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DEVELOPMENT OF GROUND WATER IN THE EL PASO DISTRICT, TEXAS, 1955-60

PROGRESS REPORT NO. 8

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ABSTRACT

Development of ground water in the El Paso district in extreme western Texas continued to expand during the period January 1955 to September 1960. During this period, 81 wells were drilled, of which 43 were for municipal supply, 11 for industrial use, 5 for irrigation, and 22 for exploration or observation purposes. By September 1960 the total number of large wells used, or available for use, excluding shallow irrigation wells, was 107. In 1959 the rate of withdrawal of ground water from all deep wells averaged 62.3 mgd (million gallons a day) as compared to 43.0 mgd in 1955. Pumpage of ground water for irrigation in the Upper and Lower Valleys decreased from 154 mgd in 1956 to about 9 mgd in 1959 owing to a substantial increase in the supply of surface water.

The annually increasing rate of withdrawal of ground water has been accomplished by the expansion of the old well fields and the development of new fields. As a consequence, water levels have declined steadily, the greatest declines occurring in the older well fields. Since 1937, water levels in the Mesa area declined as much as 33.9 feet in the old Mesa field-Biggs field area; in the City Artesian area water levels declined a maximum of 29.6 feet. The substantial recovery of the water table in the alluvium in the Upper and Lower Valleys in 1959 and 1960 shows that large quantities of ground water can be pumped over a considerable period of drought without seriously depleting the ground-water supply in the alluvium.

Pumping tests on wells in the El Paso district showed that the coefficient of transmissibility varied widely, ranging from 22,000 to more than 150,000 gpd (gallons per day) per foot in the Hueco bolson and from 34,000 to 155,000 gpd per foot in the Upper Valley.

In the Mesa area the increase in the chloride content of water has not been serious; in the City Artesian area, where salt water occurs above and below the fresh water, wells that are known to be affected by salt-water contamination are not confined to any one part of the area but are scattered throughout the artesian aquifer. In general, the contamination in the artesian area is through leaking wells and by interformational leakage.

Injection of treated water through wells is probably the most satisfactory method of artificially increasing the recharge to the aquifers underlying the Hueco bolson. Although surface pits and ponds serve as recharge structures, they tend to become clogged with sediment and the infiltration rates generally are low.

All the known sources of fresh ground water in the El Paso district are presently being developed. If the future supply of the district must come from within the State, large supplies of additional water may be obtained by demineralizing the saline water that underlies the Hueco bolson and Upper Valley or by mixing the inferior water with the fresh water, thereby extending the life of the fresh-water supply.

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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 and the western part of Hudspeth County (Plates 1 and 2). The city of El Paso is the principal city in the district and forms a great horseshoe around the southern end of the Franklin Mountains. According to the Bureau of the Census, the population of El Paso in 1960 was 276,687, an increase of about 110 percent since 1950; the population of the metropolitan area (not including Cuidad Juarez in Mexico) was 314,070. Cuidad Juarez, across the Rio Grande, had a population in 1960, according to preliminary census figures, of 290,000, an increase of nearly 140 percent since 1954.

The El Paso district has been subdivided into five areas on the basis of ground-water development (Plates 1 and 2):

(1) The Mesa area, a part of the Hueco bolson, is bounded on the east by the Quitman, Malone, Finlay, and Hueco Mountains, on the north by the New Mexico state line, on the west by the Franklin Mountains, and on the south and southwest by the rimrock or scarp at the edge of the El Paso Valley of the Rio Grande.

(2) The City Artesian area consists of that part of the Hueco bolson that includes the city of El Paso below the rimrock and the adjoining part of Cuidad Juarez, the area extending south to Ysleta.

(3) The Upper Valley, a term used locally to refer to the lower Mesilla Valley of the Rio Grande, extends from Anthony on the New Mexico-Texas state line southward to the pass between the Franklin Mountains and Cerro de Muleros in Mexico.

(4) The Lower Valley consists of the El Paso Valley extending from Ysleta southward to Fort Quitman in Hudspeth County. The occurrence of ground water in the Lower Valley is similar to that in the City Artesian area; however, the Lower Valley is primarily an irrigated farming area and is separated from the City Artesian area on that basis only.

(5) The Diablo Plateau area of this report is in Hudspeth County. It is bounded on the west and southwest by the Hueco, Finlay, and Malone Mountains, on the east by the meridian of 105°30' and on the north by the New Mexico state line.

Purpose and Scope of Investigation

This report is the eighth 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 (formerly the Texas Board of Water Engineers) and the city of El Paso. It gives a brief description of the geology of the district and a summary of the history of the ground-water development; however, its primary purpose is to present data on ground-water development, fluctuations of water levels, changes in chemical quality of the ground water, and related information compiled during the period 1955-60. Records of wells drilled in the El Paso district during the period 1954-60 and those of a few miscellaneous wells are given in Table 3, except that the table does not include records of the wells drilled in the Lower and Upper Valleys that were included in reports by Audsley (1959) and Leggat and others (1962). The results of chemical analyses of water samples collected during the period 1955-60 are given in Table 4.

For the purpose of numbering the wells, grid lines have been established at 10-minute intervals throughout the district, and the individual grids have been lettered alphabetically in each of the two counties involved. The wells are numbered consecutively within each grid; for example, well R-1 would be well 1 in the "R" grid. The grid in El Paso County was extablished during earlier investigations and was originally set up to include an area in New Mexico. Later it was decided not to include the area in New Mexico; hence the first grid on the map showing well locations in El Paso County (Plate 1) is the "Q" grid.

The fieldwork and preparation of this report were under the direct supervision of R. W. Sundstrom, district engineer in charge of ground-water investigations in Texas.

Previous Investigations

The geology, geography, and climate of the El Paso district have been described in many previous reports, the most pertinent of which are given in the list of references cited (p. 39). The most important reports on the geology and its relation to the occurrence of ground water in the El Paso Valley near El Paso and in the Hueco bolson are those by Sayre and Livingston (1954) and Knowles and Kennedy (1956). Other important reports since 1955 include one by Audsley (1959) which gives the results of exploratory drilling in search of ground-water supplies in the El Paso Valley between El Paso and Fabens, and one by Leggat, Lowry, and Hood (1962) on the ground-water resources of the lower Mesilla Valley below Anthony, New Mexico.

GEOLOGY

The following generalized discussion of the geology of the El Paso district is based chiefly on the report by Sayre and Livingston (1945) and on data collected during the current investigation. Descriptions of the geology of the district by Richardson (1909), Dunham (1935), King (1935), and Kottlowski (1958) also were helpful.

The rocks of the El Paso district can be separated into two general groups--the unconsolidated bolson deposits and river alluvium, and the consolidated igneous and sedimentary rocks of the mountains and upland areas. The unconsolidated bolson sediments, which are the most important in relation to the water supply of the district, were deposited in undrained basins (bolsons) formed chiefly by rock faulting. The bolson sediments were derived primarily from the weathering and erosion of local rock rather than being transported from great distances.

Prior to the establishment of the present course of the Rio Grande, the Franklin Mountains formed an isolated desert range surrounded by the undrained basins forming the Hueco bolson on the south and east and La Mesa bolson on the west. At the southern end of the Franklin Mountains the Cerro de Muleros and masses of igneous rock effectively separate the Hueco and La Mesa bolsons. A study of comparative altitudes of the La Mesa and Hueco bolson surfaces suggests that the sediments of the two bolsons are not continuous.

The pre-Rio Grande surface of the Hueco bolson was not entirely featureless, but probably was dotted with small undrained lakes and depressions, the lowest part of the bolson probably being in the vicinity of El Paso (Kottlowski, 1958, p. 48), where a considerable amount of clay and silt was deposited. Eventually the Rio Grande established its course through the bedrock barriers at El Paso and Fort Quitman, and began the downcutting of La Mesa and Hueco bolson surfaces to form the present Rio Grande Valley. Subsequent faulting in the Hueco bolson, indicated by faultline scarps along the east front of the Franklin Mountains, and tilting produced the present gentle westward-sloping bolson surface, which is approximately 300 to 400 feet below the La Mesa surface. The west-facing scarps on the west side of the Franklin Mountains are terraces formed by tributary streams of the Rio Grande.

The bolson sediments consist of sand, gravel, clay, and silt; however, the character of the deposits varies considerably between the Hueco bolson and La Mesa bolson. In the Hueco bolson the sediments are poorly sorted and individual layers range in thickness from 0 to about 100 feet. Electric logs of more than 150 wells indicate that the individual beds and lenses of sand, gravel, and clay are not continuous over wide areas but instead pinch out or grade laterally or vertically into finer or coarser materials. Although, in general, the sand and gravel of the bolson deposits are coarser and thicker near the Franklin Mountains, becoming finer and thinner to the east, drillers' logs of several wells reveal considerable thicknesses of fine sand and clay near the mountains. For example, during the testing of well R-69, large quantities of medium to fine sand entered the well causing its abandonment. The electric log of well R-37 (Knowles and Kennedy, 1956, Table 9) on the slope of the Franklin Mountains shows that less than 10 percent of the saturated material consisted of sand or gravel.

In general, the sands in the Hueco bolson are not cemented, although caliche has been reported at depths of several hundred feet. However, in well R-77 tightly cemented sand was found at 729 to 747 feet. Drill-stem tests and the electric log of the well show that the base of the fresh water was at a depth of 535 feet, considerably shallower than in surrounding wells (Figure 1). The lateral extent of the tightly cemented sand is not known, but it was not found in wells 1 mile north and east; moreover, the base of the fresh water in these wells was considerably deeper. The cause of cementation is not known, but the low permeability caused by the cementing material probably has retarded the movement of water; consequently, the ground water became highly mineralized.

In La Mesa bolson the sand is well sorted and moderately uniform. Electric logs of wells show that the deposits (Santa Fe group) may be divided into two distinct units--the lower unit (deep aquifer), the thickest and most uniform, consisting predominantly of sand, and the upper unit (medium aquifer), consisting of alternating beds of sand and clay. Alluvium (shallow aquifer) deposited by the Rio Grande overlies the Santa Fe group and consists of sand, gravel, clay, and silt. The alluvium has a maximum thickness of about 150 feet in the Upper Valley.

The El Paso Valley is underlain by Hueco bolson deposits and river alluvium. In the part of the valley downstream from Ysleta, the bolson deposits contain a large proportion of clay, silt, and fine sand and appear to have been deposited in moderately large undrained lakes.

The maximum thickness of the bolson deposits is not known. In the Upper Valley, well Q-178 was still in unconsolidated deposits at a depth of 1,705 feet (Leggat and others, 1962, p. 14). On the Hueco bolson, King (1935, p. 253) reported 4,920 feet of unconsolidated sediments penetrated in an oil test about 2 miles south of Newman, New Mexico. In the El Paso Valley, well AA-4 was drilled to a depth of 3,500 feet without reaching bedrock.

The consolidated rocks that crop out in the mountains and upland areas and underlie the bolson deposits are of igneous and sedimentary origin. The igneous rocks are exposed in relatively large areas in the Franklin Mountains and in isolated areas in the southern part of the Hueco Mountains. These igneous rocks are nearly impermeable and, accordingly, do not supply large quantities of water to wells.

The consolidated sedimentary rocks consist of limestone, quartzite, sandstone, and shale. A thick section of light- and dark-colored limestone forms the surface of the Diablo Plateau east of the Hueco Mountains. The limestone ranges in age from Devonian to Permian and is at least 3,450 feet thick. These deposits yield small quantities of water to domestic and stock wells; however, in most wells the water is of unsatisfactory chemical quality for public supply. In the Upper Valley the consolidated sedimentary rocks are known to yield small to moderate quantities of water to wells; most of the water, however, is moderately to highly mineralized. Sandstone of Cretaceous age, underlying a part of the area northeast of Fort Hancock and west of the Finlay Mountains (Plate 2), yields small to moderate quantities of water which is generally too highly mineralized for municipal supply.

HYDROLOGY

Ground-Water Reservoirs

Ground water in the El Paso district occurs in the unconsolidated deposits of the Hueco and La Mesa bolsons, in the river alluvium of the Upper and Lower Valleys, and in the consolidated rocks that underlie the Diablo Plateau.

The deposits of the Hueco bolson extend from the Mesa area southward under the Lower Valley across the Rio Grande to the Sierra del Presidio, a mountain range in Mexico about 10 to 20 miles southwest of the Rio Grande. In the Lower Valley, however, the bolson deposits are covered by younger deposits of sand, gravel, silt, and clay, which were laid down by the Rio Grande after it had cut its valley into the bolson.

In the Mesa area of the bolson, ground water occurs under water-table conditions and the deposits are filled with water to an altitude of about 3,735 feet at the Texas-New Mexico state line and about 3,660 feet at the southern edge of the Mesa near the rimrock (Figure 1). Except in the vicinity of heavy pumping and along the foot of the Franklin Mountains, the gradient of the water surface in the Mesa area is approximately 4 feet per mile south-southeast. The depth to water below the Mesa area varies according to the slope of the land surface. The surface of the Mesa is troughlike, sloping steeply upward toward the Franklin Mountains and more gently upward toward the east. The depth to water ranges from 206 feet in well R-53 to more than 400 feet on the slopes of the mountains. In widely scattered areas, a body of water is perched above the main body by a lens of clay of unknown areal extent. In these areas the water surface is less than 200 feet below the land surface.

Ground water moves from the Mesa area into the City Artesian area, passing beneath relatively impermeable sediments, and there becomes confined under pressure exerted by the higher elevation of the water surface underlying the Mesa. Figure 1 shows the abrupt thinning of the fresh-water sands south of the rimrock, which marks the south edge of the Mesa area. It shows also that saline water, water exceeding 750 ppm (parts per million) chloride, overlies and underlies the fresh-water body in the City Artesian area. A part of the saline water above the fresh-water zone can be attributed to the accumulation of salts resulting from evaporation of irrigation water. A larger part, however, is due to natural concentration by evaporation of ground water that formerly was discharged upward into the alluvium. Figure 2 shows that saline water adjoins the fresh-water body on the south and that the fresh-water body thins to extinction approximately 15 miles downstream from the gorge.

Figure 2 shows a small lenticular body of relatively fresh water in the vicinity of Fabens (Plate 1, well AA-34). The source of this water is probably in Mexico, being the precipitation and runoff from the east slopes of the Sierra del Presidio, southwest of the Rio Grande. Test wells indicate that this zone of relatively fresh water extends only a short distance northeast of the Rio Grande.

Recharge to the Hueco bolson is by infiltration of runoff from the mountains and precipitation on the surface of the bolson. The principal area of recharge is relatively narrow, extending along the foot of the Franklin Mountains and mountains in New Mexico. Some recharge occurs from runoff ponded in several depressions in the bolson surface. The ponded water drains rapidly from some of the depressions, whereas in others it stands for long periods, being slowly depleted by evaporation. Sayre and Livingston (1945, p. 72) estimated that the average annual recharge to the Hueco bolson northeast of the Rio Grande was about 13 mgd (million gallons per day). The amount of recharge from the Mexico side of the Rio Grande is not known but is probably less than that from the United States side.

Prior to pumping in the El Paso district, the natural recharge was approximately balanced by the natural discharge. The ground water moved southward and southeastward toward the Rio Grande where the principal method of natural discharge was by seepage upward through the confining beds of the artesian part of the aquifer into the alluvial deposits whence the water was discharged by evapotranspiration or by flow into the Rio Grande. However, as a result of heavy pumping, the hydrostatic pressure in the artesian part of the aquifer has been lowered below the level of the water table in the overlying alluvial deposits, and natural discharge upward has ceased in some places; instead, the saline water in the overlying deposits probably is moving downward into the fresh-water body.

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

Figure I

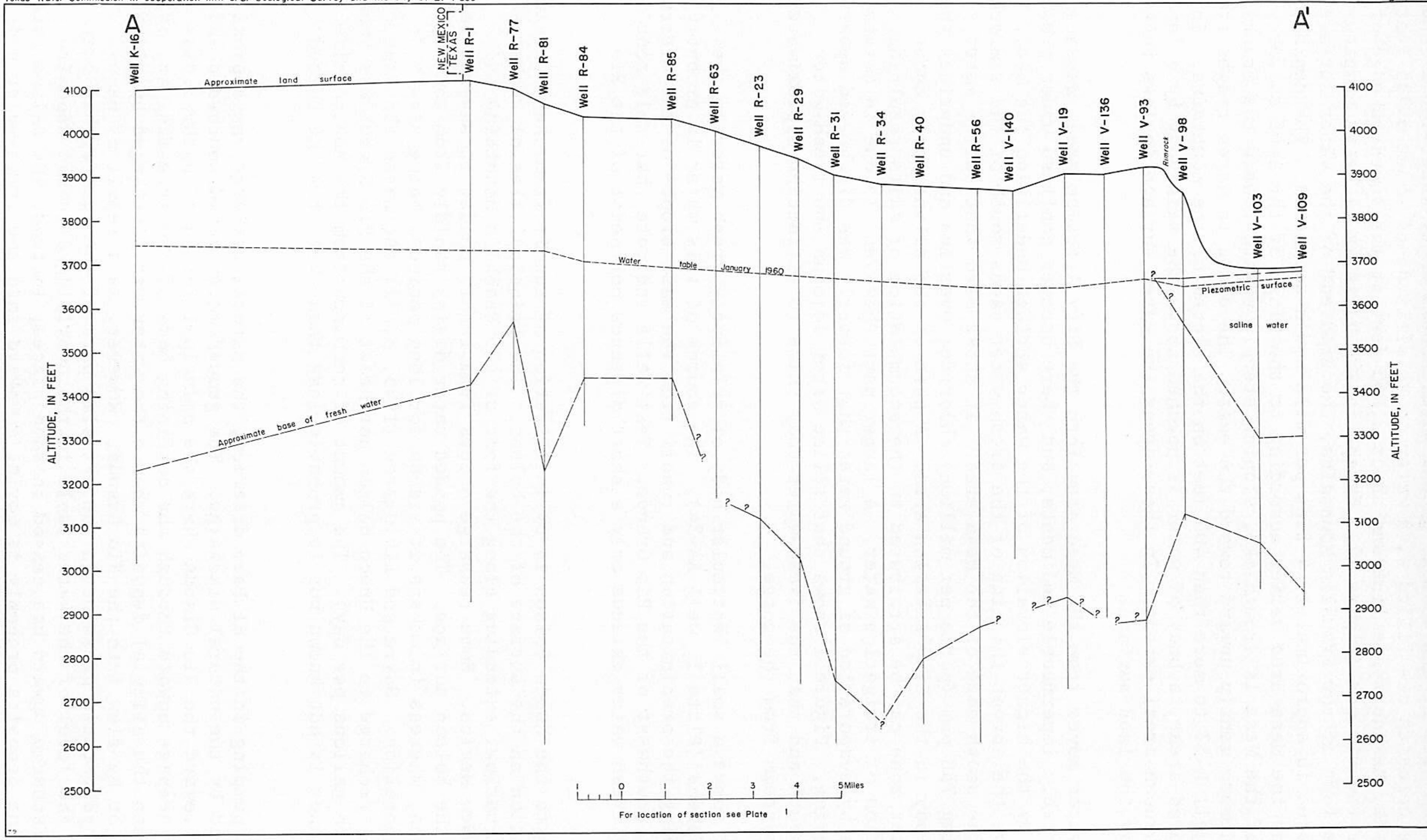

FIGURE I.- Section A-A', Hueco bolson

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

Figure 2

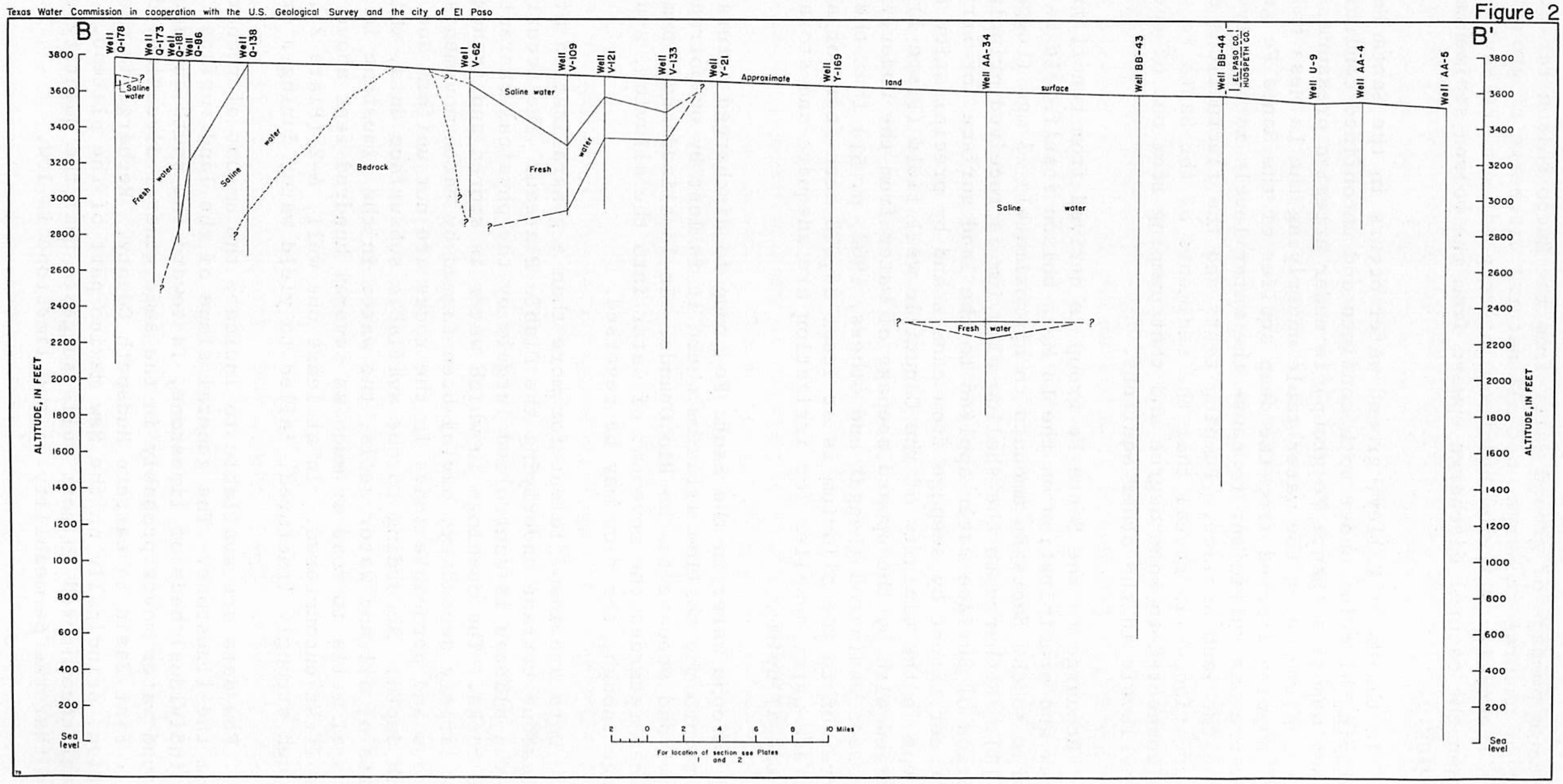

FIGURE 2.– Section B-B', from a point near Anthony, New Mexico, to Fort Hancock

Although pumpage of ground water from the Hueco bolson far exceeds the average rate of natural recharge, not all natural discharge of ground water by seepage into the valley alluvium has been intercepted. In the southern part of the bolson the natural discharge upward from the bolson sediments probably is continuing.

In the Upper Valley, ground water occurs in the Santa Fe group and the overlying alluvium under both confined and unconfined conditions. Water in the bolson deposits (Santa Fe group) is under artesian pressure, which is maintained by the altitude of the water table underlying the La Mesa bolson surface. Before pumping started from the deep aquifer of the Santa Fe group, the hydrostatic pressure was sufficient to cause the water levels in tightly cased wells to rise above the land surface. Pumping tests and the fluctuations of water levels in observation wells reveal that the sediments of the Santa Fe group and the alluvium are connected to some degree and that pumping from one of the aquifers affects the water levels in the other aquifers.

Recharge to the Santa Fe group is derived from runoff from neighboring mountains and precipitation on the La Mesa bolson itself. It is estimated that recharge to the Santa Fe amounts to approximately 13 mgd (Leggat and others, 1962, p. 18). Recharge to the shallow alluvium is received principally by the infiltration of surface water applied to the land surface for irrigation, but also to a lesser extent by seepage from canals and by precipitation on the valley floor. Except in the vicinity of the Canutillo well field (Plate 1), the alluvium is recharged also by the upward seepage of water from the underlying Santa Fe. It has been estimated (Leggat and others, 1962, p. 51) that the potential annual accretion to the alluvium is at least 36,000 acre-feet, or about 33 mgd, when surface-water supplies for irrigation are adequate and storage space is available in the alluvium.

Ground water in the Santa Fe group is discharged naturally by upward movement into the shallow alluvium where it is lost by evapotranspiration, drain flow, and seepage to the Rio Grande. In localized areas pumping from the Santa Fe has retarded the movement of water into the alluvium, and if pumpage becomes large enough, the flow may be reversed.

Data are insufficient for more than a generalization of the hydrology of the limestone terrane underlying the Diablo Plateau. The occurrence of ground water in the plateau is controlled largely by the physical character and structure of the rocks. The openings in which water is stored and transmitted to the limestone are largely secondary, having been formed by earth movements and solution. The porous and permeable zones in the rocks are not uniform and gradually disappear with depth. According to the available subsurface data, which include drill-stem tests of oil and water wells, the water in the limestone is confined, and in several wells it rose as much as several hundred feet above the point where it was first encountered. In at least one well, A-2 (Plate 2), the limestone, although strongly fractured, failed to yield water during a drill-stem test.

Few data are available to indicate the amount of recharge to and discharge from the limestone. The general slope of the land surface, as well as the dip of individual beds of limestone, is toward the south and southeast, and the ground water moves probably in the same general direction, discharging in the Salt Flat Basin in eastern Hudspeth County. Recharge is probably from precipitation, principally on the New Mexico part of the plateau. The salinity of the water encountered in most wells suggests that the quantity of recharge is small and that the permeability of the limestone is low.

Ground-Water Development

Prior to 1892, the municipal water supply of El Paso was obtained from the Rio Grande. In that year 30 wells were drilled in the bed of the river, but these were soon abandoned, and until 1904 only one well, known as the Watts well, was in use. Because the well produced water unsuitable for public supply, drinking water was shipped into the city from Deming, New Mexico. In 1904, drilling started in the Mesa area north of Fort Bliss and by 1917 the city had drilled 44 wells in its Mesa field, although only 27 were in use. The high cost and low efficiency of the Mesa plant resulted in the exploration and subsequent development of the Montana field in the City Artesian area. As development of the Montana field expanded, pumping from the Mesa field decreased and operation of the Mesa field was temporarily discontinued in 1926. The advent of more efficient deep-well turbine pumps and motors and a marked increase in the chloride content of the water from the Montana field resulted in a renewed development of the Mesa field in 1935.

During the period 1918 to 1943, the entire water supply for the city was obtained from deep wells. In 1943 the city, in conjunction with the U. S. Army, constructed a river water softening and filtration plant having a capacity of 10 mgd. The capacity of the plant was doubled in 1950.

From 1940 to 1950, the average daily consumption of water by the city increased from 9.2 mgd to 18.5 mgd, and as a consequence, the Mesa field was extended northward. During the same period, the El Paso Valley Water District drilled wells in the City Artesian area to supply water to the Ysleta area, which at that time was not part of the city of El Paso.

During the period 1951 to 1960 the city drilled 19 wells northwest of Canutillo in the Upper Valley. This included 12 shallow, 1 medium, and 6 deep wells. The medium and deep wells were the result of an exploratory drilling program during 1953 and 1954.

The exploratory drilling of 1953-54 also clearly defined the ground-water reservoir in the Hueco bolson northeast of El Paso, and as a result, the development in the Mesa area was extended northward to within 2 miles of the New Mexico-Texas line. For the purpose of discussion, the municipal development in the Mesa area is divided into four fields: the Airport, Mesa, Nevins, and Newman (Plate 1).

During 1956-57, an area in the Lower Valley in the vicinity of Ysleta and the Hueco bolson southeast of El Paso was investigated in a search for additional water for public supply and other large-scale use. The results of the investigation showed that the area was underlain by sands containing mostly inferior water (chloride content between 250 and 750 ppm) but some fresh water to depths of about 200 feet. Throughout most of the area all the water below 200 feet is saline (chloride content greater than 750 ppm). The city of El Paso drilled a test well near Fabens (AA-34) to a depth of 1,783 feet which yielded water containing only 180 ppm of chloride; however, the sulfate and fluoride contents were 476 and 3.4 ppm, in excess of the limits recommended by the U. S. Public Health Service for those constituents. The well was completed for irrigation use and plugged back to 1,647 feet to protect it against salt-water encroachment from below.

In 1957 the Hudspeth County Conservation and Reclamation District No. 1 drilled three test wells (V-1, AA-4, and AA-5) along U. S. Highway 80 to depths ranging between 708 and 3,500 feet. The wells yielded saline water and were abandoned and plugged.

Further testing of the sediments of the Hueco bolson in the valley below Fabens was undertaken by the city of El Paso in 1959 to determine the extent of the producing sands in well AA-34. The test wells ranged in depth from 1,909 to 3,000 feet. Well AA-37 produced water similar to that from well AA-34, but wells BB-43 and BB-44 both produced saline water. The data obtained from the testing indicate that the source of the water in the deep zone tapped by well AA-34 is probably to the southwest, in Mexico, and that the water extends probably only a short distance northeast of the Rio Grande.

In 1958 and 1959 the city of El Paso centered its exploration activities in the Diablo Plateau. University test no. 1 (C-1, Plate 2) was drilled in 1958 to a depth of 2,613 feet. A drill-stem test in a glauconitic sandstone between 2,242 and 2,308 feet produced water that contained 2,820 ppm chloride and 5,760 ppm dissolved solids. The water level rose to an altitude of 3,360 feet or 1,140 feet below the land surface. The test hole was abandoned and plugged. University test no. 2 (A-2, Plate 2) was drilled to a depth of 2,100 feet without encountering any water-bearing strata. Analysis of all available data in the Diablo Plateau area indicates that it is unlikely that large supplies of fresh ground water can be developed on the plateau.

During the period 1958-59, five wells (W-76, Y-278, Z-13, BB-41, and BB-42) were drilled southeast of El Paso along Interstate Highway 10 to obtain water for construction use. The wells, which ranged in depth from 300 to 400 feet, produced inferior or saline water.

In 1960 several test wells were drilled in the eastern part of the Hueco bolson to obtain a water supply sufficient for large-scale land development. Two of the wells, T-4 and T-5 (depths 105 and 467 feet) were drilled in the vicinity of the Hueco Tanks, which consist of masses of intrusive igneous rocks of Tertiary age protruding above the surface of the bolson. Well T-4 reached bedrock at 105 feet. It yielded insufficient water and the well was abandoned. Well T-5 yielded less than 15 gpm of water of good chemical quality. In the area east of El Paso between U. S. Highway 180 and Interstate Highway 10, three wells were reported to have obtained saline water from the bolson sediments.

In the southern part of the Hueco bolson between the south end of the Hueco Mountains and the rimrock of the valley, four wells (U-8, V-1, V-2, and V-3), drilled to depths ranging from 295 to 906 feet, yielded water that contained sulfate ranging from 514 to 1,440 ppm. Wells V-2 and V-3 drew water from sandstones of Cretaceous age; wells U-8 and V-1 drew from bolson sediments.

The development of ground water in the El Paso district continued to expand from January 1, 1955, to September 1, 1960. During this period, 81 wells were drilled, of which 43 were for municipal supply, 11 for industrial supply, 5 for irrigation, and 22 for exploration or observation purposes. Most of the development was in the Mesa area where 43 wells were drilled, of which 23 were for municipal supply, 5 for industrial use, and 4 for irrigation. By September 1, 1960, the total number of wells available for use, excluding shallow irrigation wells, was 107, of which 72 were for municipal supply.

Pumpage

The pumpage of ground water from deep wells in the El Paso district has increased steadily since 1906 except for a few short periods. In 1943 the city placed in operation its surface water treatment plant, causing a decrease in pumpage from wells during the period 1943 to 1947. Since 1947, however, the pumpage has increased markedly (Figure 3). The sharp rise in the use of ground water since 1950 is due largely to an increase in use for public supply, which reflects the more than 100-percent increase in population between 1950 and 1960. The expansion of defense establishments and industry also increased the consumption of water. In 1950 the rate of withdrawal of ground water from deep wells in the district was 24.3 mgd; in 1955 it was 43.0 mgd, and in 1959 it was 62.3 mgd, an increase of more than 150 percent since 1950. A breakdown of the pumpage by use for the period 1955-59 is shown in Table 1.

From 1936 to 1955 (except in 1942 and 1953), most of the pumpage was from the City Artesian area. Since 1955, however, pumpage from the Mesa area has increased at a greater rate than that from the City Artesian area. For example, during the period 1955 to 1959, inclusive, pumpage increased by 6.7 mgd from the Mesa area as compared to 2.1 mgd from the City Artesian area. Industrial use of water in the Mesa area was relatively small, ranging between 0.3 and 0.6 mgd, most of which was for cooling purposes. A small amount of ground water is pumped for irrigation in the Mesa area north and northeast of El Paso. Since 1955 the withdrawals for irrigation increased from 1.2 to 3.0 mgd, the pumpage in 1959 being slightly more than 10 percent of the total withdrawal from the Mesa area. The pumpage for irrigation probably has reached its maximum because of the lack of additional land suitable for irrigation.

Approximately 80 percent of the ground water pumped from the City Artesian area is used for public supply. Ciudad Juarez is the principal user, requiring about 15 mgd, or about 55 percent of the water pumped in 1959. The city of El Paso pumped an average of 7.4 mgd in 1959, which is a decrease of 1.1 mgd from that in 1955. In recent years the city of El Paso has reduced its pumpage from the Montana well field in the City Artesian area from 1 mgd in 1955 to about 350,000 gallons per day in 1959. The remainder of the water pumped from the City Artesian area by the city of El Paso is from scattered wells in the downtown area of El Paso and from wells recently acquired by the city from the El Paso Valley Water District. Industrial use of ground water has remained relatively constant during the 1955-59 period, averaging about 5.3 mgd, or about 20 percent of the total pumpage from the City Artesian area.

The Upper Valley is primarily an irrigated farming area. Inasmuch as ground water supplements the surface-water supply, the quantity of water pumped for irrigation is inversely related to the availability of surface water. Prior to 1943 surface water was used for most of the irrigation. Owing to the decline in the surface-water supply during the drought years (1946-56), most of the water used for irrigation was taken from ground-water sources. In 1954 about 40,000 acre-feet, or 36 mgd, was pumped for irrigation (Smith, 1956, p. 10); in 1956, when only 0.39 acre-foot per acre of surface water was allotted, 42 mgd of ground water was pumped. Because of the above-normal rainfall in 1957 and 1958, surface-water allotments for irrigation were increased to as much as 4 acre-feet per acre in 1959, and, as a result, the pumpage of ground water decreased from 29.5 mgd in 1957 to an estimated 4 mgd in 1959. Most of the water pumped for irrigation in 1959 was for land for which there are no surface-water allotments.

The pumpage for municipal and industrial use in the Upper Valley has increased from 7.0 mgd in 1955 to 16.1 mgd in 1959. The increase is due chiefly

Table 1.--Average daily pumpage of ground water in the El Paso district, 1955-59 (millions of gallons)

Year	Mesa area		City Artesian area		Upper Valley	Lower Valley	Total
	City of El Paso	Military establish-ments	City of El Paso*	Ciudad Juarez			
Public Supply							
1955	11.8	4.2	8.5	12.2	4.2	0.3	41.2
1956	12.2	4.4	8.8	12.8	8.2	0.3	46.7
1957	13.6	4.5	8.3	12.6	8.0	0.3	47.3
1958	13.3	4.2	7.7	14.1	9.2	0.3	48.8
1959	15.9	4.7	7.4	15.0	12.9	0.3	56.2
Industry							
1955	0.3		4.8		2.8	--	7.9
1956	.3		5.7		3.2	--	9.2
1957	.6		5.2		3.4	--	9.2
1958	.5		5.4		3.1	--	9.0
1959	.6		5.2		3.2	--	9.0
Irrigation							
1955	1.2		--		39.2	111.0	151.4
1956	2.1		--		42.0	112.0	156.1
1957	2.2		--		29.5	81.0	112.7
1958	2.4		--		5.0	8.0	15.4
1959	3.0		--		4.0	5.0	12.0
Totals							
1955	17.5		25.5		46.2	111.3	200.5
1956	19.0		27.3		53.4	112.3	212.0
1957	20.9		26.1		40.9	81.3	169.2
1958	20.4		27.2		17.3	8.3	73.2
1959	24.2		27.6		20.1	5.3	77.2

*Includes pumpage by the El Paso Valley Water District.

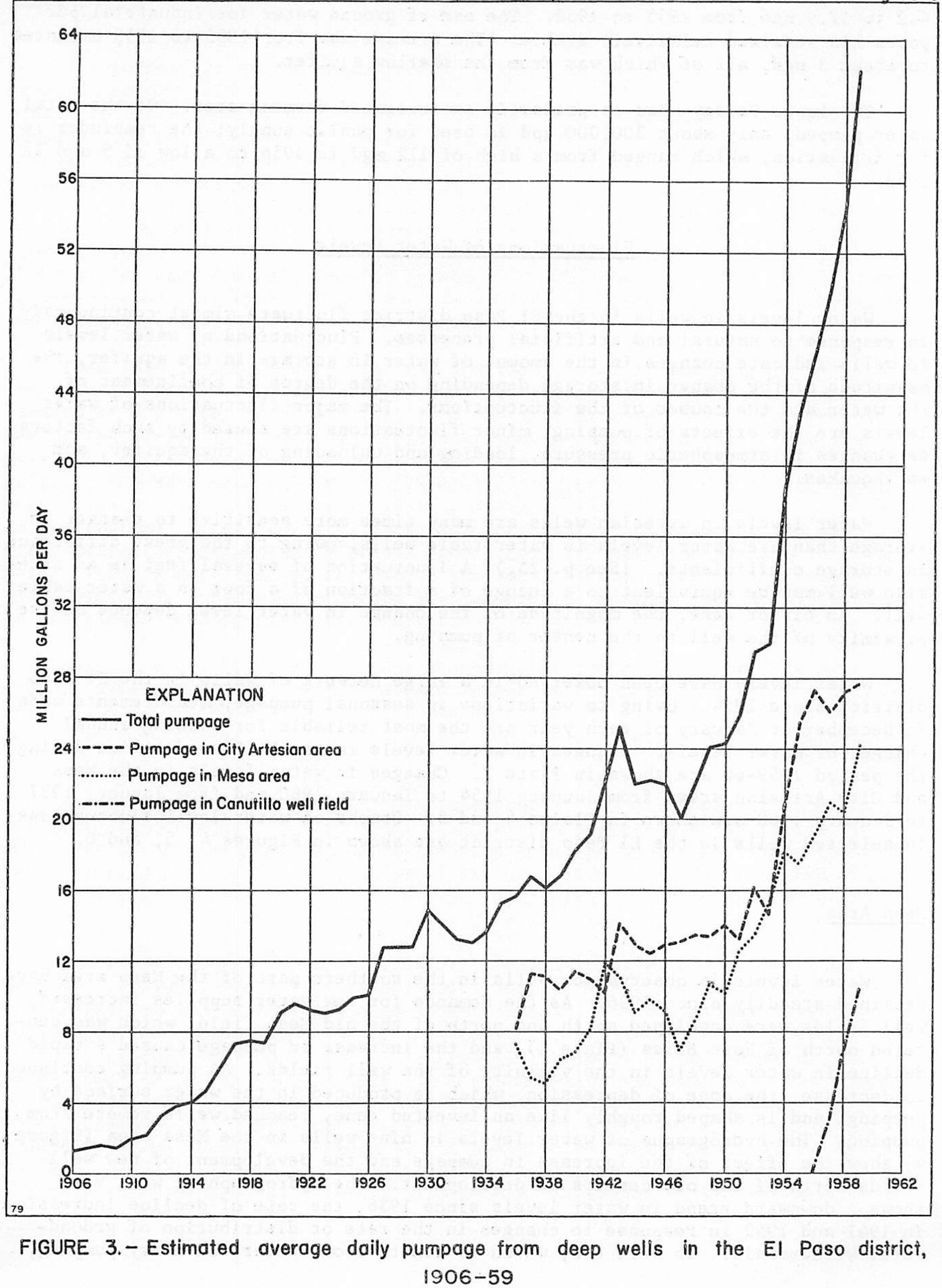

FIGURE 3.– Estimated average daily pumpage from deep wells in the El Paso district, 1906–59

to the expansion of the city's Canutillo field where the pumpage increased from 4.2 to 12.9 mgd from 1955 to 1959. The use of ground water for industrial purposes has remained relatively stable. The average use from 1955 to 1959 amounted to about 3 mgd, all of which was from the shallow aquifer.

The Lower Valley also is primarily an irrigated farming area. Of the total water pumped, only about 300,000 gpd is used for public supply; the remainder is for irrigation, which ranged from a high of 112 mgd in 1956 to a low of 5 mgd in 1959.

Fluctuations of Water Levels

Water levels in wells in the El Paso district fluctuate almost continuously in response to natural and artificial processes. Fluctuations of water levels in wells 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 such factors as changes in atmospheric pressure, loading and unloading of the aquifer, and earthquakes.

Water levels in artesian wells are many times more sensitive to changes in storage than are water levels in water-table wells, owing to the great difference in storage coefficients. (See p. 25.) A fluctuation of several feet in an artesian well may be equivalent to a change of a fraction of a foot in a water-table well. In either case, the magnitude of the change in water level depends on the proximity of the well to the center of pumping.

Water levels have been observed in a large network of wells in the El Paso district since 1954. Owing to variations in seasonal pumpage, measurements made in December or January of each year are the most reliable for showing annual changes of water levels. Changes in water levels in the El Paso district during the period 1959-60 are shown in Plate 3. Changes in water levels in the Mesa and City Artesian areas from January 1954 to January 1960 and from January 1937 to January 1960 are shown in Plates 4 and 5. Graphs of water-level fluctuations in selected wells in the El Paso district are shown in Figures 4, 5, and 6.

Mesa Area

Water levels in observation wells in the southern part of the Mesa area have declined steadily since 1936. As the demands for new water supplies increased, well fields were developed south and north of the old Mesa field, which was centered north of Fort Bliss (Plate 1), and the increase in pumpage caused a rapid decline in water levels in the vicinity of the well fields. As pumping continued to increase, the cone of depression, which is produced in the water surface by pumping, and is shaped roughly like an inverted cone, reached wells remote from pumping. The hydrographs of water levels in nine wells in the Mesa area (Figure 4) show the effect of the increase in pumpage and the development of new well fields north of the old centers of development. The hydrograph of well V-42 shows a downward trend in water levels since 1936, the rate of decline increasing in 1941 and 1952 in response to changes in the rate or distribution of ground-water withdrawals. In well R-2, which is remote from centers of heavy pumping,

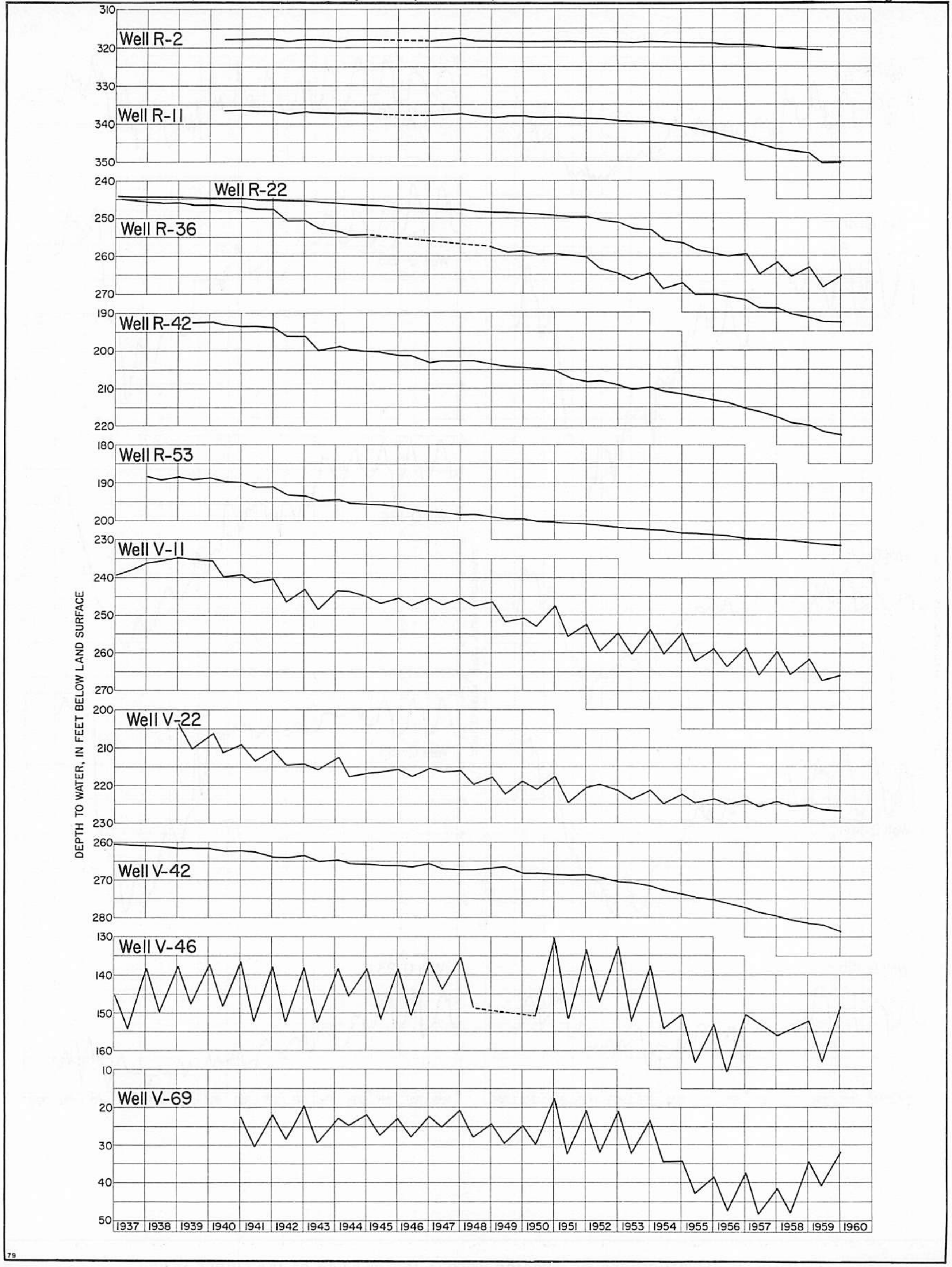

FIGURE 4.-Hydrographs of selected observation wells in the Mesa and City Artesian areas

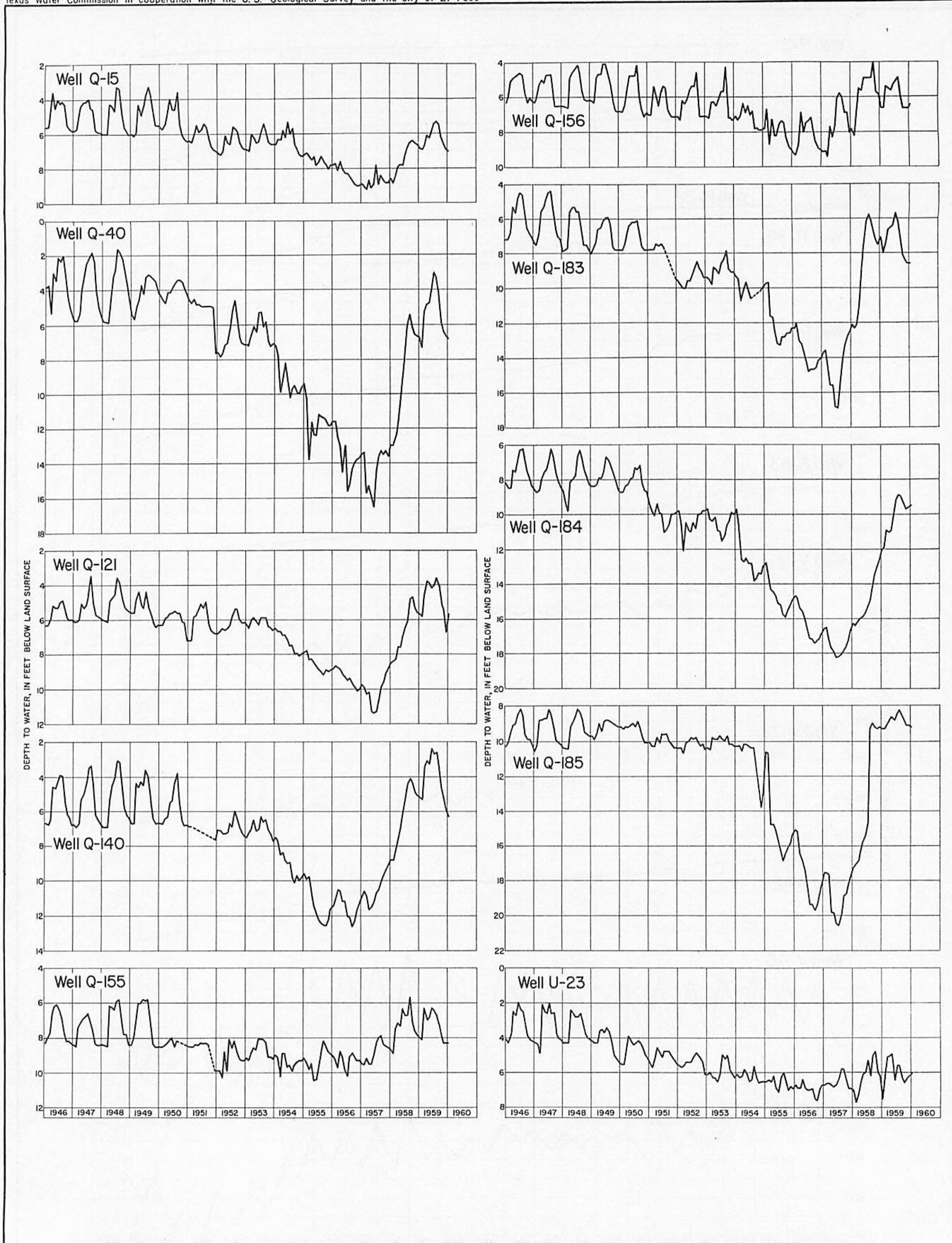

FIGURE 5.- Hydrographs of selected wells in the alluvium of the Upper Valley

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

Figure 6

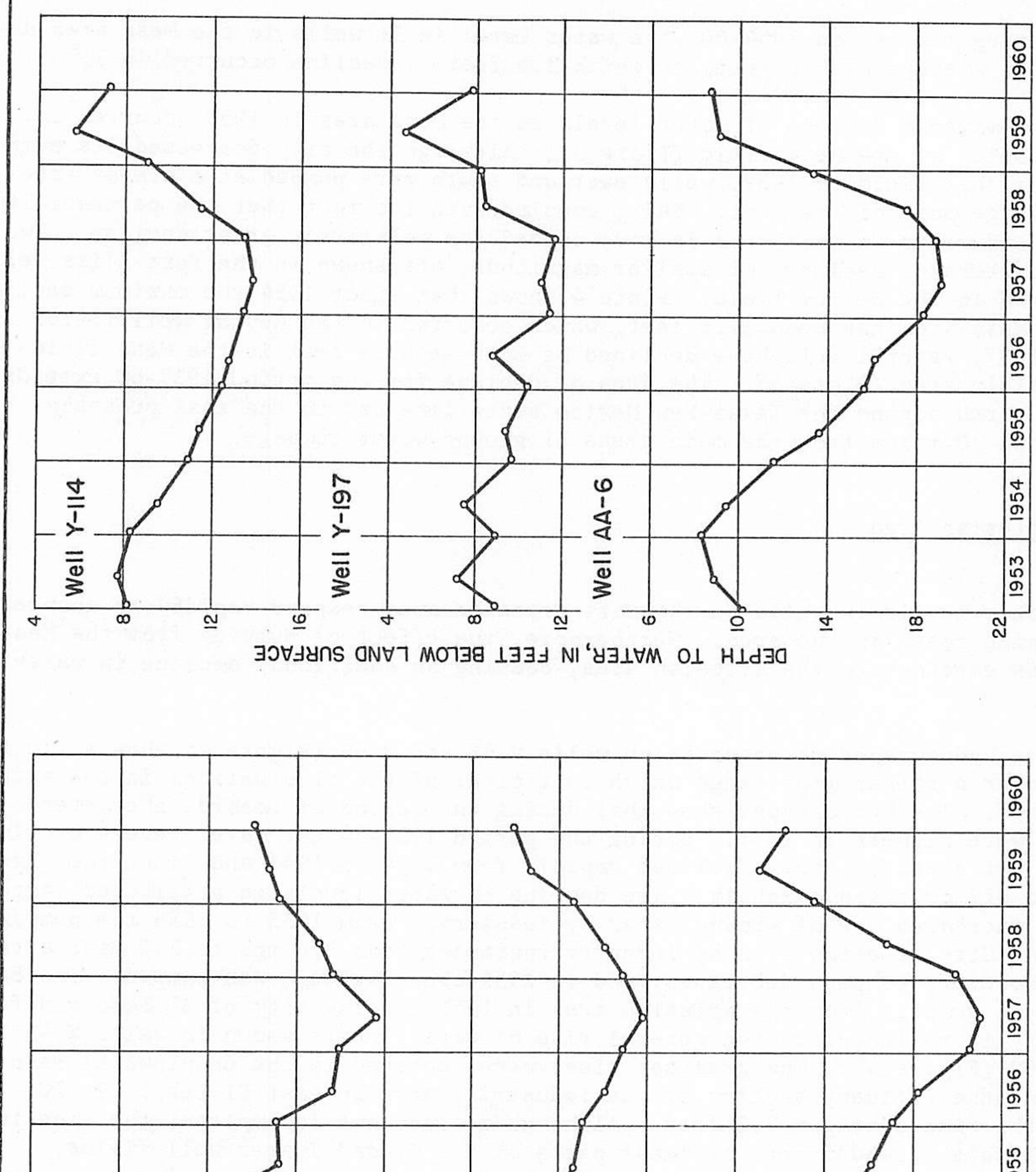

FIGURE 6.—Hydrographs of selected wells in the alluvium of the Lower Valley

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the water level remained practically the same until about 1954, when a slow but steady annual decline began. The rate of decline increased after 1956, reflecting the development of the Nevins and Newman fields.

During the period 1954-60, the water level in 31 wells in the Mesa area declined an average of 6.5 feet, of which 2.0 feet of decline occurred in 1959.

The maximum decline of water levels in the Mesa area in 1959 occurred in the vicinity of the Mesa field (Plate 3). Although the city decreased its pumpage from this field in 1959, wells east and south were pumped at a steady rate for a large part of the year. This, coupled with the fact that the permeability of the sediments in this area is low, caused the relatively great decline. Two other centers of decline, of smaller magnitude, are shown in the Fort Bliss well field and in the Nevins field. Plate 4 shows that since 1954 the maximum decline in the Mesa area has been 17.6 feet, which occurred in the Nevins well field. Since 1937, water levels have declined as much as 33.9 feet in the Mesa field-Biggs field area (Plate 5). The area of decline for the period 1937-60 extends to the north beyond the Texas-New Mexico state line and to the east probably more than 10 miles from the main areas of ground-water pumpage.

City Artesian Area

Water levels in wells in the City Artesian area respond rapidly to changes in pumping rates in the area. Furthermore, the effect of pumping from the Mesa area has extended to the artesian area, causing an additional decline in water levels.

The hydrographs of observation wells V-46 and V-69 (Figure 4) show a fluctuation over a rather wide range which is typical of the fluctuations in the artesian area. The hydrographs show that during the period of record, the water levels were highest in 1951. During the period 1951-54 the water levels declined slowly but steadily, then declined rapidly from 1954 to 1956 and since then have leveled off or risen slightly. The decline in water levels is attributed largely to the increased use of ground water by industry. From 1953 to 1956 the pumpage from the City Artesian area by industry increased from 3.6 mgd to 5.7 mgd; after 1956, however, pumpage decreased, and in 1959 about 5.2 mgd was pumped. The decrease in pumpage from the artesian area in 1959 for the city of El Paso and for industry is reflected in the general rise of water levels shown in wells V-46 and V-69 (Figure 4). The greatest rises were centered in the downtown El Paso area and the refinery section of the industrial area in east El Paso. In 20 wells the rise averaged 3.2 feet. Although records are incomplete, the rise in water levels extended into at least parts of the Ciudad Juarez well fields.

Since 1954 the water levels in 12 wells in the City Artesian area have declined an average of 9.6 feet, the maximum decline of 12.7 feet being measured in the center of the industrial area (Plate 4). A decline of about 15 feet was estimated for the well field that formerly supplied Ysleta and vicinity in southeast El Paso.

Since 1937 the water levels have declined a measured maximum of 29.5 feet in the industrial area (Plate 5). In the downtown El Paso area declines as great as 26.6 feet were measured, and a decline of 48.5 feet was reported in a well in Ciudad Juarez. Sufficient data are not available to determine the extent of the area of decline, but because of the barrier formed by the Franklin

Mountains which halts the spread of the decline to the northwest, it is probable that the effect of pumping from the City Artesian area extends a considerable distance down the Lower Valley.

Significance of Fluctuations in the Mesa and City Artesian Areas

A change in water levels in the aquifers within the Hueco bolson represents a change in the volume of ground water in storage. Declines in water levels in the City Artesian area represent very small changes in storage as compared to similar changes in the Mesa area where the water is unconfined. Although it has been assumed in the past that computations of depletion of storage in the Mesa area should approach closely the total change in storage for the Mesa and City Artesian areas, the alteration of the recharge-discharge relationship precludes a determination of the change in storage since 1937. The difference in head between the fresh-water body and the salt-water bodies in the artesian area has resulted in a change in the natural rate of discharge to the alluvium in the valley. In fact, it is probable that in at least a part of the area the movement of water has been reversed. In 1954 Knowles and Kennedy (1956, p. 43) 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. Pumpage since 1954 has amounted to 265,000 acre-feet or about 4 percent of the ground water in storage. If the estimate of average recharge of about 15,000 acre-feet per year is correct, then one-fourth of the pumpage was supplied by recharge and the depletion of the reservoir was somewhat less than 4 percent.

Upper Valley

Water levels in the alluvium in the Upper Valley fluctuate chiefly in response to changes in the availability of surface water for irrigation. In most wells (Figure 5) the water levels generally were relatively stable through 1950, except for seasonal variations. The uniformity in water levels indicates that the supply of surface water for irrigation was adequate. In general, water levels were highest during the growing season because of the infiltration of surface water applied to the land, and lowest during the winter in response to the discharge of ground water to the drains and to the river.

From 1950 to 1957, the water levels declined throughout the Upper Valley, the rate and magnitude of the decline depending on the amount of ground water pumped to supplement the steadily decreasing supply of surface water. Most water levels rose in 1957 and 1958 in response to the increase in surface-water allotments for irrigation and the substantial decrease in the pumpage of ground water. In 1959, despite a large surface-water allotment, water levels declined slightly in more than half the valley; the largest declines were in the area east of Highway 80, where the irrigation supply is entirely from ground-water sources (Plate 3). Water levels rose a maximum of 3.3 feet in 1959 in the west-central part of the valley. By January 1960 the water levels in four wells (Q-121, Q-140, Q-155, and Q-185, Figure 5) were higher than the lowest water levels in 1946, probably because silting had raised the beds of the drains and the river. In any well in the alluvium the lowest water level is controlled largely by the altitude of the bottom of a nearby drain or the river, and it occurs just before irrigation begins in the spring. In five wells

(Q-15, Q-40, Q-183, Q-184, and U-23, Figure 5) the water levels in January 1960 averaged nearly 1 foot below the lowest level in 1946, indicating that the drain and riverbed probably had been lowered.

These data show that large quantities of ground water can be pumped from the alluvium during a protracted drought without seriously depleting the ground-water supply. The recharge is substantial when surface-water allotments are adequate.

Lower Valley

The Lower Valley is an irrigated farming area, and the availability of water and fluctuations of water levels in wells that draw from the alluvium are similar to those of the Upper Valley. The hydrographs of six wells that draw from the alluvium in the Lower Valley are shown in Figure 6.

In general, the water levels in wells in the Lower Valley showed a steady downward trend from 1953 to 1957 (Figure 6). In 1957 the surface water available for irrigation increased, and consequently pumpage of ground water decreased. As a result, the water levels began to rise. In 1958 and 1959, when the surface-water supply was sufficient to cause further reduction in pumpage, the water levels continued to rise, and they were higher in January 1960 than in January 1953 in all wells except V-116 and W-21. Wells V-116 and W-21 are in the part of the valley, referred to as the City Artesian area where, in recent years, irrigation has been greatly reduced. As a consequence, less surface water has been applied for irrigation, which has resulted in less recharge to the alluvial deposits. The decline in water levels in the latter part of 1959 indicates that the ground-water reservoir is full and that the excess water is being discharged into the drains and the river.

In 1959 water levels rose throughout most of the Lower Valley except in a narrow strip along the Rio Grande, where slight declines were observed (Plate 3). Whether or not these declines may be attributed to pumping on the Mexico side of the river is not known; however, pumping on the United States side was negligible.

Pumping Tests

The development of the aquifers in the El Paso district is dependent largely upon the hydraulic properties of the aquifers, principally the ability of the aquifers to transmit and store water. These properties can be determined by laboratory or field methods, the preferred method being pumping tests of wells. This method is preferred because a large area of an aquifer can be tested, whereas samples tested in the laboratory may be representative of only small areas. Moreover, in most instances, samples collected during the drilling of a well are not representative of the undisturbed material of the aquifer.

Pumping tests have been made on 44 wells to determine the coefficients of transmissibility and storage of the aquifers in the El Paso district. The coefficient of transmissibility is expressed as the number of gallons of water a day that will flow through a strip of the aquifer 1 foot wide under a hydraulic gradient of 1 foot per foot, or through a strip of the aquifer 1 mile wide under a gradient of 1 foot per mile at the prevailing temperature. Thus, the volume of water that will flow each day through each mile-wide section of the aquifer is the product of the hydraulic gradient, in feet per mile, and the coefficient of transmissibility in gallons per day per foot. The coefficient of storage is defined as the volume of water the aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. Under water-table conditions, the coefficient of storage is approximately equal to the specific yield, which is the ratio of the volume of water a saturated material will yield by gravity to its own volume.

The results of the pumping tests are shown in Table 2. The tests were analyzed by means of a formula developed by Theis (1935, p. 519-524) to determine the coefficients of transmissibility and storage or the specific yield. A discussion of the formula, the assumptions upon which it is based and its application, is given by Wenzel and Fishel (1942, p. 87-97). A formula developed by Hantush and Jacob (1955, p. 95) for analysis of nonsteady flow in leaky systems was used to determine the constants for the deep well field in the Canutillo area of the Upper Valley.

Pumping tests were made of 35 wells in the Hueco bolson, 29 of which were in the Mesa area and 6 in the City Artesian area. The coefficient of transmissibility ranges widely because of the heterogeneous mixture of sand, gravel, and clay making up the bolson sediments. In the northern part of the Mesa area, which includes the Nevins and Newman fields, the coefficient of transmissibility generally exceeded 100,000 gpd (gallons per day) per foot; however, in three wells relatively close to the Franklin Mountains the coefficient of transmissibility ranged from 27,000 gpd per foot in well R-69 to 75,000 gpd per foot in well R-84. In eight wells in the vicinity of the Mesa field and Fort Bliss, the coefficient of transmissibility ranged from 37,000 to 108,000 gpd per foot; in most of the wells it was less than 75,000 gpd per foot. Southward, in the Airport field, the coefficient of transmissibility was higher, ranging from 94,000 to 150,000 gpd per foot in four wells.

The low coefficient of transmissibility in the vicinity of the Mesa field may be attributed to the high percentage of clay and silt in the bolson deposits in that area. Sayre and Livingston (1945, p. 28) reported a variation in the percentage of sand penetrated in wells in the Mesa field, ranging from 79 percent to as little as 20 percent. In three wells drilled in the northwestern part of the Mesa field between 1937 and 1941, the percentage of sand beds in the total saturated thickness ranged from 14 to 28. The very low coefficient of transmissibility obtained in two wells close to the Franklin Mountains, where the sands were thick and coarse, is attributed largely to the cementation of the sands. A core sample taken from 729 to 747 feet in well R-77 recovered tightly cemented sandstone, and the driller of well R-69 reported that drilling was hard because of cementation of the sand.

The specific capacity of a well generally is expressed as the rate of yield in gallons per minute per foot of drawdown. In properly developed wells equipped with gravel envelopes and screens, the specific capacities are good indicators of the ability of the formation to transmit water. Most of the wells in which specific capacities were measured are gravel packed and completed with mill-slotted casing; thus, the performance of the wells should be comparable, provided they are equally well developed. In 21 wells in the Mesa area the specific capacities ranged from 8.2 gpm per foot of drawdown, in well R-69, to 58.0 gpm per foot of drawdown, in well R-70, and averaged 24.5 (Table 2). In several wells the specific capacities were low as compared with the high transmissibilities, indicating that the wells had not been developed to their full potential.

Table 2.--Results of pumping tests in the El Paso district

Well	Transmissibility (gallons per day per foot)	Specific capacity (gallons per minute per foot of drawdown)	Well	Transmissibility (gallons per day per foot)	Specific capacity (gallons per minute per foot of drawdown)
Mesa Area					
R- 29	155,000	24.3	R- 84	75,000	19.7
R- 34	122,000	19.7	V- 2	108,000	--
R- 56	37,500	18.9	V- 3	64,500	--
R- 59	156,000	30.1	V- 4	50,000	--
R- 60	105,000	18.8	V- 5	108,000	--
R- 61	114,000	17.3	V- 7	72,000	24.0
R- 63	35,000	12.7	V- 15	71,500	--
R- 64	105,000	18.8	V- 27	52,000	--
R- 68	152,000	37.8	V- 29	56,000	--
R- 69	27,000	8.2	V- 40	94,000	--
R- 70	203,000	58.0	V- 41	120,000	38.0
R- 71	168,000	28.7	V- 93	150,000	15.7
R- 73	135,000	25.7	V-136	115,000	29.5
R- 82	152,000	32.0	V-139	63,000	22.3
			V-140	57,500	13.9
City Artesian Area					
V- 46	135,000	--	V- 52	82,000	--
V- 48	140,000	--	V- 53	129,000	--
V- 50	124,000	--	V-138	22,000	11.3
Upper Valley					
Q- 86 (shallow aquifer)	155,000	--	Q-176 (deep aquifer)	60,000	--
Q-172 (deep aquifer)	60,000	30.7	Q-180 (medium aquifer)	34,000	14.0
Q-173 (deep aquifer)	59,000	22.1	Q-189 (deep aquifer)	57,000	28.6
Q-174 (deep aquifer)	73,500	25.4	Q-197 (deep aquifer)	62,500	22.8
Q-175 (deep aquifer)	49,500	19.7			

The specific yield of sediments under water-table conditions cannot be determined accurately from pumping tests of short duration. Water drains slowly from the saturated material and complete drainage may not occur for years. Sayre and Livingston (1945, p. 29) estimated an average specific yield of 35 percent for five sand samples from the Mesa area and, on the average, the sands constituted 50 percent of the deposits; thus, the average specific yield of all the deposits in the Mesa area was estimated to be about 17.5 percent.

In the City Artesian area the coefficient of transmissibility in six wells ranged from 22,000 gpd per foot in well V-138 to 140,000 gpd per foot in well V-48. The data show that the transmissibility of the aquifer decreases southward, the direction in which the fresh-water sands decrease in thickness (Figure 2).

The coefficient of storage of the bolson sediments underlying the City Artesian area is typical of artesian conditions and considerably smaller than that of the sediments in the Mesa area. Hence, large and rapid fluctuations result from pumping. The coefficient of storage measured at five wells was relatively uniform, ranging from 0.0027 to 0.00063, and averaging 0.0015.

The specific capacities of 11 wells in the City Artesian area ranged from 10.6 gpm per foot in well V-80 to 23.0 gpm per foot in well V-101, and averaged 16.0 gpm per foot, nearly 35 percent less than the average specific capacity of wells in the Mesa area. In recent years the specific capacities of several wells have shown a marked decrease, and as a consequence a program of rehabilitation was undertaken by the city of El Paso and the Standard Oil Co. of Texas. The program, which consisted of acidization of one well (V-98) and the release of explosive charges of predetermined size opposite the screened section in two wells (V-45 and V-49), was successful to varying degrees. The increase in specific capacities in the three wells ranged from 60 to 130 percent. Rehabilitation of a fourth well, V-4, was not successful and the well was abandoned.

If geologic and hydrologic conditions are favorable, the coefficients of transmissibility and storage may be used to predict the general order of magnitude of drawdown of water levels caused by a general increase of pumping in an area. The theoretical drawdown curves in Figure 7 were computed from representative coefficients for the Mesa and City Artesian areas. Although the drawdown curve for the City Artesian area was computed on the assumption that the artesian aquifer is infinite, water-table conditions occur within finite distance and their effect will eventually tend to reduce the rate of decline because of the larger coefficient of storage in the water-table area. Nevertheless, the drawdown curve may be used to estimate the magnitude of the decline in artesian head caused by an increase in withdrawals or the interference between closely spaced wells.

In the Upper Valley the coefficient of transmissibility and the specific yield of the alluvial deposits, or shallow aquifer, was about 150,000 gpd per foot and about 10 percent, respectively (Leggat and others, 1962, p. 34). In the medium aquifer the coefficient of transmissibility was 34,000 gpd per foot; the coefficient of storage was not determined. Aquifer tests at the sites of seven wells screened in the deep aquifer of the Santa Fe group indicated an average coefficient of transmissibility of about 60,000 gpd per foot and an average coefficient of storage of 0.0007. However, after water was pumped for 24 hours from the deep aquifer, the drawdown in the wells was less than the predicted drawdown, thus indicating leakage from overlying aquifers. Thus, the coefficient of storage from the medium and deep aquifers ultimately may equal the specific yield estimated for the shallow aquifer (0.1).

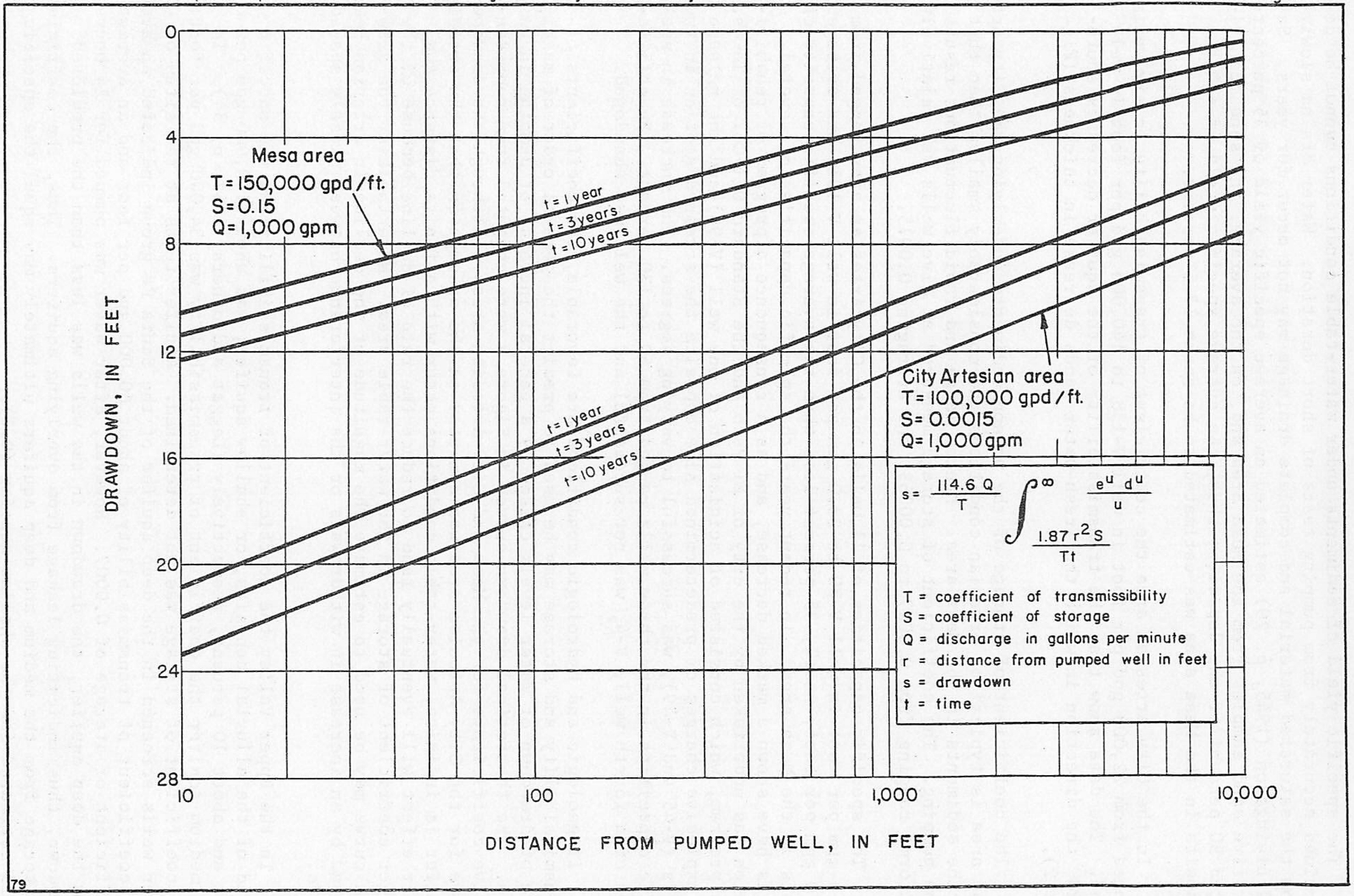

FIGURE 7.– Theoretical drawdown in the Mesa and City Artesian areas due to pumping

The specific capacities of 7 wells in the Upper Valley, 6 of which draw from the deep aquifer, ranged from 19.7 to 30.7 gpd per foot of drawdown. Well Q-180, which is screened in the medium aquifer, had a specific capacity of 14.0. In the shallow aquifer, the specific capacities of wells varied greatly, owing mainly to the lithologic character of the sediments but also to the diversity in the methods of drilling, completion, and development of the wells. For wells of similar construction and development, the specific capacities ranged from 13 to 61 gpm per foot of drawdown (Leggat and others, 1962, p. 31).

Figure 8 shows the theoretical drawdown due to pumping 1,000 gpm from a well in the deep aquifer. A discussion of the assumptions upon which the curve is based is given by Leggat and others (1962, p. 34).

The hydrologic properties and performance of wells that draw from the alluvium in the Lower Valley are similar to those of the Upper Valley.

Six wells have been drilled in the Lower Valley that obtain water from the bolson deposits underlying the alluvium. Of these, 5 are in the city of Fabens and 1 (AA-34) is 3 miles southwest of Fabens. Complete aquifer tests of these wells are not available, but data reported for well AA-34 suggest that the coefficients of transmissibility and storage are low, probably on the order of 25,000 gpd per foot and 0.0003, respectively. If these low coefficients are representative of the Lower Valley, large drawdowns and considerable mutual interference would characterize wells screened in the bolson deposits.

Little information is available regarding the hydraulic properties of the rocks underlying the Diablo Plateau. Analyses of the drill-stem test in well C-1 suggest that the coefficients of transmissibility and storage are extremely low. It required 90 minutes for water to rise in the drill stem from a depth of 2,308 feet to 1,140 feet.

Quality of Water

Descriptions of the chemical quality of the ground water in the El Paso district have been given in several previous reports (see References Cited). The present discussion is limited chiefly to a description of changes in quality that have occurred in recent years, and to potential changes. Since 1935, selected observation wells throughout the district have been sampled periodically to detect changes in quality. Table 4 gives the results of chemical analyses made since 1955, including analyses of samples from many new wells drilled since that time. 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. In addition to the routine sampling program, contamination tests were made in three wells in the City Artesian area, the chlorographs of which are shown in Figure 9. Chlorographs of four wells in the Mesa area and six wells in the City Artesian area are shown in Figure 10. These are based on samples taken after long periods of pumping. The maximum and minimum concentrations of chloride in water from 38 wells in the Mesa and City Artesian areas are shown in Figure 11. These include maximums obtained during contamination tests that are based on short periods of pumping.

Fresh ground water makes up a relatively small fraction of the total quantity of ground water in storage in the El Paso district. Where fresh ground water is available, it generally is underlain or adjoined by saline water, which is therefore a source of contamination of the available fresh-water supplies. In this report, the definition of fresh and saline water is based on the chloride content;

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Figure 8

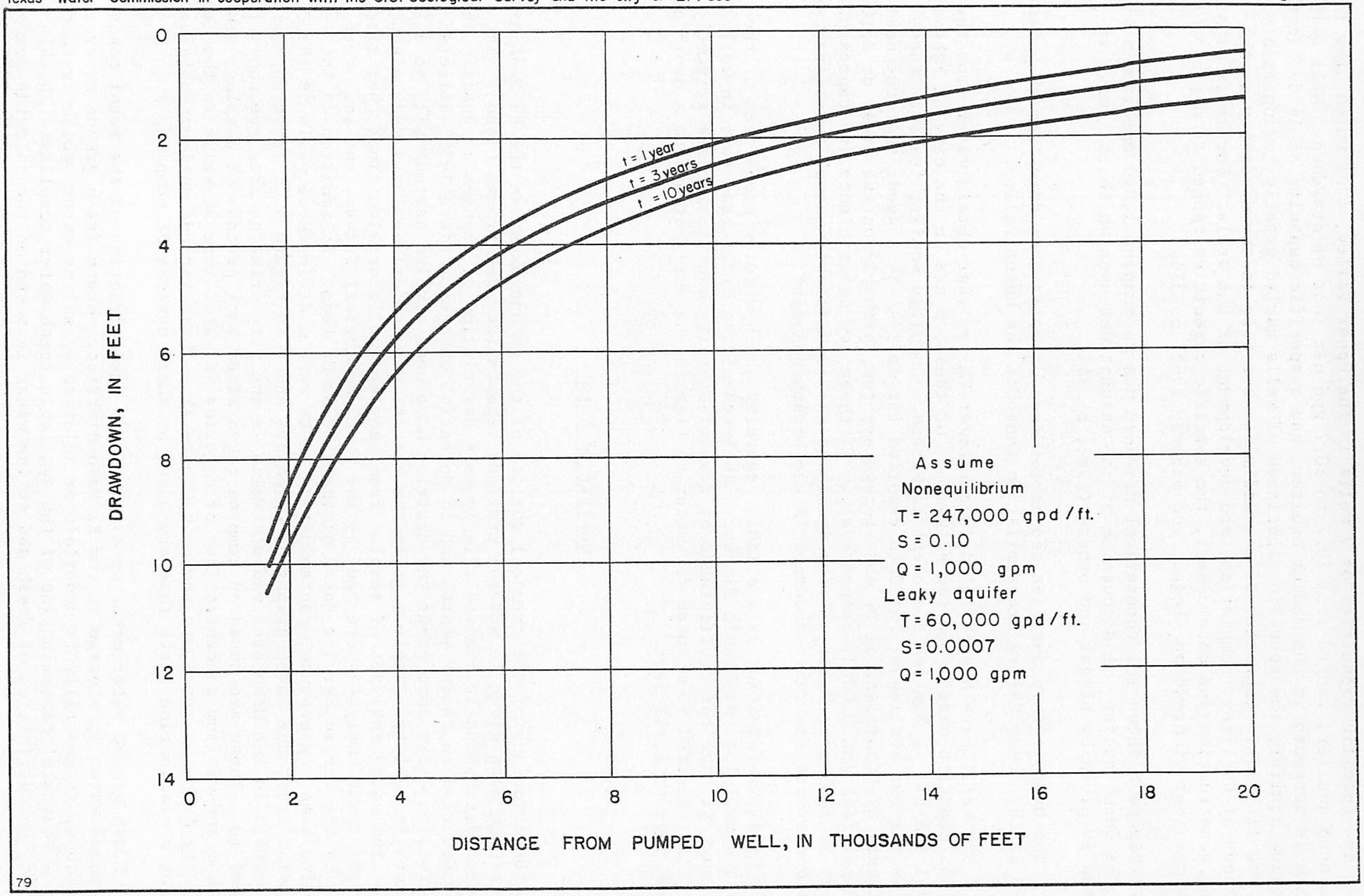

FIGURE 8.- Theoretical drawdown in an infinite aquifer (Santa Fe group) due to pumping

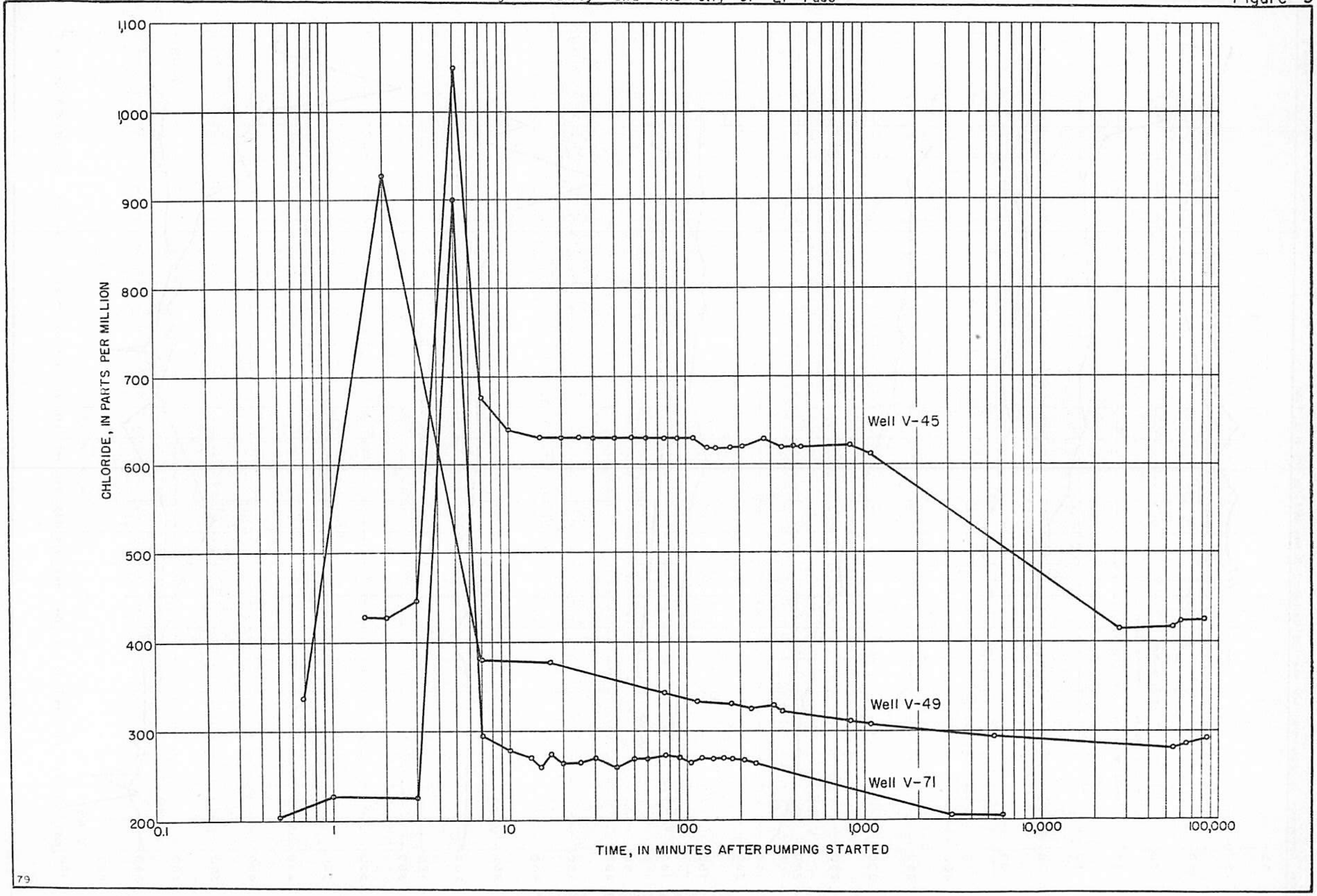

FIGURE 9.—Fluctuation of chloride concentration in water from three wells in the City Artesian area

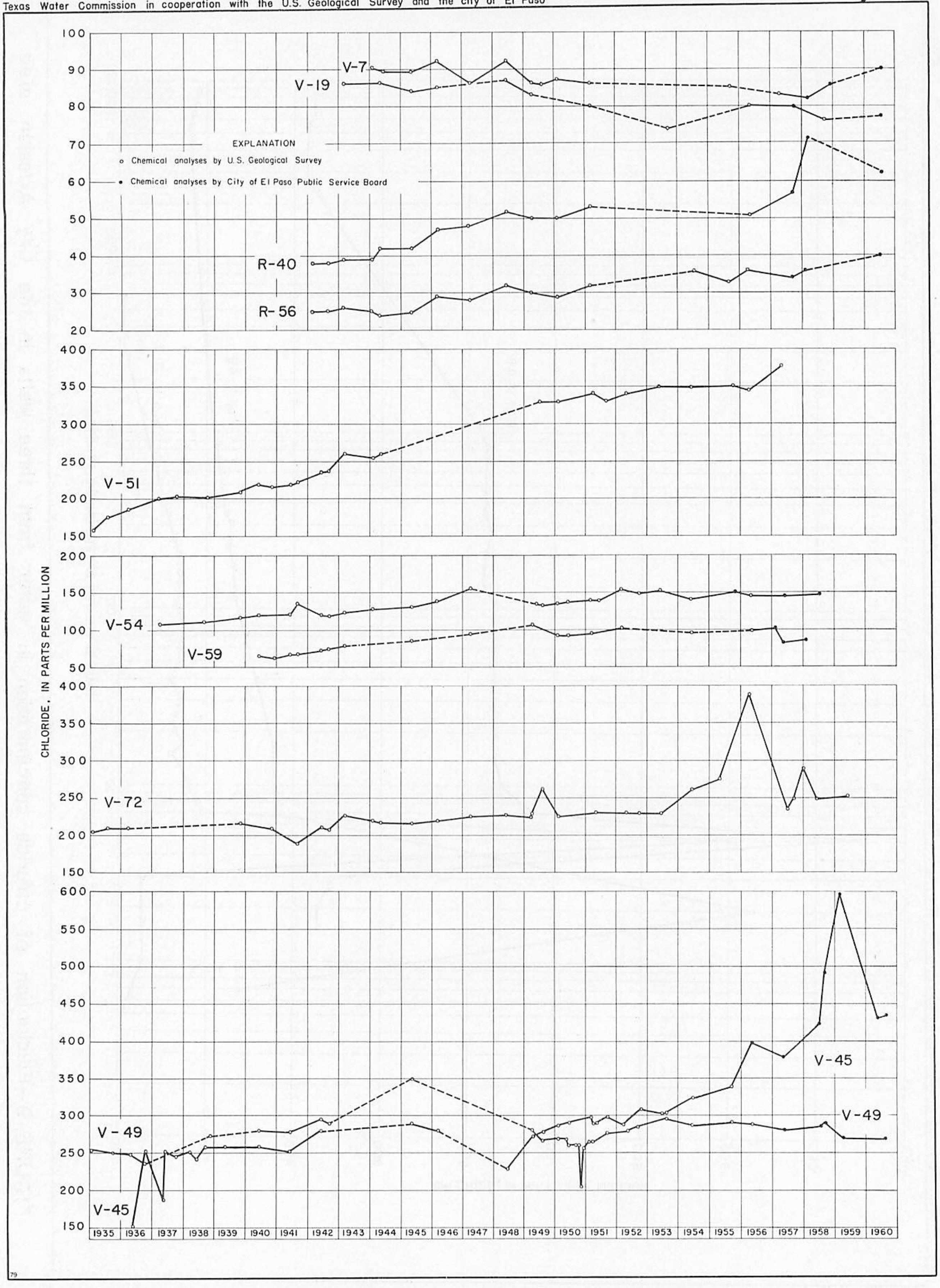

FIGURE 10.-Chlorographs of selected wells in the Mesa and City Artesian areas

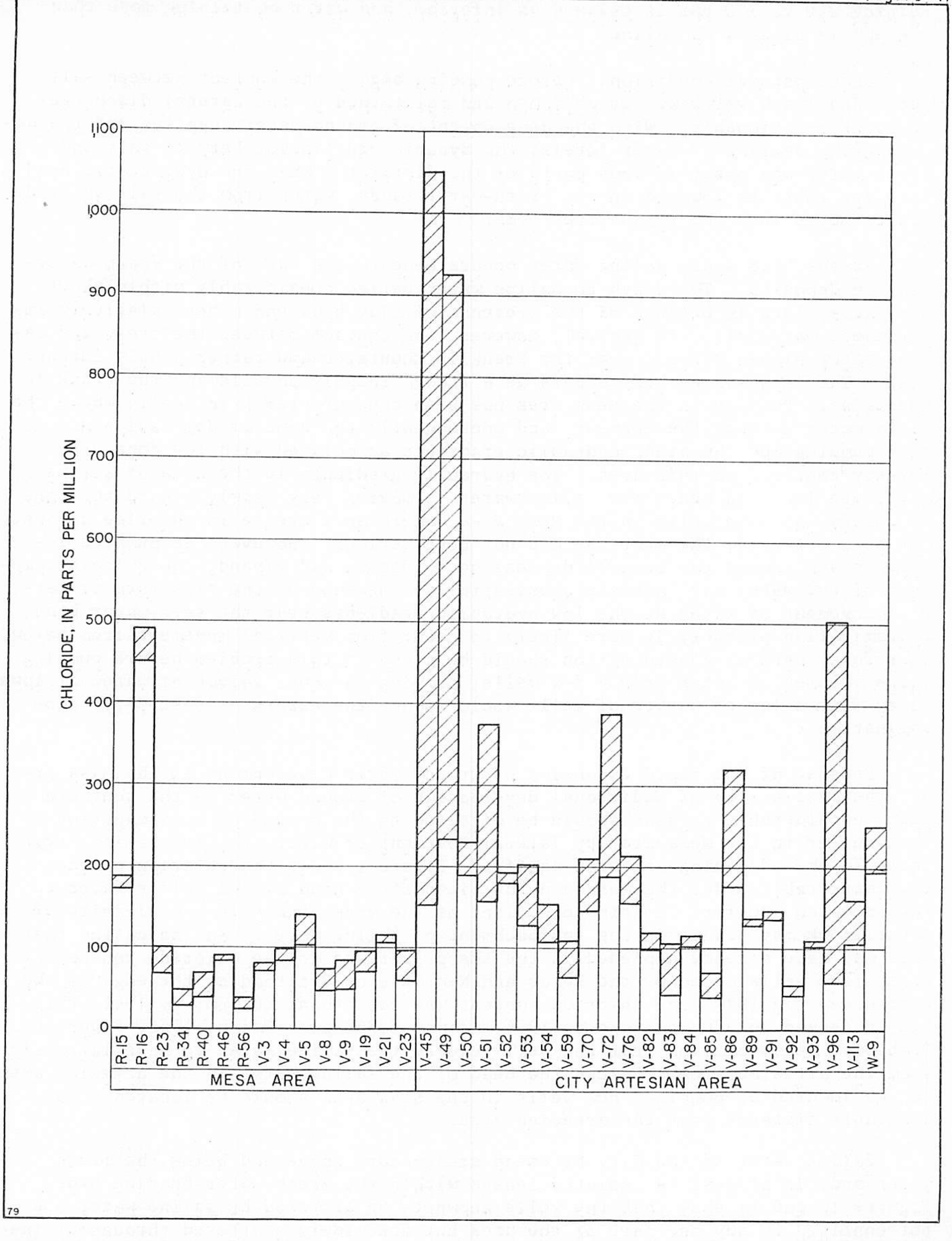

FIGURE 11.—Maximum and minimum chloride concentrations in water from selected wells in the Mesa and City Artesian areas

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.

Under natural conditions, before pumping began, the contact between salt water and fresh water was established and maintained by the natural discharge-recharge relationship. With the development of ground-water supplies and the accompanying decline of water levels, the dynamic equilibrium between salt and fresh water was upset in some parts of the district. When the hydrostatic head or water table is lowered in the fresh-water sands, water from the salt-water deposits moves into the fresh-water beds.

In the Mesa area, saline water occurs beneath and east of the fresh-water-bearing deposits. The depth to saline water varies considerably within short distances, largely because of the presence of clay beds and other relatively impermeable materials. In general, however, the contact between the fresh and saline water slopes steeply near the Franklin Mountains and rather gently further east. The fresh-water body occurs as a trough roughly paralleling the Franklin Mountains. Pumping in the Mesa area has been concentrated principally where the fresh water extends the deepest, and consequently the cone of depression due to this pumping and the steep hydraulic gradients associated with the cone are largely confined to this area. The hydraulic gradients in the area of saline water are low, and hence the saline water is moving very slowly toward the cone of depression. In wells in the Mesa area, where an increase in chloride content has been observed, the increase has not been serious. However, as pumping increases and causes the cone of depression to deepen and expand, the chloride content of the water may increase substantially. Because of the slow rate of lateral movement of water at the low hydraulic gradients near the salt-water body, contamination probably is more likely to occur from vertical movement from below. Therefore, careful consideration should be given to this problem before pumping large volumes of water from a few wells; pumping an equal volume of water at lower rates from a larger number of wells would reduce the hazard of salt-water contamination.

Because of the rapid expansion of ground-water development in the Mesa area and the possibility of additional development of ground water in the southern part, considerable thought should be directed to the hazard of contamination of the aquifer in the Mesa area by lateral movement of water from the saline-water zones in the adjoining artesian aquifer. Figure 1 shows the relation between the water table under the Mesa and the piezometric head of the saline water in the artesian aquifer. Continued decline of the water table in the vicinity of the rimrock may result in the encroachment of saline water. An indication that this may have already happened is the sharp increase in the chloride content of water from wells owned by the Texas and New Orleans Railroad at the edge of the Mesa area. In 1929, the chloride content was less than 100 ppm; by 1941, this had increased to 420 ppm; and in 1954, it was 1,760 ppm (Smith, 1956, Figure 6). Probably, heavy pumping from the wells caused the saline water to move laterally from the artesian area. Unless the head of the saline water in the artesian area can be lowered by pumping, new wells in the Mesa area should be located a considerable distance from the artesian area.

Saline water in the City Artesian area occurs above and below the fresh water and, in places, as isolated lenses within the fresh-water-bearing beds. Figures 10 and 11 show that the wells known to be affected by saline water are not confined to any one part of the area but are widely scattered throughout the artesian part of the aquifer. In some wells, the chloride content has increased steadily since 1935; in other wells, it has varied greatly, although the difference over a long period of record has been relatively small. The sharp decrease in chloride content in well V-49 in 1950 reflects the injection of treated surface water into the well during artificial-recharge operations.

In general, mineral contamination of ground-water supplies in the City Artesian area occurs through leaking casings and interformational leakage. A large part of the contaminating water moves through or around wells that penetrate the saline-water aquifer overlying the fresh-water sands. Where a well penetrates the saline-water body, the water may move along the casing from one formation to the other. Movement of the saline water through or around a well occurs only if the hydrostatic head of the saline water is higher than that of the fresh water. Large-scale pumping from the fresh-water sands has lowered the artesian head in these sands, but the head in the overlying or underlying saline water probably has not changed significantly since pumping began. In response to the difference in head, saline water may move into the fresh-water sands, either through or around the well or around the relatively impermeable clay beds or lenses.

Chlorographs of three wells (V-45, V-49, and V-72, Figure 10) and the chlorographs obtained from three pumping tests (V-45, V-49, and V-71, Figure 9) show contamination of the fresh water by saline water leaking through or around the well casing. Ordinarily, if the chloride content does not change significantly during the test, contamination is due to the lateral movement of saline water through the fresh-water sands. In these tests, the sharp increase in the chloride content shortly after pumping started indicates that saline water entered the wells while they were idle and escaped into the fresh-water sand (Figure 9). Thus, the water pumped during the early part of the test was similar to the water pumped from the well when it was last operated. Immediately after the water in the pump column had been expelled, the chloride content increased sharply, but as pumping continued the salinity decreased. The salinity in well V-45 decreased more slowly than in wells V-49 and V-71, indicating that leakage in well V-45 was relatively greater.

In the refinery section of the industrial area, some of the wells that were most seriously affected by saline-water contamination were abandoned; others were repaired or were placed in part-time service. Records of the Texas Co. reveal that in June 1956 the chloride content of well V-71 increased to 1,390 ppm, an increase of about 1,040 ppm since July 1955. As a consequence the upper stratum, which is the source of the saline water, was sealed off by repairing a leak in the casing, and pumping was resumed. In the period from October 1956 to January 1960, the chloride content ranged from 230 to 240 ppm. The chloride curve of well V-71 (Figure 9), however, reveals that saline water still is leaking into the well, though at a considerably reduced rate. This was shown during the test in April 1958, when the chloride content rose to 900 ppm after 5 minutes of pumping. After prolonged pumping the chloride content decreased to nearly 200 ppm, which was approximately the chloride content of the water pumped during the first part of the test.

The chloride content of water in wells V-54 and V-59 has increased slowly but steadily (Figure 10). Although the net increase has not been large, the trend is serious.

The mineralization in well V-51 increased at a uniformly rapid rate after 1935, and as a consequence the well was abandoned and plugged in 1957. As pumping tests were not made of well V-51 before it was abandoned, it cannot be determined definitely whether the contamination was due to interformational movement or to the leakage of water through or around the well casing. The absence of sharp peaks on the graph (Figure 10) suggests that the contamination may have been from interformational movement. The areal extent of contamination is not known, but chemical analyses of water from well V-52, about 350 feet distant, reveal that the chloride content was 180 ppm in 1958, which was similar to that of water pumped in 1951. However, the apparent absence of saline-water contamination in well V-52 may be attributed to the relatively small volume of water pumped from the well. The pressure gradient between the saline water and the fresh water probably is small, and the movement of saline water through or around the relatively impermeable clay appears to be negligible at well V-52.

An increase in the chloride content of the ground water in the Upper and Lower Valleys has been noted only in the alluvium. During periods when surface-water supplies are inadequate for irrigation, ground water is pumped as a supplemental supply. As a result, the chloride content of the ground water has increased primarily because of concentration of the salt by evaporation. When surface-water supplies become adequate, the ground-water supplies are replenished with water containing less chloride.

Ground water for public supply in the Upper Valley is obtained principally from the medium and deep aquifers of the Santa Fe group, and the chloride content of the water pumped from these aquifers has shown no increase since pumping started in 1957. However, if pumpage exceeds the average annual recharge, saline water that underlies and adjoins the fresh water will move toward the wells.

Artificial Recharge

Because of the annually increasing rate of depletion of the ground-water supply in the Hueco bolson area, considerable thought has been given to artificial methods of increasing the rate of recharge. Methods used or considered for recharging the ground-water reservoir include injection through wells and shafts, spreading runoff from the arroyos along the mountain fronts by the construction of ditches and detention dams that would tend to prevent its going beyond the natural recharge areas, and by diversion of runoff into ponds.

During the period 1948-52, the Geological Survey, in cooperation with the city of El Paso and the Texas Board of Water Engineers (now the Texas Water Commission), investigated the possibility of injecting excess treated surface water from the Rio Grande into the Montana well field, which is in the City Artesian area. The results of the recharge tests were summarized by Sundstrom and Hood (1952, p. 2-3) as follows:

1. In the Montana well field, treated surface water could be injected into four wells spaced 1,500 feet apart at a total rate of about 6 million gallons a day.

2. In the Mesa well field, treated surface water could be injected at many times the rate possible in the Montana well field.

3. Recharge in the Montana well field since 1949 has resulted in a reduction in the chloride content of the ground water in the vicinity of the well used for the experiments.

In 1959, the El Paso Electric Co. drilled well R-81, 1,483 feet deep, to be used for the disposal of saline water. The well was plugged back to a depth of 1,200 feet and a stainless-steel shutter screen was set opposite sands between 990 and 1,188 feet, the top of the screen being 150 feet below the base of the fresh water. During preliminary tests, fresh ground water, which has a temperature of 75° to 80°F, was injected successfully into the saline-water strata at rates ranging from 150 to 500 gpm. The well is presently being used on a part-time basis; the operation apparently is successful.

Since 1958, the Corps of Engineers, U. S. Army, has completed the construction of two lakes on the north edge of the Fort Bliss Cantonment. The larger lake, which can impound nearly 1,000 acre-feet of water, was bottomed in caliche; the smaller lake was completed in coarse sand underlying the caliche. From Sept. 11 to Nov. 29, 1958, the infiltration rate of the larger lake ranged from at least 0.41 to 0.03 foot per day, corrected for evaporation losses, or from 130,000 to less than 10,000 gpd per acre. Although complete records are not available, observations of percolation rates after several rains in 1959 indicate that percolation rates are higher in the smaller lake.

In 1958, the El Paso Public Service Board considered the use of a large-diameter shaft for artificial recharge. The shaft was dug in a gravel pit, which encompassed an area of about 3 acres and had a maximum depth of 15 feet. The shaft was dug to a depth of 91.6 feet, more than 300 feet above the water table. Casing, 41 inches in diameter, consisted of corrugated sheet metal, the lower 24 feet of which had been torch slotted. Storm runoff was diverted into the gravel pit, and filtration of the water entering the shaft was limited to catching flotsam on screens having relatively large openings. Water entered the shaft through a 12-inch steel pipe and was to have been measured by a Sparling meter connected to an automatic recorder. However, the meter failed to operate during the first inflow, owing possibly to the high sediment content of the water.

Data on the infiltration of storm runoff diverted to the recharge pit on July 8, Aug. 6, and Aug. 29, 1960, are shown in the following table.

Date	Rainfall (in.)	Intensity (in./hr.)	Volume impounded (gal.)	Infiltration rate (gpm)	Depth of shaft (ft.)
July 8, 1960	2.6	0.43	465,000	740	86.5
Aug. 6, 1960	2.05	6.15	8,346,000	1,525	81.4
Aug. 29, 1960	2.15	1.42	4,957,000	955	80.7

These data show that the depth of the shaft decreased approximately 10 feet, which amounted to a 40-percent reduction in the intake area of the shaft. In addition to plugging the shaft itself, the infiltration properties of the sand probably have been reduced by clogging with sediment. Samples of water obtained from the pit during the rain of July 8 indicated a minimum sediment load of 0.5 percent. On this basis, at least 9,200 cubic feet of sediment was deposited in the pit and the shaft during the three periods. It is evident, therefore, that the shaft is not operating successfully, inasmuch as 100 cubic feet of its total volume of 840 cubic feet has been filled with sediment. Most of the 13,768,000 gallons, or 42 acre-feet of water, probably percolated through the side walls and bottom of the recharge pit. According to Suter (1956, p. 360), flow through the bottom of a pit reduces almost proportionally to the square root of the area, whereas the flow through the side walls is proportional to the wall area itself. Although the permeability of the caliche in the floor of the pit no doubt has been reduced by silting, cavernous openings are present through which water flows.

Recharge of storm runoff through wells completed below the water table has not been attempted in the El Paso area. In areas where this type of recharge has been done, experience has shown that the recharge water should be filtered and treated. Recharge wells in the High Plains of Texas have been used with varying degrees of success to inject turbid, untreated water impounded in the many shallow depression ponds. The most successful of these have been pumped for short periods daily during the recharge cycle to remove as much of the accumulated silt as possible (oral communication, J. G. Cronin, 1960).

Water spreading, the oldest and most widely used method of artificial recharge, has not been practiced to any great extent in the El Paso area chiefly because of the steep slopes along the mountain fronts and the presence of caliche, which in places underlies the coarse surficial materials. In several canyons along the south and east sides of the Franklin Mountains, small dams have formed effective recharge reservoirs (Sayre and Livingston, 1945, p. 72), except that they are subject to washout by the flashy-type runoff following short but torrential rainfall. Finger dams, spaced along some of the arroyos that empty onto the bolson surface, probably could be used to increase the natural recharge by reducing the velocity and the sediment content of the water.

In summary, injection of treated water into wells is the most satisfactory method of artificially increasing the recharge to the aquifer underlying the Hueco bolson. A large percentage of the water injected through wells may be recovered during subsequent pumping. The use of wells that are finished above the water table has not proved satisfactory because of excessive clogging and the difficulty encountered in reconditioning the wells. Although surface pits and ponds serve as recharge structures, the infiltration rates generally are low, the bottoms of the pits tending to become sealed with sediment. Water spreading generally is economical and relatively easy except where slopes are steep and velocities are high. Detention dams along arroyos are effective methods of increasing recharge to the ground-water reservoir, but maintenance costs may be high.

Surface-Water Supply

Prior to 1943, only small quantities of water were pumped from the Rio Grande and the water was used principally by industries. In November 1943, the city 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 of El Paso and the U. S. Bureau of Reclamation, diversions from the Rio Grande by the city consist of (1) water to satisfy rights on farmland owned by the city, (2) surplus water in the river during the irrigation season, and (3) return flow of water from the drains. The water rights on the farmland owned by the city are available only during the period March 1 to September 30, and the amount of water diverted depends upon the supply of surface water available in Elephant Butte Reservoir, New Mexico, for irrigation of classified land in the Bureau of Reclamation project. The remainder of the water available to the city, which is chiefly the drain flow, may be diverted at any time, but generally the drain flow increases in mineralization and decreases in quantity after the irrigation season, and diversions cease soon after September 30.

Figure 12 shows the average daily diversion of surface water from the Rio Grande since 1943. The data do not include the shallow well water that was pumped into the river at Canutillo for transportation to the treatment plant. The diversions are computed on an average daily basis for the entire year;

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

Figure 12

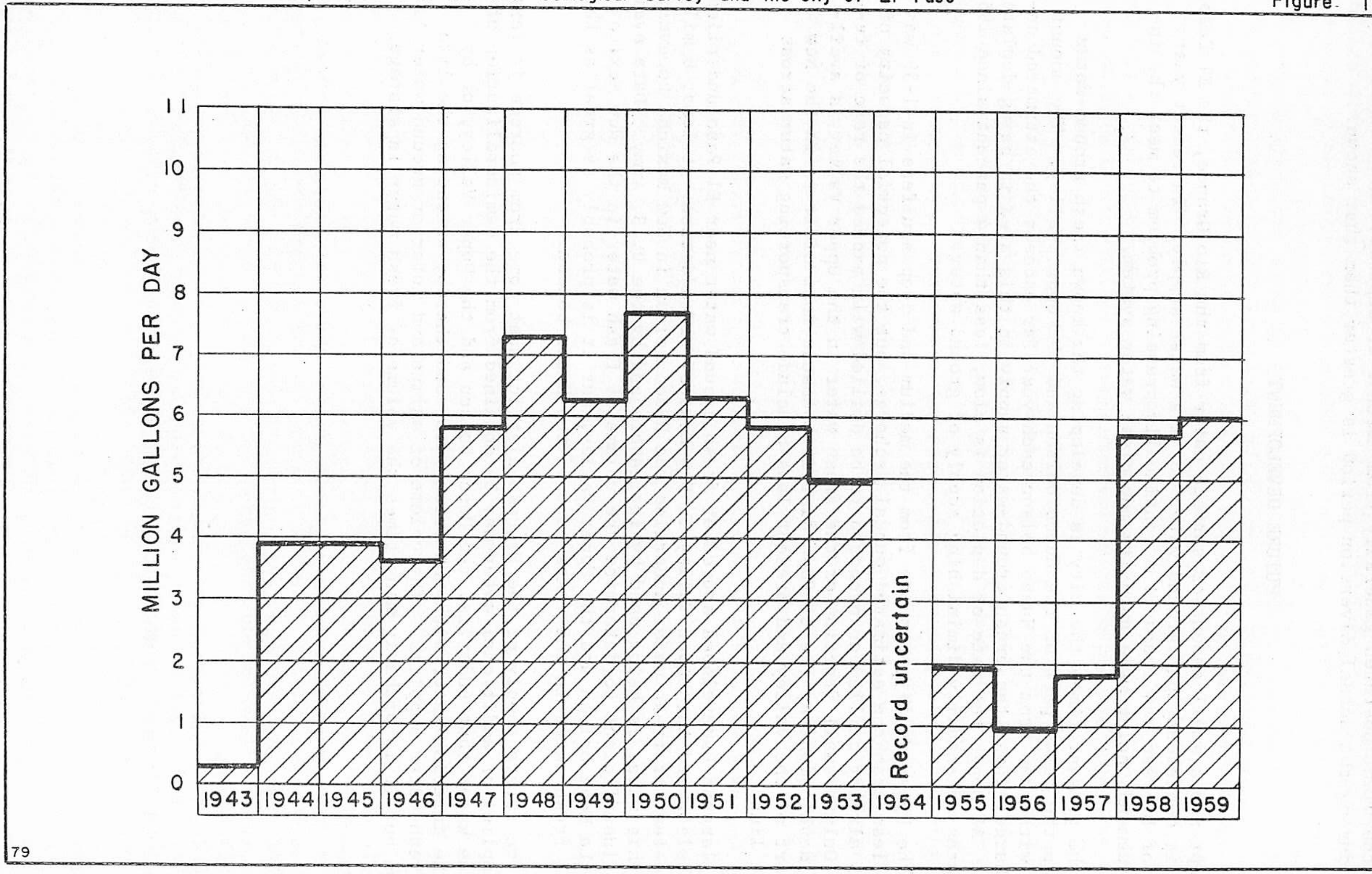

FIGURE 12.—Average daily diversion of water from the Rio Grande for municipal use at El Paso (Does not include pumpage from Canutillo well field)

however, the plant operates generally from March 1 to September 30. Therefore, the rate during the actual diversion period is greater than that shown.

FUTURE DEVELOPMENT

Except for a small amount of surface water from the Rio Grande, the El Paso district is dependent upon ground water for its water supply. In recent years the city of El Paso has found it a continually pressing problem to meet the increasing demands being made upon its municipal water system.

At the present time, the city is developing the known fresh ground-water sources in the Texas part of the Hueco bolson and the Upper Valley. The amount of water withdrawn from the Hueco bolson each year far exceeds the estimated annual recharge; thus, the fresh ground-water supply in this area is being depleted or mined. Although the rate of depletion is slow, less than 4 percent since 1954, it indicates an annually diminishing supply of ground water.

In the Upper Valley, pumpage from the medium and deep aquifers in 1959 was somewhat less than the estimated annual recharge, but the potential capacity of the wells already drilled or proposed to be drilled will exceed the rate of recharge. Only a small fraction of the fresh water in the Upper Valley is available for development by the El Paso district because most of it is in the New Mexico part of the valley and present laws preclude transporting water across the state line.

The largest undeveloped source of fresh ground water near El Paso underlies La Mesa bolson and the Upper Valley in New Mexico. In addition, at least 6 million acre-feet of fresh water underlies the Hueco bolson in New Mexico; however, part of this water is being used by irrigators and by the U. S. Army. Data available are insufficient to determine the volume of fresh water in the New Mexico parts of La Mesa bolson and the Upper Valley, but it is probably as great as the volume of fresh water in the Texas part of the Hueco bolson.

If the future supply of the El Paso district must come from sources in Texas, large supplies of additional water may be obtained from the demineralization of the saline water that underlies the Hueco bolson and the Upper Valley, or by mixing the inferior water with the fresh water and thereby extending the life of the fresh-water supplies. The volume of saline and inferior ground water is not known but it is probably many times the volume of fresh water in storage.

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*Name of agency changed to Texas Water Commission January 30, 1962.

Table 3.--Records of selected wells in the El Paso district

All wells are drilled unless otherwise noted in Remarks.
Water level : Reported water levels given in feet; measured water levels given in feet and tenths.
Method of lift and type of power: C, cylinder; E, electric; G, gasoline, butane or diesel; H, hand; N, none; T, turbine; W, windmill. 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		Method of lift	Use of water	Remarks
							Below land-surface datum (ft.)	Date of measurement			
						El Paso County					
R-58	--	--	--	--	6	--	133.1	Oct. 16, 1957	N	N	Old well.
*R-59	City of El Paso	City of El Paso	1958	725	24, 18, 12	4,050.5	334.0 333.9	Jan. 19, 1958 Oct. 26, 1959	T,E	Ind	Casing: 24-in. to 349 ft.; 18-in. slotted at 360 - 625 ft. Drawdown measured 45 ft. after 24 hours pumping at 1,350 gpm on Jan. 22, 1958. Well plugged back to 625 ft. Supplies water for El Paso Electric Co. Electric log indicates fresh water extends to about 590 ft.
R-60	City of El Paso well 27	do	1955	828	24, 18, 12	3,929.5	255.3 253.8 253.2 256.5	Aug. 6, 1956 Dec. 11, 1958 Jan. 6, 1959 Jan. 5, 1960	T,E 200	P	Pump set at 380 ft. Screened from 358 to 838 ft.
*R-61	City of El Paso well 28	do	1955	840	24, 18, 12	3,941.4	256.8 257.1 257.8 260.5	July 30, 1956 Mar. 30, 1958 Jan. 6, 1959 Jan. 5, 1960	T,E 200	P	Drawdown reported 76 ft. after 9 hours pumping at 1,379 gpm, Jan. 1956.
R-62	City of El Paso	do	1956	750	18, 12	3,968.5	280.1 282.6 283.7 286.0	Jan. 1, 1957 Jan. 1, 1958 Jan. 1, 1959 Jan. 5, 1960	N	N	Observation well. Mesa recorder.
R-63	City of El Paso well 31	do	1956	840	24, 18, 12	4,003.4	320.0 316.5 316.9 319.7	Dec. 25, 1956 Mar. 30, 1958 Jan. 6, 1959 Jan. 5, 1960	T,E 200	P	Drawdown measured 77 ft. after 24 hours pumping at 1,000 gpm on Dec. 22, 1956. Pump set at 450 ft.
*R-64	City of El Paso well 29	do	1956	870	24, 18, 12	3,954.5	274 265.6 268.9	May 1956 Jan. 6, 1959 Jan. 5, 1960	T,E 200	P	Drawdown reported 85 ft. after 24 hours pumping at 1,500 gpm May 1956.
R-65	Baptist Spanish Publishing House	W. Cass	1939	280	4	--	252.1	May 25, 1955	T,E	Ind	
*R-66	Price's Dairy well 1	Layne-Texas Co. Ltd.	1955	1,012	24, 18, 12	4,001	338	May 1955	T,E 300	Irr	Casing: 18-in. to 497 ft., slotted from 380 to 497 ft., 12-in. from 497 to 870 ft.; screened from 497 to 860 ft. Pumping level reported 400 ft. after 6 hours pumping at 2,145 gpm, May 1955. Plugged back to 870 ft.

See footnote at end of table.

Table 3.--Records of selected wells in the El Paso district--Continued

Well	Owner	Driller	Date com-plet-ed	Depth of well (ft.)	Diam-eter of well (in.)	Altitude of land surface (ft.)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft.)	Date of measurement			
*R-67	Price's Dairy well 2	Layne-Texas Co. Ltd.	1955	875	24, 18, 12	3,999	338	July 1955	T,E	Irr	Pumping level reported 366 ft. after 6 hours pumping at 1,300 gpm, July 1955. Plugged back to 753 ft.
R-68	City of El Paso well 32	City of El Paso	1957	789	18, 12	3,984.3	292.0 291.2 291.5 296.1	Nov. 15, 1957 Mar. 31, 1958 Jan. 6, 1959 Jan. 5, 1960	T,E 200	P	Casing: 18-in. slotted from 340 to 500 ft., 12-in. from 500 to 650 ft. Draw-down measured 44 ft. after 68 hours pump-ing at 1,610 gpm, Nov. 18, 1957. Temp. 79°F.
*R-69	City of El Paso well 33	do	1958	1,343	24, 18, 12	4,090	403.3 402.9 404.2	Apr. 17, 1958 Jan. 6, 1959 Jan. 5, 1960	N	N	Casing: 18-in. slotted from 412 to 511 ft., 12-in. from 561 to 1,091 ft. Draw-down measured 84.7 ft. after 24 hours pumping at 700 gpm, Apr. 17, 1958. Plugged back to 1,091 ft.
*R-70	City of El Paso well 34	do	1958	815	24, 18, 12	3,970.6	276.2 277.6 281.4	Feb. 13, 1958 Jan. 6, 1959 Jan. 5, 1960	T,E	P	Casing: 18-in. slotted from 330 to 500 ft., 12-in. from 500 to 800 ft. Drawdown measured 22.5 ft. after 8 hours pumping at 1,300 gpm, Feb. 14, 1958.
*R-71	City of El Paso well 35	do	1958	786	24, 18, 13	4,003.7	308.5 309.0 312.8	May 7, 1958 Jan. 6, 1959 Jan. 5, 1960	T,E	P	Drawdown measured 61.0 ft. after 22 hours pumping at 1,750 gpm, May 6, 1958.
*R-72	City of El Paso well 42	do	1958	1,955	24, 18, 12	4,010	316.4	June 13, 1960	N	N	Abandoned and plugged. Redrilled to 670 ft. as production well, June 1960. Draw-down measured 36.5 ft. after 8 hours pumping at 1,200 gpm, June 16, 1960. Pump to be installed.
*R-73	City of El Paso well 36	do	1958	800	24, 18, 12	3,994.8	296.3 299.2 302.8	July 7, 1958 Jan. 6, 1959 Feb. 2, 1960	T,E	P	Drawdown reported 50.5 ft. after 24 hours pumping at 1,300 gpm, July 24, 1958. Pump set at 418 ft. Plugged back to 690 ft.
R-74	U. S. Army	--	--	--	10	3,870	212.8	Apr. 22, 1958	N	N	Abandoned.
*R-75	El Paso Natural Gas Co. well 5	Layne-Texas Co. Ltd.	1958	650	20, 12	--	342	July 1959	T,-	Ind	Drawdown reported 38 ft. after 24 hours pumping at 1,000 gpm.
*R-76	U. S. Army well 14	Texas Water Wells Co.	1958	834	--	3,920	249.0	Nov. 18, 1958	T,E	P	Screen set opposite sands between 260 and 815 ft. Drawdown measured 31 ft. after 6 hours pumping at 520 gpm, Nov. 19, 1958.
*R-77	City of El Paso well E-2	City of El Paso	1958	1,210	--	4,114	--	--	N	N	Electric log indicates base of fresh water at 535 ft. Abandoned and plugged.
*R-78	City of El Paso well E-3	do	1958	631	24, 18, 12	4,070	348.9	Jan. 6, 1959	T,E 200	Ind	Casing: 18-in. slotted from 361 to 486 ft., 12-in. from 498 to bottom. Drawdown measured 48.8 ft. after 24 hours pumping at 1,480 gpm, Feb. 24, 1959.

See footnote at end of table.

Table 3.--Records of selected wells in the El Paso district--Continued

Well	Owner	Driller	Date com- plet- ed	Depth of well (ft.)	Diam- eter 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
R-79	F. Wardy	Tillary	1954	450	12	3,920	--	--	T,G 200	Irr	Discharge reported 1,000 gpm. Pump set at 300 ft.
*R-80	U. S. Army well 16	Layne-Texas Co. Ltd.	1959	819	24, 16	3,939.5	274	Aug. 1959	T,E 150	P	Casing: 16-in. screen set opposite sands between 289 and 810 ft. Drawdown reported 44 ft. after 8 hours pumping at 1,140 gpm, Aug. 21, 1959.
*R-81	El Paso Electric Co.	do	1959	1,483	--	4,070	339.0	Oct. 26, 1959	--	--	Casing: Stainless steel screen from 990 to 1,188 ft. Rise of water level 71 ft. after 24 hours recharging at 578 gpm, Oct. 27, 1959. Electric log indicates fresh water extends to 840 ft. Waste-water disposal well 1.
*R-82	City of El Paso well 40	City of El Paso	1959	885	24, 18, 12	3,930	244.2	Nov. 17, 1959	T,E 300	P	Drawdown measured 47.0 ft. after 8 hours pumping at 1,500 gpm, Nov. 17, 1959. Temp. 76°F.
*R-83	U. S. Army well 15	Layne-Texas Co. Ltd.	1959	819	24, 16	3,943.6	274	Dec. 1959	T,E 150	P	Casing: 16-in. screen set opposite sands between 293 and 810 ft. Drawdown reported 71 ft. after 24 hours pumping at 1,570 gpm, Dec. 3, 1959. Pump set at 370 ft.
*R-84	City of El Paso well 41	City of El Paso	1959	721	24, 18	4,041.7	331.6	Jan. 5, 1960	T,E 200	P	Casing: 18-in. slotted from 359 to 515 ft. Drawdown measured 71.1 ft. after 4 hours pumping at 1,400 gpm, Jan. 26, 1960. Electric log indicates fresh water extends to 620 ft. Plugged back to 515 ft. Pump set at 440 ft.
R-85	City of El Paso	do	1960	693	--	--	--	--	N	N	Test well. Electric log indicates fresh water extends to 595 ft.
R-86	City of El Paso well 44	do	1960	932	24, 18, 12	--	300.6	Aug. 12, 1960	--	N	Casing: 18-in. slotted from 318 to 540 ft., 12-in. from 540 to 770 ft. Drawdown measured 61.9 ft. after 24 hours pumping at 2,000 gpm, Aug. 13, 1960. Electric log indicates fresh water extends to 850 ft. Plugged back to 770 ft. Pump to be installed.
T-3	Navar Bros.	Payne & Ballard	1956	585	8	--	--	--	N	N	Plugged.
T-4	O'Leary Realty Co.	H. S. Payne	1960	105	--	--	25	Mar. 1960	N	N	Bedrock reported at 105 ft. Insufficient supply. Abandoned.
*T-5	do	do	1960	515	--	--	--	--	C,E	D,P	

See footnote at end of table.

Table 3.--Records of selected wells in the El Paso district--Continued

Well	Owner	Driller	Date com-plet-ed	Depth of well (ft.)	Diam-eter of well (in.)	Altitude of land surface (ft.)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft.)	Date of measurement			
*V-93	City of El Paso well 30	City of El Paso	1956	1,992	24, 18, 12	3,922.5	260.3 258.2 260.5	Mar. 27, 1958 Feb. 13, 1959 Jan. 6, 1960	T,E	P	Drawdown measured 76.7 ft. after 24 hours pumping at 1,200 gpm, Feb. 17, 1959. Electric log indicates fresh water extends to 1,045 ft. Casing: 18-in. slotted from 316 to 495 ft., 12-in. from 495 to 952 ft. Plugged back to 992 ft.
*V-136	City of El Paso well 37	do	1959	1,022	24, 18, 12	3,906.5	254.9 252.0	Apr. 2, 1959 Jan. 6, 1960	T,E	P	Drawdown measured 61.7 ft. after 24 hours pumping at 1,835 gpm, Apr. 2, 1959. Plugged back to 920 ft.
*V-137	Phelps-Dodge Corp. well 5	Layne-Texas Co. Ltd.	1956	655	--	3,760	91	July 1956	T,E	Ind	Casing: 12-in. bronze screen set opposite sands between 265 and 580 ft. Plugged back to 580 ft.
*V-138	Falstaff Brewing Inc. well 3	do	1957	524	20, 12	--	62 41.6	May 1957 Apr. 2, 1960	T,E 40	Ind	Casing: 12-in. screen from 317 to 347 ft., and from 353 to 413 ft. Drawdown reported 45 ft. after 16 hours pumping at 508 to 533 gpm, May 26, 1957. Plugged back to 420 ft. Pump set at 120 ft.
*V-139	City of El Paso well 38	City of El Paso	1959	722	24, 18, 12	3,954.5	295.8 293.8	May 14, 1959 Jan. 7, 1960	T,E	P	Casing: 18-in. slotted from 342 to 497 ft., 12-in. from 497 to 722 ft. Drawdown measured 66.3 ft. after 24 hours pumping at 1,480 gpm, May 15, 1959.
*V-140	City of El Paso well 39	do	1959	846	24, 18, 12	3,869.6	233.6	Oct. 1, 1959	T,E 200	P	Drawdown measured 128.5 ft. after 6 hours pumping at 1,815 gpm, Oct. 6, 1959. Plugged back to 750 ft.
W-73	Navar Bros.	C. H. Taylor	1948	460	--	--	415	1948	--	--	Pumping level 433 ft.
*W-74	El Paso Natural Gas Co.	Wheeler Cass	1958	795	--	--	329	Sept. 1958	N	N	Insufficient supply. Abandoned.
*W-75	Holibeke Ranch	--	1957	344	6	--	--	--	C,E	P	
*W-76	Ben Ivey	Morrison Bros.	1958	312	16	--	110	Feb. 1960	T,G	Ind	Supplied water for highway construction.
Y-277	--	Ballard & Tillary	1959	--	--	--	120.9 120.9	Sept. 2, 1960 Dec. 20, 1960	N	N	
*Y-278	H. B. Zachry	Morrison Bros.	1958	400	12	--	154.1 144.2	Feb. 3, 1960 Dec. 20, 1960	T,G	Ind	Discharge reported 150 gpm.
*Z-13	Strain Bros.	do	1958	300	16	--	184.0 183.9	Sept. 2, 1960 Dec. 20, 1960	T,G	Ind	Discharge reported 500 gpm. Pump set at 220 ft.
*AA-37	City of El Paso test well LV-3	City of El Paso	1959	1,909	6	--	--	--	N	N	Abandoned.
*BB-41	H. B. Zachry	Wheeler Cass	1959	400	12	--	212.2 212.2	Sept. 2, 1960 Dec. 20, 1960	T,G	Ind	Discharge estimated 700 gpm, Feb. 5, 1960.

See footnote at end of table.

Table 3.--Records of selected wells in the El Paso district--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
*BB-42	H. B. Zachry	Wheeler Cass	1959	350	12	--	225.1 225.8	Sept. 2, 1960 Dec. 20, 1960	T,G	Ind	Discharge estimated 350 gpm, Apr. 6, 1960.
*BB-43	City of El Paso test well LV-4	City of El Paso	1959	3,000	6	--	--	--	N	N	Abandoned.
*BB-44	City of El Paso test well LV-5	do	1959	2,158	6	--	--	--	N	N	Electric log and drill-stem tests indicate no fresh water available. Abandoned.

Hudspeth County

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
*A-1	Menzies Ranch	--	--	1,700	--	--	--	--	--	P,D,S	Supplies water for Hueco Inn. Water has odor of hydrogen sulfide.
A-2	City of El Paso University well 2	City of El Paso	1959	2,100	6	5,160	--	--	N	N	Electric log indicates no fresh water available.
*C-1	City of El Paso University well 1	do	1958	2,611	11, 7, 6	4,520	1,140	Oct. 1958	N	N	Drill-stem test and electric log indicate no fresh water available.
*H-1	Theison well 1	California Oil Co.	1930	4,850	--	5,109	1,460	Dec. 1956	T,E	S	Oil test, converted to water well. Discharge estimated 150 gpm, Dec. 19, 1956. Plug drilled out to 2,400 ft.
*U-8	Soil Conservation Service	K. Wheeler	1959	295	8	--	150	Nov. 1959	T,G	Ind	Discharge estimated 50 gpm, Dec. 10, 1959.
U-9	Hudspeth County Conservation and Reclamation Dist. No. 1, test well 2	Layne-Texas Co. Ltd.	1957	817	--	3,545	--	--	N	N	
*V-1	Soil Conservation Service	A. C. Wheeler	1959	906	--	--	--	--	T,G	Ind	Pump set at 470 ft.
*V-2	Owens-Bowden	--	1955	356	6	--	--	--	T,G	S	Water obtained from sandstone of Cretaceous age.
*V-3	do	--	1959	406	8	--	--	--	T,G	S	Casing: Slotted from 350 ft. to bottom. Water obtained from sandstone of Cretaceous age.
*AA-4	Hudspeth County Conservation and Reclamation Dist. No. 1, test well 3	Layne-Texas Co. Ltd.	1957	708	--	3,550	--	--	N	N	Electric log indicates no fresh water available. Abandoned.

See footnote at end of table.

Table 3.--Records of selected wells in the El Paso district--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
AA-5	Hudspeth County Conservation and Reclamation Dist. No. 1, test well 1	Layne-Texas Co. Ltd.	1957	3,500	--	3,520	--	--	N	N	Drill-stem test and electric log indicate no fresh water available. Abandoned.

* For chemical analyses of water from wells in the El Paso district see Table 4.

Table 4.--Chemical analyses of water from selected wells in the El Paso district, 1955-60

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

NOTE: Analyses of water from different depths in the same well are given for several wells.

Well	Owner	Depth of well (ft.)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
									El Paso County												
R-15	U. S. Army	450	Apr. 19, 1955	--	--	--	--	--	--	132	--	174	--	--	--	--	--	124	--	868	7.6
R-15	do	--	June 20, 1956	--	--	--	--	--	--	141	--	174	--	--	--	--	--	130	--	884	7.9
R-15	do	--	July 16, 1957	24	--	--	36	7.4	127	132	34	177	--	3.5	--	--	479	120	70	859	7.3
R-15	do	--	June 8, 1959	18	--	--	37	7.2	123	129	34	172	0.7	4.0	--	--	464	122	69	845	7.5
R-16	do	550	Apr. 19, 1955	--	--	--	--	--	--	92	--	490	--	--	--	--	--	242	--	1,790	7.6
R-16	do	--	June 20, 1956	--	--	--	--	--	--	85	--	472	--	--	--	--	--	226	--	1,740	7.5
R-16	do	--	July 16, 1957	26	--	--	63	14	241	89	23	450	--	8.6	--	--	870	214	71	1,660	7.1
R-16	do	--	June 8, 1959	20	--	--	64	13	244	87	24	455	.6	5.1	--	--	952	213	71	1,650	7.1
R-23	City of El Paso well 26	830	May 10, 1956	32	0.01	0.00	39	17	100 4.3	226	74	86	1.4	3.8	0.04	0.06	469	168	56	772	7.6
R-29	City of El Paso well 25	832	May 10, 1956	31	.01	.00	42	17	81 4.9	230	70	68	1.3	4.2	.03	.09	433	175	49	715	7.6
R-29	do	--	June 5, 1957	35	.00	--	42	17	86	223	70	69	1.3	4.8	--	--	435	174	52	705	7.5
R-31	City of El Paso well 24	790	Apr. 12, 1956	31	.00	--	41	14	58 3.8	221	51	38	1.5	5.2	--	--	352	160	43	575	7.7
R-34	City of El Paso well 23	814	May 10, 1956	--	--	--	--	--	--	202	--	34	--	7.5	--	--	--	150	--	535	7.5
R-40	City of El Paso well 21	806	May 31, 1956	--	--	--	--	--	--	200	--	51	--	--	--	--	--	167	--	626	7.6
bR-40	do	--	Sept.20, 1957	--	.02	.1	60	13	--	199	72	57	1.3	--	--	--	401	204	--	--	7.6
bR-40	do	--	Feb. 11, 1958	--	.02	.1	46	13	--	a215	65	71	1.5	--	--	--	448	168	--	--	8.6
R-46	U. S. Army well 11	812	May 15, 1956	39	.00	--	29	10	124	192	92	87	1.1	4.3	--	--	480	114	70	788	7.6
R-46	do	--	Sept.24, 1958	36	.03	--	54	19	83	201	91	88	1.1	8.7	--	--	482	212	46	784	7.7
R-48	U. S. Army well 12	799	July 24, 1956	38	.00	--	18	5.6	83	161	48	42	1.0	5.5	--	--	328	68	73	511	7.9
R-48	do	--	June 5, 1957	38	.00	--	20	6.6	92	166	58	51	.9	7.1	--	--	358	76	73	569	7.5

See footnotes at end of table.

Table 4.--Chemical analyses of water from selected wells in the El Paso district, 1955-60--Continued

Well	Owner	Depth of well (ft.)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
R-51	U. S. Army well 13	800	Jan. 4, 1956	36	.00	--	23	7.8	100	173	70	60	1.0	4.8	--	--	388	89	71	609	7.9
R-51	do	--	Sept.24, 1958	32	.04	--	22	7.6	97	171	68	57	.8	4.8	--	--	373	86	71	605	7.8
R-51	do	--	Apr. 4, 1960	32	.02	--	20	7.6	100	169	70	57	1.0	5.0	--	--	376	82	73	600	7.6
R-52	U. S. Army well 10	812	July 20, 1955	43	.01	--	26	8.4	125	192	93	77	1.1	5.5	--	--	480	100	73	767	8.2
R-52	do	--	Sept.24, 1958	42	.04	--	24	8.2	121	204	85	65	1.1	7.1	--	--	453	94	74	713	7.8
R-52	do	--	Apr. 4, 1960	34	.01	--	27	8.8	120	188	88	79	1.4	5.6	--	--	462	104	72	743	7.6
R-56	City of El Paso well 20	909	Sept.20, 1955	--	--	--	--	--	--	181	--	33	--	--	--	--	--	142	--	479	7.8
R-56	do	--	Apr. 10, 1956	--	--	--	--	--	--	180	--	36	--	--	--	--	--	143	--	476	7.8
R-56	do	--	Feb. 26, 1958	--	.02	0.1	36	14	--	180	42	36	.9	--	--	--	293	146	--	--	8.0
bR-59	City of El Paso	e570-585	Nov. 12, 1957	--	.14	.1	46	10	--	112	204	212	.8	--	--	--	553	154	--	--	8.1
bR-59	do	e642-658	Nov. 13, 1957	--	.12	.1	71	14	--	107	204	351	.9	--	--	--	797	234	--	--	8.2
bR-59	do	e706-726	do	--	.12	.1	66	17	--	102	180	414	1.0	--	--	--	929	232	--	--	8.2
bR-59	do	625	Jan. 7, 1958	44	--	--	30	6.5	99	146	50	100	--	4.5	--	--	406	102	68	686	7.8
R-61	City of El Paso well 28	840	Aug. 10, 1959	32	.01	.00	32	9.5	112 11	184	88	91	.9	4.0	0.02	0.09	472	119	65	767	7.5
bR-64	City of El Paso well 29	870	Oct. 23, 1957	--	.02	0.1	38	6	--	188	76	102	.9	--	--	--	466	120	--	--	7.8
R-64	do	--	Aug. 10, 1959	34	.01	.00	32	9.2	112 11	167	77	110	.9	3.0	.02	.14	471	118	65	763	7.5
cR-66	Price's Dairy well 1	e602-622	Apr. 8, 1955	--	1.8	--	52	12	267	333	126	252	--	--	--	--	1,070	180	--	--	--
cR-66	do	e726-746	Apr. 11, 1955	--	.1	--	84	16	325	105	74	580	--	--	--	--	1,240	276	--	--	--
cR-66	do	e836-857	Apr. 13, 1955	--	.1	--	93	20	527	128	85	896	--	--	--	--	1,820	315	--	--	--

See footnotes at end of table.

Table 4.--Chemical analyses of water from selected wells in the El Paso district, 1955-60--Continued

Well	Owner	Depth of well (ft.)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCo_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
cR-66	Price's Dairy well 1	e900-922	Apr. 14, 1955	--	0.4	--	115	19	576	91	174	960	--	--	--	--	--	--	--	--	--
cR-66	do	e381-860	--	--	.07	--	48	10	162	100	33	306	--	--	--	--	715	161	--	--	--
cR-67	Price's Dairy well 2	e540-560	June 7, 1955	--	.2	--	37	6	145	100	20	232	--	--	--	--	580	117	--	--	--
cR-67	do	e377-845	July 2, 1955	--	.5	--	51	8	205	98	21	356	--	--	--	--	782	160	--	--	--
R-67	do	--	July 12, 1957	38	--	--	67	12	223 8.1	82	24	435	--	6.8	--	0.07	854	216	68	1,610	7.6
bR-69	City of El Paso well 33	e702-728	Dec. 5, 1957	--	.08	0.1	38	11	--	a200	11	18	1.6	--	--	--	268	140	--	--	8.8
bR-69	do	e800-826	Dec. 6, 1957	--	.06	.1	38	10	--	a234	12	23	1.5	--	--	--	302	136	--	--	8.5
bR-69	do	e943-969	Dec. 7, 1957	--	.02	.1	26	5	--	a259	14	19	1.4	--	--	--	331	88	--	--	8.5
bR-69	do	e1,092-1,118	Dec. 8, 1957	--	.06	.1	33	7	--	a271	10	22	.5	--	--	--	340	110	--	--	8.5
bR-69	do	e1,317-1,343	Dec. 9, 1957	--	.02	.1	234	19	--	a 78	1	1,040	.1	--	--	--	1,960	662	--	--	8.2
R-69	do	e1,343-1,091	Apr. 8, 1958	34	.02	--	34	12	66 3.6	218	47	22	2.4	3.0	--	.01	332	134	49	501	8.0
R-70	City of El Paso well 34	815	Feb. 14, 1958	32	.00	--	23	5.2	75 6.6	134	44	60	.6	5.8	--	.14	322	79	65	515	7.7
bR-71	City of El Paso well 35	786	May 8, 1958	--	.02	.1	22	3	--	111	40	69	.6	--	--	--	293	68	--	--	8.2
bR-72	City of El Paso well 42	e515-540	Apr. 9, 1958	--	.02	.1	25	7	--	a149	58	70	.8	--	--	--	362	90	--	--	8.4
bR-72	do	e636-662	do	--	.02	.1	40	5	--	a122	58	130	.5	--	--	--	444	122	--	--	8.4
bR-72	do	e756-782	do	--	.02	.1	56	11	--	a 85	38	330	.6	--	--	--	740	184	--	--	8.2
bR-72	do	e875-901	do	--	.02	.1	61	10	--	a 80	33	328	.3	--	--	--	759	196	--	--	8.3

See footnotes at end of table.

Table 4.--Chemical analyses of water from selected wells in the El Paso district, 1955-60--Continued

Well	Owner	Depth of well (ft.)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
bR-73	City of El Paso well 36	e662-700	May 13, 1958	--	0.03	0.1	26	6	--	a170	64	80	0.4	--	--	--	400	90	--	--	8.4
bR-73	do	e750-800	May 15, 1958	--	.02	.1	38	9	--	102	40	267	.4	--	--	--	699	130	--	--	8.0
R-73	do	800-	July 22, 1958	33	.00	--	32	8.6	96 10	176	76	76	1.0	3.5	--	0.16	423	116	62	637	7.6
bR-75	El Paso Natural Gas Co. well 5	650	July 24, 1958	--	--	--	28	5	--	110	22	98	--	--	--	--	328	92	--	--	8.0
R-76	U. S. Army well 14	834	Feb. 24, 1959	32	.04	--	23	7.5	92	165	61	61	.9	3.0	--	--	361	88	69	595	7.6
bR-77	City of El Paso well E-2	e530-565	Oct. 24, 1958	--	.02	.1	44	7	--	160	72	289	1.3	--	--	--	774	140	--	--	7.5
bR-77	do	e667-693	Oct. 25, 1958	--	.02	.1	96	9	--	139	66	660	1.3	--	--	--	1,410	278	--	--	8.0
bR-77	do	e763-789	Nov. 4, 1958	--	.02	.1	206	0	--	105	112	1,340	1.2	--	--	--	2,860	494	--	--	8.0
bR-77	do	e868-894	Nov. 5, 1958	--	.02	.1	940	440	--	68	296	7,750	.6	--	--	--	20,300	4,300	--	--	7.5
bR-77	do	e974-1,000	Nov. 6, 1958	--	--	--	101	350	--	68	336	9,400	.7	--	--	--	16,200	1,710	--	--	7.5
bR-77	do	e1,065-1,091	Nov. 7, 1958	--	--	--	48	186	--	65	308	5,750	.8	--	--	--	10,000	890	--	--	7.7
bR-77	do	e1,185-1,211	Nov. 8, 1958	--	--	--	107	350	--	61	412	12,200	.7	--	--	--	19,200	1,720	--	--	7.5
R-78	City of El Paso well E-3	631	Feb. 24, 1959	35	.02	.00	32	7.9	101 9.1	180	71	86	.8	3.0	0.06	.18	435	112	64	704	8.1
R-80	U. S. Army well 16	819	Aug. 24, 1959	30	.01	--	18	5.4	77	146	43	45	.8	5.8	--	--	307	67	71	473	7.5
R-80	do	--	Apr. 4, 1960	31	.09	--	17	5.2	89	115	43	82	.8	1.0	--	--	336	64	75	547	7.5
R-81	El Paso Electric Co.	e990-1,188	Oct. 26, 1959	38	.06	--	913	109	3,530 26	39	669	6,940	--	--	--	--	12,200	2,730	74	19,100	7.1
bR-82	City of El Paso well 40	885	Nov. 18, 1959	--	.02	--	28	8	--	132	48	65	.1	--	--	--	327	104	--	--	7.6

See footnotes at end of table.

Table 4.--Chemical analyses of water from selected wells in the El Paso district, 1955-60--Continued

Well	Owner	Depth of well (ft.)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
R-83	U. S. Army well 15	819	Apr. 4, 1960	30	0.03	--	19	6.2	94	149	44	73	1.0	4.2	--	--	354	73	74	577	7.6
bR-84	City of El Paso well 41	e526-556	Dec. 4, 1959	--	.02	--	38	7	--	159	76	105	.1	--	--	--	475	124	--	--	7.6
bR-84	do	e621-646	Dec. 5, 1959	--	.2	--	175	33	--	87	85	805	.1	--	--	--	2,130	582	--	--	7.7
bR-84	do	e696-721	do	--	.02	--	293	64	--	65	104	1,640	.1	--	--	--	3,740	996	--	--	7.7
T-5	O'Leary Realty Co.	515	Mar. 25, 1960	39	--	--	64	9.1	65	180	110	47	.5	10	--	--	438	197	42	656	7.5
V-3	City of El Paso well 8	715	Apr. 10, 1956	--	--	--	--	--	--	189	--	52	--	--	--	--	--	198	--	641	7.7
bV-3	do	--	Sept.18, 1958	--	.02	0.1	57	19	--	198	60	56	1.0	--	--	--	450	220	--	--	7.5
V-4	City of El Paso well 11	730	May 10, 1956	--	--	--	--	--	--	198	--	89	--	--	--	--	--	215	--	791	7.7
bV-4	do	--	Mar. 18, 1959	--	.02	.1	50	12	--	224	84	99	.4	--	--	--	544	174	--	--	7.2
V-5	City of El Paso well 12	776	May 10, 1956	40	--	--	44	18	116	197	99	117	1.6	4.6	--	--	538	184	58	897	8.0
bV-5	do	--	Oct. 20, 1958	--	.02	.1	51	17	--	214	76	115	1.5	--	--	--	553	200	--	--	7.8
V-7	City of El Paso well 15	1,055	Sept.22, 1955	--	--	--	--	--	--	200	--	85	--	--	--	--	--	96	--	782	8.2
bV-7	do	--	Dec. 9, 1958	--	.02	.1	24	11	--	199	70	86	1.3	--	--	--	488	118	--	--	8.0
V-8	Biggs Air Force Base well 2	780	Nov. 3, 1955	32	.04	--	19	6.5	106	166	70	64	.9	4.0	--	--	384	74	76	630	7.7
V-8	do	--	Nov. 27, 1957	32	.02	--	21	6.7	112	168	73	74	.8	3.0	--	--	412	80	75	663	7.8
V-8	do	--	Nov. 18, 1959	32	.01	--	20	7.2	106	171	72	64	1.0	4.3	--	--	391	80	74	633	7.5
V-8	do	--	Oct. 20, 1960	30	.01	--	18	6.5	83	163	55	38	.9	5.2	--	--	320	72	72	506	7.4
V-9	City of El Paso well 16	909	May 10, 1956	--	--	--	--	--	--	182	--	51	--	--	--	--	--	72	--	615	7.9
bV-9	do	--	Oct. 20, 1958	--	.02	.1	19	12	--	187	54	53	1.1	--	--	--	383	98	--	--	8.0

See footnotes at end of table.

Table 4.--Chemical analyses of water from selected wells in the El Paso district, 1955-60--Continued

Well	Owner	Depth of well (ft.)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
V-10	Biggs Air Force Base well 1	780	Nov. 3, 1955	32	0.01	--	17	6.4	88	164	58	42	0.9	4.5	--	--	331	69	73	532	7.7
V-10	do	--	Nov. 27, 1957	32	.01	--	21	6.9	100	171	66	60	.8	4.0	--	--	377	81	73	606	7.8
V-10	do	--	Nov. 18, 1959	32	.01	--	20	6.4	81	158	56	41	.8	5.3	--	--	321	76	70	515	7.2
V-10	do	--	Oct. 20, 1960	28	.01	--	17	6.7	83	162	55	38	.9	5.6	--	--	320	70	72	505	7.6
V-14	Biggs Air Force Base	501	Apr. 18, 1955	--	--	--	--	--	--	171	--	27	--	--	--	--	--	69	--	474	7.8
V-15	do	750	July 16, 1957	19	--	--	18	4.5	84	133	52	57	--	3.0	--	--	303	64	74	519	7.5
V-19	City of El Paso well 19	950	May 10, 1956	--	--	--	--	--	--	199	--	80	--	--	--	--	--	93	--	774	7.7
bV-19	do	--	Sept.24, 1958	--	--	--	26	9	--	207	72	76	1.5	--	--	--	493	100	--	--	--
V-21	U. S. Army well 7	778	May 15, 1956	36	.02	--	51	20	99	198	101	107	1.2	5.2	--	--	517	210	51	863	7.5
V-21	do	--	Aug. 12, 1958	34	.01	--	49	19	104	199	98	108	1.2	6.2	--	--	521	200	53	862	7.6
V-23	U. S. Army well 6	784	May 15, 1956	31	.00	--	42	16	55	170	55	60	1.2	5.8	--	--	350	170	41	579	7.6
V-24	U. S. Army well 5	785	July 20, 1955	38	.00	--	36	12	56	181	41	44	.7	7.3	--	--	327	140	47	536	8.1
V-24	do	--	May 15, 1956	35	.00	--	36	13	52	182	41	40	.9	6.7	--	--	314	143	44	509	7.3
V-25	U. S. Army well 9	653	May 15, 1956	42	.00	--	44	20	48	231	50	32	.7	9.6	--	--	360	192	35	577	7.5
V-25	do	--	Aug. 11, 1958	42	.01	--	43	20	55	237	51	36	.6	11	--	--	376	190	39	593	7.6
V-38	City of El Paso	852	Oct. 28, 1955	--	--	--	--	--	--	140	--	1,500	--	--	--	--	--	1,880	--	4,850	7.9
V-41	City of El Paso well 22	766	Apr. 10, 1956	--	--	--	--	--	--	193	--	57	--	--	--	--	--	82	--	669	8.0
bV-41	do	--	Mar. 20, 1958	--	.02	0.1	22	8	--	a198	76	55	1.2	--	--	--	403	90	--	--	8.3
V-51	Falstaff Brewery Inc.	353	Oct. 28, 1955	--	--	--	--	--	--	169	--	350	--	--	--	--	--	292	--	1,540	7.9
V-51	do	--	Apr. 10, 1956	--	--	--	--	--	--	166	--	345	--	--	--	--	--	310	--	1,540	7.8
V-51	do	--	May 22, 1957	--	--	--	--	--	--	162	--	375	--	--	--	--	--	304	--	1,600	8.0

See footnotes at end of table.

Table 4.--Chemical analyses of water from selected wells in the El Paso district, 1955-60--Continued

Well	Owner	Depth of well (ft.)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
V-53	City of El Paso well 9	802	Sept. 19, 1955	--	--	--	--	--	--	186	--	134	--	--	--	--	--	74	--	880	8.2
bV-53	do	--	Feb. 26, 1958	--	0.02	0.1	19	8	--	188	77	143	0.7	--	--	--	539	80	--	--	8.2
V-54	City of El Paso well 14	905	May 10, 1956	--	--	--	--	--	--	166	--	145	--	--	--	--	--	95	--	882	7.7
bV-54	do	--	July 3, 1958	--	.02	.1	21	7	--	a162	60	147	.7	--	--	--	523	98	--	--	8.4
V-58	City of El Paso T & P well	624	June 21, 1956	30	--	--	37	11	86	172	85	66	.7	0.1	--	--	402	138	58	658	8.0
bV-58	do	--	Sept. 18, 1958	--	.02	.1	42	12	--	183	64	68	.3	--	--	--	410	152	--	--	8.0
V-59	City of El Paso well 17	720	May 10, 1956	--	--	--	--	--	--	201	--	99	--	--	--	--	--	254	--	899	7.5
bV-59	do	--	Feb. 6, 1958	--	.02	.1	48	10	--	204	113	86	.7	--	--	--	495	167	--	--	8.2
V-72	The Texas Co. well 1	694	Apr. 10, 1956	33	--	--	80	28	204	168	70	388	--	1.8	--	--	888	314	59	1,650	7.8
V-72	do	--	July 10, 1957	41	--	--	38	11	180	155	67	235	--	3.0	--	--	656	140	74	1,160	7.8
V-72	do	--	June 12, 1959	30	--	--	42	12	185	150	72	252	.9	.8	--	--	669	154	72	1,180	7.7
V-93	City of El Paso well 30	992	June 21, 1956	36	--	--	24	8.9	144	186	94	109	1.1	2.9	--	--	521	96	76	861	8.0
bV-93	do	--	Oct. 13, 1958	--	.02	.1	28	12	--	198	74	105	1.1	--	--	--	533	122	--	--	8.0
bV-93	do	--	Nov. 11, 1959	--	--	--	27	10	--	185	83	120	--	--	--	--	508	108	--	--	7.4
V-94	Phelps-Dodge Refinery well 4	612	July 31, 1956	32	--	--	25	8.9	128	175	98	93	--	2.0	--	--	473	100	74	790	8.0
V-94	do	--	June 9, 1959	30	--	--	27	7.8	126	161	89	103	.8	2.2	--	--	465	100	73	780	7.6
V-136	City of El Paso well 37	920	Apr. 2, 1959	37	.09	.01	26	8.5	137 11	183	88	119	1.3	3.2	0.05	0.15	521	100	72	851	7.9
V-137	Phelps-Dodge Refining Corp. well 5	655	June 12, 1959	28	--	--	22	7.0	106	160	85	64	.7	2.2	--	--	397	84	73	639	7.8
V-138	Falstaff Brewery, Inc. well 3	470	Mar. 28, 1960	28	--	--	54	20	186	166	97	272	--	.2	--	--	759	216	65	1,310	7.5

See footnotes at end of table.

Table 4.--Chemical analyses of water from selected wells in the El Paso district, 1955-60--Continued

Well	Owner	Depth of well (ft.)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)		Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
V-139	City of El Paso well 38	722	May 15, 1959	24	0.03	0.01	18	4.7	91	7.7	162	62	47	0.8	4.2	0.02	0.08	340	64	73	557	7.8
V-140	City of El Paso well 39	750	Oct. 2, 1959	34	.04	--	53	18	67	6.0	192	76	84	1.0	7.7	--	.18	450	206	41	727	7.3
dW-74	El Paso Natural Gas Co.	394	Oct. 6, 1958	31	--	--	158	74	--		128	759	260	.2	--	--	--	1,760	232	--	--	8.0
dW-74	do	456	Oct. 10, 1958	23	--	--	172	94	--		110	878	327	.2	--	--	--	1,980	266	--	--	7.9
dW-74	do	579	Nov. 6, 1958	22	--	--	220	100	--		159	917	383	.9	--	--	--	2,190	320	--	--	7.8
W-75	Holibeke Ranch	344	Nov. 12, 1957	36	.02	--	37	11	152		115	103	162	.6	3.8	--	--	560	138	71	969	--
W-76	Ben Ivey	312	Apr. 6, 1960	32	--	--	64	21	346		106	303	422	--	1.0	--	--	1,240	246	75	2,080	7.5
bY-278	H. B. Zachry Construction Co.	400	May 16, 1958	--	.03	.1	364	6	--		39	799	2,670	.4	--	--	--	5,140	1,140	--	--	8.2
bZ-13	Strain Bros.	300	do	--	.02	.1	400	9	--		244	286	2,010	.4	--	--	--	5,040	1,360	--	--	8.1
AA-34	City of El Paso test well LV-2	1,647	Jan. 19, 1959	24	.02	.1	12	.3	366	1.8	a 98	476	180	3.4	.0	.04	.84	1,110	31	96	1,749	8.6
bAA-37	City of El Paso test well LV-3	e1,357-1,381	June 6, 1959	--	.02	.1	30	2	--		63	572	159	.7	--	--	--	1,470	86	--	--	7.0
bAA-37	do	e1,462-1,487	do	--	.02	.1	14	0	--		65	396	198	.7	--	--	--	1,080	46	--	--	7.9
bAA-37	do	e1,613-1,637	June 7, 1959	--	.02	.1	12	0	--		83	286	178	.7	--	--	--	958	26	--	--	6.9
bAA-37	do	e1,704-1,728	June 9, 1959	--	.02	.1	11	1	--		110	396	210	.7	--	--	--	1,540	33	--	--	7.9
bAA-37	do	e1,794-1,818	do	18	--	--	17	.8	448	2.3	97	570	242	2.9	.2	--	--	1,350	46	95	2,120	8.0
bBB-41	H. B. Zachry Construction Co.	400	Feb. 5, 1960	--	.13	--	420	165	--		--	466	1,906	--	--	--	--	5,120	1,730	--	--	7.4
BB-42	do	350	Apr. 6, 1960	42	--	--	47	16	440		180	201	555	--	.8	--	--	1,390	184	84	2,400	7.5

See footnotes at end of table.

Table 4.--Chemical analyses of water from selected wells in the El Paso district, 1955-60--Continued

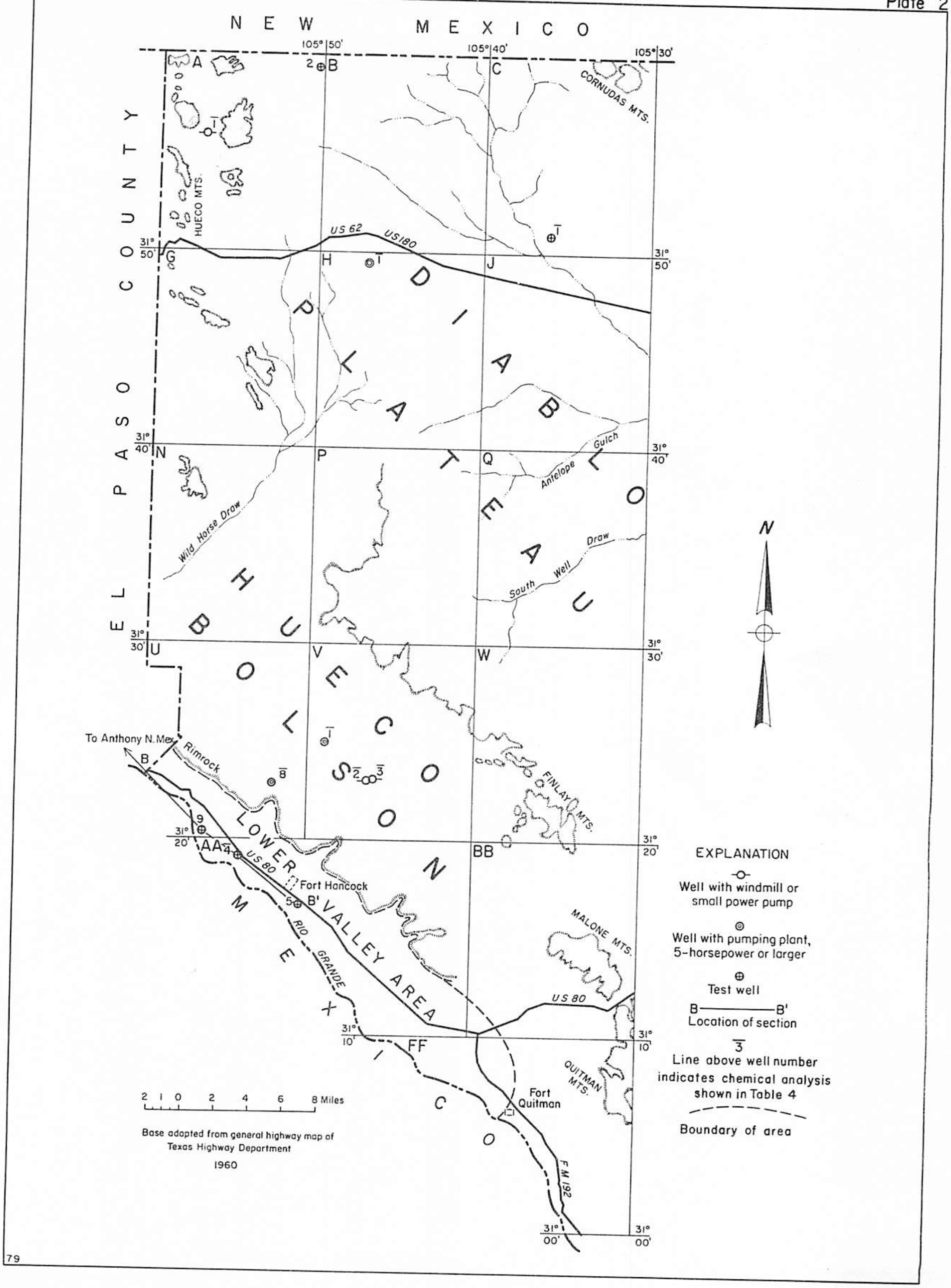
Well	Owner	Depth of well (ft.)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
bBB-43	City of El Paso test well LV-4	e182-214	June 23, 1959	--	0.02	0.1	22	0	--	217	80	89	0.5	--	--	--	517	52	--	--	7.3
bBB-43	do	e314-338	do	--	.02	.1	210	9	--	239	320	890	.5	--	--	--	2,560	564	--	--	7.3
bBB-43	do	e419-443	do	--	.02	.1	1,130	138	--	89	480	4,870	.8	--	--	--	10,800	3,390	--	--	7.1
bBB-43	do	e524-548	June 24, 1959	--	.02	.1	1,250	240	--	61	560	6,930	1.0	--	--	--	13,800	4,210	--	--	7.1
bBB-43	do	e636-660	do	--	.02	.1	1,340	234	--	52	800	7,560	1.0	--	--	--	15,500	4,320	--	--	7.4
bBB-43	do	e737-761	June 25, 1959	--	.02	.1	1,840	332	--	38	1,080	9,400	1.1	--	--	--	19,400	5,980	--	--	7.2
bBB-43	do	e846-875	do	--	.02	.1	328	29	--	52	1,080	2,890	.6	--	--	--	6,690	940	--	--	7.6
bBB-43	do	e973-1,002	June 27, 1959	--	.02	.1	408	65	--	72	1,730	4,200	.6	--	--	--	10,900	1,290	--	--	7.6
bBB-43	do	e1,078-1,104	--	--	.02	.1	651	95	--	79	4,560	6,800	1.2	--	--	--	18,700	2,020	--	--	7.2
bBB-44	City of El Paso test well LV-5	e131-155	July 23, 1959	--	.02	.1	177	43	--	128	270	1,430	.9	--	--	--	2,460	620	--	--	7.7
bBB-44	do	e245-269	do	--	.02	.1	127	27	--	a134	297	1,220	.9	--	--	--	2,790	450	--	--	8.3
bBB-44	do	e334-363	do	--	.02	.1	157	41	--	110	331	1,490	1.0	--	--	--	3,440	554	--	--	7.7
bBB-44	do	e447-471	July 24, 1959	--	.02	.1	62	15	--	124	464	955	1.0	--	--	--	2,410	218	--	--	8.2
bBB-44	do	e567-591	do	--	.02	.1	85	22	--	144	358	1,300	1.4	--	--	--	2,910	304	--	--	8.15
bBB-44	do	e672-696	July 25, 1959	--	.02	.1	60	13	--	150	323	1,160	1.6	--	--	--	2,570	202	--	--	8.15
bBB-44	do	e759-783	do	--	.02	.1	57	13	--	117	496	985	1.6	--	--	--	2,570	194	--	--	7.6

See footnotes at end of table.

Table 4.--Chemical analyses of water from selected wells in the El Paso district, 1955-60--Continued

Well	Owner	Depth of well (ft.)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
bBB-44	City of El Paso test well LV-5	e873-902	July 25, 1959	--	0.02	0.1	57	8.2	--	140	569	1,020	1.7	--	--	--	2,680	178	--	--	7.4
									Hudspeth County												
A-1	Menzies Ranch	1,700	Dec. 19, 1956	16	--	--	4.5	4.5	251	a450	134	45	1.4	0.0	--	--	679	30	95	1,070	9.0
C-1	City of El Paso University well 1	e2,242-2,308	Oct. 5, 1958	11	.01	--	28	11	2,210	928	224	2,820	3.6	--	--	--	5,760	115	98	9,730	7.9
H-1	Theison well 1	2,400	Dec. 19, 1956	16	--	--	158	59	1,660	233	1,660	1,650	2.8	3.0	--	--	5,320	636	85	5,850	7.8
U-8	Soil Conservation Service	295	Dec. 10, 1959	30	--	--	68	25	636	189	912	380	2.2	12	--	--	2,160	272	84	3,110	7.5
V-1	do	906	Dec. 11, 1959	18	--	--	77	16	837	154	1,440	310	4.4	4.2	--	--	2,780	258	88	3,730	7.0
V-2	Owens-Bowden	356	do	19	.01	.01	46	17	362 5.5	290	514	142	5.3	1.0	0.00	0.90	1,260	185	80	1,850	7.8
V-3	do	406	do	21	--	--	46	18	460	298	670	165	5.6	.0	--	--	1,530	189	84	2,220	7.7
AA-4	Hudspeth County Conservation & Reclamation District No. 1, test well 3	e2,300-2,335	Mar. 7, 1957	18	--	--	1,130	121	10,300	131	2,470	16,300	--	--	--	--	30,500	3,320	87	41,500	7.0

a - Includes equivalent of any carbonate (CO_3) present.
b - Analysis by City of El Paso.
c - Analysis by Curtis Laboratory.
d - Analysis by El Paso Natural Gas Laboratory.
e - Drill-stem test, interval sampled.



MAP OF WESTERN PART OF HUDSPETH COUNTY, SHOWING LOCATIONS OF SELECTED WELLS