N M-124
Acct I C

ED 27

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Albuquerque, New Mexico

Evaluation of the hydraulic characteristics of the Major Johnson Springs aquifer, Eddy County, New Mexico

By

R. L. Cushman

Prepared in cooperation with the

New Mexico Interstate Stream Commission

Open file report

April 1965

Contents

Illustrations

Table

Page

Evaluation of the hydraulic characteristics of the Major Johnson Springs aquifer, Eddy County, New Mexico

By

R. L. Cushman

Introduction

An aquifer about 15 square miles in area and about 100 to 150 feet thick discharges water to the channel of the Pecos River in a series of springs known collectively as the Major Johnson Springs. The springs emerge along a 1- to 2-mile reach of the river channel about 3 to 5 miles downstream from Lake McMillan (fig. 1), an artificial

Figure 1 (caption on next page) belongs near here.

reservoir that temporarily stores Pecos River water.

The principal source of water to the aquifer is leakage through the bed of Lake McMillan. The lake bed is 20 to 30 feet above the level of the water in the aquifer. The rate of leakage from the lake and recharge to the aquifer are related to lake stage; the rate of spring discharge varies with the change in water level in the aquifer; and the water level fluctuates in response to changes in rate of recharge. When the lake is dry for a month or more the discharge of the springs decreases to a few cubic feet per second, and that discharge is equal to the recharge to the aquifer from adjacent formations. If the recharge from adjacent formations ceased when leakage from Lake McMillan was zero (lake would be dry), the springs would flow until the water level in the aquifer lowered to an altitude of about 3,207 feet.

Figure 1.--Map of the Major Johnson Springs area showing location of the Major Johnson Springs aquifer, wells, and gaging stations and piezometric contours.

During a period of below normal runoff in the Pecos River when there is no water to supply Lake McMillan and the lake is dry and the discharge of Major Johnson Springs decreases to a few cubic feet per second, the water supply for the Carlsbad Irrigation District might be short. This period of short supply might be for only a month or so but it might occur when irrigation water would be needed to maintain crop growth. If water could be pumped from the Major Johnson Springs aquifer during the water-short period in a quantity sufficient to meet the emergency need, the economy of the irrigation district would be more secure. When Lake McMillan refilled after a dry period, pumping from the aquifer could be stopped, and leakage from the lake would replenish the water pumped from the aquifer.

The feasibility of pumping water from the aquifer would depend on the rate of yield by wells and the amount of water in usable storage. Construction of large yielding wells in the aquifer might be economically feasible if at least 20,000 acre-feet of water could be pumped from storage in the aquifer in a time span of 1 to 2 months; wells yielding 5,000 to 10,000 gpm (gallons per minute) would be required. The amount of water in the aquifer was estimated as 50,000 acre-feet (Theis, 1942), 30,000 acre-feet (Cox, written communication, 1964), and 46,000 acre-feet (Reeder, 1963). The rate at which water can be withdrawn from the aquifer by wells has not been estimated.

The amount of water stored in the aquifer and the rate of withdrawal can be computed if the hydraulic characteristics of the aquifer, specifically the coefficient of transmissibility (expressed in this report in terms of gallons per day through a section of aquifer 1 mile wide under a hydraulic gradient of 1 foot per mile) and the coefficient of storage (a dimensionless number that is the ratio of the volume of water released or taken into storage per unit surface area of the aquifer per unit change in the head in the aquifer) are known.

Purpose and scope

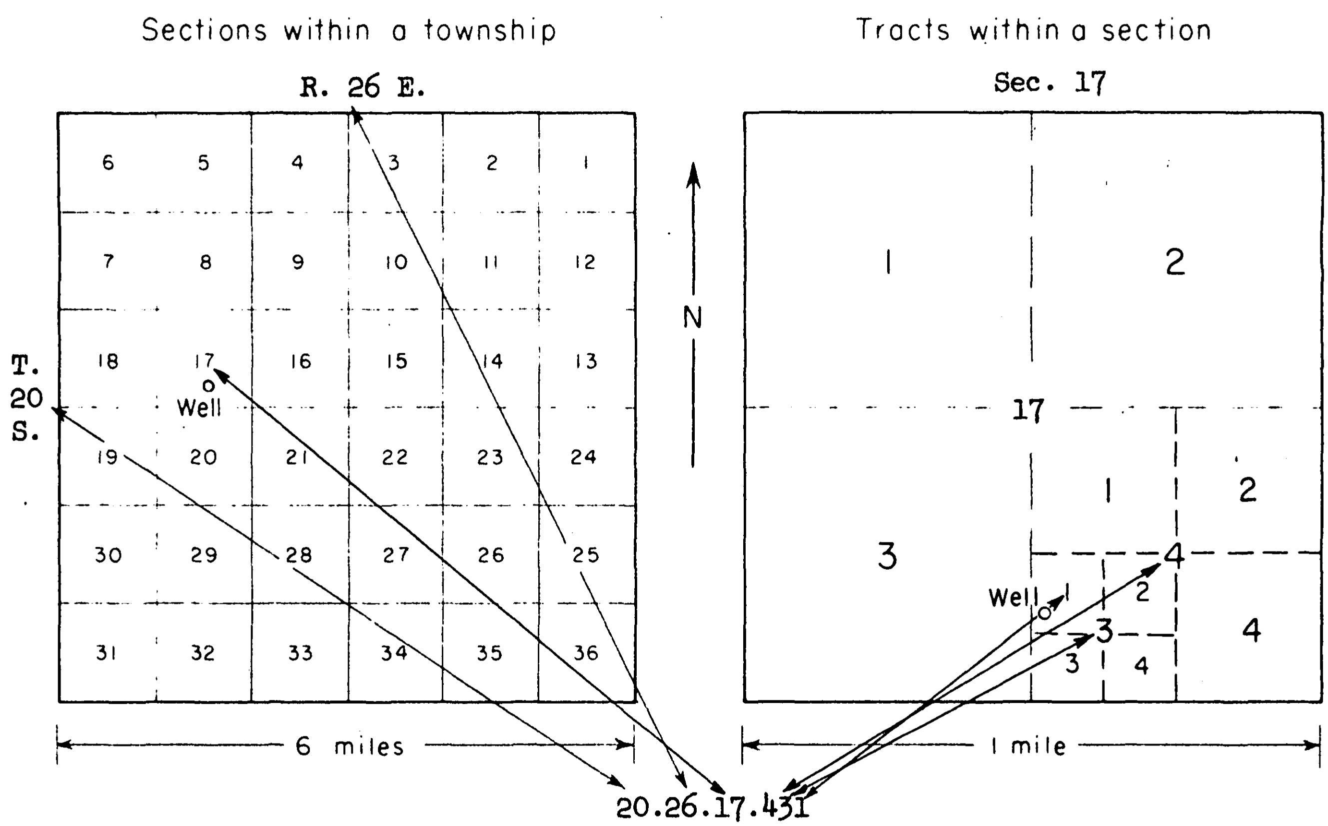
The Interstate Stream Commission asked the U.S. Geological Survey to evaluate the coefficients of transmissibility and storage of the Major Johnson Springs aquifer using only data already collected by various agencies and data that might become available in November and December 1964 from a data-collection program in progress. After a cursory search of the geologic and hydrologic information available, data for the period of record January 1957 to December 1964, inclusive, were selected for use in evaluating hydraulic characteristics of the aquifer. The data used consisted of: 1) water-level measurements in 13 wells tapping the aquifer; 2) discharge records for gaging stations on the Pecos River (Kaiser Channel) near Lakewood, N. Mex., Pecos River below McMillan Dam, N. Mex., Pecos River at damsite 3, near Carlsbad, N. Mex.; 3) miscellaneous seepages studies on the Pecos River between McMillan Dam and the damsite 3 gaging station; 4) reports on stage and contents of Lake McMillan; 5) rating curve for Lake McMillan showing stage-water area relation; 6) precipitation and evaporation data from the weather station at Lake Avalon; and 7) logs of test holes.

Acknowledgements

Logs and other data from test drilling by the U.S. Bureau of Reclamation were used to limit and define the aquifer. A preliminary map showing the 1964 resurvey of Lake McMillan was made available by the Carlsbad Irrigation District. E. R. Cox and W. K. Dein, U.S. Geological Survey, geologist and engineer, respectively, were most helpful in supplying current ground- and surface-water data and in making suggestions about geologic and hydrologic conditions in the area. The limits of the Major Johnson Springs aquifer described in this report are modified from the limits of an aquifer recognized by Cox (written communication, 1964) in the Permian Seven Rivers Formation. The piezometric contours shown on figure 1 were prepared by Cox (written communication, 1964) from water-level data for years 1955-57.

System of numbering wells in New Mexico

All wells referred to in this report are identified by a location number used by the Geological Survey and the State Engineer for numbering water wells in New Mexico. The location number is a description of the geographic location of the well, based on the system of public land surveys. It indicates the location of the well to the nearest 10-acre tract. The location number consists of a series of numbers corresponding to the township, range, section, and tract within a section, in that order, as illustrated below. All wells in this report are in T. 20 S., R. 26 E.



The Major Johnson Springs aquifer

The aquifer that discharges at Major Johnson Springs is in the Seven Rivers Formation; however, the Major Johnson Springs aquifer comprises only a small part of that formation. The term "Major Johnson Springs aquifer" is a useful reference term [illegible] for this report.

Test drilling indicates that the Major Johnson Springs aquifer consists of limestone, dolomite, gypsum, shale, and siltstone. Solution has removed much of the readily soluble gypsum leaving a porous and permeable rock skeleton. The size of solution openings ranges from fractions of an inch to 1 or 2 feet. Larger openings may be present but have not been revealed in test drilling.

The outline of the Major Johnson Springs aquifer as shown in figure 1 encompasses about 10,000 acres. Within the area outlined the altitudes of water levels in wells tapping the aquifer are within a few tenths of a foot of a common altitude, and the fluctuations of the water level in those wells have an identical pattern in time and magnitude. (See figure 2.) The common altitude of the water levels

Figure 2 (caption on next page) belongs near here.

and the similarity in water-level fluctuations are the principal basis for drawing the aquifer limits shown in figure 1.

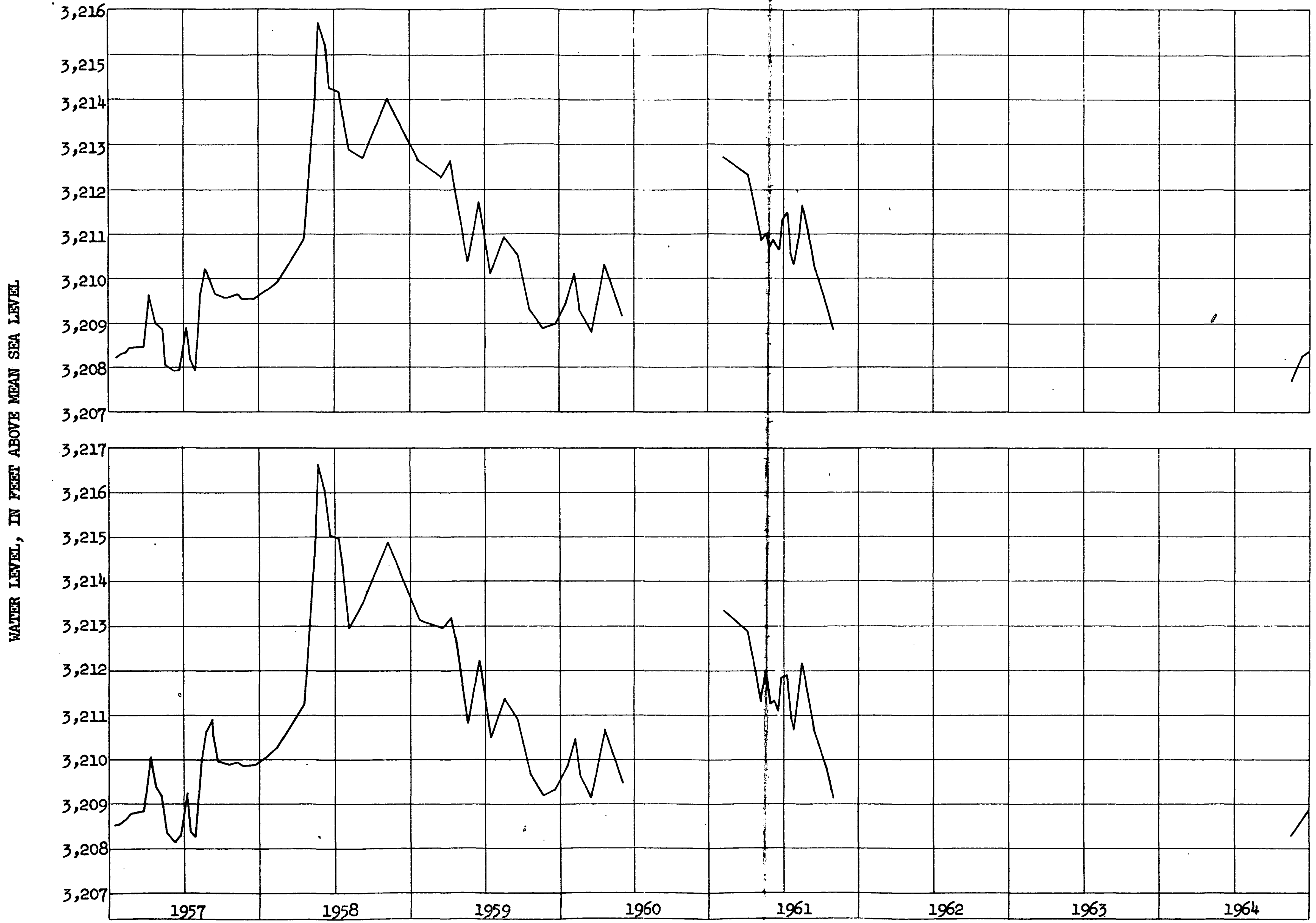


Figure 2.--Water level in well 20.26.11.413 (lower graph) and well 20.26.15.313 (upper graph) in the period 1957-64, Eddy County, N. Mex.

The eastern limit of the aquifer occurs where the permeability of the Seven Rivers Formation decreases abruptly. Parts of the aquifer that are thin were excluded from the main outline of the aquifer. For example, the altitudes of the water levels in well 20.26.12.424 indicated that when the altitude of the common water level in the aquifer is greater than 3,212 feet, the water-level fluctuations in that well are similar to the levels in other wells in the aquifer; when the water level is less than 3,212 feet, the fluctuations are dissimilar. This change in fluctuation was interpreted as indicating that the base of the Major Johnson Springs aquifer at that well is at an altitude of about 3,212 feet, thus the aquifer is about 4 feet thick near the well. The limit of the aquifer was drawn on figure 1 to exclude the area near well 20.26.12.424.

The western and southern limits of the aquifer were drawn where the ground-water gradients steepen abruptly. (See figure 1.) The gradient in the aquifer proper is about 0.2 foot per mile, whereas north, west, and south of the aquifer limits shown in figure 1, the gradients are 20 feet per mile or more.

The limits of the aquifer beneath Lake McMillan are arbitrary and have not been proven by test drilling. Rapid leakage of water from the lake to the aquifer indicates that the aquifer extends beneath the lake. Cox (oral communication) reports that whirlpools have been seen in the southern part of the lake. He concludes that the silt seal in the lake bottom is breached occasionally and water drains rapidly downward to underlying solution openings in the Major Johnson Springs aquifer.

The saturated thickness of the Major Johnson Springs aquifer is between 100 and 150 feet along the northeast-southwest axis; this assumes an upper limit of saturation at an altitude of 3,216 feet. The thickness probably decreases toward the outer limits of the basin to a minimum of 100 feet. For the purposes of this study, the aquifer thickness is assumed to be at least 100 feet within the aquifer's outline shown on figure 1. If the aquifer is 100 feet thick and has an areal extent of 10,000 acres, the volume of aquifer is about 1,000,000 acre-feet.

Recharge

Recharge to the Major Johnson Springs aquifer is comprised of leakage from Lake McMillan plus inflow from adjacent formations.

Leakage from Lake McMillan was computed as the difference between the measured inflow to and the measured outflow from the lake after adjusting the difference for change in lake storage. Measured inflow to the lake is the discharge recorded at the Pecos River (Kaiser Channel) near Lakewood gaging station, discharge of Four Mile Draw near Lakewood, and precipitation on the water surface of the lake. Measured outflow is the discharge at the Pecos River below McMillan Dam gaging station, flow from the lake through a channel that does not pass the gaging station, and evaporation from the water surface of the lake. These data are summarized in table 1, by months, for the period 1957-64.

Data about the amount of water stored in the lake during the period of study were questionable. The lake bed was surveyed in October 1956 and again in October 1964. The latter survey shows a reduction in storage capacity in relation to comparable stage of the lake. Data have not been analyzed to indicate how the storage capacity change should be apportioned among the years between 1956 and 1964. In this report, the 1956 storage-stage survey rating was used for the years 1957-60, inclusive, and the 1964 rating was used for the years 1961-64, inclusive.

Table 1.--Inflow-outflow summary of Lake McMillan to determine leakage from the lake, 1957-64.

[Reservoir content and lake area in years 1956-64 based on lake capacity survey of 1956; contents and lake area in years 1961-64 based on survey of 1964; inflow is discharge of Pecos River (Kaiser Channel) near Lakewood and Four Mile Draw near Lakewood; outflow is discharge of Pecos River below McMillan Dam; evaporation in inches is 0.7 of pan evaporation at Lake Avalon.]

Date	Reservoir content		Inflow (ac-ft)	Outflow (ac-ft)	Average area of lake (acres)	Evaporation		Precipitation		Leakage loss		Average stage of lake (ft)
	First of month (ac-ft)	Gain or (-) loss (ac-ft)				(inches)	(ac-ft)	(inches)	(ac-ft)	(ac-ft)	(cfs)	
Jan. 1957	9,170	1,530	3,700	0	3,060	3.41	870	0.04	10	1,310	21	19.20
Feb.	10,700	310	2,830	0	3,180	3.67	970	.35	90	1,640	30	19.50
March	11,010	6,430	10,570	0	3,380	6.40	1,800	.75	210	2,550	42	20.20
April	17,440	-13,560	1,770	11,390	3,000	8.06	2,010	.01	0	1,930	32	19.00
May	3,880	560	4,080	2,140	1,700	9.50	1,350	3.30	470	500	8	16.00
June	4,440	- 2,320	6,440	4,000	2,700	10.30	2,320	.02	0	2,440	41	18.30
July	2,120	1,130	9,550	7,270	1,075	11.05	990	.86	770	930	15	15.05
Aug.	3,250	8,240	28,420	14,230	3,325	9.36	2,600	1.27	350	3,700	60	20.00
Sept.	11,490	- 3,470	9,070	10,810	2,525	7.34	1,540	.05	10	200	3	17.70
Oct.	8,020	1,900	5,090	1,800	2,800	4.01	940	4.06	950	1,400	23	18.55
Nov.	9,920	1,730	3,970	0	3,160	2.33	610	.94	250	1,880	32	19.45
Dec.	11,650	1,160	3,770	0	3,310	2.83	780	0	0	1,830	30	19.95
Jan. 1958	12,810	2,080	4,490	0	3,450	2.24	640	1.35	390	2,160	35	20.45
Feb.	14,890	540	3,340	0	3,550	3.42	1,010	.82	240	2,030	37	20.75
March	15,430	10,200	20,000	3,590	3,930	3.76	1,230	.95	310	5,290	86	22.00
April	25,630	2,310	19,580	12,690	3,820	7.88	2,510	1.05	330	2,400	40	21.60
May	27,940	9,800	67,800	44,780	5,300	8.58	3,790	.40	180	9,610	157	25.20
June	37,740	- 1,640	23,810	15,570	5,540	10.30	4,750	.58	270	5,400	91	25.75
July	36,100	-10,470	12,200	12,760	5,300	10.05	4,640	1.11	490	5,760	94	25.20
Aug.	25,630	10,200	26,870	10,320	4,240	8,85	3,130	4.03	1,430	4,650	76	22.80

Table 1.--Inflow-outflow summary of Lake McMillan to determine leakage from the lake, 1957-64 - Continued

Date	Reservoir content		Inflow (ac-ft)	Outflow (ac-ft)	Average area of lake (acres)	Evaporation		Precipitation		Leakage loss		Average stage of lake (ft)
	First of month (ac-ft)	Gain or (-) loss (ac-ft)				(inches)	(ac-ft)	(inches)	(ac-ft)	(ac-ft)	(cfs)	
1958 Continued												
Sept.	35,830	3,030	30,280	29,780	5,520	5.24	2,410	5.97	2,740	6,800	110	25.70
Oct.	38,860	- 560	13,260	7,320	5,570	3.34	1,550	2.98	1,380	6,330	103	25.80
Nov.	38,300	- 940	8,660	3,760	5,540	2.87	1,330	.83	380	4,890	82	25.75
Dec.	37,360	380	8,730	1,700	5,570	2.36	1,090	T	0	5,560	91	25.80
Jan. 1959	37,740	0	6,260	850	5,570	2.82	1,310	.04	20	4,120	67	25.80
Feb.	37,740	450	6,530	1,000	5,570	3.62	1,680	.08	40	3,440	62	25.80
March	38,190	- 8,310	3,940	4,710	5,430	6.68	3,020	.15	70	4,590	75	25.50
April	29,880	-14,630	2,350	12,000	3,960	6.73	2,220	.17	60	2,820	47	22.10
May	15,250	7,970	16,230	3,970	3,700	8.65	2,660	4.47	140	1,770	29	21.20
June	23,220	-14,920	4,020	12,680	3,810	7.93	2,520	.65	210	3,950	66	21.60
July	8,300	6,950	25,640	14,710	3,270	7.46	2,030	2.66	720	2,670	44	19.75
Aug.	15,250	6,910	27,400	14,240	3,740	7.56	2,360	1.25	390	4,280	70	21.50
Sept.	22,160	-12,990	510	8,460	3,570	6,84	2,030	.19	60	3,070	52	20.80
Oct.	9,170	- 1,840	1,110	630	2,780	4.23	980	.79	180	1,520	25	18.50
Nov.	7,330	1,400	3,100	120	2,800	3.04	710	T	0	870	15	18.55
Dec.	8,730	2,120	4,110	0	3,030	2.22	560	.29	70	1,500	25	19.10
Jan. 1960	10,850	480	5,160	2,450	3,270	2.06	560	.25	70	1,740	28	19.80
Feb.	11,330	0	3,860	1,400	3,180	4.23	1,120	T	0	1,340	23	19.50
March	11,330	9,410	15,510	1,880	3,400	5.62	1,590	.13	40	2,670	44	20.30

Table 1.--Inflow-outflow summary of Lake McMillan to determine leakage from the lake, 1957-64 - Continued

Date	Reservoir content		Inflow	Outflow	Average area of lake	Evaporation		Precipitation		Leakage loss		Average stage of lake
	First of month (ac-ft)	Gain or (-) loss (ac-ft)	(ac-ft)	(ac-ft)	(acres)	(inches)	(ac-ft)	(inches)	(ac-ft)	(ac-ft)	(cfs)	(ft)
1960 Continued												
April	20,740	-15,600	7,260	17,140	3,330	8.53	2,370	T	0	3,350	56	20.05
May	5,140	8,180	17,950	8,260	2,275	10.58	2,000	0.55	100	- 390		17.10
June	13,320	1,930	19,340	9,160	4,025	9.40	3,150	1.63	550	5,650	95	22.35
July	15,250	22,770	b55,960	43,770	4,840	7.70	3,110	3.28	1,320	-12,370		24.15
Aug.	38,020	- 8,880	11,900	11,830	5,200	8.82	3,820	1.69	730	5,860	96	25.00
Sept.	29,140	-12,620	3,010	9,210	4,060	6.77	2,290	.19	60	4,190	71	22.45
Oct.	16,520	16,660	23,500	3,730	4,060	4.77	1,610	4.52	1,530	3,030	49	22.45
Nov.	33,180	0	10,490	4,930	5,180	3.18	1,370	0	0	4,190	71	24.95
Dec.	33,180	- 260	12,090	8,760	5,170	a2.30	990	1.84	790	3,390	55	24.90
Jan. 1961	27,300	3,870	12,560	4,660	5,430	1.90	860	.99	450	3,620	59	25.50
Feb.	31,170	270	10,060	4,820	5,540	3.19	1,470	.29	130	3,630	65	25.75
March	31,440	- 4,140	7,610	5,350	5,450	5.98	2,720	.71	320	4,000	65	25.55
April	27,300	-13,680	5,430	14,210	4,240	8.91	3,150	T	0	1,750	29	22.80
May	13,620	- 2,020	6,640	4,300	3,800	10.82	3,430	.24	80	1,010	16	21.55
June	11,600	160	17,540	10,540	3,725	10.00	3,100	1.16	360	4,100	69	21.30
July	11,760	6,120	28,920	17,520	3,350	10.12	3,830	.05	10	1,460	24	20.10
Aug.	17,880	- 4,580	21,360	17,960	4,410	8.93	3,280	.08	30	4,730	77	23.15
Sept.	13,300	- 7,560	1,430	6,260	3,350	6.92	1,930	.46	130	930	16	20.10
Oct.	5,740	- 1,830	1,660	1,510	2,600	6.40	1,390	.05	10	600	10	17.95

19

Table 1.--Inflow-outflow summary of Lake McMillan to determine leakage from the lake, 1957-64 - Continued

Date	Reservoir content		Inflow (ac-ft)	Outflow (ac-ft)	Average area of lake (acres)	Evaporation		Precipitation		Leakage loss		Average stage of lake (ft)
	First of month (ac-ft)	Gain or (-) loss (ac-ft)				(inches)	(ac-ft)	(inches)	(ac-ft)	(ac-ft)	(cfs)	
1961 Continued												
Nov.	3,910	4,940	7,040	0	3,010	2.06	520	1.90	480	2,060	35	19.05
Dec.	8,850	2,460	6,140	0	3,450	2.39	690	.12	30	3,020	49	20.45
Jan. 1962	11,310	1,990	5,170	0	3,660	a2.10	640	.74	230	2,770	45	21.10
Feb.	13,300	- 2,560	3,870	2,980	3,750	4.82	1,500	.12	40	1,990	36	21.35
March	10,740	14,600	24,700	3,070	4,630	6.36	2,460	.13	50	4,620	75	22.60
April	25,340	-16,880	2,730	16,040	3,875	7.70	2,480	.79	250	1,340	23	21.80
May	8,460	- 3,920	3,820	4,810	2,725	11.03	2,500	.88	200	630	10	18.35
June	4,540	10,420	29,940	9,950	3,990	10.38	3,450	1.54	-510	6,630	112	22.20
July	14,960	- 2,900	10,230	10,570	3,500	8.39	2,450	3.58	1,050	1,160	19	20.60
Aug.	12,060	-10,960	9,540	15,790	3,370	9.95	2,790	T	0	1,920	31	20.15
Sept.	1,100	10,510	20,870	4,740	3,550	6.13	1,810	2.35	700	4,510	76	20.75
Oct.	11,610	- 1,850	3,590	2,560	3,440	5.00	1,430	.72	200	1,650	27	20.40
Nov.	9,760	560	3,270	0	3,425	3.48	990	T	0	1,720	29	20.35
Dec.	10,320	990	4,070	10	3,540	2.08	610	.26	80	2,540	41	20.70
Jan. 1963	11,310	1,200	4,280	0	3,660	a2.20	670	.09	30	2,440	40	21.10
Feb.	12,510	950	3,680	0	3,750	3.77	1,180	.24	80	1,630	29	21.40
March	13,460	10,440	21,870	3,640	4,425	7.74	2,860	0	0	4,930	80	23.20
April	23,900	-14,530	1,620	12,240	3,900	10.47	3,400	1.49	480	990	17	21.90
May	9,370	- 4,180	2,540	4,480	2,925	9.42	2,300	1.09	270	210	3	18.85

Table 1.--Inflow-outflow summary of Lake McMillan to determine leakage from the lake, 1957-64 - Continued

Date	Reservoir content		Inflow (ac-ft)	Outflow (ac-ft)	Average area of lake (acres)	Evaporation		Precipitation		Leakage loss		Average stage of lake (ft)
	First of month (ac-ft)	Gain or (-) loss (ac-ft)				(inches)	(ac-ft)	(inches)	(ac-ft)	(ac-ft)	(cfs)	
1963 Continued												
June	5,190	4,180	18,130	7,120	3,650	11.31	3,440	.18	50	3,440	58	21.05
July	9,370	3,140	20,720	13,610	3,010	12.08	3,110	.20	50	910	15	19.05
Aug.	12,510	9,110	23,100	5,950	4,475	9.63	3,600	3.44	1,280	5,720	93	23.30
Sept.	21,620	- 6,830	8,780	8,800	4,660	6.49	2,520	.22	90	4,380	74	23.70
Oct.	14,790	- 2,580	1,050	0	3,790	5.53	1,750	.27	90	1,970	32	21.50
Nov.	12,210	- 450	2,640	0	3,650	4.12	1,250	T	0	1,840	31	21.05
Dec.	11,760	450	3,310	0	3,650	2.18	660	.18	50	2,250	37	21.05
Jan. 1964	12,210	- 150	2,650	0	3,660	3.85	1,170	.03	10	1,640	27	21.10
Feb.	12,060	- 150	2,600	0	3,660	3.12	950	.09	30	1,830	32	21.10
March	11,910	- 1,450	1,800	0	3,580	7.25	2,160	.24	70	1,160	19	20.85
April	10,460	- 140	17,850	13,950	3,230	10.23	2,760	0	0	1,280	22	19.70
May	10,320	- 6,610	1,940	4,870	3,080	11.58	2,970	.29	80	790	13	19.25
June	3,710	- 3,070	3,820	4,670	2,275	12.02	2,280	.27	50	- 10	-	17.10
July	640	1,420	9,930	5,310	2,430	12.20	2,470	.84	170	900	15	17.45
Aug.	2,060	- 2,060	0	1,770	325	10.18	280	.58	20	30	1	13.90
Sept.	0	0	0	0	0	6.80	0	2.14	0	0	0	13.30
Oct.	0	0	c 0	0	0	6.28	0	T	0	0	0	13.30
Nov.	0	210	c1,640	0	250	4.40	90	.10		1,320	22	13.75
Dec.	210	586	c1,790									

a-Estimated.
b-Discharge of Pecos River near Artesia was 89,330 ac-ft.
c-Preliminary subject to revision.

A curve showing the relation between lake stage and leakage was prepared (fig. 3), but the curve is only an approximation because

Figure 3 (caption on next page) belongs near here.

of the wide scatter of the data points. The curve was drawn by giving greater weight to the leakage-stage data for the period 1957-60 (data shown by circles). The Lake McMillan leakage-stage relations computed for the period 1961-64 (shown by crosses on figure 3) contain at least one known inaccuracy. The lake stage-content relation for that period was known but the lake stage-area relation was not. The stage-area relation of the 1956 survey was used in computing precipitation additions and evaporation losses for the 1961-64 period. The error introduced by using the 1956 survey data may be small. A curve drawn using the 1961-64 data would show less leakage for comparable stages than the curve shown in figure 3. The curve in figure 3 was used in computing leakage during periods of less than 1 month and those that extended from part of a month to part of the next month. Leakage values were taken from table 1 when a computation was made that involved records for several months.

A change in lake stage and the resulting change in leakage rate occurs about 10 days before the change in recharge rate is apparent in the aquifer. This 10-day lag relation was determined from a comparison of the graphs of water level in well 20.26.17.334 and stage of the lake (fig. 4). The lag period was taken into account only when

Figure 4 (caption on next page) belongs near here.

computing leakage-recharge relations for periods of storage of less than 3 months, but the lag period was not used in computation intervals lasting more than 3 months.

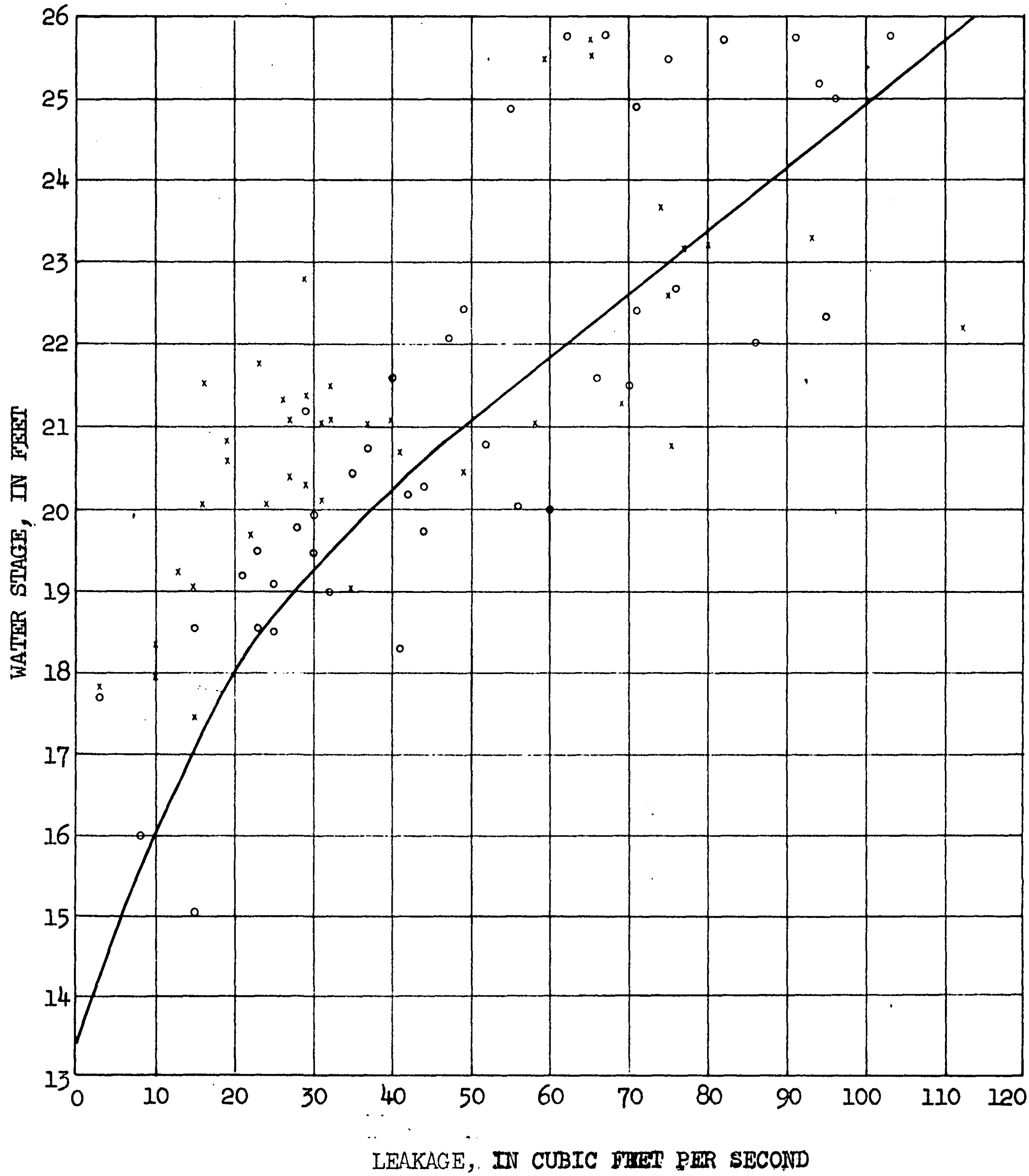


Figure 3.--Relation of water stage to leakage from Lake McMillan, Eddy County, N. Mex. Circles are data for the period 1957-60 and crosses are data for the period 1961-64.

Figure 4.--The water stage in Lake McMillan, the water level in well 20.26.17.334, and the discharge of the Pecos River at damsite 3 gaging station when there is no flow from Lake McMillan, 1957-64, Eddy County, N. Mex.

The recharge to the Major Johnson Springs aquifer from adjacent formations was estimated from the discharge of the springs when the lake was dry. Lake McMillan was dry from August 8 to November 21, 1964, inclusive; therefore, leakage from the lake was zero and was not contributing water to the spring discharge. The discharge of Major Johnson Springs decreased to about 10 cfs in September 1964 and remained at that rate until Lake McMillan started to fill in November 1964. The discharge of 10 cfs is interpreted as the rate at which the Major Johnson Springs aquifer was being recharged from adjacent formations in 1964, principally from the alluvium west of the aquifer.

The rate of inflow from adjacent formations probably fluctuates seasonally and through a period of years. It was noted that the discharge of Major Johnson Springs decreased to about 10 cfs when Lake McMillan was dry for several months in a few years prior to 1957. An interpretation could be that the change in the rate of inflow from adjacent formations is small in the period 1957-64. Proving the validity of that interpretation would require a more complete study of water data than was possible during the preparation of this report. The coefficients of storage and transmissibility given in this report were computed using a constant 10 cfs inflow to the Major Johnson Springs aquifer from adjacent formations.

No distinction is made in this report about the source of water that enters the aquifer from adjacent formations. Some of the water is new to the Pecos River and some is seepage from the Pecos River to those formations at places upstream from Lake McMillan. Seepage losses from the Pecos River upstream from the lake that reach the Major Johnson Springs aquifer are assumed, in this report, to enter the aquifer from adjacent formations.

Discharge

Water is discharged from the Major Johnson Springs aquifer by wells and by the Major Johnson Springs.

Water is pumped from the aquifer by three irrigation wells and three domestic and stock wells. Most of the pumpage is by the irrigation wells. Assuming that 3 feet of water is applied per acre on 270 acres irrigated by wells and none of the water returns to the aquifer, pumpage each year would be about 800 acre-feet, or an equivalent of about 1 cfs continuous discharge from the aquifer.

The discharge of Major Johnson Springs varies continuously. An approximation of the discharge rate is computed as the difference in discharge between the gaging stations Pecos River below McMillan Dam and Pecos River at damsite 3. The actual discharge of the springs is larger than the difference in discharge between the two gaging stations because of water losses in the river channel. At times, some surface flow enters the Pecos River between the two gaging stations. The amount of that inflow was estimated and deducted from the discharge at the damsite 3 gaging station for the periods used in calculating the aquifer characteristics.

A close relation was found between the altitude of the water level in the aquifer and the discharge of the springs when only spring discharge is in the river (no flow is passing the Pecos River below Lake McMillan gaging station). (See figure 5.) The water levels in 13 wells tapping

Figure 5 (caption on next page) belongs near here.

the aquifer were compared. The levels in all wells at any selected time were within a few tenths of a foot of a common level, and the fluctuations of levels were similar in time and magnitude. The water-level record of well 20.26.17.334 was selected as a key record because it was more complete than that of the other wells; a water-stage recorder had been operated almost continuously on the well in the periods July 1957 to August 1960 and January to August 1961. The rating curve shown in figure 5 was prepared after comparing the hydrograph of well 20.26.17.334 and the discharge of the Pecos River at damsite 3 when there was no flow in the Pecos River above the springs. Large flows released from Lake McMillan submerge the spring orifices and cause back-pressure on the springs, which decreases the discharge of the springs. The discharge of the springs cannot be determined from the curve in figure 5 when large flows cover the springs.

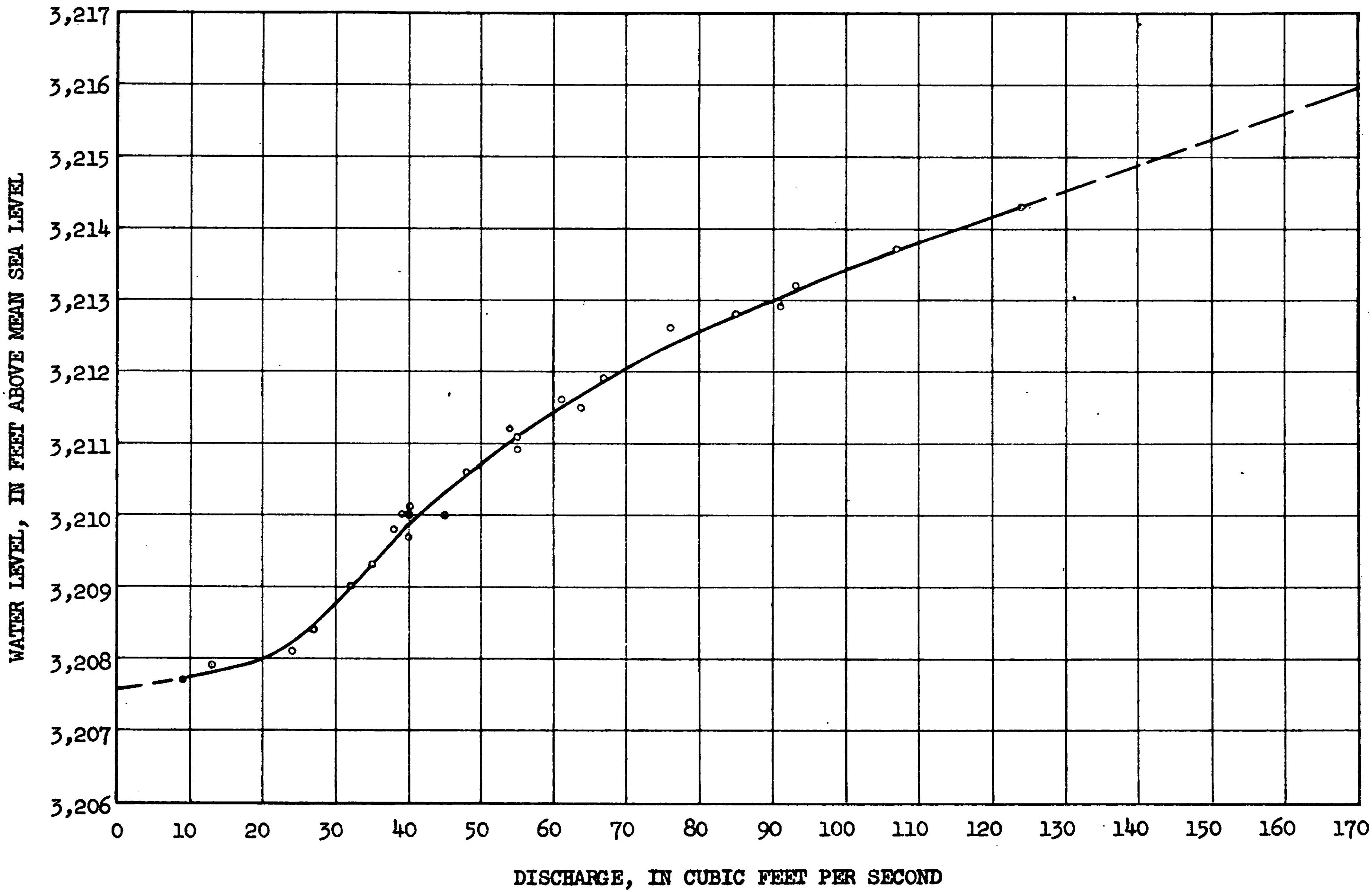


Figure 5.--Relation of water level in well 20.26.17.334 to discharge in the Pecos River at damsite 3 gaging station when the flow is entirely from Major Johnson Springs, Eddy County, N. Mex.

The curve in figure 5 must be corrected for channel losses to determine the actual flow of the springs. Channel losses of as much as 10 cfs have been measured during flows of less than 50 cfs. The accuracy of measuring discharges of more than 100 cfs precludes determining channel losses within the range of the actual losses. Losses are estimated to be as much as 10 cfs and may be more in flows greater than 100 cfs. The 10 cfs was assumed as a maximum for the computations in this report. Evaporation losses in the channel vary from about 0.5 cfs during the winter to as much as 3 cfs in the summer. No attempt was made to adjust the curve in figure 5 for seasonal changes in water loss in the channel of the river below the springs. When the discharge of the Pecos River at damsite 3 gaging station includes water released from Lake McMillan and spring discharge, the actual discharge of the springs is computed by apportioning the channel losses shown in figure 6 between apparent spring discharge

Figure 6 (caption on next page) belongs near here.

(apparent spring discharge read from rating curve in figure 5) and the water that is released from the lake. The apportioning of losses was made in this report as follows: apparent discharge rate of springs divided by the discharge rate of the Pecos River at damsite 3 and multiplied by the loss that is shown on figure 6 for the discharge rate at the damsite 3 station.

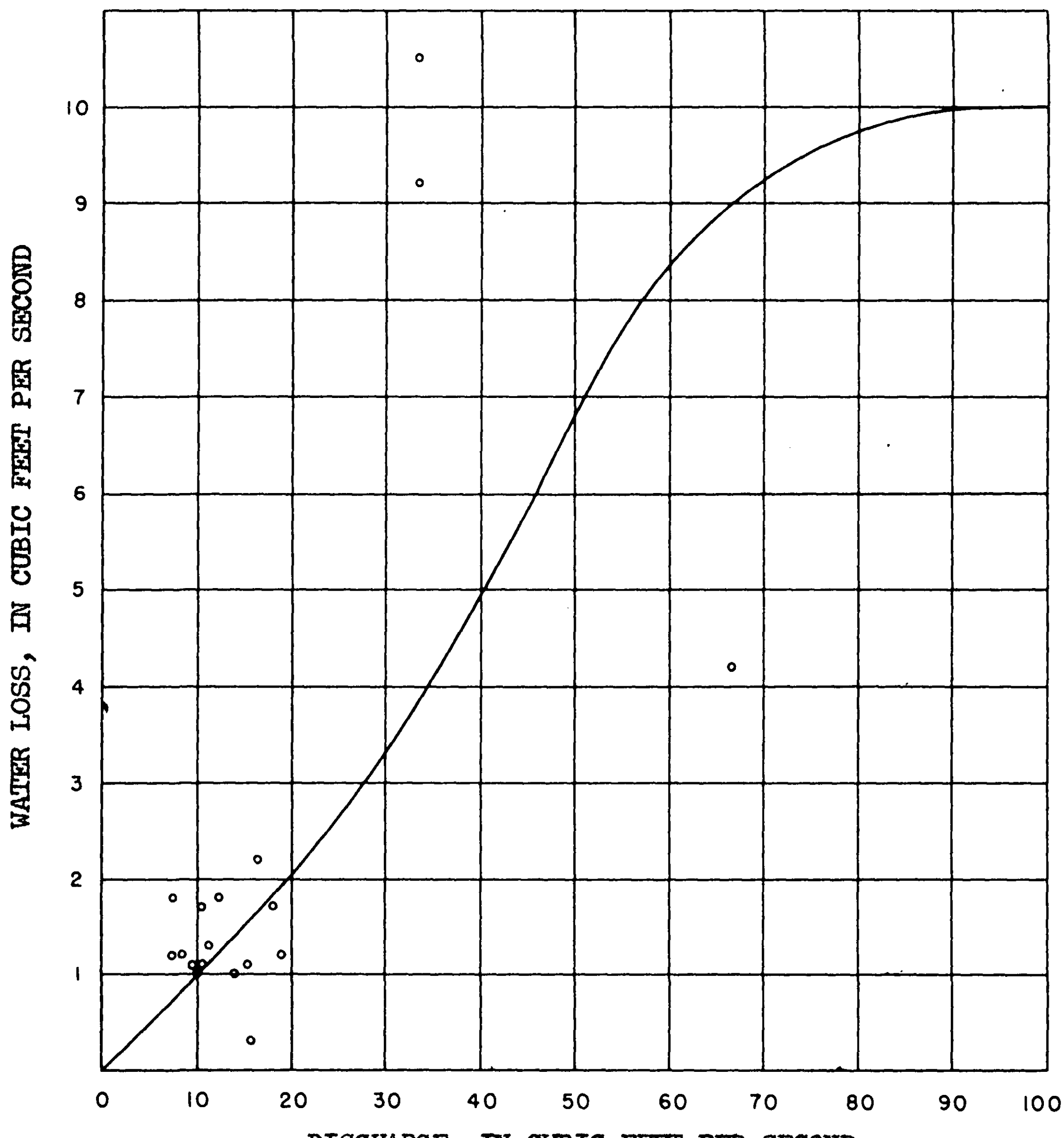


Figure 6.--Relation of discharge in the Pecos River at damsite 3 gaging station to loss of water in the river channel between Major Johnson Springs and the gaging station.

There seems to be little or no discharge from the aquifer to adjacent formations; however, the proof of this is not conclusive. The hydraulic gradients in the formations west and south of the aquifer are toward it. An exception may be in secs. 4 and 9, T. 20 S., R. 26 E. where pumping from wells in the alluvium in and west of those sections lowered the water level in the alluvium in 1963 and 1964 to about 1 or 2 feet below the altitude of the water surface in the Major Johnson Springs aquifer. The water levels in the alluvium were depressed to this level for about 1 month in each of those years. Because the gradient was low and toward the alluvium only a short time, the loss of water from the Major Johnson Springs aquifer to the alluvium probably was small to negligible during the period of study 1957-64. Loss of water to the alluvium was considered zero in computations made for this report. The losses might increase, in future years, if there are larger declines in the water levels in the alluvium.

Coefficient of storage

The coefficient of storage of the Major Johnson Springs aquifer was computed by the relation

$$S=\frac{R-D}{V_A}$$

where

S=coefficient of storage, dimensionless

R=recharge to aquifer, in acre-feet

D=discharge from aquifer, in acre-feet

V_A=volume of aquifer through which a change of water storage occurred, in acre-feet

The following table contains a summary of eight computations made to determine values of the storage coefficient.

Period of computation	Recharge (acre-feet)	Discharge (acre-feet)	Water level in aquifer: Average altitude above msl (feet)	Net change (+)rise (-)decline (feet)	Volume of aquifer in storage change (acre-feet)	S
1- 1-57 to 1- 1-58	27,500	24,700	3,209.3	+1.0	10,000	0.28
1- 1-58 to 3- 1-58	5,400	5,200	3,210.0	+ .3	3,000	.07
5- 1-58 to 6- 1-58	9,800	2,400	3,214.0	+5.0	50,000	.15
1- 1-58 to 1- 1-59	68,100	53,500	3,212.8	+3.3	33,000	.42
10- 1-58 to 2- 1-59	23,300	25,900	3,213.5	-2.2	22,000	.10
10- 1-59 to 12-31-59	5,700	7,400	3,209.5	-2.6	26,000	.14
1- 1-59 to 1- 1-60	41,800	43,100	3,211.2	-3.8	38,000	.03
8-24-64 to 10-21-64	1,000	1,500	3,207.8	- .3	3,000	.17

Computations of the storage coefficient could not be made for all periods in the years 1957-64. The lack of sufficient water-level data for the aquifer in the period 1961-64 precluded computation in most of that period. The changing leakage conditions in Lake McMillan as the result of silt accumulating in the lake made the results of computations for the 1961-64 period less certain.

The coefficients of storage were between 0.03 and 0.42 and are in the range that is associated with water-table conditions. The average is about 0.17. This value might be applicable only to that part of the aquifer between altitudes 3,207 and 3,216 feet; the storage coefficient of the aquifer below 3,207 feet may be the same or less. Until additional information is available about the aquifer, the value of 0.17 can be considered, tentatively, as representative of the aquifer's storage characteristic to a depth of about 100 feet. If the coefficient of storage is 0.17 and the volume of the aquifer is 1,000,000 acre-feet, the amount of water in storage would be about 170,000 acre-feet or about 1,700 acre-feet for each foot of aquifer thickness. This is more than three times the amount estimated by Theis (1938) and Reeder (1963).

Coefficient of transmissibility

The coefficient of transmissibility of the Major Johnson Springs aquifer was computed by the relation

$$T=\frac{Q}{WI}$$

where

T=coefficient of transmissibility, in gallons per day per foot

Q=discharge, in gallons per day

I=hydraulic gradient, in feet per mile

W=width of aquifer, in miles

The basic assumption in computing T was that when the water level in the aquifer was static, the only flow in the aquifer would be water leaking from Lake McMillan and inflow from adjacent formations because drainage from the aquifer would be zero. In addition, it was assumed that the discharge Q, which was equal to the leakage from Lake McMillan plus one-half the rate of inflow from adjacent formations, moved normal to the section A-B (fig. 1) enroute to Major Johnson Springs.

The hydraulic gradient in the aquifer at section A-B was computed from the altitude of the water levels in wells 20.26.11.413 and 20.26.15.313. (See figure 2.) The width of the section A-B is about 2.3 miles.

Two periods, December 1957 and December 1959, were the only ones in which water levels were known to be static. The following table summarizes the computations for T.

	December 1957	December 1959
Lake McMillan leakage (from table 1)	30 cfs	25 cfs
Lake McMillan leakage (from spring discharge)	35 cfs	28 cfs
One-half of inflow from adjacent formations	5 cfs	5 cfs
I, hydraulic gradient	0.20 ft per m	0.19 ft per m
W, width of aquifer at section A-B	2.3 miles	2.3 miles
Q_T (from table and inflow)	2.26×10^7 gpd	1.94×10^7 gpd
Q_S (from spring discharge and inflow)	2.58×10^7 gpd	2.20×10^7 gpd
T (using Q_T)	4.9×10^7	4.4×10^7
T (using Q_S)	5.6×10^7	4.9×10^7

Large-diameter wells that tap the full saturated thickness of the aquifer should be capable of yielding 5,000 to 10,000 gpm by pumping because of the high transmissibility of the aquifer. If the high transmissibility extends to that part of the aquifer beneath the Pecos River in sec. 27, T. 20 S., R. 26 E. where the altitude of the river channel is about 3,200 feet, wells tapping the aquifer there probably would flow several thousand gallons per minute. Flowing wells in the river channel in sec. 27 probably could dewater the aquifer several feet below the 3,207-foot altitude of the lowest known spring orifice. Control valves on the wells could regulate the flow in accordance with the needs. The wells could be closed when flow in the river was higher than the mouths of the wells.

Summary

1. The Major Johnson Springs aquifer is about 100 to 150 feet thick and encompases an area of about 10,000 acres.
2. The principal source of recharge to the aquifer in 1957-64 was leakage from Lake McMillan; some water was contributed from adjacent formations. The rate of inflow from the adjacent aquifers was assumed to be a constant 10 cfs for the period 1957-64.
3. The rate of leakage from Lake McMillan to the aquifer is related to the stage of the lake. The leakage-stage relation is not constant from year to year because silt accumulating in the lake is reducing the storage capacity-stage relation. The leakage rate also decreases with time when the lake stage remains static for several weeks or months.
4. Water levels in wells tapping the Major Johnson Springs aquifer are within a few tenths of a foot of a common altitude; therefore, the hydraulic gradient is small, about 0.2 foot per mile. The levels in wells fluctuate in patterns that are similar in time occurrence and magnitude; consequently, the change in stage in the aquifer can be monitored by one well.
5. There is a close relation between the water level in a well tapping the aquifer and the discharge of the springs when the discharge in the Pecos River at damsite gaging station 3/ is only that of the springs. When there is additional flow in the river, the spring orifices are submerged to greater depths, and the resulting back-pressure changes the aquifer head-spring discharge relationship.

6. Water losses in the channel between the springs and damsite 3 gaging station vary with the rate of discharge in the river and with the rate of evaporation. Studies of channel losses indicate a range of from 1 to 10 cfs, the amount was related to the discharge rate at the Pecos River at damsite 3 gaging station.

7. The coefficient of storage in that part of the aquifer between altitudes 3,207 and 3,216 feet is about 0.17. If this coefficient is representative of the upper 100 feet of aquifer, about 170,000 acre-feet of water (1,700 acre-feet per foot of aquifer thickness) is stored in the aquifer, much of which can be withdrawn by wells.

8. The coefficient of transmissibility is about 5.0×10^7 gpd per foot. Well yields of 5,000 to 10,000 gpm should be possible by pumping. Flowing wells drilled in sec. 27 where the mouths of the wells are at an altitude of about 3,200 feet probably could dewater the aquifer several feet below the mouth of the lowest known spring.

Selected references

Cox, E. R., 1957, Preliminary results of test drilling between Lake McMillan and Major Johnson Springs, Eddy County, New Mexico: U.S. Geol. Survey open-file report, 28 p., 3 figs.

Reeder, H. O., 1963, Tritium used as a ground-water tracer between Lake McMillan and Major Johnson Springs, Eddy County, New Mexico, with a section on "Laboratory aspects of tracer selection and tritium detection," by L. L. Thatcher: U.S. Geol. Survey TEI-839, 120 p., 15 figs.

Theis, C. V., 1938, Origin of water in Major Johnson Springs, near Carlsbad, New Mexico: N. Mex. State Engineer 12th and 13th Bienn. Repts., p. 251-252.

Theis, C. V., and Sayre, A. N., 1942, Geology and ground water, in [U.S.] Natl. Resources Planning Board, Pecos River Joint Investigation--Reports of the participating agencies: Wash., U.S. Govt. Printing Office, p. 58.

Figure 1.--Map of the Major Johnson Springs area showing location of the Major Johnson Springs aquifer, wells, and gaging stations and piezometric contours.

4.--The water stage in Lake McMillan, the water level in well 20.26.17.334, and the discharge of the Pecos River at damsite 3 gaging station when there is no flow from Lake McMillan, 1957-64, Eddy County, N. Mex.