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PROGRESS REPORT

ON THE

GROUND-WATER SUPPLY

OF

MIMBRES VALLEY, NEW MEXICO

1938 - 1941

By

CLYDE S. CONOVER AND P. DONALD AKIN

GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

Prepared in Cooperation With the State Engineer
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INTRODUCTION

GENERAL FEATURES OF THE AREA

Mimbres Valley lies in Luna County, in the southwestern part of New Mexico. The part of the Mimbres Valley mainly dealt with in this report is the lower course of the Mimbres River west, south, and east of Deming, in which large quantities of ground-water are pumped for irrigation, industrial, stock, and domestic supplies.

The Mimbres River rises in the Mogollon and Mimbres Mountains in Grant County, northwest of Deming. The lower course of the Mimbres River lies in a broad flat bolson which occupies nearly all of Luna County. The bolson opens south into Mexico and east to the Rio Grande and is almost completely divided into two parts in Luna County by a series of north-south mountain ranges—Cooks Range, the Florida Mountains, and the Tres Hermanas Mountains.

In the upper stretches of the Mimbres River there is a perennial flow that is used for irrigation. The normal flows that are not used for irrigation readily sink into the ground upon leaving the bedrock floor of the mountains near the northern boundary of Luna County. The lower course of the stream receives only infrequent flood flows which seldom reach east of the Florida Mountains. San Vicente Arroyo, one of the main tributaries of the Mimbres River, enters it from the west near Spalding, about 16 miles northwest of Deming. Small perennial flows are sustained in the upper tributaries of San Vicente Arroyo but only flood flows reach the Mimbres River.

The bolson is underlain to a considerable depth by alluvial materials in which a large volume of ground water has accumulated. Irrigation by pumping of this ground water is practiced west, south, and east of Deming. The ground-water basin like the bolson itself is divided into two smaller ground-water basins by Cooks Range, the Florida Mountains, and the Tres Hermanas Mountains, and in addition by an underground ridge that extends from the Little Florida Mountains to Cooks Range. The underground ridge forms a ground water dam as is evidenced by the steep gradient of the water table as the ground water passes over this barrier[1].

The important basic facts about the occurrence and use of ground water in the bolson have been summarized by White[2] as follows:

1 White, W. N., Progress report on the ground-water supply of Mimbres Valley, N. Mex.; New Mexico State Eng., 10th Bienn. Rept. p. 184, 1932.
2 White, W. N., Progress report on the ground-water supply of Mimbres Valley, N. Mex.; New Mexico State Eng., 11th Bienn. Rept., pp. 111, 112, 1934.

"The greater part of the ground-water supply of the Mimbres Valley comes from the main Mimbres River and from San Vicente Arroyo and its tributaries. These streams, which enter the valley at its north end, shrink rapidly upon reaching the plain and in times of low flow disappear within a short distance after leaving the bedrock of their mountain courses. Minor amounts are contributed by the run-off from Cooks Range and the Florida Mountains and by rainfall on the floor of the valley northward from Spalding, but practically none comes from rainfall on the valley south of Spalding."

"Though the quantity of water stored in the underground reservoir is very large, the annual recharge to this reservoir is relatively small, and it is estimated that during the period 1908 to 1928 the annual increment to the supply was only between 10,000 to 11,000 acre-feet.

"Nearly everywhere in the valley the ground water is moving from northwest to southeast at a rate which averages between 2 and 3 feet a day. The slope of the water table ranges from 25 to 35 feet to the mile north of Black Mountain and from 10 to 15 feet to the mile south of it.

"The estimated average depth of water used in irrigation is 20 inches and the consumption of water in 1929, including supplies used for domestic and industrial purposes amounted to about 10,500 acre-feet. The mean annual pumpage from 1914 to 1929 almost certainly did not exceed 10,000 acre-feet a year."

PREVIOUS WORK

In the period from 1910 to 1913 Darton[3] made the first published study of the occurrence of ground water in the Mimbres Valley. In this study he pointed out that there was a vast amount of water stored underground in the Mimbres bolson but that the rate of replenishment was low, and gave a large number of data concerning the nature of the aquifer and the depth to water in various parts of the bolson.

In 1927, Fiedler[4] made a reconnaissance of the area, established some observation wells, and installed 5 automatic water level recorders. In 1928, White[5] began a series of quantitative studies of the ground water of the bolson. He investigated the manner and amount of recharge to the basin, the nature of the underground flow, and estimated the amount of water taken out of the basin by pumping. He established a series of observation wells in which the changes in water level have been observed at frequent intervals from 1929 to the present. Summa-

3 Darton, N. H., Underground water of Luna County, New Mexico; U. S. Geol. Survey Water-Supply Paper 345, pp. 25-40, 1915. Darton, N. H., Geology and underground water of Luna County, New Mexico; U. S. Geol. Survey Bull. 618, 1916.

4 Fiedler, A. G., Report on a reconnaissance of the ground-water area of the Mimbres Valley, Luna County, New Mexico; New Mexico State Eng., 8th Bienn. Rept. pp. 159-171, 1928.

5 White, W. N., Preliminary report on the ground-water supply of Mimbres Valley, New Mexico; New Mexico State Eng. 9th Bienn. Rept. pp. 130-152, 1930. White, W. N., Preliminary report on the ground-water supply of Mimbres Valley, New Mexico; U. S. Geol. Survey Water-Supply Paper 637, pp. 69-90, 1931. White, W. N., Progress report on the ground-water supply of Mimbres Valley, New Mexico; New Mexico State Eng. 10th Bienn. Rept., pp. 183-228, 1932. White, W. N., Progress rept. on ground-water supply of Mimbres Valley; New Mexico State Eng. 11th Bienn. Rept., pp. 109-126, 1934.

ries of the records of water levels in these wells from the beginning of observation until 1934 have been given by White[6].

A progress report for the period 1934-1938 giving data on climate, stream flow, amount of pumpage and changes in water level has been given by Theis[7].

Complete records of water levels in observation wells are published in U. S. Geological Survey Water-Supply Papers 886, 911, and 941.

SCOPE OF PRESENT REPORT

The present progress report gives data on climate, stream flow, pumpage, change in water levels, and other hydrological data collected from January 1938 through 1941. The work was done under the general direction of O. E. Meinzer, Geologist in Charge of the Division of Ground Water of the Geological Survey of the United States Department of the Interior and under the immediate supervision of Chas. V. Theis, Geologist in Charge of Ground Water Investigations in New Mexico of the Geological Survey. All the work has been done in cooperation with the State Engineer of New Mexico. Mr. Conover prepared the data for the years 1938 and 1939 and prepared a report which is largely contained in the present report. After Mr. Conover left for military service in 1941, Mr. Akin continued the collection of data and prepared the present report.

RAINFALL AND STREAM FLOW

The immediate effect of precipitation in Mimbres Valley during the growing season is to cause a dimunition of pumping and allow a partial recovery of water levels in the irrigated areas. Exceptional rainfall in the mountainous areas in the headwaters of the streams gives a rise to floods on the Mimbres River, San Vicente Arroyo, and other streams, which recharge the ground-water reservoir.

The following table gives the precipitation at stations in and near the Mimbres Valley as reported by the United States Weather Bureau. Fort Bayard and Silver City are in the foothills at the north end of the Valley, about 50 miles northwest of Deming, near the headwaters of the Mimbres River and tributaries; Florida is east of Cooks Range on the Atchison, Topeka and Santa Fe Railroad, about 15 miles northeast of Deming; and Deming, Gage, and Columbus are on the bolson floor. Gage is about 20 miles west of Deming on the Southern Pacific Railroad and Columbus is about 30 miles south of Deming and just north of the boundary between the United States and Mexico.

6 White, W. N., op. cit., (10th Bienn. Rept.) pp. 193-227. White, W. N., op. cit., (11th Bienn. Rept.) pp. 123-125.

7 Theis, C. V., Progress report on the ground-water supply of the Mimbres Valley, New Mexico; New Mexico State Eng., 12th and 13th Bienn. Rept., pp. 137-153, 1938.

PRECIPITATION IN INCHES, AND DEPARTURE FROM NORMAL IN THE MIMBRES VALLEY

Year and Month	DEMING Precipitation	DEMING Departure	COLUMBUS Precipitation	COLUMBUS Departure	FT. BAYARD Precipitation	FT. BAYARD Departure	SILVER CITY Precipitation	SILVER CITY Departure	GAGE Precipitation	FLORIDA Precipitation
1938										
January	0.30	−0.05	0.28	−0.32	0.35	−0.49	0.41	−0.40	T	0.23
February	0.40	−0.14	0.38	−0.12	0.81	−0.18	1.31	+0.21	0.60	0.48
March	0.48	−0.03	0.00	−0.52	0.61	−0.38	1.33	+0.23	0.50	0.67
April	0.00	−0.26	0.00	−0.31	0.12	−0.47	0.17	−0.55	T	0.05
May	0.00	−0.23	0.00	−0.22	T	−0.43	0.00	−0.36	T	0.03
June	1.17	+0.77	2.15	+1.55	1.93	+1.15	1.52	+0.78	0.54	1.41
July	1.92	−0.10	3.32	+1.18	4.41	+1.17	5.01	+1.60	2.39	2.66
August	T	−1.80	0.05	−2.12	0.58	−2.91	1.50	−1.35	0.55	0.02
September	3.53	+2.37	3.86	+2.92	5.18	+3.11	4.77	+3.16	1.86	5.40
October	0.00	−0.73	T	−0.60	0.05	−1.22	0.22	−0.86	T	0.00
November	0.00	−0.43	0.05	−0.63	0.13	−0.66	0.24	−0.60	0.00	0.00
December	1.55	+0.98	1.13	+0.39	1.95	+0.84	2.31	+1.05	1.92	1.70
The Year	9.35	+0.35	11.22	+1.20	16.12	−0.47	18.79	+2.91	8.36	12.65
Accumulated Departure from 1934		+3.19		−2.60		−7.53		+14.32	−3.05	

PRECIPITATION IN INCHES, AND DEPARTURE FROM NORMAL IN THE MIMBRES VALLEY
(continued)

Year and Month	DEMING Precipitation	DEMING Departure	COLUMBUS Precipitation	COLUMBUS Departure	FT. BAYARD Precipitation	FT. BAYARD Departure	SILVER CITY Precipitation	SILVER CITY Departure	GAGE Precipitation	FLORIDA Precipitation
1939										
January	0.25	−0.10	0.34	−0.26	0.91	+0.07	1.37	+0.56	0.47	0.00
February	0.40	−0.14	0.20	−0.30	0.74	−0.25	1.51	+0.41	0.49	0.67
March	0.22	−0.29	0.10	−0.42	0.91	−0.08	2.05	+0.95	0.18	0.40
April	0.31	+0.05	0.70	+0.39	0.44	−0.15	0.59	−0.13	0.08	T
May	0.00	−0.23	0.00	−0.22	0.01	−0.42	0.08	−0.28	T	0.00
June	0.00	−0.40	0.07	−0.53	0.28	−0.50	0.39	−0.35	0.00	0.00
July	0.80	−1.22	2.24	+0.10	1.54	−1.70	1.88	−1.53	T	2.01
August	1.35	−0.45	0.81	−1.36	4.11	+0.62	2.37	−0.48	1.82	0.80
September	2.43	+1.27	2.76	+1.82	1.94	−0.13	2.86	1.25	2.42	0.30
October	1.22	+0.49	0.28	−0.32	1.46	+0.19	1.98	+0.90	0.60	1.35
November	0.50	+0.07	1.11	+0.43	1.13	+0.34	1.26	+0.42	1.37	0.30
December	0.52	+0.05	0.49	−0.25	0.91	−0.20	2.00	+0.74	0.45	0.60
The Year	8.00	−1.00	9.10	−0.92	14.38	−2.21	18.34	+2.46	7.88	6.43
Accumulated departure from 1934		+2.19		−3.52		−9.74		+16.78	−5.13	

PRECIPITATION IN INCHES, AND DEPARTURE FROM NORMAL IN THE MIMBRES VALLEY
(continued)

Year and Month	DEMING Precipitation	DEMING Departure	COLUMBUS Precipitation	COLUMBUS Departure	FT. BAYARD Precipitation	FT. BAYARD Departure	SILVER CITY Precipitation	SILVER CITY Departure	GAGE Precipitation	FLORIDA Precipitation
1940										
January	0.28	−0.07	0.40	−0.20	0.50	−0.34	0.62	−0.19	0.35	0.02
February	0.83	+0.29	0.61	+0.14	2.40	+1.41	3.82	+2.72	1.17	0.83
March	0.10	−0.41	0.02	−0.50	0.62	−0.37	0.55	−0.55	T	T
April	0.52	+0.26	0.37	+0.06	0.55	−0.04	0.74	+0.02	0.82	0.75
May	1.09	+0.86	0.76	+0.54	1.40	+0.97	0.90	+0.54	0.55	1.12
June	0.66	+0.26	1.08	+0.43	1.71	+0.93	0.90	+0.16	3.20	1.52
July	0.33	−1.69	1.00	−1.14	2.55	−0.69	1.66	−1.75	0.70	1.51
August	0.13	−1.67	0.95	−1.22	3.45	−0.04	5.84	+2.99	1.22	0.75
September	0.33	−0.83	0.79	−0.15	1.32	−0.75	0.42	−1.19	0.45	0.40
October	0.15	−0.58	0.43	−0.17	0.16	−1.11	0.28	−0.80	0.13	0.37
November	0.51	+0.08	0.37	−0.31	3.29	+2.50	2.73	+1.89	1.57	1.07
December	0.80	+0.23	0.89	+0.15	2.27	+1.16	2.99	+1.73	1.34	0.78
The year	5.73	−3.27	7.65	−2.37	20.22	+3.63	21.45	+5.57	11.50	9.12
Accumulated departure from 1934		−1.08		−5.89		−6.09		+22.35	−3.59	

PRECIPITATION IN INCHES, AND DEPARTURE FROM NORMAL IN THE MIMBRES VALLEY
(continued)

Year and Month	DEMING Precipitation	DEMING Departure	COLUMBUS Precipitation	COLUMBUS Departure	FT. BAYARD Precipitation	FT. BAYARD Departure	SILVER CITY Precipitation	SILVER CITY Departure	GAGE Precipitation	FLORIDA Precipitation
1941										
January	1.51	+1.16	2.18	+1.58	1.52	+0.68	2.37	+1.56	1.56	2.46
February	1.46	+0.92	1.40	+0.90	1.35	+0.36	1.29	+0.19	1.42	1.19
March	0.67	+0.16	1.09	+0.57	1.41	+0.42	1.42	+0.32	0.83	0.67
April	1.67	+1.41	1.11	+0.80	1.18	+0.59	1.01	+0.29	0.94	1.54
May	0.79	+0.56	0.33	+0.11	0.80	+0.37	0.82	+0.46	0.54	0.27
June	0.22	−0.18	0.60	0.00	0.62	−0.16	0.79	+0.05	0.33	0.36
July	1.17	−0.85	1.27	−0.87	4.31	+1.07	3.55	+0.14	1.13	1.43
August	1.52	−0.28	2.07	−0.10	5.37	+1.88	4.08	+1.23	2.62	4.02
September	3.41	+2.25	3.06	+2.12	3.09	+1.02	3.93	+2.32	4.41	3.06
October	1.17	+0.44	2.25	+1.65	1.26	−0.01	1.37	+0.29	1.06	1.48
November	0.30	−0.13	0.00	−0.68	0.28	−0.51	0.57	−0.27	T	0.21
December	1.00	+0.43	0.79	+0.05	1.92	+0.81	3.35	+2.09	0.68	1.13
The year	14.89	+5.89	16.15	+6.13	23.11	+6.52	24.55	+8.67	15.52	18.72
Accumulated departure from 1934		+4.81		+0.24		+0.43		+31.02	+1.97	

As indicated by the tables, the general amount of precipitation in 1938 was greater than in 1939 and 1940. In 1938 there was an excess of precipitation in Deming, Columbus and Silver City, whereas in 1939 all stations except Silver City received less than normal precipitation. In 1940, there was a considerable deficiency of precipitation at Deming and Columbus, but Fort Bayard and Silver City received more than normal precipitation. The rainfall in 1941 was unusually great and the precipitation at all stations was much greater than normal.

Records of the discharge of the Mimbres River at Faywood Gaging Station, about 25 miles northwest of Deming, are given below:

MONTHLY DISCHARGE IN ACRE-FEET OF MIMBRES RIVER AT FAYWOOD GAGING STATION, 1937-1941

(From published and unpublished reports of the Geological Survey)

	1937	1938	1939	1940	1941
January	0	387	102	591	3,110
February	3,630	186	285	2,650	5,820
March	11,680	190	261	2,040	6,800
April	3,850	147	150	327	4,560
May	593	90	144	548	3,380
June	153	48	88	1,650	189
July	138	157	1,370	2,000	1,020
August	253	66	5,750	2,190	4,450
September	1,960	1,710	2,960	571	3,740
October	142	60	576	245	2,470
November	197	29	274	341	1,160
December	362	74	472	1,170	1,090
Total	22,958	3,135	12,432	14,323	37,789

ANNUAL DISCHARGE IN ACRE-FEET OF MIMBRES RIVER AT FAYWOOD GAGING STATION, 1930-1941

1930	20,900	1936	3,442
1931	18,100	1937	22,958
1932	7,100	1938	3,135
1933	8,243	1939	12,432
1934	2,510	1940	14,323
1935	7,590	1941	37,789

The average annual flow of the Mimbres River at Faywood from 1908 to 1933, exclusive of 1911 and 1929, for which records are not available, was 15,900 acre-feet and, exclusive of the very wet years of 1914, 1915, and 1916, was 10,400 acre-feet.[8] The average annual flow for the period from 1933 to 1938 inclusive was less than 8,000 acre-feet. The greater flows of 1937 and 1939 were accompanied by a small rise of the water level in observation wells located north of Black Moun-

8. White, W. N., op. cit., (11th Bienn. Rept.), p. 115.

tain. During 1941, the water level in these wells rose sharply, except in well 21.10.6.000 in which the water level does not seem to change a great deal from year to year. The magnitude of the rise in these wells during 1941 was from 3.80 feet in well 22.10.18.121 to 14.03 feet in well 21.11.13.000. Water levels also rose as much as 3.90 feet in the irrigated area southwest of Deming during 1941, as shown by figure 10.

WATER PUMPED FROM WELLS

All of the water used in the lower Mimbres Valley for domestic and stock needs, municipal and industrial supply and for irrigation is obtained from the ground-water supply, except for a small amount of flood water that is used to supplement irrigation by ground water. The greatest use by far is for irrigation.

The monthly pumpage for the city of Deming is given in the following table. These figures are master meter readings and represent the total amount of water pumped by the city.

PUMPAGE OF GROUND WATER BY DEMING, NEW MEXICO
(Courtesy Deming City Water Department)

	Acre Feet				Average thousands of gallons per day			
Month	1938	1939	1940	1941	1938	1939	1940	1941
Jan.	17.757	19.086	18.804	10.130	186.6	200.6	197.7	201.1
Feb.	21.439	15.410	25.985	17.996	249.5	179.3	292.0	209.4
Mar.	25.659	29.483	32.234	23.857	269.7	309.9	338.8	250.8
Apr.	31.384	31.414	37.718	16.088	340.9	341.2	410.0	174.7
May	38.668	37.652	42.883	42.266	406.4	395.8	450.8	444.3
June	47.356	59.357	44.116	54.598	514.4	644.7	479.2	593.0
July	32.422	45.165	52.916	52.975	340.8	474.7	556.2	556.8
Aug.	51.940	46.958	48.634	51.033	546.0	493.6	511.2	536.4
Sept.	26.070	37.670	a76.054	44.977	283.2	409.2	....	488.5
Oct.	28.804	28.072	....	25.781	302.8	295.1	....	271.0
Nov.	19.272	24.376	22.388	32.720	209.3	264.8	243.2	355.4
Dec.	18.680	21.499	19.959	26.540	196.4	226.0	209.8	279.0
Total	359.471	396.143	421.691	407.961	320.9	353.7	375.4	364.2

	1938	1939	1940	1941
Kilowatt hours used in pumping water	113,280	133,500	141,082	145,833
Acre feet per 1000 kilowatt hours	3.18	2.97	2.99	2.80

The population of Deming, as reported by the Census Bureau, was 3608 in 1940. The pumpage in 1940 was 422 acre-feet, or an average of 375,400 gallons a day. This indicates an average daily pumpage of about 104 gallons a day per capita in that year.

a Figure for September and October combined.

The city of Deming obtains its water supply from three wells, 150, 316, and 400 feet deep, equipped with pumps having reported discharge rates of 300, 150 and 650 gallons a minute, respectively.

The following table shows the power consumption for non-irrigation pumpage during the year from 1938 to 1941, inclusive.

POWER CONSUMPTION FOR NON-IRRIGATION PUMPAGE
Kilowatt hours
(Courtesy Deming Ice and Electric Company)

	1938	1939	1940	1941
City of Deming	113,280	133,500	141,082	145,833
Southern Pacific RR.	46,740	52,140	57,060	58,480
Other	15,106	12,486	36,945	26,356
TOTAL	175,126	198,126	235,087	230,669

Assuming that the other non-irrigation pumpage systems have about the same ratio of water discharged to power consumed as the Deming City Water Works, or say 3 acre-feet for each 1000 kilowatt hours, the yearly non-irrigation pumpage for the period from 1938 to 1941 is as follows:

1938	525 Acre-feet
1939	594 Acre-feet
1940	705 Acre-feet
1941	690 Acre-feet

The crops grown in the Mimbres Valley are essentially those of low water requirement. The approximate acreage of various crops in 1939 in the Mimbres Valley, as kindly furnished by W .W. Donaldson, Luna County Agricultural Extension Agent, are as follows:

Crop	Acres
Pinto beans	4,600
Cotton	1,800
Hegari	2,100
Other grain sorghums	200
Corn	400
Vegetable oil	150
Legumes	400
Small grain pastures	500
Miscellaneous crops	350
Total	10,500

Rough surveys were made during the summers of 1939, 1940 and 1941 to determine approximately the amount of land being irrigated in the Mimbres Valley each year as a base for determining the amount of water used. In the fall of 1940, a plane-table survey of the irrigated areas was made by the State Engineer of New Mexico. Fig. 1 shows the tracts which were irrigated during the course of the surveys in 1939 and 1941. The irrigated acreages as determined from these surveys are given below.

1939	10,300 acres
1940	11,700 acres
1941	12,200 acres

Included in the above figures are about 400 acres of irrigated land in outlying districts which are not shown in Fig. 1. The figures do not include about 200 acres of irrigated land southeast of Columbus which were mapped by the State Engineer in 1940.

Practically all of the pumps are of the deep-well turbine type, powered by electric motors or by internal combustion engines which use natural gas, distillate, or gasoline for fuel. Nearly all of the pumps powered by electricity are equipped with direct drive vertical motors.

During 1939, 1940 and 1941, a total of 35 electrically driven pumps distributed over the valley were rated as to power consumption, discharge, and acreage irrigated. In the following table are shown the pumping lift, the water output per 1000 kilowatt hours, and the year the pump was rated for these wells.

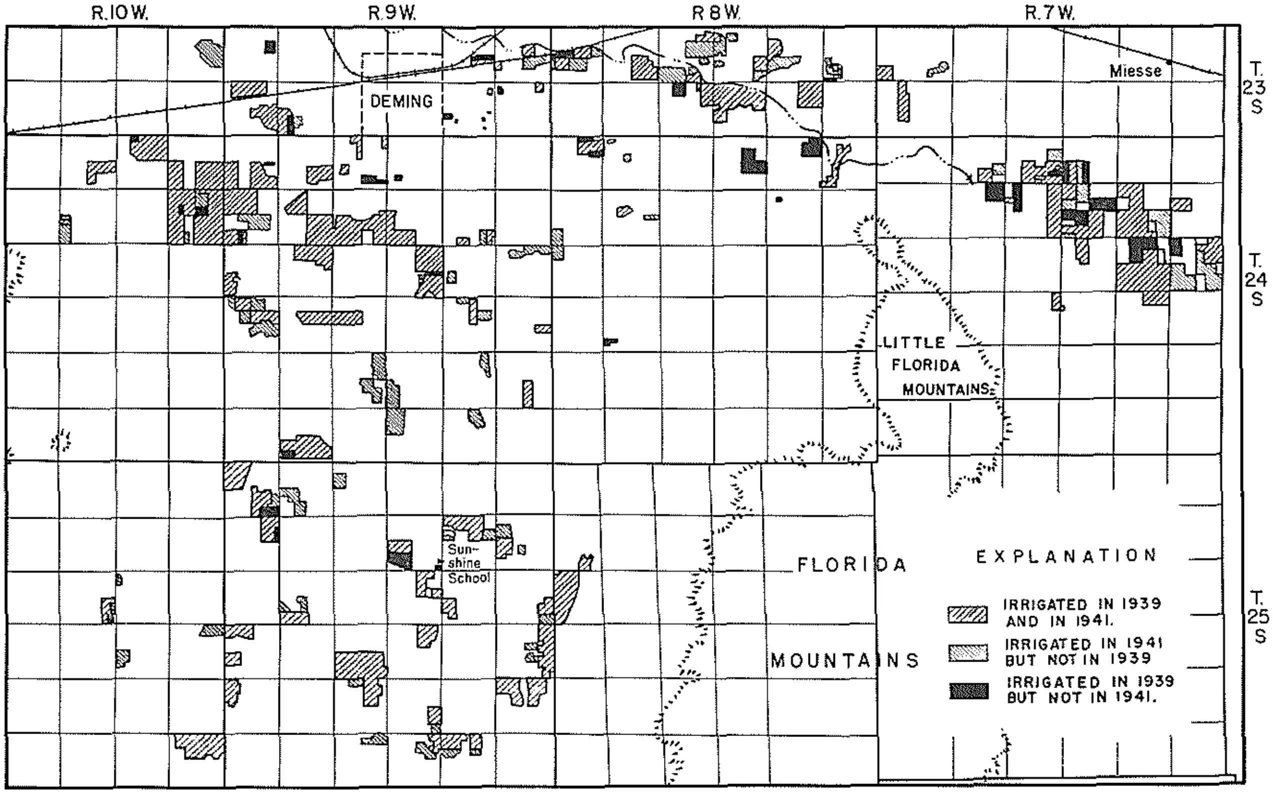

FIG. 1. Areas irrigated with water from wells in Mimbres Valley.

Well location number	Lift in feet	Acre-feet of water pumped per 1000 K.W.H. used	Year rated
23.7.31.121	a100	3.54	1941
23.7.31.321	a120	4.55	1941
23.8.26.131	42	8.22	1940
23.8.34.211	a 70	6.94	1940
24.7.11.111	a105	2.99	1939
24.7.11.411	a100	2.99	1939
24.8.1.333	29	17.55	1939
24.8.5.111	50	4.00	1939
24.9.6.311	93	2.74	1939
24.9.6.411	----	2.95	1941
24.9.6.431	96	4.56	1941
24.9.7.211	97	6.04	1941
24.9.7.331	----	3.65	1941
24.9.8.121	----	6.00	1941
24.9.9.411	----	5.50	1940
24.9.9.441	----	3.96	1939
24.9.21.131	95	6.48	1939
24.9.23.211	----	5.57	1940
24.9.28.221	93	4.45	1941
24.9.28.411	----	7.04	1941
24.10.1.411	----	1.64	1941
24.10.1.412	----	3.46	1941
24.10.3.411	----	5.42	1940
24.10.12.111	90	5.74	1939
24.10.12.123	a100	5.86	1939
24.10.12.221	92	3.21	1939
24.10.12.311	----	4.14	1941
24.10.12.411	98	5.15	1939
24.10.12.432	105	4.35	1939
25.9.4.113	----	5.50	1940
25.9.14.312	76	7.94	1940
25.9.17.311	88	5.43	1941
25.9.21.311	83	6.42	1939
25.9.24.222	61	12.15	1939
25.10.36.222	74	5.27	1940

The amount of water discharged by the pumps listed in the preceding table per 1000 kilowatt hours of power consumed varied from a minimum of 1.64 to a maximum of 17.55 acre-feet, and averaged 5.42 acre-feet. The large variation is due to the variation in pumping lifts and overall efficiencies of the pumping plants. The amount of water applied to the land varied considerably from year to year due to the difference in rainfall during the growing season. The average water use per acre on the farms served by these pumps, using the pump ratings in the table together with individual power consumption and irri-

a Approximate

gated acreage, was 1.81 acre-feet in 1939, 2.09 acre-feet in 1940, and 1.65 acre-feet in 1941. By multiplying these figures by the total irrigated acreages in the valley for the respective years, the total pumpage for irrigation is computed as 18,643 acre-feet in 1939, 24,453 acre-feet in 1940, 20,130 acre-feet in 1941.

The following table shows by years the acreage irrigated with ground water in the Mimbres Valley, the estimated pumpage of ground water, and the precipitation during the growing season. This table is in part based on figures reported by White[9], 1929-1932, and Theis[10], 1933-1937.

ESTIMATED IRRIGATED ACREAGE AND PUMPAGE IN THE MIMBRES VALLEY

Year	Area irrigated (acres)	Pumpage for irrigation (acre-feet)	Precipitation at Deming, Apr.-Sept. (inches)	Estimated irrigation water use (inches)	Total water used by crops (inches)
1929	6,200		7.02		
1930	7,000		5.96		
1931	6,500	a10,000	6.43	a19	a25
1932	6,000		4.85		
1933	5,500		7.49		
1934	5,500	9,500	5.36	21	26
1935	7,800	13,000	6.74	20	27
1936	8,800	14,500	5.45	20	25
1937	9,500	15,800	6.28	20	26
1938	9,100	15,100	6.62	20	27
1939	10,300	18,700	4.89	22	27
1940	11,700	24,500	3,06	25	28
1941	12,200	20,100	8.78	20	29

a Average annual use for years 1929 to 1933.
9 White, W. N., op. cit., (11th Bienn. Rept.), p. 115.
10 Theis, C. V., op. cit., (12th Bienn. Rept.), pp. 140, 142.

The following table shows the use of electrical power and the number of pumping plants in the valley for the period from 1937 to 1941 inclusive.

USE OF ELECTRICAL POWER AND NUMBER OF PUMPING PLANTS IN THE MIMBRES VALLEY
(Courtesy Deming Ice and Electric Company)

	1937	1938	1939	1940	1941
Electrical power consumed in pumping groundwater for irrigation, K.W.H.	[1]2,222,910	2,027,969	2,419,245	3,062,225	2,839,121
Electrical power consumed in pumping groundwater for industrial purposes, K.W.H.	186,209	175,921	198,126	235,087	230,669
Total electrical power consumed in pumping groundwater, K.W.H.	2,409,119	2,203,890	2,617,371	3,297,312	3,069,790
Number of electrically driven irrigation pumps in use	107	122	128	150	145
Number of other irrigation pumps in use			39	49	62
Number of irrigation pumps not in use				12	19
Number of industrial pumping plants electrically driven	11	12	10	8	8
Total number of pumps			[2]177	219	234

The electrical power consumption for irrigation varies considerably from year to year due to the variation in the acreage irrigated by means of electric pumps, to variation in the water-use per acre due to rainfall and crop variation, to the change in pumping water-levels from year to year, and to change in pump efficiencies from year to year. Though all of these factors cannot be evaluated, it is probable that the

1 Correction of figure published in 12th and 13th Biennial Report
2 Used pumps only

major part of the yearly variation in the power consumption is due to the variation in acreage irrigated by electrical power and to the variation in water-use.

TRANSMISSIBILITY OF THE BOLSON DEPOSITS

The fundamentally important physical characteristics of an aquifer are its ability to transmit water and its capacity to store water. The ability to transmit water is called the transmissibility of the aquifer and is expressed quantitatively by a coefficient of transmissibility, defined as the number of gallons of water which will move in one day through a vertical strip of the aquifer one foot wide under a unit hydraulic gradient. The capacity to store water is represented quantitatively by the coefficient of storage of the aquifer which is defined as the volume of water, in cubic feet, released from storage in a column of the aquifer having a base one foot square when the water table or other piezometric surface is lowered one foot.

The effects of pumping from wells in an aquifer in which these two physical characteristics can be assumed to be constant can be determined by the following formula[11]:

$$v = 114.6\ F/T \int_{z}^{\infty} \frac{e^{-u}}{u}\, du$$

in which

v = drawdown at any point, in feet;
F = rate of discharge of the well, in gallons a minute;
T = coefficient of transmissibility, as defined above;
$z = 1.87\ r^2\ s/T\ t$
r = distance from the discharging well to the point where drawdown is to be determined, in feet;
s = coefficient of storage, as defined above;
t = time the well has been discharging, in days.
e = natural logarithm base.
u = a dimensionless quantity, varying between the limits given.

One method of determining the transmissibility of an aquifer is by measuring the rate of recovery of water level in a well that has been pumped at a constant rate for a measured length of time. The coefficient of transmissibility is determined from the following formula[12]:

$$T = (264\ F/v')\ (\log_{10} t/t')$$

in which

T = coefficient of transmissibility as defined above;
F = rate of discharge of well, in gallons a minute;
v' = residual drawdown at any instant, in feet;

11 Theis, C. V., The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., pp. 519-524, 1935.
12 Theis, C. V., op. cit., p. 522.

t = interval of time since pumping started to time of measuring residual drawdown.
t' = interval of time since pumping stopped to time of measuring residual drawdown.

In January and March, 1940, four wells were pumped and the rate of recovery of water level measured. In the following tables the data on two of these wells are given:

RATE OF RECOVERY OF WATER LEVEL IN THE STEVE HRNA WELL (24.10.12.432)

Static depth to water, 77.85 feet.
Pumping depth to water, 100 ± feet.
Pumping started 6:16 p. m., March 13, 1940
Pumping stopped 7:37 a. m., March 15, 1940
Pumping time, 2,241 minutes = c
Pumping rate, 300 gals. a minute

Time	Time since stop (min.) t'	Time since start (min.) t' + c	$\frac{t'+c}{t'}$	Depth to water (feet)	Residual drawdown (feet) v'
Mar. 15, 1940					
8:00 a. m.	23	2,264	98.3	87.80	9.95
8:08	31	2,272	73.2	87.10	9.25
8:11	34	2,275	66.8	86.93	9.08
8:15	38	2,279	60.0	86.66	8.81
8:20	43	2,284	53.0	86.37	8.52
8:25	48	2,289	47.7	86.10	8.25
8:30	53	2,294	43.3	85.90	8.05
8:35	58	2,299	39.6	85.69	7.84
8:40	63	2,304	36.6	85.50	7.65
8:45	68	2,309	34.0	85.32	7.47
8:50	73	2,314	31.6	85.14	7.29
9:01	84	2,325	27.7	84.77	6.92
9:15	98	2,339	23.8	84.40	6.55
9:31	114	2,355	20.6	84.07	6.22
9:45	128	2,369	18.5	83.83	5.98
10:00	143	2,384	16.65	83.55	5.70
10:15	158	2,399	15.20	83.30	5.45
10:30	173	2,414	13.9	83.08	5.23
10:45	188	2,429	12.9	82.89	5.04
11:00	203	2,444	12.0	82.71	4.86
11:20	223	2,464	11.05	82.49	4.64
12:31 p. m.	294	2,535	8.62	81.86	4.01
1:00	323	2,564	7.93	81.68	3.83
1:31	354	2,595	7.34	81.48	3.63
2:00	383	2,624	6.85	81.31	3.46

RATE OF RECOVERY OF WATER LEVEL IN THE STEVE HRNA WELL—Contd.

Time	Time since stop (min.) t'	Time since start (min.) t' + c	$\frac{t'+c}{t'}$	Depth to water (feet)	Residual drawdown (feet) v'
2:35	418	2,659	6.35	81.13	3.28
3:15	458	2,699	5.88	80.96	3.11
4:15	518	2,759	5.32	80.72	2.87
5:15	578	2,819	4.87	80.53	2.68
6:15	638	2,879	4.51	80.35	2.50
8:15	758	2,999	3.96	80.05	2.20
11:23	946	3,187	3.36	79.68	1.83
Mar. 16					
7:17 a. m.	1,420	3,661	2.58	79.14	1.29
2:55 p. m.	1,878	4,119	2.19	78.75	0.90
6:36	2,099	4,340	2.07	78.65	0.80
Mar. 17					
8:43 a. m.	2,946	5,187	1.76	78.33	0.48

RATE OF RECOVERY OF WATER LEVEL IN THE W. H. GANT WELL (25.10.36.222)

Static depth to water, 58.77 feet.
Pumping depth to water, 69.20 feet
Pumping started 11:07 a. m., January 10, 1940
Pumping stopped 12:32 p. m., January 11, 1940
Pumping time, 1,525 minutes = c
Pumping rate, 400 gals. a minute

Time	Time since stop (min.) t'	Time since start (min.) t' + c	$\frac{t'+c}{t'}$	Depth to water (feet)	Residual drawdown (feet) v'
Jan. 11, 1940					
12:33 p. m.	1	1,526	1,526	63.87	5.10
12:35	3	1,528	510	62.98	4.21
12:36	4	1,529	382	62.64	3.87
12:37	5	1,530	306	62.34	3.57
12:38	6	1,531	255	62.10	3.33
12:40	8	1,533	191	61.78	3.01
12:415	9.5	1,534.5	161	61.57	2.80
12:46	14	1,539	110	61.12	2.35
12:48	16	1,541	96.0	60.98	2.21
12:50	18	1,543	85.6	60.86	2.11
12:53	21	1,546	73.5	60.70	1.93

RATE OF RECOVERY OF WATER LEVEL IN THE W. H. .GANT WELL—Contd.

Time	Time since stop (min.) t′	Time since start (min.) t′+ c	$\frac{t'+c}{t'}$	Depth to water (feet)	Residual drawdown (feet) v′
12:56	24	1,549	64.4	60.59	1.82
1:00	28	1,553	55.5	60.45	1.68
1:05	33	1,558	47.2	60.32	1.55
1:12	40	1,565	39.1	60.18	1.41
1:20	48	1,573	32.8	60.05	1.28
1:30	58	1,583	27.3	59.93	1.16
1:45	73	1,598	21.9	59.72	0.95
2:00	88	1,613	18.4	59.74	0.97
2:20	108	1,633	15.1	59.68	0.91
2:40	128	1,653	12.9	59.63	0.86
3:00	148	1,673	11.3	59.60	0.83
4:00	208	1,733	8.33	59.54	0.77
7:22	410	1,935	4.72	59.47	0.70
Jan. 12					
8:49 a. m.	1,217	2,742	2.25	59.32	0.55
4:55 p. m.	1,703	3,228	1.89	59.25	0.48
Jan. 13					
9:26 a. m.	2,694	4,219	1.57	59.19	0.42
Jan. 14					
9:57 a. m.	4,165	5,691	1.37	59.13	0.36

If the aquifer from which the well is pumped is of such a nature that the coefficients of transmissibility and storage are essentially constant, the recovery curves will plot as straight lines going through the origin, when the ordinates are log (t/t′) and the abscissas are residual drawdowns. Figure 2 shows the plotted recovery curves of all four wells. The recovery curves for wells 24.10.12.411 and 24.10.12.432 plot essentially as straight lines and that of well 24.10.12.411 goes through the origin. The curves for wells 24.7.10.111 and 25.10.36.222 show decided breaks and are composed essentially of intersecting straight lines.

The departure of the recovery curves from straight lines is in all probability caused by irregularities in the transmissibility and storage capacity of the water-bearing strata in the vicinity of the wells on which the tests were made. The irregularity of these characteristics is probably to be correlated with the lenticular character of the alternating clayey and sandy beds of the alluvial deposits from which the wells draw water. Future research may possibly derive from these irregularities in the recovery curves the nature of the variation in the aquifer but at present it seems impossible to do so.

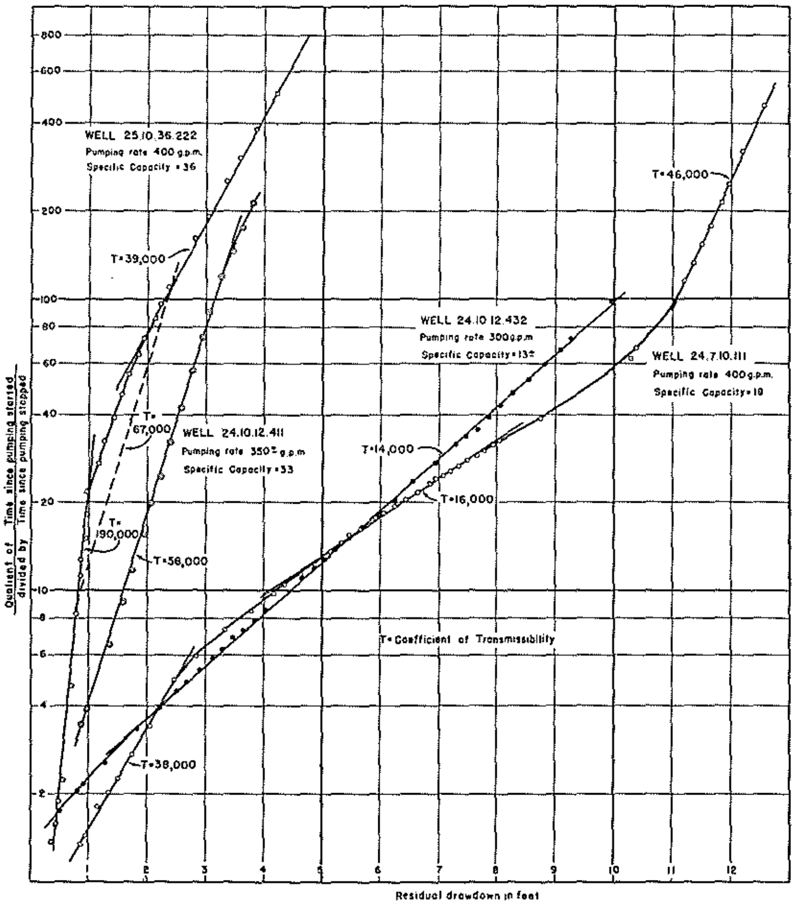

FIG. 2. Recovery of Water Level After Pumping in 4 Wells in Mimbres Valley.

The transmissibilities as computed from these recovery curves are shown on the figure. Wells 24.10.12.411 and 24.10.12.432 are approximately one-fourth mile apart. In this short distance the transmissibility apparently varies from 58,000 to 14,000. The shallower well indicated the higher transmissibility. The recovery curve for well 24.7.10.111 consists of three straight segments which individually would indicate transmissibilities of 46,000, 16,000 and 38,000. The low specific capacity indicates that the correct value is probably somewhere close to 16,000. The recovery curve of the W. H. Gant well (25.10.36.222), consisting of two straight lines, gives transmissibilities of 39,000 and 190,000. The correct figure, as indicated by the average slope and the high specific capacity of the well, is probably 67,000.

In 1936 Mr. Eugene Calkins, of Deming, measured for the Geological Survey the rate of recovery of the water levels in 11 pumped wells scattered throughout the area. These measurements were of varying degrees of accuracy. The values of transmissibility ranged from 17,000 to 152,000. The recovery curves have the characteristics exhibited by those shown in figure 2.

In the spring of 1941, a test well located about 3½ miles southeast of Deming (24.9.6.431) was drilled to a depth of 1001 feet. The drilling of the well was made possible through the cooperation of the State Engineer of New Mexico, a farmer's committee at Deming, the Geological Survey, and the Bureau of Agricultural Economics. Mr. C. Richard Murray, of the Geological Survey, supervised the drilling and testing of the well and made a preliminary report[13] on the well after its completion. The well casing was perforated at various points between depths of 303 and 442 feet. Below 653 feet the well was left uncased.

The pumping tests made on this well indicated a specific capacity of about 10 and a transmissibility of about 21,000 for the well. The uncased part of the well yielded only about 0.2 gallon per minute per foot of drawdown before the casing above was perforated.

In the early part of 1942 recovery measurements were made on the Emanual Vocale well (24.9.7.211) about one-quarter mile south of the deep test well. The Vocale well had been deepened to about 400 feet and the casing was perforated at various points from about 70 feet to the bottom of the hole. The measurements made indicated a transmissibility of about 40,000 and a specific capacity of about 22.

The following table gives the probable average transmissibilities of the aquifer as determined from wells on which the rate of recovery of water levels has been measured. The high transmissibility obtained from the J. N. Williams well (24.10.2.211) may be due to a gravel lens of high permeability. The values in the table seem to indicate that the aquifer has a transmissibility of about 20,000 in the area east of the Little Florida Mountains, and a transmissibility of about 60,000 south of Deming.

13 Murray, C. Richard. Preliminary report on the completion of the New Mexico State Engineer Deming Test Well with sample log.

PROBABLE VALUES OF COEFFICIENT OF TRANSMISSIBILITY AS DETERMINED BY RECOVERY CURVES IN MIMBRES VALLEY, NEW MEXICO

Owner	Location number of well	Pumping rate, in gallons per minute	Probable average transmissibility	Date of test
Unknown	24.6.3.111	225	35,800	August 1936
J. N. McDugall	24.7.8.22	145	25,300	September 1936
G. D. Hatfield	24.7.10.111	400	16,000	January 1940
Percival and Dyer	24.7.13.22	200	17,000	August 1936
State of New Mex.	24.9.6.431	465	21,000	May 1941
Emanual Vocale	24.9.7.211	450	40,000	March 1942
O. H. Cooper	24.9.17.121	265	20,000	July 1936
L. L. Gaskill	24.9.21.131	400+	[1]17,000	February 1940
J. N. Williams	24.10.2.211	575	152,000	August 1936
R. O. Wasdin	24.10.12.411	350+	58,000	March 1940
Steve Hrna	24.10.12.432	300	14,000	March 1940
Roderick and Wheeler	25.9.7.212	240	67,000	July 1936
Mrs. Paulk	25.9.15.211	385	50,000	July 1936
A. P. McBride	25.9.28.211	390	65,000	July 1936
F. Chvojka	25.9.30.111	210	52,000	August 1936
W. H. Gant	25.10.36.222	400	67,000	January 1940
Unknown	26.9.3.411	315	77,000	August 1936
I. Kennedy	26.10.11.111	390	65,000	July 1936

Following is a table showing the specific capacities of several wells in the valley, that is, the number of gallons of water a minute produced by the wells for each foot of drawdown. The measurements were taken at various times in the course of obtaining recovery data, pump ratings, and other data.

1 Determined from record obtained by an automatic water-stage recorder, on abandoned well 20 feet from pumped well.

SPECIFIC CAPACITIES OF WELLS IN THE MIMBRES VALLEY

Owner	Well location number	Specific capacity
A. J. Interridian	23.8.34.111	20
J. N. Williams	23.8.34.211	5
A. Earnest	23.9.25.313	27
J. R. Smyer Estate	24.7.9.111	10
G. D. Hatfield	24.7.10.111	18
Bessie Kretek	24.8.1.333b	44
J. B. Wells	24.9.6.311	17
State of New Mex.	24.9.6.431	a10
W. G. Jonas	24.9.6.431b	20
Emanual Vocale	24.9.7.211	22
L. L. Gaskill	24.9.21.131	17
John Hrna	24.9.28.221	18
R. S. Pond	24.10.3.411	15
R. O. Wasdin	24.10.12.411	33
Steve Hrna	24.10.12.432	13
G. W. McCann Estate	25.9.14.311	22
W. W. Barracks	25.9.17.311	18
A. V. Speir	25.9.21.311	38
A. P. McBride	25.9.28.211	33
W. H. Gant	25.10.36.222	36
I. Kennedy	26.10.11.111	26

An approximate value of the amount of underground flow in the Mimbres Valley may be obtained by use of the values of coefficients of transmissibility. The slope of the water table averages approximately 12 feet to the mile south of Deming[14]. The width of the bolson plain from the Florida Mountains west to the Snake Hills is about 10 miles. Using a coefficient of transmissibility of 60,000, the underflow in this area is about 8,000 acre-feet per year. This is, however, not the total underflow, as ground water flow east across the underground dam north of the Florida Mountains is an amount that cannot be determined with any accuracy by this method because the gradient of the water table changes very rapidly near the ground water dam.

The bolson deposits of Mimbres Valley consist of irregular lenses of silt, sand, gravel, and clay. The water in these beds is semi-confined and exhibits some artesian effects. Further, there appear to be elongated or shoe-string lenses of gravel in the deposits which influence the direction in which water levels are drawn down by a pumped well. Figure 3 shows a graph of the water level in an abandoned well equipped with an automatic water-stage recorder and also shows the periods of pumping of three nearby wells. Well 24.10.12.411 is one-fourth mile due north, well 24.10.12.432 is one-fourth mile east, and well 24.10.12.123

a For part of well between 303 and 442 feet depth; upper aquifers cased off.
14 White, W. N., op. cit. (10th Bienn. Rept.), pp. 184 and 188.

is about three-fourths of a mile northwest of the recorder well. The irregular fluctuations of the water level shown in the graph are caused by fluctuations of barometric pressure. The fact that the well consistently indicates barometric changes is a probable indication of semi-confined or artesian conditions. This characteristic is also exhibited in well 24.7.14.221, equipped with an automatic water-stage recorder, located in the heavily pumped district east of the under-ground dam. As shown in figure 3, well 24.10.12.411 (¼ mile north of the recorder well) has an appreciable effect on the water level in the recorder well but well 24.10.12.432 (¼ mile east of recorder well) and other wells in the neighborhood do not seem to affect it significantly during short periods of pumping. This is evidence of a gravel stringer giving a preferential direction of drawdown of water level when well 24.10.12.411 is pumped.

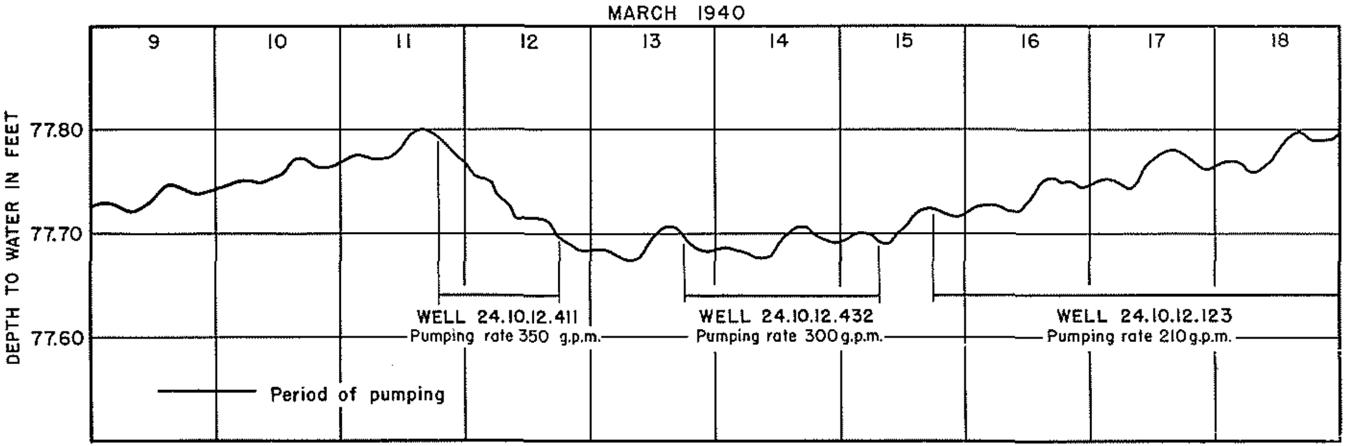

FIG. 3. Fluctuation of water level in well 24.10.12.431 and the periods of pumping in neighboring wells.

CHANGES IN WATER LEVEL

Changes of water level in wells indicate changes in the amount of water stored in the aquifer caused by pumping and variation in natural recharge and discharge. Continuous records of water levels, therefore, furnish means of determining whether the ground-water supply is being depleted and, if so, at what rate.

A depth-to-water map, figure 4, has been prepared for January, 1940, based on measurements of depth to water in 100 wells distributed throughout the valley. The map shows an area of comparatively shallow water just west of the underground dam that extends northward from the Little Florida Mountains to Cooks Range. Just east of this dam the depth to water increases considerably in a short distance, changing from less than 20 feet to water to more than 80 feet to water in about three miles. From this point of greatest depth, the depth to water decreases more or less uniformly to the north, east, and south.

Westward from the underground dam the depth to water increases gradually until near Deming water is about 60 feet deep and in the vicinity of Black Mountain more than 90 feet. Southward from Deming the depth to water decreases gradually until in the gap between the Florida Mountains and Tres Hermanas Mountains about 19 miles south of Deming the depth to water is less than 20 feet. The effect of this gap is to narrow the width of the underflow with a consequent increase in the height of the ground water.

The first study of ground water in the Deming area, made by Darton[15] gives the depth to water from 1910 to 1914 in many wells distributed over the present areas of heavy pumping. These depths to water are in general the reports of well drillers and well owners but they give a true general picture of the depth to water in the Mimbres Valley between 1910 and 1914. On the basis of these reports, a map similar to figure 4, showing the depth to water, was prepared.

A comparison of figure 4 and the depth-to-water map of 1913 gives the change in ground-water level for approximately a 27-year period. Direct comparison of water levels in the same wells for both times could not be made as many of the old wells have been filled in and others lost, and the wells that might be in existence were not adequately described or located so that they can now be recognized. The method of comparing maps is subject to minor errors but in general gives a true picture of the conditions. The resultant map, figure 5, shows the change in water level that has occurred between 1913, when the ground-water development was just beginning, and January 1940.

The map shows a lowering of ground-water level of more than 10 feet over the whole area where pumping of ground water is practiced. A small area just east of the underground dam that extends from the Little Florida Mountains to Cooks Range shows a lowering of more than 35 feet. This excessive lowering is due to the large amount of pumping in this area coupled with the effect of the underground dam,

15 Darton, N. H., op. cit. (Bull. 618, p. 1.)

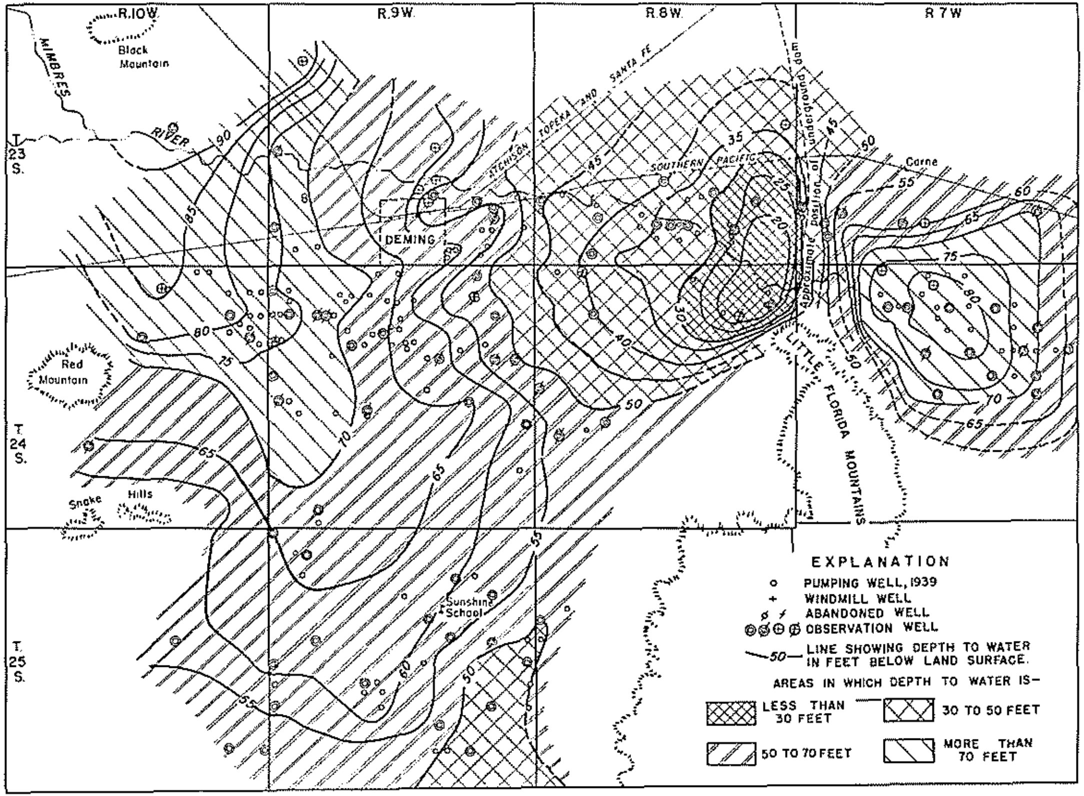

FIG. 4. Depth to water in a part of the Mimbres Valley in January 1940.

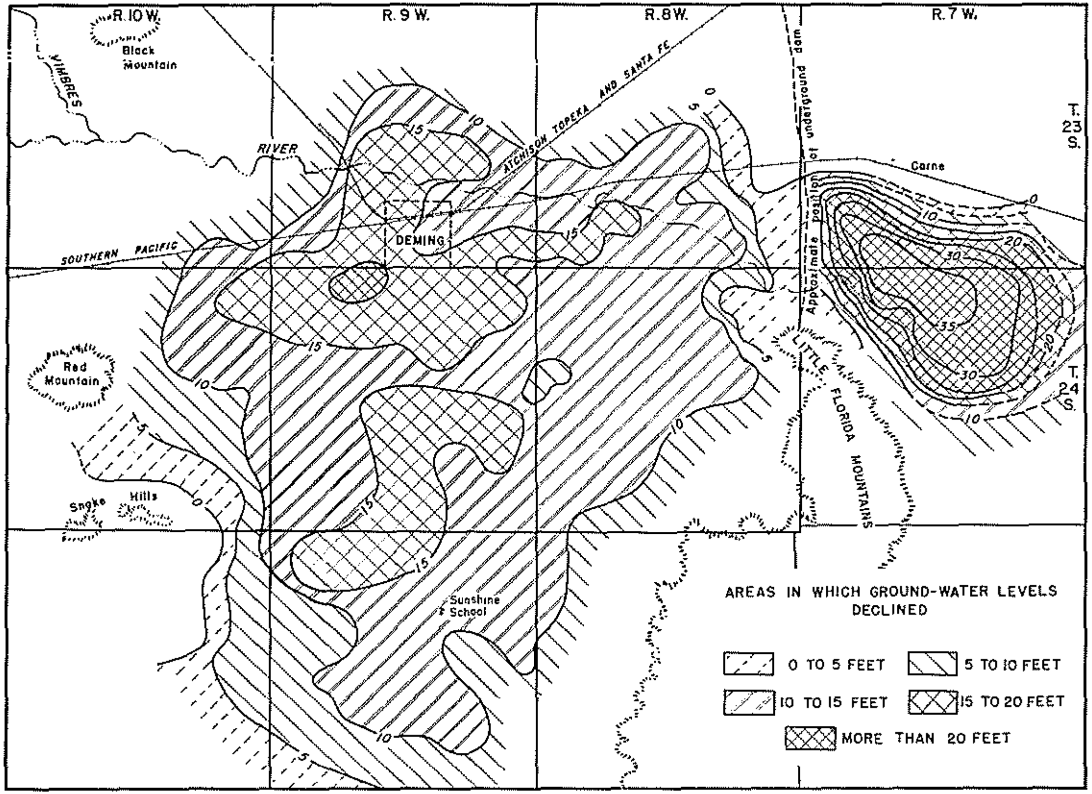

FIG. 5. Decline of ground-water levels in a part of Mimbres Valley from 1913 to 1940.

which restricts the underground flow into this area from the west and thus limits the amount of storage from which the wells can draw.

The area just west of the underground dam shows a decline of only about 5 feet. Pumps located in this area tend to divert for irrigation the natural underflow discharge over the underground dam with a consequent small withdrawal from storage.

Figure 6 shows the change in water level over the valley for the 10-year period from 1930 to 1940. This map is based on changes in water level that occurred in observation wells. It shows that in the heavily pumped area west of Deming the water level has declined at an average rate of more than one foot a year, that in the area just west of the underground dam the rate has been about one-half foot a year, and that in the area east of the underground dam the average decline has amounted to more than 1½ feet a year. In the lightly pumped area south of Deming the water level has apparently declined about one-half foot a year. Only one well in this area has a record for the period 1930 to 1940.

Maps showing the change in water level for 1938 and 1939, based on observations made on wells in January of each year, at which time very little pumping is done and water levels are near their highest point, are shown in figures 7 and 8. Readings for any one year are subject to minor local effects such as pumping in the vicinity of an observation well and the time since pumping of the well used for observations was stopped. The length of the pumping season, and particularly the time it ends, results in different intervals of time for the recovery of water levels before measurements of depth to water are made in January of each year. One year's record is also affected by small changes in the amount of recharge.

The map for the period January 1938 to January 1939, figure 7, shows a maximum lowering of more than one foot in the heavily pumped area west of Deming, a rise of more than one-half foot west of the underground dam, and a lowering of more than one foot east of the underground dam. The change in water levels for this year reflects chiefly the decrease in pumping and probable early stopping of pumps as compared to preceding and succeeding years.

The map for the period January 1939 to January 1940, figure 8, shows a greater decline than in the previous year, caused mainly by the increased amount of pumping. In this period the ground-water level apparently declined approximately 2 feet in the three heavily pumped areas, that west of Deming and those just west and east of the underground dam; while in the lightly pumped area south of Deming the decline reached a maximum of about one foot. The water level for this period declined more than 2 feet over an area of about 2.5 square miles and more than 1.5 feet over an area of about 17 square miles.

Figure 9 shows the change in ground-water levels from January 1940 to January 1941. During this period the ground-water levels declined over the whole area shown. The decline amounted to more than 1 foot over an area of about 81 square miles, and to more than 1.5 feet

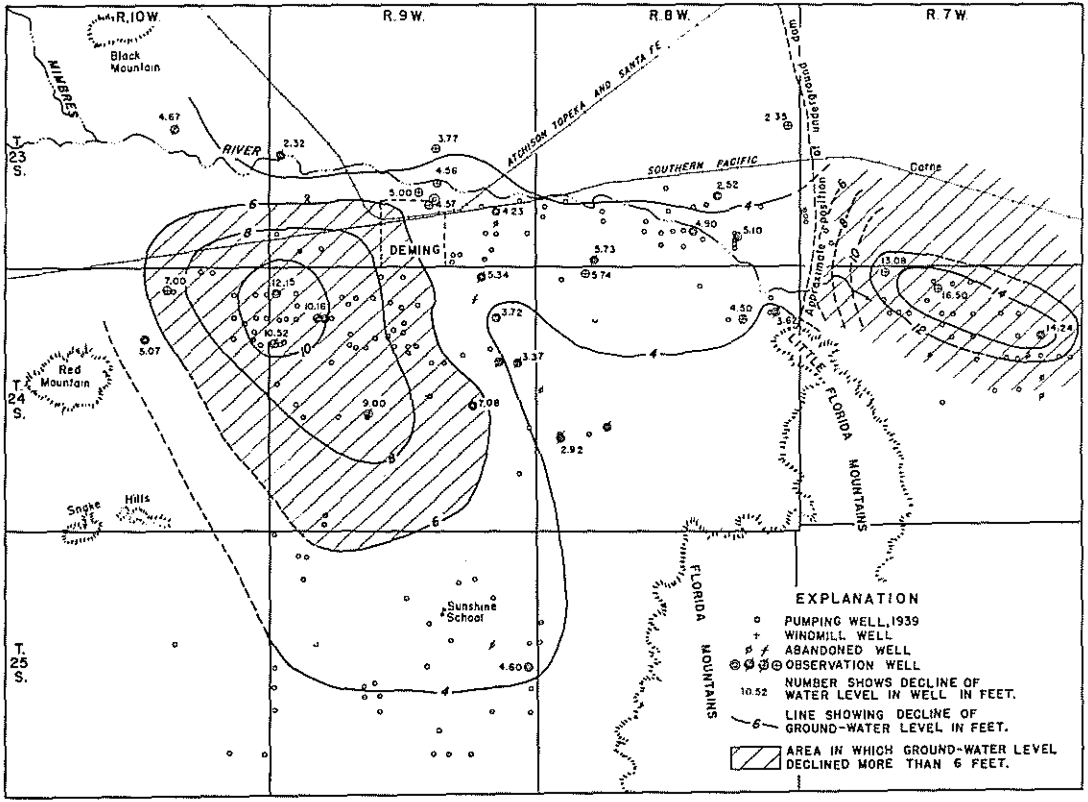

FIG. 6. Decline of ground water levels in a part of Mimbres Valley from January 1930 to January 1940.

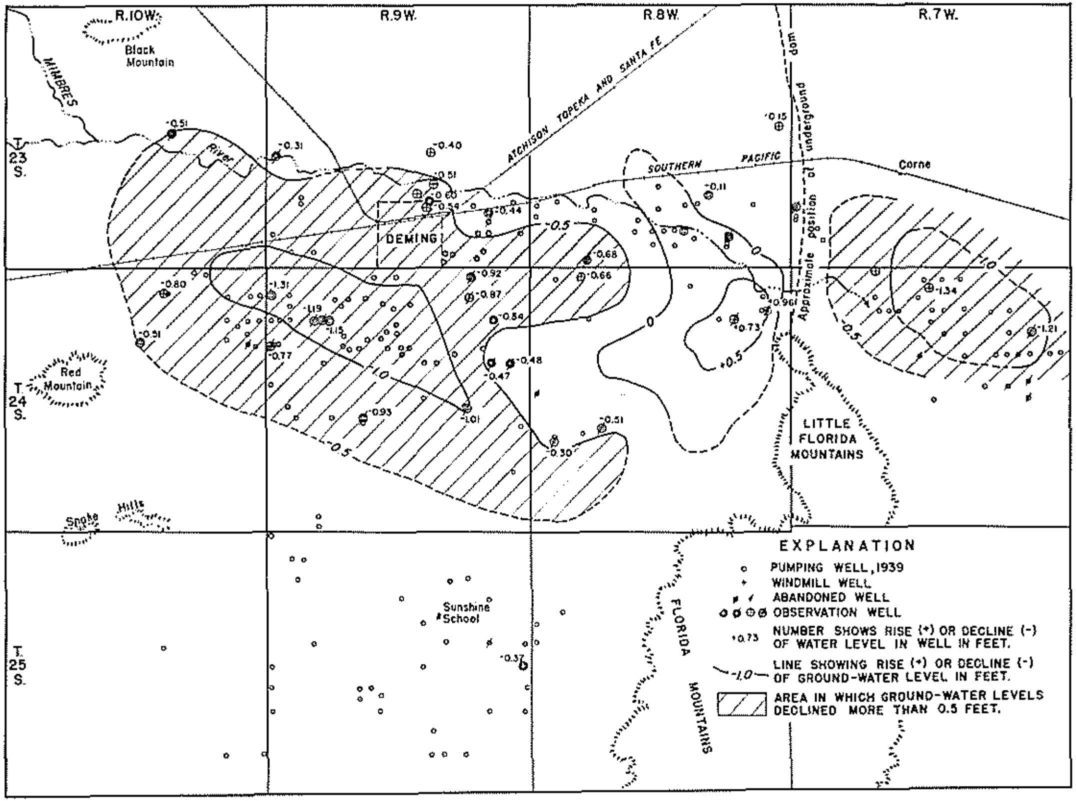

FIG. 7. Change in ground-water levels in a part of Mimbres Valley from January 1938 to January 1939.

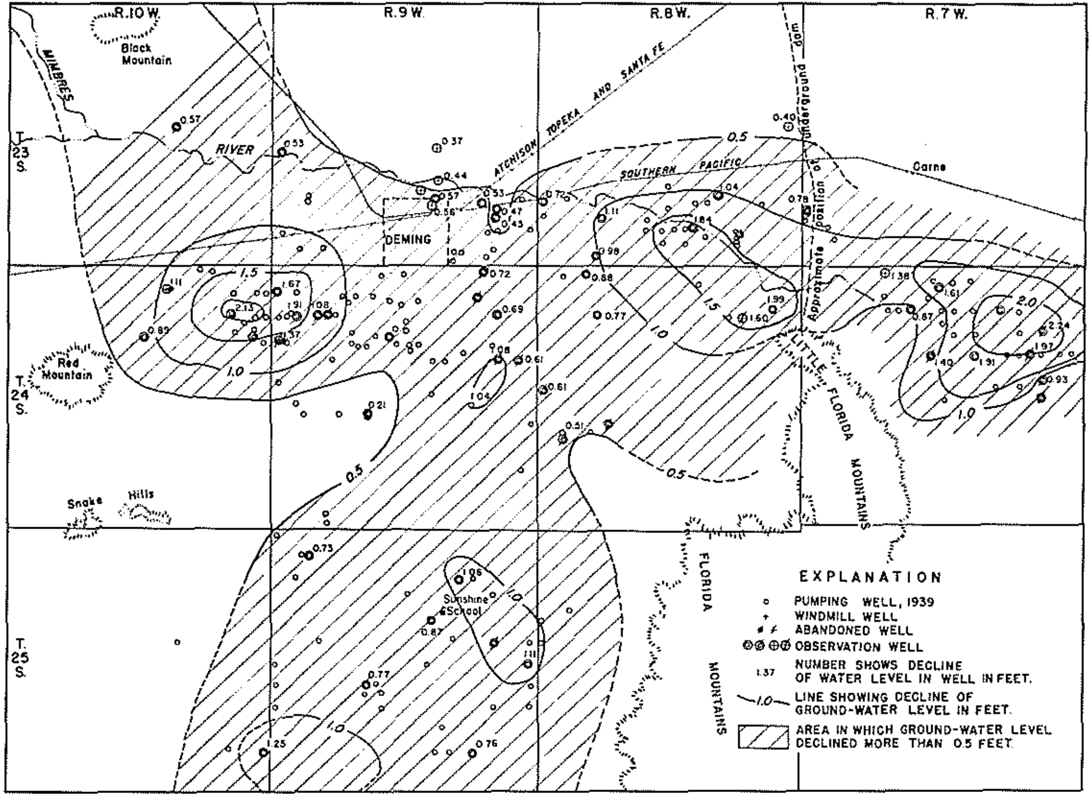

FIG. 8. Change in ground-water levels in a part of Mimbres Valley from January 1939 to January 1940.

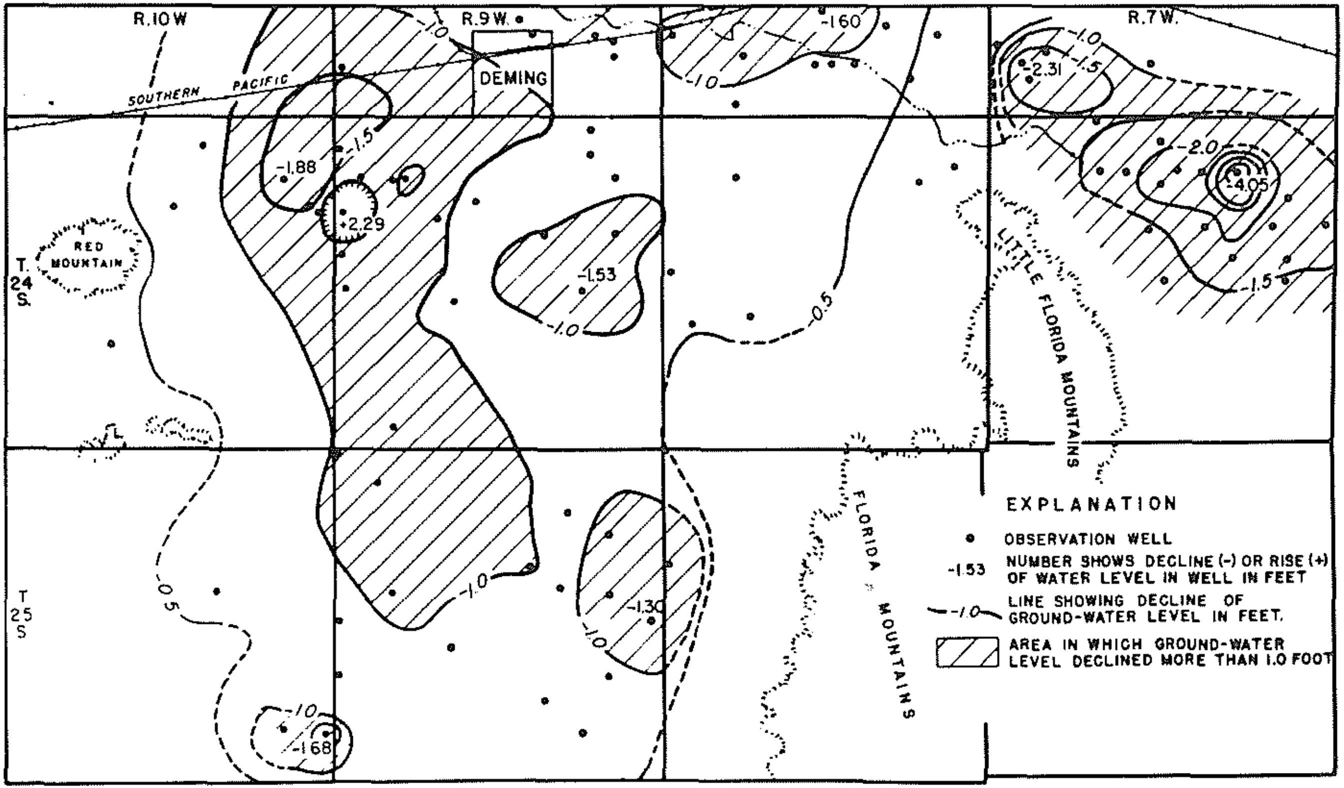

FIG. 9. Change in ground-water levels in a part of Mimbres Valley from January 1940 to January 1941.

over an area of about 46 square miles. In the heavily pumped area east of the Little Florida Mountains, the maximum recorded decline was 4.05 feet, in well 24.7.11.111. In the small area of heavy pumping west of the ground-water dam extending north from the Little Florida Mountains, the maximum decline was 1.60 feet. The maximum recorded decline in the heavily pumped area just west and south of Deming was 1.88 feet. In this area, a rise of 2.29 feet was recorded for well 24.9.7.331, the rise being caused by the deepening in March 1940 of an irrigation well about 60 feet away to a depth of 245 feet with a consequent rise in water level. In the lightly pumped area from about 7 to 12 miles south of Deming, the maximum decline in the water level was 1.30 feet.

The change in the ground-water level from January 1941 to January 1942 is shown in figure 10. Except for small areas south of Deming and east of the ground-water dam, the water-level in the valley did not decline as much during 1941 as in 1940 and substantial rises of the water level were observed in some areas. This was probably due to some extent to actual re-charge to the area but it is probable that a large part of the rise or decreased lowering was due to the decrease in pumpage, occasioned by the relatively large rainfall during the year, which permitted ground-water flowing from outlying districts to raise the water level in the vicinity of the pumps.

The water level was higher in 1942 than in 1941 in an area of about 20 square miles to the west and south of Deming, being 1 foot higher in an area of 11 square miles with a maximum rise of 3.90 feet in well 24.10.3.411b, an irrigation well. A rise of 5.26 feet was observed in well 24.10.3.411, a windmill well approximately 94 feet west of well 24.10.3.411b; however, it is believed that the water-level change in the former well is of more significance and, therefore, the change in the water-level in the windmill well is not indicated in the figure.

The water level fell during the year in an area of about 85 square miles in the vicinity of Deming, and to the south and east of Deming. It declined more than 1 foot in an area of 1.5 square miles south of Deming, in an area of about 1 square mile north and east of Deming, and in an area of about 13 square miles south of Deming. The greatest observed fall in this area was 2.17 feet in well 24.9.28.221.

The water levels rose over an area of about 44 square miles adjacent to the Florida Mountains and the Little Florida Mountains, and above and to the west of the ground-water dam. In this area the water level rose more than 1 foot in a small area lying north of the tip of the Little Florida Mountains and west of the ground-water dam. The greatest observed rise in this area was 1.10 feet in well 23.8.35.211b.

East of the Little Florida Mountains and the ground-water dam, the water level declined much more than in the rest of the valley. In this area the water level fell more than 1 foot over about 20 square miles, with a maximum drop of 3.40 feet in well 23.7.31.120.

Hydrographs of four abandoned wells, two deep and two shallow, from 1927, when the record was begun, to 1939 are shown in figure 11. Well 24.9.13.111, deep, and well 24.9.13.112, shallow, are about one-

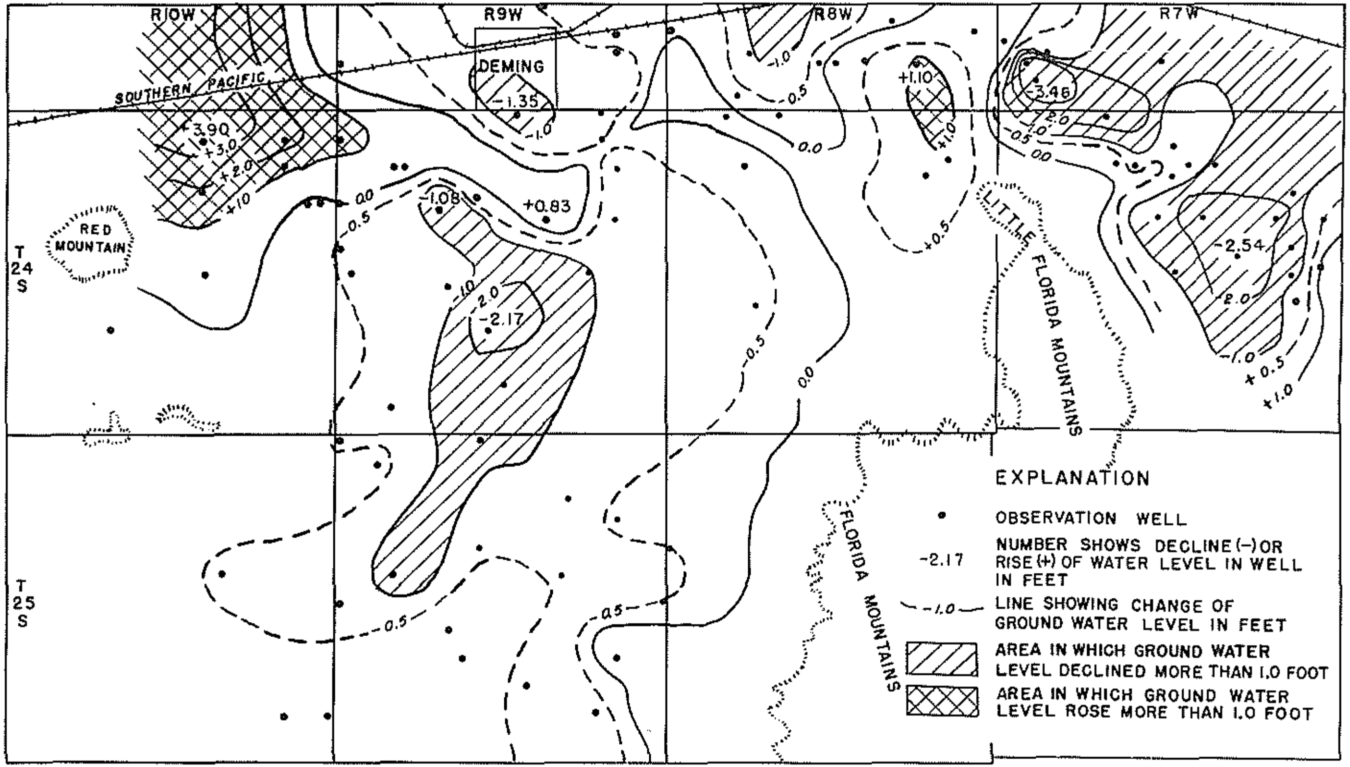

FIG. 10. Change in ground-water levels in a part of Mimbres Valley from January 1941 to January 1942.

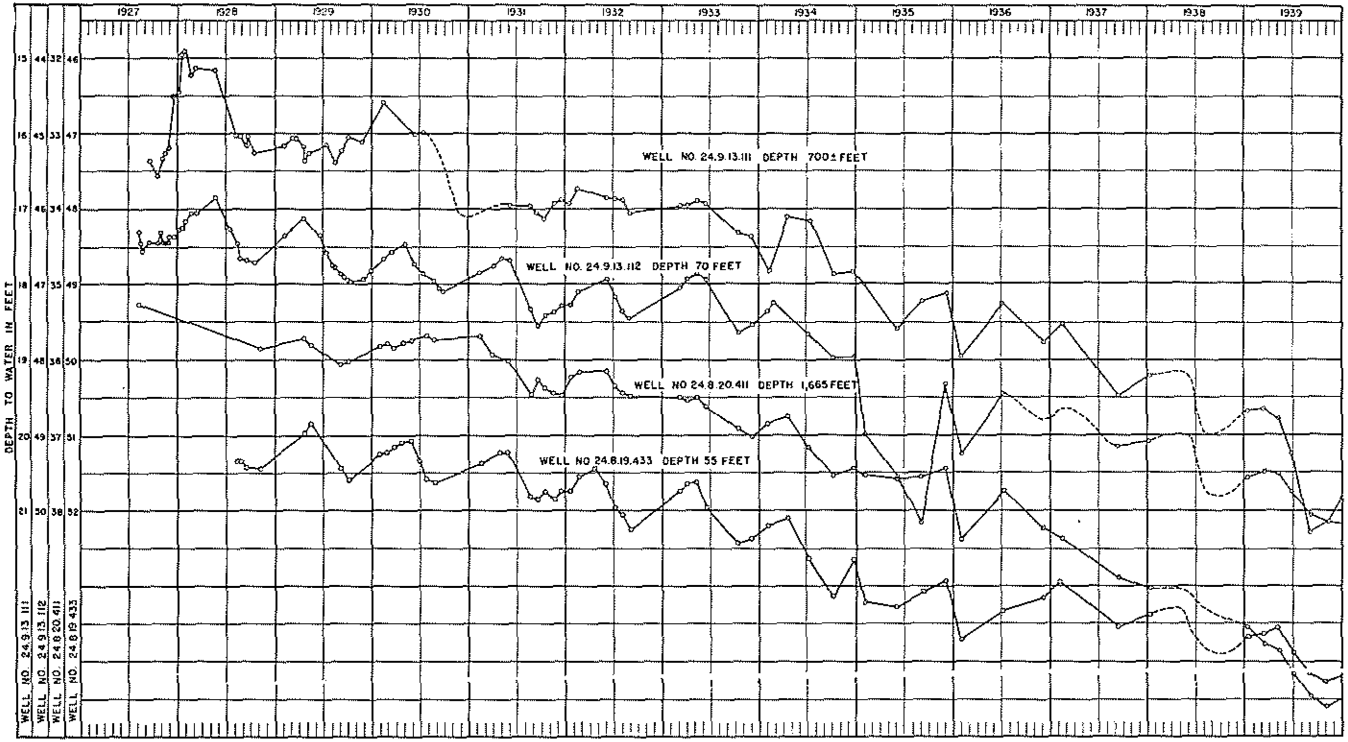

FIG. 11. Hydrographs of two unused deep wells and two unused shallow wells in Mimbres Valley.

fourth mile apart and over one mile from any heavily pumped wells. Well 24.8.20.411, deep, and well 24.8.19.433, shallow, are about one mile apart and about three miles from any heavily pumped wells. These four wells have not been used during the period of record. The hydrographs of the four wells are similar and show a progressive decline in water level. The seasonal fluctuations show characteristics caused by pumping for irrigation. The deep wells have shown a tendency toward a greater decline in water level than their companion shallow wells. Artesian effects are seen in the apparently small lag between the pumping season and the change in water level in these four wells which are distant from the pumping. Artesian conditions are also shown by the fact that the water level in the deep wells is considerably higher than those in the shallow wells. No casing records could be found for the two deep wells but it is probable that the casings are perforated opposite all water-bearing beds. These hydrographs show an increase in the rate of decline in the later years as the amount of pumping was increased.

Figure 12 shows hydrographs for 1939 and a part of 1940 for three wells equipped with automatic water-stage recorders. Well 21.10.6 is located in the recharge area on the Mimbres River 20 miles northwest of Deming on the Tigner Ranch. Well 24.7.14.221 is located in the heavily pumped area east of the underground dam. Well 24.10.12.431 is located in another heavily pumped district west of Deming. In the Mimbres Valley, some water is usually pumped during April before cotton is planted, after which little water is pumped until around the last of May and the first of June when watering of sorghum grains and pinto beans is begun. Pumping is fairly constant from then on, except for minor interruptions caused by showers, until the end of the pumping season in September or October. The hydrographs for wells 24.7.14.221 and 24.10.12.431 show fluctuations corresponding to these periods of pumping. The hydrograph for well 24.7.14.221 shows that the decline and recovery of water level in the area east of the Florida Mountains proceeded approximately at a uniform rate, whereas the hydrograph of well 24.10.12.431 shows that the decline and recovery of water level in the area west of Deming proceeded at a diminishing rate during the period of observation.

When water is pumped from an aquifer of large areal extent the resultant cone of depression continually expands and the wells draw water from larger and larger areas and, as a consequence, the decline of water level proceeds at a diminishing rate. When water is pumped from an aquifer of small areal extent the resultant cone of depression reaches the boundaries of the aquifer, after which the area of draft cannot be increased and, as a consequence, the rate of decline of water level proceeds at an approximately constant rate. It would seem, therefore, that the ground-water basin east of the underground dam in which well 24.7.14.221 is located is of small areal extent. As shown in figure 5, the area of drawdown in this area is apparently small which indicates that the alluvial deposits to the north, east, and south of this area of pumping are probably of low permeability. These deposits of low permeability form virtual walls for this ground-water basin, thus lim-

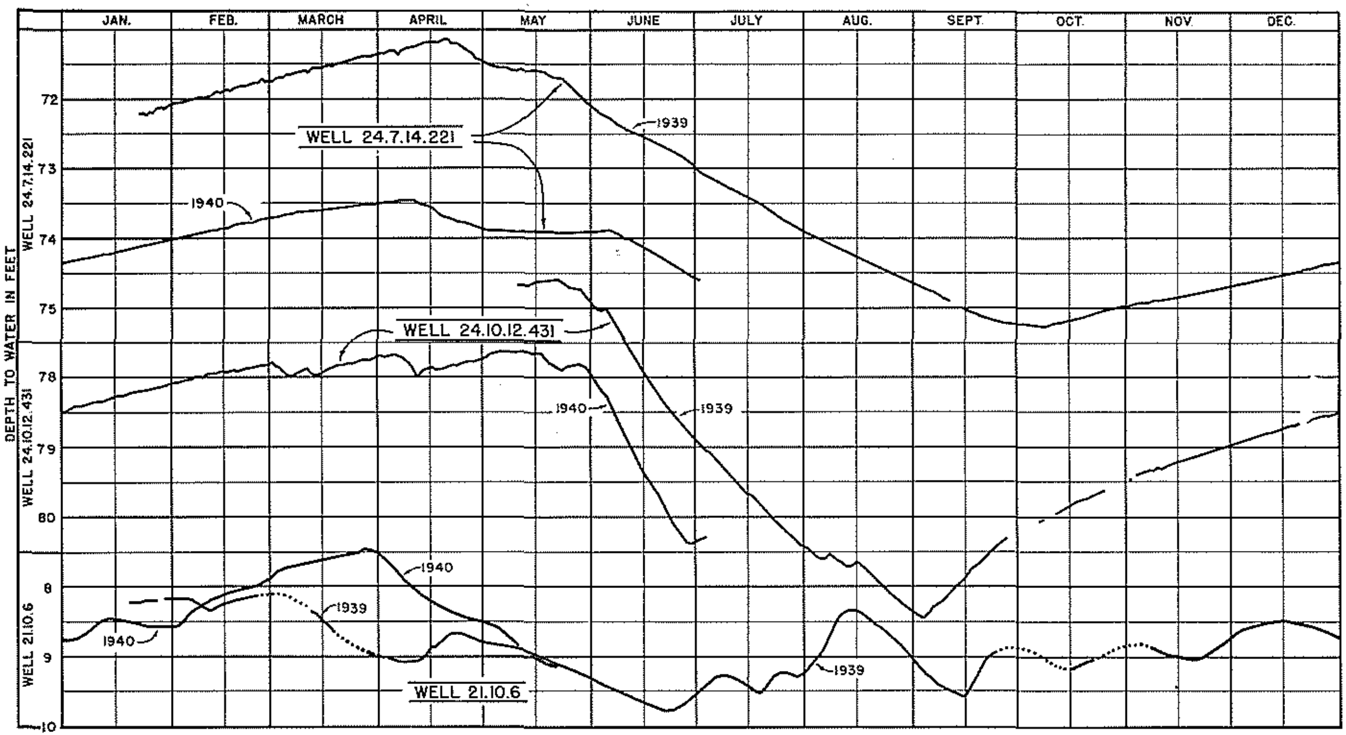

Fig. 12. Hydrographs of three wells equipped with water stage recorders.

iting the volume from which ground water can be drawn into the wells. The wells in this area draw water from a reservoir of fairly small areal extent and the water level fluctuates as a straight line in a manner rather similar to the way in which the water level would fluctuate in a surface reservoir from which water was being pumped seasonally at a given rate, and which was being constantly fed by a stream at a somewhat lower rate. Most of the recharge to this small reservoir probably comes from the west, over or perhaps through the ground-water dam. As the recovery of water level in well 24.7.14.221 was approximately one-half of the maximum drawdown of more than 4 feet, it would seem to indicate that in this area approximately one-half of the water pumped in 1939 was taken from storage and the remainder was furnished by flow over or through the underground dam and, probably to a small extent, by flow through the apparently less permeable sediments to the north.

The maximum drawdown of the water level in well 24.10.12.431 was approximately 5 feet. The recovery and drawdown curves for this well are of the type obtained from wells pumping from storage from an aquifer of large areal extent. Small rises in the water level in the recorder well are the result of cessations of pumping of surrounding wells, usually due to showers.

The hydrograph for well 21.10.6 shows the effect of intermittent recharge caused by flows in the Mimbres River. The greater amount of recharge occurs in the winter months.

The following table gives the yearly measurements of depth to water in observation wells in the Mimbres Valley for 1938, 1939, 1940 and 1941. In 1941, 136 observation wells were measured in January and 69 of these wells were measured bi-monthly in order to observe the trend of the water level caused by pumping and natural phenomena throughout the year. In the table the wells are divided into groups corresponding in general to those used by White[16].

Water level readings are given as depth below land-surface datum, a datum that corresponds to the actual land surface as closely as it can be determined but which is referred to one or more permanent points in the vicinity in order to make it definite. These readings can be compared with those previously published in the 10th, 11th, and 13th Biennial Reports of the State Engineer by the addition (+) of the value in the correction column to the previously published figures, or its subtraction (—) from the previous figures.

The well location number serves the dual purpose of locating and designating a well. The number is divided into segments by periods. The first segment gives the number of the township south of the New Mexico Base Line. The second gives the range west of the New Mexico Principal Meridian. The third is the section. The fourth denotes the ten-acre tract in the section. The section is divided into 4 quarters, numbered 1, 2, 3, and 4 for the NW, NE, SW, and SE quarters respectively. The first digit in the fourth segment gives the number of the

16 White, W. N., op. cit. (11th Bienn. Rept.), pp. 121-125.

quarter. Each quarter-section is similarly divided into four 40-acre tracts numbered in the same manner. The second digit gives the number of the 40-acre tract. The 40-acre tract is similarly diivded into 4 ten-acre tracts, numbered in the same manner, and the third digit gives the number of the ten-acre tract. Thus well 23.9.27.142 is a well in the NE¼SE¼NW¼, Sec. 27, T. 23 S., R. 9 W. In case there is more than one well in a ten-acre tract small letters a, b, c, etc., are arbitrarily added to distinguish the well. In case the well cannot be located within a ten-acre tract, 0 is used as the third digit and in case it cannot be located within 40 acres 0 is also used as the second digit. In case it cannot be located more closely than the section the entire fourth segment is omitted. Wells in lots in odd-sized sections are designated by "L" and the lot number, as for instance well 23.7.30.L16 in lot 16 of section 30.

DEPTH TO WATER IN MIMBRES VALLEY, FEET BELOW LAND-SURFACE DATUM, IN JANUARY OF EACH YEAR, 1938-1942

Group A. Observation wells within 3 miles of Mimbres River, subject to recharge

Well location number	Correction	1938	1939	1940	1941	1942
21.10.6	—0.16	8.25	8.22	8.72	8.28	8.17
21.11.13	—0.50	37.90	42.26	44.30	43.28	29.25
21.11.35.310	0.00	26.54	31.30	30.22	24.41	18.77
22.10.6.233	....	....	....	....	62.74	....
22.10.18.121	0.00	72.45	73.96	74.45	74.43	70.63
22.10.20.210	....	....	....	88.72	93.18	....
22.11.2.210	0.00	27.70	31.70	31.54	29.53	21.44
22.11.13.122	0.00	64.10	66.01	66.55	66.42	61.50
22.11.13.221	0.00	71.09	72.80	73.40	73.37	68.89
22.11.14.222	0.00	(a)	(a)	58.94	58.43	52.23
22.11.23.222	0.00	58.32	52.61	53.12	53.13	47.43
23.9.7.240	....	....	....	97.06	97.49	97.81
23.9.19.131	0.00	71.30	71.61	72.14	72.86	....
23.9.22.200	—0.48	61.29	61.69	62.06	62.53	62.95
23.10.15	—1.25	91.94	92.45	93.02	93.55	92.81

DEPTH TO WATER IN MIMBRES VALLEY, FEET BELOW LAND-SURFACE DATUM, IN JANUARY OF EACH YEAR, 1938-1942
(continued)

Group B. Observation wells in or near heavily pumped area southwest of Deming.

Well location number	Correction	1938	1939	1940	1941	1942
23.9.27.142	—0.50	57.95	(b)	59.14	59.83	60.57
23.9.27.221	—0.50	55.79	56.30	56.74	57.35	57.80
23.9.27.411	—0.85	52.04	52.58	53.14	53.84	(d)
23.9.27.412	—2.50	52.15	52.75	53.32	(d)	....
23.9.31.110	....	....	....	75.38	76.84	77.18
24.9.6.311	—1.30	72.60	73.91	75.58	77.34	75.95
24.9.6.431	....	....	....	....	....	57.90
24.9.7.211	....	....	75.72	77.63	78.76	e67.49
24.9.7.331	—0.25	74.48	75.25	76.62	74.33	74.33
24.9.8.111	0.00	71.45	72.64	73.72	75.02	74.09
24.9.8.112	—0.25	70.70	(a)	72.57	74.10	73.76
24.9.8.121	0.00	69.70	70.85	(d)	....	....
24.9.8.440	....	....	....	68.60	70.04	71.12
24.9.9.411	....	....	65.16	66.00	66.22	66.48
24.9.15.221	....	....	....	61.60	62.62	61.79
24.9.18.311	....	....	....	72.38	73.65	74.17
24.9.19.121	....	....	....	72.82	74.16	74.75
24.9.21.131	0.00	68.08	69.01	69.22	74.16	70.68
24.9.28.221	....	....	....	....	62.88	65.05
24.9.32.311	....	....	....	69.00	70.40	71.27
24.9.34.111	....	....	....	....	59.13	60.82
24.10.1.311	....	....	....	....	80.90	78.45
24.10.3.411	—0.10	84.60	85.40	86.51	87.27	82.01
24.10.3.411b	....	....	....	....	79.24	75.34
24.10.10.311	0.00	60.20	80.71	b81.60	82.42	80.43
24.10.12.111	....	....	79.69	81.82	83.70	82.60
24.10.12.431	....	....	....	78.31	79.82	79.83
24.10.12.432a	....	....	....	77.29	78.43	78.58
24.10.12.432b	....	....	....	78.05	79.18	79.27
24.10.22.211	....	....	....	....	69.88	69.61
24.10.29.222	....	....	....	....	63.87	64.07

DEPTH TO WATER IN MIMBRES VALLEY, FEET BELOW LAND-SURFACE DATUM, IN JANUARY OF EACH YEAR, 1938-1942 *(continued)*

Group C. Observation wells in lightly pumped areas east and southeast of Deming.

Well location number	Correction	1938	1939	1940	1941	1942
23.7.17.200	----	----	----	----	----	92.90
23.7.30.L16	—1.00	(a)	24.52	25.30	25.74	25.44
23.7.30.400	----	----	----	58.42	59.90	60.84
23.7.31.120	----	----	----	39.49	41.80	45.07
23.7.31.140	----	----	----	40.60	42.33	45.79
23.7.33.211	----	----	----	59.99	60.80	b62.20
23.8.3.300	----	----	----	----	----	131.14
23.8.13.400	—0.40	c36.47	36.62	37.02	37.40	37.47
23.8.25.311	----	----	----	20.75	21.00	20.88
23.8.26.131	0.00	31.08	31.19	32.23	33.17	33.25
23.8.28.231	----	----	----	----	----	43.50
23.8.28.241	----	----	----	40.23	41.83	42.78
23.8.29.433	----	----	42.56	43.67	44.94	45.94
23.8.30.133	----	----	44.96	45.68	46.89	46.97
23.8.32.323	—2.25	37.67	38.35	39.33	40.25	40.74
23.8.33.221	----	----	----	35.66	36.57	37.00
23.8.34.111	----	----	----	33.52	34.41	34.29
23.8.34.211	—1.50	31.90	31.65	33.49	34.40	33.87
23.8.35.210	—0.70	(a)	c29.18	29.41	(d)	----
23.8.35.211b	----	----	----	----	29.70	28.60
23.9.25.311	0.00	54.22	54.66	55.13	55.79	55.95
23.9.25.330	----	----	58.47	58.90	59.59	60.25
23.9.26.410	----	----	53.64	54.17	54.87	55.23
24.8.1.333	—0.03	15.40	14.44	16.43	16.54	15.57
24.8.1.333b	----	----	----	----	17.22	16.20
24.8.3.111	—2.50	31.08	(d)	----	----	----
24.8.4.111	----	----	----	----	35.59	35.99
24.8.5.110	—1.00	39.37	40.03	40.91	42.99	42.74
24.8.7.300	----	----	----	----	----	39.06
24.8.8.120	----	----	40.21	40.98	41.85	42.09
24.8.11.200	—2.00	15.75	15.02	16.62	16.90	16.10
24.8.18.331	----	----	50.72	51.33	52.05	(d)
24.8.19.433	—1.00	53.38	53.68	54.19	54.71	(d)
24.8.20.411	—1.07	39.04	39.55	40.46	41.19	41.78
24.9.2.221	—2.46	51.24	52.16	52.88	53.80	54.48
24.9.2.421	0.00	50.75	b51.62	52.03	52.82	53.33
24.9.3.121	----	----	----	----	59.09	----
24.9.12.111	0.00	50.76	51.30	51.99	52.80	53.53
24.9.13.111	—1.00	19.21	19.68	20.76	22.03	22.67
24.9.13.112	0.00	49.09	49.57	50.18	(d)	----
24.9.23.211	—0.13	63.15	64.16	65.20	66.73	67.76

DEPTH TO WATER IN MIMBRES VALLEY, FEET BELOW LAND-SURFACE DATUM, IN JANUARY OF EACH YEAR, 1938-1942
(*continued*)

Group D. Observation wells in heavily pumped area east of Florida Mountains

Well location number	Correction	1938	1939	1940	1941	1942
24.7.4.424	—1.00	79.09	80.43	82.04	83.93	84.58
24.7.5.200	—0.50	(a)	76.20	77.58	79.00	b81.21
24.7.8.221	----	----	----	78.47	80.45	80.63
24.7.9.111	----	----	77.25	78.12	79.94	80.88
24.7.9.241	----	----	----	----	87.00	87.75
24.7.10.111	----	----	----	84.90	87.29	88.02
24.7.10.211	----	----	----	82.47	84.72	86.30
24.7.11.111	----	----	74.69	78.95	83.00	----
24.7.12.131	—2.25	66.98	(d)	----	----	----
24.7.12.311	—2.25	67.90	69.11	71.35	73.25	74.83
24.7.13.212	----	----	----	66.53	68.42	68.02
24.7.13.311	----	----	69.97	70.90	72.69	74.18
24.7.14.221	----	----	72.33	74.30	76.12	78.32
24.7.14.331	----	----	----	76.38	78.32	80.82
24.7.15.122	----	----	79.36	81.27	82.95	85.49
24.7.16.211	----	----	76.53	77.93	79.36	----
24.7.16.211b	----	----	----	----	----	81.08
24.7.21.222	----	----	----	70.19	71.50	72.55
24.7.24.111	----	----	----	69.79	71.14	72.44
24.7.24.211	----	----	----	----	69.86	68.82
24.7.24.312	----	----	----	----	68.60	69.62
24.7.26.113	----	----	----	----	68.62	72.19

DEPTH TO WATER IN MIMBRES VALLEY, FEET BELOW LAND-SURFACE DATUM, IN JANUARY OF EACH YEAR, 1938-1942 (*continued*)

Group E. Observation wells in lightly pumped areas south of Deming and southeast of Columbus

Well location number	Correction	1938	1939	1940	1941	1942
25.8.18.111	----	----	----	50.00	51.21	51.71
25.9.4.211	----	----	----	----	63.70	65.03
25.9.6.111	----	----	----	----	65.14	65.70
25.9.6.421	----	----	66.41	67.14	69.27	69.67
25.9.11.114	----	----	60.01	61.07	61.92	62.65
25.9.12.311	----	----	----	56.69	57.81	58.26
25.9.13.311	----	----	----	51.90	53.14	(d)
25.9.14.311	----	----	----	57.10	58.00	58.53
25.9.15.211	----	----	59.78	60.65	61.67	62.22
25.9.17.311	----	----	----	64.38	65.73	66.83
25.9.19.111	----	----	----	62.41	63.01	63.63
25.9.21.311	----	----	63.48	64.25	65.00	65.38
25.9.24.222	0.00	46.05	46.42	47.53	48.83	49.35
25.9.25.111	----	----	----	47.54	48.50	47.74
25.9.27.422	----	----	----	53.42	54.19	54.90
25.9.30.111	----	----	----	55.78	56.50	----
25.9.35.210	----	----	47.21	47.97	48.72	49.33
25.10.15.422	----	----	----	----	57.92	58.49
25.10.36.111	----	----	----	58.84	59.95	60.34
25.10.36.222	----	----	56.94	58.19	59.87	60.25
26.9.2.221	----	----	----	----	39.69	----
26.9.4.331	----	----	----	----	52.28	52.65
26.9.11.211	----	----	----	37.30	37.73	38.08
26.10.1.100	−0.50	(a)	(b)	58.02	58.47	59.27
27.8.8.411	----	----	----	24.29	23.50	23.45
27.9.2.211	----	----	----	15.51	17.17	11.17
29.7.4.111	----	----	----	----	4.71	----
29.7.18.211	----	----	----	----	0.50	6.45
29.8.12.244	----	----	----	----	7.11	7.13
29.8.13.111	----	----	----	----	6.49	6.44

a Unable to measure.

b Windmill pumping.

c Previous measuring point destroyed; new measuring point could not be accurately referred to old point. Possible discrepancy of a few tenths of a foot between preceding and succeeding record.

d Measurements discontinued.

e Well deepened causing rise in water level.

CONCLUSIONS

As stated in previous reports[17], the flow of ground water in Mimbres Valley before development of the water was begun was in an approximate state of dynamic equilibrium, that is, the natural discharge was equal to the natural recharge over a period of years. The pumping of wells is a new discharge imposed upon the aquifer, thus upsetting the equilibrium. Before equilibrium can again be reached, this new discharge must be balanced by either an equal increase in the amount of natural recharge, an equal decrease in the amount of natural discharge, or a combination of the two. Until a new equilibrium is established, water must be pumped from storage with a consequent fall in water levels. As a large increment of the recharge to the aquifer is dependent upon the frequency and size of the flows of the Mimbres River and tributaries and the rate that these flows can sink into the ground and be saved from evaporation, pumping will have no effect in increasing this natural recharge. A small additional recharge may be caused by seepage underground of the water applied on the lands for irrigation and of local rainfall in the area, but this amount is generally of minor importance.

The continuous records of water levels in observation wells, particularly those in the recharge area, Group A, and records of stream flow show that, except for 1941, there has been no large increment of recharge in the last 12 years. The exceptionally large rainfall of 1941 caused a significant rise in the water levels in the wells in Group A, especially in those wells located north of Black Mountain. The water level also rose in the irrigation district southwest of Deming and in other smaller areas during 1941, and the overall decline of the water level in the heavily pumped districts was not as great during 1941 as in previous years. However, despite the favorable reaction of water levels in 1941, the high water levels of 1941 and 1942 were considerably lower than those in 1930 and 1931 for corresponding wells.

These facts indicate that significant amounts of recharge to the aquifer can occur during years of exceptional rainfall such as in 1941, but such exceptional years occur infrequently and the recharge effects are likely to be offset by extremely dry years in the long run. Moreover, it seems that, for comparable years of precipitation and runoff, the recharge to the aquifer at present may possibly be less than before the development of pumping. More efficient use of the waters of the upper Mimbres River for irrigation has probably decreased to some extent the flood flows of the Mimbres River and thus reduced somewhat the recharge to the aquifer.

A small amount of discharge has been saved by the drying of Florida Lake[18] in sec. 1, T. 24 S., R. 7 W. but it does not seem probable that the natural discharge in other areas has been diminished by pumping.

It follows, therefore, that most of the water that has been pumped has been derived by depletion of the storage in the underground reser-

17. White, W. N., op. cit., (9th Bienn. Rept.), p. 148.
Theis, C. V., op. cit., (12th and 13th Bienn. Rept.), p. 151.
18. Theis, C. V., op. cit. p. 151.

voir. The water levels will continue a downward trend, probably as long as water is pumped and almost certainly for many years. The larger increments of recharge added in unusually wet years such as 1941 will cause a pause in the lowering of the water level in some areas, but the effects will probably be offset by further lowering of water levels in drier years. If the amount of pumping remains approximately the same the rate of lowering of the water levels from year to year will probably diminish somewhat, except possibly in the constricted reservoir east of the Little Florida Mountains. However, because of the time lag in producing interference between distant wells, the diminution in the rate of lowering may not become significant for several years, and additional use of water will almost certainly increase the rate of lowering.

As has been stated by White[19] and by Theis[20], no additional development of pumping plants should be undertaken in the heavily pumped areas, but a small amount of new development could be undertaken in lightly pumped areas.

Pumping of ground water causes a cone of depression in the water table whose boundaries continue to expand as time goes on. Locating of new wells in lightly pumped areas will not cause large drawdowns in the immediate future but in time such additional development will contribute to the drawdown caused by other wells.

The amount of rainfall in the Mimbres Valley is such that dry farming methods are not successful and lack of surface water supplies make it necessary that water for crops be obtained from wells. Therefore, the value of the crop land depends primarily on the availability of ground water at a cost that will permit a profit on the crops. Increase in the pumping lift causes an increase in the cost of water with a consequent decrease in the profit per acre. For these reasons the pumping of the ground water in the Mimbres Valley should be carried on in the most conservative manner.

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19 White, W. N., op. cit. (9th Bienn. Rept.), pp. 151, 152; (10th Bienn. Rept.), p. 183; (11th Bienn. Rept.), p. 125.

20. Theis, C. V., op. cit. (12th & 13th Bienn. Repts.), p. 152.