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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGY AND GROUND-WATER RESOURCES OF THE BALMORHEA AREA WESTERN TEXAS

Prepared in cooperation with the
TEXAS BOARD OF WATER ENGINEERS

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 849-C

UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary
GEOLOGICAL SURVEY
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BY
WALTER N. WHITE, HOYT S. GALE, AND S. SPENCER NYE

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GEOLOGY AND GROUND-WATER RESOURCES OF THE BALMORHEA AREA, WESTERN TEXAS

By WALTER N. WHITE, HOYT S. GALE, and S. SPENCER NYE

ABSTRACT

Balmorhea is the center of a thriving farming community, the lands of which are irrigated with water derived chiefly from large springs but partly from the storm flow of Toyah Creek. The storm flow of the creek and a part of the winter flow of the springs is stored in a reservoir near Balmorhea and used later to supplement the flow of the springs. The present investigation was made to determine the geologic and hydrologic relations of the springs, whether additional water can be obtained from wells, and what effect the withdrawal of large amounts of water from wells would have upon the discharge of the springs.

Balmorhea is situated near the foot of the Davis and Barrilla Mountains and along the southwestern margin of the Toyah Basin. The mountains and adjacent basin are drained by Toyah and Limpia Creeks. The group of springs around Balmorhea occur in the floor of the valley of Toyah Creek. They have been divided into artesian springs—Phantom Lake, Giffin and San Solomon Springs; and gravity springs—Toyah Creek, Saragosa, East Sandia and West Sandia Springs. The combined discharge of the springs during dry years is about 23,000 gallons a minute, of which amount the artesian springs supply more than 90 percent.

The underground reservoir which supplies the artesian springs is the fractured and cavernous Lower Cretaceous limestone. This limestone, about 500 feet thick, is underlain by impermeable rocks, probably of Permian age, and is overlain by impermeable Upper Cretaceous strata that have a maximum thickness of about 500 feet. These are in turn overlain in the mountains by Tertiary lava and on the plains by gravel and other surficial deposits. The Lower Cretaceous limestone is at the surface or covered by a thin layer of gravel in a belt that lies athwart the stream channels and extends from Gomez Peak southeastward along the foothills of the Davis Mountains. In this belt all the streams suffer heavy seepage losses. From this belt the limestone dips gently northeastward to the axis of a northwestward-trending syncline and then rises to the surface in the vicinity of Phantom Lake, where a part of the water is discharged. About 1,000 feet northeast of this lake is a northwestward-trending fault of small displacement, on the northeast side of which the limestone is downthrown. Northeastward from this fault the limestone rises gently and appears at the surface about a mile to the northeast, where it is again downfaulted, but the throw is not sufficient to affect the movement of the water. For several miles to the north the water-bearing Lower Cretaceous limestone is covered by 400 to 500 feet of impermeable Upper Cretaceous strata.

It is believed that the Lower Cretaceous rocks are again near the surface and covered by only a thin mantle of gravel and other surficial deposits at San Solomon and Giffin Springs and that just northeast of the springs a fault crosses the valley along which the impermeable Upper Cretaceous rocks are faulted into a position opposite the Lower Cretaceous rocks, thus obstructing further northward movement of the water in the Lower Cretaceous limestone and forcing it to issue as large springs.

Between this fault and Brogada the Lower Cretaceous rocks are believed to lie at a depth of about 500 feet and are overlain by Upper Cretaceous strata and a blanket of gravel and other surficial deposits, which are the source of the water of Toyah Creek, Sandia, and Saragosa Springs. Northeast of Brogada the Lower Cretaceous lies at a greater depth, and the mantle of gravel is much thicker.

Wells put down to the limestone in the vicinity of San Solomon and Giffin Springs would decrease the flow of the springs. The effect of wells in limestone between the fault near these springs and the Brogado Hills on the flow of the springs would depend on the completeness with which the fault cuts off northward movement of ground water in the limestone. If the movement of water across the fault has been prevented, the limestone may be nearly impervious and the water in it may be highly mineralized. Wells in the surficial gravel near Balmorhea may yield a few second-feet of water, but such wells may deplete the flow of Toyah Creek, Saragosa, or Sandia Springs. Wells in the Saragosa district, north of Brogada Hills, would probably encounter the limestone at 1,000 to 1,200 feet. The yield of such wells cannot be predicted but they would not be expected to interfere with the springs.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

Balmorhea is the center of a thriving farming community the lands of which are irrigated with water derived, for the most part, from large springs. During prosperous years the total area under irrigation has been about 10,000 acres. In 1932, a year of depression and low prices, the area irrigated was estimated at about 7,000 acres. The Reeves County Water Improvement District No. 1, a cooperative organization, made up of the owners of most of the farms in the area, has a reservoir (see pl. 11 and fig. 3) that is used to store a part of the winter flow of the springs, together with floodwaters of Toyah Creek when such waters are available. The reservoir originally had a capacity of about 6,000 acre-feet, but silting has reduced its capacity, so that a considerable part of the floodwater and of the winter flow of the springs passes the reservoir. As a result there is a shortage of water during the late summer and fall in years when the irrigated acreage is large. The shortage is not serious enough to result in destruction of the crops, but it is sufficient to reduce the yield from some of the lands.

The community would be materially benefited if water could be withdrawn by wells from the natural underground reservoirs without depleting the flow of the springs. The shortage during the later part of the irrigation season would thereby be relieved, and additional lands might be irrigated. On the other hand, if the operation of wells should materially reduce the flow of the springs the community would suffer serious loss—a loss that might be irreparable if the wells were put down by outside interests for the irrigation of new lands and the owners of the springs had no recourse.

The chief purpose of the investigation in the Balmorhea district, therefore, was to obtain information that will throw light on this problem. A necessary part of the investigation was the compiling of an authoritative record of the flow of the springs, which will serve as evidence, if necessary, to protect the rights of the owners of the springs.

The field work was done chiefly in the years 1931–33. The geology of the Davis and Barrilla Mountains and the Balmorhea district was studied. Weirs and automatic water-stage recorders were maintained for about 2 years on Phantom Lake, San Solomon, Giffin, West Sandia, and East Sandia Springs, by means of which continuous records were obtained. Gages were installed on Limpia Creek and the streams in Cherry, Madera, Big Aguja, and Little Aguja Canyons, and a water-stage recorder was maintained in Madera Canyon. Several series of measurements were made with current meters along these streams in order to determine losses by seepage and gains by ground-water inflow in several relatively short stretches. Discharge measurements were made to determine losses by seepage from the main canal and laterals of the Reeves County Water Improvement District No. 1. The water table in the valley of Toyah Creek near Balmorhea was mapped. The depths to the water levels in 13 selected shallow wells were measured monthly and sometimes weekly for nearly two years, and a water-stage recorder was maintained on one of the wells for about 1½ years. Analyses were made of the waters of the large springs.

In general, the parts of this report dealing with geology were prepared by Hoyt S. Gale, and the parts dealing with ground water conditions by Walter N. White and S. Spencer Nye. Preliminary studies of the geology and ground water conditions of this area and the surrounding region were made by S. S. Nye. Most of the measurements of the flow of the springs and streams were made by V. W. Rupp. The investigation was conducted under the general direction of O. E. Meinzer, geologist in charge of the Ground Water Division of the Geological Survey.

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The writers are indebted to H. P. Bybee, of the University of Texas, and to P. B. King, of the Geological Survey of the United States Department of the Interior, for geologic data supplied by them and for their helpful criticism, and to J. J. Bayles, in charge of the Texas Agricultural Farm near Balmorhea, for climatologic and other data. Special acknowledgments are due the board of directors of the Reeves County Water Improvement District No. 1 for their cooperation. Mr. A. C. Shreyer gave valuable assistance and advice. Mr. Edgar George and Mr. T. M. Delaney gave efficient assistance in the field and otherwise expedited the investigation.

TOPOGRAPHY AND DRA NAGE

Balmorhea has an altitude of about 3,200 feet. It is situated on the southwestern margin of the Toyah Basin outwash plain, on Toyah Creek, near the foot of the Davis and Barrilla Mountains (see fig. 3). These mountains are characterized by flat tops, steep slopes, and narrow V-shaped canyons. Most of the summits of the Davis Mountains are 5,000 to 6,000 feet above sea level, but Star Mountain and Timber Mountain, two of the most conspicuous flat-topped mountains in this part of the range, rise to 6,350 and 6,442 feet, respectively. The highest peak in the Barrilla Range reaches an altitude of 5,560 feet. The surface between the mountains and Balmorhea and around Balmorhea is broken by several low ridges or isolated hills. These include a ridge or line of low hills between Balmorhea and the Davis Mountains, which is parallel to the front of the mountains, and a narrow northwest-southeast ridge about 3 miles long east of Balmorhea, which is known as the Brogada Hills. The mountains and adjacent plain are drained by Toyah Creek, which is formed about 6 miles southwest of Balmorhea by the junction of streams flowing from Big Aguja, Little Aguja, and Madera Canyons. Toyah Creek at times carries great quantities of storm water, but generally it is dry except for a short stretch of about 4 miles near Balmorhea, in which there is a perennial flow of spring water. Most of the storm water is diverted near Balmorhea into a reservoir belonging to the Reeves County Water Improvement District No. 1. During heavy floods a part of the water passes the reservoir diversion dam and either seeps into the gravels of the outwash plain or empties into Toyah Lake, which is about 30 miles to the north. The adjacent area on the north is drained by a creek flowing from Cherry Canyon and that on the south by Limpia Creek, which in part of its course is called Barrilla Draw. Both have perennial flow in the mountains but lose their water soon after reaching the foothills. Both carry large amounts of floodwater at times.

The Toyah Basin is noted for its two groups of large springs, one of which is located near Balmorhea and the other near Fort Stockton. The Balmorhea group consists of six springs, or groups of springs, that appear at irregular intervals in the floor of the valley of Toyah Creek, called Phantom Lake, San Solomon, Giffin, Saragosa, West Sandia, and East Sandia Springs, and another minor group of springs and seeps that rise in the bed of Toyah Creek. The location of all these springs is shown on plate 11 and on figures 3 and 4. San Solomon Spring, Phantom Lake Spring, and Giffin Spring rise from a vast reservoir in cavernous limestone. The others have their source in relatively shallow sand and gravel and are essentially water-table springs.

The springs have a combined discharge of about 23,000 gallons a minute during dry years and a much larger discharge during wet years. Measurements of the discharge of all the springs are given on pages 121–144.

CLIMATE

The climate of Balmorhea and the adjacent region is semiarid, and in most years farming cannot be carried on successfully without irrigation. In summer the days are hot but the nights are cool. The winters are comparatively mild, but killing frosts are not uncommon between November and March.

The United States Weather Bureau has obtained records of precipitation at the State Agricultural Experiment Station, near Balmorhea, since 1923; at Fort Davis, 30 miles south of Balmorhea, during 55 years since 1857; and at Fort Stockton, 50 miles east of Balmorhea, during 60 years since 1870. The average annual precipitation during the periods of observation down to 1936, inclusive, was as follows: Balmorhea, 13.43 inches; Fort Davis, 16.51 inches; and Fort Stockton, 14.89 inches.

In most years between 1924 and 1936 the precipitation at the three stations showed a similar trend, but there were exceptions to that general rule. For example, in 1933 the precipitation was about the average at Fort Stockton, but it was much below the average at Balmorhea and at Fort Davis; in 1936 it reached well above the average at Fort Davis and about the average at Balmorhea, but it was below the average at Fort Stockton. If the long-time records at Fort Davis and Fort Stockton are accepted as a basis for estimate, it would appear that the average annual precipitation at Balmorhea from 1924 to 1936 did not differ materially from the long-time average in that vicinity but that the proportion of very dry years, namely 4 out of 13, was unusually high. Exceptional years in the Balmorhea record were 1932, with a precipitation of 28.15 inches; 1933, with only 6.43 inches, and 1934, with 3.89 inches.

The precipitation in the Davis Mountains averages considerably higher than that at Balmorhea, but no accurate information is available from which a comparison can be made. Some pine timber is found on the tops of the mountains, notably on Timber Mountain, but the mountain vegetation in general consists of cedars and brush and shrubs that are common to semiarid regions. The rain storms, particularly in summer, are erratic. Rain often falls in the mountains when none falls at Balmorhea, and sometimes the opposite occurs.

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At times rain falls on a part of the mountains and produces a run of storm water in one canyon, while in adjacent areas the canyon streams remain dry.

The following tables, taken from the records of the United States Weather Bureau, give the annual precipitation at Fort Davis from 1855 to 1860, from 1870 to 1890, and from 1902 to 1936; the annual precipitation at Fort Stockton from 1870 to 1886 and from 1894 to 1936; the monthly precipitation at Balmorhea from October 1923 to December 1936; and the daily precipitation at Balmorhea from September 1931 to September 30, 1933.

Annual precipitation, in inches

Fort Davis, Jeff Davis County, Tex.

Year	Precipitation	Year	Precipitation	Year	Precipitation
1855	21.21	1883	14.22	1919	20.22
1856	25.94	1884	22.56	1920	23.11
1857	19.82	1885	14.22	1921	10.10
1858	14.12	1886	12.64	1922	12.33
1859	22.55	1887	18.50	1923	18.17
1860	8.52	1888	18.11	1924	14.14
1870	12.67	1889	11.34	1925	16.65
1871	6.78	1890	18.34	1927	13.09
1872	10.01	1902	14.95	1928	14.30
1873	16.29	1903	12.39	1929	14.03
1874	20.10	1904	20.19	1930	15.80
1875	27.68	1905	23.13	1931	15.54
1876	23.92	1912	12.93	1932	25.56
1877	16.16	1913	18.82	1933	11.73
1878	15.43	1914	23.95	1934	9.40
1879	21.41	1915	11.98	1935	10.87
1880	23.48	1916	10.10	1936	20.37
1881	27.54	1917	9.35		
1882	20.22	1918	14.30	Average	16.51

Fort Stockton, Pecos County, Tex.

Year	Precipitation	Year	Precipitation	Year	Precipitation
1870	18.58	1898	7.29	1919	24.79
1871	5.88	1899	10.22	1920	21.39
1872	12.99	1900	19.58	1921	10.32
1873	11.20	1901	10.17	1922	12.11
1874	13.90	1902	11.42	1923	18.83
1875	16.78	1903	12.00	1924	9.82
1876	12.45	1904	15.97	1925	20.43
1877	13.00	1905	20.65	1926	18.32
1878	12.47	1906	19.27	1927	12.12
1879	5.12	1907	12.01	1928	18.80
1880	33.76	1908	12.31	1929	16.30
1881	12.65	1909	11.27	1930	9.00
1882	25.56	1910	4.07	1931	15.97
1883	27.39	1911	20.24	1932	24.61
1884	24.07	1912	10.31	1933	14.63
1885	20.02	1913	13.11	1934	6.87
1886	9.84	1914	22.88	1935	10.12
1894	10.73	1915	13.92	1936	12.75
1895	27.70	1916	7.95		
1896	16.33	1917	5.68	Average	14.89
1897	11.21	1918	14.54		

Monthly precipitation, in inches, at Balmorhea, Reeves County, Tex., 1923–36

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1923	----	----	----	----	----	----	----	----	0.90	1.48	1.48	2.17	----
1924	Tr.	1.98	0.33	0.46	0.02	Tr.	1.50	0.21	2.64	1.74	Tr.	0.23	9.11
1925	Tr.	.00	.00	2.22	1.43	.13	2.13	3.73	2.27	2.65	Tr.	.09	14.65
1926	.60	.00	1.68	.75	1.50	1.36	2.60	2.68	2.09	2.69	.74	1.62	18.31
1927	.13	.44	.63	Tr.	.37	.54	.94	.46	3.74	.37	.00	.58	8.20
1928	.01	.12	.03	.39	1.33	.66	4.97	4.62	3.06	.93	.64	.12	16.88
1929	.00	.77	.93	.84	1.28	1.33	.59	.92	2.13	1.81	.33	.23	11.16
1930	.32	.16	.47	1.50	.93	4.87	.72	2.82	.47	1.98	.85	.73	15.82
1931	1.13	.90	.89	3.47	1.35	1.69	1.25	1.47	.43	.21	.86	2.25	15.90
1932	.48	3.79	.58	.45	2.19	.48	1.55	3.60	11.64	1.20	Tr.	2.19	28.15
1933	.08	.61	Tr.	.03	.22	.42	.60	1.09	.92	2.20	.23	.03	6.43
1934	.39	.07	.29	.32	.23	1.03	.52	.81	.14	Tr.	.08	.01	3.89
1935	Tr.	.71	Tr.	.45	1.58	.97	.50	3.20	2.57	1.06	.34	1.95	12.43
1936	.54	.00	.82	.09	2.65	.48	.95	.59	5.15	.56	1.81	.11	13.75
Average	.28	.73	.55	.85	1.16	1.07	1.45	2.01	2.72	1.34	.52	.87	13.43

Rainfall, in inches, at Balmorhea, Tex., Oct. 1, 1931, to Sept. 30, 1933

1931	Inches
Oct. 11	0.06
Oct. 12	.09
Oct. 13	.06
Total	.23
Nov. 16	.03
Nov. 17	.21
Nov. 25	.01
Nov. 26	.05
Nov. 30	.56
Total	.86
Dec. 1	.92
Dec. 2	.15
Dec. 7	.47
Dec. 8	.12
Dec. 17	.15
Dec. 18	.44
Total	2.25
1932	
Jan. 4	.03
Jan. 11	.34
Jan. 15	.08
Jan. 22	.03
Total	.48
Feb. 14	.13
Feb. 15	.37
Feb. 17	.03
Feb. 18	.17
Feb. 19	.40
Feb. 20	.75
Feb. 21	1.06
Feb. 22	.80
Feb. 23	.08
Total	3.79
Mar. 2	.01
Mar. 4	.38
Mar. 5	.14
Mar. 12	.05
Total	.58

1932	Inches
Apr. 26	0.27
Apr. 27	.18
Total	.45
May 10	.33
May 11	.34
May 14	.14
May 16	.03
May 24	.48
May 25	.35
May 27	.10
May 29	.40
Total	2.19
June 19	.20
June 22	.28
Total	.48
July 3	.17
July 4	.14
July 7	.70
July 8	.08
July 9	.03
July 10	.07
July 22	.26
July 26	.05
July 30	.05
Total	1.55
Aug. 7	.21
Aug. 8	.04
Aug. 9	.12
Aug. 12	.20
Aug. 18	.16
Aug. 26	.07
Aug. 27	.03
Aug. 29	.05
Aug. 30	2.72
Total	3.60
Sept. 2	1.03
Sept. 3	.05
Sept. 4	2.63
Sept. 5	.10
Sept. 6	.39

1932	Inches
Sept. 7	1.83
Sept. 8	.44
Sept. 19	.01
Sept. 22	.26
Sept. 23	.16
Sept. 24	.03
Sept. 25	.13
Sept. 26	.44
Sept. 27	.02
Sept. 28	.35
Sept. 29	3.30
Sept. 30	.47
Total	11.64
Oct. 1	.07
Oct. 2	.07
Oct. 10	.05
Oct. 13	.39
Oct. 14	.19
Oct. 15	.01
Oct. 20	.09
Oct. 21	.28
Oct. 25	.05
Total	1.20
Nov.	[1]
Dec. 9	.13
Dec. 10	.05
Dec. 14	.34
Dec. 15	.13
Dec. 17	.07
Dec. 22	.07
Dec. 23	.91
Dec. 29	.03
Dec. 30	.46
Total	2.19
1933	
Jan. 7	.06
Jan. 8	.02
Total	.08

1933	Inches
Feb. 8	0.05
Feb. 25	.28
Feb. 26	.28
Total	.61
Mar.	[1]
Apr. 25	.03
May 17	.08
May 24	.04
May 25	.10
Total	.22
June 2	.13
June 13	.05
June 19	.05
June 29	.19
Total	.42
July 17	.09
July 18	.27
July 19	.18
July 31	.06
Total	.60
Aug. 2	.02
Aug. 12	.09
Aug. 16	.04
Aug. 24	.08
Aug. 26	.04
Aug. 27	.06
Aug. 28	.04
Aug. 29	.58
Aug. 30	.13
Aug. 31	.01
Total	1.09
Sept. 1	.75
Sept. 2	.01
Sept. 9	.05
Sept. 13	.04
Sept. 14	.07
Total	.92

[1] Trace.

GENERAL GEOLOGY

The rocks exposed in the vicinity of Balmorhea comprise Lower and Upper Cretaceous marine sediments, Tertiary volcanic deposits and lava flows, and Quaternary alluvial deposits. The Cretaceous sediments are probably underlain by a succession of Triassic, Permian, and older strata that are exposed in adjoining areas, particularly in the Delaware and Guadalupe Mountains to the northwest and in the Glass Mountains and Marathon area to the southeast. The occurrence of these rocks has been extensively studied in recent years by geologists working for the various oil companies, and a large amount of information has been published concerning them. This material and field study centering in the Toyah Basin, including the Balmorhea area, made by Mr. Gale in the spring and fall of 1932 and a part of the spring of 1933 provide the basis for the following summary of the geology of the area.

LOWER CRETACEOUS ROCKS

The big springs of Balmorhea and Fort Stockton are believed to have their source in an extensive network of fissures and solution passages in limestones of the Comanche series of Lower Cretaceous age, which are the oldest strata exposed near Balmorhea. The Comanche section includes, besides the limestones, interbedded calcareous shale and a basal unit composed of sand or sandstone, at places containing gravel, which, although not exposed near Balmorhea, is found in outcrops near Kent to the northwest and in the foothills of the Glass Mountains near Hovey to the southeast. The limestones are mainly massive, thick-bedded, and very fossiliferous. They weather characteristically to dark-colored craggy or solution-rounded ledges and low rolling to hilly topography.

The total thickness of the Lower Cretaceous at Balmorhea is not known, because the base of the series is not exposed near that place and, so far as is known, none of the wells that have been drilled in the area have penetrated the series. Near Fort Stockton, east of Balmorhea, it has been shown that the maximum thickness of the series is about 600 feet, and near Limpia postoffice, 16 miles due south of Balmorhea, a deep well passed through about 700 feet of Lower Cretaceous rocks. It is believed that the Lower Cretaceous thins toward the northwest and that in the vicinity of Balmorhea the series is approximately 500 feet thick.

The uppermost limestone of the Lower Cretaceous series is well exposed near Phantom Lake Spring in a ridge that extends northwest from the spring along the south side of the Old Spanish Trail Highway. This limestone contains several "sinks" or deep, cavernous channels and crevices in this general vicinity, and from one of these crevices emerges the water that feeds Phantom Lake. The section is repeated in a parallel ridge on the north side of the highway by a fault that passes near the spring (see pl. 11). This area of outcrop of the Lower Cretaceous extends almost continuously from these exposures to and beyond the Texas & Pacific Railroad at San Martine in a gradually broadening band that is structurally a faulted anticline plunging toward the southeast. A second faulted anticline, parallel to the front of the Davis Mountains and to the first-mentioned anticline, passes through the summit of Star Mountain and brings the limestone to the surface again in a large area in the hills at the foot of the steep slope east of Gomez Peak (see fig. 4). This anticline has been carved by erosion into a broad valley, which is adjacent to the steep front of the mountains and lies athwart the courses of all the streams from Cherry Creek to Aguja Creek. The anticline plunges to the southeast, and the Lower Cretaceous limestone finally disappears beneath the stream deposits that underlie the surface in most places in the valley. The southeasternmost exposure of the Lower Cretaceous along this anticline is found in a small outcrop in the channel of Madera Creek 5 or 6 miles southwest of Phantom Lake Spring, where the creek crosses the axis of the anticline. Cherry, Madera, Aguja, and Little Aguja Creeks and other smaller streams that cross the anticline lose much of their water or disappear altogether into the gravel. It is believed that this water passes through the gravel and enters the Lower Cretaceous rocks that doubtless immediately underlie the gravel a part of the way across the anticlinal valley.

There is an extensive exposure of Lower Cretaceous limestone southeast of Balmorhea and east and southeast of the Barrilla Mountains in an area that is crossed by Limpia Creek and other streams from the north slope of the Davis Mountains. Limpia Creek disappears entirely during moderate or low stages in that part of its course and in a stretch underlain by gravels immediately above the outcrop. The Lower Cretaceous is also exposed in an area in the center of the main anticline of the Barrilla Mountains southeast of Balmorhea and may take in considerable water there.

UPPER CRETACEOUS ROCKS

The Upper Cretaceous rocks in this area are mostly of clayey composition, but they include some limestones in the lower part of the series that may be subject to solution channeling. On the whole, the rocks of this series are relatively impermeable and serve as an effective confining layer for the water that gets into the underlying Lower Cretaceous strata. In localities where they have been dropped down by faulting and lie against the Lower Cretaceous rocks they may serve as a barrier and cause the water to rise to the surface as springs. It appears that such structure is responsible for the large springs near Balmorhea.

The Upper Cretaceous series in this region has a thin-bedded flaggy or hard platy limestone at the base, which weathers to a noticeably rusty-red and yellow color on exposure. When freshly broken most of this limestone is chalky-white in color, and most hillsides formed on it are covered by dense, flaggy slabs that ring when struck with a hammer. Somewhat higher in the section these beds become more thinly stratified and shaly, and some of the massive limestone weathers into chips like a shale but retains in the chips the firmness of a dense white limestone.

Above the limestones of Upper Cretaceous age near Balmorhea is a considerable thickness of clay, described as blue clay by drillers when it is fresh and below the zone of weathering. In some exposures the weathered surface is soft and ochre yellow in color. This material, being nonresistant to erosion, forms featureless valleys in places where it is unprotected by a capping of harder rocks. It is usually covered in the valleys by an overwash of later detritus and on steep hillsides by talus and landslides from the hard rocks above.

Exposures of Upper Cretaceous strata that are relatively limited in area may be seen at several places between Balmorhea and the Davis Mountain front. The beds are most prominently exposed immediately beneath the lavas on the steep front of the Davis Mountains and in the foothills, and there are several extensive exposures in the broad anticlinal valley extending from Star Mountain nearly to Gomez Peak. An exposure in which the Upper Cretaceous series in normal sequence is most nearly complete is found high on the slope on the east side of Gomez Peak under the steep escarpment, but even here the soft clay beds are much obscured by slides and talus of the hard rock from the ledges above. Another exposure of these beds is found in the west half of sec. 15, block 13, H. and G. N. R. R. survey, a little more than a mile northeast of Phantom Lake, but this section is far from complete. A good exposure of the clay that overlies the limestone in the lower part of the Upper Cretaceous is found in a cut on the north bank of Toyah Creek about a mile and a half west of Balmorhea.

The thickness of the Upper Cretaceous series has not been determined in the vicinity of Balmorhea. The section exposed on the steep front of Gomez Peak indicates that the series is probably at least 500 feet thick, and it may be thicker beneath some of the valleys. Two wells, each approximately 400 feet deep, at Balmorhea, are reported to have penetrated clay and shale to their full depth. A well 600 feet deep about 20 miles southeast of Balmorhea, in the valley of Limpia Creek at the east end of the Barrilla Mountains, is reported to have gone through blue clay, probably all of Upper Cretaceous age, all the way. The east end of these mountains, however, has a synclinal structure, and the Upper Cretaceous beds may be uncommonly thick in the area. The evidence suggests a thickness of at least 500 or 600 feet in most places, but it may be considerably more than 600 feet in other places.

TERTIARY VOLCANIC ROCKS

After the deposition of the Cretaceous rocks in this region there was a withdrawal of the seas and slight folding of the previously deposited strata, then the rocks were subjected to considerable erosion.

Volcanic rocks having a total thickness of 1,500 to 2,000 feet were laid down on the eroded surface of the Upper Cretaceous rocks during early Tertiary time. These rocks form the capping of the Davis and Barrilla Mountains and of many ridges and hills on their flanks. They were probably originally spread far beyond their present area of outcrop but have been removed from many parts of the area by erosion. The lowest bed of the volcanic succession is generally white tuff or ash, indicating that the first volcanic eruptions were of the explosive type. Above the basal tuffs is a widespread bed of volcanic breccia, composed of angular fragments of the volcanic rock in a matrix of lava. The breccia is overlain by lava flows of rhyolitic composition. Above these are beds of tuff and at least two flows of lava, which are of trachytic composition. The different parts of the series are so closely related that they are probably the product of a single cycle of volcanic activity.

As the volcanic rocks form the summits of the Davis and Barrilla Mountains, they occupy a belt that receives rainfall greater than that of the adjoining lowlands. Much of the lava is exceedingly porous, because it is fractured and jointed, and some of it is slaggy and naturally full of cavities. It thus absorbs much of the water that falls on it. Some of the layers of tuff are claylike and impermeable, so that water descending through the overlying permeable lavas does not pass through them but flows along their surfaces to emerge in springs along their outcrops. In general, the volcanic rock rests on the impervious clays of the Upper Cretaceous, and where this contact lies above the gradient of the main drainage channels, as it does in many places, most of the water absorbed by the volcanic rocks is again fed into the surface drainage or stream and terrace gravels within the mountain area. The volcanic series dips below stream gradients in certain structurally depressed areas, and it is likely that where this occurs the porous lava forms large reservoirs for the accumulation and storage of ground water below the level of the streams. The water thus stored is probably prevented from penetrating directly to the Lower Cretaceous limestone by the relatively impermeable basal volcanic tuff and Upper Cretaceous clay. In some localities, however, it may eventually reach the limestone by first rising into the streams or into the gravels underlying them and then moving downstream to structurally high areas in which the gravels lie directly on the limestone. The largest of these structural depressions near Balmorhea is on the axis of a long syncline extending from Limpia Creek, at the place where the creek flows between the Davis and Barrilla Mountains, northwestward beyond the valley of Cherry Creek.

After the extrusion of the lava in the Davis Mountain region, and presumably while its surface was being eroded, the region was subjected to gentle deformation, which produced a series of broad folds involving the lavas and underlying rocks. The area of the volcanics seems to have been depressed somewhat, perhaps in a partial compensation for the weight of the lava masses. This deformation took place in mid-Tertiary, and perhaps in Miocene time.

LATE TERTIARY, PLEISTOCENE, AND RECENT ALLUVIAL DEPOSITS

Gravels and alluvial deposits overlie the bedrock in the lowlands northeast of the Davis Mountains. Available records of water-well drilling in the Balmorhea area show that the gravels in a few places are 50 feet deep or slightly deeper but that in most places they are 15 to 25 feet deep. In places the Cretaceous bedrock is exposed at the surface and the gravel is absent.

GEOLOGIC STRUCTURE AND ITS RELATION TO THE OCCURRENCE OF THE GROUND WATER

In the foregoing summary of the geology references have been made to the distribution of the rock formations about Balmorhea and to the geologic structures in which these formations are involved. The accompanying areal geologic map and profile showing the structure (see pl. 11) are drawn to the same vertical and horizontal scales, and if the interpretations are correct they should give a true picture of the position and attitude of these formations on the surface and underground.

The profile section follows a line drawn from the triangulation monument on the prominent lava hills about 2 miles southwest of Phantom Lake Spring in a northeasterly course approximately transverse to the main structural lines of the district.

The distribution of the rocks, which nearly everywhere are covered by gravels and other surface formations, is interpreted from the geologic map of the available outcrops and the structure indicated by them. The thickness of the Upper and Lower Cretaceous is taken as 500 feet for each, which is probably within about 100 feet of their true thickness.

EXPLANATION

Tertiary volcanics
(Lava flows, tuffs, and breccia)

Upper Cretaceous sediments
(Clay, shale, and limestones)

Lower Cretaceous limestone

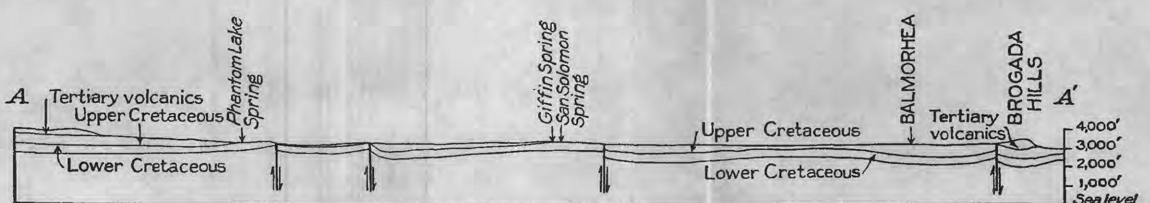
Spring

Fault
U *upthrow*
D *downthrow*

Anticline and pitch of axis

Syncline

Strike and dip



Section along line A-A'

1 0 1 3 MILES

GEOLOGIC MAP AND SECTION OF BALMORHEA AREA, TEXAS, SHOWING THE RELATIONS BETWEEN THE LARGE SPRINGS AND THE GEOLOGIC STRUCTURE.

There is an unconformity between the Upper Cretaceous series and the overlying lavas, the Cretaceous rocks having been folded into gentle anticlines and synclines and extensively eroded in the epoch between the withdrawal of the Upper Cretaceous sea and the deposition of the Tertiary lavas. Therefore it cannot be predicted which part of the Cretaceous series will be found immediately beneath the base of the lavas in any particular locality.

Both lava flows and Cretaceous strata were involved in folding subsequent to the distribution of the lava, but this is relatively insignificant in the small section of these beds included in the diagram. The faulting to which the whole section has been subjected and which is an important feature in the section is believed to have taken place in early Pleistocene time and to have affected all the rocks in the area except such Pleistocene gravels or alluvium as have accumulated since that deformation. Aside from the permeability of the strata themselves, the geologic structure is undoubtedly the controlling factor that determines the movement of the water underground and the existence and location of the big springs.

The principal area of intake of the water discharged by the springs is apparently in the anticlinal valley adjacent to the steep front of the Davis Mountains (see p. 91 and fig. 4), where a large part of the flow of the mountain streams disappears into Lower Cretaceous limestone or into stream gravels that overlie the limestone. The limestone dips to the northeast from the axis of the anticlinal valley to the axis of a major northwest-southeast trending syncline and then rises to the surface in the vicinity of Phantom Lake Spring. The axis of the syncline is marked by a range of volcanic hills, a part of which is shown in the lower left corner of plate 11. In this syncline the base of the Lower Cretaceous probably sinks to a depth of 1,000 to 1,200 feet or more below the major stream grades. The water probably fills the limestone in this syncline to the height of its confining rim on the northeast and is brought to or near the surface at the outcrop of the reservoir beds in the vicinity of Phantom Lake. About 1,000 feet northeast of Phantom Lake there is a clearly defined fault, on the south side of which the Lower Cretaceous strata have been tilted up steeply and on the north side of which the whole section has been dropped down, bringing relatively impermeable Upper Cretaceous strata against the Lower Cretaceous limestone. The Upper Cretaceous rocks on the north side of this fault may thus constitute an underground barrier to the passage of ground water at this place and cause the water to rise to the surface in Phantom Lake Spring. The spring emerges in a channel developed by solution along a fissure in the massive limestone that extends underground below the present water surface. Phantom Lake stands over a sink hole where the limestone has fallen in, but there is no evidence of faulting at the lake. The course of surface drainage below Phantom Lake is in approximately the same direction as the line of the structure section.

Immediately northeast of the Phantom Lake fault the strata rise gently toward the surface in the same manner as near Phantom Lake. This rise might have a general tendency to bring the water up again, or such part of it as sinks in this fault block, but it is again interrupted by a fault, the surface trace of which is obscured but is believed to lie almost a mile northeast of Phantom Lake (see pl. 11).

The structure is shown in conspicuous outcrops in the channel of the stream from Phantom Lake about 1½ miles northeast of the spring and about 1,000 feet north of the Old Spanish Trail Highway. At this place the upper part of the Upper Cretaceous lies at the surface and is capped by a remnant of Tertiary lava. Therefore the area is structurally low.

No evidence of irregularities is known between this outcrop and the vicinity of Toyahvale and San Solomon and Giffin Springs. The broad, relatively level alluvium-covered area that extends many miles both northwest and southeast from Toyah Creek in this part of the district is evidently eroded on the little-resistant clays of the upper part of the Upper Cretaceous section.

The valley within a radius of a mile of San Solomon and Giffin Springs is covered everywhere with a mantle of gravel or other detritus, but a clue as to the probable character of the structure in their vicinity is afforded by the evidence on the south slope of the lava hills that project into the valley about a mile east of the springs. It is believed that the straight line that bounds the southwestern side of the mass of volcanic rocks that extends northwestward from the Barrilla Hills marks the trace of a fault. On the southwest side of this fault the Lower Cretaceous limestone is believed to be near the surface, and on the northeast side the Upper Cretaceous clays are again faulted down against the water-bearing limestone. The springs themselves are fair evidence of this. The inferred relations are shown by the structure section.

The basin between the fault near San Solomon Spring and the Brogada Hills, which is the part of the valley in which Balmorhea is situated, is mostly if not entirely underlain at shallow depth by the clay of the Upper Cretaceous section. There is evidence of this fact in a number of outcrops, and this general structure is also indicated in the regional relations. In this part of the valley the top of the Lower Cretaceous rocks probably is about 500 feet below the surface. At the western foot of the Brogada Hills there is considerable disturbance of the beds, and the fact that they are composed of Tertiary lava indicates that these hills are a down-faulted block along the southwest side of which impermeable Upper Cretaceous rocks are faulted against the Lower Cretaceous limestone. If this assumption is correct the fault has produced a more or less effective barrier to the northeastward movement of underground water in the limestone in this area.

The extensive plains that lie east of the Brogada Hills are developed, so far as present evidence shows, on a broad structurally depressed area that begins at the west with the syncline in the lava shown in the Brogada Hills. There is a reasonable probability that the fault line bounding these hills on the southwest separates the Balmorhea Basin from the ground-water basin east of the Brogada Hills. Evidence of this is seen in the fact that so much of the ground water of the upper basin has been brought to the surface above this line of displacement. The ground water in the lower or Saragosa Basin is probably derived in part from the overflow from the Toyah Creek drainage system, in part from the northern flanks of the Barrilla Mountains, and possibly in large part from the Lower Cretaceous limestone near the center of the Barrilla Mountains, where it may be close enough to the surface to receive water through the gravels from surface streams.

The blanket of gravel that underlies the Saragosa plains is thicker than the gravel in the Balmorhea Basin. According to general reports of water wells that have been drilled, it seems that this thickening takes place abruptly near the settlement of Brogada and increases eastward. The Saragosa Basin is filled with a coarse impermeable boulder conglomerate. Water wells sunk through this upper gravel find water in a loose and clean sand below it. Tests of this sand indicate that, in general, it does not yield enough water to warrant considering it as a possible source of adequate new irrigation supplies.

According to the foregoing interpretations of the structure, the Lower Cretaceous limestones in the Saragosa area should yield artesian water if they are as porous or as much channeled there as they are in many other places. These beds are structurally lower in the Saragosa Basin than they are either to the east or west of it, as they lie in the southern extension of the Toyah trough. There is little to indicate the depth at which the limestones would be encountered in this area, but it seems unlikely that they would be at a depth greater than 1,000 or 1,200 feet. It is probable that the ground water in this trough is derived largely from areas other than those that supply the springs near Balmorhea, and the Lower Cretaceous limestone in the Saragosa Basin east of Brogada may be, therefore, a promising source of additional water supply.

SPRINGS

The springs near Balmorhea are of two kinds—artesian springs, whose waters issue under artesian pressure, and gravity springs, whose waters flow because the water table is above the land surface at the site of the spring, so that water tends to drain from the water-bearing beds. The large San Solomon, Phantom Lake, and Giffin Springs belong to the first class, and the Saragosa, West Sandia, East Sandia, and Toyah Creek Springs to the second. The locations of these springs are shown on plate 11 and figures 3 and 4.

ARTESIAN SPRINGS

The artesian character of Phantom Lake, San Solomon, and Giffin Springs is proved by the fact that they appear at the surface of the ground and would flow at the surface if they were permitted to do so. Phantom Lake Spring issues from an A-shaped opening in Lower Cretaceous limestone at the base of a ridge about 8 miles southwest of Balmorhea. It is located at the northwestern edge of a large depression apparently formed as the result of the collapse of the roof of a cavern in the limestone. The water flows into a small pond, called Phantom Lake, and thence is carried through a canal to irrigated lands in the valley below.

San Solomon and Giffin Springs rise from gravel deposits in the floor of the valley near Toyahvale, about 4 miles southwest of Balmorhea. The water originally came to the surface, forming a swamp of considerable size, which drained into Toyah Creek. San Solomon Spring now issues from gravel in the bottom of a large well-built bathing pool. The water is beautifully clear, and the discharge at all times is that of a good-sized creek. It is not surprising, therefore, that this spring is one of the leading scenic attractions of the region. The Giffin Springs rise from gravel at or near the head of four short pits or trenches that finger out from a central outlet trench. When first used for irrigation, the flow of the springs was diverted into canals that were cut only a few feet below the surface. Eighteen or twenty years ago in the hope of obtaining a large increase in flow, the points of discharge of San Solomon and Giffin Springs were lowered by trenches and pits of considerable depth excavated at both sites. Then new deeper outlet canals were constructed, the one at San Solomon Spring having a depth of about 20 feet and the one at Giffin Springs a somewhat lesser depth.

The high- and low-level canals at both springs are available for diversion, but the low-level canal from San Solomon Spring is used infrequently because its use does not increase the flow sufficiently to justify the inconvenience of distributing water from the lower level.

In the course of the investigation, efforts were made to determine the flow of San Solomon Spring both when discharging into the high-level canal and when discharging into the low-level canal, but the demands for water for irrigation would not permit an accurate determination of the flow at the respective levels. However, a few measurements were made. On November 10, 1931, the discharge through the high-level canal was 30.9 second-feet, and three measurements made 10 and 11 days later, on November 20 and 21, showed that the discharge through the low-level canal was 37.7, 37.6, and 38.0 second-feet. These measurements indicate a difference in flow between the two levels of 6 to 7 second-feet. The spring had been discharging through the high-level canal for about a month prior to the measurement on November 10, and during that time the flow had not varied more than 1 or 2 second-feet. It had been discharging through the low-level canal for 8 or 9 days before the measurements at that canal were made. The computed difference in flow at the two levels, therefore, may have approximated closely the correct difference for the period. Whether or not the flow would gradually decrease if the outlet should be maintained at the lower level for a long time is not known. It appears probable that it might.

The discharge of all three springs was well sustained even during several successive dry years. Phantom Lake Spring has a somewhat wider variation in flow than the other two. The lowest discharge of San Solomon Spring recorded by the Geological Survey was 26.5 second-feet on April 26, 1923 (p. 121), and the highest was about 71 second-feet on October 7, 1932 (p. 131). The lowest recorded flow of Phantom Lake Spring was 10 second-feet on October 16, 1931 (p. 142), and the highest 114 second-feet October 2 and 3, 1932 (p. 127). The discharge of the Giffin Springs is relatively small, the smallest recorded daily flow being 2.9 second-feet March 4, 1925, and the largest between 6 and 7 second-feet in October 1932. Daily records of the discharge of the springs during a period of about 2 years, 1931–33, are given on the following pages: Phantom Lake Spring (pp. 127–128), San Solomon Spring (pp. 130–131), Giffin Springs (pp. 129–130).

The flow of Phantom Lake Spring and San Solomon Spring increases very soon after heavy rains, the rise occurring more quickly and the rate of increase being greater in Phantom Lake Spring than in San Solomon Spring. For example: The discharge of Phantom Lake Spring had remained relatively constant at about 13 second-feet from December 21, 1931, to February 22, 1932. During the period February 20 to 22, 1932, 2.41 inches of rain was recorded at Balmorhea, the heaviest fall occurring February 21, and as a result all the canyons had a substantial flow of storm water. The discharge of Phantom Lake Spring began to increase February 22 and reached 20 second-feet February 23 and 25 second-feet February 27. The flow of San Solomon Spring, which had remained constant at about 30 second-feet for several weeks, began to increase on the afternoon of February 23, about 24 hours after the rise started at Phantom Lake.

The flow continued to increase gradually and reached a maximum of 36 second-feet February 27, after which it gradually decreased.

The rainfall in this district from August 30 to September 30, 1932, amounted to 14.36 inches and was the heaviest on record. The first heavy fall, 2.72 inches, occurred August 30 and was quickly followed by large runs of storm water from the mountain canyons. The flow of Phantom Lake Spring, which had been relatively constant at 12 to 13 second-feet for several months, began to increase on the evening of August 29 and reached about 46 second-feet September 11. It then gradually decreased to about 25 second-feet September 26, at which time it again began to increase and continued until it reached a maximum of 114 second-feet October 3. The flow of San Solomon Spring, which had remained at 32 to 33 second-feet for several months, began to increase August 29 and continued until September 14, when it was about 65 second-feet. It then slowly decreased, reaching a minimum of about 54 second-feet September 27, when it again began to increase and continued until it reached a maximum of about 71 second-feet October 7.

The temperature of Phantom Lake, San Solomon, and Giffin Springs is normally high. It was the same, 78° F., for all three in October 1931. After the increase in flow in September 1932 the temperature was 71° in Phantom Lake Spring and 74° in San Solomon Spring. On March 11, 1933, it was 77½° in Phantom Lake Spring and 73½° in San Solomon Spring.

Ordinarily the water discharged from the springs is perfectly clear, but soon after the start of the abrupt increases in flow in August and September 1932 the water from Phantom Lake and San Solomon Springs became cloudy owing to the suspension in it of a very fine light-colored sediment.

Normally the water of the springs has rather a high mineral content, but it becomes quite fresh during periods of peak discharge. This is well illustrated by the table on page 101 which gives the comparative results of analyses of samples obtained during periods of moderate flow in the fall of 1930 and of high flow in the fall of 1932. When the samples were taken in 1930 the discharge was not measured, but it was known to be at a moderate or rather low stage. In the fall of 1932 the discharge of all the springs was abnormally high. When their waters were sampled on September 12 and 13, 1932, Phantom Lake Spring had a discharge of 45 second-feet and San Solomon Spring 64 second-feet. On October 7, 1932 when the waters were again sampled, Phantom Lake Spring had a discharge of about 82 second-feet, San Solomon Spring 71 second-feet, and Giffin Springs 6 second-feet. These samples show that the decline in the mineral content of the water at high stages is remarkably large. The decline in the total dissolved solids is shown in the following table:

Total dissolved solids in waters from the large springs near Balmorhea at different dates

Phantom Lake Spring		San Solomon Spring		Giffin Springs	
Date	Total dissolved solids (parts per million)	Date	Total dissolved solids (parts per million)	Date	Total dissolved solids (parts per million)
Oct. 28, 1930	2,309	Oct. 28, 1930	2,196	Dec. 6, 1930	2,098
Sept. 12, 1932	723	Sept. 13, 1932	875		
Oct. 7, 1932	144	Oct. 7, 1932	562	Oct. 7, 1932	547

The most outstanding disclosure of this record is the change in the discharge at Phantom Lake Spring from a highly mineralized water to water containing probably very little more mineral matter than the Davis Mountain streams. The decline in the mineralization of the water from San Solomon and Giffin Springs, while large, was markedly less than the decline in Phantom Lake Spring.

Analyses of water from the large springs near Balmorhea, Tex.

[Analyzed by M. D. Foster and L. A. Shinn; parts per million]

Spring	Date of collection	Total dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (calculated)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Iron (Fe)	Silica (SiO_2)	Total hardness as $CaCO_3$
Phantom Lake	Oct. 28, 1930	2,309	191	86	473	285	691	655	0.55	0.04	19	830
Do	Sept. 12, 1932	[1] 723	81	27	[1] 139	170	205	186	1.4			[1] 313
Do	Oct. 7, 1932	[1] 144	[2] 44		[1] 10	131	[2] 20	4				111
San Solomon	Oct. 28, 1930	2,196	190	80	448	286	651	610	.90	.04	19	803
Do	Sept. 13, 1932	[1] 975	102	35	[1] 200	264	270	238	.38			[1] 398
Do	Oct. 7, 1932	[1] 562	[2] 88		[1] 93	189	[2] 175	100				276
Giffin	Dec. 6, 1930	[1] 2,098	189	80	[1] 437	284	635	608				[1] 800
Do	Oct. 7, 1932	[1] 547	[2] 80		[1] 109	183	[2] 140	124				234

[1] Calculated. [2] By turbidity.

The persistent discharge of great quantities of water by the large springs during months or even years of drought indicates that they are fed from a large reservoir or from a series of smaller reservoirs. Most of the water must be derived from rainfall and run-off that enters the reservoir at no great distance from the springs. This is indicated by the abrupt increase in the discharge of Phantom Lake and San Solomon Springs following heavy rains and large runs of muddy water from the mountain canyons, by the decrease in the dissolved minerals in the spring water, and by the lowering of the temperature of the water and its cloudy character at such times. The data all tend to substantiate the conclusions stated in the section on the geology of the area and the relation of the springs to the geologic structure.

GRAVITY SPRINGS

Saragosa, West Sandia, and East Sandia Springs rise from gravels in the bottom of shallow drainage channels near Balmorhea. The Toyah Creek Springs issue from gravel at many points in the bed of Toyah Creek in a stretch of 3 or 4 miles southwest and northeast of Balmorhea. The uppermost point of emergence of the Saragosa and Toyah Creek Springs shifts considerably up and down stream from year to year and from season to season. The position of the principal West Sandia Spring now appears to be fixed at a point in a shallow drainage channel on the southeastern border of Balmorhea, but it is reported that about 30 years ago this spring emerged more than half a mile southwest of Balmorhea, or about a mile up the valley from its present location. For a time after the heavy rains of August and September 1932, small seeps in the channel above and below the spring were discharging more ground water than the spring itself. The East Sandia Spring appears at the base of the western slope of the Brogada Hills, and so far as could be learned it has always been where it is today.

As determined by instrumental leveling, the heads of the Saragosa and Toyah Creek Springs in November 1931 were a few feet below the water levels in nearby shallow wells that draw from the gravel; likewise, the outlet of the main West Sandia Spring was 1 to 2 feet lower than the water level in well 20, one of the shallow observation wells that are discussed later in this report. The outlets of the East Sandia Spring apparently are about at the level of the shallow water table immediately above the spring, but this was not exactly determined.

Saragosa Spring enters Toyah Creek and joins the ground-water discharge of that stream a few hundred feet above the Balmorhea bridge. The measured discharge of the spring in second-feet was as follows: November 6, 1932, 9.9; January 23, 1933, 8.2; March 14, 1933, 6.7; May 16, 1933, 6.4; July 11, 1933, 5.6.

The inflow, in second-feet, of ground water into Toyah Creek from its head down to a point about 500 feet below the Balmorhea bridge, consisting of the combined flow of the Saragosa and Toyah Creek

Springs, was as follows: November 6, 1932, 30.7; January 23, 1933, 12.8; March 14,1933, 9.4; May 16, 1933, 9.2; July 11, 1933, 8.3. According to records of the Reeves County Water Improvement District the combined discharge of the springs down to the same point ranged from 4.8 to 6 second-feet during December 1931 and January 1932 and from 5.8 to 8.3 second-feet in June, July, and August 1932. The rates of flow shown by the measurements made prior to the floods in August and September 1932 probably are much nearer the average long-time flow than the rates as shown by measurements made during the months succeeding the floods.

The daily discharge of West Sandia Spring from November 17, 1931, to August 28, 1933, is given in the tables on pp. 136 and 137. According to one set of measurements made on October 17, 1932, shortly after the heavy rains, the discharge of the principal spring amounted to 0.6 second-foot, and the seepage inflow above it to 0.2 second-foot, while the inflow between the spring and the gaging station 4,000 feet below it amounted to 1.4 second-feet. A part of this was diverted above the gage and was not taken into account in the gaging records. The mean monthly discharge of East Sandia Spring, in second-feet, and the monthly run-off, in acre-feet, from November 23, 1931, to September 23, 1933, are given in the table on page 138.

The temperature of the water from Saragosa and East and West Sandia Springs is materially lower than the temperature of the water of any of the large springs. On March 14, 1933, the following temperatures (Fahrenheit) were recorded: Saragosa Spring, 67½°; West Sandia Spring, 63½°; East Sandia Spring—3 outlets—55°, 58°, and 64°.

The Saragosa, West Sandia, East Sandia, and Toyah Creek Springs clearly are gravity springs and have their source in the gravel. They appear at levels slightly below the water table in the gravel. Their temperature is much lower than that of the large springs and is not materially different from the temperature of the water from shallow wells in the vicinity. The discharge of the Saragosa and Toyah Creek Springs apparently increases and decreases and the position of their uppermost outlets shifts up and down the streams with the rise and fall of the water table. The position of East Sandia Spring is stationary and that of the main West Sandia Spring is nearly stationary. This may be due to the fact that these two springs are fed from solution channels in the cemented gravels and that these channels are not directly connected with the shallow water table. The basal conglomerate is encountered in nearly all the shallow wells in the Balmorhea district and is known to be cavernous in places. Irrigation streams amounting to a second-foot or more have been known to disappear into these passages. The map (fig. 3) indicates that the slope of the water table is in the same direction as that of the land and that the movement of the ground water in the gravel, with some variations, is directly down the valley. It shows further that the altitude of the Saragosa and West and East Sandia Springs conforms closely to the altitude of the water table in their vicinities.

As shown by the following analyses, the water from these springs is similar in character to the water from the artesian springs.

Partial analyses of water from gravity springs near Balmorhea, Tex.

[Parts per million. Analyses by E. W. Lohr and L. A. Shinn]

Spring	Date of collection	Total dissolved solids	Calcium (Ca)	Magnesium (Mg)
Toyah Creek	Nov. 13, 1931		200	81
Saragosa	Dec. 7, 1930	2,846	272	102
East Sandia	Dec. 7, 1930	2,999	276	101

Spring	Sodium and potassium (Na+K) (calculated)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$
Toyah Creek	463	222	705	655		832
Saragosa	584	332	868	842	5.0	1,098
East Sandia	631	309	992	840	6.0	1,104

SHALLOW GROUND WATER

Most of the water for domestic use and stock in this area is obtained from wells. A description of 41 of the wells is given in the table on page 107, and the location of each is indicated in figure 3 by a number that corresponds to the number assigned to it in the table. All the wells in the vicinity of Balmorhea terminate in the gravel, none are more than 60 feet deep, and most of them are less than 30 feet deep. The depth to water was measured in all the wells, and the measuring points at the top of most of them were connected by lines of levels and the altitude of these points referred to a common assumed datum. In this way the water-table map (fig. 3) was prepared.

Thirteen wells were selected for observation and were measured periodically over a period of several years. The records of these measurements are shown in the tables on pp. 108–111. They show that the water levels in the wells are, in general, moderately low but that the levels rise when heavy rains fall, when Toyah Creek is in flood, or when nearby lands are irrigated. It is evident, therefore, that the principal sources of the ground water in the gravel are rainfall and seepage from irrigation canals and irrigated lands. Seepage from the large springs doubtless contributes to the shallow ground water. As

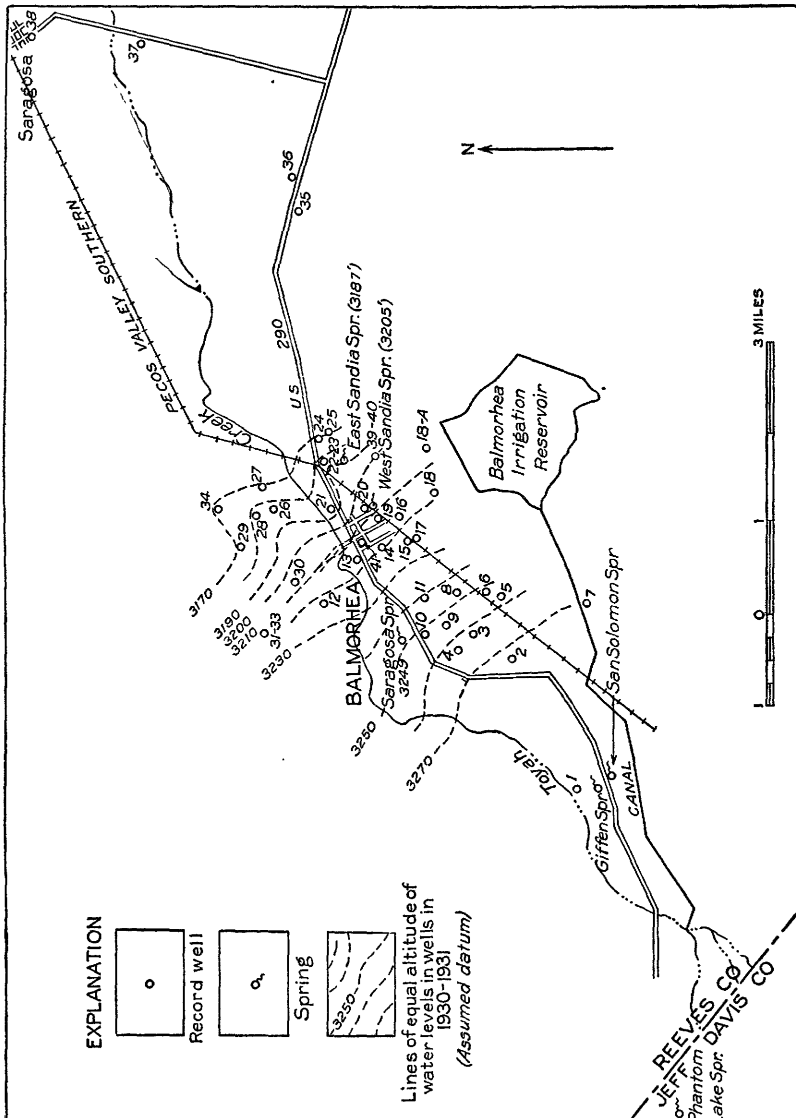


FIGURE 3.—Map of the vicinity of Balmorhea, Tex., showing location of wells and springs and approximate shape and slope of the water table. By Walter N. White.

previously stated, the water in the gravels is believed to be the source of the Saragosa, West Sandia, East Sandia, and Toyah Creek Springs.

The chemical character of this water is shown by the partial analyses in the table following.

Partial analyses of water from wells in vicinity of Balmorhea, Tex.

[Well numbers correspond with numbers in table of well records. Analyses by E. W. Lohr and L. A. Shinn; parts per million]

Well No.	Owner	Depth of well (feet)	Date of collection	Total dissolved solids (calculated)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (calculated)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$ (calculated)
1	Balmorhea Livestock Co.	20	Dec. 7, 1930	2,770	325	67	560	334	849	810	5.0	1,087
2	A. C. Schreyer	14	do	2,293	230	73	471	288	706	655	5.0	874
4	A. W. Wigley	20	Nov. 13, 1931		370	145	787	438	1,174	1,170		1,520
6	Sedro Garcia	20	do		306	86	574	330	881	835		1,118
11	Mrs. Nell B. Westerman	20	do		332	126	764	324	1,131	1,110		1,347
12	J. P. Hill	22	do		300	143	721	302	1,366	875		1,336
13	Rosenbaum Co.	15	do		305	109	699	349	1,046	960		1,209
17	do	11	do		322	93	590	290	965	870		1,186
18	Mrs. Paul Renz	12	do		347	91	551	268	858	940		1,241
24	E. P. Stuckler	13	do		319	144	849	382	1,291	1,118		1,388
27	B. W. Vanderson	20	do		273	114	647	293	1,031	882		1,150
28	E. W. Backus	18	do		350	155	792	320	1,491	1,005		1,510
30	W. E. Gould	36	Dec. 7, 1930	1,342	301	35	111	337	363	335	12	896
37	Saragosa School	158	Dec. 6, 1930	3,283	346	137	595	334	1,009	982	15	1,427

RECORDS OF WELLS

Records of wells in vicinity of Balmorhea, Tex.

No.	Distance from Balmorhea (miles)	Owner	Water level			Altitude of bench mark [1] (feet)	Use of water [2]	Method of lift [3]
			Depth (feet)	Below bench mark (feet)	Date			
1	3¾ SW	Balmorhea Livestock Co.	175	16.29	Nov. 10, 1931	3,349	D, S	W.
2	2 SW	A. C. Schreger	14	13.99	Oct. 31, 1930	3,286	D, S	W.
3	1¾ SW	Charles Weinacht	15	13.73	do	3,275	S	W.
4	do	A. W. Wigley	20	14.39	do	3,278	D, S	W.
5	1¾ SSW	Humble Oil & Refining Co.	14	14.47	Nov. 13, 1931	3,272	D, S	H.
6	1½ SSW	S. Garcia	20	13.91	Oct. 31, 1930	3,266	D, S	H.
7	2¾ SSW	S. A. Sharpe	20±	12.86	do	3,286	D, S	H.
8	1¼ SSW	H. A. Jones	20±	14.98	do	3,263	D, S	W.
9	1¼ SW	do	19	11.65	Nov. 13, 1931	3,265	S	H.
10	do	W. A Knapp	17	12.22	Nov. 1, 1930	3,264	N	E.
11	1 SW	Mrs. Nell B. Westerman.	20	11.61	do	3,251	S	W.
12	¾ NW	—— Hill	22	11.70	Nov. 3, 1930	3,234	D, S	H.
13	¼ W	Rosenbaum Co	15	13.45	Nov. 1, 1930	3,231	D, S	W.
14	¼ SW	T. A. Odell	10	7.95	do	3,228		H.
15	½ S	Rosenbaum Co	9	9.35	do	3,234	D, S	H.
16	do	A. W. Wigley	17	6.89	do	3,225	N	None.
17	do	Rosenbaum Co	11	9.88	do	3,233	D, S	H.
18	1 SE	Mrs. Paul Renz	12	4.20	Nov. 13, 1931	3,221	S	W.
18 A	1¼ SE	Unknown	20±	4.71	do	3,211	(4)	(4)
19	In Balmorhea	do	Unknown	5.53	Nov. 6, 1931	3,221	N	None.
20	do	Toyah Valley State Bank.	7	5.69	Nov. 1, 1930	3,214	N	None.
21	½ NE	J. F. Meier	24	23.27	do	3,208	D, S	W.
22	1 NE	P. V. S. Ry	10	5.56	do	3,198	N	None.
23	do	Unknown	Unknown	2.16	Oct. 31, 1931	3,194	N	None.
24	1¼ NE	E.P. Stuckler	13	11.68	Nob. 6, 1930	3,186	D, S	W.
25	do	Mike Tesero	21.5	19.63	Nov. 1, 1930	3,188	D, S	H.
26	1 NNE	J. P. Cole	17	14.65	Nov. 3, 1930	3,198	D, S	H.
27	1¼ NE	B. W. Vanderon	20	20.66	do	3,190	D, S	H.
28	1¼ NNE	E. W. Backus	18	16.60	Nov. 1, 1930	3,197	D, S	W.
29	1½ N	Perry Wegnon	50	34.35	Nov. 3, 1930	3,204	D, S	W.
30	1 NW	W. E. Gould	36	26.88	Nov. 1, 1930		D, S	W.
31	1½ NW	do	58	30	Nov. 3, 1930		P	E.
32	do	do	53	41.51	Nov. 1, 1930		N	None.
33	do	do	60	46.82	do		P	G.
34	1¾ NNE	Mrs. W. E. Gould	19	16.52	Nov. 3, 1930	3,188	N	W.
35	3¾ ENE	State of Texas	220	180±	Nov. 5, 1930		D, S	W.
36	4 ENE	A. H. Mills	117	112.9	do		N	W.
37	6 NE	Saragosa School	158	139.2	Nov. 3, 1930		D	W.
38	6¾ NE	J. H. Downs	158	137.6	do		D, S	W.
39	¾ E	G. F. Renz	26	9.80	Nov. 2, 1931	3,210	D, S	C.
40	do	do	18	9.21	do	3,209	D, S	S.
41	In Balmorhea	Reeves County Water Improvement District.	202	5.56	Nov. 1, 1930			None.

[1] Assumed datum.
[2] D, Domestic; S, stock; P, public supply; N, not used.
[3] W, Windmill; H, hand; E, electric motor; G, gas engine; S, siphon.
[4] Test hole.

DEPTH TO WATER LEVEL

Records of water levels in wells

[For location and description of wells see preceding table]

3. CHARLES WEINACHT

[Measuring point, top of edge of pipe clamp, on south side, at ground level]

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
1930, Oct. 31	13.73	1932, Dec. 10	7.77	1933, May 19	[5] 8.74
1931, Mar. 8	14.50	Dec. 14	7.95	May 20	9.00
Dec. 11	13.72	1933, Jan. 21	7.59	May 27	8.72
1932, Jan. 19	[1] 14.26	Jan. 28	8.12	June 2	8.40
Feb. 15	15.00	Feb. 4	8.16	June 10	8.92
Apr. 13	[2] 9.74	Feb. 11	8.18	June 17	[5] 7.60
May 30	11.61	Feb. 18	8.30	June 24	[5] 6.95
Aug. 4	11.52	Feb. 25	8.48	July 8	[6] 8.47
Aug. 21	11.80	Mar. 4	[4] 8.75	July 15	9.65
Sept. 17	7.60	Mar. 4	9.15	July 27	[6] 8.85
Oct. 1	[3] 3.56	Mar. 11	[5] 4.71	Aug. 5	8.68
Oct. 15	5.96	Apr. 1	8.35	Aug. 19	9.54
Oct. 22	6.18	Apr. 9	8.50	Aug. 26	11.17
Oct. 30	6.58	Apr. 16	[5] 8.20	Sept. 2	[7] 11.08
Nov. 5	6.61	Apr. 23	8.40	Sept. 23	9.49
Nov. 12	6.91	Apr. 29	8.45		
Nov. 19	5.49	May 7	9.00		

5. HUMBLE OIL & REFINING CO.

[Measuring point, bench mark in top of wood cover, 2 feet above ground level]

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
1931, Nov. 13	14.47	1932, Dec. 10	7.19	1933, May 14	9.90
Dec. 11	11.42	1933, Jan. 10	7.68	May 20	10.15
1932, Jan. 19	[1] 12.86	Jan. 14	7.86	May 27	10.42
Feb. 15	[2] 11.04	Jan. 28	8.22	June 3	10.65
May 30	10.08	Feb. 4	8.40	June 10	11.03
Aug. 4	11.11	Feb. 11	8.60	June 17	11.22
Sept. 17	11.50	Feb. 18	8.65	June 24	11.80
Oct. 1	[3] 8.61	Feb. 25	[4] 8.70	July 8	12.68
Oct. 15	6.79	Mar. 11	9.37	July 15	13.01
Oct. 22	6.72	Apr. 1	9.67	July 29	13.32
Oct. 30	6.54	Apr. 9	9.30	Aug. 5	13.52
Nov. 5	6.77	Apr. 16	9.37	Aug. 26	13.95
Nov. 12	6.92	Apr. 23	9.58	Sept. 2	[7] 14.10
Nov. 19	7.01	Apr. 26	9.62	Sept. 23	13.66
Dec. 3	7.24	May 7	9.76		

7. S. A. SHARPE

[Measuring point, bench mark in plank, on north side, at ground level]

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
1930, Oct. 31	12.86	1932, Jan. 19	9.44	1932, Aug. 4	15.73
1931, Mar. 8	[2] 10.37	Feb. 15	[1] 8.00	Aug. 20	16.48
Nov. 7	13.08	Apr. 13	9.50		
Dec. 11	10.96	May 30	12.89		

See footnotes at end of table.

Records of water levels in wells—Continued

10. W. A. KNAPP

[Measuring point, bench mark in east end and south side of middle cross beam, 1 foot above ground level]

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
1930, Nov. 1	12.22	1932, Dec. 12	6.08	1933, May 14	8.80
1931, May 8	11.00	1933, Jan. 10	7.18	May 20	9.05
Nov. 4	9.89	Jan. 14	7.47	May 27	9.03
Dec. 11	13.02	Jan. 21	7.30	June 3	8.70
1932, Jan. 19	[1] 12.79	Jan. 28	7.45	June 10	9.18
Feb. 13	[2] 11.00	Feb. 4	7.60	June 17	8.80
Apr. 13	11.00	Feb. 11	7.98	June 24	9.12
May 30	10.80	Feb. 18	8.16	July 8	9.22
Aug. 4	10.85	Feb. 25	8.35	July 15	9.78
Aug. 20	11.59	Mar. 4	[4] 8.63	July 29	9.69
Sept. 17	6.60	Mar. 11	[6] 8.22	Aug. 5	9.98
Oct. 1	[3] 4.51	Apr. 1	8.80	Aug. 12	10.52
Oct. 8	4.80	Apr. 9	8.78	Aug. 19	10.18
Oct. 15	5.18	Apr. 16	8.28	Aug. 26	10.70
Oct. 22	5.38	Apr. 23	8.64	Sept. 1	10.78
Oct. 30	5.81	Apr. 29	8.40	Sept. 23	[7] 7.58
Nov. 5	6.36	May 7	8.85		

12. —— HILL

[Measuring point, top edge of upper wood frame, on east side opposite cut in frame, at ground level]

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
1930, Nov. 3	11.70	1933, Jan. 21	8.03	1933, May 28	8.85
1931, Dec. 11	11.89	Jan. 28	8.16	June 4	9.13
1932, Jan. 19	[1] 13.10	Feb. 4	8.60	June 11	8.90
Feb. 15	13.00	Feb. 11	8.62	June 18	9.20
Apr. 13	[2] 9.23	Feb. 14	8.70	June 25	9.45
May 30	11.42	Feb. 25	8.76	July 8	9.05
Aug. 4	9.98	Mar. 4	[4] 9.00	July 15	9.08
Aug. 20	10.72	Mar. 11	8.36	July 29	9.50
Sept. 17	5.79	Apr. 1	8.68	Aug. 5	9.82
Oct. 15	[3] 5.46	Apr. 9	[6] 8.22	Aug. 11	[6] 9.74
Oct. 22	5.79	Apr. 16	[6] 8.15	Aug. 19	10.08
Oct. 30	6.18	Apr. 23	8.68	Sept. 2	[7] 9.32
Nov. 5	6.46	Apr. 29	8.47	Sept 23	8.66
Dec. 10	7.06	May 7	8.22		
1933, Jan. 10	7.86	May 14	8.75		
Jan. 14	7.93	May 20	8.85		

See footnotes at end of table.

Records of water levels in wells—Continued

16. A. W. WIGLEY

[Measuring point, southwest edge of concrete cross beam, opposite cut in concrete, at ground level]

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
1930, Nov. 1	6.89	1932, Mar. 21	[5] 2.55	1932, July 23	4.07
1931, Mar. 8	4.20	Mar. 26	4.11	July 30	5.29
Nov. 12	4.91	Apr. 2	4.45	Aug. 6	5.86
Nov. 19	5.50	Apr. 9	4.49	Aug. 13	6.04
Nov. 23	5.73	Apr. 12	3.25	Aug. 16	6.16
Dec. 3	5.99	Apr. 16	4.18	Aug. 20	[5] 5.47
Dec. 10	5.69	Apr. 23	4.41	Aug. 30	[3] 3.35
Dec. 19	5.87	Apr. 27	[6] 3.25	Sept. 3	4.25
Dec. 26	5.79	Apr. 30	3.87	Sept. 4	4.25
Dec. 29	5.83	May 7	4.59	Sept. 4	1.47
1932, Jan. 2	[1] 5.77	May 14	4.85	Sept. 4	[3] .82
Jan. 9	5.67	May 28	4.95	Sept 10	1.97
Jan. 16	5.76	June 3	[6] 3.45	Sept. 17	2.76
Jan. 23	5.73	June 4	3.86	Sept. 24	2.91
Jan. 28	5.67	June 8	4.50	Oct. 1	[3] 1.03
Jan. 30	4.79	June 10	[6] 3.15	Oct. 9	2.37
Feb. 6	4.93	June 11	3.68	Oct. 15	2.17
Feb. 11	[5] 2.35	June 17	4.05	Oct. 22	1.89
Feb. 13	4.15	June 18	[6] 3.72	Oct. 29	2.15
Feb. 20	4.19	June 25	4.24	Nov. 5	2.73
Feb. 23	[2] 2.55	June 30	4.66	1933, July 29	4.45
Feb. 27	3.41	July 2	5.45	Aug. 5	[6] 4.31
Feb. 29	3.53	July 4	[6] 4.05	Aug. 26	4.13
Mar. 5	3.71	July 9	5.35	Sept. 2	[6] 3.23
Mar. 12	4.22	July 16	5.56	Sept. 23	3.65
Mar. 19	4.21	July 22	[6] 3.35		

20. TOYAH VALLEY STATE BANK

[Measuring point, cross in top of west brick in top row, at ground level]

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
1930, Nov. 1	5.69	1932, Dec. 10	4.28	1933, May 14	4.03
1931, Mar. 8	5.70	1933, Jan. 10	3.98	May 20	4.20
Nov. 10	5.67	Jan. 21	4.09	May 27	4.58
Dec. 11	5.60	Jan. 28	4.00	June 4	4.35
1932, Jan. 19	[1] 5.45	Feb. 4	4.08	June 11	4.50
Feb. 15	[2] 3.95	Feb. 11	4.08	June 18	4.40
Aug. 4	4.9	Feb. 18	4.10	June 25	4.30
Aug. 20	4.95	Feb. 25	4.00	July 8	4.76
Sept. 17	3.8	Mar. 4	[4] 3.92	July 15	5.00
Oct. 1	[3] 2.56	Mar. 11	4.02	July 21	4.80
Oct. 15	3.51	Apr. 1	3.73	Aug. 5	4.79
Oct. 22	3.55	Apr. 9	3.74	Aug. 11	4.92
Oct. 30	3.96	Apr. 16	3.80	Aug. 19	4.62
Nov. 5	4.04	Apr. 22	3.67	Aug. 25	[7] 4.72
Nov. 12	4.14	Apr. 26	4.03	Sept. 2	4.04
Nov. 19	4.19	May 7	3.96	Sept. 25	3.36

22. PECOS VALLEY SOUTHERN RAILWAY

[Measuring point, copper-nail bench mark, on south side of well curb, 3 feet above ground level]

Date	Water level above (+) or below (−) measuring point (feet)	Date	Water level above (+) or below (−) measuring point (feet)	Date	Water level above (+) or below (−) measuring point (feet)
1930, Nov. 1	−5.56	1932, Oct. 15	+1.92	1933, Apr. 29	−1.18
1931, Mar. 8	−4.50	Oct. 22	+3.22	May 7	−1.30
Dec. 10	−1.65	Oct. 20	+0.15	May 14	−1.32
1932, Feb. 15	[2] −1.00	Nov. 5	−0.04	May 20	−1.52
Apr. 13	−1.00	Nov. 10	−1.28	May 28	−1.65
May 30	−0.4	Nov. 19	−0.49	June 11	−1.78
Aug. 4	−1.18	1933, Apr. 1	−1.00	Do	−1.95
Aug. 20	−1.80	Apr. 9	−1.10	June 17	−2.00
Sept. 17	[3] +1.3	Apr. 16	−1.14	June 25	−2.00
Oct. 1	[3] +3.9	Apr. 23	−1.20		

See footnotes at end of table.

Records of water levels in wells—Continued

23. ALONG EAST SIDE OF PECOS VALLEY SOUTHERN RAILWAY RIGHT-OF-WAY

[Measuring point, bench mark in top of board lining, on west side of well, about 2 feet below ground level]

Date	Water level above (+) or below (−) measuring point (feet)	Date	Water level above (+) or below (−) measuring point (feet)	Date	Water level above (+) or below (−) measuring point (feet)
1931, Oct. 31	−2.16	1932, Nov. 5	−0.04	1933, Mar. 4	−0.72
Dec. 10	−1.65	Dec. 10	−0.69	Mar. 11	−0.83
1932, Feb. 15	[2] −1.00	1933, Jan. 10	−0.28	July 8	−2.19
May 30	−0.04	Jan. 14	−0.38	July 15	−2.34
Aug. 4	−1.18	Jan. 21	−0.53	July 22	−2.38
Aug. 25	−1.8	Jan. 28	−0.58	July 29	−2.50
Sept. 17	[3] +1.3	Feb. 4	−0.52	Aug. 5	−2.52
Oct. 1	([8])	Feb. 11	−0.54	Aug. 19	−2.72
Oct. 15	+1.92	Feb. 18	−0.62	Aug. 28	[7] −2.82
Oct. 22	+3.22	Feb. 25	−0.65	Sept. 2	−0.20
Oct. 30	+0.05				

26. J. P. COLE

[Measuring point, edge of concrete collar, on northeast side of well, opposite cut in collar, 1 foot above ground level]

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
1930, Nov. 3	14.65	1932, Dec. 10	11.53	1933, May 7	11.91
1931, Mar. 8	[5] 12.16	1933, Jan. 10	11.48	May 14	12.20
Nov. 3	14.44	Jan. 14	11.65	May 20	12.42
Dec. 11	14.95	Jan. 21	11.84	June 4	12.65
1932, Jan. 19	[1] 15.96	Jan. 28	12.01	June 11	12.68
Feb. 15	[2] 14.95	Feb. 4	12.00	June 18	[5] 12.23
Apr. 3	14.95	Feb. 11	12.30	June 25	12.55
May 30	14.4	Feb. 18	11.28	July 8	12.59
Aug. 4	14.45	Feb. 25	[4] 11.60	July 15	[5] 12.21
Aug. 20	14.47	Mar. 4	13.18	July 29	12.83
Sept. 17	12.52	Mar. 11	[5] 11.57	Aug. 5	12.86
Oct. 15	[3] 10.21	Apr. 1	12.02	Aug. 11	12.55
Oct. 22	10.25	Apr. 9	12.14	Aug. 19	12.98
Oct. 30	10.12	Apr. 16	12.28	Aug. 26	[7] 13.22
Nov. 5	10.44	Apr. 23	[6] 11.20	Sept. 2	12.68
Dec. 3	11.51	Apr. 29	11.05	Sept. 23	12.21

34. MRS. W. E. GOULD

[Measuring point, bench mark in 1- by 12-inch plank, at south side of hole in plank, at ground level]

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
1930, Nov. 3	16.52	1932, Dec. 10	11.85	1933, May 7	13.28
1931, Mar. 8	[5] 16.94	1933, Jan. 10	12.88	May 14	13.85
Nov. 3	16.67	Jan. 14	13.00	May 20	13.98
Dec. 11	17.40	Jan. 21	13.11	May 28	14.18
1932, Jan. 6	[1] 17.43	Jan. 28	13.22	June 4	14.35
Jan. 19	17.62	Feb. 4	13.24	June 11	14.42
Feb. 15	[2] 17.00	Feb. 11	13.32	June 18	14.53
Apr. 13	16.63	Feb. 18	13.40	June 25	14.60
May 30	16.3	Feb. 25	[4] 13.48	July 8	15.18
Aug. 4	17.05	Mar. 4	13.30	July 15	15.35
Sept. 17	[3] 11.80	Mar. 11	13.31	July 29	15.70
Oct. 15	8.31	Apr. 1	13.42	Aug. 5	15.81
Oct. 22	9.05	Apr. 9	13.48	Aug. 11	16.26
Oct. 30	9.74	Apr. 16	13.60	Aug. 19	15.78
Nov. 5	10.22	Apr. 23	12.62	Aug. 26	15.62
Dec. 3	11.68	Apr. 29	12.90	Sept. 23	[7] 14.65

[1] Rainfall from August 1931 to January 1932, inclusive, was about 27 percent below 13-year average.
[2] Rainfall was 3.79 inches in February 1932, about 5 times the 13-year average.
[3] Rainfall was 15.24 inches in August and September 1932, more than 3 times the 13-year average.
[4] Rainfall in January and February 1933 was only 0.69 inch.
[5] Adjoining field under irrigation.
[6] Adjoining field recently irrigated.
[7] Rainfall April to August 1933, inclusive, was about a third of 13-year average.
[8] Water running over top of well

INTAKE OF GROUND WATER

AREAS OF INTAKE

As has been pointed out in the section on the geology of this district (pp. 90–97), the principal area of intake or replenishment for the large springs at Balmorhea is within a long narrow anticlinal valley that parallels the eastern escarpment of the Davis Mountains west, northwest, and southwest of the springs. In this valley the beveled edges of the Lower Cretaceous limestones appear at the surface or lie beneath a mantle of stream and terrace gravel not far below the surface, and their honeycombed and cavernous members absorb and store a large part of the local rainfall and mountain run-off. The length of this intake area is not exactly known. It is believed, however, that the limestones may take in water along the anticline all the way from Big Aguja Canyon northwestward to the vicinity of San Martine, in Pecos County, a distance of about 35 miles. (See fig. 4.)

The creeks from Big Aguja, Little Aguja, Madera, and Cherry Canyons lose heavily between the mouths of their canyons and the downstream boundary of the anticline. The Lower Cretaceous rocks take in considerable water, also, in an area of outcrop along Limpia Creek about 20 miles southeast of Balmorhea. Practically all the discharge of Limpia Creek disappears during moderate and low stages in that locality.

The lavas of the Davis Mountains have an important part in the intake system. They absorb much of the mountain rainfall and run-off. The water moves downward through joints and crevices in the rocks until it reaches relatively impermeable layers of volcanic rock or tuff or underlying Upper Cretaceous clays. It then moves laterally and appears as springs or seeps in the mountain canyons and on the slopes of the eastern escarpment, where it is largely dissipated by evaporation and transpiration. A part, however, reaches the canyon streams, in places maintaining a small perennial flow, or is absorbed by the gravels of the streams and adjacent terraces. In at least one locality considerable stream water apparently is absorbed by the volcanic rocks in places where synclinal structure has brought them below stream level. This is on Limpia Creek near old Limpia post office, about 15 miles south of Balmorhea. The water that enters there may rise into the stream gravels below the lower limb of the syncline and through them eventually reach the intake area of the Lower Cretaceous rocks, 15 to 20 miles below.

The gravels, also, have an important part in the intake system. Much of the district between Balmorhea and the mountains is underlain by stream and terrace gravels, and in places tongues of these gravels extend a considerable distance into the mountains. The gravels serve as both reservoir and conduit. They absorb a part of the water that is discharged by the mountain seeps and springs and a part of the rainfall and run-off on the escarpment of the mountain front and the belt between the escarpment and outcrop of the Lower Cretaceous rocks. This water moves slowly in the gravels in a downstream direction until it reaches the outcrop of the Lower Cretaceous rocks and gradually seeps into the reservoir in these rocks. The

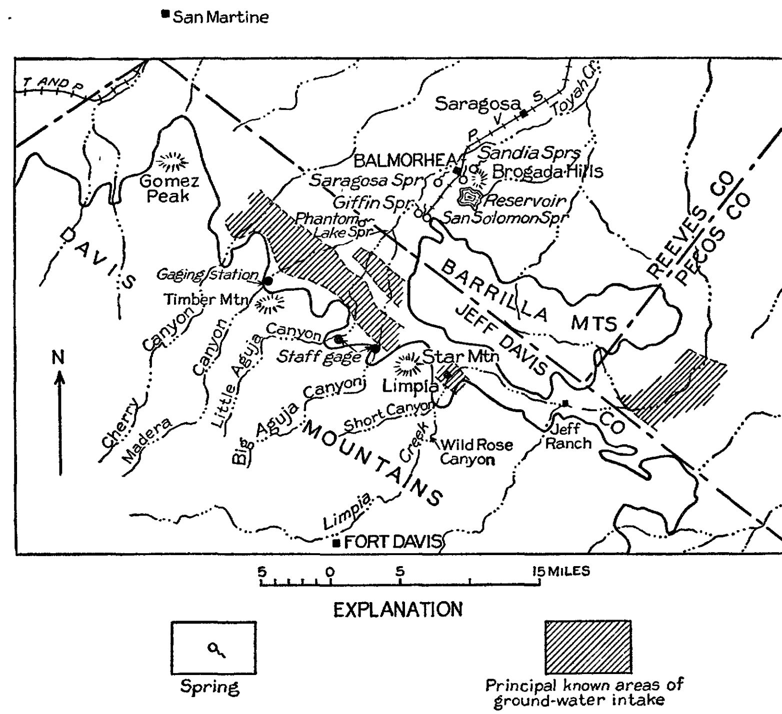


FIGURE 4.—Map of part of Toyah Basin, Tex., showing the springs and areas of ground-water intake near Balmorhea. By Walter N. White.

igneous rocks and gravels, therefore, constitute an essential part of the extensive storage and regulatory system by which the flow of the large springs is maintained during periods of drought lasting for months and even years.

The water that supplies the flow of the smaller springs at Balmorhea is derived from the Toyah Valley gravels. It is replenished by rainfall on the valley floor and by seepage from Toyah Creek, from canals, ditches, and irrigated lands, and to some extent from the large springs. (See fig. 3.)

INTAKE FROM STREAMS

In 1932 and 1933 a program of stream measurement was undertaken on several of the mountain streams, including miscellaneous measurements on Limpia Creek, to obtain information both as to the volume of run-off from the mountains and the extent of losses by seepage from the mountain streams in crossing the intake area of the Lower Cretaceous limestones. A permanent gaging station was established in Madera Canyon and equipped with a continuous water-stage recorder. Temporary staff gages were installed on the streams that issue from Cherry, Big Aguja, and Little Aguja Canyons and read daily or weekly for several months. Many miscellaneous measurements of the discharge of these streams and of Limpia Creek were made with a current meter, and several series of such measurements were made on each stream to determine seepage losses on the intake area of the Lower Cretaceous limestones and gains and losses in several other sections, mostly below the mouths of the canyons. Most of the "seepage measurements" were made on a declining stage and therefore tend to show losses in each section smaller than the true losses, or even a gain when actually there may have been a substantial loss. However, in making the measurements, the stream gager moved in a downstream direction at a rate not much faster than the movement of the stream; in this way a large part of the error, due to changes in stage while the seepage measurements were in progress, can be eliminated, and reasonably accurate estimates can be made of the losses and gains in the sections during periods when the rates of stream discharge were comparable.

The records obtained at the gaging stations on Limpia and Barilla Creeks and in Madera Canyon have been published in several reports of the Geological Survey on stream measurement. Most of the results of the measurements in 1932 and 1933 were published in Water-Supply Paper 748 [1] and are republished in this report (see pp. 121–144). These results are discussed below by streams.

LIMPIA CREEK

Two gaging stations have been maintained on Limpia Creek. The upper one, known as Limpia Creek, near Fort Davis, was near the site of the old Limpia post office, in the canyon about 16 miles south of Balmorhea. The lower one, known as Barrilla Creek, near Saragosa, was about 30 miles downstream, on the bridge at the crossing of State Highway 190 (Old Spanish Trail), where the stream is commonly known as Barrilla Creek or Draw. The site of the upper station is above any known outcrop of the Lower Cretaceous limestones, whereas the lower site is below a section in which the streams cross several miles of outcrop of these limestones.

The upper station was established February 27, 1925, and maintained until August 30, 1932, when it was destroyed by flood. The lower station was installed December 6, 1924, and discontinued July

[1] Surface-water supply of the United States, 1933, part 8, Western Gulf of Mexico basins: U. S. Geol. Survey Water-Supply Paper 748, pp. 140–160, 171–174, 1935.

15, 1926. It was reestablished September 20, 1932, and a few days later, on September 29, was destroyed when the highway bridge was carried away by one of the largest floods that has occurred on this creek in the memory of residents in this part of Texas. Neither station was rebuilt. Funds were not available to meet the high cost of construction of the type of gaging station necessary to withstand large floods. Moreover, in the stretch of the creek in which the lower station is located, the shifting of the channel with each flood prevents the compilation of a satisfactory rating curve.

The flood of August 30, 1932, which destroyed the upper station, is estimated to have reached a peak discharge of about 14,000 second-feet. During most of the period from December 6, 1924, to July 15, 1926, there was no discharge at either station, but from March to September 1925 several runs of storm water occurred, in which the discharge amounted to a total of about 4,800 acre-feet at the upper station and about 11,000 acre-feet at the lower station. The sites of the two stations are about 40 miles apart, and the drainage from about 100 square miles of mountains, mostly less than 5,000 feet in altitude, enters the stream between them.

The yearly discharge of Limpia Creek at the upper station in Limpia Canyon is given below:

Discharge of Limpia Creek in Limpia Canyon 16 miles southwest of Balmorhea

[Drainage area, 272 square miles. Water year October 1 to September 30]

	Acre-feet
1925, Feb. 27 to Sept. 30	4, 080
1925–26	5, 770
1926–27	661
1927–28	7, 160
1928–29	839
1929–30	894
1930–31	1, 610
1931–32 (Oct. 1 to Aug. 27)	2, 590

Five series of current-meter measurements were made on Limpia Creek to determine seepage losses and gains in several stretches above and below the site of the gaging station in Limpia Canyon. These measurements indicate that the volume of the stream is increased by the inflow of seepage from the vicinity of Fort Davis down to a point about 2 miles above the site of the gage. Below that point, the stream loses water in several stretches and disappears entirely during low and moderate stages before reaching observation points 19 to 22 miles below the station, that is, 9 to 12 miles below the Jeff ranch. (See fig. 3.) The loss in the vicinity of the gaging station was as follows: October 8, 4.2 second-feet; November 1, 8.6 second-feet; November 21, 4.1 second-feet; August 3, 1933, 12.6 second-feet. The loss between the Jeff ranch and points of measurement half a mile to a mile downstream was 6.2 feet on November 1, 1932, and 2.4 second-feet on November 21, 1932. On October 8, 1932, a flow of 65.1 second-feet disappeared between the Jeff ranch and the observation point 12 miles downstream.

MADERA CANYON

The gaging station in Madera Canyon is located about three-quarters of a mile above the mouth of the canyon. It was installed July 28, 1932, and has been in continuous operation ever since. As estimated from the topographic maps of the Fort Davis and Valentine quadrangles, the canyon drains about 54 square miles above the gage, the area consisting of the slopes of mountains most of whose summits are more than 5,500 feet above sea level. The daily records at the station have been published each year by the Geological Survey.[2] These records are fairly accurate for low and moderate stages of stream discharge but much less accurate for high stages. The estimated total annual discharge for each of the years in the period 1932–36 is given in the following table:

Discharge of Madera Canyon, 1932–36

[Water year, Oct. 1 to Sept. 30]

	Acre-feet
1932, Aug. 1 to Sept. 30	14, 800
1932–33	6, 000
1933–34	244
1934–35	637
1935–36	4, 200

According to the daily record, the discharge from August to October 1932 amounted to about 17,000 acre-feet (see table, p. 122), or approximately two-thirds of the total recorded discharge in the period 1932–36. Altogether, in this period of 4 years and 2 months there were 64 days on which the average discharge during the 24 hours was more than 25 second-feet. Of these days, 25 were in August, September, and October 1932, 18 in August and September 1933, 1 in July 1935, and 20 in May and September 1936. During most of the period the stream was dry or the daily discharge was less than 3 second-feet. The maximum discharge, somewhat more than 2,000 second-feet, occurred on September 29 and 30, 1932.

Nine series of discharge measurements were made to determine seepage losses from Madera Canyon between the gaging station and points 2 to 10 miles below it. The maximum flow at the gaging station during these studies was 67.5 second-feet, the minimum 5.2 second-feet, and the average about 27 second-feet (see table, p. 123). None of the water reached Toyah Creek, about 12 miles below the station, and

[2] See records for Madera Canyon near Toyahvale, Tex., in Water-Supply Papers 748, 763, 788, 808, 828, and 858.

most of it was lost within the first few miles. For example, on September 2, 1932, all but 2.2 second-feet of a discharge of 67.5 second-feet was lost within 8.2 miles of the gage, and on October 6, 1932, a discharge of 37.3 second-feet disappeared entirely within 4 miles. On August 27, 1933, a loss of only 6.1 second-feet was indicated in a stretch of 6.2 miles below the gaging station, but these measurements were made during a rapidly declining stage and the true loss probably was much greater. No determinations of seepage losses were made during flood stages when the discharge amounted to several hundred second-feet, but at such times the loss must be heavy, as the water spreads over a wide expanse of gravel.

CHERRY CANYON

Cherry Canyon drains about 70 square miles of mountainous land, as compared with about 54 miles drained by Madera Canyon, and the two drainage areas are similar in ruggedness and altitude. A staff gage was installed on the stream about half a mile below the mouth of the canyon, on August 1, 1932, and was read daily until November 13 of that year and again from August 30 to September 9, 1933. In the intervening period, the gage was read weekly. From this fragmentary record of gage heights, supplemented by miscellaneous measurements with a current meter, the conclusion is reached that the discharge of Cherry Canyon from August 1, 1932, to September 30, 1933, was materially greater than the discharge of Madera Canyon during corresponding periods. The seepage studies disclosed that the stream disappears within a relatively short stretch below the gaging station during low and moderate stages; for example, discharges of 13.5 second-feet on September 15, 1932, and 31.2 second-feet on October 7, 1932, were entirely lost within 2½ miles of the gage. (See table, p. 138.)

BIG AGUJA CANYON

Many measurements were made in 1932 and 1933 of the discharge of Big Aguja Canyon at or near the dam of the Texas & Pacific Railway; the largest discharge, computed at more than 4,000 second-feet, occurred September 7, 1932. (See tables, pp. 126, 142.)

A staff gage was installed in the canyon July 27, 1932, and read intermittently until September 1, 1933. The drainage area above the gage is about 47 square miles, as compared with 54 square miles above the gaging station in Madera Canyon. The two areas apparently are similar topographically. The records indicate that the discharge of Big Aguja canyon was greater than the discharge from Madera Canyon in the early part of September 1932 and somewhat less in the later part of that month, but the record in Big Aguja Canyon is too fragmentary and too short to justify any conclusions as to whether the run-off over a long period of time is comparable to that in Madera Canyon.

Seepage surveys were made on September 1, 3, and 13 and October 6, 1932 (see table, p. 142) to determine losses between the gaging station and Toyah Creek, 9.6 miles below the gage. On September 1 the entire flow, amounting to 18.7 second-feet, was lost before Toyah Creek was reached. Similarly, on September 13, the entire flow of 8.6 second-feet was lost. On October 6, the loss was 18.4 second-feet, including the discharge at the station and the inflow from tributaries below. On September 3, only 26.6 second-feet was lost from a discharge of 45.4 second-feet, but the measurements on that date were taken on a rapidly declining stage and the actual loss probably was greater.

LITTLE AGUJA CANYON

Many measurements of the discharge of Little Aguja Canyon and of its South Fork were made in 1932 and 1933 (see table, p. 125), and the maximum discharge from the main canyon was estimated as 2,640 second-feet on August 29, 1932. The stage of the stream was recorded daily for a few weeks in the later part of the summer of 1932 at a temporary staff gage, set at a point in the canyon above which approximately 31 square miles is drained. From the gage-height record and a few current-meter measurments, it is estimated that the discharge of the canyon during July and August was about 8,000 acre-feet, or a little more than half the discharge of Madera Canyon.

Seepage surveys were made on this stream August 17, September 1, 13, 14, and 20, and October 6, 1932. In these surveys, it was found that the entire discharge of the stream, ranging from 1.3 to 26.8 second-feet, was lost before Toyah Creek was reached (see table, p. 125).

DISCHARGE OF GROUND WATER

The table below, compiled from the gaging records, gives the approximate mean discharge of Phantom Lake, San Solomon, Giffin, West Sandia, and East Sandia Springs for the period of record, October 1931 to September 1933.

Mean discharge of Phantom Lake, San Solomon, Giffin, West Sandia, and East Sandia Springs, in second-feet

[For records of daily discharge see pp. 127–138]

	1	2	3
Phantom Lake	13	35	18
San Solomon	33	60	40
Giffin	4.7	5.6	5.0
West Sandia	1.1	1.7	1.3
East Sandia	1.1	1.3	1.2
Total	53	104	65

1. October 1931; December 1931 to August 1932.
2. September to December 1932.
3. January 1933.

The total discharge of the five springs amounted to 53 second-feet, or about 23,800 gallons a minute, in the first period; 104 second-feet, or about 46,700 gallons a minute, in the second period; and 65 second-feet, or about 29,300 gallons a minute in the third. In the first period the rainfall at Balmorhea was materially above the average, due to a fall of 2.25 inches in December 1931 and 3.79 inches in February 1932. In the second period the rainfall was abnormally high, amounting in the month of September alone to 11.64 inches, or about 85 percent of the average annual rainfall. In the third period, the rainfall was about 40 percent below the average. The total discharge during the three periods, aggregating almost 2 years, was at the average rate of about 48,000 acre-feet a year.

The records of the combined discharge of the Saragosa and Toyah Creek Springs are too few to warrant making an estimate of their mean discharge during the same periods, but the available measurements indicate that it may have been about 9 to 10 second-feet, or at the rate of 6,500 to 7,000 acre-feet a year. Thus the flow of all the springs from the fall of 1931 to the fall of 1933 probably averaged about 54,000 to 55,000 acre-feet a year.

As approximately 25,000 acre-feet of the discharge occurred in the 4 months September to December 1932, following abnormally heavy rains, the mean discharge of the springs during the period of record, must have been materially greater than their long-time average discharge.

CONCLUSIONS

Phantom Lake, San Solomon, and Giffin Springs are fed from an extensive system of solution channels in Lower Cretaceous limestone, that constitute in the aggregate a very large reservoir. The Lower Cretaceous rocks are underlain by rocks of Permian age, which in other parts of the basin of Toyah Creek yield water that is rather highly mineralized. Water enters the Lower Cretaceous limestone along the front of the Davis Mountains, and probably all or nearly all of that water is discharged by the springs. The limestone is close to the surface along the northeast edge of a syncline at Phantom Lake Spring. A few hundred feet east of the spring relatively impermeable strata of Upper Cretaceous age are dropped down against the limestone on the northeast side of a fault, thereby creating a barrier which causes the water to rise to the surface in the spring. The throw of this fault is not great, and a large part of the underground water escapes over the crest of the barrier and continues underground toward San Solomon and Giffin Springs. In the vicinity of San Solomon Spring the limestone again comes nearly to the surface, and a short distance east of the spring the Upper Cretaceous strata crop out in such a way that it seems necessary to assume that here, also, they are dropped down against the limestone on the northeast side of a fault. This fault presumably is of considerably greater throw than the one immediately below Phantom Lake Spring. It may create a practically complete barrier to the movement of the water in the limestone and bring all or nearly all of the flow to the surface in San Solomon and Giffin Springs.

Saragosa, West Sandia, East Sandia, and Toyah Creek Springs have their source in the relatively thin surficial gravel. In the valley between Toyahvale and the Brogada Hills the maximum depth of the gravel is not more than 60 feet, and in most places it is less than 40 feet. Between the Brogada Hills and Saragosa the gravel and associated sand, silt, and clay are several hundred feet thick; there the deposits are not very permeable and the water table is low.

A well put down in the vicinity of Phantom Lake or San Solomon Springs above the faults might tap the limestone reservoir at shallow depth, but it would be practically certain to decrease the flow of the springs. Between the San Solomon Spring-Giffin Springs fault and the Brogada Hills the water-bearing horizon in the Lower Cretaceous limestone is probably from 500 to 1,000 feet beneath the surface, perhaps between 700 and 800 feet. If the fault barrier just below the springs is very tight, the withdrawal of water from the limestone in this stretch by means of a well would not affect the flow of the springs. If the barrier is not complete, a well in that area would tend to decrease the flow of the springs. In this connection, the following possibility should be kept in mind: If the fault below the springs offers an effective barrier to the down-valley movement of the water underground, solution channeling may not have developed extensively in the limestone below the barrier because of lack of circulation. If the limestone between San Solomon Spring and the Brogada Hills is relatively tight the water in it may be comparatively highly mineralized.

Before a well is put down in this part of the valley the San Solomon and Giffin Springs should be equipped with automatic measuring devices and an accurate continuous record kept of their flow. A similar record should be kept while the well is being operated to determine whether its operation affects the springs.

Shallow wells in the gravel in parts of the Balmorhea district may yield a few second-feet of water, but such wells, if improperly located or pumped too heavily, may deplete the flow of Toyah Creek, Saragosa, or Sandia Springs. The flow of these springs is effectively utilized only during the growing season, and in view of this and of the urgent need for an additional supply of water during the relatively short critical period of the growing season, an attempt to develop shallow ground water would appear to be justified. If the wells were put down near the upper end of the district, 3 to 4 miles southwest of Balmorhea, it is possible that the withdrawal of water from them would not seriously affect the flow of the springs until after the critical period of the growing season. Then during the succeeding months the normal recharge to the shallow ground-water reservoir could be expected to replenish the supply stored in the gravel. Some water might also be obtained by means of shallow wells in the moist area subject to seepage from the Balmorhea irrigation reservoir, between the reservoir and Balmorhea. If wells are sunk in the gravel and pumped for irrigation, especially in the district near Balmorhea, the development should proceed cautiously, and in the meantime continuous accurate records should be kept of the flow of Saragosa, Sandia, and Toyah Creek Springs, and of the position of the water table.

In the district between the Brogada Hills and Saragosa the limestone is at greater depth, perhaps 1,000 to 1,200 feet. It is probable that any water that occurs in the limestone in that area is shut off from the reservoir that supplies the large springs at Balmorhea, and that it has its source partly in separate areas of intake and partly in the overflow that passes from those springs. A deep well in this district, therefore, would not be expected to interfere with the springs.

A deep well in the vicinity of Balmorhea, perhaps at 1,200 to 1,300 feet, would probably reach a water-bearing horizon in the basal Lower Cretaceous sands or in the Permian rocks. The quality of the water that might be encountered in these rocks, however, is not known.

RECORDS OF DISCHARGE AND SEEPAGE

Records of the discharge of the streams and springs and of seepage gains and losses from the streams and canals of the Balmorhea district, taken from Water-Supply Paper 748,[3] are given in the pages following.

Miscellaneous measurements of the discharge, in second-feet, of San Solomon, Giffin, Saragosa, and Toyah Creek Springs near Balmorhea, Tex.

Date	San Solomon Spring	Giffin Springs	Saragosa and Toyah Creek Springs	Date	San Solomon Spring	Giffin Springs	Saragosa and Toyah Creek Springs
1919, Aug. 20	34.7		4.8	1924, Oct. 17	37.7		
1922, July 20	37.0	3.9	5.9	1925, Jan. 8	38.2		
1923, Apr. 26	26.5	5.4		Mar. 4	36.3	2.9	
Sept. 25	35.0			June 2	34.3	3.4	
1924, June 3	32.3	3.9		1935, Feb. 6	30.4		
June 4	33.4			July 2	32.8		
Sept. 6	34.4			Aug. 13	31.6		
Sept. 7	35.4			1936, Apr. 15	30.4		

[3] Surface-water supply of the United States, 1933, part 8, Western Gulf of Mexico basins; U. S. Geol. Survey Water-Supply Paper 748, 180 pp., 1935.

Discharge, in second-feet, of creek in Madera Canyon near Toyahvale, Tex., 1932–33

Day	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	June	July	Aug.	Sept.
1932–33												
1	0	21	530	2.1		1.1	0.2	0.5	0	3.5	0	102
2	0	34	141	2.1		.9	.2	.5	0	2.6	0	119
3	0	85	108	2.1		.8	.2	.4	0	2.0	0	44
4	0	38	51	2.1		.7	.2	.4	0	.7	0	24
5	0	42	40	2.1		.7	.2	.4	0	.2	0	19
6	0	87	40	2.1		.7	.2	.4	0	.1	0	13
7	0	659	30	2.1	1.4	.7	.2	.3	0	.1	0	9.1
8	0	351	22			.6	.2	.3	0	0	0	7.2
9	0	138	16			.6	.2	.3	0	0	0	6.9
10	0	138	11			.6	.2	.3	0	0	0	103
11	0	54	16			.5	.2	.2	0	0	0	104
12	0	30	16			.5	.2	.1	0	0	0	67
13	0	14	11			.5	.2	.1	0	0	0	58
14	0		7.5			.4	.2	.1	0	0	0	70
15	0	14	7.5		1.2	.4	.2	.1	0	0	0	39
16	0	14	16		1.1	.4	.2	.1	0	0	0	27
17	0	14	7.5		1.1	.4	.2	.1	0	0	0	19
18	0	14	7.5		1.1	.4	.2	.1	0	0	0	15
19	0	9.0	7.5	1.4	.9	.4	.2	.1	0	0	0	81
20	0	5.1	7.5		.7	.3	.2	.1	0	0	0	139
21	0	5.1	7.5		.7	.2	.2	.1	0	0	0	28
22	0	5.1	7.5		.8	.2	.2	0	0	0	0	16
23	0	9.0	7.5		2.3	.2	.1	0	0	0	0	11
24	0	9.0	7.5		2.1	.2	.1	0	0	0	5.3	7.9
25	0	9.0	7.5		1.8	.3	.3	0	0	0	24	5.6
26	0	9.0	7.5		1.6	.3	.4	0	0	0	11	4.4
27	0	9.0	7.5		1.3	.3	.5	0	0	0	124	3.5
28	27	134	4.4		1.3	.3	.5	0	17	0	78	3.0
29	321	2,190	4.4		1.2	.3		0	5.9	0	42	2.6
30	810	2,040	4.4		1.6	.3		0	5.8	0	213	2.1
31	94		4.4		1.3	.3		0		0	60	

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1932				
July 28–31	0	0	0	0
August	810	0	40.4	2,480
September	2,190	5.1	206	12,300
The period				14,800
1932–33				
October	530	4.4	37.5	2,310
November			1.56	93
December			1.35	83
January	1.1	.2	.47	29
February	.5	.1	.22	12
March	.5	0	.16	9.8
June	17	0	.96	57
July	3.5	0	.30	18
August	213	0	18.0	1,110
September	139	2.1	38.3	2,280
The year	530	0	8.28	6,000

NOTE.—No flow during April and May 1933.

Discharge measurements in Madera Canyon to determine losses by seepage between a point 13.3 miles above and a point 3.5 miles above Toyahvale, Tex., 1932–33

Date	Stream	Location	Distance from initial point (miles)	Discharge (second-feet)			
				Main stream	Tributary	Gain or loss in section	Total gain or loss
1932							
Sept. 1	Madera Canyon	Gage	13.3	23.2			
1	do	Madera Spring road crossing	7.1	3.9		−19.3	−19.3
1	do	8.2 miles below gage	5.1	0		−3.9	−23.2
2	do	Gage	13.3	67.5			
2	do	Madera Springs road crossing	7.1	41.8		−25.7	−25.7
2	do	8.2 miles below gage	5.1	2.2		−39.6	−65.3
2	do	Duncan Kingston crossing	3.5	.5		−1.7	−67.0
3	do	Gage	13.3	41.8			
3	do	Madera Springs road crossing	7.1	16.1		−25.7	−25.7
3	do	8.2 miles below gage	5.1	8.3		−7.8	−33.5
3	do	Duncan Kingston crossing	3.5	4.5		−3.8	−37.3
12	do	Gage	13.3	28.7			
12	Madera Springs Creek	Mouth	11.3		0.5		
12	Madera Canyon	Madera Springs road crossing	7.1	7.2		−22.0	−22.0
12	do	8.2 miles below gag	5.1	2.5		−4.7	−26.7
15	do	Gage	13.3	14.5			
15	do	Madera Springs road crossing	7.1	.3		−14.2	−14.2
15	do	8.2 miles below gage	5.1	.2		−.1	−14.3
21	do	Gage	13.3	5.2			
21	do	Rock outcrop	7.5	0		−5.2	−5.2
21	do	Madera Springs road crossing	7.1	.3		+.3	−4.9
21	do	0.2 miles below Madera Springs road crossing	6.9	0		−.3	−5.2
21	do	8.2 miles below gage	5.1	.6		+.6	−4.6
24	do	Gage	13.3	6.7			
24	Side canyon	Mouth	13.2		.3		
24	Madera Canyon	1.5 miles below gage	11.8	6.7		−.3	−.3
24	do	2.5 miles below gage	10.8	1.0		−5.7	−6.0
24	do	3.5 miles below gage	9.8	.2		−.8	−6.8
Oct. 6	do	Gage	13.3	37.3			
6	Madera Springs Creek	Mouth	11.3		1.5		
6	Madera Canyon	2.6 miles below gage	10.7	22.6		−16.2	−16.2
6	do	3.7 miles below gage	9.6	4.5		−18.1	−34.3
6	do	Limestone outcrop	9.3	0		−4.5	−38.8
1933							
Aug. 27	do	Gage	13.3	17.5			
27	do	Madera Springs road crossing	7.1	11.4		−6.1	−6.1
27	do	Duncan Kingston crossing	3.5	0		−11.4	−17.5

Discharge measurements of Toyah Creek to determine losses by seepage between a point 1.2 miles above and a point 8.8 miles below Toyahvale, Tex., 1932–33

Date	Stream or diversion	Location	Distance from initial point (miles)	Discharge (second-feet)				
				Main stream	Tributary	Diversion	Gain or loss in section	Total gain or loss
1932								
Nov. 6	Toyah Creek	Aloma settlement	1.0	13.6				
6	Project waste	0.9 mile above Balmorhea	3.9		0.3			
6	Saragosa Springs Creek	150 feet above mouth	4.7		9.9			
6	Toyah Creek	500 feet below Balmorhea Bridge	4.8	29.1			+5.3	+5.3
6	do	500 feet below Moore Dam	5.8	30.7			+1.6	+6.9
6	do	Saragosa Dam	8.8	29.0			−1.7	+5.2
1933								
Jan. 23	do	1.8 miles above Balmorhea Bridge	3.0	0				
23	Saragosa Springs Creek	200 feet above mouth	4.7		8.2			
23	Toyah Creek	300 feet below Balmorhea Bridge	4.8	12.5			+4.3	+4.3
23	do	300 feet below Moore Dam	5.8	12.8			+.3	+4.6
23	do	Saragosa Dam	8.8	10.5			−2.3	+2.3
Mar. 14	do	United States Highway 290 crossing	−1.2	2.5				
14	do	1.8 miles above Balmorhea	3.0	0			−2.5	−2.5
14	Saragosa Springs Creek	200 feet above mouth	4.7		6.7			
14	Toyah Creek	500 feet below Balmorhea Bridge	4.8	9.4			+2.7	+.2
14	Moore Canal	150 feet below takeout	5.8			5.3		
14	Toyah Creek	500 feet below Moore Dam	5.8	4.8			+.7	+.9
14	Saragosa Canal	50 feet below takeout	8.8			6.0		
14	Toyah Creek	50 feet below Saragosa Dam	8.8	.2			+1.4	+2.3
May 16	do	1.8 miles above Balmorhea Bridge	3.0	0				
16	Saragosa Springs Creek	50 feet above mouth	4.7		6.4			
16	Toyah Creek	500 feet below Balmorhea Bridge	4.8	9.2			+2.8	+2.8
16	Moore Canal	2,000 feet below Moore Dam	5.8			7.3		
16	Toyah Creek	500 feet below Moore Dam	5.8	1.6			−.3	+2.5
16	Saragosa Canal	50 feet below Saragosa Dam	8.8			4.0		
16	Toyah Creek	do	8.8	0			+2.4	+4.9
July 11	do	1.8 miles above Balmorhea Bridge	3.0	0				
11	Saragosa Springs Creek	200 feet above mouth	4.7		5.6			
11	Toyah Creek	500 feet below Balmorhea Bridge	4.8	8.3			+2.7	+2.7
11	Moore Canal	2,000 feet below Moore Dam	5.8			7.0		
11	Toyah Creek	500 feet below Moore Dam	5.8	1.6			+.3	+3.0
11	Saragosa Canal	125 feet below Saragosa Dam	8.8			3.5		
11	Toyah Creek	50 feet below Saragosa Dam	8.8	0			+1.9	+4.9

Discharge measurements in Little Aguja Canyon to determine losses by seepage between a point 15.5 miles above and a point 2.2 miles above Toyahvale, Tex., 1932

Date	Stream	Location	Distance from initial point (miles)	Discharge (second-feet)			
				Main stream	Tributary	Gain or loss in section	Total gain or loss
Aug. 17	Little Aguja Canyon	Temporary staff gage	15.5	1.3			
17	do	2.8 miles below staff gage	12.7	1.0		−0.3	−0.3
17	South Fork of Little Aguja Canyon	0.2 mile above mouth	11.5		0.4		
17	Little Aguja Canyon	5.5 miles below gage	10.0	.4		−1.0	−1.3
17	do	7.0 miles below gage	8.5	.6		+.2	−1.1
17	do	8.5 miles below gage	7.0	.4		−.2	−1.3
17	do	9.6 miles below gage	5.9	.2		−.2	−1.5
17	do	300 feet above limestone bluff	4.3	.1		−.1	−1.6
17	do	Upper end of limestone bluff	4.3	0		−.1	−1.7
17	do	Lower end of limestone bluff	4.0	.2		+.2	−1.5
17	do	Mouth	2.2	0		−.2	−1.7
Sept. 1	do	3 miles below gage	12.5	12.1			
1	South Fork of Little Aguja Canyon	0.2 mile above mouth	11.5		6.4		
1	Little Aguja Canyon	Mouth	2.2	0		−18.5	−18.5
13	do	50 feet below mouth of South Fork	11.3	22.8			
13	do	100 feet above limestone bluff	4.3	0		−22.8	−22.8
13	do	50 feet above limestone bluff	4.3	.1		+.1	−22.7
13	do	0.1 mile below limestone bluff	3.9	0		−.1	−22.8
14	do	50 feet below mouth of South Fork	11.3	11.2			
14	do	0.5 mile below white bluff	8.2	0		−11.2	−11.2
20	do	60 feet below mouth of South Fork	11.3	4.1			
20	do	150 feet above upper Duncan road	9.5	0		−4.1	−4.1
20	do	100 feet above white bluff	8.7	.6		+.6	−3.5
20	do	600 feet below white bluff	8.6	0		−.6	−4.1
20	do	Second white bluff	7.8	.6		+.6	−3.5
20	do	0.1 mile below second white Bluff	7.7	0		−.6	−4.1
Oct. 6	do	200 feet below mouth of South Fork	11.2	26.8			
6	do	Lower Duncan road crossing	6.0	26.5		−.3	−.3
6	Wet-weather springs	Limestone bluff	4.3		.2		
6	Little Aguja Canyon	50 feet below limestone bluff	3.9	2.2		−24.5	−24.8
6	do	4,000 feet above mouth	3.0	0		−2.2	−27.0

Discharge measurements in Big Aguja Canyon to determine losses by seepage between a point 11.8 miles above and a point 2.2 miles above Toyahvale, Tex., 1932

Date	Stream	Location	Distance from initial point (miles)	Discharge (second-feet)			
				Main stream	Tributary	Gain or loss in section	Total gain or loss
Sept. 1	Big Aguja Canyon	Temporary staff gage	11.8	18.7			
1	do	Above mouth of Seven Springs Creek	7.3	4.4		−14.3	−14.3
1	Seven Springs Creek	Mouth	7.2		0.5		
1	Big Aguja Canyon	do	2.2	0		−4.9	−19.2
3	do	Temporary staff gage	11.8	45.4			
3	do	Above mouth of Seven Springs Creek	7.3	35.7		−9.7	−9.7
3	Seven Springs Creek	Mouth	7.2		.4		
3	Big Aguja Canyon	do	2.2	19.2		−16.9	−26.6
13	do	Temporary staff gage	11.8	8.6			
13	Walnut Canyon	Mouth	7.5		.2		
13	Big Aguja Canyon	Above mouth of Seven Springs Creek	7.3	5.6		−3.2	−3.2
13	Seven Springs Creek	Mouth	7.2		4.8		
13	Big Aguja Canyon	do	2.2	0		−10.4	−13.6
Oct. 6	do	Temporary staff gage	11.8	10.3			
6	do	Above pipe-line crossing	9.6	5.6		−4.7	−4.7
6	Break in Texas & Pacific pipe line	Canyon crossing	9.5		1.5		
6	Big Aguja Canyon	Below pipe-line crossing	9.5	7.1		0	−4.7
6	Walnut Canyon	Mouth	7.5		.6		
6	Big Aguja Canyon	Above mouth of Seven Springs Creek	7.3	14.0		+6.3	+1.6
6	Seven Springs Creek	Mouth	7.2		6.1		
6	Big Aguja Canyon	3 miles above mouth	5.2	0		−20.1	−18.5
6	do	½ mile above mouth	2.7	0		0	−18.5
6	do	0.4 mile above mouth	2.6	.1		+.1	−18.4
6	do	Mouth	2.2	.1		0	−18.4

Discharge, in second-feet, of Phantom Lake Spring near Toyahvale, Tex., 1931–33

Day	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1931–32										
1	-------	13	13	20	16			12	13	[2]18
2	-------	13	13	19	16		[1]13	12	12	[2]18
3	-------	13	13	17	16			13	12	18
4	-------	13	13	16	16		13	13	12	[2]19
5	-------	13	13	16	16		13	13	12	[2]23
6	-------	13	13	18	15		13	12	12	[2]26
7	-------	13	13	18	14		13	12	12	34
8	-------	13	13	20	14	[1]14	13	[2]13	12	42
9	-------	13	13	21	14		13	13	13	45
10	-------	13	13	22	14		13	13	13	45
11	-------	13	13	22	14		13	12	13	46
12	-------	14	13	22	[2]14		13	12	13	45
13	-------	13	13	22			13	13	13	42
14	-------	13	13	21			13	13	13	40
15	-------	13	13	20			13	13	13	37
16	-------	13	13	20			13	13	13	35
17	-------	13	13	19			13	13	13	34
18	-------	13	13	19			13	13	13	33
19	-------	13	13	18			13	13	13	[2]32
20	-------	13	13	[2]17			13	13	13	31
21	[2]13	13	13	[2]17	[1]14		13	13	12	30
22		13	15	[2]17			13	13	12	29
23		13	20	[2]17		[1]13	13	13	12	[2]26
24		13	19	[2]16			13	13	12	26
25	[1]13	13	22	[2]16			13	13	12	26
26		13	24	[2]16			12	13	12	25
27		13	25	[2]16			12	13	12	28
28		13	24	16			12	13	12	34
29	[2]13	13	22	16			12	[2]13	13	54
30	[2]13	13	-------	16			12	13	14	89
31	13	13	-------	16	-------		-------	13	17	------

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1932–33												
1	104	31	21	18	17	16	16	16	15	[2]15	14	
2	114	30	21	18	17	16	16	16	16	[2]15	14	[1]42
3	114	30	21	18	17	16	16	17	[2]16	15	14	
4	109	29	21	18	17	16	16	17	[2]16	15	14	47
5	102	28	21	18	17	16	16	17	[2]16	15	14	46
6	88	28	21	18	17	16	16	17	[2]16	15	14	46
7	82	27	21	18	17	16	16	[2]17	[2]16	[2]15	14	44
8	75	26	21	18	17	16	16	[2]17	16	[2]15	14	43
9	73	26	21	18	17	16	16	[2]17	16	[2]15	14	43
10	70	26	20	18	17	16	16	[2]17	16	15	14	42
11	67	25	20	18	17	16	16	17	16	14	14	42
12	64	25	20	18	17	16	16	17	15	14	14	43
13	63	25	20	18	17	16	16	17	15	14	14	43
14	61	24	20	18	17	16	16	16	15	14	[2]14	
15	60	24	20	18	17	16	16	16	15	14	[2]14	
16	57	24	19	18	17	16	16	16	15	14	[2]14	[1]36
17	55	24	19	18	17	16	16	16	15	14	14	
18	53	23	19	18	17	16	16	16	15	14	14	
19	51	23	19	18	17	16	16	16	14	14	14	
20	49	23	19	18	17	16	16	16	14	14	14	[2]28
21	46	23	19	18	17	16	16	16	14	14	14	[2]28
22	44	23	19	18	17	16	16	16	15	14	14	[2]28
23	43	23	19	18	17	16	16	16	15	14	14	27
24	42	23	19	18	17	16	16	16	15	14	14	26
25	39	23	19	18	17	16	16	16	15	14	[2]14	25
26	38	22	19	18	16	16	16	16	15	14	[2]14	24
27	37	22	19	18	16	16	16	16	15	14	[2]14	22
28	35	22	19	17	16	16	16	16	[2]15	14	14	21
29	33	21	19	17	-------	16	16	15	[2]15	14	16	21
30	32	21	19	17	-------	16	16	15	[2]15	14	[1]24	21
31	31	-------	18	17	-------	16	-------	15	-------	[2]14		------

[1] Estimated. [2] Partly estimated.

Discharge, in second-feet, of Phantom Lake Spring near Toyahvale, Tex., 1931–33—Continued

Day	Oct.	Nov.	Dec.	Day	Oct.	Nov.	Dec.	Day	Oct.	Nov.	Dec.
1933				1933				1933			
1	20	16		11	17	16		21	16	16	[1] 16
2	20	16		12	17	15		22	16	16	16
3	20	16		13	17	15		23	16		16
4	19	16		14	17	15		24	16		16
5	19	16	[1] 16	15	17	16	[1] 16	25	16		
6	19	16		16	17	16		26	16	[1] 16	16
7	19	16		17	17	16		27	16		16
8	18	16		18	17	16		28	16		16
9	18	16		19	17	16		19	16		16
10	17	16		20	16	16		30	16		16
								31	16	-------	16

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1931–32				
December 21–31	----------	----------	13.0	284
January	14	13	13.0	799
February	25	13	15.3	880
March	22	16	18.3	1,130
April	----------	----------	14.4	857
May	----------	----------	13.5	830
June	13	12	12.8	762
July	13	12	12.8	787
August	17	12	12.7	781
September	89	18	34.3	2,040
The period	----------	----------	----------	9,150

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1932–33				
October	114	31	62.3	3,830
November	31	21	24.8	1,480
December	21	18	19.7	1,210
January	18	17	17.9	1,100
February	17	16	16.9	939
March	16	16	16.0	984
April	16	16	16.0	952
May	17	15	16.3	1,000
June	16	14	15.2	904
July	15	14	14.3	879
August	----------	14	14.7	904
September	----------	21	35.1	2,090
The year	114	14	22.5	16,300
1933				
October	20	16	17.2	1,060
November	----------	----------	15.9	946
December	----------	----------	16.0	984
The period	----------	----------	----------	2,990

[1] Estimated.

Discharge, in second-feet, of Giffin Springs at Toyahvale, Tex., 1931–33

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1931–32												
1	-------	4.3	[1] 3.7	3.6	4.5	4.6	4.7	4.7	4.6	4.7	[1] 4.7	[1] 4.7
2	-------	4.2	[1] 3.7	3.6	4.5	4.6	4.7	4.7	4.7	4.7	4.7	4.7
3	-------	4.1	3.7	3.6	4.5	4.6	4.7	4.6	4.7	4.7	4.7	4.7
4	-------	4.1	3.6	3.6	4.5	4.6	4.7	4.6	4.7	4.7	4.7	
5	-------	4.1	3.6	3.6	4.5	4.6	4.7	4.6	4.7	4.7	4.7	
6	-------	[1] 4.1	3.6	3.6	4.5	4.6	4.7	4.6	4.7	4.7	4.7	
7	-------	4.1	3.6	3.6	4.5	4.6	4.7	4.6	4.7	4.7	4.7	
8	-------	[1] 4.1	3.6	3.6	4.5	4.6	4.7	4.6	4.6	4.7	4.7	[1] 4.8
9	-------	[1] 4.1	3.6	3.6	4.5	4.6	4.7	4.6	4.6	4.7	4.7	
10	-------	[1] 4.1	3.6	3.6	4.5	4.6	4.7	4.6	4.6	4.7	4.7	
11	-------	[1] 3.9	3.6	3.6	4.5	4.6	[1] 4.7	4.6	4.6	4.7	4.6	
12	-------	[1] 3.9	3.6	3.6	4.5	4.6	[1] 4.7	4.6	4.6	4.7	4.6	
13	-------	3.9	3.6	3.6	4.5	[1] 4.6	[1] 4.7	4.6	4.6	4.6	4.6	
14	-------	3.8	3.6	3.6	4.5	[1] 4.6	[1] 4.7	4.6	4.6	4.6	4.6	[1] 4.9
15	-------	3.8	3.6	3.6	4.5	4.6	[1] 4.7	4.6	4.6	4.6	4.6	[1] 5.2
16	-------	3.8	3.6	3.6	4.6	4.6	[1] 4.7	4.6	4.6	4.6	4.6	
17	-------	3.8	3.6	3.6	4.6	4.6	[1] 4.7	4.6	4.6	4.6	4.6	[1] 5.4
18	-------	3.8	[1] 3.6	3.6	4.6	4.6	4.7	4.6	4.6	4.6	4.6	
19	-------	3.8	[1] 3.6	3.6	4.6	4.6	4.7	4.6		4.6	4.6	
20	-------	3.8	3.6	3.6	4.6	4.6	4.7	4.6	[1] 4.6	4.6	4.6	
21	-------	3.8	3.6	4.1	4.6	4.6	4.7	4.6		4.6	4.6	
22	-------	3.8	3.6	4.2	4.6	4.6	4.7	[1] 4.6		4.6	4.6	
23	-------	3.7	3.6	4.3	4.6	4.6	4.7	[1] 4.6	[1] 4.7	4.6	4.6	
24	-------	3.7	3.6	4.3	4.6	4.6	4.7	[1] 4.6		4.6	4.6	[1] 5.3
25	4.7	3.7	3.6	4.3	4.6	4.6	4.7	[1] 4.6	4.7	4.6	4.6	
26	4.7	3.7	3.6	4.5	4.6	4.6	4.7	[1] 4.6	4.7	4.6	4.6	
27	4.7	3.7	3.6	4.5	4.6	4.6	4.7	[1] 4.6	4.7	4.6	4.6	
28	4.7	3.7	3.6	4.5	4.6	4.6	4.7	[1] 4.6	4.7	4.6	4.6	
29	4.6	3.7	3.6	4.5	4.6	4.6	4.7	4.6	4.7		[1] 4.7	
30	4.6	3.7	3.6	4.5	-------	4.7	4.7	4.6	4.7	[1] 4.6	[1] 4.7	
31	4.5	-------	3.6	4.5	-------	4.7	-------	4.6	-------		4.7	------

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1932–33												
1					4.9		5.1	4.9	[1] 5.0	4.9	4.9	[1] 5.3
2					4.9		5.1	4.9	[1] 5.0	4.9	4.7	[1] 5.4
3					4.9		5.1	4.9	[1] 5.0	4.9	4.7	------
4					[1] 4.9		5.0	4.9	5.0	4.9	4.7	------
5					[1] 4.9	5.0	5.0	4.9	5.0	4.9	4.7	------
6					[1] 4.9		5.0	4.9	5.0	4.9	4.7	------
7					[1] 4.9		5.0	4.9	5.0	4.9	4.7	------
8					[1] 4.9		5.0	4.9	5.0	[1] 4.9	4.7	------
9					[1] 4.9	5.1	5.0	4.9	5.0	[1] 4.9	4.7	------
10					[1] 4.9	5.1	5.0	4.9	5.0	[1] 4.9	4.7	------
11					4.9	5.1	5.0	4.9	5.0	[1] 4.9	4.7	------
12					4.9	5.1	5.0	4.9	5.0	[1] 4.9	4.7	------
13					4.9	5.1	5.0	4.9	5.0	[1] 4.9	4.7	------
14					4.9	5.1	5.0	4.9	4.9	4.9	4.7	------
15					4.9	5.1	5.0	4.9	4.9	4.9	4.7	------
16		5.9		5.3	4.9	5.1	[1] 5.0	4.9	4.9	4.9	4.6	------
17	6.1		5.6			5.1	[1] 5.0	4.9	4.9	4.9	4.6	------
18						5.1	[1] 5.0	4.9	4.9	4.9	4.6	------
19						5.1	[1] 5.0	4.9	4.9	4.9	4.6	------
20						5.1	[1] 5.0	5.0	4.9	4.9	4.6	------
21						5.1	[1] 5.0	5.0	4.9	4.9	4.6	------
22						5.1	[1] 5.0	5.0	4.9	4.9	4.6	------
23					5.0	5.1	[1] 5.0	5.0	4.9	4.6	4.6	------
24						5.1	[1] 5.0	5.0	4.9	4.5	4.6	------
25						5.1	[1] 5.0	5.0	4.9	4.3	4.6	------
26						5.1	5.0	5.0	4.9	4.3	[1] 4.6	------
27						5.1	5.0	5.0	4.9	4.3		------
28						5.1	4.9	5.0	4.9	4.6		------
29					------	5.1	4.9	5.0	4.9	4.9	4.9	------
30					------	5.1	4.9	5.0	4.9	4.9		------
31		------		4.9	------	5.1	------	5.0	------	4.9		------

[1] Estimated, partly estimated, or interpolated.

Discharge, in second-feet, of Giffin Springs at Toyahvale, Tex., 1931–33—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1931–32				
October 25–31	4.7	4.5	4.64	64
November	4.3	3.7	3.89	231
December	3.7	3.6	3.61	222
January	4.5	3.6	3.88	239
February	4.6	4.5	4.55	262
March	4.7	4.6	4.61	283
April			4.70	280
May	4.7	4.6	4.61	283
June			4.65	277
July	4.7	4.6	4.64	285
August	4.7	4.6	4.64	285
September			5.06	301
The period				3,010
1932–33				
October			6.10	375
November			5.90	351
December			5.60	344
January			5.29	325
February			4.94	274
March			5.07	312
April	5.1	4.9	5.00	298
May	5.0	4.9	4.94	304
June	5.0	4.9	4.94	294
July	4.9	4.3	4.81	296
August			4.70	289
September 1–2	5.4	5.3	5.35	21
The period				3,480

Discharge, in second-feet, of San Solomon Spring at Toyahvale, Tex., 1931–33

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1931–32												
1		[1] 31			30	[1] 36	34	[1] 32	[1] 32	32	[1] 34	[1] 42
2		31			30	36	34	[1] 32	[1] 32	32	[1] 33	[1] 43
3		31			30	36	34	[1] 32	32	[1] 32	32	43
4		31			30	36	34	[1] 32	32	[1] 33	32	[1] 44
5		30	[2] 37		30	35	34	32	32	[1] 33	32	[1] 48
6		30			30	35	[1] 34	32	32	[1] 33	32	[1] 49
7		30			30	35	[1] 33	32	33	[1] 33	[1] 32	[1] 54
8		[1] 30			30	35	33	33	33	33	[1] 32	[1] 58
9		[1] 30			30	35	33	33	[1] 34	[1] 33	[1] 32	[1] 60
10		[1] 30		[1] 35	30	35	33	33	[1] 34	33	32	62
11		[1] 30			30	35	[1] 32	32	[1] 34	33	[1] 32	63
12					30	[1] 34	[1] 32	32	[1] 33	33	32	64
13					30	[1] 34	[1] 32	32	[1] 33	[1] 33	32	64
14	[1] 32				30	[1] 34	[1] 32	32	[1] 33	[1] 32	32	[1] 65
15	32	[2] 38			30	34	[1] 32	32	[1] 33	[1] 32	32	[1] 65
16	32				30	34	[1] 32	32	[1] 33	[1] 33	32	[1] 64
17	32				30	34	[1] 32	32	[1] 33	[1] 33	32	[1] 64
18	32				30	34	[1] 32	32	33	[1] 33	32	[1] 64
19	32		[2] 36		30	33	[1] 32	32	[1] 33	[1] 33	32	[1] 63
20	32	[1] 38			30	33	[1] 31	32	[1] 32	[1] 33	32	[1] 62
21	32	[1] 38		[2] 32	30	33	[1] 31	32	[1] 32	[1] 33	33	[1] 57
22	[1] 32				30	33	[1] 31	32	[1] 32	[1] 33	33	[1] 56
23	[1] 32	[2] 38		[2] 30	30	33	[1] 31	32	[1] 32	33	[1] 33	56
24	32				31	33	31	32	[1] 32	[1] 33	33	56
25	32				32	[1] 33	31	32	32	[1] 33	[1] 33	55
26	32	[2] 37		[2] 30	34	[1] 33	32	32	[1] 32	[1] 33	33	55
27	32		[2] 35	30	36	33	32	32	[1] 33	[1] 33	33	54
28	32		[2] 35	30	36	[1] 33	32	32	32	[1] 33	32	[1] 54
29	31		[1] 35	30	36	[1] 33	32	32	32	[1] 34	[1] 32	[1] 60
30	[1] 31		[2] 35	30		33	32	32	32	34	[1] 37	[1] 66
31	[1] 31		[2] 35	30		33		32		[1] 34	40	

[1] Partly estimated or interpolated. [2] Estimated.

Discharge, in second-feet, of San Solomon Spring at Toyahvale, Tex., 1931–33—Continued

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1932-33												
1	66	66	56	[1] 46	41	40	36	[1] 36		[1] 34	[1] 34	48
2	[1] 68	66	55	[1] 46	41	40	36	[1] 36		34	34	51
3	[1] 69	66	55	[1] 45	41	40	36	[1] 36		[2] 34	35	54
4	[1] 70	65	54	[1] 45	41	40	36	[1] 36			34	55
5	70	[1] 65	54	[1] 45	40	40	36	[1] 36		[2] 36	34	55
6	[1] 70	64	54	[1] 44	[1] 40	40	[1] 36	36			34	55
7	[1] 71	64	53	[1] 44	40	39	36	36		[2] 38	34	55
8	[1] 71	64	53	[1] 44	40	39	36	36		38	34	55
9	[1] 71	64	53	[1] 43	40	39	[1] 36	37	[2] 36	38	34	55
10	[1] 70	64	52	[1] 43	40	39	[1] 36	37		38	35	[1] 55
11	[1] 70	64	52	[1] 43	40	38	36	37		38	35	56
12	[1] 70	64	52	[1] 43	40	38	36	37		37	35	56
13	[1] 70	64	52	[1] 43	40	38	36	37		37	35	56
14	[1] 70	64	52	[1] 43	40	38	36	37		37	35	56
15	70	64	52	[1] 42	40	38	36	37		37	35	56
16	70	63	51	[1] 42	40	38	36	37		37	35	56
17	70	63	50	[1] 42	40	38	36	37	[1] 36	37	35	56
18	70	62	49	[1] 42	40	38	36	37	35	37	[1] 35	55
19	69	62	48	[1] 42	41	38	36	37	34	37	35	55
20	69	62	47	[1] 42	41	38	36	37	34	37	35	55
21	69	[1] 61	47	[1] 41	41	37	[1] 36	37	34	37	35	55
22	68	60	47	41	41	37	[1] 36	37	[1] 34	[1] 37	35	56
23	68	60	46	41	41	37	36	37	[1] 34	[1] 38	35	56
24	68	59	46	41	41	37	36	36	[1] 35	[1] 38	35	55
25	68	59	[1] 46	41	41	37	[1] 36	36	[1] 35	[1] 38	35	55
26	68	58	[1] 46	41	41	37	36	36	[1] 35	[1] 37	35	[1] 55
27	67	58	[1] 46	41	41	37	36	36	[1] 35	37	35	
28	67	57	[1] 46	41	40	[1] 37	36	36	[1] 35	[2] 36	35	[2] 54
29	67	57	[1] 46	41	------	[1] 36	36	36	[1] 34	[2] 35	40	
30	66	56	[1] 46	41	------	[1] 36	36	[1] 36	[1] 34	34	41	
31	66	------	[1] 46	41	------	[1] 36	------	[1] 36	------	34	44	------

Day	Oct.	Nov.	Dec.	Day	Oct.	Nov.	Dec.	Day	Oct.	Nov.	Dec.
1933				1933				1933			
1		44	[1] 39	11		41	41	21	46	40	[2] 40
2		43	[1] 39	12	[2] 50	41	41	22	46	40	40
3		43	40	13		41	41	23	46	40	40
4		43	[1] 40	14	46	41	41	24	46	40	40
5	[2] 50	42	40	15	46	41	41	25	45	40	39
6		42	40	16	46	41		26	45	40	[1] 39
7		42	41	17	[1] 46	41		27	45	40	39
8		42	41	18	[1] 46	41	[2] 40	28	45	40	39
9		42	41	19	46	40		29	44	39	39
10		42	41	20	46	40		30	44	39	39
								31	44	------	38

[1] Partly estimated or interpolated. [2] Estimated.

Discharge, in second-feet, of San Solomon Spring at Toyahvale, Tex., 1931–33—Continued

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1931–32				
October 14-31	32	31	31.8	1,140
November			35.0	2,080
December			36.2	2,230
January			33.3	2,050
February	36	30	30.9	1,780
March	36	33	34.1	2,100
April	34	31	32.3	1,920
May	33	32	32.1	1,970
June	34	32	32.5	1,930
July	34	32	32.9	2,020
August	40	32	32.7	2,010
September	66	42	57.0	3,390
The period				24,600
1932–33				
October	71	66	68.9	4,240
November	66	56	62.2	3,700
December	56	46	50.1	3,080
January	46	41	42.6	2,620
February	41	40	40.5	2,250
March	40	36	38.1	2,340
April	36	36	36.0	2,140
May	37	36	36.5	2,240
June		34	35.3	2,100
July	38	34	36.6	2,250
August	44	34	35.4	2,180
September		48	54.8	3,260
The year	71	34	44.7	32,400
1933				
October		44	47.4	2,910
November	44	39	41.0	2,440
December	41	38	40.0	2,460
The period				7,810

Discharge measurements of main canal of Reeves County Water Improvement District No. 1 to determine losses by seepage between source and end, near Balmorhea, Tex., 1931 and 1933

Date	Stream or diversion	Location	Distance from initial point (miles)	Discharge (second-feet)				
				Main stream	Tributary	Diversion	Gain or loss in section	Total gain or loss
1931								
Oct. 27	Main canal	300 feet below Solomon Spring	0	32.0				
27	Carpenter take-out		.8			2.81		
27	Giffin Spring		1.4		1.34			
27	Reservoir take-out		1.4			2.83		
27	Henry Jones take-out		1.4			.40		
27	North canal take-out		2.2			.27		
27	Gate leakage	Total leakage between points on main canal				.12		
27	Main canal	Crenshaw garage, Balmorhea	4.0	25.3			−1.6	−1.6
27	Walker take-out		6.0			.61		
27	Gate leakage	Total leakage between points on main canal				.10		
28	Main canal	Highway crossing	7.0	21.4			−3.2	−4.8
28	Highway ditch take-out		7.0			5.94		
28	Sol Mayer take-out		8.0			5.20		
28	Saragosa canal		8.4		1.98			
28	Siphon ditch take-out		8.4			8.98		
28	Gate leakage	Total leakage between points on main canal				.60		
28	Main canal	150 feet below Siphon ditch	8.4	1.42			−1.2	−6.0
28	Gate leakage	Total leakage between points on main canal				.70		
28	Main canal	½ mile above end of system	11.4	.38			−.3	−6.3
1933								
Jan. 11	Main canal	500 feet below Giffin canal junction	1.8	48.7				
11	North spill	Knapp's corner	3.1			26.3		
11	Main canal	Balmorhea Hotel	4.7	19.9			−2.5	−2.5
11	Gate leakage	Total of 2 leaks				.1		
11	West Sandia canal	Gage	5.6		1.8			
11	Main canal	Brogada	6.0	22.2			+.6	−1.9
11	Lateral diversion		6.6			.8		
11	Main canal		7.1	20.2			−1.2	−3.1
11	Gate leakage	Total of 3 leaks				.2		
11	Main canal		8.1	21.0			+1.0	−2.1
12	Siphon ditch	Weir 75 feet below main canal	9.6			1.8		
12	Main canal		9.7	17.1			−2.1	−4.2
12	do		11.1	17.4			+.3	−3.9
Mar. 13	do	500 feet below Giffin canal junction	1.8	11.3				
13	do	Wigley road crossing	2.8	11.4			+.1	+.1
13	Gate leakage	Knapp's corner	3.1			.1		
13	Main canal	400 feet above Highway Garage	4.7	11.0			−.3	−.2
13	West Sandia canal	50 feet above highway	5.6		1.3			

Discharge measurements of main canal of Reeves County Water Improvement District No. 1 to determine losses by seepage between source and end, near Balmorhea, Tex., 1931 and 1933—Continued

Date	Stream or diversion	Location	Distance from initial point (miles)	Discharge (second-feet)				
				Main stream	Tributary	Diversion	Gain or loss in section	Total gain or loss
1933								
Mar. 13	Main canal	1 mile below Brogada	6.3	11.9			−0.4	−0.6
13	do	Highway crossing	7.7	11.9			0	−.6
13	Experiment farm spill	do	8.3		.6			
13	Main canal	Above Saragosa canal junction	9.6	12.5			0	−.6
13	do	½ mile below Siphon ditch	10.1	8.3				
13	do	Saragosa road crossing	11.1	8.8			+.5	+.5
14	do	500 feet below Giffin canal junction	1.8	8.2				
14	Gate leakage		3.0			.1		
14	do		3.7			.1		
14	Main canal	400 feet above Highway Garage	4.7	7.8			−.2	−.2

Discharge measurements of laterals of Reeves County Water Improvement District No. 1 to determine losses by seepage near Balmorhea, Tex., 1931

Date	Stream or diversion	Location	Distance from initial point (miles)	Discharge (second-feet)			
				Main stream	Diversion	Gain or loss in section	Total gain or loss
Oct. 27	Carpenter take-out	Point of diversion	0	2.81			
27	do	Point of delivery	1.0	2.73		−0.08	−0.08
27	Reservoir take-out	Point of diversion	0	2.83			
27	do	Confluence with reservoir creek	1.0	2.33		−.50	−.50
27	Highway ditch	Point of diversion	0	9.32			
27	Mills ditch	do	.8		5.91		
27	Highway ditch	Below mills ditch take-out	.8	3.80		+.39	+.39
27	do	Point of delivery to Mayer farm	1.3	3.84		+.04	+.43
28	Siphon ditch	Point of diversion	0	9.32			
28	do	Point of delivery to Fane Down farm	2.3	6.19		−3.13	−3.13
Nov. 16	Moore canal	300 feet below Moore Dam	0	4.29			
16	do	Pecos Valley Southern Ry. crossing	.5	4.35		+.06	+.06
16	Saragosa canal	1,000 feet below diversion dam	0	1.97			
16	do	Weir	.5	1.68		−.29	−.29
18	Giffin Spring canal	do	0	3.80			
18	do	Siphon	.8	4.06		+.26	+.26

Discharge measurements of reservoir outlet canal of Reeves County Water Improvement District No. 1 to determine losses by seepage between release gate at reservoir and junction with main canal, near Balmorhea, Tex., 1932–33

Date	Stream or diversion	Location	Distance from initial point (miles)	Discharge (second-feet)			
				Main stream	Diversion	Gain or loss in section	Total gain or loss
1932							
July 22	Outlet canal	0.1 mile below release gate	0.1	52.2			
22	Gate leakage	0.3 mile below release gate	.3		0.4		
22	Outlet canal	3.5 miles below release gate	3.5	48.0		−3.8	−3.8
26	do	0.1 mile below release gate	.1	42.1			
26	Gate leakage	0.3 mile below release gate	.3		.3		
26	Outlet canal	0.7 mile below release gate	.7	40.9		−.9	−.9
26	do	1.7 miles below release gate	1.7	41.1		+.2	−.7
26	do	2.4 miles below release gate	2.4	39.8		−1.3	−2.0
26	do	50 feet above main canal	3.5	41.5		+1.7	−.3
Aug. 17	do	0.1 mile below release gate	.1	1.8			
17	do	0.4 mile below release gate	.4	2.1		+.3	+.3
17	do	2.6 miles below release gate	2.6	1.6		−.5	−.2
1933							
July 20	do	0.2 mile below release gate	.2	14.2			
20	do	0.4 mile above main canal	3.1	11.6		−2.6	−2.6
26	do	0.2 mile below release gate	.2	7.2			
26	do	0.6 mile above main canal	2.9	6.0		−1.2	−1.2

Discharge, in second-feet, of West Sandia Spring at Balmorhea, Tex., 1931–33

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1931–32												
1	------	------	[1]1.1	1.1		1.3	1.3	1.2		1.1	[1]1.1	[1,2]1.1
2	------	------	[1]1.1	1.1		1.3	1.2	1.1		1.1	[1]1.1	[1,2]1.3
3	------	------	1.2	1.1	[1]1.1	1.3	1.2	1.1		1.1	[1]1.1	[2]1.4
4	------	------	1.2	1.1		1.4	1.2	1.1	[1]1.1	1.1	1.1	[1,2]1.4
5	------	------	1.2	1.1		1.4	1.2	1.1		1.1	1.1	[1,2]1.4
6	------	------	1.2	1.1	[1]1.1	1.3	1.2	1.0		1.1	1.1	[1,2]1.5
7	------	------	1.2	1.1	[1]1.1	1.3	1.2	1.0	[1]1.1	1.1	1.1	[1,2]1.5
8	------	------	1.2	1.1	[1]1.2	1.3	1.2	1.0	[1]1.1	1.1	1.1	[1,2]1.6
9	------	------	1.2	1.1	[1]1.2	1.3	1.2	[1]1.0	1.1	1.1	1.1	[1,2]1.7
10	------	------	1.2	1.1	[1]1.2	1.3	1.2	[1]1.0	1.1	1.1	1.1	[1,2]1.7
11	------	------	1.2	1.1	[1]1.2	1.3	1.2	[1]1.1	1.1	1.1	1.0	
12	------	------	1.2	1.1	[1]1.2	1.3	1.2		1.1	[1]1.1	1.0	
13	------	------	1.1	1.1	[1]1.2	[1]1.3	1.2		1.1	[1]1.1	1.0	
14	------	------	1.1	1.1	1.2	[1]1.3	1.2		[1]1.1	[1]1.1	1.0	
15	------	------	1.1	1.1	1.2	1.3	[1]1.2		[1]1.1	1.1	1.0	[1]1.7
16	------	------	1.1	1.1	1.2	1.3	[1]1.2	[1]1.2	[1]1.1	1.1	1.0	
17	------	1.1	1.1	1.1	1.2	1.3	[1]1.2		[1]1.1	1.1	1.0	
18	------	1.1	1.1	1.1	1.2	1.3	[1]1.2		[1]1.1	1.1	1.0	
19	------	1.1	1.1	1.1	1.2	1.3	[1]1.2		[1]1.1	1.0	1.0	1.7
20	------	1.1	1.1	1.1	[1]1.2	1.3	[1]1.2		[1]1.1	1.0	[1]1.0	1.7
21	------	1.1	1.1	1.1	[1]1.3	[1]1.3	[1]1.2		1.1	1.0	[1]1.0	1.7
22	------	1.1	1.1	1.1	[1]1.3	1.3	[1,2]1.3		[1]1.1	1.0	[1]1.0	1.7
23	------	1.1	1.1	1.1	[1]1.3	1.3	[1,2]1.3		[1]1.1	1.0	[1]1.0	1.7
24	------	[1]1.1	1.1	1.1	[1]1.3	1.2	[2]1.3		[1]1.2	1.0	1.0	[1]1.7
25	------	[1]1.1	1.1	[1]1.1	[1]1.3	1.2	1.2	[1]1.1	1.2	1.0	1.0	1.6
26	------	[1]1.1	1.1	[1]1.1	[1,2]1.4	1.2	1.2		1.2	1.0	1.0	[1]1.6
27	------	[1]1.1	1.1	[1]1.1	[1,2]1.4	1.2	1.2		1.2	1.0	1.0	[1]1.6
28	------	[1]1.1	1.1	1.1	1.3	1.3	1.2		1.2	1.0	1.0	[1,2]1.7
29	------	[1]1.1	1.1	1.1	1.3	[1]1.3	1.2		1.2	1.0	1.0	[1,2]1.7
30	------	[1]1.1	1.1	1.1	------	[1]1.3	1.2		1.1	[1]1.0	[1]1.0	[1,2]1.7
31	------	------	1.1	[1]1.1	------	[1]1.3	------		------	[1]1.0	[1]1.0	------

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
1932–33											
1	[1]1.8	1.8	1.7		[1]1.7	[1]1.6	[1]1.3	[1]1.2		1.1	1.1
2		1.8	1.7		[1]1.7	[1]1.6	[1]1.3	[1]1.2	[1]1.2	1.1	1.1
3		1.8	1.6		[1]1.7	[1]1.6	[1]1.3	[1]1.2		1.1	1.1
4		1.8	1.6		1.7	[1]1.6	[1]1.3	[1]1.3	[1]1.2	1.1	1.1
5		1.8	1.6	[1]1.7	1.7	[1]1.6	1.3	[1]1.2	[1]1.2	1.1	1.1
6		1.8	1.6		1.7	[1]1.6	1.3	[1]1.2	[1]1.2	[1]1.1	1.1
7		1.7	1.6		1.7	[1]1.6	1.3	[1]1.2	1.2	[1]1.1	1.1
8		1.7	1.7		1.7	1.6	1.3	[1]1.2	1.2	[1]1.1	1.0
9		1.7	1.7		1.7	1.6	1.3	[1]1.2	1.2	[1]1.1	1.0
10	[1]1.9	1.7	1.7	[1]1.7	1.6	1.6	1.3	[1]1.2	1.2	[1]1.1	1.0
11		1.7	1.7	1.7	1.6	[1]1.5	1.3	[1]1.2	1.2	[1]1.1	1.0
12		1.7	1.7	1.7	1.6	[1]1.5	[1]1.3	[1]1.2	1.2	1.1	1.0
13		1.7	1.7	1.7	1.6	[1]1.5	[1]1.3	1.2	1.2	1.1	1.0
14		1.7	1.7	1.7	1.6	[1]1.5	[1]1.3	1.2	1.2	1.1	[1]1.0
15		1.7	1.7	1.7	1.6	1.5	[1]1.3		1.2	[1]1.1	[1]1.0
16		1.7	1.7	1.7	[1]1.6	[1]1.5	[1]1.3		1.2	1.1	[1]1.0
17	[1]1.9	1.7	1.7	1.6	[1]1.6	[1]1.5	[1]1.3		1.1	1.1	[1]1.0
18		[1]1.7	1.7	1.6	[1]1.6	[1]1.5	[1]1.3		1.1	1.1	[1]1.0
19		[1]1.7	1.7	1.6	1.6	[1]1.5	[1]1.3		1.1	1.1	[1]1.0
20		[1]1.7	1.7	1.6	1.6	[1]1.4	[1]1.3		1.1	1.1	[1]1.1
21		[1]1.7	1.7	1.6	1.6	[1]1.4	[1]1.3		1.1	1.1	[1]1.1
22		[1]1.7	1.7	1.5	1.6	[1]1.4	[1]1.3		1.1	1.1	1.1
23	[1]1.9	[1]1.7	[1]1.7	1.5	[1]1.6	[1]1.4	[1]1.3	[1]1.2	1.1	1.1	1.1
24		[1]1.7	[1]1.7	1.5	[1]1.6	[1]1.4	1.3		1.1	1.1	1.1
25		[1]1.7		[1]1.5	[1]1.6	[1]1.3	1.2		1.1	1.1	1.1
26		[1]1.7		[1]1.6	[1]1.6	[1]1.3	1.2		1.1	1.1	1.1
27		1.7	[1]1.7	[1]1.7	[1]1.6	[1]1.3	1.2		1.1	1.1	1.1
28		1.7		[1]1.7	[1]1.6	[1]1.3	1.2		1.1	1.1	1.1
29	1.9	1.7		[1]1.8	------	[1]1.3	1.2		1.1	[1]1.1	------
30	1.8	1.7		[1]1.8	------	[1]1.3	1.2		1.1	[1]1.1	------
31	1.8	------		[1]1.7	------	[1]1.3	------		------	[1]1.1	------

[1] Discharge estimated or partly estimated.
[2] May include some storm run-off or irrigation waste water.

Discharge, in second-feet, of West Sandia Spring at Balmorhea, Tex., 1931–33—Con.

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1931–32				
November 17-30	1.1	1.1	1.10	31
December	1.2	1.1	1.13	69
January	1.1	1.1	1.10	68
February	1.4	1.1	1.21	70
March	1.4	1.2	1.29	79
April	1.3	1.2	1.21	72
May			1.11	68
June			1.12	67
July	1.1	1.0	1.06	65
August	1.1	1.0	1.03	63
September	1.7	1.1	1.61	96
The period				748
1932–33				
October			1.89	116
November	1.8	1.7	1.72	102
December			1.68	103
January			1.66	102
February	1.7	1.6	1.63	91
March	1.6	1.3	1.47	90
April	1.3	1.2	1.28	76
May			1.20	74
June			1.15	68
July	1.1	1.1	1.10	68
August 1-28	1.1	1.0	1.06	59
The period				949

Discharge measurements of West Sandia Creek to determine losses by seepage between a point 4,000 feet above gage and gage 0.8 mile east of Balmorhea, Tex., Oct. 17, 1932

Stream	Location	Distance above gage (feet)	Discharge (second-feet)			
			Main stream	Tributary	Gain or loss in section	Total gain or loss
West Sandia Creek	300 feet above West Sandia Spring	4,000	0.2			
Do	80 feet below West Sandia Spring	3,620	.6		+0.4	+0.4
Canal wasteway	500 feet below West Sandia Spring	3,200		0.1		
West Sandia Creek	Gage	0	2.2		+1.5	+1.9

Discharge, in second-feet, of East Sandia Spring at Balmorhea, Tex., 1931–33

Month	Maximum	Minimum	Mean	Run-off in acre-feet
1931–32				
November 23–30	1.1	1.1	1.10	17
December	1.1	1.0	1.06	65
January	1.1	1.1	1.10	68
February		1.1	1.22	70
March			1.27	78
April			1.20	71
May			1.20	74
June	1.2	.9	1.05	62
July			1.07	66
August		1.0	1.04	64
September			1.35	80
The period				715
1932–33				
October			1.35	83
November	1.3	1.2	1.23	73
December			1.21	74
January			1.28	79
February	1.4	1.2	1.34	74
March			1.32	81
April			1.30	77
May			1.16	71
June			1.09	65
July	1.0	1.0	1.00	61
August	1.1	.9	.92	57
September 1–23			1.10	50
The period				845

Discharge measurements of Cherry Canyon to determine losses by seepage between a point 1.5 miles above and a point 2.5 miles below gage near Toyahvale, Tex., 1932

Date	Location	Distance from initial point (miles)	Discharge (second-feet)		
			Main stream	Gain or loss in section	Total gain or loss
Sept. 15	Gage	0	13.5		
15	500 feet above Kingston line fence	2.0	0	−13.5	−13.5
21	1.5 miles above gage	−1.5	1.2		
21	Gage	0	5.0	+3.8	+3.8
Oct. 7	do	0	31.2		
7	2.5 miles below gage	2.5	0	−31.2	−31.2

NOTE.—Gage is 10 miles above United States Highway 290 crossing.

Discharge measurements of Limpia Creek to determine losses by seepage between a point 12.3 miles above and a point 40.2 miles below Fort Davis, Tex., 1932–33

Date	Stream or diversion	Location	Distance from initial point (miles)	Discharge (second-feet)				
				Main stream	Tributary	Diversion	Gain or loss in section	Total gain or loss
1932								
Oct. 8	Limpia Creek	0.8 mile below Wild Rose Canyon	14.7	31.0				
8	Short Canyon	100 feet above mouth	15.8		1.8			
8	Limpia Creek	500 feet below old Limpia post office	18.2	46.0			+13.2	+13.2
8	do	3 miles below old Limpia post office	21.2	41.8			−4.2	+9.0
8	Horse Thief Canyon	Mouth	27.7		1.2			
8	Runey Canyon	do	27.9		1.5			
8	Limpia Creek	Jeff ranch house	28.2	65.1			+20.6	+29.6
8	do	9 miles below Jeff ranch	37.2	4.2			−60.9	−31.3
8	do	12 miles below Jeff ranch	40.2	0			−4.2	−35.5
18	do	12.3 miles above old Fort Davis lane	−12.3	.1				
18	do	12 miles above old Fort Davis lane	−12.0	0			−.1	−.1
18	do	11.3 miles above old Fort Davis lane	−11.3	.2			+.2	+.1
18	do	11 miles above old Fort Davis lane	−11.0	0			−.2	−.1
18	do	10.3 miles above old Fort Davis lane	−10.3	.5			+.5	+.4
18	do	9.8 miles above old Fort Davis lane	−9.8	0			−.5	−.1
18	do	9.7 miles above old Fort Davis lane	−9.7	.1			+.1	0
18	do	7.9 miles above old Fort Davis lane	−7.9	.6			+.5	+.5
18	do	6 miles above old Fort Davis lane	−6.0	5.7			+5.1	+5.6
18	Side canyon	5.9 miles above old Fort Davis lane	−5.9		.5			
18	Limpia Creek	3.7 miles above old Fort Davis lane	−3.7	5.7			−.5	+5.1
18	do	1.3 miles above old Fort Davis lane	−1.3	5.3			−.4	+4.7
18	Grayson diversion	Old Fort Davis lane	0			0.5		
18	Limpia Creek	First Fort Davis-Toyahvale crossing	1.2	3.8			−1.0	+3.7
19	do	do	1.2	3.8				
19	Side canyon	2.1 miles below old Fort Davis lane	2.1		.4			
19	do	do	2.1		.2			
19	Limpia Creek	4.2 miles below old Fort Davis lane	4.2	8.0			+3.6	+7.3
19	Side canyon	4.8 miles below old Fort Davis lane	4.8		.5			
19	Limpia Creek	7.2 miles below old Fort Davis lane	7.2	8.8			+.3	+7.6
19	do	10.2 miles below old Fort Davis lane	10.2	8.4			−.4	+7.2
19	Frazier Canyon	Mouth	10.3		.4			
19	Limpia Creek	Upper end of Wild Rose Canyon	11.7	9.4			+.6	+7.8
19	do	Lower end of Wild Rose Canyon	14.0	12.9			+3.5	+11.3
19	Short Canyon	Mouth	15.8		.1			
19	Limpia Creek	Old Limpia post office	18.2	14.0			+1.0	+12.3
Nov. 1	do	do	18.2	8.2				
1	do	3 miles below old Limpia post office	21.2	5.4			−2.8	−2.8
1	do	5.9 miles below old Limpia post office	24.1	4.6			−.8	−3.6

Discharge measurements of Limpia Creek to determine losses by seepage between a point 12.3 miles above and a point 40.2 miles below Fort Davis, Tex., 1932–33—Continued

Date	Stream or diversion	Location	Distance from initial point (miles)	Discharge (second-feet)				
				Main stream	Tributary	Diversion	Gain or loss in section	Total gain or loss
1932								
Nov. 1	Limpia Creek	Jeff ranch house	28.2	6.2			+1.6	−2.0
1	do	1 mile below Jeff ranch house	29.2	0			−6.2	−8.2
21	do	Upper end of Wild Rose Canyon	11.7	4.0				
21	do	Lower end of Wild Rose Canyon	14.0	6.1			+2.1	+2.1
21	do	Old Limpia post office	18.2	4.7			−1.4	+.7
21	do	3 miles below old Limpia post office	21.2	2.0			−2.7	−2.0
21	do	6 miles below old Limpia post office	24.2	1.1			−.9	−2.9
21	do	Jeff ranch house	28.2	2.4			+1.3	−1.6
21	do	0.5 mile below Jeff ranch house	28.7	0			−2.4	−4.0
1933								
Aug. 3	do	75 feet below mouth of Short Canyon	15.8	12.6				
3	do	Old Limpia post office	18.2	4.0			−8.6	−8.6
3	do	0.5 mile below old Limpia post office	18.7	0			−4.0	−12.6

Miscellaneous discharge measurements near Balmorhea, Tex., during the years ending Sept. 30, 1932, and Sept. 30, 1933

Date	Stream	Tributary to or diverting from—	Locality	Discharge
1931				
Oct. 26	Madera Canyon	Toyah Creek	13.3 miles above Toyahvale, Tex.	0
1932				
July 18	do	do	do	0
Sept. 2	Toyah Creek	Pecos River	U. S. Highway 290 crossing near Toyahvale, Tex.	463
2	do	do	do	551
7	do	do	Old county steel bridge 3 miles below Balmorhea, Tex.	[1] 26,100
29	do	do	do	11,400
1933				
Aug. 8	do	do	Flow of springs in creek 2.5 miles east of Hoban station and 14 miles below Saragosa, Tex.	[2] 1.5
July 10	Little Aguja Canyon	Toyah Creek	18 miles above Toyahvale, Tex	[2] .05
1931				
Oct. 26	do	do	Odell ranch 15½ miles above Toyahvale, Tex.	0
1932				
July 18	do	do	do	0
29	do	do	do	0
Aug. 16	do	do	do	0
17	do	do	do	1.32
29	do	do	do	[1] 2,640
Dec. 16	do	do	do	[2] .06
1933				
Jan. 26	do	do	do	[2] .03
Mar. 9	do	do	do	0
Apr. 10	do	do	do	0
July 10	do	do	do	0
May 18	South Fork of Little Aguja Canyon.	Little Aguja Canyon	1½ miles above mouth, near Toyahvale, Tex.	.47
July 10	do	do	do	.24
1932				
Sept. —	do	do	1¼ miles above mouth, near Toyahvale, Tex.	1,410
1931				
Oct. 26	do	do	¼ mile above mouth, near Toyahvale, Tex.	[2] .2
1932				
Aug. 16	do	do	do	[2] .30
17	do	do	do	[2] .32
Sept. 1	do	do	do	6.45
Dec. 16	do	do	do	[2] .33
1933				
Jan. 26	do	do	do	[2] .16
Mar. 9	do	do	do	[2] .13
Apr. 10	do	do	do	[2] .20
May 18	do	do	do	[2] .15
July 10	do	do	do	0
Mar. 9	Big Aguja Canyon	Toyah Creek	200 feet below spring, 3 miles above Texas & Pacific Ry. Co. dam, 15.6 miles above Toyahvale, Tex.	1.02
9	do	do	500 feet above Texas & Pacific Ry. Co. reservoir, 13.6 miles above Toyahvale. Tex.	1.69

[1] Determined by slope-area method. [2] Estimated.

Miscellaneous discharge measurements near Balmorhea, Tex., during the years ending Sept. 30, 1932, and Sept. 30, 1933—Continued

Date	Stream	Tributary to or diverting from—	Locality	Discharge
1933				*Sec.-ft.*
May 18	Big Aguja Canyon	Toyah Creek	On spillway of Texas & Pacific Ry. Co. dam 12.6 miles above Toyahvale, Tex.	[2] 0.14
July 10	do	do	do	[2] .25
1931				
Oct. 26	do	do	¾ mile below Texas & Pacific Ry. Co. dam 11.8 miles above Toyahvale, Tex.	[2] [3] .1
1932				
July 18	do	do	do	[2] [3] .32
Aug. 16	do	do	do	[2] [3] .3
Sept. 1	do	do	do	[3] 18.7
3	do	do	do	[3] 45.4
6	do	do	do	[3] 151
7	do	do	do	[3] 4,360
13	do	do	do	[3] 8.6
20	do	do	do	[3] 2.56
Oct. 6	do	do	do	[3] 10.3
Dec. 16	do	do	do	[3] 1.13
1933				
Jan. 26	do	do	do	[3] 1.36
Mar. 9	do	do	do	[3] .12
Apr. 10	do	do	do	[2] [3] .15
May 18	do	do	do	[2] [3] .09
July 10	do	do	do	[3] .17
May 18	Duncan diversion	Big Aguja Canyon	Just below point of diversion, 11.8 miles above Toyahvale, Tex.	1.05
July 10	do	do	do	.95
1931				
Oct. 20	Seven Springs	do	State highway 17 about 7½–8½ miles south of Toyahvale, Tex.	[2] .10
1932				
July 18	do	do	do	[2] .13
Aug. 16	do	do	do	[2] .15
Dec. 16	do	do	do	[2] .09
1933				
Jan. 26	do	do	do	[2] .16
Mar. 9	do	do	do	[2] .04
Apr. 10	do	do	do	[2] .36
May 18	do	do	do	[2] .09
July 10	do	do	do	[2] .14
1932				
Aug. 1	Madera diversion canal.	Toyah Creek	Bridge on State highway 17, ¼ mile south of Toyahvale, Tex.	[2] .34
17	do	do	do	8.19
30	do	do	do	1,930
30	do	do	do	1,650
Sept. 1	do	do	do	3.22
2	do	do	do	81.2
1931				
Oct. 16	Phantom Lake Spring.	do	Source, near Toyahvale, Tex.	[4] 12.6
17	do	do	do	[5] 10.8
19	do	do	do	[5] 11.3
21	do	do	do	[5] 10.9
21	do	do	do	[5] 10.0
22	do	do	do	[5] 11.0
22	do	do	do	[5] 10.9
22	do	do	do	[5] 11.1
22	do	do	do	[5] 10.9
22	do	do	do	[5] 11.3
19	Giffin Springs	do	Source, Toyahvale, Tex.	[6] 4.26
20	do	do	do	[7] 3.82
21	do	do	do	[7] 3.64
24	do	do	do	[7] 4.07
24	do	do	do	[7] 4.03
24	do	do	do	[7] 4.15

[2] Estimated.
[3] Does not include J. C. Duncan diversion 25 feet below section.
[4] Lake level normal.
[5] Lake level 1 foot above normal.
[6] Flow in low ditch.
[7] Flow in high ditch.

Miscellaneous discharge measurements near Balmorhea, Tex., during the years ending Sept. 30, 1932, and Sept. 30, 1933—Continued

Date	Stream	Tributary to or diverting from—	Locality	Discharge
1931				*Sec.-ft.*
Nov. 10	San Solomon Spring	Toyah Creek	Source, Toyahvale, Tex	[7] 30.9
20	do	do	do	[6] 37.7
21	do	do	do	[6] 37.6
21	do	do	do	[6] 38.0
Dec. 29	do	do	do	[6] 35.4
1932				
Jan. 28	do	do	do	[7] 31.2
1933				
July 13	do	do	do	[7] 28.6
24	do	do	do	[7] 37.6
26	do	do	do	[7] 36.9
1932				
Nov. 6	Saragosa Spring	do	½ mile west of Balmorhea, Tex	9.15
1933				
Jan. 23	do	do	do	8.22
Mar. 14	do	do	do	6.69
May 16	do	do	do	6.36
July 11	do	do	do	5.59
29	Stock streams	do	Released for stock water from Reeves County Water Improvement District No. 1 canal system near Balmorhea, Tex.	[2] .89
29	Sandia Creek	do	¾ mile east of State Experiment Farm, near Balmorhea, Tex.	[2] .45
1932				
Sept. 8	Reservoir north spillway.	Sandia Creek	2 miles southeast of Balmorhea, Tex.	225
17	do	do	do	.72
Oct. 1	do	do	do	1,450
Aug. 2	Texas & Pacific farm well No. 2.	Toyah Creek	Hoban station, 16 miles south of Pecos, Tex.	2.26
2	Texas & Pacific farm well No. 1.	do	do	1.86
8	Texas & Pacific farm well No. 4.	do	do	1.95
July 18	Cherry Canyon	do	5 miles above Jeff Davis-Reeves County line, near Toyahvale, Tex.	0
Aug. 27	do	do	do	3.10
27	do	do	do	1.37
Sept. 15	do	do	do	13.5
21	do	do	do	4.98
27	do	do	do	5.66
29	do	do	do	[1] 5,320
Oct. 7	do	do	do	31.2
Dec. 15	do	do	do	[2] .10
1933				
Jan. 25	do	do	do	[2] .13
Mar. 12	do	do	do	[2] .08
Apr. 10	do	do	do	0
May 18	do	do	do	0
July 7	do	do	do	0
29	J. L. Moore stock stream.	Cherry Canyon	¾ mile above Balmorhea-Toyah road crossing, 6 miles northeast of Balmorhea, Tex.	[2] .16
1932				
Aug. 5	Youngblood south well.	Toyah Creek	75 feet east of Pecos Valley Southern Ry. 13½ miles south of Pecos, Tex.	3.99
5	Youngblood north well.	do	½ mile east of Pecos Valley Southern Ry. 13 miles sonth of Pecos, Tex.	3.04
5	J. H. Sudbrock well	do	½ mile west of Pecos Valley Southern Ry. 13½ miles south of Pecos, Tex.	2.07
5	John Wendt well	do	150 feet east of Pecos Valley Southern Ry. 11½ miles south of Pecos, Tex.	2.77
11	Balmorhea Livestock Co. well.	do	1 mile east of Pecos Valley Southern Ry., 8 miles south of Pecos, Tex.	.65
8	W. A. Gardner well	do	¾ mile west of Pecos Valley Southern Ry., 4½ miles south of Pecos, Tex.	.95
1933				
Aug. 2	Limpia Creek	Barrilla Creek	Lower end of Wild Rose Canyon, 14 miles below Fort Davis, Tex.	[2] 3

[1] Determined by slope-area method.
[2] Estimated.
[6] Flow in low ditch.
[7] Flow in high ditch.

Miscellaneous discharge measurements near Balmorhea, Tex., during the years ending Sept. 30, 1932, and Sept. 30, 1933—Continued

Date	Stream	Tributary to or diverting from—	Locality	Discharge
1932				*Sec.-ft.*
Sept. 26	Limpia Creek	Barrilla Creek	Old Limpia post office, 12 miles south of Toyahvale, Tex.	121
Aug. 13	Southern Crude Oil Co. flowing well.	do	About 25 miles southeast of Pecos, Tex.	[8] 1.96
Oct. 28	Humble Thompson flowing well.	Leon Creek	9 miles west of Fort Stockton, Tex.	[9] .33
Aug. 24	Leon Springs and flowing wells.	do	Just above Leon Springs Reservoir, 7 miles west of Fort Stockton, Tex.	16.0
1933				
Aug. 18	do	do	do	18.0
1932				
Aug. 3	Comanche Springs	Comanche Creek	Main canal ¼ mile below diversion dam, at Fort Stockton, Tex.	40.9
24	do	do	do	[10] 45.0
Sept. 14	do	do	do	44.3
Oct. 10	do	do	do	46.7
26	do	do	do	47.7
Nov. 10	do	do	do	48.6
22	do	do	do	50.0
Dec. 14	do	do	do	49.1
1933				
Mar. 17	do	do	do	[10] 48.2
Apr. 11	do	do	do	47.8
May 16	do	do	do	47.0
July 2	do	do	do	48.0
19	do	do	do	[11] 47.8
27	do	do	do	46.8
Aug. 4	do	do	do	45.9
10	do	do	do	44.3
14	do	do	do	[11] 46.0
18	do	do	do	45.1
Sept. 29	do	do	do	[11] 43.4
1932				
Oct. 28	Adobe Springs	do	11 miles east of Fort Stockton, Tex.	.37
28	Miracle and two other flowing wells.	do	12 miles northeast of Fort Stockton, Tex.	1.39
28	Tourney No. 1 flowing well.	do	do	5.23
28	Trans-Pecos No. 1 flowing well.	do	12½ miles northeast of Fort Stockton, Tex.	.97
26	Six Shooter Draw	Pecos River	2 miles below Tunis Spring, 23 miles east of Fort Stockton, Tex.	2.34
26	Tunis Spring	Six Shooter Draw	21 miles east of Fort Stockton, Tex.	1.73
Nov. 10	do	do	do	1.98
1933				
Jan. 13	do	do	do	1.71
Mar. 17	do	do	do	1.94
May 16	do	do	do	1.73

[8] Well opened to full capacity 20 minutes before measurement was started.
[9] Well partly shut off.
[10] Spring openings and channels being cleaned.
[11] Spring water backed up over spring openings by growth in creek channel.

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