GEOHYDROLOGY OF MAJOR JOHNSON SPRINGS AND CARLSBAD SPRINGS, NEW MEXICO

by

Data Collection and Evaluation Section
Data and Engineering Services Division

Texas Department of Water Resources

LP-23

February, 1978

TABLE OF CONTENTS

TABLES

TABLE OF CONTENTS (Cont'd.)

FIGURES

TABLE OF CONTENTS (Cont'd.)

GEOHYDROLOGY OF MAJOR JOHNSON SPRINGS AND CARLSBAD SPRINGS, NEW MEXICO

INTRODUCTION

The purpose of this study is to document the depletion of ground water as a result of man's activities, and, prove that these activities have caused depletions of the "new water" contributions to the flows of Major Johnson and Carlsbad Springs. At each spring system, "new water" is as defined by the accounting procedures given in the Review of Basic Data (Pecos River Commission, 1960) to account for the accretion of previously unmeasured ground water. In addition, the study intends to prove that certain seepage losses from the Pecos River System between Major Johnson Springs and Carlsbad, New Mexico, which previous to 1955 reappeared as spring flow at Carlsbad Springs, are being diverted by man's activities from the subsurface leakance component prior to reaching the springs.

It is anticipated that the findings of this study will be used in the TEXAS VS. NEW MEXICO United States Supreme Court No. 65 original lawsuit which is scheduled for trail beginning February 27, 1978.

Special acknowledgement is extended to Mr. Zack Dean of the Texas Department of Water Resources for his evaluation and computation of seepage from the Pecos River and reservoirs from the Artesia gage to Carlsbad, New Mexico, as well as Dr. Quentin Martin's computer program computations of "new water" at Carlsbad Springs after 1957. Acknowledgement is also extended to Mr. George E. Welder of the U. S. Geological Survey of Albuquerque, New Mexico for his aid in the securing of basic data.

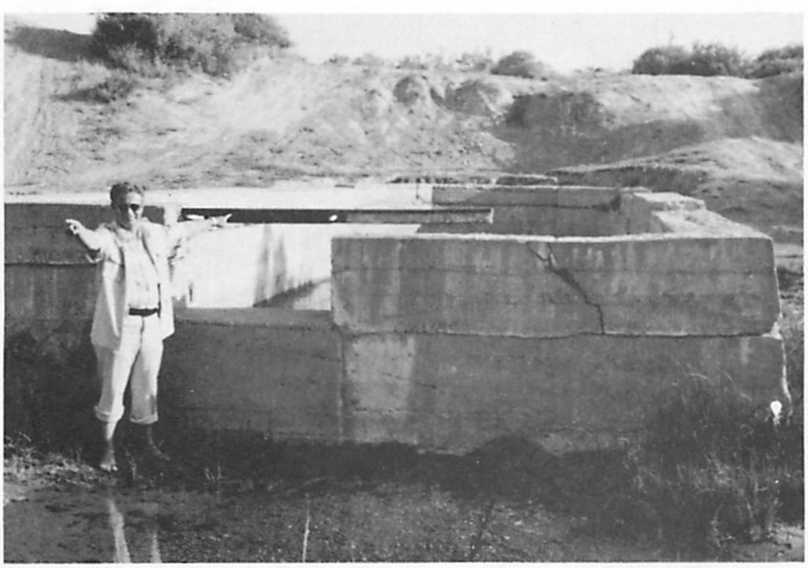
Major Johnson Springs is a system of springs which are located in the southeasternmost limit of the Roswell Artesian Basin in central Eddy County, New Mexico. These springs are situated in and immediately adjacent to the Pecos River channel approximately four (4) river miles downstream from McMillan Dam (Figure 1) and they occur in the river channel at about elevation 3,208.

Carlsbad Springs is also a system of springs which are located approximately four (4) river miles below Lake Avalon Dam in and adjacent to the Pecos River channel at the extreme northwest edge of the city of Carlsbad, New Mexico (Figure 1). Figure 2 shows a group of three photos, two of which were taken at Carlsbad Springs; one between 1949 and 1952 and the other in 1975. The remaining photo, taken in 1914, is also thought to have been taken at the same spring. The 1914 photo shows an extremely large flow. Total flow from all springs in the system ranged from 41 to 69 cfs (cubic feet per second) at the approximate time (between 1949 to 1952) photo B was taken (Table 3). In 1975 when photo C was taken, the total spring flow was 29.8 cfs (Table 3). These photos illustrate a marked chronological reduction in total spring flow.

The administrative boundary of the Carlsbad Underground Water Basin, as declared by the New Mexico State Engineer in October 1947 and extended in 1952, 1958, 1964 and 1975 is shown on Figure 3.

A. A spring near Carlsbad, New Mexico discharging into the Pecos River, taken about 1914 (Fogg, 1914).

B. Carlsbad Spring discharging into the Pecos River near Carlsbad, located about 200 yards east of Southern Canal Flume, taken between 1949 to 1952 (Hendrickson and Jones, 1952).



C. Carlsbad Spring near the Pecos River, located about 200 yards east of Southern Canal Flume, taken May 13, 1975 (TDWR Photo).

FIGURE 2.
PHOTOS OF CARLSBAD SPRING NEAR CARLSBAD, NEW MEXICO

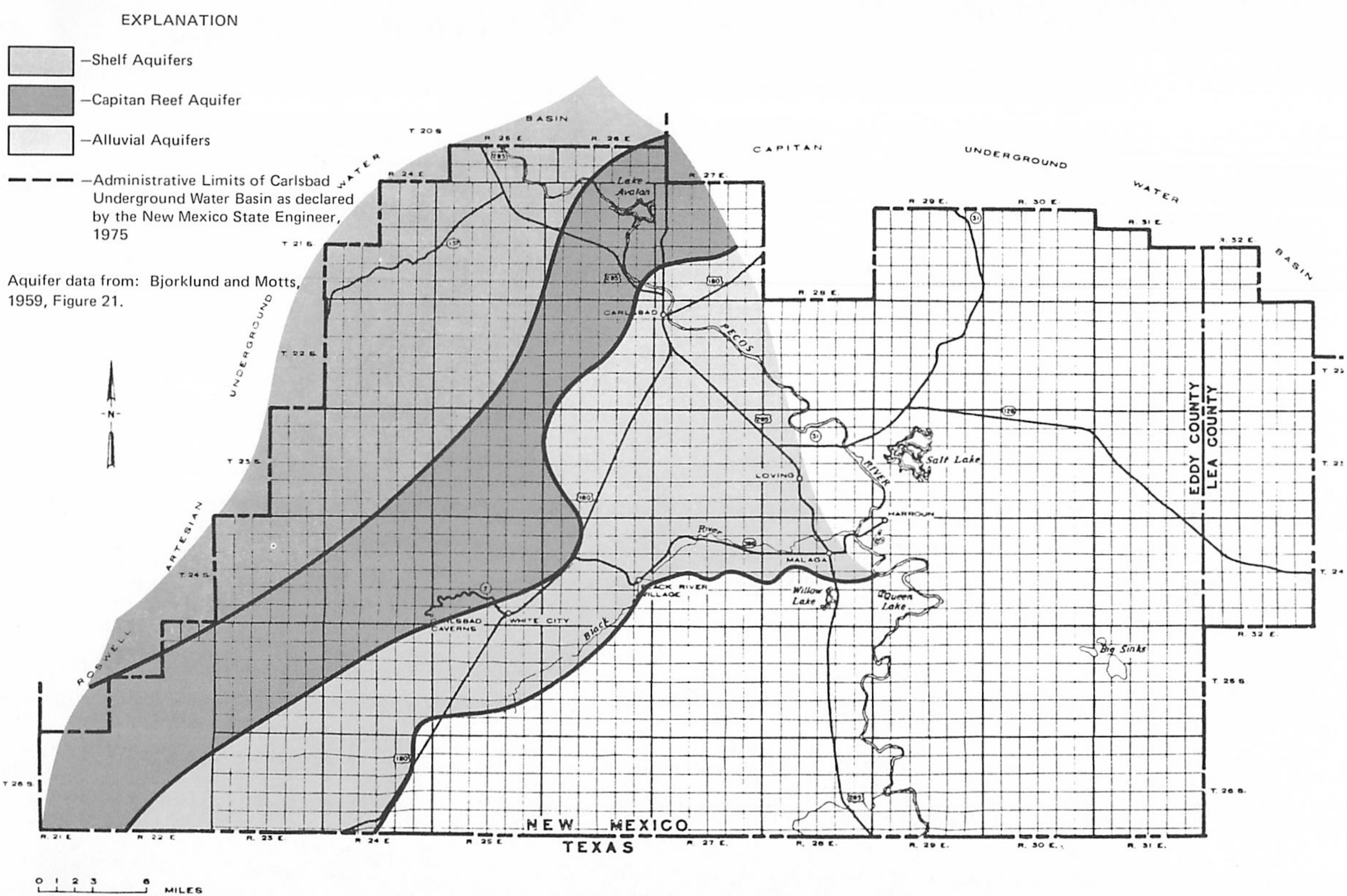


FIGURE 3.
APPROXIMATE AREAL EXTENT OF SELECTED AQUIFERS
IN THE CARLSBAD UNDERGROUND WATER BASIN

GENERAL GEOLOGY

Sedimentary deposits, which geologically are Permian and Quaternary in age, are the principal ground-water bearing rocks which either underlie or crop out in the Pecos River Valley between the Artesia gage and Carlsbad Springs (Figures 1 and 4).

The Permian age rocks were deposited in three separate environments: shelf or back reef, self margin or reef, and basin or fore reef.

Shelf or back reef sediments, which were deposited in the southeasternmost limits of the Roswell Artesian Basin, underlie most of the study area. Lithologically, these rocks are composed of thin-bedded limestone and dolomites which are generally light colored, calcareous sandstones and siltstones, clay and red silt, and evaporites (Cox, 1967, p. 8). Geologic units laid down in this environment include the San Andres, Grayburg, Queen, Seven Rivers, Yates, and Tansill Formations (Figure 4). The above units, except the San Andres, are the equivalents of the Chalk Bluff Formation in the Roswell Artesian Basin.

Reef masses were developed and are present in a narrow band in the shelf margin area. These are present at the city of Carlsbad, New Mexico and trend in a northeast-southwest direction across the southeastern one-third of Eddy County (Hendrickson and Jones, 1952, p. 17). Figure 3 shows the approximate limits of this reef development.

Lithologically, reefs are composed of massive fossiliferous limestone which are gray to white in color (Cox, 1967, p. 8). Deposits known to be reefs and which are present within the study area are the Goat Seep and Capitan limestones.

Basin or fore reef rocks were deposited adjacent to and seaward or southeast of the reef masses in an area referred to as the Delaware Basin. Sediments deposited in this environment are predominantly dark-colored limestone, and calcareous and quartzose sandstone (Delaware Mountain Group), clay, red silt, and evaporites (Rustler Formation), and evaporites (Castile Formation) (Cox, 1967, p. 8).

Permian water-bearing rocks of the study area, listed in ascending order, are: San Andres and Grayburg Formations; Queen Formation and its reef equivalent, the upper part of the Goat Seep limestone; Seven Rivers, Yates, and Tansill Formations and their reef equivalent, the Capitan limestone; and the Rustler and Castile Formations (Cox, 1967, p. 9).

Quaternary alluvium is present as residual cover throughout much of the Pecos River valley.

Figures 1 and 4 delineate the limits of the above listed aquifers, indicate their thickness, and show their stratigraphic and structural relationships.

GEOHYDROLOGY

Major Johnson Springs

Cox (1967, p. 21) stated that ground-water movement in the vicinity of Major Johnson Springs is complex. Movement is complicated not only by different facies of the rocks but by perched water tables and differences in permeabilities of these hydrologic units. It is further complicated by the seepage which occurs from Lake McMillan and the Pecos River.

Ground water which contributes to flow of the springs moves through the shallow aquifer (alluvium and the Seven Rivers Formation) mostly from the northeast toward Major Johnson Springs. This water is composed mainly of seepage which occurs at Lake McMillan, and seepage which occurs upstream on the Pecos River between the Artesia and Kaiser gages (Cox, 1967, p. 21) (Figure 1). In addition to the above ground-water flow, current thinking is that there is leakage or subsurface inflow from the deep underlying artesian aquifer (Grayburg and/or Queen Formation?) which also feeds the shallow aquifer and Major Johnson Springs (G. E. Welder, 1978, oral communication) (Figure 4). Therefore, the total flow of Major Johnson Springs is composed of previously unmeasured water ("new water"), seepage from the Pecos River between the Artesia and Kaiser Channel gages, and seepage from Lake McMillan.

Carlsbad Springs

Water issuing at Carlsbad Springs flows upward through interconnected solution channels in the Capitan Limestone (reef) aquifer into and upward through the overlying alluvium and discharges into the Pecos River at the northwest edge of Carlsbad, New Mexico. The Capitan Limestone (reef) aquifer system also extends westward along the shelf margin into the underlapping Goat Seep Limestone (reef) and northwestward into shelf or back reef area into the Tansill, Seven Rivers, Queen, and Grayburg Formations which are the Chalk Bluff equivalents of the Roswell Artesian Basin (Bjorklund and Motts, 1959, p. 5). Figures 1 and 4 show the areal extent of the aquifers. Figure 4 shows their lithological, structural, and hydrological relationships.

As stated in the Report on Review of Basic Data (Pecos River Commission, 1960, pp. 15-1 and 15-2), discharge from Carlsbad Springs is derived from five sources: (a) channel percolation between Major Johnson Springs and Dam Site No. 3 gage, (b) seepage from Avalon Reservoir and from the Pecos River channel between Dam Site No. 3 gage and the reservoir, (c) seepage from the Carlsbad Project main channel, (d) return flow from irrigation, and (e) previously unmeasured water discharged from the Capitan Limestone (reef) aquifer and adjacent limestone formations.

GROUND-WATER DEVELOPMENT AND WATER LEVEL DECLINES

Major Johnson Springs

As previously stated, Major Johnson Springs is located in the extreme southeastern part of the Roswell Artesian Basin. Water levels in the vicinity of Major Johnson Springs are thought to be influenced by artesian ground-water development in the Roswell Artesian Basin to the north and west of the springs.

Development from the San Andres deep artesian aquifer of the Roswell Artesian Basin began in 1891 (Pecos River Compact Commission, 1949, p. 2). Based on the number of existing wells during the period 1905-1925 (Fielder and Nye, 1933, p. 225), average annual pumpage from the deep artesian aquifer appears to have been on the order of 140,000 acre-feet. Subsequent to 1925, ground-water withdrawals increased to the year 1946 when pumpage exceeded 340,000 acre-feet. By the latter part of the nineteen thirties, development began in the shallow alluvial aquifer north and west of Major Johnson Springs. During the period 1937 to 1976, the alluvial aquifer sustained less than one-half of the total annual basin pumpage. After 1947, ground-water withdrawals from both aquifers generally increased to the year 1965 when pumpage was approximately 460,000 acre-feet. Following this peak pumpage in 1965, withdrawals decreased to a low of 339,000 acre-feet per year and then gradually increased again to 441,000 acre-feet in 1976 (Texas Department of Water Resources, 1978, p. 5).

Water-level declines in the vicinity of Major Johnson Springs in Eddy County, as reflected in well 20.26.8.1211 (shallow aquifer), are shown on Figure 7. The location of the well is shown on Figure 1. These water levels show a steady and marked decline since the year 1942 and are very similar to the declines in artesian well 12.25.23.113 which is known as the Orchard Park well (Texas Department of Water Resources, 1978, Figure 4). Based on the similarity of water levels in the shallow aquifer in the vicinity of Major Johnson Springs and those in the Orchard Park well, it is thought that these water levels are indicating a similar pattern of ground-water development in the entire Roswell Artesian Basin which includes the Major Johnson Springs area.

Carlsbad Springs

In 1905, the city of Carlsbad, New Mexico drilled the first large-capacity wells in the Carlsbad Springs area. These wells were used to irrigate the city parks. About 1930, the first wells were drilled for the irrigation of crops. At the beginning of 1945, there were about 25 irrigation wells in operation and by 1955 a total of 240 irrigation wells had been completed (Reeder, et al., 1959, pp. 194-195). By 1955, an undetermined number of municipal, industrial, domestic, and stock wells also had been drilled. Additional well development in the Capitan Limestone (reef) aquifer after 1955 included the drilling and completion from 1960 to 1962 of municipal wells by the city of Carlsbad in Sheep Draw and Dark Canyon in a well field which is located approximately nine and one-half miles southwest of Carlsbad. After 1963, records of the New Mexico State Engineer (NMSE) indicate use of the city's well field in Carlsbad was discontinued (Collins, R. B., 1978).

Pumpage in the Carlsbad Springs area is principally from the Capitan Limestone (reef) aquifer and the alluvium. Pumpage from the Capitan Limestone (reef) aquifer is of primary concern for the purposes of analyzing "new water" flows at Carlsbad Springs. During 1954, the total quantity of ground water pumped was about 67,500 acre-feet (includes 200 acre-feet for domestic and stock use). Approximately 16,300 acre-feet of this amount was pumped from the Capitan Limestone (reef) aquifer and about 51,200 acre-feet was pumped from the alluvium (Reeder, et al., 1959, p. 195). In 1960, out of a total of 36,900 acre-feet of ground water pumped for all purposes except domestic and stock, approximately 14,000 acre-feet was pumped from the Capitan Limestone (reef) aquifer and approximately 23,000 acre-feet was pumped from the alluvium (Ballance, et al., 1962, p. 102).

Figure 10 is an idealized model which illustrates the pumpage from the Capitan Limestone (reef) aquifer for the period 1939-1977. This figure shows the following. During the period 1939-1946, pumpage averaged 4,210 acre-feet per year. Pumpage in 1947 from the Capitan Limestone (reef) aquifer was approximately 7,200 acre-feet and it increased steadily to the year 1954 when pumpage was approximately 16,300 acre-feet. After 1954, pumpage ranged from 13,000 to 20,200 acre-feet per year. Part of the total pumpage for the period 1971-1977 (Figure 10) was estimated from NMSE documentations of the city of Carlsbad's and International Minerals and Chemical Corporation's pumpages (Collins, R. B., 1978). An additional estimated 5,000 acre-feet per year was added to account for irrigation pumpage for the 1971-1977 period (Hudson and Barton, 1974, p. 60).

Water levels in well 22.26.2.242 for the period 1946-1976 are also included on Figure 10. This hydrograph shows that water levels declined rapidly during the period 1949-1954 and declined gradually to the present time. The rate of decline of water levels correlates well with the development (pumpage) of the Capitan Limestone (reef) aquifer after 1946 (Figure 10).

WATER LEVEL - "NEW WATER" STUDIES

Major Johnson Springs

Method of Analysis.--The primary objective of this analysis is to show the relationship of the change in ground-water storage of the aquifer contributing to Major Johnson Springs and the comparable chronological change in discharge at the springs. Within this framework, the hydrological components of measured water within the Pecos River System and the previously unmeasured water or "new water" component can be determined on an annual basis. The component of flow or discharge at the springs of "new water" has been established by Senate Document 109 as the "1947 Condition" and quantitatively is 25 cfs. Any "new water" flow less than 25 cfs was considered as a deficit flow and is indicative of a depletion of ground-water storage in the contributing aquifer due to excessive pumpage.

Consequently, two wells (20.26.7.122 and 20.26.8.1211) were selected to establish an adequate length of historical water-level record to monitor the change in ground-water storage in the contributing aquifer (Welder, 1977). Water levels in wells 20.26.7.122 and 20.26.8.1211 were correlated for the period 1939-1963 by plotting the water-level data furnished from the U. S. Geological Survey in Albuquerque, New Mexico (Figure 5). Well 20.26.8.1211 (Moutray well) was finally selected as the index well and its water levels were plotted against "new water" discharge for the period 1946-1954 (W. E. Hale, 1960) and "new water" for the period 1957-1976 as computed by the Department's personnel to obtain a correlation between head in the aquifer and "new water" discharge (Figure 6). "New water" (1957-1976) was computed as given in the Review of Basic Data (Pecos River Commission, 1960) except that a 3 CFS loss was estimated between the Artesia and Kaiser gages for the years 1964-1976 and the gage below Major Johnson Spings

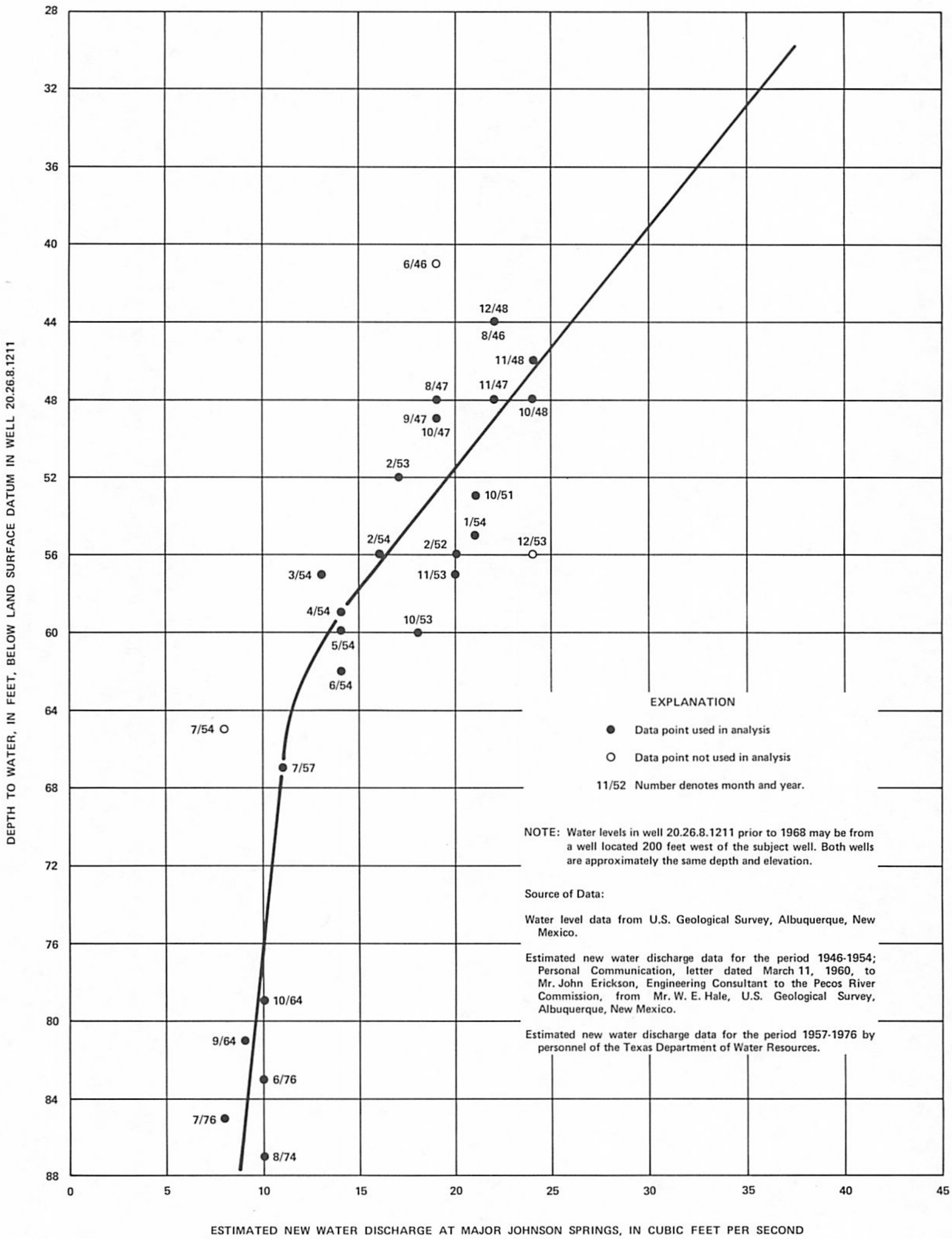


Figure 6

Correlation of Depth to Water in Well 20.26.8.1211 and Estimated New Water Discharge at Major Johnson Springs (Eddy County, New Mexico) for the Period 1946-1976 was utilized for the years 1974 and 1976. Next, estimated average annual water levels in the Moutray well (20.26.8.1211) were plotted and used with the appropriate "new water" discharges as shown in Figure 6 and the average annual "new water" discharge for the period 1939-1976 was obtained as shown in Figure 7.

This average annual "new water" was further broken down into an estimated monthly and annual discharge for the period 1939-1976 as shown in Table 1. Discharge rates (Figure 6) for January and August were derived by employing the January and December high water levels and the August low water level from the above mentioned hydrographs for the determinate year. The intervening monthly flow rates were estimated by interpolation. When necessary, these flow rates were modified to correspond to water-level fluctuations in the Orchard Park well (12.25.23.113) hydrograph, since there is a water-level correlation between the Orchard Park well and the index well (20.26.8.1211).

Any "new water" flow less than 25 cfs or 18,100 acre-feet per year was considered to be a deficit flow or deficit discharge of "new water" at Major Johnson Springs. Table 2 shows this as yearly and cumulative deficit flow for the period 1947-1976. Table 2 was prepared by using the annual discharges in Table 1 and subtracting each of them from the "1947 Condition" "new water" discharge of 25 cfs or 18,100 acre-feet per annum.

Results.--Figure 7 gives the estimated average annual "new water" discharge at Major Johnson Springs, compares it with the declines in water levels, and illustrates the deficit flows at the springs during the period 1947-1976 which are associated with the declines in water levels due to excessive pumping. Table 1 shows the estimated monthly and annual discharge at Major Johnson Springs. And finally, Table 2 shows the total cumulative deficit "new water" flow or that cumulative amount less than the established "1947 Condition" to be 251,800 acre-feet for the period 1947 through 1976. This cumulative amount is about 46 percent of the total cumulative amount which could have been expected as "new water" under the "1947 Condition."

Table 1.--Estimated Monthly and Annual Discharges of New Water Contribution to Major Johnson Springs (Eddy County, New Mexico) for the Period 1939-1976, in 1,000's of Acre-Feet

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1939	2.337	2.055	2.275	2.142	2.214	2.083	2.152	2.091	2.083	2.214	2.142	2.275	26.063
1940	2.275	2.071	2.091	1.904	1.906	1.785	1.783	1.783	1.726	1.906	1.904	2.091	23.225
1941	2.091	1.888	2.091	2.023	2.091	2.023	2.029	2.029	2.261	2.460	2.499	2.582	26.067
1942	2.582	2.277	2.398	2.142	2.152	2.023	2.029	2.029	2.083	2.275	2.321	2.460	26.771
1943	2.460	2.166	2.337	2.202	2.214	2.083	2.091	2.091	2.023	2.152	2.083	2.152	26.054
1944	2.152	2.013	2.091	1.904	1.906	1.785	1.783	1.783	1.726	1.906	2.023	2.152	23.234
1945	2.152	1.944	2.029	1.785	1.722	1.607	1.660	1.660	1.607	1.722	1.845	1.968	21.701
1946	1.968	1.777	1.906	1.726	1.722	1.488	1.476	1.476	1.428	1.599	1.785	1.906	20.257
1947	1.906	1.722	1.783	1.607	1.537	1.309	1.291	1.291	1.250	1.414	1.428	1.537	18.075
1948	1.537	1.438	1.537	1.428	1.475	1.428	1.353	1.353	1.369	1.475	1.488	1.537	17.418
1949	1.537	1.388	1.476	1.428	1.414	1.309	1.291	1.291	1.309	1.537	1.666	1.722	17.368
1950	1.722	1.499	1.599	1.428	1.414	1.250	1.107	1.107	1.190	1.599	1.666	1.783	17.364
1951	1.783	1.555	1.660	1.488	1.414	1.190	1.107	1.107	1.071	1.291	1.428	1.537	16.631
1952	1.537	1.438	1.476	1.309	1.168	1.012	.922	.922	.893	1.107	1.309	1.414	14.507
1953	1.414	1.222	1.168	.774	.738	.714	.695	.695	.678	.738	.893	1.107	10.836
1954	1.107	.944	.922	.714	.738	.678	.689	.689	.666	.738	.952	1.291	10.128
1955	1.291	1.111	1.045	.893	.861	.774	.738	.738	.714	.799	.893	.984	10.841
1956	.984	.748	.738	.672	.689	.660	.683	.683	.660	.683	.714	.799	8.713

Table 1.--Estimated Monthly and Annual Discharge of New Water Contribution to Major Johnson Springs (Eddy County, New Mexico) for the period 1939-1976, in 1,000's of Acre-Feet--Continued

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1957	.799	.628	.676	.637	.658	.637	.658	.658	.637	.658	.678	.861	8.185
1958	.861	.722	.799	.714	.738	.655	.676	.676	.655	.676	.714	.799	8.685
1959	.799	.666	.676	.655	.676	.643	.664	.664	.643	.670	.655	.695	8.106
1960	.695	.633	.676	.625	.646	.613	.609	.609	.589	.633	.655	.787	7.770
1961	.787	.694	.676	.655	.639	.595	.596	.596	.577	.646	.655	.695	7.811
1962	.695	.611	.646	.625	.615	.595	.590	.590	.571	.615	.625	.676	7.454
1963	.676	.611	.627	.607	.615	.595	.584	.584	.565	.646	.655	.689	7.454
1964	.689	.633	.615	.595	.615	.547	.566	.566	.547	.615	.625	.646	7.259
1965	.646	.583	.646	.625	.560	.536	.553	.553	.536	.566	.625	.664	7.093
1966	.664	.600	.658	.637	.652	.625	.646	.646	.631	.664	.649	.670	7.742
1967	.670	.583	.646	.625	.646	.536	.553	.553	.536	.621	.625	.646	7.240
1968	.646	.604	.609	.565	.584	.536	.553	.553	.536	.646	.625	.658	7.115
1969	.658	.589	.646	.625	.615	.541	.560	.560	.541	.615	.625	.664	7.239
1970	.664	.589	.646	.625	.615	.541	.560	.560	.541	.615	.625	.658	7.239
1971	.658	.589	.646	.625	.615	.541	.560	.560	.541	.615	.625	.664	7.239
1972	.664	.615	.652	.619	.615	.583	.578	.578	.583	.627	.625	.664	7.403
1973	.664	.589	.646	.595	.590	.571	.590	.590	.571	.596	.595	.639	7.236
1974	.639	.578	.633	.595	.566	.530	.541	.541	.524	.578	.625	.670	7.020
1975	.670	.605	.621	.583	.578	.547	.553	.553	.553	.590	.601	.633	7.087
1976	.633	.592	.621	.595	.609	.524	.541	.541	.530	.609	.625	.695	7.115

Table 2.--Yearly and Total Cumulative Deficit Flow at Major Johnson Springs for the Period 1947-1976, in 1,000's of Acre-Feet

Year	Estimated New Water Discharge, Major Johnson Springs	1947 Condition New Water Discharge, Major Johnson Springs	Deficit
1947	18.1	18.1	0
1948	17.4	18.1	0.7
1949	17.4	18.1	0.7
1950	17.4	18.1	0.7
1951	16.6	18.1	1.5
1952	14.5	18.1	3.6
1953	10.8	18.1	7.3
1954	10.1	18.1	8.0
1955	10.8	18.1	7.3
1956	8.7	18.1	9.4
1957	8.2	18.1	9.9
1958	8.7	18.1	9.4
1959	8.1	18.1	10.0
1960	7.8	18.1	10.3
1961	7.8	18.1	10.3
1962	7.5	18.1	10.6
1963	7.5	18.1	10.6
1964	7.3	18.1	10.8
1965	7.1	18.1	11.0
1966	7.7	18.1	10.4
1967	7.2	18.1	10.9
1968	7.1	18.1	11.0
1969	7.2	18.1	10.9
1970	7.2	18.1	10.9

Table 2.--Yearly and Total Cumulative Deficit Flow at Major Johnson Springs for the Period 1947-1976, in 1,000's of Acre-Feet-Continued

Year	Estimated New Water Discharge, Major Johnson Springs	1947 Condition New Water Discharge, Major Johnson Springs	Deficit
1971	7.2	18.1	10.9
1972	7.4	18.1	10.7
1973	7.2	18.1	10.9
1974	7.0	18.1	11.1
1975	7.1	18.1	11.0
1976	7.1	18.1	11.0
		Total	251.8

Carlsbad Springs

Method of Analysis.--Although it is of prime interest to show the relationship of the change in ground-water storage of the aquifer contributing "new water" to Carlsbad Springs—namely, the Capitan Limestone (reef) aquifer—and the comparable chronological change in discharge at the springs; it is also necessary in this analysis to consider the influence of excessive pumpage on the quality of water both in the contributing aquifer and at the springs. The reason for this is that historically the ground-water quality in the Capitan Limestone (reef) aquifer has been characteristically better than the quality of the water in the Pecos River System above Carlsbad Springs. Excessive pumpage of the shallow and Capitan Limestone (reef) aquifers causes a depletion of their storage which in turn induces inflow or leakance from the measured water of the Pecos River System which includes seepages from Lake Avalon, the river, and canals. The leakage of this poorer quality water into the Capitan Limestone (reef) aquifer as leakance is revealed in the historical ground-water quality record of the aquifer as well as that of Carlsbad Springs. With this in mind, it becomes evident that the amount of its head which is controlled by pumpage which in turn induces leakage from the Pecos River System or measured water. Consequently, previously measured water has been intercepted by excessive pumping of the shallow and Capitan Limestone (reef) aquifers. In a sense, this interception is analogous to the geomorphologic term "stream piracy" which is when the headward erosion of a stream (excessive pumpage) intercepts the upper part of another stream (previously measured water).

The component of discharge at Carlsbad Springs that is "new water" was established by Senate Document 109 as the "1947 Condition" and quantitatively is 19 cfs. "New water" contributions from the Capitan Limestone (reef) aquifer ranged from 23 to 35 cfs between 1939-1946 and averaged 35 cfs in 1946 as given in the Report on the Review of Basic Data (Pecos River Commission, 1960). However, for the purposes of this study any "new water" discharge less than 19 cfs was considered to be a deficit flow and is indicative of the depletion of groundwater storage due to excessive pumpage from the contributing aquifer. This deficit is further compounded by leakance which replaces a portion of the deficient storage.

The analysis begins by correlating the water levels from two wells (21.27.19.33 in the Tansill aquifer and 22.26.2.242 in the Capitan Limestone (reef) aquifer) in order to provide an adequate length of historical water-level record to monitor the head in the contributing aquifer. This extended the water-level record from the fall of 1946 and/or from 1954 (Figure 8). Next, well 22.26.2.242 was selected as the index well and its estimated average annual water levels were calculated by averaging the January and December high water levels and then averaging this result with the annual low water level which usually occurred in August or September (Figure 10).

The accounting procedures as used by Bjorklund and Motts, 1959 of the U.S. Geological Survey and in the Report on Review of Basic Data (Pecos River Commission, 1960) were utilized in plotting the "new water" discharge graph in Figure 10 for the period 1939-1957. For the period 1958-1976, a computer program using the same accounting procedures (Pecos River Commission, 1960) was developed by the Department's Dr. Quentin Martin and utilized to complete the graph on "new water" discharge. This computer program was verified by closely duplicating the historical "new water" discharge for Carlsbad Springs for the period 1937-1957. Within the computer program, the total spring flow was determined using the following procedures: (1) total flow from 1958-1969 was assumed equal to the total flow gaged at the Pecos River station at Carlsbad less the flow gaged at the stations below Lake Avalon which measure spills from the reservoir including those of the Main Canal; (2) total flow from 1970-1973 and 1975-1976 was assumed equal to flow measured at the Pecos River gaging station below Dark Canyon less the flow of the

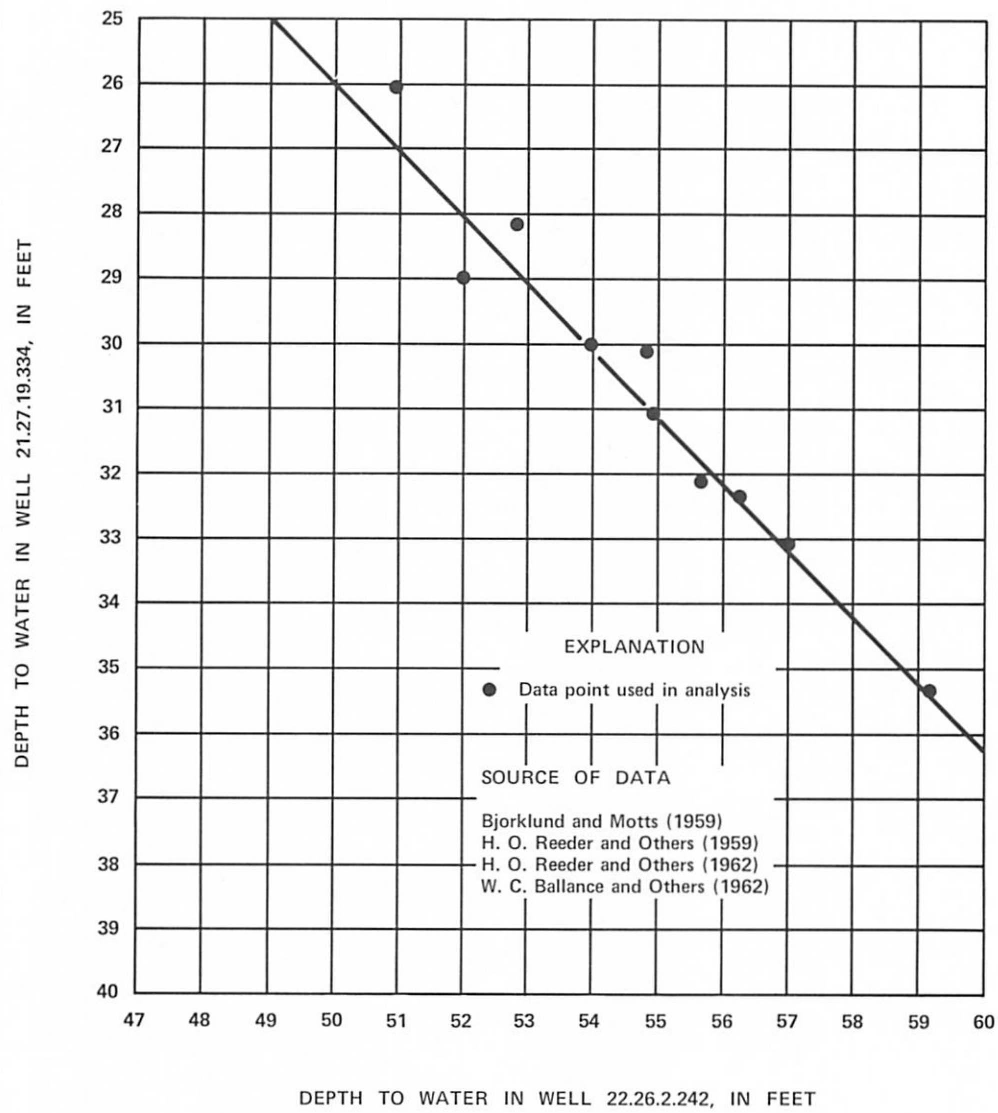


Figure 8

Correlation of Depth to Water in Observation Wells 21.27.19.334 and 22.26.2.242 (Eddy County, New Mexico), for the Period 1948-1960

Pecos River below Avalon Dam; (3) total flow for 1974 (365 days) was determined the same way as the two above periods except that flows from the tributary Dark Canyon for September and October 1974 were subtracted; and (4) no adjustments were made after 1957 to account for minor diversions by the city of Carlsbad Golf Course, E. J. Hines, Mrs. F. V. Dowling, evaporation losses from Bataan Recreational Lake (built in 1970), and tributary inflow from Dark Canyon during August 23-24, 1971, August 28, 1972, and September 3-15, 1972.

In Figure 10, losses from the Carlsbad Spring System (1954-1976)to the shallow and Capitan Limestone (reef) aquifers are shown as leakance. This water originated from seepage between Major Johnson Springs and Dam Site No. 3 gage, seepage from Lake Avalon which is underlain by alluvium and the Capitan Limestone (reef) aquifer, seepage from the Pecos River Channel between Dam Site No. 3 and Lake Avalon, percolation from the Carlsbad Project canals, and irrigation return flows. Table 3 illustrates the accounting procedures used to analyze these losses or leakance from the Carlsbad Spring System.

To substantiate the movement of water from the "seepage component of the Pecos River System" in the Carlsbad Springs area into the Capitan Limestone (reef) aquifer, Figure 10 shows water quality as chloride concentration plots of three wells (21.26.36.221, 21.27.30.434, and 22.26.1.144) completed in the Capitan Limestone (reef) aquifer and the comparable plot for Carlsbad Springs. It is interesting to note several pertinent facts as revealed by these water quality graphs: (1) the concentrations of chloride of the water from the wells prior to 1950 are much less than those at the springs, (2) the upward trend in the discharge of the springs is nearly parallel from the early 1940's to 1950, (3) the upward trend or increase in chloride concentrations is continuous in the water from wells 22.26.1.144 and 21.27.30.434 from the early 1940's to the present (January, 1978), (4) the chloride concentrations begin to decrease steadily after 1954 to the present (January, 1978) in the springs which is indicative of proportionally more water coming from the Capitan Limestone (reef)

Table 3.--Accounting Procedures for the Measurement of New Water Discharge and Losses to the Carlsbad Spring System, in Cubic Feet Per Second 1/, 2/

Year	Total Spring Flow at Carlsbad Gage	Canal Seepage	Irrigation Return Flow	Avalon Leakage	Channel Seepage above #3 Gage	New Water at Springs
1939	72	12	1	27	5	27
1940	66	12	1	25	5	23
1941	95	8	1	35	5	46
1942	102	11	1	33	5	52
1943	95	12	1	28	5	49
1944	84	9	1	24	5	45
1945	78	7	1	24	5	41
1946	71	7	1	23	5	35
1947	62	6	1	20	5	30
1948	55	7	1	21	5	21
1949	69	10	1	30	5	23
1950	67	10	1	27	5	24
1951	54	9	1	21	5	18
1952	41	7	1	20	5	8
1953	35	5	1	23	5	1
1954	38	5	1	27	5	0
1955	42	10	1	27	5	-1
1956	37	9	1	21	5	1

Table 3.--Accounting Procedures for the Measurement of New Water Discharge and Losses to the Carlsbad Spring System, in Cubic Feet Per Second 1/, 2/--Continued

Year	Total Spring Flow at Carlsbad Gage	Canal Seepage	Irrigation Return Flow	Avalon Leakage	Channel Seepage above #3 Gage	New Water at Springs
1957	27	6	1	22	5	-7
1958	38.1	8.0	1.0	29.8	5.0	-5.5
1959	39.2	9.2	1.0	34.4	5.0	-10.3
1960	28.2	8.5	1.0	23.9	5.0	-10.3
1961	35.7	9.4	1.0	33.3	5.0	-12.9
1962	24.3	8.8	1.0	22.2	5.0	-12.8
1963	20.0	6.9	1.0	25.3	5.0	-18.4
1964	14.3	3.6	1.0	25.6	5.0	-21.3
1965	8.1	4.3	1.0	18.8	5.0	-21.0
1966	18.2	5.2	1.0	22.3	5.0	-15.2
1967	16.5	7.0	1.0	29.5	5.0	-25.9
1968	16.6	6.5	1.0	25.0	5.0	-20.9
1969	14.6	7.3	1.0	22.7	5.0	-21.3
1970	20.5	6.9	1.0	33.5	5.0	-25.9
1971	12.0	5.0	1.0	25.6	5.0	-24.8
1972	11.1	6.0	1.0	21.1	5.0	-21.9
1973	17.1	9.4	1.0	29.0	5.0	-27.0
1974	16.2	5.2	1.0	24.2	5.0	-19.6

Table 3.--Accounting Procedures for the Measurement of New Water Discharge and Losses to the Carlsbad Spring System, in Cubic Feet Per Second 1/, 2/--Continued

Year	Total Spring Flow at Carlsbad Gage	Canal Seepage	Irrigation Return Flow	Avalon Leakage	Channel Seepage above #3 Gage	New Water at Springs
1975	29.8	6.2	1.0	32.7	5.0	-15.1
1976	10.5	3.5	1.0	26.3	5.0	-25.5

1/ Data for the period 1939-1957 from:
Report on Review of Basic Data, 1960, Table 15-1.

2/ Data for the period 1958-1976 from a computer analysis developed by Zack Dean (TDWR) using the accounting procedures in Review of Basic Data (1960).

aquifer, and (5) from 1954 through 1968 most years show a high chloride concentration during the winter months and a low chloride concentration during the summer, which corresponds to the winter high stage in Lake Avalon (springs predominantly supported by surface water seepages) and the low indicative of spring flows coming proportionally more from the Capitan Limestone (reef) aquifer.

And finally on Figure 10 in the lowermost graph, pumpage has increased throughout the historical hydrological record for the Carlsbad Springs area, thus causing overdevelopment and an increasing rate in the depletion of ground-water storage.

Results.--The influence of excessive pumpage related to the Carlsbad Springs System is overwhelmingly evident in the historical hydrological record as analyzed in the preceding discussion. It has caused ground-water waste in terms of water quality degradation due to the leakage (leakance) to the Capitan Limestone (reef) aquifer of the poorer quality measured water above Carlsbad Springs. The record (Figure 10 and Table 3) shows that following the stepped-up increase in pumpage in 1953: the contribution of "new water" to the springs from the Capitan Limestone (reef) aquifer dropped to zero in 1954 and that large quantities of poorer quality water began to move into the shallow and reef aquifers as leakance after 1956 from the measured water from the Pecos River System. Seasonal changes in the water quality issuing from the springs after 1953 correlate well with the high and low stages in Lake Avalon; thus, pointing to the main sources of water supporting the springs, namely, the Pecos River System measured water above the springs (Lake Avalon and shallow alluvium aquifer) and the Capitan Limestone (reef) aquifer. Even though the ground-water quality continued to deteriorate in a portion of the Capitan Limestone (reef) aquifer, the water quality in the springs began to improve in 1955 due to lessor amounts of previously measured water reaching the springs after 1953.

Water levels in well 22.26.2.242 (Figure 10) correlate well with the "new water" contribution to the springs for the period 1947-1953. After 1953, estimated average annual water levels slowly declined and ranged from about 3103.5 to 3098.5 feet above sea level; thus, indicating the Capitan Limestone (reef) aquifer continues to contribute ground water to the springs as the elevation of the water surface at Lake Tansill is approximately 3095 feet above sea level (many of the springs are located in Lake Tansill below 3095).

Using the "1947 Condition" established by Senate Document 109 of 19 cfs or 13,800 acre-feet as the minimum "new water" contribution from the Capitan Limestone (reef) aquifer, the total deficit flow at Carlsbad Springs from 1947 to 1976 as "new water" and leakance is estimated to be 584,700 acre-feet (Figure 10 and Table 4). The 19 cfs used in the determination of the total deficit is considerably less than the average discharge during the eight years prior to 1947.

Table 4.--Yearly and Total Cumulative Deficit Flow at Carlsbad Springs for the Period 1947-1976, in Cubic Feet Per Second and Thousands of Acre-Feet

Year	Estimated "New Water" Discharge[1/], Carlsbad Springs (CFS)	1947 Condition New Water Discharge, Carlsbad Springs (CFS)	Deficit CFS	Deficit Thousands of Acre-Feet
1947	30	19	11	8.0
1948	21	19	2	1.4
1949	23	19	4	2.9
1950	24	19	5	3.6
1951	18	19	- 1	- 0.7
1952	8	19	-11	- 8.0
1953	1	19	-18	-13.0
1954	0	19	-19	-13.8
1955	- 1	19	-20	-14.5
1956	1	19	-18	-13.0
1957	- 7	19	-26	-18.8
1958	- 5.5	19	-24.5	-17.7
1959	-10.3	19	-29.3	-21.2
1960	-10.3	19	-29.3	-21.2
1961	-12.9	19	-31.9	-23.1
1962	-12.8	19	-31.8	-23.0
1963	-18.4	19	-37.4	-27.1
1964	-21.3	19	-40.3	-29.2
1965	-21.0	19	-40.0	-29.0
1966	-15.2	19	-34.2	-24.8
1967	-25.9	19	-44.9	-32.5
1968	-20.9	19	-39.9	-28.9
1969	-21.3	19	-40.3	-29.2
1970	-25.9	19	-44.9	-32.5

Table 4.--Yearly and Total Cumulative Deficit Flow at Carlsbad Springs for the Period 1947-1976, in Cubic Feet Per Second and Thousands of Acre-Feet--Continued

Year	Estimated "New Water" Discharge 1/, Carlsbad Springs (CFS)	1947 Condition New Water Discharge, Carlsbad Springs (CFS)	Deficit CFS	Deficit Thousands of Acre-Feet
1971	-24.8	19	-43.8	-31.7
1972	-21.9	19	-40.9	-29.6
1973	-27.0	19	-46.0	-33.3
1974	-19.6	19	-38.6	-27.9
1975	-15.1	19	-34.1	-24.7
1976	-25.5	19	-44.5	-32.2
		Total Deficit (Thousands of Acre-Feet)		-584.7

1) Negative values of "New Water" indicate subsurface losses to the Carlsbad Spring System from Pecos River sources.

CONCLUSIONS

Major Johnson Springs

Due to excessive pumping, the water levels in the ground-water reservoir or aquifer system contributing "new water" to Major Johnson Springs have declined; thus, causing deficit "new water" flow rates below the "1947 Condition" of 18,100 acre-feet annually established by Senate Document 109. These water-level declines are widespread in the Roswell Artesian Basin as exhibited by the declines in the index Moutray well 20.26.8.1211 and similar declines in the Orchard Park well 12.25.23.113 near Roswell.

Based on the water-level declines in the Moutray well 20.26.8.1211 and the "1947 Condition" "new water" flow of 18,100 acre-feet annually, the total ground-water deficit in the contributing reservoir caused by excessive pumping for the period 1947-1976 is approximately 251,800 acre-feet or about 46 percent of the expected "1947 Condition" "new water."

Carlsbad Springs

Ground-water withdrawals from the shallow and Capitan Limestone (reef) aquifers starting in 1951 has caused water levels to decline thus causing "new water" flows at Carlsbad Springs to fall below the "1947 Condition" (19 cfs). In addition, certain seepage losses from the Pecos River System above Carlsbad, New Mexico, which prior to 1955 reappeared as springflow at Carlsbad Springs, are being intercepted due to ground-water withdrawals. A portion of these seepage losses are moving into the Capitan Limestone (reef) aquifer and causing a gradual deterioration of the aquifer's water quality.

The total deficit of "new water" plus intercepted seepage losses from the Pecos River System for the period 1947-1976 is approximately 584,700 acre-feet. This deficit is based on the "1947 Condition" of 19 cfs of previously unmeasured water flow as stated in Senate Document 109. However, the deficit would be much greater if the average historical "new water" flows for the period 1939-1946 were used to represent the "1947 Condition," or if the historical "new water" flow for the year 1947 was used to represent the "1947 Condition."

SELECTED REFERENCES

Ballance, W. C., et al., 1962, Ground-water levels in New Mexico, 1960: N. Mex. State Engineer, Tech. Rept. 27, 215 p.

Bjorklund, L. J., and Motts, W. S., 1959, Geology and water resources of the Carlsbad area, Eddy County, New Mexico: U.S. Geol. Survey open-file rept., 322 p., 14 pls., 54 figs.

Boyer, J., Feb. 1, 1978, Personal Communication by phone resulting in the transmittal of water quality information from a sample of Carlsbad Spring water (21.26.25.333) taken on Jan. 28, 1978 by R. L. Bluntzer, Texas Dept. of Wtr. Resources. Analysis performed by Texas Dept. of Health.

Busch, F. E., and Hudson, J. D., 1967, Ground-water levels in New Mexico, 1965: N. Mex. State Engineer, Tech. Rept. 34, 124 p.

Collins, R. B., Jan. 27, 1978, Personal Communication, Tabulations and oral qualifications of pumpage and well data for the city of Carlsbad and International Minerals and Chemical Corporation: N. Mex. State Engineers Office, Roswell, N. Mex., given to R. L. Bluntzer, Texas Dept. of Wtr. Resources, 3 p. and notes.

Cox, E. R., 1967, Geology and hydrology between Lake McMillan and Carlsbad Springs Eddy County, New Mexico: U.S. Geol. Survey Water-Supply Paper 1828, 48 p.

Fielder, A. G., and Nye, S. S., 1933, Geology and ground-water resources of the Roswell artesian basin, New Mexico: U.S. Geol. Survey Water-Supply Paper 639, 372 p., 37 figs.

Fogg, P. M., 1914, Report on the investigation of the Pecos River in Texas: U. S. Reclamation Service, 65 p.

Hale, W. E., Mar. 11, 1960, Written Communication, by Hale, U.S. Geol. Survey, Albuquerque, N. Mex. to John Erickson, Engineering Consultant to Pecos River Comm., transmitting estimated new water discharge data on Major Johnson Springs for the period 1946-1954.

Hendrickson, G. E., and Jones, R. S., 1952, Geology and ground-water resources of Eddy County, New Mexico: N. Mex. State Bur. of Mines and Min. Resources, Ground-Water Rept. 3, 169 p.

Hougland, R. W., Jan. 26, 1978, Tabulation of water quality-ppm, IMC pipeline discharge: International Mining and Chemical Corp., Carlsbad, N. Mex.,1 p.

Hudson, J. D., and Borton, R. L., 1974, Ground-water levels in New Mexico, 1970: N. Mex. State Engineer, Tech. Rept. 39, 123 p.

Mann, O. P., 1976, Watermaster report Pecos Valley Surface Water District 1975 irrigation season: Pecos Valley Surface Water District Watermaster, N. Mex. State Engineer Office, 43 p.

Pecos River Commission, 1960, Report on review of basic data to Engineering Advisory Committee: Appendix 11 and Appendix 15, 13 p. and 11 p., respectively.

Pecos River Compact Commission, 1949, Compact entered into by the States of New Mexico and Texas, relating to the waters of the Pecos River-together with the report of the Engineering Advisory Commission to the Pecos River Compact Commission: presented by Mr. O'Mahoney, August 19 (Legislature day June 2), 1949, U.S. 81st Congress, 1st Session, Senate Document 109, Public Law 91, 172 p.

Reeder, H. O., et al., 1959, Annual water-level measurements in observation wells, 1951-1955 and atlas of maps showing changes in water levels for various periods from beginning of record through 1954, New Mexico: N. Mex. State Engineer Office, Tech. Rept. 13, 339 p.

_____________________, 1960, Ground-water levels in New Mexico, 1956: N. Mex. State Engineer, Tech. Rept. 19, 251 p.

_____________________, 1961, Ground-water levels in New Mexico, 1957: N. Mex. State Engineer, Tech. Rept. 22, 306 p.

_____________________, 1962, Ground-water levels in New Mexico, 1958: N. Mex. State Engineer, Tech. Rept. 23, 288 p.

Seth, W. A., Dec. 22, 1977, Written Communication, by Seth, U.S. Dept. of Interior, Bur. of Reclamation, Amarillo, Texas, to H. D. Davis, Executive Director, Texas Dept. of Wtr. Resources, transmitting data on dike construction at Lake McMillan and channel construction at Kaiser Channel.

Texas Department of Water Resources, 1978, Base flow geohydrology in the Pecos River between Acme and Artesia, New Mexico: Texas Dept. of Wtr. Resources unpublished paper, 26 p.

U. S. Geological Survey, 1960, Compilation of records of surface waters of the United States through September 1950, Part 8. Western Gulf of Mexico Basins: U.S. Geol. Survey Water-Supply Paper 1312, 633 p.

_____________________, 1977, Water resources data for New Mexico water year 1976: U.S. Geol. Survey Water-Data Rept. NM-76-1, 655 p.

U. S. Geological Survey, Jan. 1978, Tabulations of water quality in wells and springs in the Carlsbad Springs area: U.S. Geol. Survey, Albuquerque, N. Mex., Received by the Texas Dept. of Wtr. Resources.

U. S. National Resources Planning Board, 1942, Regional planning, part X-the Pecos River joint investigation in the Pecos River Basin in New Mexico and Texas— summary, analysis, and findings with atlas of plates 1 to 34, 206 p.

Welder, G. E., Mar. 23, 1977, Written Communication, by Welder, U.S. Geol. Survey, Albuquerque, N. Mex., to R. M. Whitenton, Interstate Compact Coordinator, Texas Wtr. Rights Comm., transmitting water level measurements on well 20.26.8.1211.

____________, Jan. 31, 1978, Personal Communication by telephone, by Welder, U.S. Geol. Survey, Albuquerque, N. Mex., to W. B. Klemt, Texas Dept. of Wtr. Resources.

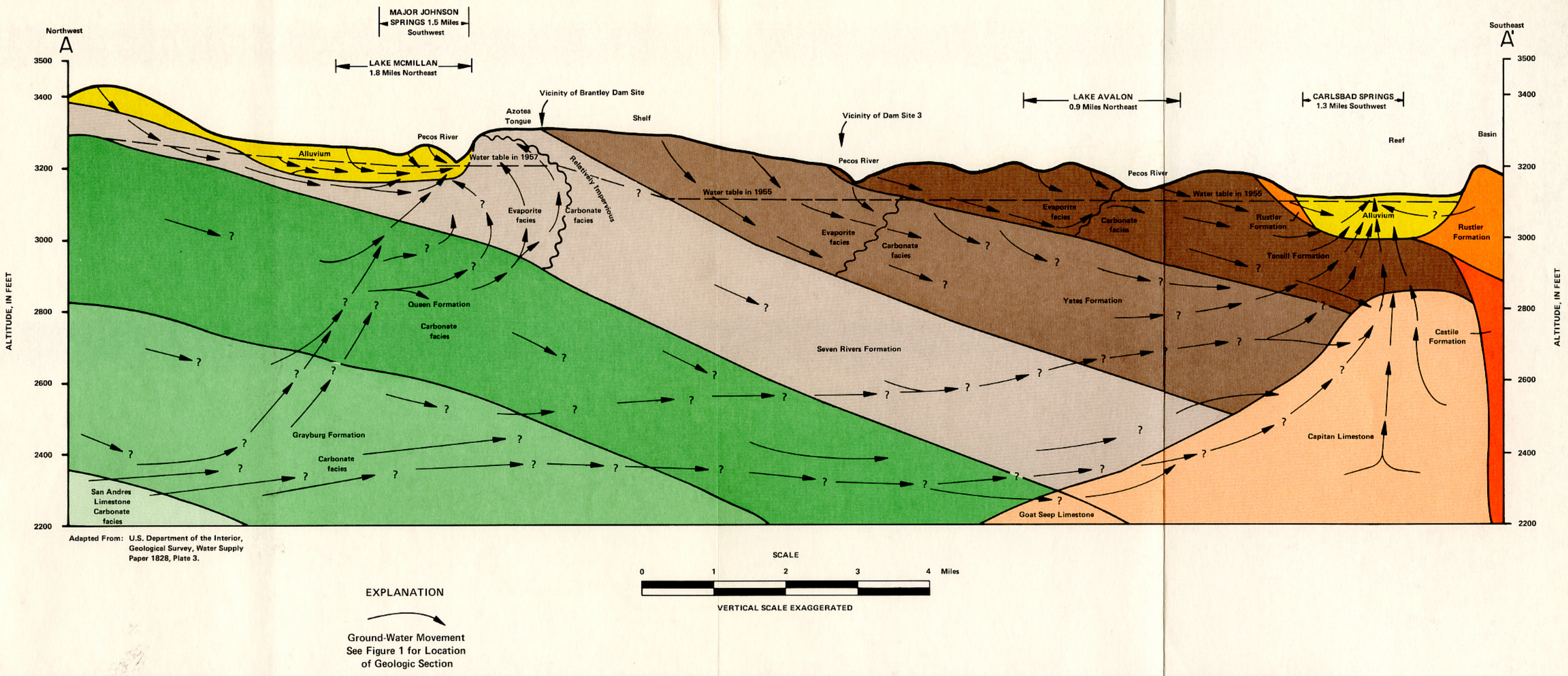
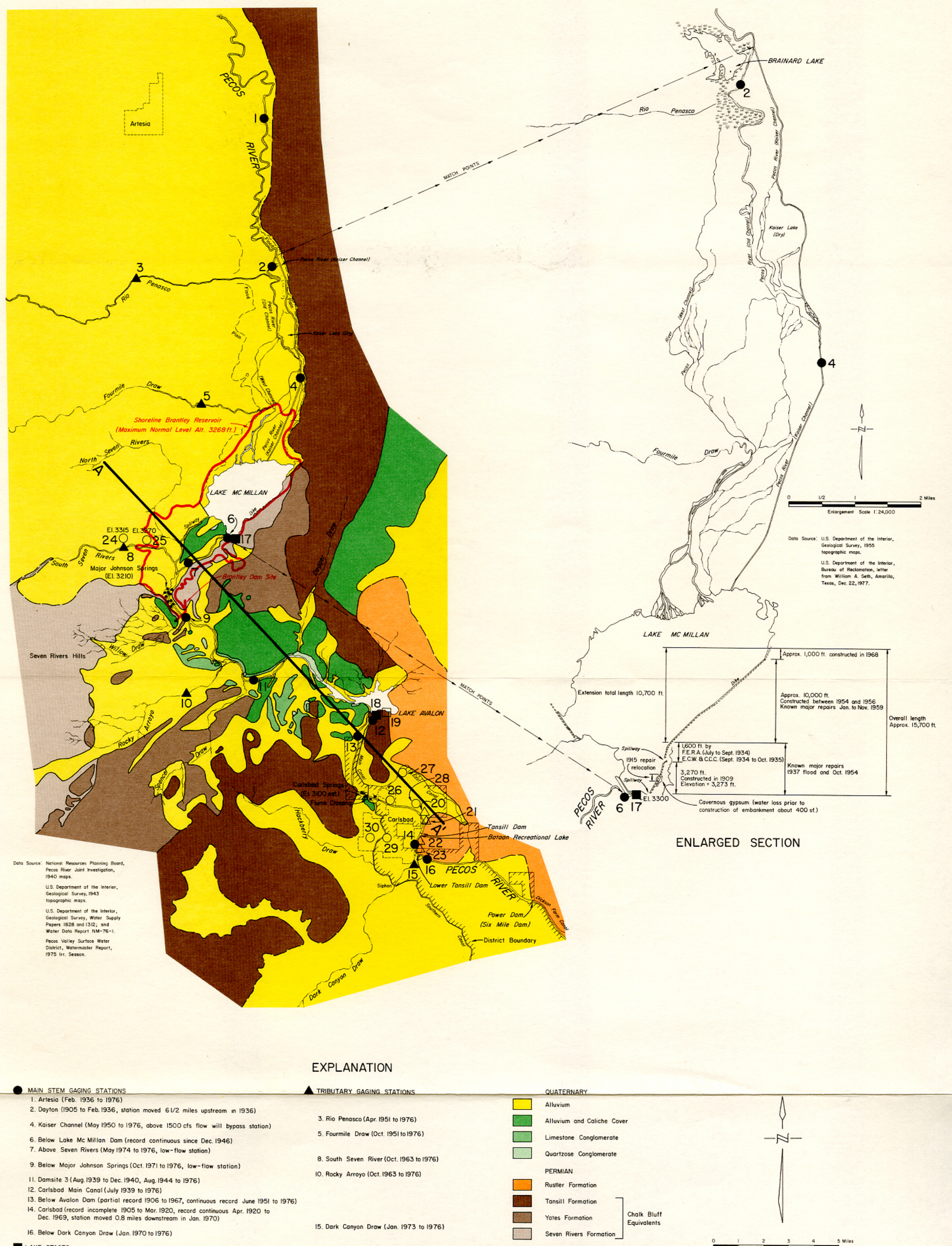


Figure 4

Idealized Cross Section A-A' Showing Geohydrology and Permian Facies Change Relationships in the Vicinity of Major Johnson and Carlsbad Springs, Eddy County, New Mexico



Data Source: National Resources Planning Board, Pecos River Joint Investigation, 1940 maps.
U.S. Department of the Interior, Geological Survey, 1943 topographic maps.
U.S. Department of the Interior, Geological Survey, Water Supply Papers 1828 and 1312; and Water Data Report NM-76-1.
Pecos Valley Surface Water District, Watermaster Report, 1975 Irr. Season.

EXPLANATION

● MAIN STEM GAGING STATIONS
1. Artesia (Feb. 1936 to 1976)
2. Dayton (1905 to Feb. 1936, station moved 6 1/2 miles upstream in 1936)
4. Kaiser Channel (May 1950 to 1976, above 1500 cfs flow will bypass station)
6. Below Lake Mc Millan Dam (record continuous since Dec. 1946)
7. Above Seven Rivers (May 1974 to 1976, low-flow station)
9. Below Major Johnson Springs (Oct. 1971 to 1976, low-flow station)
11. Damsite 3 (Aug. 1939 to Dec. 1940, Aug. 1944 to 1976)
12. Carlsbad Main Canal (July 1939 to 1976)
13. Below Avalon Dam (partial record 1906 to 1967, continuous record June 1951 to 1976)
14. Carlsbad (record incomplete 1905 to Mar. 1920, record continuous Apr. 1920 to Dec. 1969, station moved 0.8 miles downstream in Jan. 1970)
16. Below Dark Canyon Draw (Jan. 1970 to 1976)

▲ TRIBUTARY GAGING STATIONS
3. Rio Penasco (Apr. 1951 to 1976)
5. Fourmile Draw (Oct. 1951 to 1976)
8. South Seven River (Oct. 1963 to 1976)
10. Rocky Arroyo (Oct. 1963 to 1976)
15. Dark Canyon Draw (Jan. 1973 to 1976)

■ LAKE STAGES
17. Lake Mc Millan
18. Lake Avalon

□ WEATHER STATION
19. Lake Avalon

△ DIVERSIONS
20. North Pump, City of Carlsbad Golf Course
21. South Pump, City of Carlsbad Golf Course
22. E.J. Hines
23. Mrs. F.V. Dowling

○ WATER LEVEL AND QUALITY OBSERVATION WELLS
24. Well 20.26.7.122
25. Well 20.26.7.1211
26. Well 21.26.36.221
27. Well 21.27.19.334
28. Well 21.27.30.434
29. Well 22.26.1.144
30. Well 22.26.2.242

QUATERNARY
- Alluvium
- Alluvium and Caliche Cover
- Limestone Conglomerate
- Quartzose Conglomerate

PERMIAN
- Rustler Formation
- Tansill Formation
- Yates Formation
- Seven Rivers Formation

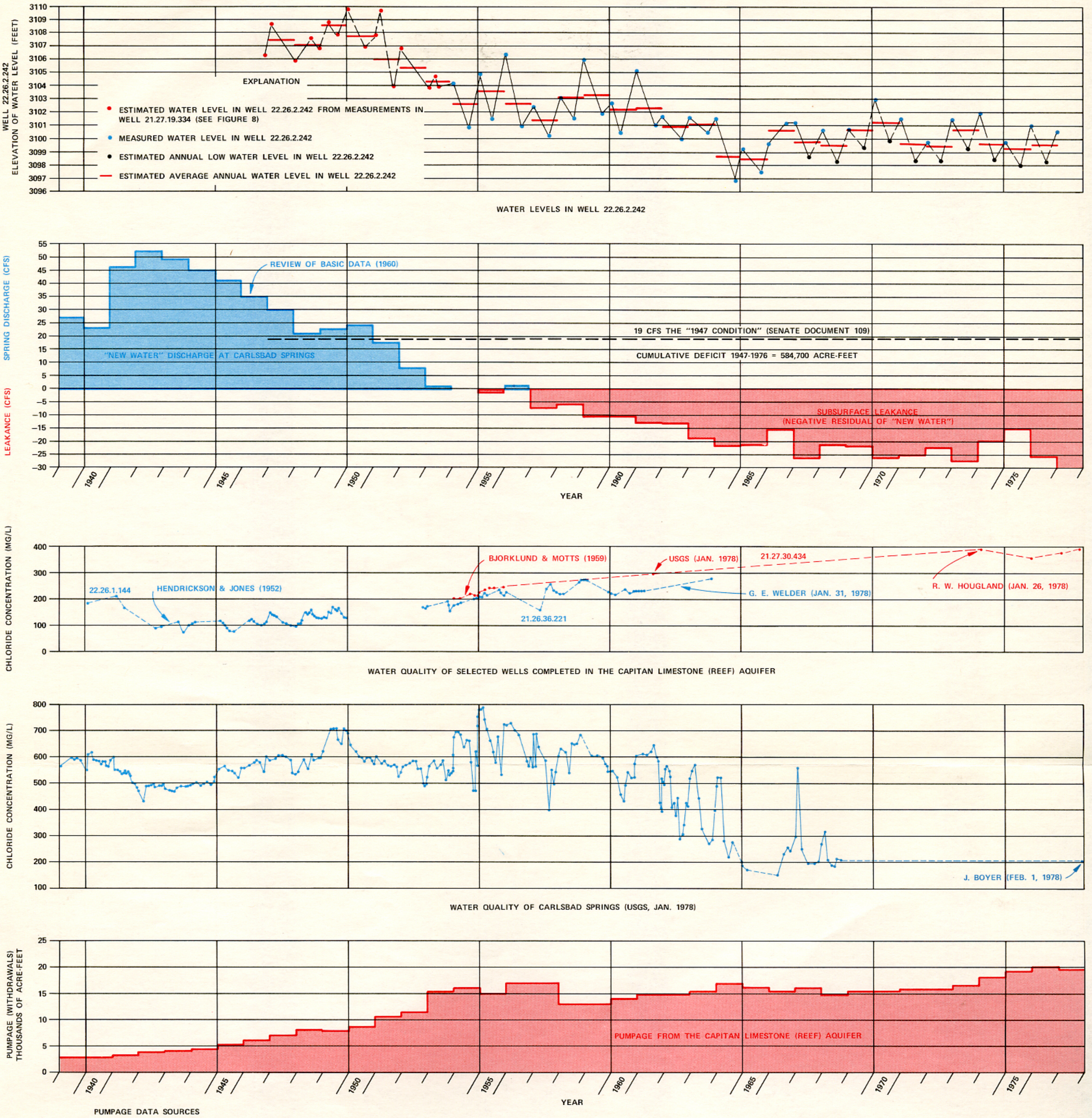
Tansill, Yates and Seven Rivers Formations: Chalk Bluff Equivalents

A———A' Approximate Line of Geologic Cross Section (Figure 4)

Scale 1:62,500 (0–5 Miles)

Figure 1

Generalized Geologic Map of the Artesia-Carlsbad Area; Eddy County, New Mexico Showing Key Pecos River Historical Hydrologic Data Collection Points and Expanded View of the Lake McMillan-Kaiser Channel Area

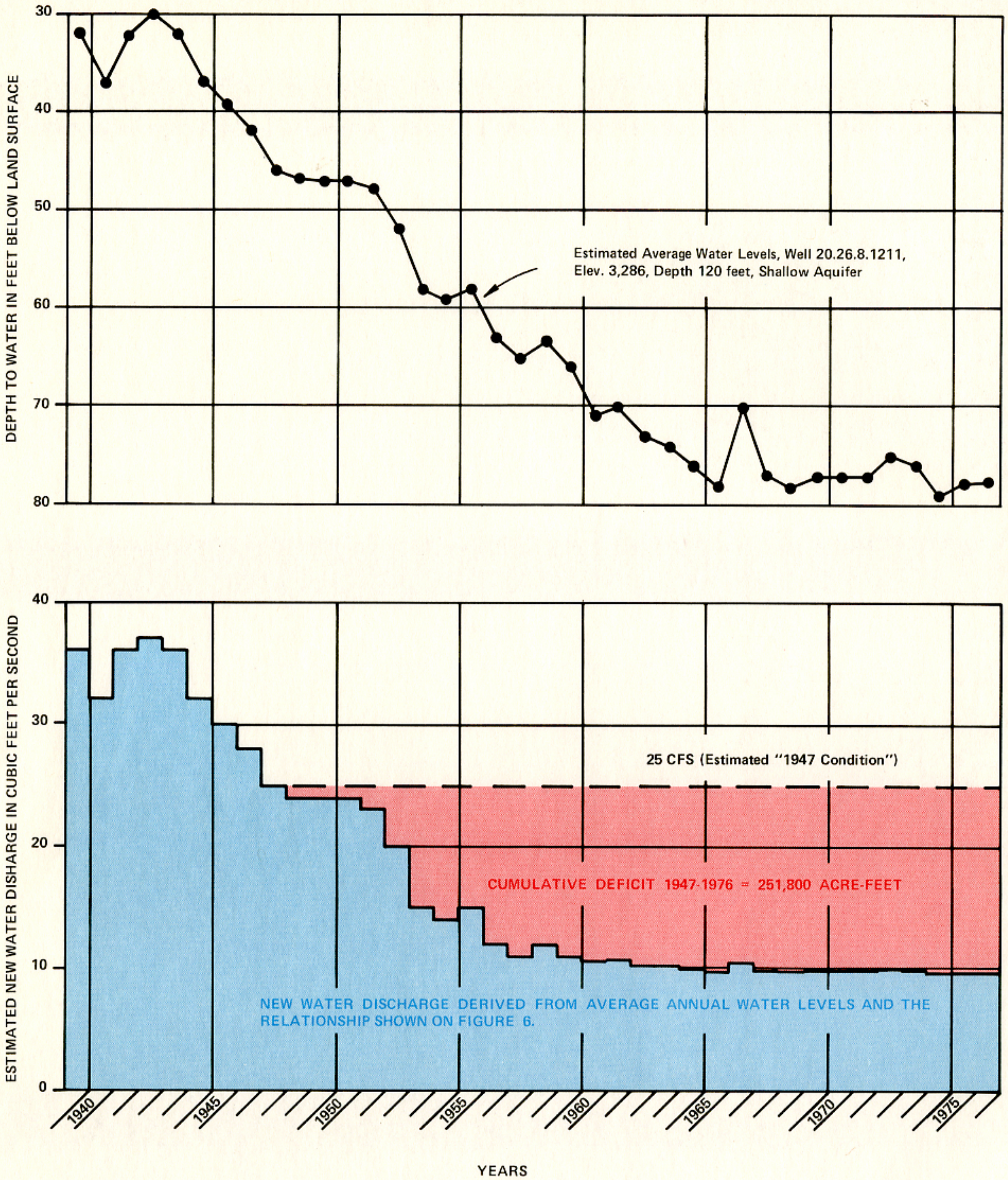


PUMPAGE DATA SOURCES

1939-1953	BJORKLUND & MOTTS (1959)
1954	H. O. REEDER, et al. (1959)
1955	BJORKLUND & MOTTS (1959)
1956	H. O. REEDER, et al. (1960)
1957	H. O. REEDER, et al. (1961)
1958	H. O. REEDER, et al. (1962)
1959-1960	W. C. BALLANCE, et al. (1962)
1961-1965	BUSCH & HUDSON (1967)
1966-1970	HUDSON & BORTON (1974)
1971-1977	R. B. COLLINS (JAN. 27, 1978)

Figure 10

Idealized Graphical Model of the Carlsbad Springs Area
Showing Pumpage (Withdrawals), "New Water" Discharge, Leakance, Water Levels,
and Water Quality of Selected Wells in the Capitan Limestone (Reef) Aquifer
with Associated Water Quality of Carlsbad Springs Discharge



Source of Data

Water level data from U.S. Geological Survey, Albuquerque, New Mexico.

Estimated "1947 Condition" new water discharge from Senate Document 109.

Estimated new water discharge for the period 1939-1976 by personnel of the Texas Department of Water Resources.

Figure 7

Comparison of Depth to Water in Well 20.26.8.1211 and Estimated New Water Discharge from Major Johnson Springs (Eddy County, New Mexico) for the Period 1939 - 1976

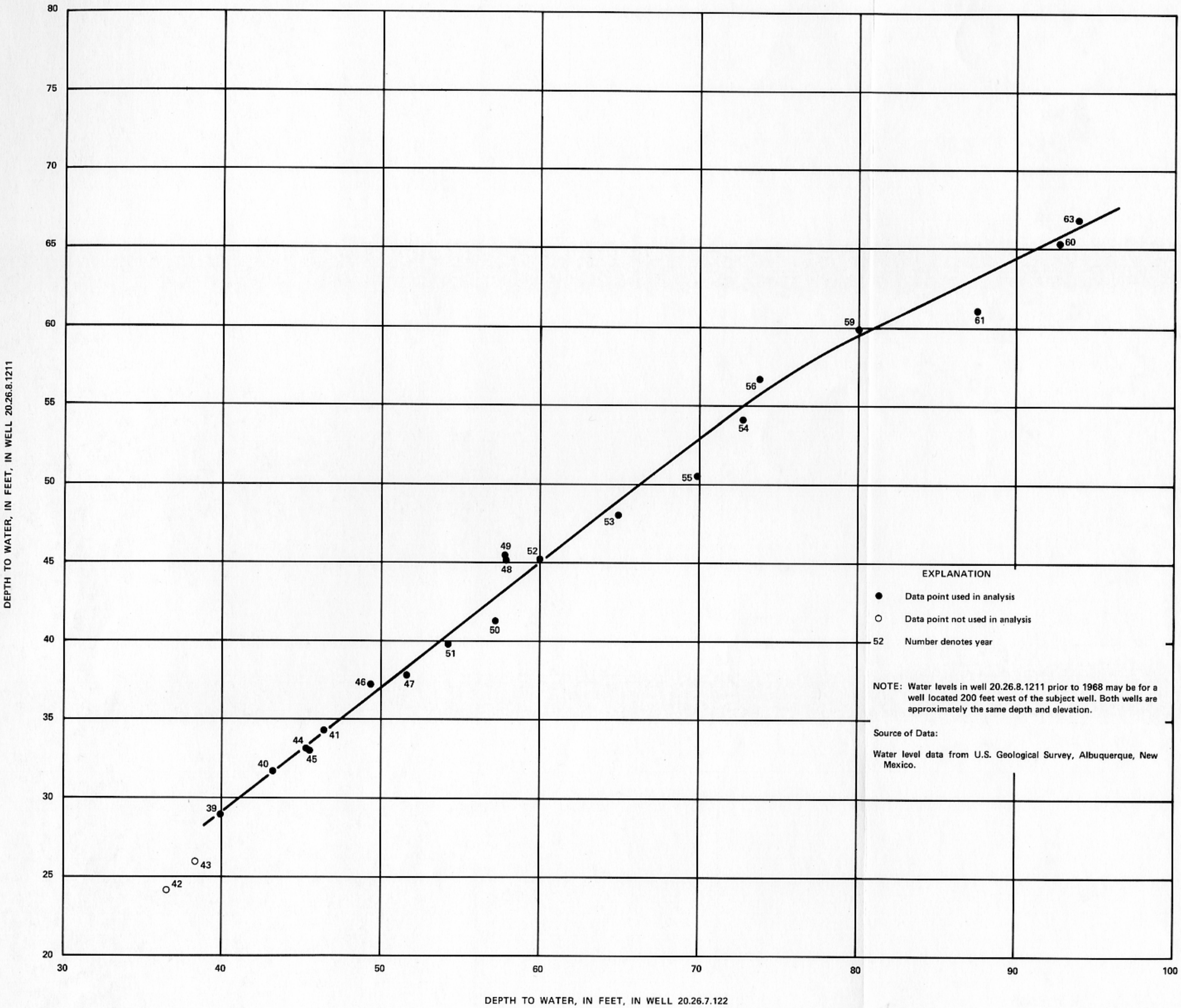


Figure 5

Correlation of Depth to Water in Observation Wells 20.26.7.122 and 20.26.8.1211 (Eddy County, New Mexico), for the Period 1939 - 1963