BULLETIN 6514

# DEVELOPMENT OF GROUND WATER IN THE EL PASO DISTRICT, TEXAS, 1960-63

PROGRESS REPORT NO. 9

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# DEVELOPMENT OF GROUND WATER IN THE EL PASO DISTRICT, TEXAS, 1960-63

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### ABSTRACT

The development of ground water in the El Paso district expanded only slightly during the period September 1960 to January 1963. Twenty wells were drilled during this period, of which 10 were for municipal supply, 4 for industrial use, and 6 for observation purposes. By January 1, 1963, the total number of wells used or that could be put into use, excluding shallow irrigation wells, was 133, of which 97 were for municipal supply.

In 1947, the rate of withdrawal of ground water from deep wells in the district for municipal, industrial, and irrigation use was about 20 mgd (million gallons per day) and increased to 73.2 mgd in 1962. The city of El Paso pumped 40.8 mgd, or about 56 percent of the total pumpage from deep wells in 1962. In 1960 and 1962, about 9 mgd was pumped for irrigation in the Upper and Lower Valleys; in 1961, when surface-water supplies were insufficient, 33.2 mgd of ground water was pumped to irrigate about 63,000 acres.

Expansion of the well fields and the accompanying increase in pumpage have caused a rapid decline in water levels in and near the newer fields, the magnitude of the decline decreasing with distance from the centers of pumping. Since 1959, water levels in the Mesa area declined as much as 8.8 feet near the center of the Nevins field and a maximum of 8.0 feet in the Airport field; water levels in the City Artesian area declined a maximum of 4.2 feet. Since January 1960, water levels in the alluvium of the Upper and Lower Valleys have remained relatively stable, except for seasonal fluctuations.

The volume of theoretically recoverable fresh water in the saturated deposits of the Hueco bolson in Texas is approximately 7,500,000 acre-feet; about 6,800,000 acre-feet is in the Mesa area and 700,000 acre-feet is in the City Artesian area. Approximately 560,000 acre-feet of fresh water is in storage in the bolson deposits (Santa Fe Group) and alluvium in the Upper Valley in Texas; about 150,000 acre-feet is in the alluvium. Probably about 50 percent of the fresh water in storage can be withdrawn by wells before it becomes contaminated by saline water.

Fresh water in the Mesa area of the Hueco bolson occurs in a trough of irregular width and depth roughly parallel to the Franklin Mountains; fresh water in the City Artesian area is overlain and underlain by sands containing saline water. Changes in the chloride content of water from wells in the Mesa area have been small; whereas, analyses of water from some of the wells in the City Artesian area have indicated increases in chloride content.

The city of El Paso surface-water treatment plant is capable of diverting 20 mgd from the Rio Grande for municipal use. A new contract with the Bureau of Reclamation will allow the city to divert an additional 23.7 mgd from the Rio Grande when surface-water supplies are adequate.

The city of El Paso is presently developing all known sources of fresh ground water in the Hueco bolson and Upper Valley areas in Texas. A potential source of water supply is the large volume of saline water underlying the Hueco bolson and Upper Valley in Texas, which may be used by mixing with the fresh water or by desalinization.

# DEVELOPMENT OF GROUND WATER IN THE EL PASO DISTRICT, TEXAS, 1960-63

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## INTRODUCTION

### Location and Extent of Area

The El Paso district, as defined in this report, is in the extreme western part of Texas and includes all of El Paso County (Plate 1). Ciudad Juarez in Mexico is included in the report area because of pumpage for municipal supplies from the same aquifer that supplies the city of El Paso.

The city of El Paso in the United States and Ciudad Juarez in Mexico are the principal cities in the area and are separated by the Rio Grande. According to the Bureau of Census, the population of El Paso in 1960 was 276,687 and the population of the metropolitan area was 314,070. The population of the city in December 1962 was estimated at about 291,600. Ciudad Juarez had a population of 306,000 in 1960 and an estimated 335,000 in December 1962.

The El Paso district was subdivided by Leggat (1962, p. 3) into four general areas on the basis of ground-water development (Plate 1): (1) the Mesa area, (2) the City Artesian area, (3) the Upper Valley, and (4) the Lower Valley.

### Purpose and Scope of Investigation

This report is the ninth of a series of reports (see references cited) presenting information on the ground-water resources of the El Paso district obtained by the U.S. Geological Survey in cooperation with the Texas Water Commission and the city of El Paso. It brings up to date information on ground-water development and pumpage, fluctuation of water levels, changes in chemical quality of water, and related information compiled during the period 1960-63. Records of wells drilled in the El Paso district during the period 1960-62 and those of a few wells not included in the report by Leggat (1962) are given in Table 2. The results of chemical analyses of water samples collected during the period 1960-63 are given in Table 3.

For the purpose of numbering the wells, grid lines have been established at 10-minute intervals of latitude and longitude throughout the district and individual grids have been lettered alphabetically. The wells are numbered consecutively within each grid; for example, well Q-1 would be well 1 in the Q grid.

The fieldwork and preparation of this report were under the administrative direction of O. M. Hackett, chief of the Ground Water Branch, U.S. Geological Survey, and under the direct supervision of A. G. Winslow, district geologist in charge of ground-water investigations in Texas.

### Previous Investigations

The geology, geography, and climate of the El Paso district have been described in previous reports. The geology and its relation to the occurrence of ground water in the district were discussed by Sayre and Livingston (1945), Knowles and Kennedy (1958), Leggat and others (1962), and Leggat (1962). Additional data pertaining to ground-water investigations in the El Paso district may be found in reports by Scalapino (1949), Smith (1956), Audsley (1959), and Davis and Leggat (1962).

## HYDROLOGY

### Ground-Water Development and Pumpage

Ground water in the El Paso district occurs principally in the unconsolidated deposits of the Hueco and La Mesa bolsons and in the shallow alluvium of the Upper and Lower Valleys of the Rio Grande.

Exploratory drilling during the period from 1953 to 1960 indicated that large ground-water reservoirs exist northwest of Canutillo in the Upper Valley and in the western part of the Mesa area of the Hueco bolson adjacent to the Franklin Mountains. In other areas, such as in the Lower Valley southeast of Ysleta and the eastern part of the Mesa area, fresh ground-water supplies were found only in small quantities or none at all were found.

The principal areas of ground-water development in the El Paso district are shown in Plate 1. Changes in the names and extent of some of the city of El Paso well fields are shown also as compared to those used in the report by Leggat (1962, pl. 1). The Nevins and Newman well fields are combined as the Nevins well field; the Montana well field is included in the Downtown well field; and the Lower Valley well field includes all the wells formerly owned by the El Paso Valley Water District No. 1, which now belong to the city of El Paso.

Ground-water development and pumpage in the El Paso district prior to September 1960 were described by Leggat (1962, p. 11-16). Since September 1960, the development has expanded only slightly. Only one small wildcat area was explored, which was in the upland northeast of Canutillo in the Upper Valley (Plate 1). Three wells, for public supply and industrial use, were drilled to depths ranging from 500 to 600 feet. The drilling indicated that the area is underlain by bolson deposits of sand, clay, and boulders, containing water with a chloride content ranging from 215 to 345 ppm (parts per million). Logs of the wells indicate that most of the water is produced from the interval above 450 feet; the underlying deposits consist of loosely to tightly cemented limestone conglomerate that yields only small quantities of water.

Since September 1960, 20 wells were drilled of which 10 were for municipal supply, 4 for industrial use, and 6 for observation or exploration purposes.

Most of the new development was in the Mesa and City Artesian areas where 9 wells were drilled, 7 for municipal supply and 2 for industrial use. Five wells were drilled in the Upper Valley, 3 for municipal supply and 2 for industrial use. By January 1, 1963, the total number of wells that were used or could be put into use, excluding shallow irrigation wells, was 133, of which 97 were for municipal supply. Ciudad Juarez has 33 municipal wells that may be used, of which 14 have been drilled since 1959.

Pumpage of ground water from deep wells in the El Paso district has increased from about 20 mgd (million gallons per day) in 1947 to 73.2 mgd in 1962 keeping pace with the increase in population and expansion of industries (Figure 1). The city of El Paso is the principal user of ground water from deep wells in the district. In 1962, the city pumped 40.8 mgd or about 56 percent of the total water pumped from deep wells; Ciudad Juarez pumped 15.2 mgd; industries, 7.6 mgd; military establishments, 5.3 mgd; and 4.3 mgd was pumped for irrigation. Of the 40.8 mgd pumped by the city of El Paso in 1962, about 55 percent was from the Mesa area, 27 percent from the Canutillo area, and 18 percent from the City Artesian area.

A breakdown of the pumpage by use for the period 1960-62 is shown in Table 1. Listed in the table is the pumpage from both deep and shallow wells including shallow industrial and irrigation wells on the New Mexico side of the Upper Valley below Anthony.

In 1960, pumpage from the Mesa area was 29.3 mgd, an increase of 5.1 mgd over that of 1959. Pumpage from the Mesa area has continued to increase and by 1962, 33.6 mgd was pumped. Of the water pumped from the Mesa area, about 65 percent was for the public supply of El Paso. Industrial pumpage increased from 0.8 mgd in 1959 to 1.7 mgd in 1962, principally due to the expansion of the El Paso Electric Newman plant. Since 1959, pumpage for irrigation has increased from 3.0 to 4.3 mgd in 1962.

Pumpage of ground water from the City Artesian area in 1962 was 28.4 mgd, an increase of only 800,000 gallons per day since 1959. Ciudad Juarez is the main user, pumping 15.2 mgd, or 54 percent of the total from the artesian area in 1962. Pumpage by the city of El Paso increased from 7.1 mgd in 1960 to 8.7 mgd in 1961. The pumpage decreased to 7.3 mgd in 1962 because of less pumpage from wells in the Lower Valley well field and increased use of water from the Canutillo well field. During the period 1959-62, industrial use of ground water increased from 5.2 to 5.9 mgd and averaged about 20 percent of the total pumpage from the City Artesian area in 1962.

The pumpage of ground water for public supply and industrial use in the Upper Valley increased each year during the period 1960-62. In 1960, pumpage amounted to 17.4 mgd, 1.3 mgd more than in 1959; in 1962, it increased to 18.1 mgd. Pumpage from the shallow, medium, and deep aquifers in the city of El Paso Canutillo well field averaged 13.9 mgd from 1960-62, inclusive. During the same period, industrial pumpage increased from 3.0 to 3.7 mgd, all of which was from the shallow aquifer.

Irrigated farming is practiced extensively in the Upper Valley. When the surface-water supply for irrigation is inadequate, ground water is pumped as a supplemental supply. In 1960 and 1962, when 3.25 acre-feet per acre of surface water was allotted, only 4 mgd was pumped for irrigation, most of which was for land not entitled to surface-water allotments. In 1961, when 2.45 acre-feet

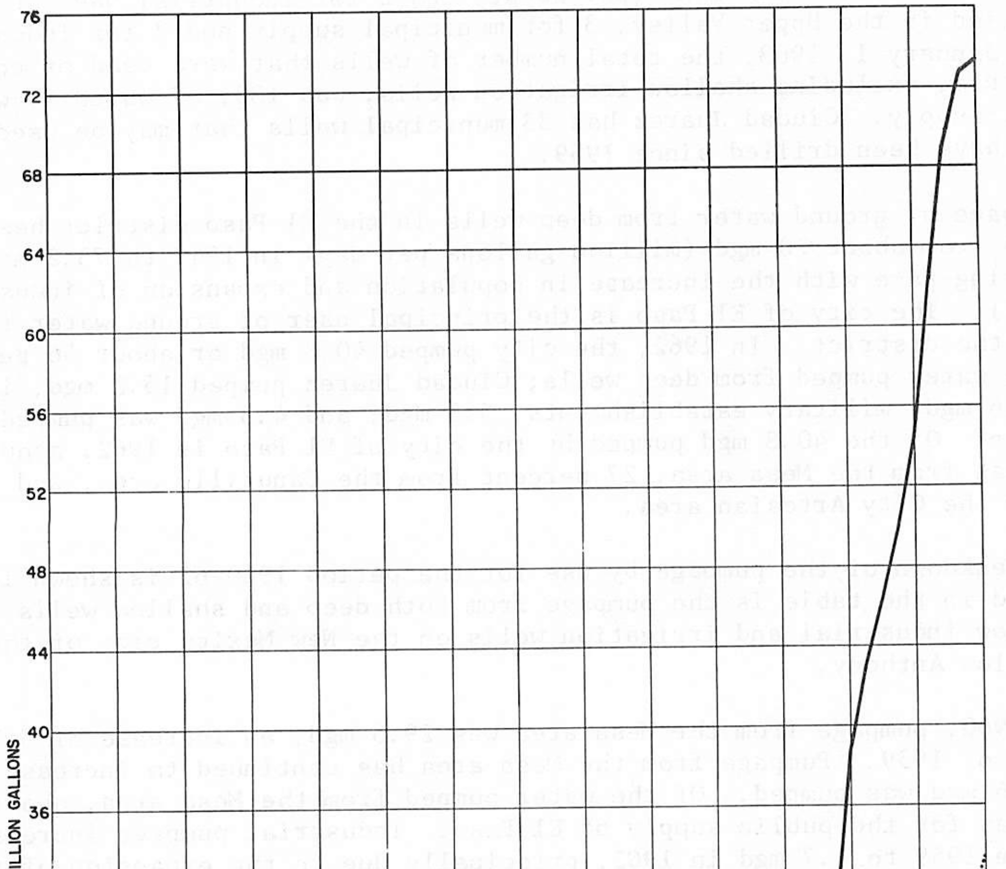


Figure 1

## Estimated Average Daily Pumpage From Deep Wells in the El Paso District, 1906–62

U.S. Geological Survey in cooperation with the Texas Water Commission and the city of El Paso

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Table 1.--Average daily pumpage of ground water in the El Paso district, 1960-62 (millions of gallons)

| Year | Mesa area | | City Artesian area | | Upper Valley | Lower Valley | Total |
|---|---|---|---|---|---|---|---|
| **Public Supply** | | | | | | | |
| | City of El Paso | Military Establishments | City of El Paso | Ciudad Juarez | | | |
| 1960 | 19.1 | 4.6 | 7.1 | 14.8 | 14.4 | 0.4 | 60.8 |
| 1961 | 20.5 | 4.6 | 8.7 | 15.6 | 14.5 | .4 | 64.3 |
| 1962 | 22.3 | 5.3 | 7.3 | 15.2 | 14.4 | .4 | 64.9 |
| **Industry** | | | | | | | |
| 1960 | 1.6 | | 5.8 | | 3.0 | -- | 10.4 |
| 1961 | 1.5 | | 5.5 | | 3.4 | -- | 10.4 |
| 1962 | 1.7 | | 5.9 | | 3.7 | -- | 11.3 |
| **Irrigation** | | | | | | | |
| 1960 | 4.0 | | -- | | 4.0 | 5.0 | 13.0 |
| 1961 | 4.0 | | -- | | 9.6 | 23.6 | 37.2 |
| 1962 | 4.3 | | -- | | 4.0 | 5.0 | 13.3 |
| **Totals** | | | | | | | |
| 1960 | 29.3 | | 27.7 | | 21.4 | 5.4 | 83.8 |
| 1961 | 30.6 | | 29.8 | | 27.5 | 24.0 | 111.9 |
| 1962 | 33.6 | | 28.4 | | 22.1 | 5.4 | 89.5 |

per acre of surface water was allotted, about 9.6 mgd of ground water was pumped for the supplemental irrigation of about 15,000 acres.

The Lower Valley also is primarily an irrigated farming area, and the source of the water used for irrigation is similar to that in the Upper Valley. Of the total water pumped, only about 400,000 gpd (gallons per day) is used for public supply; the remainder is for irrigation, which ranged from 23.6 mgd in 1961 to 5 mgd in 1960 and 1962 to irrigate approximately 48,000 acres.

## Fluctuation of Water Levels

Water levels in wells in the El Paso district fluctuate almost continuously in response to natural and artificial processes. The fluctuations or changes in water level in a well indicate changes in the amount of water in storage in the aquifer, the magnitude of the change in storage depending on the degree of confinement of the water and the causes of the fluctuations. The major fluctuations of water levels are the effects of pumping; minor fluctuations are caused by changes in atmospheric pressure, loading and unloading the aquifer, and earthquakes, and may have only a temporary effect.

Water levels have been observed in a large network of wells in the El Paso district since 1954. Measurements made in December or January each year are the most reliable for showing annual changes of water levels because of the effects of variations in seasonal pumpage.

### Mesa Area

The fluctuation of water levels in most wells in the Mesa area closely reflects the changes in the rate of ground-water withdrawal. The hydrographs of representative wells in the Mesa area (Figure 2) show that since 1953, water levels in wells in and near the old Mesa field, which was centered north of Fort Bliss (Plate 1), declined steadily and in wells remote from this field the water levels declined at a slow rate or were relatively stable. Beginning about 1954, the demand for new water supplies increased, and as a consequence, well fields were developed south and north of the old Mesa field. The accompanying increase in pumpage caused a rapid decline in water levels in and near the new fields, the magnitude of the decline decreasing with distance from the centers of heavy pumping. Figure 1 shows that since 1958, the withdrawals of water from the Mesa area increased markedly. A part of this increase is attributed to the northward expansion of the Nevins well field and to the eastward expansion of the Airport field. The rate of decline in the water levels in wells R-62 and V-42 (Figure 3) in the Nevins and Airport well fields increased markedly during the period 1960-63 compared to the rate of decline prior to 1960.

During the period 1954-63, the water levels in the Mesa area declined a measured maximum of 19.1 feet, in well R-22 in the southern part of the Nevins field (Plate 2); however, a decline of about 22 feet was estimated for the central part of the Nevins field. The water level declined 18.3 feet in well V-42 near the center of the Airport field during the same period. Data are insufficient to determine the extent of the area of decline, but it is probable that the effect of pumping from the Mesa area extends to the north several miles beyond the Texas-New Mexico state line and to the east possibly to the eastern boundary of the Hueco bolson.

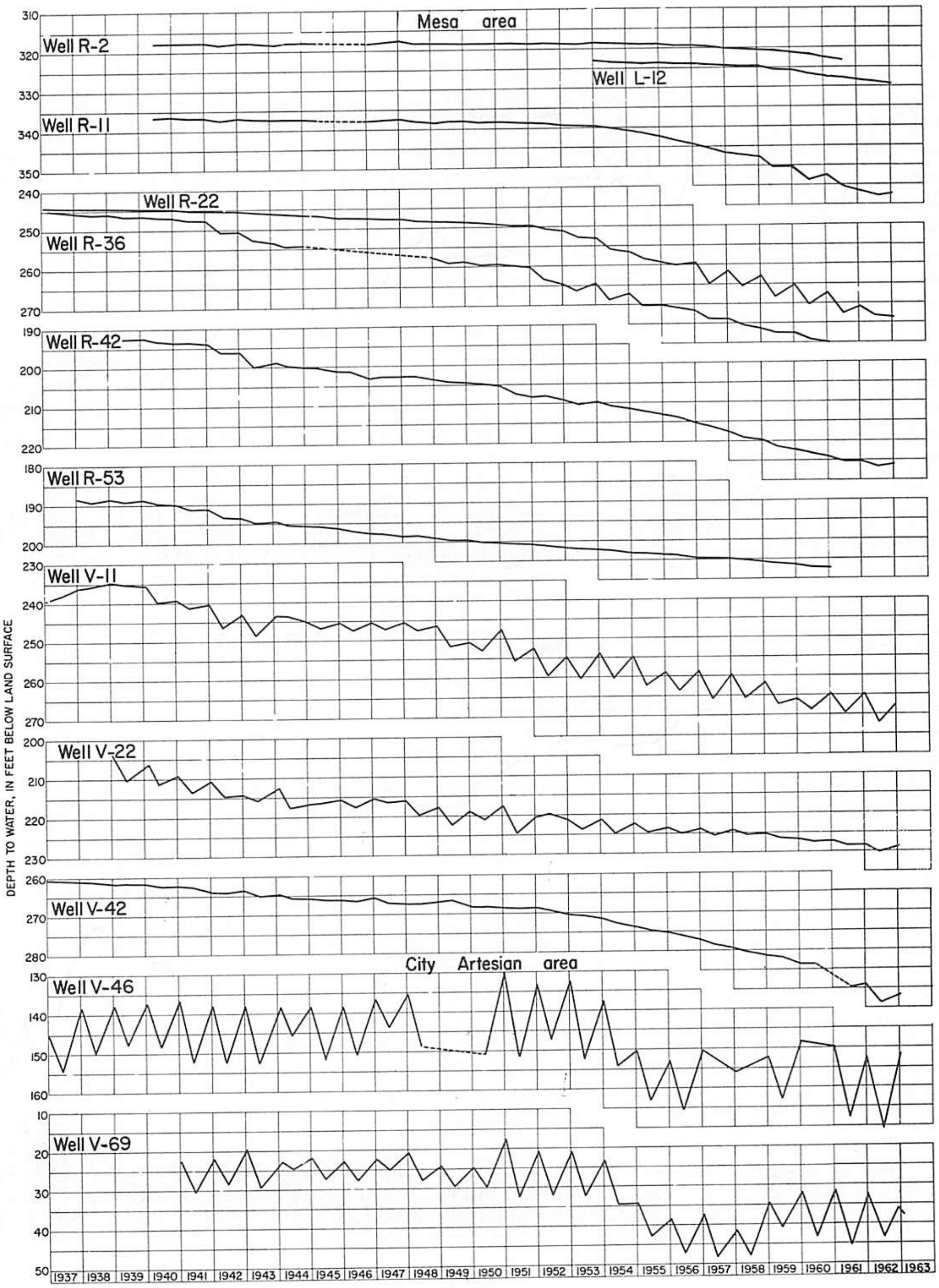


Figure 2

## Hydrographs of Selected Observation Wells in the Mesa and City Artesian Areas

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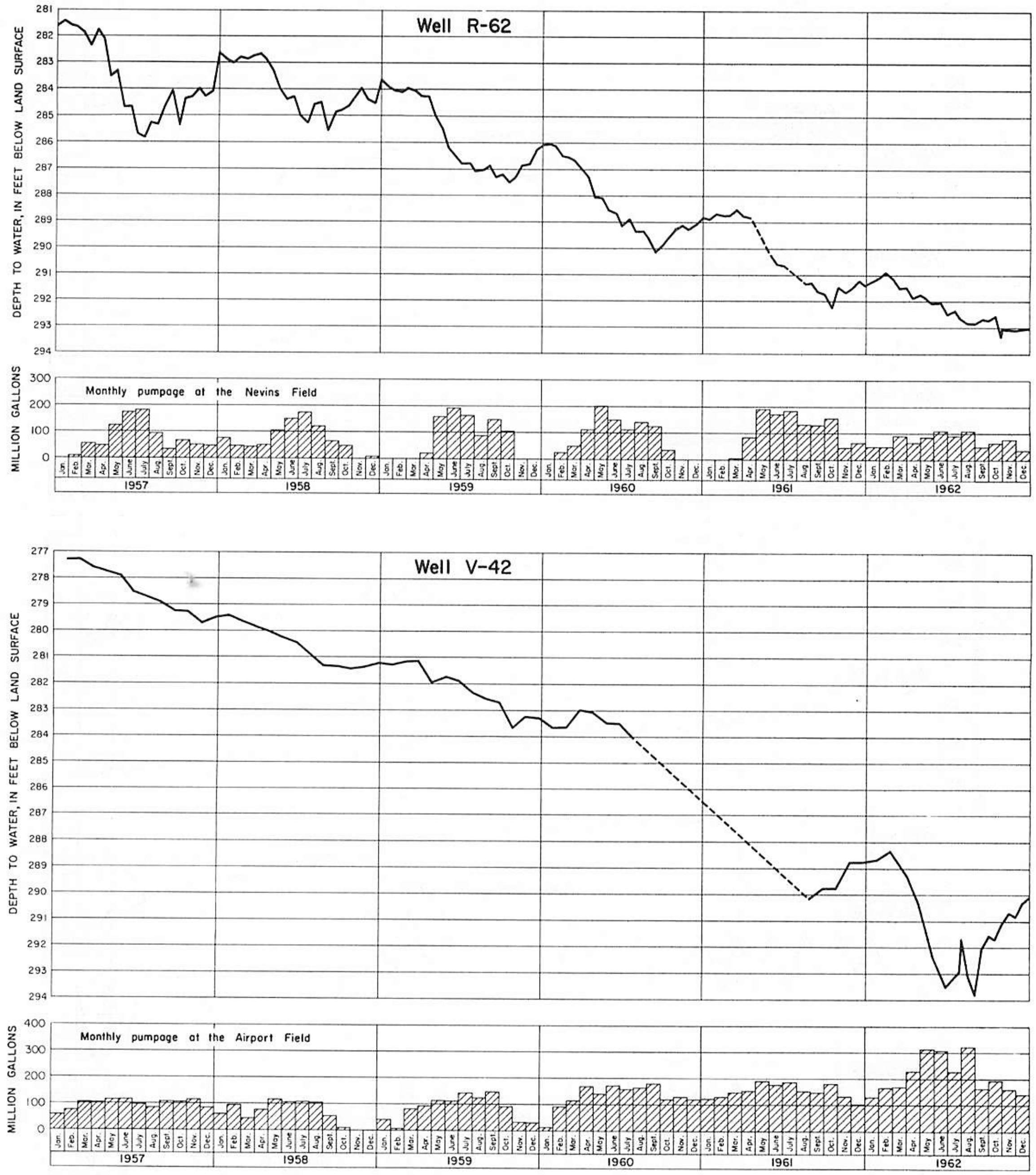


Figure 3

Relation of Pumpage to Depth to Water in the Nevins and Airport Well Fields of the City of El Paso

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Since 1959, water levels in the Mesa area declined as much as 8.8 feet in the Nevins field and 8.0 feet in the Airport field (Plate 3). In 33 wells, the levels declined an average of 3.8 feet, of which 1.6 feet of decline occurred in 1962. In the old Mesa field, the declines generally were less than 3 feet, reflecting the change in the centers of concentrated withdrawals.

The approximate changes in water levels in the Mesa area during the period 1962-63 are shown in Plate 4. The largest declines were centered in the Airport field. Water levels rose in a part of the old Mesa field, reflecting a decrease in the rate of withdrawal from that part of the field.

## City Artesian Area

Water levels in wells in the City Artesian area fluctuate over a rather wide range typical of the fluctuations in an artesian aquifer. The hydrographs of wells V-46 and V-69 (Figure 2) show that water levels were highest in 1951 after which the levels declined slowly until about 1954 when the rate of decline increased markedly with the lowest levels being reached in 1958. The water levels rose from 1958 to 1960 and since then have declined slightly.

Since 1954 the water levels in 11 wells in the City Artesian area have declined an average of 11.6 feet. The maximum measured decline was 14.6 feet in a well in the Downtown well field (Plate 2); however, decline of about 18 feet was estimated in the Lower Valley field.

The changes in water levels in the City Artesian area since 1959 are shown in Plate 3. In 13 wells, the water levels declined an average of 2.54 feet. The largest declines were in or near the Downtown field where the water levels declined as much as 4.2 feet. In the southwestern part of the area water levels rose as much as 2.4 feet. The rise is attributed largely to the shutting down of wells that formerly were used to supply the city and industry.

In 1962, the water-level declines were centered principally in the Downtown well field (Plate 4). In this part of the area, the water levels declined as much as 3.2 feet. Eastward, in the Lower Valley well field and the refinery section, water levels rose a maximum of 1 foot. Water levels rose in the southwestern part of the area.

## Upper Valley

Changes in water levels in the alluvium in the Upper Valley are closely related to the availability of surface water for irrigation. Infiltration of the surface water applied to the land for irrigation causes a general rise in the water levels in the wells. However, when the surface-water supplies are inadequate and ground water is required for irrigation, the water levels decline. In general, the water levels are highest during the summer because of infiltration of surface water and lowest during the winter in response to the discharge of ground water to the valley drains.

During the period 1960-62, the supply of surface water generally was adequate, except in 1961, when small, supplemental ground-water supplies were pumped (Table 1). Figure 4 shows that, except for seasonal fluctuations, the water levels in 10 observation wells in the alluvium remained relatively stable from January 1960 to January 1963.

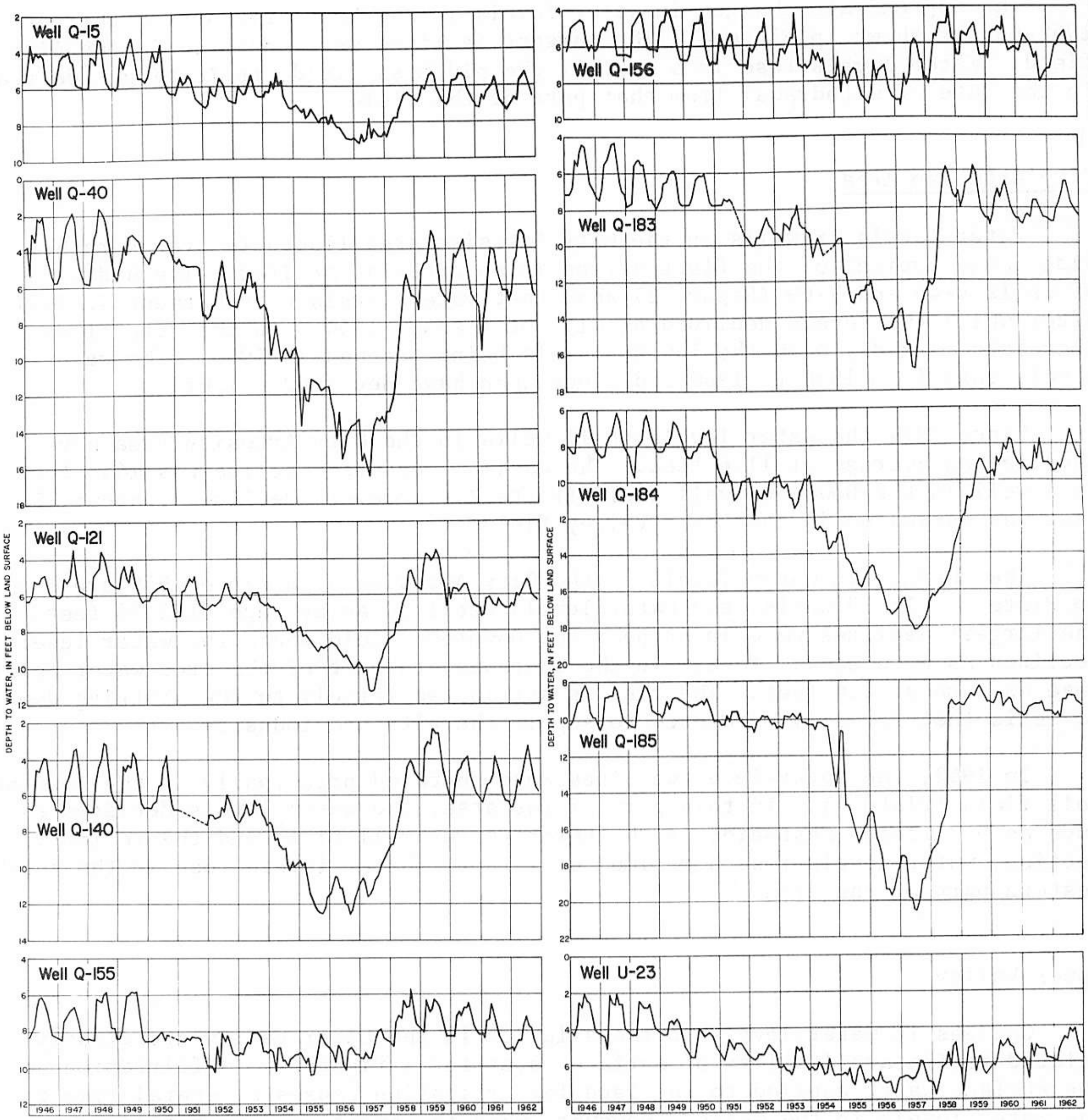


Figure 4

Hydrographs of Selected Wells in the Alluvium of the Upper Valley

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Plate 3 shows that the water levels declined slightly in the eastern and northeastern parts of the valley and rose slightly in a strip through the central and southwestern parts. In 1962, the water levels rose throughout the Upper Valley, except in two small areas where the decline in 3 wells averaged only 0.2 foot. In the rest of the valley, the water levels rose as much as 1.5 feet, the rises averaging 0.4 foot in 38 wells.

Figure 5 shows the relation of pumpage to depth to water in observation wells in the city of El Paso Canutillo well field. The hydrograph of well Q-86, in the shallow aquifer, shows that the water level was lowest during 1957 when available surface-water supplies from the Rio Grande for use by the city were only 1.8 mgd (Figure 9) and 5.1 mgd of ground water was pumped from the shallow city wells. Well Q-182, also in the shallow aquifer, is north of the city's shallow well field and is affected principally by pumpage from nearby irrigation wells, and to a smaller degree by pumpage from the city wells in the medium and deep aquifers.

The hydrograph of well Q-176, in the deep aquifer, shows large fluctuations of water levels because of the well's proximity to influencing deep wells. A lesser range in fluctuation of water levels in well Q-181, also in the deep aquifer, is due to the greater distance from heavy pumpage. Both wells show an overall decline during the period of record.

The fluctuation of water levels in well Q-203, in the medium aquifer, was caused mainly by pumpage from the shallow aquifer, indicating a degree of interconnection between the two aquifers. The fluctuations follow nearly the same pattern as those in wells Q-176 and Q-181; however, the similarity is apparent only after continued heavy pumpage from deep wells in the northern part of the well field.

## Lower Valley

The Lower Valley is primarily an irrigated farming area and the availability of water and fluctuations of water levels in wells that tap the alluvium are similar to those of the Upper Valley. The hydrographs of six wells in the alluvium in the Lower Valley are shown in Figure 6. The water levels in the wells were relatively stable during the period 1960-63, except for seasonal fluctuations, despite the decrease in the surface-water allotments in 1961 and the accompanying increase in ground-water use for irrigation. Plate 3 shows that during the 1960-63 period the water levels generally rose slightly in the eastern part of the valley and in a few isolated areas near the Rio Grande. In most of the area between U.S. Highway 80 and the river, the water levels declined slightly.

In 1962, water levels generally rose throughout most of the Lower Valley, except in two areas near the Rio Grande, where declines reached a maximum of 0.8 foot and averaged about 0.2 foot in 9 wells. In other parts of the valley, the water levels rose a maximum of 1.5 feet; the rises averaged 0.69 foot in 44 wells.

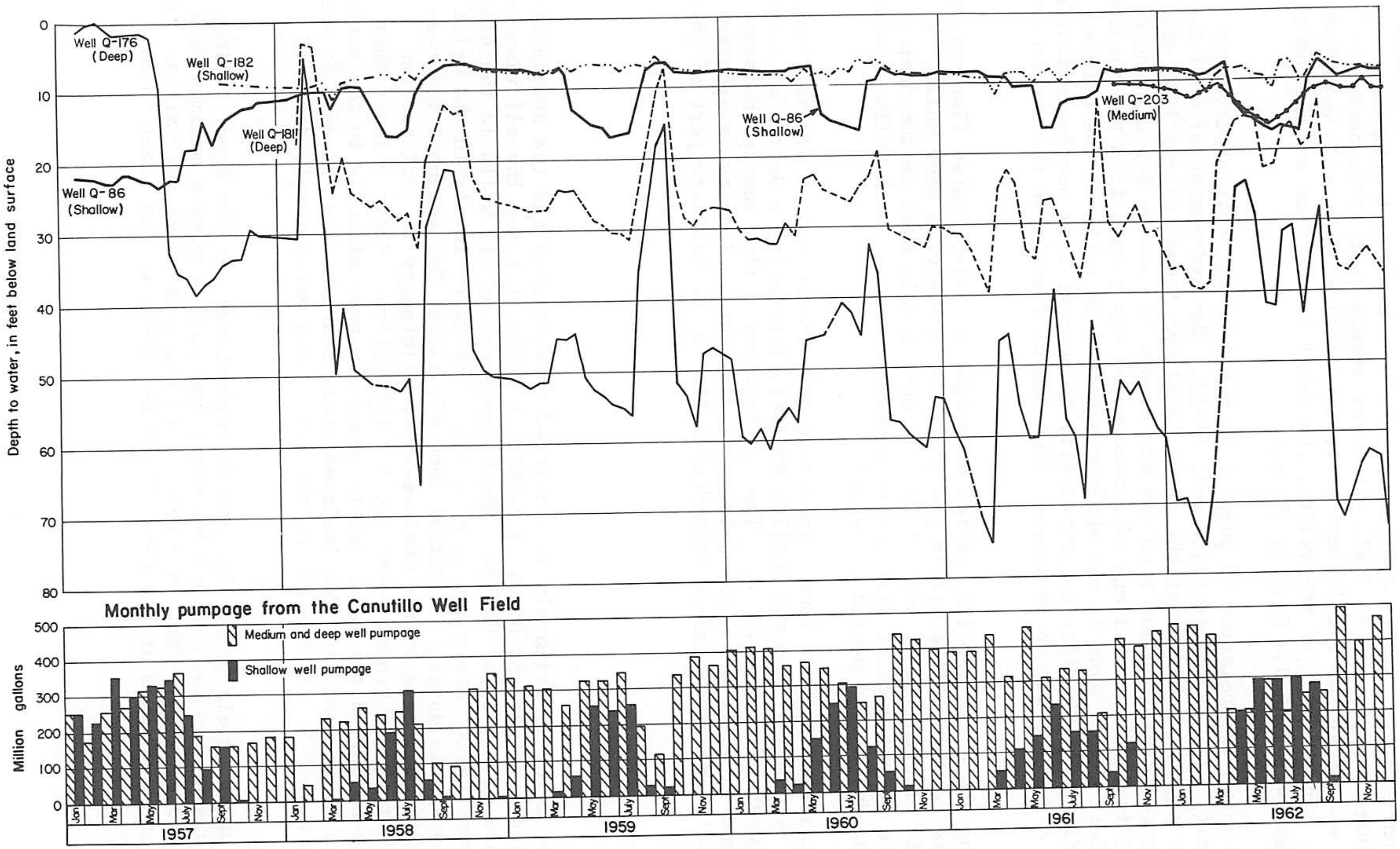


Figure 5

Relation of Pumpage to Depth to Water in the Canutillo Well Field of the City of El Paso

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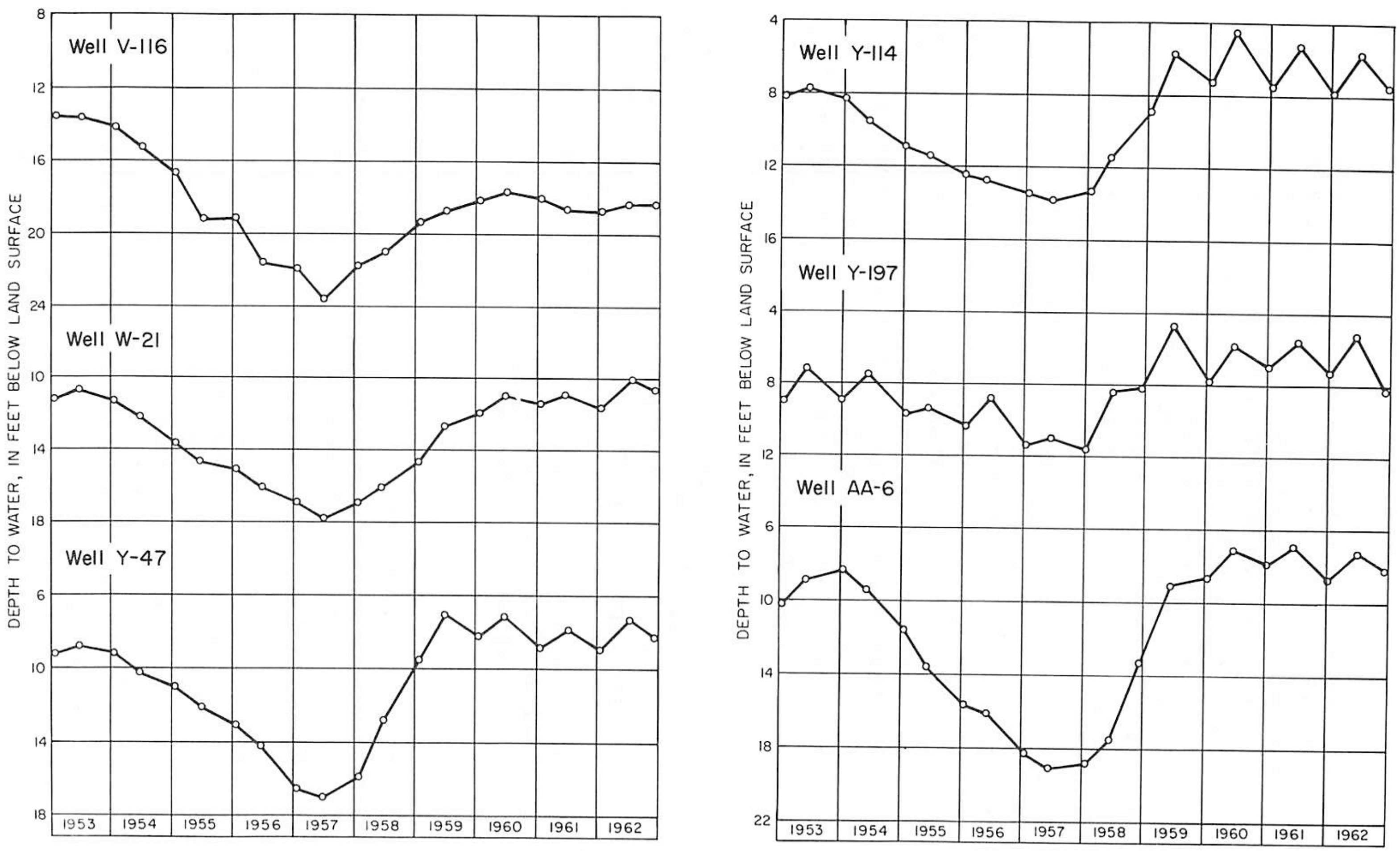


Figure 6

Hydrographs of Selected Wells in the Alluvium of the Lower Valley

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## Ground-Water Storage and Recovery

### Hueco Bolson

The saturated thickness of the deposits in the Hueco bolson in Texas that contain fresh water (less than 250 ppm of chloride) is shown by 100-foot contours on the isopachous map in Plate 5. In the Mesa area above the rimrock, the thickness was computed from the difference between the altitude of the base of the fresh water (Plate 6) and the altitude of the water table in the Mesa area (not shown). In the area below the rimrock, or City Artesian area, the fresh ground water is under artesian pressure and is underlain and overlain by saline water (more than 750 ppm of chloride); in this area, the thickness was determined from the aggregate screened intervals of each well.

Computations indicate that the volume of saturated material in the Hueco bolson in Texas is at least 50,000,000 acre-feet. Assuming an average specific yield of 15 percent for the bolson deposits, it is estimated that the Hueco bolson in Texas contains about 7,500,000 acre-feet of theoretically recoverable water having a chloride content of less than 250 ppm. Of this total, about 6,800,000 acre-feet of recoverable fresh water is in the Mesa area and 700,000 acre-feet in the City Artesian area. These estimates are conservative to some extent because some of the test wells in the Mesa area did not reach salt water and the altitude of the base of the fresh water may be lower in some areas than indicated in Plate 6. Also, the estimated specific yield may be larger than 15 percent.

Data from wells in the City Artesian area were insufficient to determine accurately the total thickness of fresh-water-bearing beds. It was assumed that reasonable consideration was given to placement of screen in the wells opposite the interval of the bolson deposits containing only fresh water; therefore, only those intervals were used in determining the aggregate thickness at each well. However, as the screens are usually placed opposite the thicker sections of sand bodies and may not include the thinner sands and less permeable deposits containing fresh water, the estimated volume of 700,000 acre-feet of fresh water may be conservative.

The percentage of water in the City Artesian area that can be recovered probably is less than in the water-table part of the Hueco bolson. Continued pumping in the artesian area will reduce the hydrostatic pressure in the fresh-water sands, allowing the overlying and underlying saline water to move into the fresh-water-bearing sands.

In 1954, Knowles and Kennedy (1958, p. 37) estimated that 7.4 million acre-feet of theoretically recoverable water was in storage in the water-table part of the Hueco bolson in Texas. This estimate, however, was based on the total thickness of saturated sand and gravel in the bolson deposits and a specific yield of 35 percent. Also, the computations did not include much of the Mesa area south of parallel 31°50' or any of area east of the 100-foot contour (Knowles and Kennedy, 1958, pl. 11).

Pumpage from the Hueco bolson since 1954 has amounted to about 463,000 acre-feet. Assuming that about 7.5 million acre-feet of fresh water was in storage in the Mesa and City Artesian areas in 1954 and the estimate of average recharge of about 15,000 acre-feet per year is correct (Sayre and Livingston, 1945, p. 72), then one-fourth of the pumpage was supplied by recharge and the reservoir has been depleted nearly 5 percent during the period 1955-1962, inclusive.

Although about 7.5 million acre-feet of water is theoretically recoverable from the Hueco bolson, probably only about 50 percent of the fresh water could be recovered before it became contaminated by saline water. On the basis of 50 percent recovery and an average recharge of about 15,000 acre-feet per year to the reservoir, 60 million gallons per day could be withdrawn from storage for about 75 years. This period could be extended by means of artificial recharge to the bolson deposits at times when water from the river is available, or by mixing the fresh water with inferior water (250 to 750 ppm of chloride).

### Upper Valley

In 1958, Leggat and others (1962, p. 38-39) estimated that 560,000 acre-feet of theoretically recoverable water with a chloride content of less than 250 ppm was in storage in the alluvium and bolson deposits (Santa Fe Group) in the Texas part of the Upper Valley; approximately 150,000 acre-feet was in the alluvium.

Pumpage from the Santa Fe Group since 1958 has been about 50,500 acre-feet or about 12 percent of the 410,000 acre-feet of fresh water presumed to be available in the Santa Fe in Texas. If the estimate of average recharge of about 14,500 acre-feet per year is correct (Leggat and others, 1962, p. 18), then all of the pumpage was supplied by recharge and the reservoir has not been depleted.

All the fresh water in storage cannot be withdrawn by wells. Where the fresh-water sands are underlain by saline water, probably no more than half the fresh water can be recovered before it becomes unsuitable for public supply.

The amount of water that can be recovered will depend on the withdrawal rate. The rated capacities of the present facilities and existing wells in the Upper Valley are about 24 mgd, or almost double the rate of estimated recharge to the medium and deep aquifers. If the wells were operated continuously at peak capacity the saline water would probably move toward the wells and by contamination the quantity of recoverable fresh water in storage would be reduced. That this may be already occurring is indicated in Figure 8, which shows a sharp increase in the chloride content of the water from well Q-181 from 114 ppm in 1961 to 190 ppm in 1962.

## Quality of Water

The fresh ground water is only a small part of the total quantity of water in storage in the El Paso district. The fresh-water sands generally are underlain, overlain, or adjoined by sands containing slightly saline water, the water generally increasing in salinity with depth as well as laterally. In this report, water containing less than 250 ppm of chloride is classed as fresh, water containing 250 to 750 ppm is classed as inferior, and water containing more than 750 ppm is classed as saline.

Plate 6 shows the approximate altitude of the base of the fresh-water-bearing deposits (less than 250 ppm of chloride) in the Mesa area. The contact between the fresh water and inferior water (250 to 750 ppm of chloride) was determined by analysis of water from drill stem tests and interpretation of electric logs. In the Mesa area, the fresh water occurs in a trough of irregular width and depth roughly parallel to the Franklin Mountains. The trough is relatively narrow near the Texas-New Mexico state line but widens and deepens progressively southward. In general, the slope of the base of the fresh water is rather steep near the mountains and becomes more gentle to the east. A ridge or nose in the base of the fresh water extends southward between Highways State 213 and FM 2529 to the vicinity of U.S. 54. Data are not sufficient to explain fully the ridge; however, the bolson deposits underlying the ridge generally are less permeable than in adjacent areas and probably have not been flushed out by fresh water to as great a depth.

Table 3 gives the results of chemical analyses of water samples made since 1959. Most of these analyses were made by the U.S. Geological Survey, and some were made by the Public Service Board of the city of El Paso. During the period 1960 to 1963, most of the chemical analyses were for the purpose of detecting changes in the chloride content of the ground water. When chemical changes are noted in the composition of the water, the chloride generally is the constituent showing the greatest change; therefore, it is used as an indicator of changes in the quality of the water. Selected wells throughout the district have been sampled periodically since 1935 to detect these changes.

Graphs showing the changes in chloride content of water from 4 wells in the Mesa area and 6 wells in the City Artesian area are shown in Figure 7. The water samples were taken after the wells had been pumped at least 24 hours in order to secure representative samples of water in the aquifers. The chlorographs of wells R-40, R-56, V-7, and V-19 show that the chloride content has varied throughout the period of record, although the net change in most of the wells has been relatively small. In wells in the Mesa area, the increase has not been serious; however, as pumping increases and causes the cone of depression to deepen and expand, the movement of saline water toward the wells may accelerate.

The fresh-water-bearing beds in the City Artesian area are overlain and underlain by deposits containing saline water; consequently, mineral contamination of the ground-water supplies may occur through interformational leakage or leaking casings. The chloride content of water from well V-45 (Figure 7) increased from about 250 ppm in 1937 to about 300 ppm in 1953; since then the chloride content has increased rapidly and by July 1963, it was 470 ppm. Tests have indicated that saline water enters the wells while they are idle and escapes into the fresh-water sands. During the early part of the pumping periods, the salinity of the water increases sharply, but as pumping continues the saline water is removed and the chloride content decreases. This is reflected in the sharp increase in chloride content during 1958-59, when water samples were collected from the well before it had been pumping long enough to remove the saline water. If the well had been in operation for several days before sampling, the chloride content probably would have been much less. Nevertheless, the increase in the chloride content as shown in Figure 7 indicates that leakage is substantial and that contamination may be expected to increase and eventually perhaps affect well V-49.

The wells known to be affected by contamination are not confined to any particular locality but are erratically distributed throughout the City Artesian area. The chloride content of water from well V-49, three-quarters of a mile from well V-45, decreased from 350 ppm in 1945 to about 210 ppm in 1950;

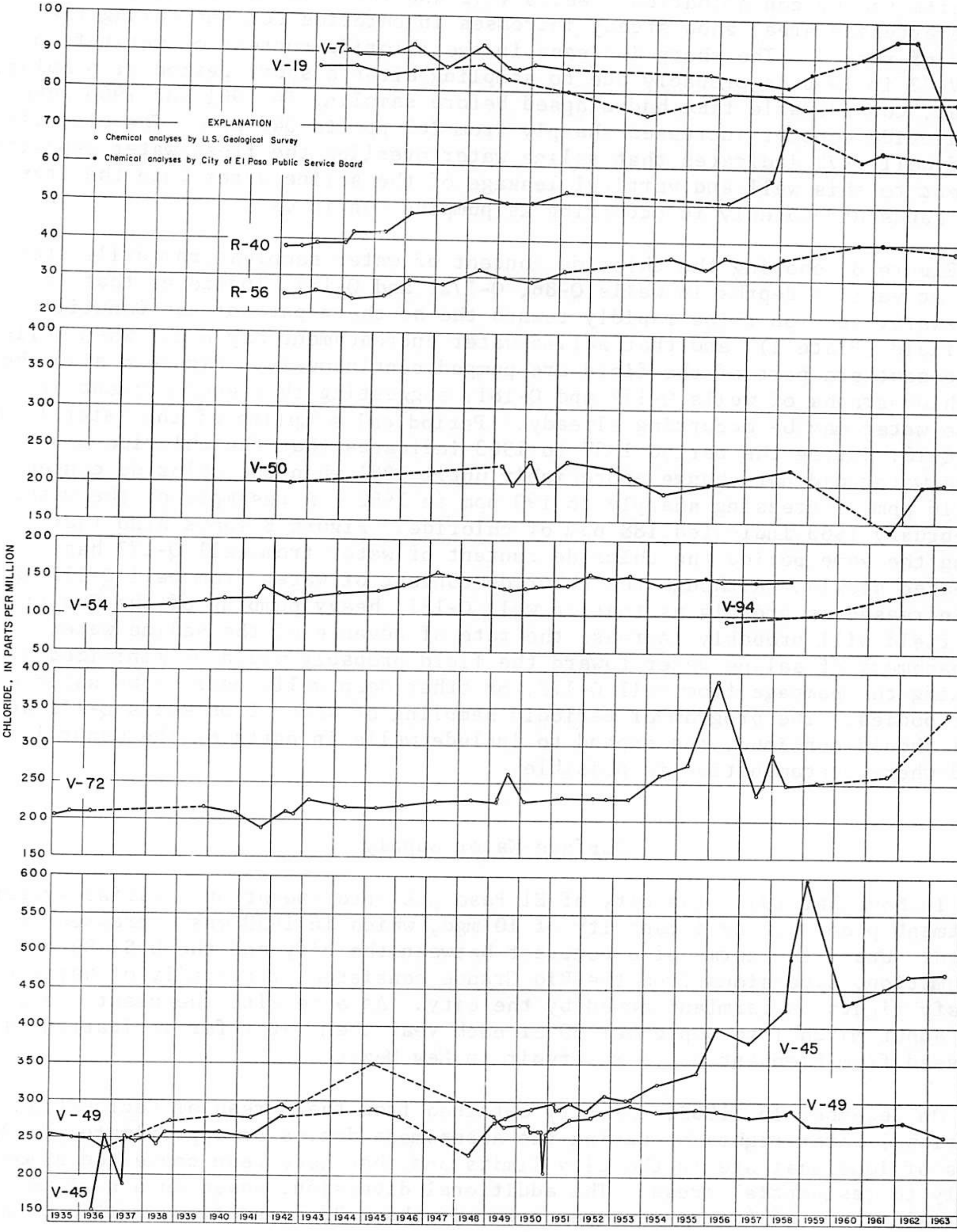


Figure 7

**Chlorographs of Selected Wells in the Mesa and City Artesian Areas**

U.S. Geological Survey in cooperation with the Texas Water Commission and the city of El Paso

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since then it increased to 290 ppm in 1953 and decreased to 255 ppm in 1963. Although well V-49 was more heavily pumped, the contamination has been less than at well V-45. Wells V-50 and V-54, also in the City Artesian area, have not been affected by contamination. Wells V-72 and V-94, in the refinery section of the artesian area, show steady increases in chloride content during the period of record. The sharp increase in the chloride content of water from well V-72 in 1956 is probably due to sampling after a short period of pumping; however, considerable time had elapsed before sampling in 1961 and 1963 when the chloride content increased sharply from 262 ppm to 345 ppm. The electric log of well V-72 indicates that saline water overlies the fresh-water deposits adjacent to this well and vertical leakage of the saline water into the fresh-water sands undoubtedly is occurring as pumping continues.

Figure 8, showing the chloride content of water samples from drill stem tests at various depths in wells Q-86, Q-172, and Q-181, indicates that the fresh-water section thins rapidly toward the southern part of the Canutillo well field (Plate 1), and that saline-water encroachment may occur when wells in the southern part of the field are pumped continuously. Figure 8 also shows the chlorographs of wells Q-172 and Q-181, suggesting that encroachment of saline water may be occurring already. Periodical sampling of the water from well Q-181 during the period 1957 to 1963 indicates that the chloride content of the water did not change appreciably until 1961 when the chloride content was 116 ppm, increasing sharply to 190 ppm in 1962. A resample of the water in February 1963 indicated 188 ppm of chloride. Figure 8 shows also that during the same period the chloride content of water from well Q-172 has increased slowly. Although the chloride content of water from well Q-172 has not increased as greatly as that in well Q-181, heavy pumping of the Canutillo well field will probably increase the rate of advance of the saline water. Encroachment of saline water toward the field probably would be minimized by reducing the pumpage from well Q-172, or other deep wells near known saline-water bodies. The program of periodic sampling of water from wells Q-172 and Q-181 should continue, and expand to include wells in parts of the Canutillo field where contamination is possible.

## Surface-Water Supply

In November 1943, the city of El Paso put into operation a surface-water treatment plant having a capacity of 10 mgd, which in 1950 was increased to 20 mgd. Under the terms of a contract between the city and the U.S. Bureau of Reclamation, diversions from the Rio Grande consisted principally of water to satisfy rights on farmland owned by the city. As a result, the plant operates from about March 1 to September 30 of each year when water for irrigation is released from Elephant Butte Reservoir in New Mexico.

On December 15, 1962, the city obtained from the Bureau of Reclamation additional water rights by paying the assessment duties on approximately 4,000 acres of land that are in the city limits and that have been converted almost wholly to residential areas. The additional diversion, based on a surface-water allotment of 4 acre-feet per acre, is about 23.7 mgd for 7 months of a year.

Figure 9 shows the average daily diversion of surface water from the Rio Grande by the city since 1943. Although the treatment plant operates only about 200 days each year, the average daily diversions were computed on the basis of an entire year. Water from the shallow aquifer in the Canutillo well

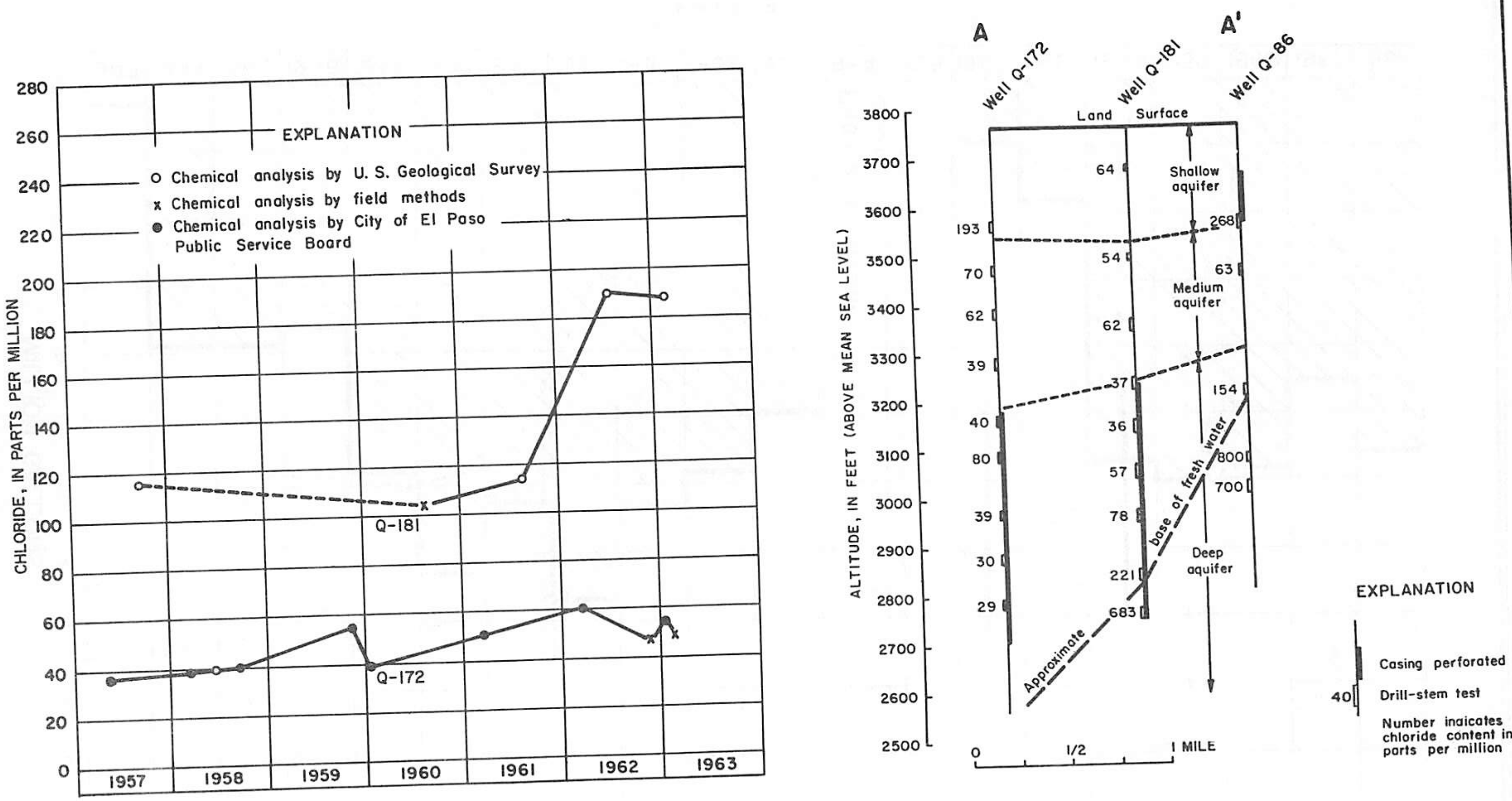


Figure 8

Relation of Chloride Content of Water in Wells Q-86, Q-172, and Q-181, and Increase in Chloride Content of Water Due to Pumping From Canutillo Well Field

U.S. Geological Survey in cooperation with the Texas Water Commission and the city of El Paso

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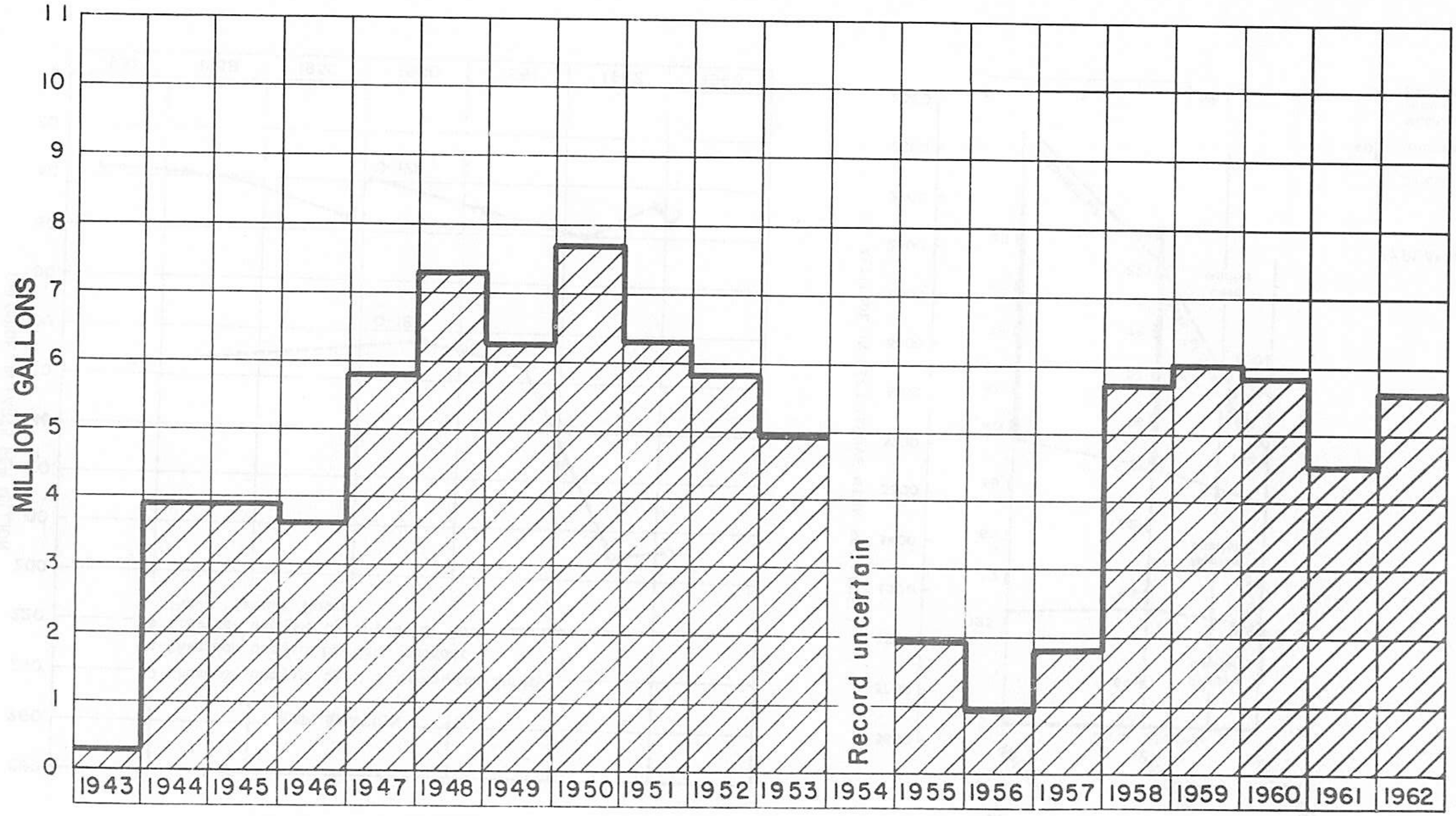


Figure 9

Average Daily Diversion of Water From the Rio Grande for Municipal Use at El Paso

U.S. Geological Survey in cooperation with the Texas Water Commission and the city of El Paso

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field (Plate 1) is pumped into the Rio Grande for delivery to the treatment plant and is not included in the diversion data.

## FUTURE DEVELOPMENT

Although additional surface-water supplies have been made available to the city of El Paso, ground-water supplies will continue to be the most important source of supply in the El Paso district. Increasing demands on municipal supplies during the summer peak period has caused the city of El Paso to utilize maximum pumpage from the well fields in the Mesa and Upper Valley areas. During 1962, approximately 83 percent of the total supply was obtained from ground-water sources.

The city is presently developing all known fresh ground-water sources in the Hueco bolson and Upper Valley areas in Texas. Additional wells for municipal supply are being drilled in existing well fields. The volume of theoretically recoverable fresh ground water in storage in the El Paso district in Texas is at least 7.5 million acre-feet; however, possibly less than 50 percent of the fresh water can be recovered before it becomes so contaminated by saline water as to be unsuitable for public supply.

Assuming that the future ground-water supply must come from sources in Texas, the only supplies remaining to be tapped are the undetermined but large quantities of water ranging in quality from inferior to saline that underlie and adjoin the fresh water in the Hueco bolson and Upper Valley in Texas. This water represents a large potential supply for the El Paso district which could be used by mixing with the fresh water or by desalinization.

# REFERENCES CITED


Audsley, G. L., 1959, Records of wells and results of exploratory drilling in the El Paso Valley and Hueco bolson southeast of El Paso, Texas: Texas Board Water Engineers open-file rept., 145 p.

Davis, M. E., and Leggat, E. R., 1962, Reconnaissance of the ground-water resources of the upper Rio Grande Basin in Texas: Texas Water Commission open-file rept., 145 p.

Knowles, D. B., and Kennedy, R. A., 1958, Ground-water resources of the Hueco bolson, northeast of El Paso, Texas: U.S. Geol. Survey Water-Supply Paper 1426, 186 p.

Leggat, E. R., 1962, Development of ground water in the El Paso district, Texas, 1955-60, Progress Report No. 8: Texas Water Commission Bull. 6204, 55 p.

Leggat, E. R., Lowery, M. E., and Hood, J. W., 1962, Geology and ground-water resources of the lower Mesilla Valley, Texas and New Mexico: Texas Water Commission Bull. 6203, 195 p.

Sayre, A.N., and Livingston, Penn, 1945, Ground-water resources of the El Paso area, Texas: U.S. Geol. Survey Water-Supply Paper 919, 190 p.

Scalapino, R. A., 1949, Ground-water resources of the El Paso area, Texas, Progress Report No. 6: Texas Board Water Engineers duplicated rept., 22 p.

Smith, R. E., 1956, Ground-water resources of the El Paso district, Texas, Progress Report No. 7: Texas Board Water Engineers Bull. 5603, 33 p.

Table 2.--Records of selected wells in the El Paso district, Texas

All wells are drilled unless otherwise noted in remarks column.
Water level : Reported water levels given in feet; measured water levels given in feet and tenths.
Method of lift and type of power: E, electric; G, gasoline, butane or Diesel engine; N, none; T, turbine. Number indicates horsepower.
Use of water : D, domestic; Ind, industrial; Irr, irrigation; N, none; P, public supply; S, stock.

| Well | Owner | Driller | Date completed | Depth of well (ft) | Diameter of well (in.) | Altitude of land surface (ft) | Water level: Below land-surface datum (ft) | Water level: Date of measurement | Method of lift | Use of water | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Q-193 | Texas State Highway Dept. | Brown & Ledford | 1959 | 190 | 6 | -- | 140 | Nov. 1959 | T,E | P | Casing: 6-in. slotted from 180-190 ft. Reported discharge 200 gpm. |
| Q-194 | Mountain Pass Canning Co. | Butte Pump Co. | 1958 | 300 | 8 | -- | 20 | May 1958 | T,E | Ind | Casing: 8-in. slotted from 250-300 ft. Reported discharge 500 gpm. |
| Q-195 | do | do | 1958 | 300 | 4 | -- | 20 | May 1958 | T,E | Ind | Casing: 4-in. slotted from 250-300 ft. Reported discharge 120 gpm. |
| Q-196 | City of El Paso well 114 | City of El Paso | 1960 | 551 | 24, 18 | -- | 23.1 | Feb. 2, 1960 | T,G | Irr | Casing: 18-in. slotted from 900-260 ft. Drilled to 551 ft, plugged back to 260 ft. Measured discharge 800 gpm, Feb. 3, 1960. |
| *Q-197 | City of El Paso well 206 | do | 1960 | 1,206 | 24, 18, 12 | -- | 48.1 | May 2, 1960 | -- | N | Casing: 12-in. slotted from 635-1,200 ft. Fresh-water sands extend at least to 1,206 ft. Drawdown measured 92.5 ft after 24 hours pumping 2,090 gpm. To be used for public supply. |
| *Q-198 | Westway well 1 | W. Cass | 1960 | 600 | 4 | 4,055 | 260.5 | Aug. 9, 1960 | N | N | Casing: 4-in. slotted from 330-600 ft. Reported discharge 25 gpm, Aug. 1960. Temp. 78°F. |
| *Q-199 | Westway well 2 | do | 1960 | 504 | 24, 12 | 3,975 | 209.1 | Oct. 26, 1960 | T,E | P | Casing: 12-in. slotted from 220-410 ft. Measured drawdown 100 ft after 4 hours pumping 750 gpm, Oct. 13, 1960. Well plugged back to 410 ft. |
| *Q-200 | Border Steel Rolling Mill | Layne-Texas Co. Ltd. | 1960 | 602 | 24, 16 | 3,900 | 150 | Dec. 1960 | T,E | P,Ind | Casing: 16-in. slotted from 200-430 ft. Reported drawdown 45 ft after 24 hours pumping 909 gpm, Dec. 1960. Well plugged back to 440 ft. |
| *Q-201 | City of El Paso well 302 | City of El Paso | 1961 | 461 | 24, 18 | 3,770 | 12.2 | Mar. 8, 1961 | -- | N | Casing: 18-in. slotted from 275-444 ft. Measured drawdown 75.2 ft after 8 hours pumping 1,200 gpm, Mar. 8, 1961. |

See footnotes at end of table.

Table 2.--Records of selected wells in the El Paso district, Texas--Continued

| Well | Owner | Driller | Date completed | Depth of well (ft) | Diameter of well (in.) | Altitude of land surface (ft) | Water level: Below land-surface datum (ft) | Water level: Date of measurement | Method of lift | Use of water | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Q-202 | City of El Paso well 303 | City of El Paso | 1961 | 1,102 | 24, 18 | -- | 7.6 | Sept. 26, 1961 | -- | N | Casing: 18-in. slotted from 356-550 ft. Measured drawdown 87 ft after 8 hours pumping 1,600 gpm, Sept. 11, 1961. Well plugged back to 550 ft. |
| *Q-203 | City of El Paso well CR-5 | do | 1961 | 937 | 6 | -- | 10.4 | Oct. 17, 1961 | N | N | Observation well. Canutillo recorder. Well plugged back to 545 ft. |
| Q-204 | Border Steel Rolling Mill | Brown & Ledford | 1961 | 229 | 10, 8 | -- | 130 | July 1961 | T,E | Ind | Casing: 8-in. slotted from 209-229 ft. Reported discharge 25 gpm, July 1961. |
| R-87 | City of El Paso | City of El Paso | 1959 | 91 | 41 | -- | -- | -- | N | N | Casing: 41-in. slotted from 66-90 ft. Dug well. Well used for recharge experiment. |
| R-88 | City of El Paso well 52 | do | 1961 | 1,252 | 24, 18, 12 | 4,127 | 438.4 | Mar. 5, 1962 | -- | N | Casing: 18-in. slotted from 480-802 ft; 12-in. from 802-1,152 ft. Measured drawdown 67.0 ft. after 20 hours pumping 1,065 gpm, Mar. 5, 1962. Well plugged back to 1,152 ft. To be used for public supply. |
| *R-89 | City of El Paso well E-4 | do | 1962 | 825 | 24, 18 | 4,064 | 359.2 | Aug. 6, 1962 | -- | N | Casing: 18-in. slotted from 376-665 ft. Measured drawdown 36.5 ft after $6\frac{1}{2}$ hours pumping 1,200 gpm, Aug. 7, 1962. Well plugged back to 665 ft. To be used for industrial supply. |
| T-6 | O'Leary Realty | H. S. Payne | 1960 | 160 | -- | -- | -- | -- | N | N | Abandoned in bedrock |
| T-7 | do | do | 1960 | 430 | 10 | -- | 380 | Sept. 1960 | T,G | P | Casing: 10-in. slotted from 390-430 ft. Reported discharge 60 gpm. |
| *T-8 | D. R. Ponder | Layne-Texas Co. Ltd. | 1962 | 510 | 10 | -- | 392 | Aug. 1962 | N | N | Casing: 10-in. slotted from 380-480 ft. Reported drawdown 73 ft after 3 hours pumping 22 gpm, Aug. 1962. |
| *V-42 | City of El Paso well MR-2 | City of El Paso | 1961 | 1,092 | 5 | 3,944 | 289.4 | Aug. 18, 1961 | N | N | Drilled as replacement of observation well V-42. Well plugged back to 750 ft. |
| *V-141 | City of El Paso well 45 | do | 1960 | 930 | 24, 18, 12 | 3,952 | 292.9 | Nov. 28, 1960 | T,E | P | Casing: 18-in. slotted from 320-500 ft; 12-in. from 500-830 ft. Measured drawdown 85.3 ft after 8 hours pumping 1,400 gpm, Dec. 6, 1960. Well plugged back to 830 ft. |

See footnotes at end of table.

Table 2.--Records of selected wells in the El Paso district, Texas--Continued

| Well | Owner | Driller | Date completed | Depth of well (ft) | Diameter of well (in.) | Altitude of land surface (ft) | Water level: Below land-surface datum (ft) | Water level: Date of measurement | Method of lift | Use of water | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *V-142 | City of El Paso well 46 | City of El Paso | 1960 | 831 | 24, 12 | 3,946 | 281.0 | Nov. 18, 1960 | T,E | P | Casing: 18-in. slotted from 320-550 ft; 12-in. from 550-745 ft. Measured drawdown 53.8 ft after 8 hours pumping 1,200 gpm, Nov. 18, 1960. Well plugged back to 745 ft. |
| *V-143 | City of El Paso test well 47 | do | 1960 | 722 | 4 | 3,988 | 300.7 | Nov. 15, 1960 | N | N | Observation well. Well plugged back to 490 ft. Temp 75°F. |
| *V-144 | City of El Paso well 48 | do | 1961 | 705 | 24, 18, 12 | 3,946 | 281.4 | Jan. 23, 1961 | T,E | P | Casing: 18-in. slotted from 299-500 ft; 12-in. from 500-618 ft. Measured drawdown 13.0 ft after 8 hours pumping 1,000 gpm, Jan. 23, 1961. Well plugged back to 618 ft. Temp 78°F. |
| *V-145 | City of El Paso well 49 | do | 1961 | 993 | 24, 18, 12 | 3,933 | 289.4 | June 23, 1961 | -- | N | Casing: 18-in. slotted from 398-536 ft; 12-in. from 536-838 ft. Measured drawdown 60.6 ft after 8 hours pumping 1,600 gpm, June 23, 1961. Well plugged back to 838 ft. |
| *V-146 | City of El Paso well 50 | do | 1961 | 901 | 24, 18, 12 | 3,938 | 291.1 | June 19, 1961 | -- | N | Casing: 18-in. slotted from 383-520 ft; 12-in. from 520-747 ft. Measured drawdown 62.4 ft after 8 hours pumping 1,400 gpm, June 19, 1961. Well plugged back to 747 ft. |
| *V-147 | Standard Oil Co. well 9 | W. Cass | 1961 | 803 | 20, 14, 12 | -- | 163 | Feb. 1962 | T,E | Ind | Casing: 14-in. screened from 225-330 ft; 12-in. from 330-750 ft. Reported drawdown 32.5 ft after 24 hours pumping 720 gpm, Feb. 1961. Well plugged back to 750 ft. |
| V-148 | Standard Oil Co. well 10 | do | 1961 | 951 | -- | -- | -- | -- | N | N | Abandoned. Insufficient water. |
| V-149 | East Side Development & Country Club | Layne-Texas Co. Ltd. | 1961 | 595 | -- | -- | -- | -- | N | N | Test well. |
| V-150 | Biggs Air Force Base well 2-A | do | 1961 | 775 | 24, 16, 10 | -- | 270 | Aug. 1961 | T,E, 125 | P | Casing: 16-in. screen from 316-400 ft; 10-in. from 440-760 ft. Reported drawdown 58 ft after 23 hours pumping 1,200 gpm, Aug. 23, 1961. |

See footnotes at end of table.

Table 2.--Records of selected wells in the El Paso district, Texas--Continued

| Well | Owner | Driller | Date completed | Depth of well (ft) | Diameter of well (in.) | Altitude of land surface (ft) | Water level: Below land-surface datum (ft) | Water level: Date of measurement | Method of lift | Use of water | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| V-151 | Price's Dairy | Layne-Texas Co. Ltd. | 1956 | 562 | 26, 20, 12, 10 | -- | 76 | May 1956 | T,E | D,S, Ind | Casing: 10-in. screen from 272-550 ft. Reported drawdown 33 ft after 24 hours pumping 662 gpm, May 5, 1956. |
| *BB-46 | J. Burner | K. C. Wheeler | 1960 | 428 | 10 | -- | 52.8 | Sept. 2, 1960 | T,E | S,Irr | Casing: 10-in. slotted from 261-428 ft. Reported drawdown 110 ft after 24 hours pumping 1,000 gpm, May 1960. |

*For chemical analysis of water from selected wells in the El Paso district see Table 3.

Table 3.--Chemical analyses of water from selected wells in the El Paso district, 1960-62

(Analyses given are in parts per million, except specific conductance, pH, percent sodium, and sodium adsorption ratio)

| Well | Owner | Depth of well (ft) | Date of collection | Silica ($SiO_2$) | Iron (Fe) | Manganese (Mn) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Flouride (F) | Nitrate ($NO_3$) | Phosphate ($PO_4$) | Boron (B) | Dissolved solids | Hardness as $CaCO_3$ | Percent sodium | Sodium adsorption ratio (SAR) | Specific conductance (micromhos at 25°C) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Q-181 | City of El Paso well CR-3 | 1,013 | Aug. 1, 1961 | 44 | -- | -- | 23 | 1.4 | *115 | | 70 | 91 | 114 | -- | 0.0 | -- | -- | 422 | 64 | 80 | 6.2 | 683 | 7.6 |
| Q-181 | do | 1,013 | July 13, 1962 | 37 | -- | -- | 42 | 2.3 | *144 | | 62 | 102 | 190 | 0.8 | .0 | -- | -- | 548 | 114 | 73 | 5.9 | 930 | 7.4 |
| Q-181 | do | 1,013 | Feb. 13, 1963 | -- | -- | -- | -- | -- | -- | -- | 64 | -- | 188 | -- | -- | -- | -- | -- | 119 | -- | -- | 936 | 7.5 |
| b/ Q-197 | City of El Paso well 206 | c/ 88-118 | Feb. 27, 1960 | -- | -- | -- | 23 | 6 | -- | -- | 117 | 130 | 96 | -- | -- | -- | -- | 619 | 82 | -- | -- | -- | 8.4 |
| b/ Q-197 | do | c/ 184-209 | Feb. 28, 1960 | -- | -- | -- | 16 | 3 | -- | -- | 172 | 131 | 43 | -- | -- | -- | -- | 607 | 50 | -- | -- | -- | 8.3 |
| b/ Q-197 | do | c/ 275-300 | do | -- | -- | -- | 31 | 4 | -- | -- | 110 | 202 | 96 | -- | -- | -- | -- | 771 | 94 | -- | -- | -- | 8.1 |
| b/ Q-197 | do | c/ 394-419 | Feb. 29, 1960 | -- | -- | -- | 29 | 4 | -- | -- | 143 | 174 | 92 | -- | -- | -- | -- | 686 | 90 | -- | -- | -- | 7.9 |
| b/ Q-197 | do | c/ 513-538 | do | -- | -- | -- | 15 | 8 | -- | -- | 76 | 137 | 34 | -- | -- | -- | -- | 428 | 50 | -- | -- | -- | 7.9 |
| b/ Q-197 | do | c/ 623-648 | Mar. 1, 1960 | -- | -- | -- | 20 | 8 | -- | -- | 104 | 161 | 33 | -- | -- | -- | -- | 506 | 54 | -- | -- | -- | 7.9 |
| b/ Q-197 | do | c/ 739-764 | do | -- | -- | -- | 15 | 7 | -- | -- | 88 | 99 | 39 | -- | -- | -- | -- | 418 | 44 | -- | -- | -- | 8.0 |
| b/ Q-197 | do | c/ 845-870 | Mar. 2, 1960 | -- | -- | -- | 6 | 0 | -- | -- | 85 | 57 | 29 | -- | -- | -- | -- | 405 | 20 | -- | -- | -- | 8.5 |
| b/ Q-197 | do | c/ 965-990 | do | -- | -- | -- | 4 | 0 | -- | -- | 85 | 99 | 28 | -- | -- | -- | -- | 334 | 19 | -- | -- | -- | 8.2 |
| b/ Q-197 | do | c/ 1,116-1,141 | do | -- | -- | -- | 3 | 0 | -- | -- | 83 | 42 | 26 | -- | -- | -- | -- | 265 | 12 | -- | -- | -- | 8.2 |
| Q-197 | do | 1,200 | May 3, 1960 | 29 | 0.01 | 0.01 | 5.0 | .1 | 86 | 1.0 | a/ 81 | 74 | 43 | .7 | .0 | 0.03 | 0.09 | 279 | 13 | 92 | .10 | 438 | 8.8 |
| Q-198 | Westway well 1 | 600 | Oct. 13, 1960 | 22 | -- | -- | 96 | 51 | *175 | | 265 | 218 | 272 | -- | 1.5 | -- | -- | 966 | 449 | 46 | 3.6 | 1,620 | 7.2 |
| Q-199 | Westway well 2 | 410 | do | 33 | .69 | .16 | 64 | 38 | 166 | 13 | 189 | 219 | 215 | .4 | 1.0 | .06 | .27 | 843 | 316 | 52 | 4.1 | 1,380 | 7.5 |
| Q-200 | Border Street Rolling Mill Co. | 440 | Dec. 2, 1960 | 28 | .17 | -- | 68 | 38 | *246 | | 198 | 199 | 345 | 1.8 | 1.0 | -- | -- | 1,020 | 326 | 62 | 5.9 | 1,770 | 7.2 |

See footnotes at end of table.

Table 3.--Chemical analyses of water from selected wells in the El Paso district, 1960-62--Continued

| Well | Owner | Depth of well (ft) | Date of collection | Silica ($SiO_2$) | Iron (Fe) | Manganese (Mn) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Flouride (F) | Nitrate ($NO_3$) | Phosphate ($PO_4$) | Boron (B) | Dissolved solids | Hardness as $CaCO_3$ | Percent sodium | Sodium adsorption ratio (SAR) | Specific conductance (micromhos at 25°C) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| b/ Q-201 | City of El Paso well 302 | c/ 250-275 | Feb. 16, 1961 | -- | 0.02 | -- | 3 | 0 | -- | -- | 99 | 116 | 55 | 0.7 | -- | -- | -- | 414 | 9 | -- | -- | -- | 8.4 |
| b/ Q-201 | do | c/ 435-460 | Feb. 17, 1961 | -- | .02 | -- | 2 | 0 | -- | -- | 109 | 181 | 54 | -- | -- | -- | -- | 558 | 8 | -- | -- | -- | 8.5 |
| b/ Q-201 | do | 444 | Feb. 20, 1961 | -- | .02 | -- | 3 | 0 | -- | -- | 92 | 88 | 52 | .9 | -- | -- | -- | 197 | 9 | -- | -- | -- | 8.6 |
| b/ Q-202 | City of El Paso well 303 | c/ 253-278 | Aug. 7, 1961 | -- | .04 | -- | 11 | 3 | -- | -- | 110 | 121 | 65 | .9 | -- | -- | -- | 556 | 40 | -- | -- | -- | 9.4 |
| b/ Q-202 | do | c/ 344-369 | do | -- | .04 | -- | 11 | 2 | -- | -- | 111 | 104 | 55 | .5 | -- | -- | -- | 348 | 36 | -- | -- | -- | 9.1 |
| b/ Q-202 | do | c/ 434-459 | Aug. 8, 1961 | -- | .03 | -- | 10 | 1 | -- | -- | 99 | 96 | 65 | .4 | -- | -- | -- | 365 | 30 | -- | -- | -- | 8.7 |
| b/ Q-202 | do | c/ 528-553 | do | -- | .08 | -- | 9 | 4 | -- | -- | 99 | 93 | 65 | .6 | -- | -- | -- | -- | 40 | -- | -- | -- | 8.8 |
| b/ Q-202 | do | c/ 633-658 | Aug. 9, 1961 | -- | .03 | -- | 8 | 2 | -- | -- | 101 | 85 | 67 | .5 | -- | -- | -- | 364 | 28 | -- | -- | -- | 9.0 |
| b/ Q-202 | do | c/ 779-804 | do | -- | .03 | -- | 7 | 1 | -- | -- | 104 | 105 | 55 | .4 | -- | -- | -- | 376 | 21 | -- | -- | -- | 9.0 |
| b/ Q-202 | do | c/ 935-960 | Aug. 10, 1961 | -- | .05 | -- | 20 | 1 | -- | -- | 55 | 89 | 350 | .4 | -- | -- | -- | 660 | 54 | -- | -- | -- | 8.3 |
| b/ Q-202 | do | c/ 1,075-1,101 | do | -- | .07 | -- | 53 | 5 | -- | -- | 41 | 398 | 540 | .5 | -- | -- | -- | 1,542 | 152 | -- | -- | -- | 9.1 |
| Q-203 | City of El Paso well CR-3 | 445-545 | Feb. 14, 1963 | 34 | .05 | -- | 8.5 | 0.0 | *81 | | 78 | 75 | 37 | 1.0 | 0.0 | -- | -- | 275 | 21 | 89 | 7.7 | 413 | 7.9 |
| R-15 | U.S. Army | 450 | Aug. 18, 1961 | -- | -- | -- | -- | -- | -- | -- | 130 | -- | 173 | -- | -- | -- | -- | -- | 116 | -- | -- | 838 | 6.9 |
| R-16 | do | 550 | do | -- | -- | -- | -- | -- | -- | -- | 96 | -- | 452 | -- | -- | -- | -- | -- | 219 | -- | -- | 1,660 | 6.7 |
| R-40 | City of El Paso well 21 | 806 | July 27, 1963 | -- | -- | -- | -- | -- | -- | -- | 196 | -- | 62 | -- | -- | -- | -- | -- | 182 | -- | -- | 676 | 7.7 |
| R-48 | U.S. Army well 12-A | 814 | May 16, 1961 | 37 | .00 | -- | 19 | 6.4 | *84 | | 160 | 54 | 44 | 1.0 | 7.0 | -- | -- | 340 | 74 | 71 | 4.2 | 533 | 7.4 |
| R-51 | U.S. Army well 13 | 800 | do | 37 | .08 | -- | 19 | 6.6 | *88 | | 166 | 55 | 45 | 1.0 | 6.9 | -- | -- | 340 | 74 | 72 | 4.4 | 546 | 7.4 |

See footnotes at end of table.

Table 3.--Chemical analyses of water from selected wells in the El Paso district, 1960-62--Continued

| Well | Owner | Depth of well (ft) | Date of collection | Silica ($SiO_2$) | Iron (Fe) | Manganese (Mn) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Flouride (F) | Nitrate ($NO_3$) | Phosphate ($PO_4$) | Boron (B) | Dissolved solids | Hardness as $CaCO_3$ | Percent sodium | Sodium adsorption ratio (SAR) | Specific conductance (micromhos at 25°C) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R-52 | U.S. Army well 10 | 812 | May 16, 1961 | 43 | 0.2 | -- | 24 | 8.7 | *117 | | 201 | 83 | 62 | 1.3 | 9.0 | -- | -- | 447 | 96 | 73 | 5.2 | 713 | 7.4 |
| R-56 | City of El Paso well 20 | 909 | July 26, 1963 | -- | -- | -- | -- | -- | -- | -- | 178 | -- | 38 | -- | -- | -- | -- | -- | 154 | -- | -- | 480 | 7.7 |
| R-63 | City of El Paso well 31 | 840 | Aug. 28, 1962 | 31 | .12 | -- | 32 | 15 | 104 | 2.9 | 222 | 64 | 81 | 1.5 | 2.8 | -- | 0.11 | 443 | 142 | 61 | 3.8 | 748 | 7.3 |
| R-68 | City of El Paso well 32 | 650 | do | 33 | .01 | -- | 30 | 9.0 | 104 | 9.8 | 170 | 74 | 90 | .9 | 1.8 | -- | .16 | 437 | 112 | 64 | 4.3 | 735 | 7.4 |
| R-71 | City of El Paso well 35 | 700 | July 25, 1962 | 32 | .02 | 0.00 | 22 | 4.5 | 65 | 4.7 | 118 | 34 | 58 | .7 | 4.0 | 0.03 | .12 | 283 | 73 | 64 | 3.3 | 462 | 7.4 |
| R-72 | City of El Paso well 42 | 670 | May 25, 1962 | 33 | .04 | .00 | 30 | 6.6 | 81 | 4.5 | 149 | 55 | 73 | .6 | 5.9 | .01 | .13 | 363 | 102 | 62 | 3.5 | 604 | 7.3 |
| R-76 | U.S. Army well 14 | 817 | June 14, 1961 | 34 | .01 | -- | 21 | 6.9 | *84 | | 154 | 52 | 54 | .9 | 5.8 | -- | -- | 338 | 81 | 69 | 4.1 | 554 | 7.5 |
| R-82 | City of El Paso well 40 | 825 | May 25, 1962 | 31 | .07 | .00 | 22 | 5.9 | 71 | 7.0 | 135 | 46 | 54 | .8 | 6.3 | .02 | .15 | 310 | 79 | 64 | 3.5 | 501 | 7.4 |
| R-83 | U.S. Army well 15 | 818 | May 16, 1961 | 31 | .00 | -- | 18 | 6.1 | *78 | | 136 | 40 | 56 | 1.1 | 6.3 | -- | -- | 306 | 70 | 71 | 4.1 | 505 | 6.9 |
| R-84 | City of El Paso well 41 | 515 | July 14, 1962 | 35 | .05 | .00 | 25 | 5.8 | 114 | 7.8 | 150 | 67 | 106 | 1.0 | 2.2 | .02 | .05 | 438 | 86 | 72 | 5.3 | 724 | 7.2 |
| R-86 | City of El Paso well 44 | 770 | May 25, 1962 | 31 | .03 | .00 | 18 | 4.0 | 64 | 3.7 | 110 | 28 | 55 | .8 | 6.2 | .03 | .12 | 265 | 61 | 68 | 3.6 | 434 | 7.4 |
| R-89 | El Paso Electric Co. well 4 | 665 | Aug. 20, 1962 | 37 | -- | -- | 28 | 6.6 | *126 | | 180 | 78 | 97 | 1.1 | 2.5 | -- | -- | 465 | 97 | 74 | 5.6 | 777 | 7.5 |
| T-8 | D. R. Ponder | 480 | Aug. 22, 1962 | 27 | -- | -- | 66 | 5.8 | *426 | | 54 | 344 | 502 | 1.2 | .8 | -- | -- | 1,400 | 188 | 83 | 14 | 2,440 | 7.0 |
| V-7 | City of El Paso well 15 | 1,078 | July 27, 1963 | -- | -- | -- | -- | -- | -- | -- | 204 | -- | 68 | -- | -- | -- | -- | -- | 94 | -- | -- | 811 | 7.6 |
| V-15 | Biggs Air Force Base | 750 | Aug. 18, 1961 | -- | -- | -- | -- | -- | -- | -- | 134 | -- | 58 | -- | -- | -- | -- | -- | 64 | -- | -- | 525 | 7.5 |

See footnotes at end of table.

Table 3.--Chemical analyses of water from selected wells in the El Paso district, 1960-62--Continued

| Well | Owner | Depth of well (ft) | Date of collection | Silica ($SiO_2$) | Iron (Fe) | Manganese (Mn) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Flouride (F) | Nitrate ($NO_3$) | Phosphate ($PO_4$) | Boron (B) | Dissolved solids | Hardness as $CaCO_3$ | Percent sodium | Sodium adsorption ratio (SAR) | Specific conductance (micromhos at 25°C) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V-19 | City of El Paso well 19 | 950 | July 26, 1963 | -- | -- | -- | -- | -- | -- | -- | 200 | -- | 78 | -- | -- | -- | -- | -- | 96 | -- | -- | 842 | 7.5 |
| V-42 | City of El Paso well MR-2 | c/ 393-418 | July 14, 1961 | 25 | -- | -- | 16 | 6.3 | *92 | | 184 | 62 | 30 | 0.9 | 5.3 | -- | -- | 328 | 66 | 75 | 4.9 | 523 | 7.8 |
| b/ V-42 | do | c/ 489-514 | July 13, 1961 | -- | 0.02 | -- | 18 | 6 | -- | -- | 193 | 94 | 45 | .7 | -- | -- | -- | 361 | 70 | -- | -- | -- | 8.3 |
| b/ V-42 | do | c/ 616-641 | July 14, 1961 | -- | .02 | -- | 18 | 4 | -- | -- | 205 | 83 | 55 | .7 | -- | -- | -- | 377 | 62 | -- | -- | -- | 8.0 |
| b/ V-42 | do | c/ 751-776 | July 15, 1961 | -- | .02 | -- | 16 | 4 | -- | -- | 157 | 60 | 70 | .6 | -- | -- | -- | 356 | 58 | -- | -- | -- | 8.1 |
| V-42 | do | c/ 902-927 | Aug. 17, 1961 | -- | -- | -- | -- | -- | -- | -- | 120 | 52 | 130 | -- | -- | -- | -- | -- | 50 | -- | -- | 717 | 7.8 |
| V-42 | do | c/ 1,067-1,092 | Aug. 19, 1961 | -- | -- | -- | -- | -- | -- | -- | 40 | 106 | 1,250 | -- | -- | -- | -- | -- | 535 | -- | -- | 4,100 | 6.6 |
| V-45 | City of El Paso well 3 | 862 | Aug. 2, 1961 | -- | -- | -- | -- | -- | -- | -- | 108 | -- | 452 | -- | -- | -- | -- | -- | 346 | -- | -- | 1,730 | 7.5 |
| V-45 | do | 862 | July 18, 1963 | -- | -- | -- | -- | -- | -- | -- | 146 | -- | 470 | -- | -- | -- | -- | -- | 420 | -- | -- | 1,790 | 7.1 |
| V-49 | City of El Paso well 4 | 882 | Aug. 2, 1961 | -- | -- | -- | -- | -- | -- | -- | 160 | -- | 272 | -- | -- | -- | -- | -- | 180 | -- | -- | 1,220 | 7.5 |
| V-49 | do | 882 | July 18, 1963 | -- | -- | -- | -- | -- | -- | -- | 160 | -- | 255 | -- | -- | -- | -- | -- | 184 | -- | -- | 1,150 | 7.3 |
| V-72 | The Texas Co. well 1 | 694 | Aug. 2, 1961 | -- | -- | -- | -- | -- | -- | -- | 146 | -- | 262 | -- | -- | -- | -- | -- | 150 | -- | -- | 1,210 | 7.6 |
| V-72 | do | 694 | July 16, 1963 | -- | -- | -- | -- | -- | -- | -- | 146 | -- | 345 | -- | -- | -- | -- | -- | 242 | -- | -- | 1,440 | 7.2 |
| V-94 | Phelps Dodge Refining Co. well 4 | 612 | Aug. 3, 1961 | -- | -- | -- | -- | -- | -- | -- | 176 | -- | 125 | -- | -- | -- | -- | -- | 113 | -- | -- | 859 | 7.9 |
| V-94 | do | 612 | Aug. 15, 1963 | -- | -- | -- | -- | -- | -- | -- | 168 | -- | 155 | -- | -- | -- | -- | -- | 136 | -- | -- | 991 | 7.3 |
| V-98 | Standard Oil Co. well 7 | 750 | Aug. 2, 1961 | -- | -- | -- | -- | -- | -- | -- | 191 | -- | 110 | -- | -- | -- | -- | -- | 104 | -- | -- | 848 | 8.0 |
| V-138 | Falstaff Brewing Co. well 3 | 413 | Aug. 4, 1961 | -- | -- | -- | -- | -- | -- | -- | 153 | -- | 275 | -- | -- | -- | -- | -- | 217 | -- | -- | 1,300 | 7.6 |

See footnotes at end of table.

Table 3.--Chemical analyses of water from selected wells in the El Paso district, 1960-62--Continued

| Well | Owner | Depth of well (ft) | Date of collection | Silica ($SiO_2$) | Iron (Fe) | Manganese (Mn) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Flouride (F) | Nitrate ($NO_3$) | Phosphate ($PO_4$) | Boron (B) | Dissolved solids | Hardness as $CaCO_3$ | Percent sodium | Sodium adsorption ratio (SAR) | Specific conductance (micromhos at 25°C) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V-141 | City of El Paso well 45 | 830 | Dec. 1, 1960 | 27 | 0.04 | -- | 17 | 6.7 | *82 | | 170 | 58 | 30 | 0.7 | 5.2 | -- | -- | 311 | 70 | 72 | 4.3 | 496 | 7.6 |
| V-142 | City of El Paso well 46 | 745 | Nov. 19, 1960 | 30 | .02 | 0.01 | 23 | 7.2 | 104 | 7.9 | 146 | 59 | 98 | .7 | 2.5 | 0.07 | 0.03 | 404 | 87 | 70 | 4.8 | 669 | 8.0 |
| V-143 | City of El Paso test well 47 | c/ 697-722 | Nov. 9, 1960 | -- | -- | -- | -- | -- | -- | -- | 71 | 368 | 1,620 | -- | -- | -- | -- | -- | 570 | -- | -- | 5,580 | 7.6 |
| V-143 | do | 480 | Nov. 14, 1960 | 28 | -- | -- | 24 | 7.4 | *162 | | 134 | 44 | 200 | .8 | 4.5 | -- | -- | 537 | 90 | 80 | 7.4 | 957 | 8.1 |
| V-143 | do | 480 | July 17, 1962 | 30 | -- | -- | 26 | 6.1 | *159 | | 122 | 43 | 202 | .8 | 4.4 | -- | -- | 531 | 90 | 79 | 7.3 | 944 | 7.4 |
| V-144 | City of El Paso well 48 | 618 | Jan. 24, 1961 | 30 | .00 | -- | 20 | 5.3 | 114 | 7.8 | 139 | 59 | 106 | .7 | 2.8 | -- | .11 | 414 | 72 | 75 | 5.8 | 698 | 7.5 |
| b/ V-145 | City of El Paso well 49 | 838 | June 26, 1961 | -- | .02 | -- | 19 | 9 | -- | -- | 165 | 89 | 75 | .6 | -- | -- | -- | 378 | 84 | -- | -- | -- | 8.1 |
| b/ V-146 | City of El Paso well 50 | c/ 485-510 | Apr. 18, 1961 | -- | .02 | -- | 10 | 6 | -- | -- | 145 | 70 | 40 | .6 | -- | -- | -- | 360 | 50 | -- | -- | -- | 8.9 |
| b/ V-146 | do | c/ 645-670 | do | -- | .02 | -- | 8 | 3 | -- | -- | 137 | 94 | 50 | .6 | -- | -- | -- | 339 | 33 | -- | -- | -- | 9.2 |
| b/ V-146 | do | c/ 776-801 | do | -- | .02 | -- | 16 | 2 | -- | -- | 133 | 109 | 115 | .7 | -- | -- | -- | 405 | 49 | -- | -- | -- | 9.0 |
| V-147 | Standard Oil Co. well 9 | 750 | May 25, 1962 | 32 | .10 | -- | 22 | 6.3 | *116 | | 156 | 78 | 85 | .8 | 2.5 | -- | -- | 420 | 81 | 76 | 5.6 | 694 | 7.3 |
| BB-46 | J. Burner | 421 | Apr. 25, 1962 | 29 | -- | -- | 40 | 11 | 208 | 3.6 | 218 | 143 | 195 | 1.4 | .5 | -- | -- | 738 | 145 | 75 | 7.5 | 1,250 | 7.7 |

a/ Includes equivalent of any carbonate ($CO_3$) present.
b/ Analyses by city of El Paso.
c/ Drill-stem test, interval tested.
* Sodium and potassium calculated as sodium (Na).