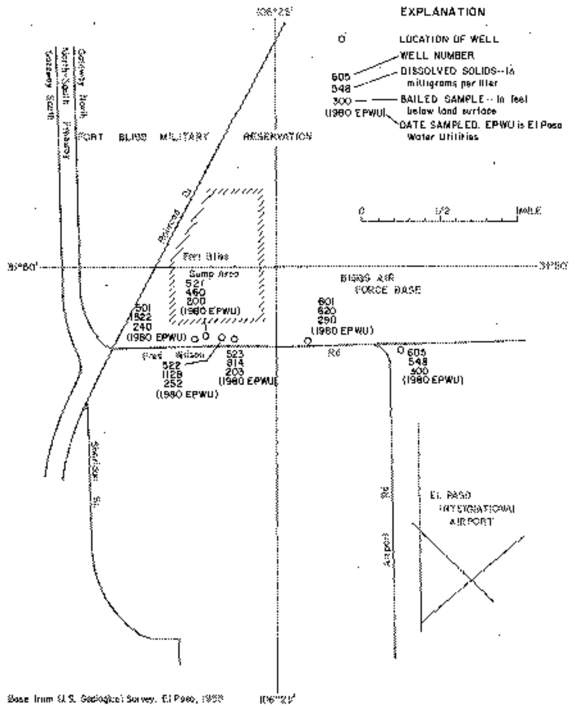

Figure 23.—Dissolved-Solids Concentrations in Samples Bailed From Wells in the Vicinity of the Old Mesa Well Field, 1980

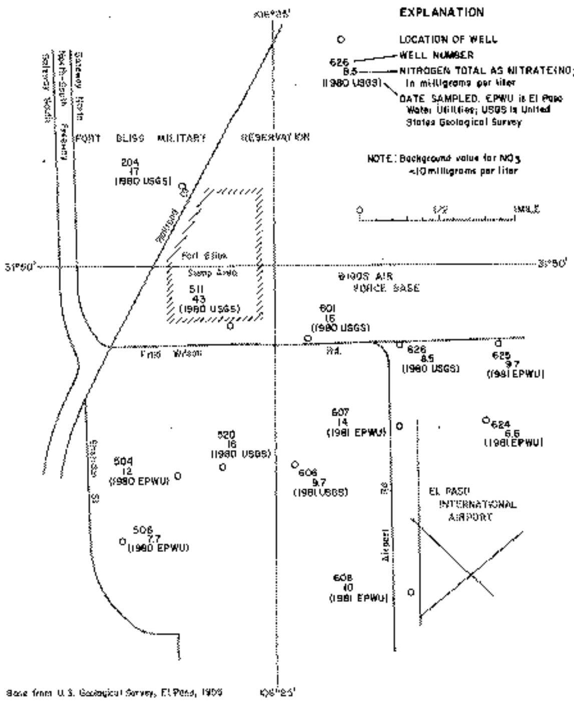

Figure 24.—Total Nitrogen Concentrations in Samples Pumped From Selected Wells in the Vicinity of the Old Mesa Well Field, 1980-81

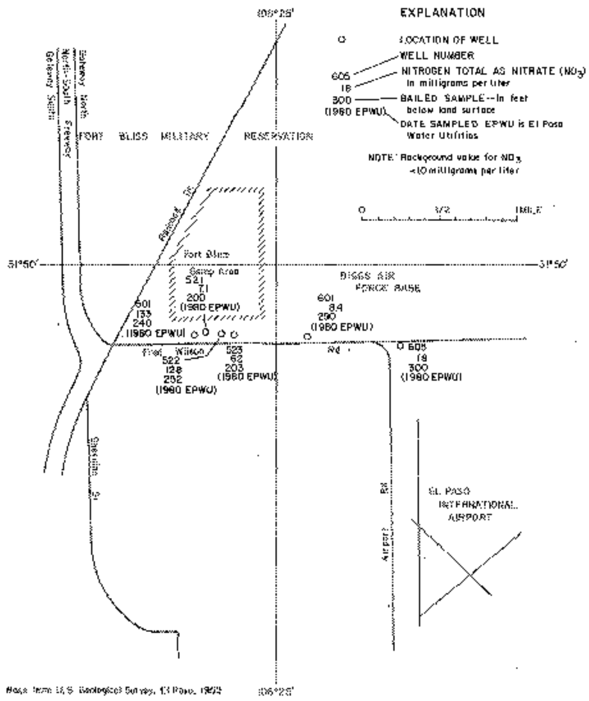

Figure 25.—Total Nitrogen Concentrations in Samples Bailed From Wells in the Vicinity of the Old Mesa Well Field, 1980

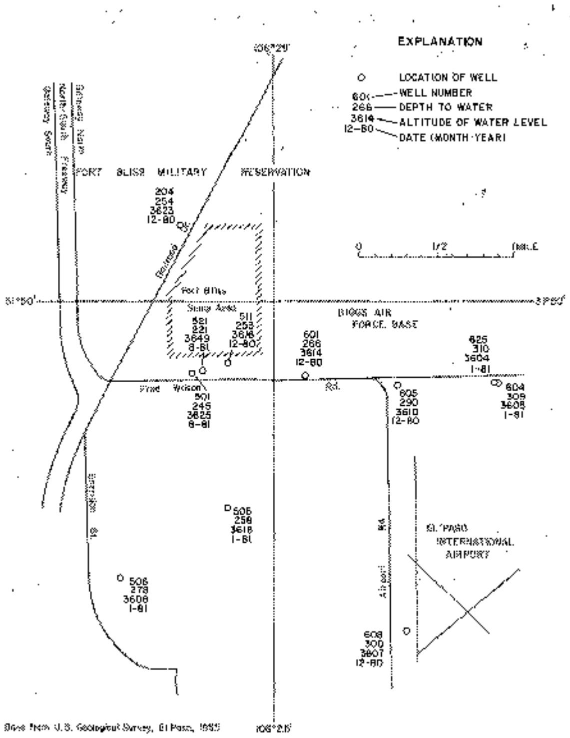

Figure 26.—Water Levels in Selected Wells in the Vicinity of the Old Mesa Well Field

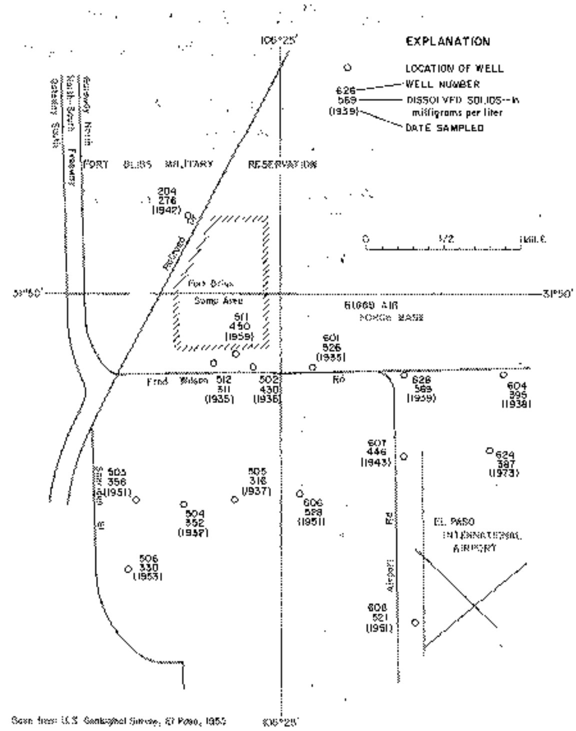

Figure 27.—Dissolved-Solids Concentrations in Samples From Wells in the Vicinity of the Old Mesa Well Field—Historic Data

Agricultural Irrigation Project in Northeast El Paso

Starting in the early 1950's, several irrigation farms were established on the mesa part of the Hueco bolson. The farms were all in the area which has been, or soon will be, developed into northeast El Paso. From 1950 through 1975 the farms collectively pumped an estimated 111,000 acre-feet of fresh ground water from bolson wells. Most of the irrigation water was primarily used for growing alfalfa hay on a 622-acre dairy farm (Figure 28).

All of the water pumped at the dairy farm was from wells P-1 and P-2 (State numbers JL-49-05-303 and 304). In addition to the well pumpage, the farm used cooling tower effluent for crop irrigation. The effluent was purchased and piped from the El Paso Electric Company's Newman generating plant located 2 miles west-northwest of the farm.

Table 6 shows the quantity and quality of water applied on the dairy farm from 1956 when it was established through 1975 when it was abandoned. During the 20 years of operation, the farm pumped about 99,000 acre-feet of water containing about 926 mg/L average dissolved solids and purchased about 3,000 acre-feet of slightly saline water (2,750 mg/L average dissolved solids).

Figure 28 shows the location of the dairy farm and selected wells in the vicinity of the farm. The well records and much of the water-quality data are also given in the 1980 report by Alvarez and Buckner.

Figure 29 is a graph showing annual rates of irrigation applications on the farm and the weighted average dissolved solids in the water. The annual weighted averages ranged from 775

Table 6.—Summary of Quantity and Dissolved-Solids Concentrations in Irrigation Water Applied to a 622-Acre Dairy Farm in Northeast El Paso

Year	Applied water (acre-feet)			Dissolved solids in applied water (mg/L)		
	Pumped	Purchased	Total	Pumped	Purchased	Weighted Average
1956	2,148	—	2,148	775	—	775
1957	2,455	—	2,455	844	—	844
1958	2,455	—	2,455	855	—	855
1959	3,253	—	3,253	868	—	868
1960	4,511	—	4,511	878	—	878
1961	4,511	—	4,511	888	—	888
1962	4,809	—	4,809	900	—	900
1963	5,304	—	5,304	913	—	913
1964	6,281	—	6,281	923	—	923
1965	7,390	139	7,329	955	2,750	988
1966	6,091	250	6,341	885	2,750	959
1967	5,526	315	5,841	1,005	2,750	1,099
1968	4,889	264	5,153	1,180	2,750	1,260
1969	6,445	308	6,753	820	2,750	908
1970	5,831	282	6,113	850	2,750	938
1971	5,819	371	6,190	830	2,750	945
1972	6,755	321	7,076	983	2,750	1,063
1973	6,530	314	6,844	1,050	2,750	1,128
1974	6,591	326	6,917	1,035	2,750	1,116
1975	1,559	206	1,765	1,085	2,750	1,279
Total	99,153	3,096	102,249	—	—	—
Average	—	—	—	926	2,750	976

to 1,279 mg/L. The total annual salt load ranged from about 2,000 tons in 1956 to 10,000 tons in 1974. The total applied salt load for 1956-75 was about 130,000 tons.

Starting in about 1965, the salinity of water pumped from several EPWU wells southwest and downgradient from the farm began to increase. The salinity increase was initially attributed to an invasion (upconing) of saline water into the freshwater zone. The continued degradation of water quality in these and other wells in the vicinity of the farm prompted a cooperative investigation by the El Paso Water Utilities and the Geological Survey in 1974. The data collected during and subsequent to the 1974 investigation identified a spreading plume of ground water containing dissolved-solids concentrations exceeding the background levels in northeast El Paso.

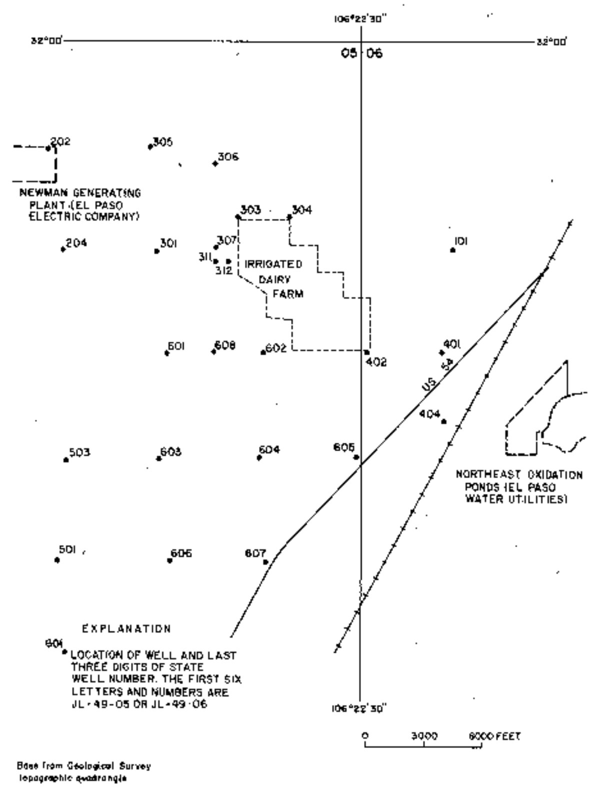

Figure 28.—Location of an Abandoned 622-Acre Dairy Farm and Selected Wells in Northeast El Paso

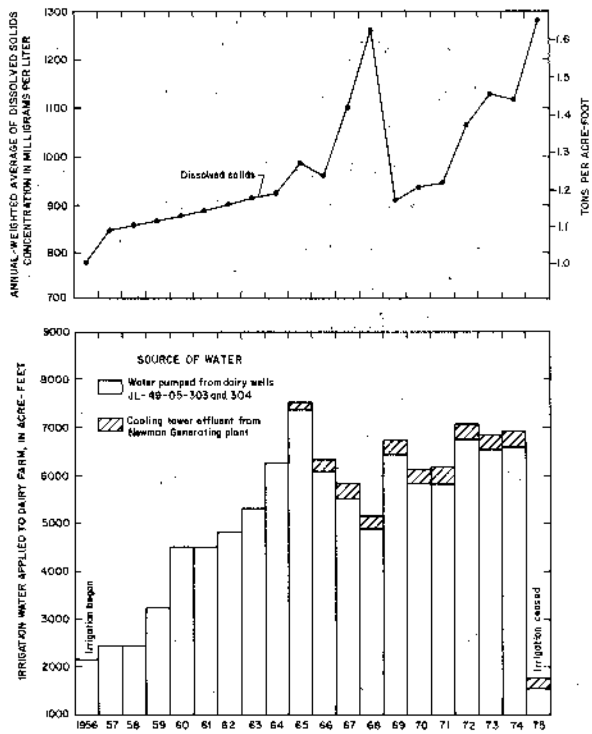

Figure 29.—Quantity and Dissolved-Solids Concentrations of Irrigation Water Applied to the Dairy Farm

The available hydrologic data used for the investigation consisted of chemical analyses of water samples collected from 18 wells, periodic water-level measurements in several wells, and fluid resistivity logs in 3 affected wells. A map showing depths to water and altitude of the water table in 1903 (predevelopment) and January 1980 was prepared for use in defining the thickness of the unsaturated zone (Figure 30). This zone totaled about 310 feet in 1903 and 355 feet in 1980. The direction of flow in the saturated zone was south to southeast in 1980.

Dissolved-solids, chloride, and sulfate concentrations were selected as indicators of the deep percolation of inferior-quality water, and graphs were plotted to show the variations in these indicators with location and time (Figure 31). Maps showing the areal distribution of the dissolved solids in 1966, 1974-76, and 1980 were also drawn in an attempt to delineate the approximate lateral extent of the contamination plume with time (Figures 32a-c).

The salinity (dissolved-solids concentration) maps in Figures 32a and b show the development of a plume of water with higher salinity in the vicinity of the irrigated area from 1966 to the mid 1970's. Figure 32c indicates the plume has dissipated somewhat from the mid 1970's to 1980. The graphs in Figure 31 show that the increased fluctuations were greatest immediately west and southwest of the farm. In many cases there were short-term changes that were somewhat erratic and difficult to explain. The graphs for the more distant wells are reasonably stable; however, they generally show slight increases as do many other wells outside the area of investigation mapped on Figure 31.

The selection of total dissolved solids as an indicator of contamination was not entirely satisfactory because of the presence of saline water beneath and east of the freshwater zone. In an effort to better define the extent of the contamination problem, water samples were collected for nutrient analyses in 1980-81. The concentrations of total nitrogen as nitrate determined in those samples are shown in Figure 33.

The 1980-81 nitrate concentrations ranged from less than 5 mg/L to more than 20 mg/L. The highest concentrations occurred in two samples from well JL-49-05-602 (EPWU production well number 35) located about 0.25 mile southwest and downgradient from the dairy farm (Figures 28, 30, and 33). The nitrate levels of 20.4 and 29.2 mg/L in the 1980-81 samples from well 35 exceeded the background level of less than 10 mg/L by factors of 2 to 3.

During early 1974, the EPWU pulled the pumps from well 35 and two other city production wells, 34 and 56, which are also downgradient from the farm. On February 26, 1974, water samples bailed from various depths in the three wells showed nitrate concentrations as follows:

Well no.		Depth sampled (feet below land surface)	Nitrogen as NO_3 (mg/L)
EPWU	State		
35	JL-49-05-602	410	30
		440	30
		570	24
		600	28
34	JL-49-05-604	400	31
		500	23
		800	22
56	JL-49-06-402	370	37
		440	26
		520	19
		560	23

A comparison of the water-quality (chemistry) trends in Figure 31 and the records for application of inferior quality irrigation water in Figure 29 suggests about an 8-year lag between the beginning of irrigation in 1956 and the first observed deterioration of water quality (increased dissolved solids). A further study of the trends in Figures 29 and 31 suggests that the lag time diminished to about 3 years after the initial aquifer response. The decreased response time may reflect the loss of the earlier water to storage in the unsaturated zone. After the initial buildup of soil moisture, transit time for water to move through the unsaturated zone is expected to be shortened. The data on the maps and graphs are insufficient for accurate determination of the areal extent of the plume or the velocity at which it was spread. The graphs and maps do indicate that most of the inferior water has dispersed in the downgradient direction or has been withdrawn by nearby wells.

The investigation revealed a complex pattern of fluctuations of water chemistry. These fluctuations suggest a plume of inferior-quality water is spreading downgradient from the dairy farm and indicate that deep percolation of irrigation water at the farm may be the principal source of the contaminant. However, the farm cannot be identified as the sole source of the contaminant.

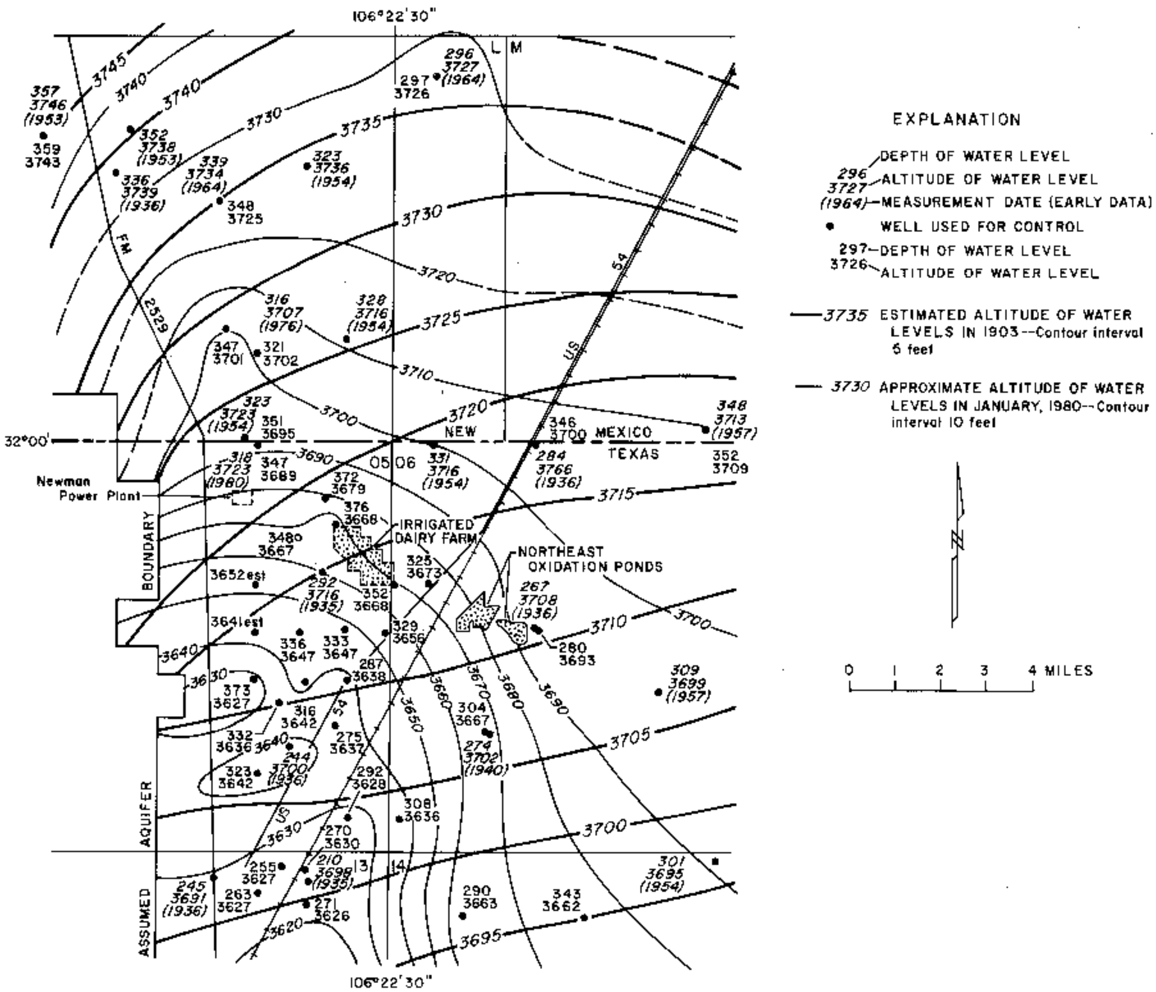

Figure 30.—Depths to Water and Approximate Water-Table Elevations for Early Data and January 1980, in Northeast El Paso and Adjacent Areas in New Mexico

Several factors complicate the identification of its origin. One source could be the continued leaching of salts historically deposited in the soils but flushed down by the excess irrigation water. This could be supported by the data showing that the salinity of some of the well-water samples was higher than the original irrigation water, even though these well-water samples were a composite from over 300 feet of screened aquifer. Furthermore, the volume of water that is available for deep percolation (applied less evaporation, crop consumption, and runoff) is considerably reduced from the applied volume, of which about 95 percent was pumped from two on-site wells. However, the salinity of leachate would be expected to be somewhat higher than the applied water because of evaporation.

Another possible source of inferior-quality water in northeast El Paso is the EPWU's northeast sewage oxidation ponds located 1.5 to 3 miles southeast of the dairy farm (Figure 28). During 1963 through 1979, inflow to the ponds totaled about 74,600 acre-feet and in 1979 was about 5,900 acre-feet. Percolation from the ponds has been estimated at 2.9 million gallons per day (3,250 acre-feet per year) based on water-budget studies (Environmental Impact Statement, draft "Wastewater treatment facilities, northeast El Paso, Texas," February 1980). The configuration of the water table in the vicinity of the ponds in 1980 (Figure 30) shows that a mound about 5 feet high has developed, and this mounding may reflect deep percolation of impounded sewage.

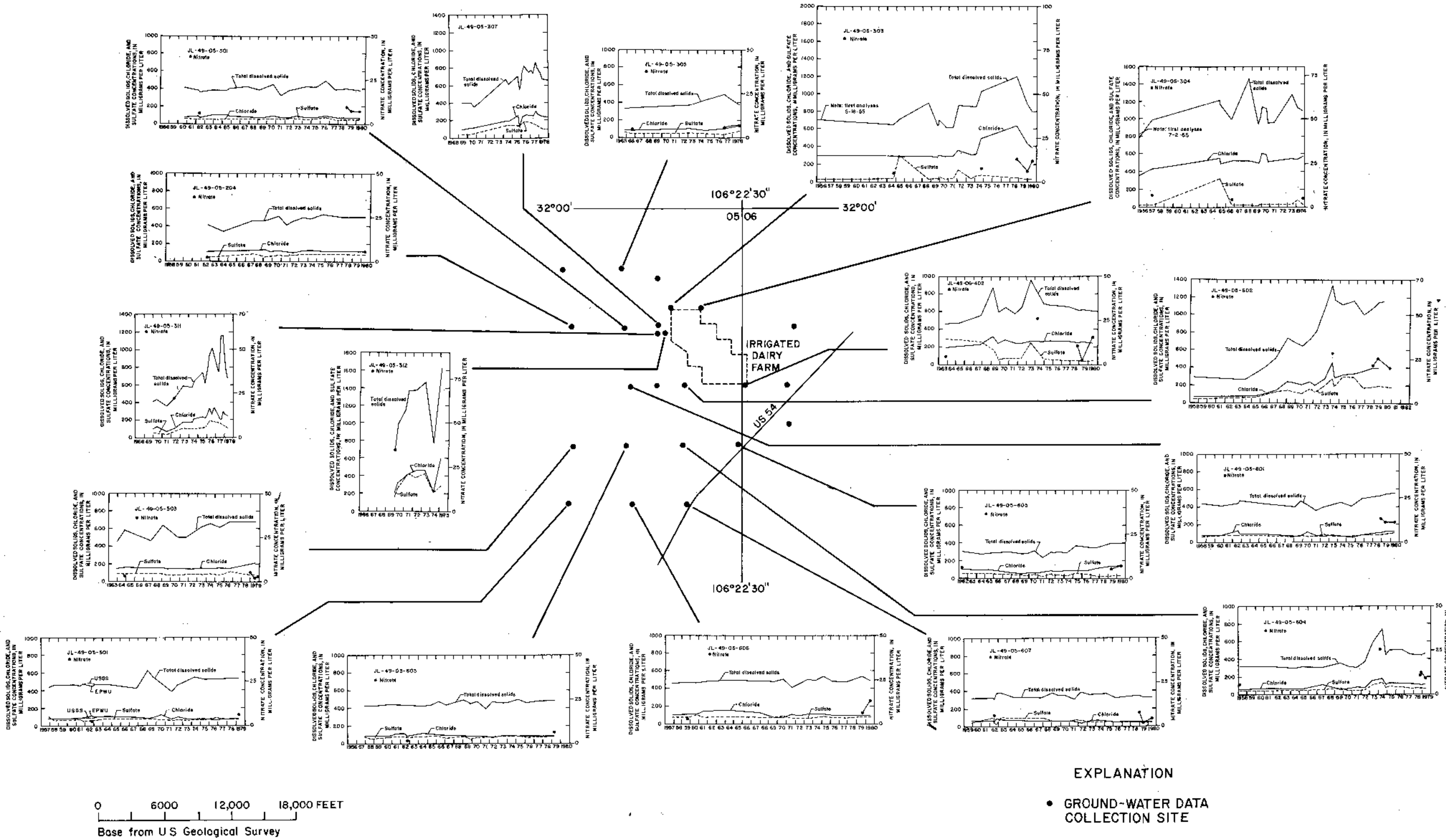

Figure 31

Variations in Dissolved-Solids, Chloride, and Sulfate Concentrations in Water From Wells in the Vicinity of the Dairy Farm, 1957-80

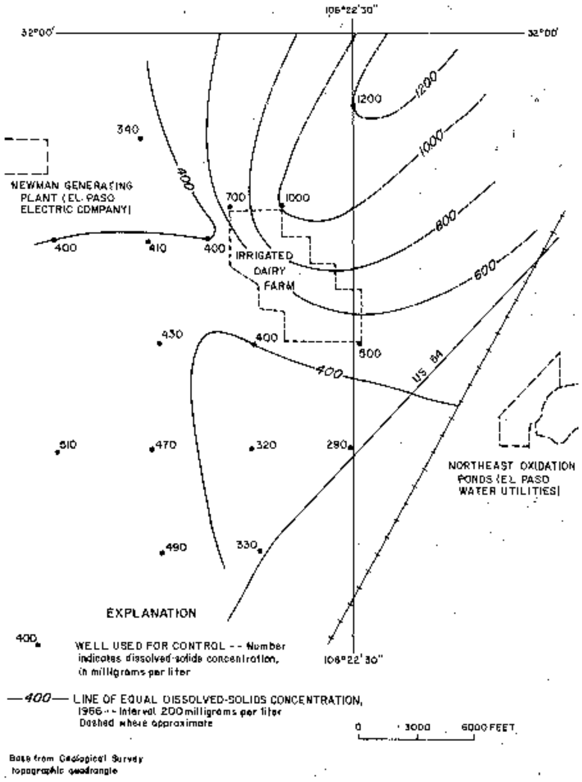

Figure 32a.—Approximate Areal Distribution of the Dissolved-Solids Concentration in Water From Wells in the Vicinity of the Dairy Farm, 1966

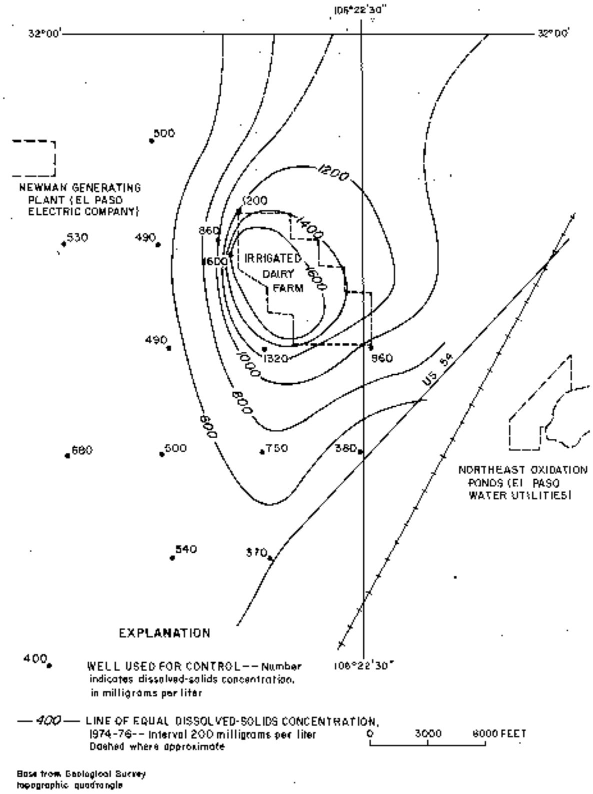

Figure 32b.—Approximate Areal Distribution of the Dissolved-Solids Concentration in Water From Wells in the Vicinity of the Dairy Farm, 1974-76

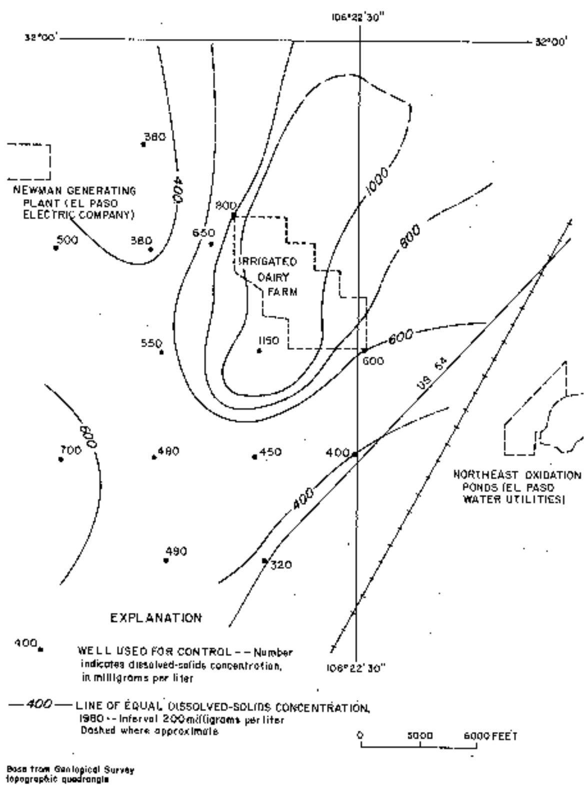

Figure 32c.—Approximate Areal Distribution of the Dissolved-Solids Concentration in Water From Wells in the Vicinity of the Dairy Farm, 1980

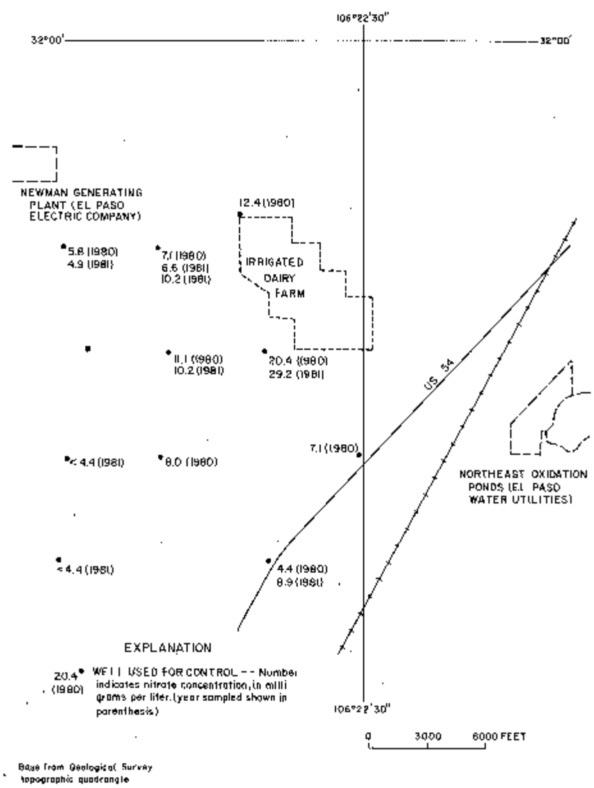

Figure 33.—Concentrations of Nitrate in Water From Wells in the Vicinity of the Dairy Farm, 1980 and 1981

In 1982, construction started on a tertiary treatment plant at the north-east oxidation ponds. The plant is part of the Hueco bolson recharge project (HBRP), which will treat sewage to drinking water standards and recycle the water via injection wells (Environmental Impact Statement draft "Wastewater treatment facilities, northeast El Paso, Texas," February 1980; Garza and others, 1980). The project is planned to include a 10 million gallons per day (11,000 acre-feet per year) advanced waste treatment plant with a pipeline system to 10 injection wells. The injection wells will be spaced at distances from pumping wells so that there will be a minimum of 2 years residence time in the bolson prior to production. The existing oxidation ponds will be abandoned upon completion of the treatment plant and injection facilities.

Ground-Water Availability

The most important aspect of the ground-water resources of the El Paso area is the amount of freshwater stored in the Hueco bolson, the principal aquifer, and specifically the amount of water which could be withdrawn without incurring a serious overdraft. The overdraft could create an unacceptable reduction in well yields, deterioration of water quality beyond accepted standards, and possible land-surface subsidence.

Figure 34 shows the 1970-80 withdrawals of ground water in the United States (Texas) and Republic of Mexico (Ciudad Juarez) parts of the Hueco bolson metro area. The figure also shows recent projections of future pumping rates by various Federal, State, and local agencies. These projections, based primarily on anticipated population growth and per capita water consumption, extend to the years 2020 or 2030 and are all subject to revision.

During the current investigation, the chemistry data for wells in the Hueco bolson were compiled and plotted to define areas having similar levels of dissolved-solids concentrations (Figure 18) and areas of significant changes in dissolved solids (Figure 19). These data and the altitudes of the water table in January 1980 (Figure 14), the top of the freshwater in the El Paso Valley, and the base of the freshwater in 1973 (Figure 35) were used to estimate the approximate volume of sediments containing freshwater in the Texas part of the Hueco bolson metro area in January 1980.

Figure 36 shows the approximate thickness of sediments containing water with dissolved-solids concentrations less than 1,500 mg/L. The mapped area, which is restricted to the Texas part of the Hueco bolson metro area, is underlain by an estimated 54.2 million acre-feet of sediments with fresh to slightly saline water. Most of the sediments, about 29.0 million acre-feet, contain water with dissolved-solids concentrations ranging from 500 to 1,000 mg/L. About 24.6 million acre-feet of sediments contain water with less than 500 mg/L dissolved-solids concentrations, and approximately 0.6 million acre-feet of sediments contain water with 1,000 to 1,500 mg/L dissolved solids.

Digital-model studies (Meyer, 1976) indicate a value of 0.1856 for specific yield as a reasonable approximation for the saturated section of the Hueco bolson. Using this value, the volumes of theoretically recoverable resources in 1980 would yield 4.57 million acre-feet of very fresh water (dissolved-solids concentrations less than 500 mg/L), about 5.38 million acre-feet of freshwater (500 to 1,000 mg/L dissolved-solids concentrations), and about 0.11 million acre-feet of slightly saline water (1,000 to 1,500 mg/L dissolved solids). The freshwater resources would total about 10.0 million acre-feet.

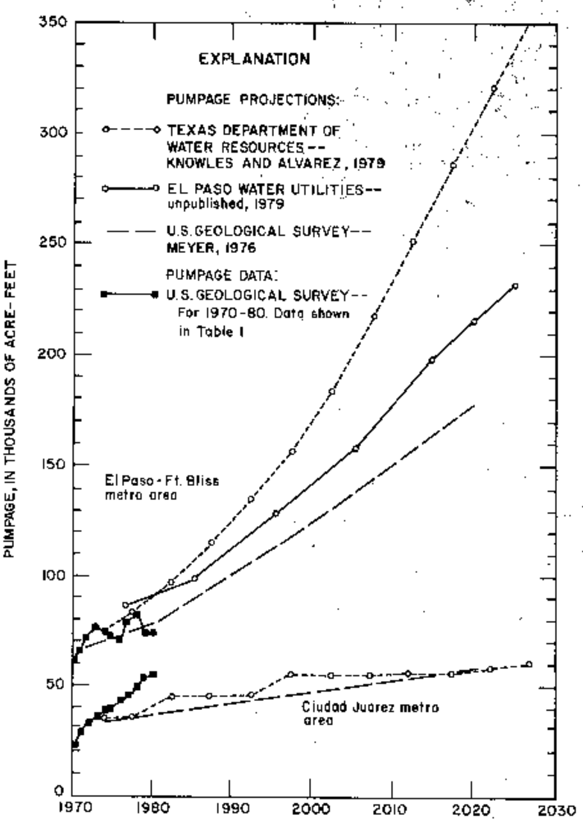

Figure 34.—Recorded and Projected Withdrawals of Ground Water From the Hueco Bolson Metro Area, 1970-2030

In addition to the estimated 10.0 million acre-feet of freshwater reserves, there is an estimated 4 million acre-feet of slightly saline water (1,000 to 3,000 mg/L dissolved-solids concentrations) stored within and outside the Texas part of the Hueco bolson metro area. Part of the slightly saline water may be blended with freshwater to accepted quality standards and used for municipal and industrial supply.

Table 7 shows recent estimates of freshwater in storage in the Texas part of the metro area starting in 1903 and projecting to the year 2030. The projected volumes in storage are theoretically recoverable and were computed using an average specific yield of 0.1856 calculated by Meyer (1976) and the projected rates of pumping shown in Figure 34. All of the projections were made prior to the initiation of the Hueco bolson recharge project. A scheduled three-dimensional solute transport model study of the bolson will incorporate the conservation aspects of the recharge project. This study will also update the recent projections of future rates of ground-water withdrawals as shown in Figure 34 and the volumes of water remaining in storage as shown in Table 7.

RIO GRANDE

The quantity of flow and concentrations of dissolved solids in the Rio Grande at El Paso for 1943-80 is shown in Table 8. The annual discharge for that period averaged about 317,000 acre-feet. The maximum and minimum flows were 631,800 acre-feet in 1943 and 57,481 acre-feet in 1956. Concentrations of dissolved solids in monthly samples ranged from 427 mg/L in August 1957 to 3,832 mg/L in November 1957. For the 34-year period 1943-76, the dissolved solids in monthly samples averaged 1,142 mg/L, and for the same period the discharge-weighted dissolved solids concentration averaged 819 mg/L. Drain flow returns and sewage outfalls contribute most of the low flow in the river, which accounts for the wide seasonal range in dissolved-solids concentrations. In general the dissolved-solids concentrations are highest during periods of low flow and are lowest during periods of high flow.

SUMMARY AND CONCLUSIONS

Located in the far western tip of Texas, the El Paso area includes most of El Paso County, some adjacent areas in New Mexico, and Ciudad Juarez in Mexico. The economy of the area is

Table 7.—Estimates and Projections of Freshwater in Storage in the Texas Portion of the Hueco Bolson, 1903-2030 (million acre-feet)

Year	Meyer (1976)	Texas Water Development Board (1977)	Hickerson (1979)[1]	Knowles and Alvarez (1979)	Current investigation
1903	11.45	—	—	—	—
1973	10.64	—	—	10.6	—
1980	—	—	—	—	10.0
1990	9.8	—	9.1	9.6	—
2020	7.4	—	4.4	5.6	—
2030	—	2.73	2.1	3.7	—

[1]Estimates made discounting recharge of mostly slightly to moderately saline water from shallow aquifer.

NOTE: Proposed recycling of tertiary treated sewage unaccounted in all projections.

dependent upon the use of ground water for municipal, industrial, and military supply, augmented by diversions of flow from the Rio Grande for crop irrigation and limited municipal supply.

In the El Paso area, significant pumping of ground water began in the early 1900's. Development gradually increased to the early 1950's, when it accelerated accompanying rapid population growth. In 1980, pumpage for municipal, industrial, and military supply totaled 164,354 acre-feet. Most of the water, 132,652 acre-feet, came from the Hueco bolson. The Mesilla bolson and Rio Grande alluvium supplied 27,461 and 4,241 acre-feet. These three aquifers are interstate and international in extent.

Pumpage from the Mesilla bolson and Rio Grande alluvium in the lower Mesilla Valley averaged about 31,000 acre-feet per year in 1979-80. Most of the water, 21,000 to 22,000 acre-feet, came from wells in the El Paso Water Utilities Canutillo Field. In 1980, shallow wells pumped 578 acre-feet, medium-depth wells 10,290 acre-feet, and deep wells 10,049 acre-feet. Water levels in shallow wells are generally 5 to 15 feet below land surface and may decline as much as 10 to 15 feet during years of heavy pumping. Water levels in medium-depth wells are normally a few feet below the levels in shallow wells. Water levels in deep wells, which reflect changes in artesian pressure in the deep aquifer, range from 20 to 100 feet below land surface and have declined about 20 feet since the mid-1950's.

The quality of water from shallow wells in the Canutillo field ranges from fresh to slightly saline. Most of the freshwater (dissolved-solids concentrations of less than 1,000 mg/L) is pumped from wells near the Rio Grande and Canutillo lateral which are line sources of recharge. Dissolved-solids concentrations in water from medium-depth wells range from 328 to 741 mg/L. Increases in dissolved solids in these wells are attributed to interformational leakage and insuffi-

Table 8.—Summary of Flow and Concentrations of Dissolved Solids in the Rio Grande at El Paso, 1943-80[1]

Year	Dissolved solids (mg/L) Range of monthly samples	Average of monthly samples	Discharge-weighted average	Flow in the Rio Grande (acre-feet) El Paso station	Delivered to Mexico
1943	669-1,221	862	750	631,800	61,309
1944	677-1,250	903	787	611,900	61,798
1945	669-1,324	889	802	568,900	60,684
1946	713-1,236	914	816	497,900	60,466
1947	669-1,294	981	824	458,860	58,012
1948	691-1,324	968	838	431,680	60,689
1949	655-1,221	870	750	463,540	60,256
1950	669-1,294	916	772	472,630	60,602
1951	809-1,375	1,072	905	252,000	33,059
1952	530-1,530	1,032	736	283,680	49,890
1953	655-1,537	1,000	743	264,500	37,760
1954	684-2,229	1,249	956	93,725	10,147
1955	802-2,839	1,502	1,015	67,089	8,185
1956	993-3,200	1,905	1,052	57,481	7,864
1957	427-3,832	1,858	596	139,571	23,290
1958	655-3,251	1,267	721	392,863	60,050
1959	610-1,750	1,130	831	385,810	60,110
1960	669-1,706	1,154	860	378,260	60,320
1961	713-1,670	1,119	867	300,690	48,610
1962	677-1,618	1,044	802	376,116	60,057
1963	713-1,655	1,174	875	263,711	39,693
1964	809-2,640	1,522	1,059	64,307	6,653
1965	434-2,273	1,341	566	202,392	36,658
1966	552-2,111	1,117	691	308,782	49,618
1967	655-1,743	1,131	816	232,744	29,829
1968	728-1,670	1,155	890	264,408	39,677
1969	610-1,831	1,100	780	365,407	59,884
1970	684-1,618	1,070	824	360,719	60,065
1971	684-1,677	1,116	824	244,156	34,847
1972	691-2,162	1,328	905	133,568	15,515
1973	588-2,118	1,181	831	301,789	60,000
1974	588-1,699	1,014	750	382,953	60,050
1975	728-1,559	1,025	846	360,959	60,052
1976	588-1,530	943	780	402,835	60,172
1977	691-2,008	1,206	—	214,553	24,824
1978	521-2,560	1,373	—	156,024	14,903
1979	432-2,260	1,059	—	312,594	60,055
1980	531-1,710	985	—	353,983	60,033

[1]Data from International Boundary and Water Commission annual bulletins (1943-80).

cient depth of screen setting. Dissolved-solids concentrations in water from deep production wells range from 252 to 340 mg/L. One deep observation well showed a significant increase in dissolved solids attributed to excessive depth of screen setting and a progressive development of brackish water from deep sand zones in the southern part of the field.

Natural (boundary) recharge to the aquifers in the lower Mesilla Valley has been estimated at 18,000 acre-feet per year. About 0.8 million acre-feet of freshwater and 0.3 million acre-feet of slightly saline water are in storage in the Texas part of the valley.

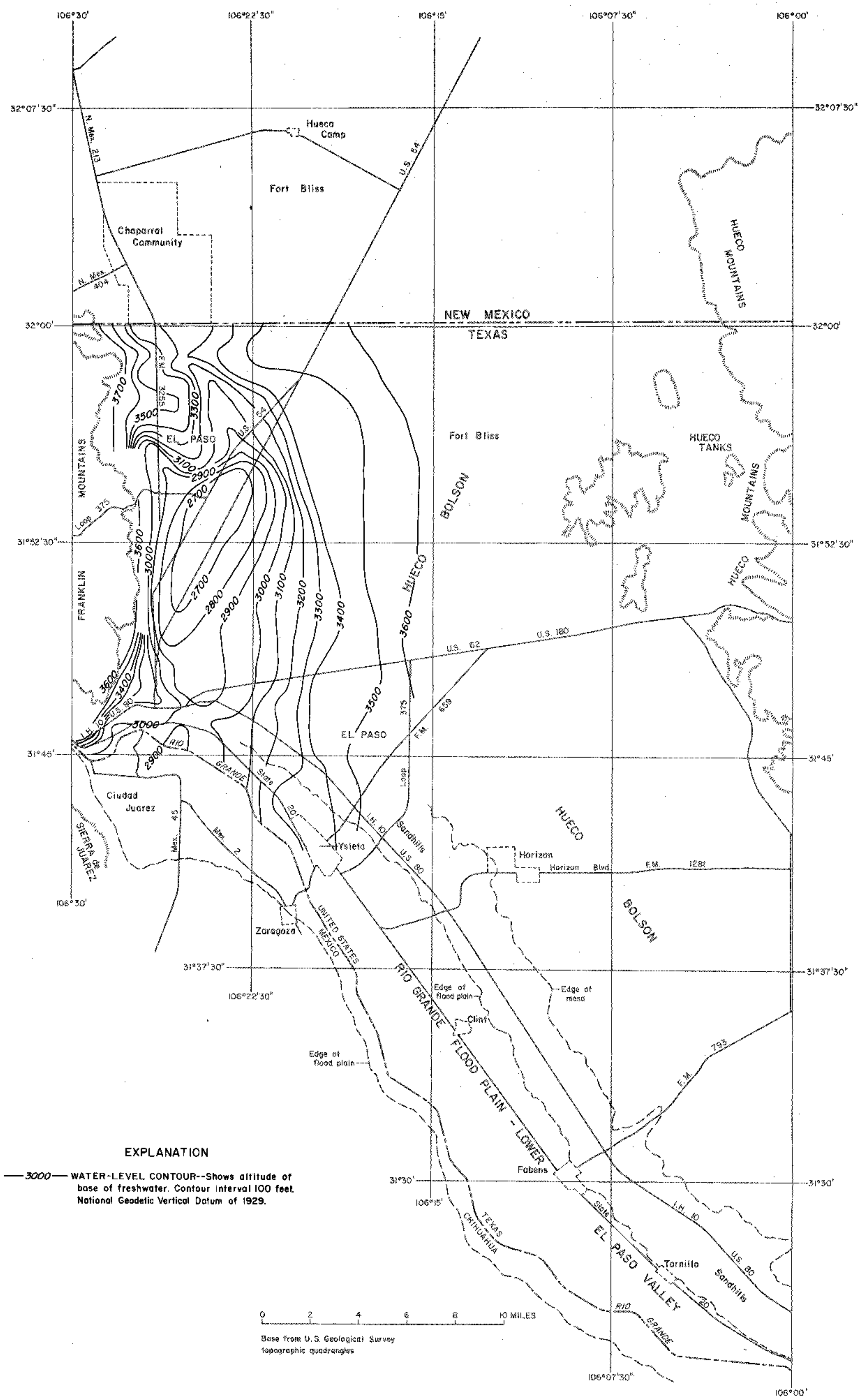

Figure 35
Approximate Altitude of the Base of Freshwater in the
Hueco Bolson, 1973

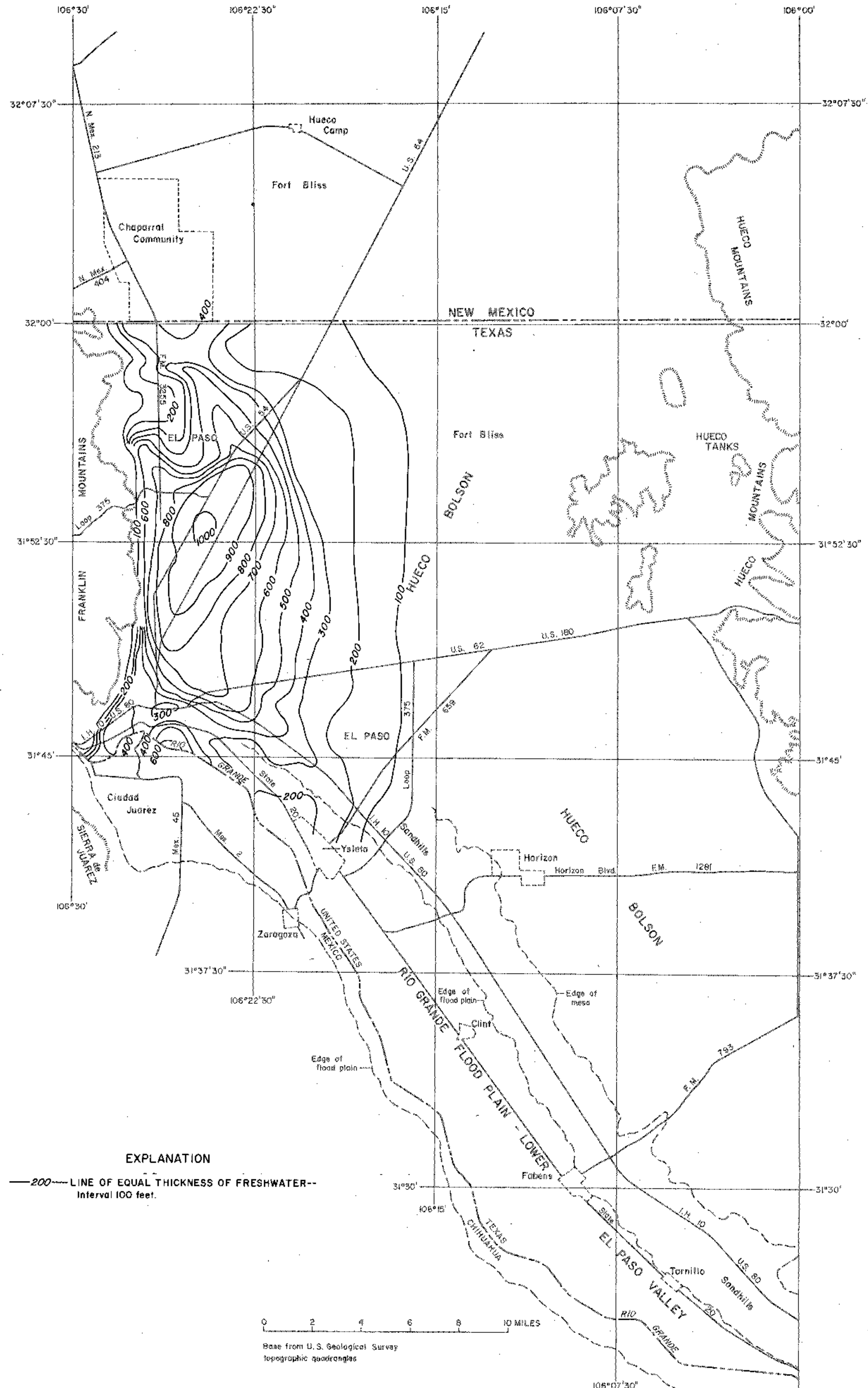

Figure 36
Estimated Thickness of Sediments Containing Freshwater in the Hueco Bolson, January 1980

Irrigation of cropland in the lower Mesilla valley and El Paso-Juarez Valley is mainly from diversion of flow in the Rio Grande supplemented by pumping wells. Consequently, the amount of ground water pumped varies inversely with surface-water availability. There was a full 3-foot surface-water allotment in 1980, and irrigation pumping was minimal during that year.

In 1980, pumpage in the El Paso-Fort Bliss-Ciudad Juarez metro part of the Hueco bolson totaled 129,231 acre-feet. Most of the water, about 114,000 acre-feet, was for municipal supply, with 58,213 acre-feet used in El Paso and 55,808 acre-feet used in Ciudad Juarez. The 1906-80 pumpage in the metro area totals about 3.0 million acre-feet, with 2.2 million acre-feet pumped in the United States and 0.8 million acre-feet pumped in Mexico.

Withdrawals of ground water during 1906-80 caused water levels in bolson wells to decline about 130 feet in the downtown sections of El Paso and Ciudad Juarez. In that area, rates of decline currently exceed 5 feet per year and are approaching 10 feet per year. The historical declines diminish away from centers of pumping and are less than 10 feet along the eastern and southern boundaries of the metro area.

Water from most wells in the Hueco bolson metro area contains less than 1,000 mg/L dissolved solids. Dissolved solids in recent samples from 148 wells in and near El Paso and Fort Bliss averaged 642 mg/L, and samples from 45 wells in Ciudad Juarez averaged 736 mg/L. Dissolved solids are increasing at an average rate of about 10 mg/L per year in the United States part and about 30 mg/L per year in Mexico. Most of the deterioration in water quality is attributed to downward leakage of brackish water from the shallow alluvial aquifer and to deep percolation of applied lawn and crop irrigation water. Abandoned wells act as local conduits for vertical leakage between layers in the aquifers.

Excluding interformational leakage, recharge to the Hueco bolson has been estimated at about 5,640 acre-feet per year. In 1980 an estimated 10.0 million acre-feet of freshwater was in storage in the Texas part of the metro area. About 4.6 million acre-feet contained dissolved-solids concentrations of less than 500 mg/L and 5.4 million acre-feet contained dissolved-solids concentrations of 500 to 1,000 mg/L.

A significant volume of slightly saline water, as much as 4 million acre-feet, is in recoverable storage in the Texas part of the Hueco bolson. Part of this water may be available for blending with freshwater to provide for municipal-industrial supply. The planned recycling of tertiary-treated sewage could also extend the life of the Hueco bolson, the principal aquifer.

During 1943-80, flow in the Rio Grande at El Paso ranged from 57,481 acre-feet to 631,800 acre-feet and averaged about 317,000 acre-feet per year. Dissolved-solids concentrations in monthly samples of flow during 1943-80 ranged from 427 to 3,832 mg/L. For the 34-year period 1943-76, dissolved-solids concentrations in monthly samples averaged 1,142 mg/L, and the discharge-weighted values averaged 819 mg/L.

The numerous studies which have been made on the ground-water resources in the El Paso area have reasonably defined the volume of freshwater in storage. The ratio of the volume in storage to the rate of annual withdrawals is small compared to most of the major population centers in the southwest and this ratio is decreasing at a significant rate because of the area's increasing population growth and water demand.

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