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ANALYSIS OF RELATIONSHIP BETWEEN ARTESIAN PRESSURE HEAD AND PRECIPITATION AND CONSUMPTIVE USE ROSWELL ARTESIAN BASIN, NEW MEXICO

By

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1941

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INTRODUCTION

Recently there has been considerable discussion concerning the decline of the artesian pressure head of the Roswell Artesian Basin. As a result of these discussions, and current opinion, it was felt that a study was needed to bring together all of the available facts which would be useful in determining the cause of the lowering of the pressure head. Six artesian wells equipped with continuous water stage recorders are being maintained at the present time for recording the artesian water levels. Water level measurements and pressure tests are made annually in approximately eighty-five artesian wells in the basin. Studies are made of the precipitation recorded at Roswell and Artesia. Permanent records are made of these findings at the Artesian Well Supervisor's Office. Also, the United States Geological Survey is making studies of the waters of the basin in addition to the original investigations made by Mr. Fiedler and Mr. Nye.

It has been mentioned that there are six wells being used as recorder wells; however, three of these wells were not equipped until 1940, and the records are too short for use in this report. The remaining three wells have been in operation approximately 15 years, and the records are used in this report. They are the Berrendo, Orchard Park and Artesia wells.

BERRENDO

The Berrendo Well is located in the SW¼SW¼SW¼ of Section 9. Township 10 South, Range 24 East, N.M.P.M. (10.24.9.333), or approximately three miles north of the City of Roswell, New Mexico. From the log records, we find this well to be 259 feet in depth, and to contain 164 feet of 10-inch diameter casing. The well was drilled in 1906, and from the log, it is shown that the previous water carrying strata was in limestone. There is, however, at the present time a variance of opinion concerning the type of water that is found in this immediate area, and some indications are shown that in the area surrounding the Berrendo Recorder Well and areas west, there may be strictly ground water conditions, rather than artesian. The writer, over two years ago, after the drilling of a number of wells in this area, came to the conclusion that water in the area mentioned possibly was not of an artesian source. The facts remain that a confining bed of a nature able to hold water under

pressure, as found in other parts of the basin, is either negligible, or non-existent in the Berrendo area referred to. This assumption may upon further study develop into more of a reality, and may possibly mean that water in the area will be defined as shallow ground water. A more detailed discussion of this theory will be explained later. It is not the intention here to give the idea that the whole of the Berrendo area obtains water from the shallow ground water source, but only that portion lying around and to the west of the recorder well. It is yet too early to give any approximate boundary. It is known that wells in this area, which have been recorded as being artesian wells, have been found by the writer and others, to be obtaining water from the valley fill formation, rather than from limestone, which is the common carrier for artesian water.

The table given below shows the mean annual water surface elevation in feet above sea level at the Berrendo Well. The data includes those years from 1927 to 1940, inclusive.

1927	1928	1929	1930	1931	1932	1933
*71.76	71.57	68.91	69.41	69.50	69.88	69.64
1934	1935	1936	1937	1938	1939	1940
66.90	67.05	65.61	65.31	65.28	64.10	63.00

*3500.00 feet must be added to each value to determine feet above sea level.

Elsewhere in this report will be found a graph showing the mean annual water surface elevation as given above, in order that a clearer idea may be obtained. This graph is given in conjunction with the mean annual precipitation at Roswell during this period. There will also be found on the graph other factors which may, or may not, have affected the conditions of the artesian head, and each factor will be discussed in this report.

Below is given a table of the accumulated excess or deficiency in the mean annual water surface at the Berrendo Recorder. The table shows the loss or gain for each year over, or under, the previous year, with the final accumulated loss or gain during the period from 1927 to 1940, inclusive.

Year	Mean Water Surface Elevation Above Sea Level (ft.)	Loss or Gain (ft.)	Accumulated Loss (ft.)
1927	3571.76	------	------
1928	3571.57	—0.19	—0.19
1929	3568.91	—2.66	—2.85
1930	3569.41	+0.50	—2.35
1931	3569.50	+0.09	—2.26
1932	3569.88	+0.38	—1.88
1933	3569.64	—0.24	—2.12

1934	3566.90	—2.74	—4.86
1935	3567.05	+0.15	—4.71
1936	3565.61	—1.44	—6.15
1937	3565.31	—0.30	—6.45
1938	3565.28	+0.03	—6.48
1939	3564.10	—1.18	—7.66
1940	3563.00	—1.10	—8.76

Total loss in 14 years: 8.76 feet.
Average annual loss: 0.626 foot.

It can be seen that by the loss or gain method of determining the total head during the period, a loss of 8.76 feet is recorded, or an average loss per year of 0.626 foot. Five years, namely, 1930, 1931, 1932, 1935 and 1938 show a rise over each previous year. The rise in 1938 was too small to fairly judge, but it is shown that this year did not decline. All other years showed a loss in mean annual pressure head of from 0.19 foot to 2.74 feet.

While precipitation in the basin does not have any direct effect on the pressure head of the artesian water, it does show a distinct indirect effect. This is caused by the lessened use of water after any form of precipitation over the basin proper. The graph covering the Berrendo Well clearly shows this effect and will be discussed more fully later.

Below is a tabulation showing the annual precipitation at Roswell for the period covered by this report, followed by columns showing the yearly departures from the long-time mean and the accumulated departures since 1924.

Year	Annual Precipitation (in.)	Excess or Deficiency for Year (in.)	Accumulated Departures (in.)
1925	11.53	— 3.41	— 3.41
1926	14.79	— 0.15	— 3.56
1927	4.83	—10.11	—13.67
1928	15.04	+ 0.10	—13.57
1929	12.39	— 2.55	—16.12
1930	10.47	— 4.47	—20.59
1931	14.42	— 0.52	—21.11
1932	18.83	+ 3.89	—17.22
1933	8.79	— 6.15	—23.37
1934	6.87	— 8.07	—31.44
1935	10.54	— 4.40	—35.84
1936	11.82	— 3.12	—38.96
1937	15.27	+ 0.33	—38.63
1938	8.15	— 6.79	—45.42
1939	12.61	— 2.33	—47.75
1940	14.09	— 0.85	—48.60

Accumulated deficiency since 1924: 48.60 in.
Average annual deficiency: 3.04 in.

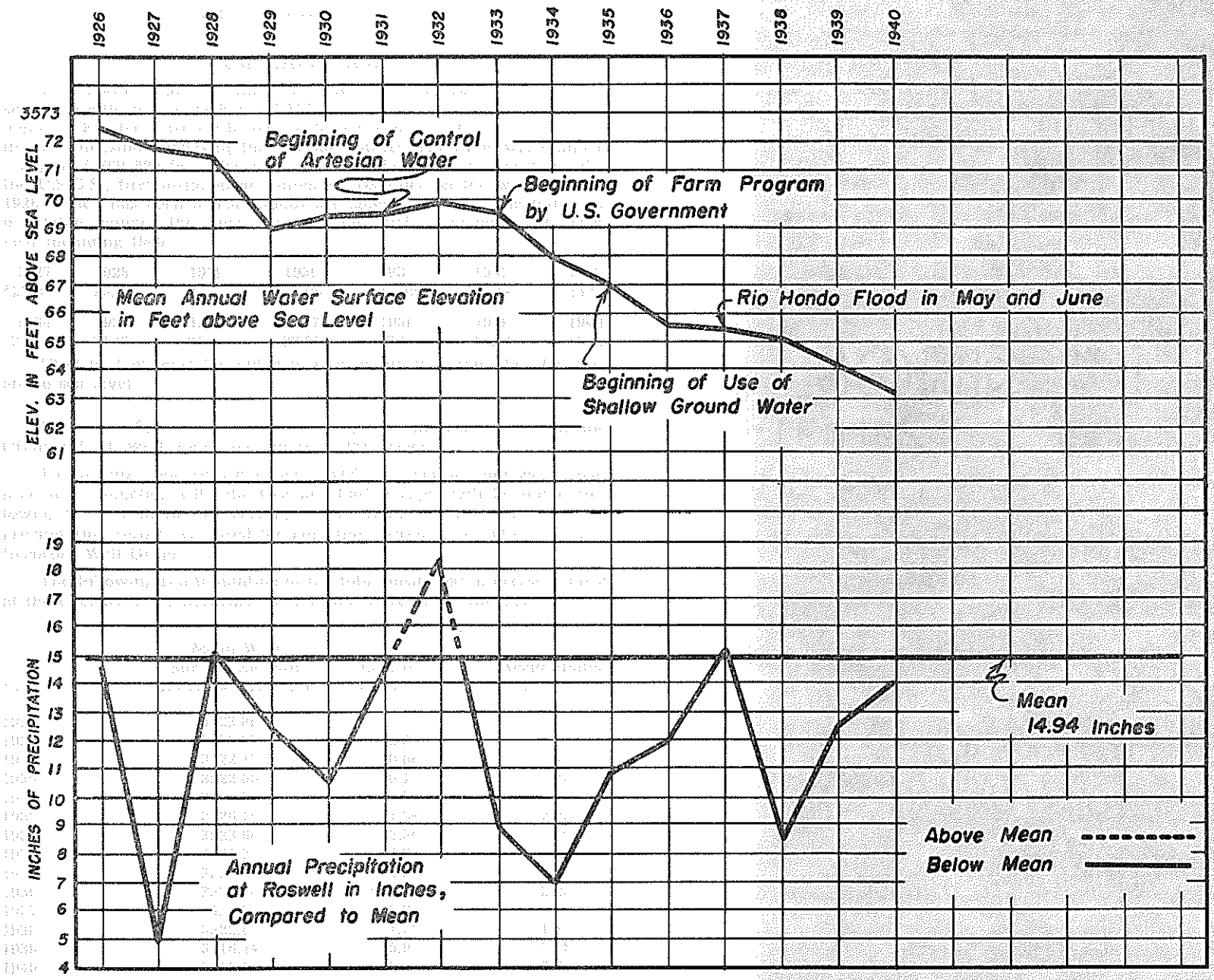
From this tabulation it is seen that, during the period covered, there was a total of 48.60 inches accumulated deficiency in precipitation in a period of 16 years, or a total of 3.25 years of average precipitation of 14.94 inches per year.

By studying the precipitation graph it can be seen that only three years of the 16 year period have been above average in precipitation: 1928, 1932 and 1937. All other years have been from 0.25 inch below average to 10.11 inches below in 1927. Since 1932 the precipitation has ranged from 0.85 inch to 8.09 inches below, except for the year 1937 which was 0.33 inch above.

In 1929 the mean annual water surface elevation fell from 3571.57 feet in 1928 to 3568.91 feet, or a lowering of 2.66 feet. In comparison, the precipitation decreased from 15.04 inches in 1928 to 12.38 inches in 1929, a decrease of 2.66 inches. From this comparison each rise and fall of the pressure head may be followed and related to precipitation until 1935. From 1935 the water level continues to fall, while there is some increase in precipitation. This may be from the fact that in the year 1934 the rainfall decreased to 6.87 inches, and the artesian head was unable to recover after a dry year. Also, in 1935, the use of shallow ground water became prominent; the relation of the artesian to shallow ground water will be discussed later. As it is known that the Berrendo area is over-appropriated and over-developed, undoubtedly the pressure head will continue to fall until this over-appropriation has been eliminated. This elimination of over-appropriation, however, is probably impossible.

One distinct fact stands out on the Berrendo graph which is interesting to note. This is the attempt of the head to straighten out in 1940, rather than continue a decline as in 1939. In 1940 the head recovered somewhat in relation to the precipitation. The apparent attempt of the pressure head to remain steady in 1937 may perhaps be attributed to the Rio Hondo flood in May and June of that year. The delayed action in showing in the Berrendo area carries out the writer's theory that the artesian water is under very little pressure, due to either the non-existence of a confining bed or its existence only in places. Thus it reacts more or less like shallow ground water, which is slow to react to pumping and barometric effects.

Another theory, which is little thought of with regards to precipitation, is that when precipitation falls over the basin during the irrigation season the time at which the rainfall comes is important; whether it is received immediately prior to an irrigation, or after water has been taken from the basin. If the basin has received a heavy shower or rainfall during an irrigation period and makes that irrigation unnecessary, or at least causes less artesian water to be used, the result is that the amount which would have been necessary for such an irrigation would be left in the basin for future use. This theory, while it does not show in any immediate effect on the pressure head, will certainly show in a yearly average, and is important enough to mention here.



BERRENDO WELL

COMPARISON OF WATER LEVEL AND PRECIPITATION

ORCHARD PARK

Well M-19, located in the SW¼NW¼NW¼ of Section 23, Township 12 South, Range 25 East, N.M.P.M., was drilled in 1906 to a total depth of 810 feet, using 645 feet of 8-inch casing. The casing was set into the limestone overlying the artesian aquifer. The water was found at a depth of 790-800 feet. The State of New Mexico, in cooperation with the U.S.G.S., first installed an automatic recorder on the well in June, 1926, which has been in continuous use since that time. The following is a table showing the mean annual water surface elevations for each year including 1940:

1927	1928	1929	1930	1931	1932	1933
*23.89	23.03	22.17	22.06	24.80	26.14	23.64
1934	1935	1936	1937	1938	1939	1940
21.27	21.63	21.64	23.87	22.65	16.74	16.10

*3500.00 feet must be added to each value to obtain the elevation above sea level.

The above figures were used in composing the graph covering the Orchard Park Well, found elsewhere in this report.

The precipitation record which covers this period, and which was used in conjunction with the Orchard Park Graph, will be found following the information concerning the Berrendo Recorder, as the same precipitation record was used for both the Berrendo and Orchard Park Recorder Well Graphs.

The following is a tabulation of the total mean loss in pressure head at the Orchard Park Recorder for the time covered by this report:

Year	Mean Water Surface Elevation Above Sea Level (ft.)	Loss or Gain (ft.)	Accumulated Loss (ft.)
1927	3523.89	------	------
1928	3523.03	— 0.86	— 0.86
1929	3522.17	— 0.86	— 1.72
1930	3522.06	— 0.11	— 1.83
1931	3524.80	+ 2.74	+ 0.91
1932	3526.14	+ 1.34	+ 2.25
1933	3523.64	— 2.50	— 0.25
1934	3521.27	— 2.37	— 2.62
1935	3521.63	+ 0.36	— 2.26
1936	3521.64	+ 0.01	— 2.25
1937	3523.87	+ 2.23	— 0.02
1938	3522.65	— 1.22	— 1.24
1939	3516.74	— 5.91	— 7.15
1940	3516.10	— 0.64	— 7.79

Total loss in 14 years: 7.79 ft.
Average annual loss: 0.418 ft.

From the above tabulation it is shown that the Orchard Park Recorder Well had a total mean loss in the 14 year period of 7.79 feet, or an average loss of 0.418 foot per year. It can also be seen that the pressure head averaged approximately the same until 1937, when it began to suddenly decline. The year 1940 halted this decline. In each of the peak years of precipitation, 1932, 1937, and 1940, there is a decided change in the mean annual pressure heads, while the head tends to fall during the years of little precipitation. During the years 1935, 1936 and 1937, we find a continued rise in mean annual precipitation, and the corresponding result in the water level graph. This continues until 1937, when there is a sudden rise in the mean annual level, caused perhaps indirectly by the Rio Hondo flood in May and June of 1937.

In comparing the Berrendo records with the Orchard Park records, we can see that the Orchard Park Well is able to recover in head after any small increase in recharge or rainfall over the basin. It is possible that the sudden rise in 1937 was caused by the decrease in use of water in the northern end of the basin, causing the cone of depression to rise in that area, with the resulting sudden influx of pressure towards the Orchard Park area. This, together with the increase in rainfall for the year, would aid a rise in the water table. After a study of the mean annual water surface elevation graph at Orchard Park, it is interesting to note that the water table has halted its "steady fall" which, in reality, existed only one year, that of 1939. In 1940 it remained approximately the same as at the end of 1939, declining a total of only 0.64 feet, a decided difference as compared to 5.91 feet of lowering in 1939.

ARTESIA

The Artesia Recorder Well is located in the SW¼SW¼SW¼ of Section 5, Township 18 South, Range 26 East, N.M.P.M. This well has been equipped with an automatic water stage recorder since March, 1931, after the recorder was removed from a well approximately one and one-half miles north of the present location. The present well is 1056 feet in depth, with 726 feet of 8 inch casing set into the limestone overlying the artesian acquifer.

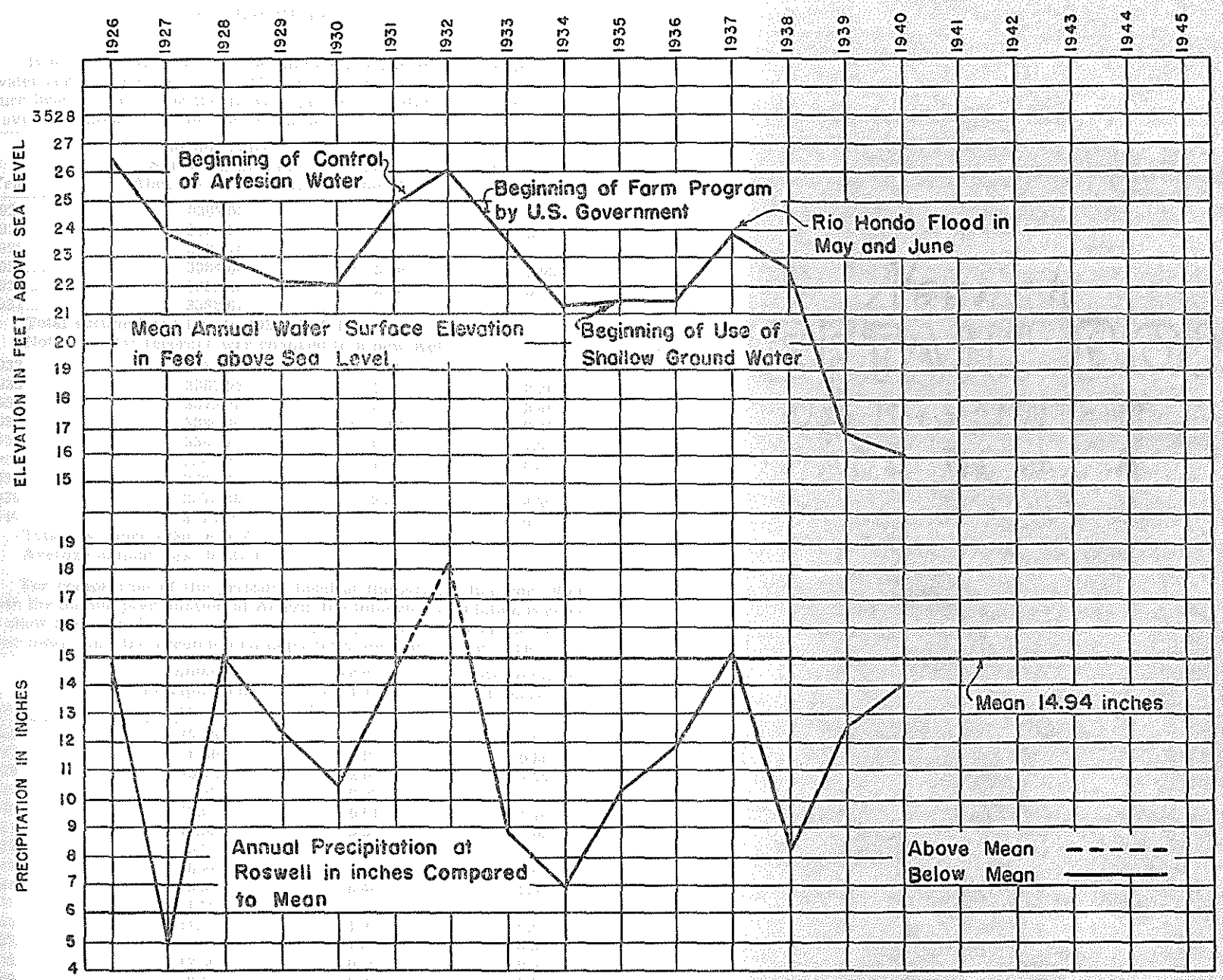
The following tabulation is the mean annual water surface elevation in feet above sea level for each year:

1926	1927	1928	1929	1930	1931†	1932	1933
*87.53	84.34	81.10	84.60	82.40	82.61	84.09	82.92

1934	1935	1936	1937	1938	1939	1940
79.20	80.30	81.27	82.35	81.23	78.36	76.20

*3300.00 feet must be added to each value to obtain the elevation above sea level.

†Recorder was changed to new well in this year.



ORCHARD PARK WELL

COMPARISON OF WATER LEVEL AND PRECIPITATION

Below are tabulated the accumulated excesses or deficiencies in water surface elevation from 1926, showing the total mean loss in pressure head by years for the 15 year period, and illustrating those years having the greatest decline or rise in head.

Year	Mean Water Surface Elevation Above Sea Level (ft.)	Loss or Gain (ft.)	Accumulated Loss (ft.)
1926	3387.53	.....	.....
1927	3384.34	— 3.19	— 3.19
1928	3381.10	— 3.24	— 6.43
1929	3384.60	+ 3.50	— 2.93
1930	3382.40	— 2.20	— 5.13
1931	3382.61	.....	.....

Total accumulated loss to 1931: 5.13 ft.

Note: In 1931 recorder was changed to a new well.

1932	3384.09	+ 2.43	+ 2.43
1933	3382.92	— 2.17	+ 0.26
1934	3379.20	— 3.72	— 3.46
1935	3380.30	+ 1.10	— 2.36
1936	3381.27	+ 0.97	— 1.39
1937	3382.35	+ 1.08	— 0.31
1938	3381.23	— 1.12	— 1.43
1939	3378.36	— 2.87	— 4.30
1940	3376.20	— 2.16	— 6.46

Total loss since 1930: 6.46 ft.

Average annual loss: 0.587 ft.

For comparison of the pressure head at the Artesia Recorder Well with the annual precipitation at Artesia the following tabulation is given to show the precipitation by years, the yearly departures from the long-time mean, and the accumulated departures for the 15 year period.

Year	Annual Precipitation (in.)	Excess or Deficiency for Year (in.)	Accumulated Departures (in.)
1926	17.55	+ 5.05	+ 5.05
1927	6.59	— 5.91	— 0.86
1928	15.13	+ 2.63	+ 1.77
1929	12.48	— 0.02	+ 1.75
1930	12.51	+ 0.01	+ 1.76
1931	17.82	+ 5.32	+ 7.08
1932	20.93	+ 8.43	+15.51
1933	6.44	— 6.06	+ 9.45
1934	6.04	— 6.46	+ 2.99
1935	11.39	— 1.11	+ 1.88
1936	11.11	— 1.39	+ 0.49
1937	11.43	— 1.07	— 0.58
1938	12.50	0.00	— 0.58
1939	9.11	— 3.39	— 3.97
1940	10.79	— 1.71	— 5.68

Accumulated deficiency: 5.68 in.

Average annual deficiency: 0.379 in.

From the above two tabulations it is observed that the water level has fallen approximately three feet per year for the past two years. As with the Berrendo and Orchard Park Wells, the Artesia Well showed a slight halt in decline in 1940. Though it is of small consequence, it is gratifying to note.

While the Artesia Recorder does not show any emphasized halt, its tendency is that way. If 1941 is anywhere normal in precipitation over the Basin as a whole, we should see some entirely different results this year. To date this year, from the precipitation received during March, the artesian head shows an interesting increase over the corresponding dates in 1940.

To attempt to interpret further the lowering of the pressure head of the artesian basin, it must be remembered that during the investigation by Arthur M. Morgan of the shallow ground water resources, he theorized on the sources of recharge. He stated that lowering the water table of the shallow ground water would reduce the pressure exerted downward against the confining bed of the artesian water, thus allowing that water to be released under reduced pressure, and allowing it to escape and percolate upward into the valley in an attempt to reach an equilibrium. From Mr. Morgan's report, (State Engineer's Bulletin No. 5, Page 30) I quote him in part as follows:

> "In the north end of the artesian basin the large artesian springs in the vicinity of Roswell prove that prior to the decline in artesian head large amounts of artesian water were forced to the surface through natural avenues of escape. This water had to pass through the valley fill to reach the surface and undoubtedly considerable water was contributed to the valley fill in transit. At the present time the large surface flow from the springs has ceased, but the underground flow in the valley fill is probably maintained, although at a decreased rate. In the Roswell vicinity the Chalk Bluff formation had been largely removed by erosion prior to the deposition of the valley fill, and locally it is entirely absent. The opportunity for natural leakage from the artesian system is therefore greatest in this area where, in places, there is comparatively little obstruction to the upward movement of the water."
>
> "According to Nye[1], the artesian head in the deeper acquifers of the Chalk Bluff formation is, as a rule, higher than in the shallower acquifers. It appears that the water in the Chalk Bluff formation gradually moves upward from lower to higher acquifers and eventually by devious paths is discharged at the surface or into the valley fill."

Again on page 31 of the same report, I further quote Mr. Morgan:

> "Natural leakage of artesian water from the San Andres limestone is believed to be the principal source of the shallow ground water. Before the drilling of artesian wells, this source

1 Fiedler, A. & Nye, S. S., p. 131—Geology and Groundwater Resources of the Roswell Artesian Basin, N. M., U. S. Geol. Survey Water-Supply Paper 693.

probably contributed almost all the recharge in the valley fill. Since the development of the artesian basin, this source of shallow ground water has decreased and additional sources have been introduced but it is probably still the principal source of recharge."

By observation of both the shallow ground water and artesian water, it has been found that both levels lower in a proportionate rate to each other.

In 1933 the United States Government began a program for the benefit of the farmers who would consent to enter into agreements with the government. The program was concerned with various acts, such as reducing cotton acreages, and the rotation of crops. Crops such as sweet clover and alfalfa were to be planted to act as soil builders. While the plan of soil building, with crops designed to pay at the same time, is of important value, it had disastrous effects on the artesian head of the basin; as I will attempt to set out. Alfalfa and sweet clover, it has been determined, use approximately 4.35 acre feet of water per acre per annum, while other crops such as sorghums, grains, cotton, etc. use only one half of that quantity.

For a comparative estimate of the use of water, I have taken the year 1937 and compared it to 1940, showing the consumptive use of water in relation to the acreage under irrigation in the basin. Herein below, I have tabulated the years, crop acreages, and use of water:

1937	
Irrigated Area	Consumptive Use
112,964 Acres	231,564 Acre Feet

1940	
Irrigated Area	Consumptive Use
102,859 Acres	282,862 Acre Feet

According to the survey made by the U. S. G. S. on the consumptive use of water, and the A. C. A. records there was in cultivation approximately 51,000 acres of cotton in the basin in 1937, and in 1940 approximately 33,000 acres; a reduction of 18,000 acres. In comparison in 1937, 21,000 acres were under irrigation for alfalfa, while in 1940 a total of nearly 33,000 acres of alfalfa were being irrigated. On the basis that cotton requires 2.18 acre feet of water per acre per annum we see in 1940 a reduction in use of water on cotton of 39,240 acre feet from that of 1937. During the same year, 1940, there was an increase of 52,000 acre feet on alfalfa, at the rate of 4.35 acre feet of water per acre per annum; a gross increase in use of water of 19,960 acre feet per annum. This figure, however, represents all sources of water in the basin, and since 50.6 per cent of all lands in the basin are irrigated from artesian water, this would mean a total increase in use of water of 10,100 acre feet of artesian water alone. Also 1796 acres of clover were placed under irrigation in 1940 as compared to none in 1937, which indicated

an additional 7813 acre feet of water which was not being used at all or was being irrigated under crops requiring much less water in 1937. The amount of artesian water irrigating its proportionate share of clover would be 3954 acre feet.

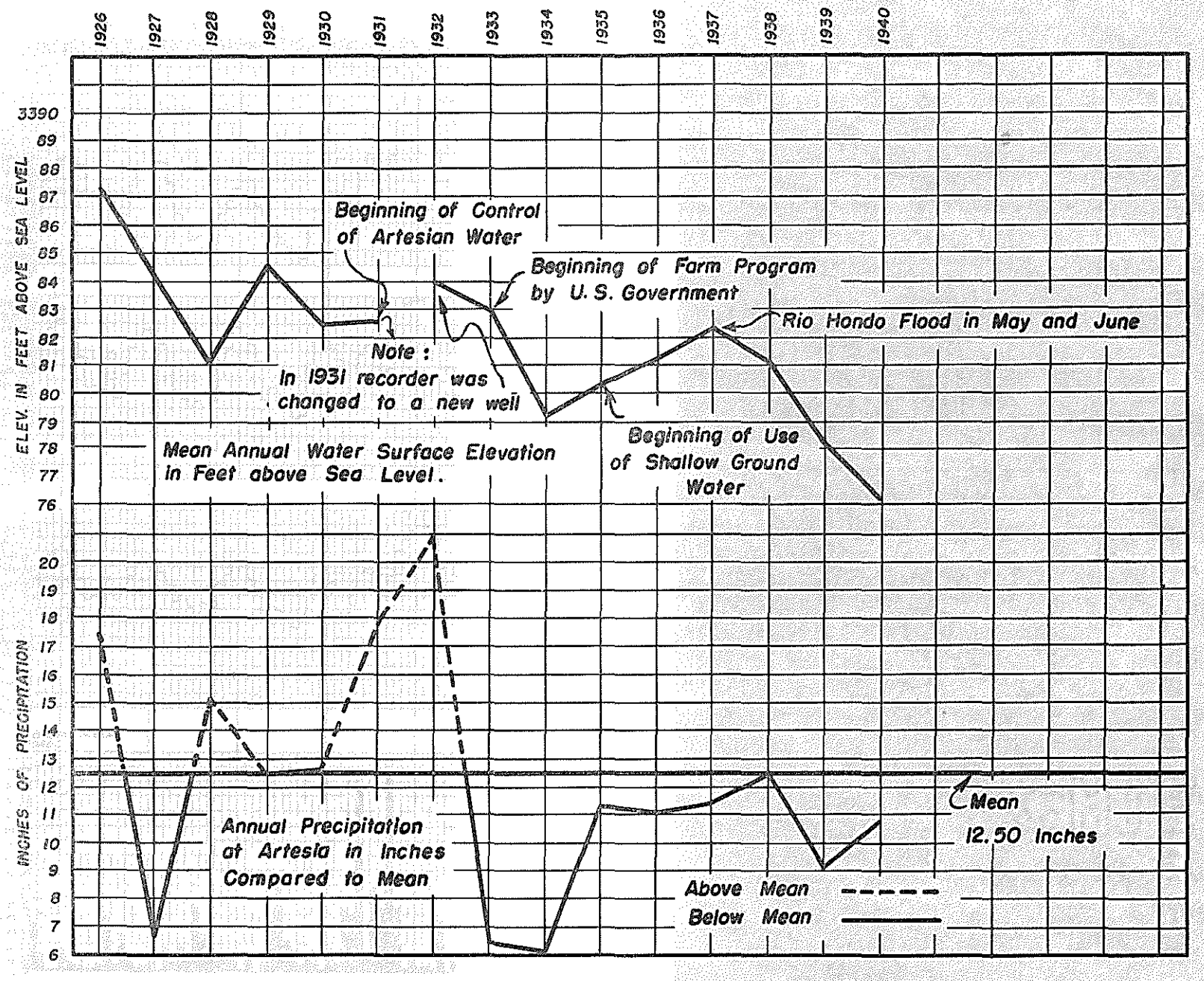
Taking everything into consideration, 51,298 acre feet more water was used in 1940 than in 1937. The proportionate share of artesian water would represent an increase of 25,957 acre feet. Note that there was a 10,105 acre reduction of crops during this period.

It can safely be said that the decline in artesian head can be attributed a great deal to the increase in use of water on alfalfa during the past several years.

For interesting contrast the following tabulation is set out, showing the various types of crops in the basin, and the required amounts of water needed for each:

Crop	Water Requirements (Acre Feet Per Acre Per Annum)
Cotton	2.18
Alfalfa	4.35
Corn	2.18
Grain Sorghum	2.18
Sweet Sorghum	2.18
Small Grain	2.18
Vegetables	2.18
Clover	4.35
Orchards	2.18
Other Crops	2.18

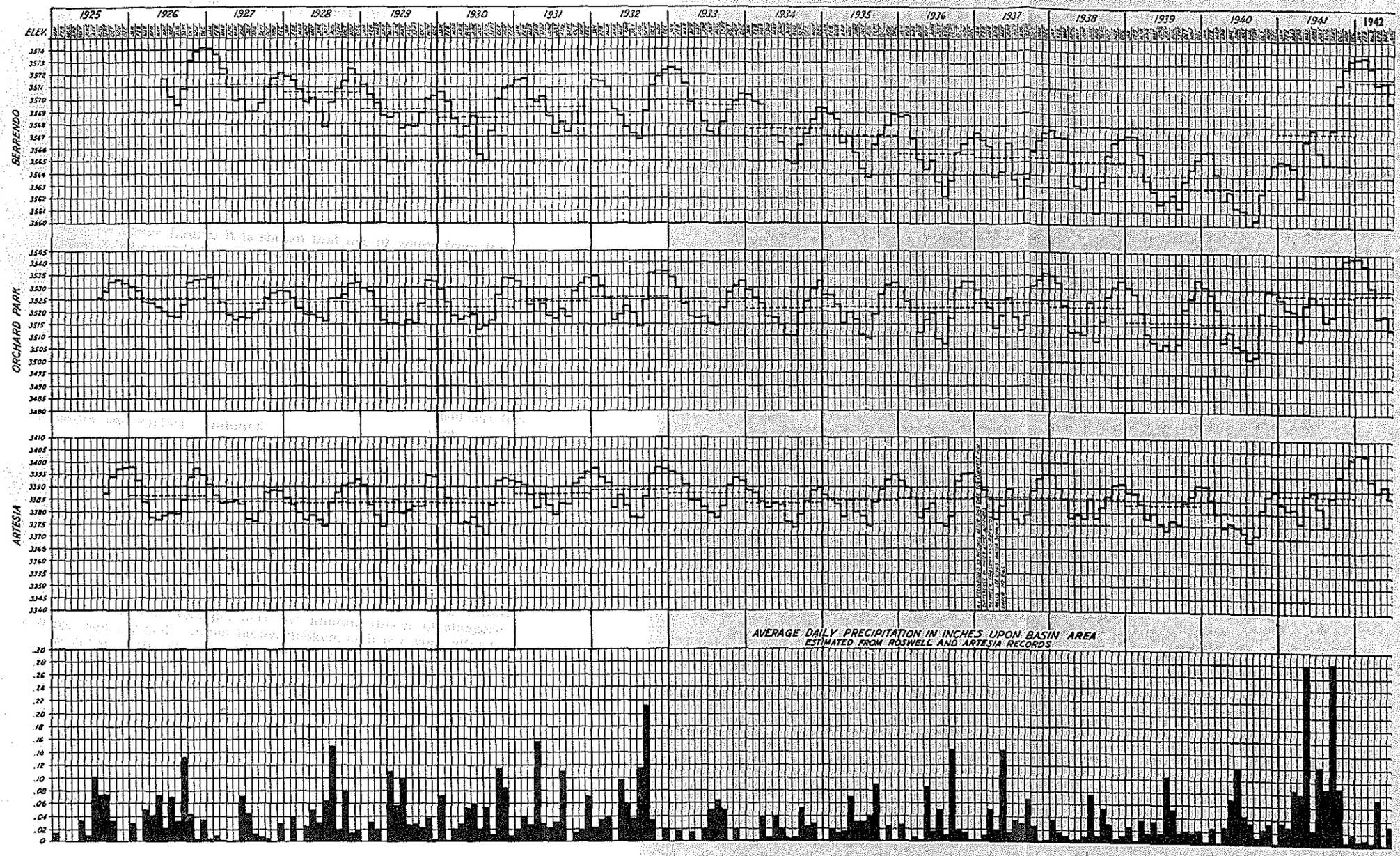
In the latter part of May and the first part of June, 1937, the Rio Hondo overflowed its banks and ran through the City of Roswell on three separate days. The flood originated above Riverside, New Mexico, approximately 35 miles west of Roswell, but the water remained in the banks until reaching a point about 15 miles west of the City of Roswell where the channel was too small to carry the increased amount of water, and the flood spread over the plain west of the eastern edge of the artesian intake area. Undoubtedly, much of the water was received in the artesian basin as well as in the valley fill, and in quantities sufficient to show a decided recharge into both the basin and the fill. Such an apparent recharge is shown on the Berrendo graph, 1937 showing an attempt to straighten out and remain somewhat the same as 1936. The year 1938 also shows very little decline.



ARTESIA WELL

COMPARISON OF WATER LEVEL AND PRECIPITATION

GRAPH SHOWING MEAN MONTHLY AND MEAN ANNUAL WATER SURFACE ELEVATIONS IN OBSERVATION WELLS, ROSWELL ARTESIAN BASIN—NEW MEXICO



WATER APPLIED IN 1939

From the Department of Agriculture records, it has been estimated that the following amounts of water were applied to lands and other uses in 1939:

Artesian	150,590 acre feet
Shallow Ground Water	76,377 acre feet
Surface Water	32,580 acre feet
Total	259,547 acre feet

From the above figures it is shown that use of water from the artesian source far exceeds the use of any other water; the artesian water being 58.0 per cent of all. Conforming with the above, I am tabulating below the amounts of water used, broken down to show the types of water used in 1939, and the amounts and supplements of other waters.

Used directly from artesian wells	135,000 acre feet
Artesian wells supplemented by shallow	8,550 acre feet
Artesian wells supplemented by Hagerman Canal	1,020 acre feet
From Hagerman Canal only	3,265 acre feet
Artesian, shallow and surface combined	640 acre feet
Artesian and surface combined	2,220 acre feet

The above tabulation is concerned with artesian water and its complements only; other sources of water are not included unless they are connected with the artesian source directly.

Of the 267,000 acre feet of water from all sources used in 1939, 112,000 acre feet were used on alfalfa and sweet clover, while the remaining 155,000 acre feet were used on other crops. In other words, to show the importance of the use of water on alfalfa, it is found that 41.9 per cent of all of the water used in the basin in 1939 was on alfalfa and clover. Taking into consideration the water requirements of alfalfa, at the rate of 4.35 acre feet per acre per annum, this is of staggering proportions and certainly cannot be overlooked, as it is a very vital factor in the cause of the lowering of head in the artesian basin.

I have, in this report, attempted to set out all of the factors considered important, more sanely and intelligently to consider the supposed alarm in the lowering of the artesian head. After looking at each problem as it is set forth, it does not, to me, present such an alarming position as I previously thought. I trust it will aid in consideration of the problem at hand.

Roswell, New Mexico

April 8, 1941