QUALITY OF WATER OF PECOS RIVER IN TEXAS

By W. D. Collins and H. B. Riffenburg

INTRODUCTION

Water from Pecos River, although generally recognized as not of the highest quality, is nevertheless used for the irrigation of considerable areas in western Texas. The quality of the water varies so much from time to time and from one point to another that it seemed desirable to take advantage of the opportunity afforded by studies of discharge to make analyses of the water at different stages of the river. During the period covered by the analyses the river water below Barstow was rarely suitable for irrigation, and most of the time the water from Angeles to Barstow would ordinarily be classed as poor to fair in quality as regards its use for irrigation.

ACKNOWLEDGMENTS

The samples analyzed for this report were collected under the direction of C. E. Ellsworth, district engineer of the United States Geological Survey. Data relating to Pecos River and irrigation in the Pecos Valley are taken largely from three manuscript reports of the Bureau of Reclamation:

Memorandum on the Pecos drainage basin in New Mexico and Texas, by C. T. Pease, October, 1923.

Report on preliminary investigations for Pecos River storage at the Red Bluff reservoir site, N. Mex.-Tex., by E. E. Teeter and Willis T. Lee, 1924.

The Pecos River compact, report by C. T. Pease, February, 1925.

Stream-flow data for the period covered by the analyses were furnished by C. E. Ellsworth; those for earlier years are taken from published water-supply papers.

Analyses 1–5 are taken from United States Geological Survey Water-supply Paper 274; Nos. 20, 56, 100, 132, 172, and 212 were made by Miss Margaret D. Foster; the other analyses for this report were all made by H. B. Riffenburg.

PECOS RIVER BASIN

The Pecos River basin is described by Follansbee and Dean[1] as follows:

Pecos River, one of the most important tributaries of the lower Rio Grande, drains an area comprising approximately 32,000 square miles and extending from the Taos Mountains in northern New Mexico to the southern edge of the western Panhandle region in Texas. Its source is on the eastern slope of the Santa Fe Range in the extreme western corner of Mora County, at an elevation of 11,000 feet, and its course is southward nearly to Punta Pajarita, thence southeastward to the southeast corner of Guadalupe County, thence southward again to Carlsbad, and then once more southeastward to its junction with the Rio Grande at Moorhead, Valverde County, Tex. Except for some of the upper tributaries the branches of the Pecos are intermittent, though at times they carry large floods. The chief tributaries are Rio de la Vaca, Rio Tecolote, Gallinas River, Canyon Blanco, Pentado [Pintada] Canyon, Alamo Gordo Creek, Salt Creek, Felix, Penasco, Seven Rivers, Delaware, Toyah, and Comanche Creeks. Below Fort Sumner there are no important tributaries from the east, as the boundary of effective surface drainage of the Pecos parallels the river at a distance of 50 miles. The few streams in this section rise in the edge of the high plains but lose their waters in the porous soil within a few miles. Many of the streams in the western portion of the basin sink before reaching the Pecos, and it is probable that the streams actually reaching the Pecos lose much water by seepage after leaving the mountains.

The upper Pecos flows through narrow valleys and deeply cut gorges nearly down to Fort Sumner, and in this portion of the basin the elevations range from 4,500 feet to 11,000 feet above sea level. Below Fort Sumner the canyon-like walls of the Pecos are replaced by low rolling hills and at Roswell the gradation from the flood plains to the rolling prairie of the lower part of the drainage basin is imperceptible. Arroyos and gulches are rare, and canyons are practically unknown. Elevations in the lower section of the basin range from 1,000 feet at the mouth to 4,500 feet near the foothills.

The distribution of precipitation throughout the Pecos basin is somewhat peculiar. Near the source of the river there is a very small area in which the mean annual precipitation is 20 inches or more, but * * * the rate drops to 15 inches at Anton Chico and less than 13 inches at Santa Rosa. From this point to Carlsbad there is a narrow strip coinciding practically with the immediate valley of the Pecos where the precipitation is between 12 and 13 inches, and east and west of this narrow area it increases to 15 inches or more. Below Carlsbad the increase is fairly uniform to 19 inches at the mouth. Except on the mountains in the upper section of the basin, where much of it occurs as snow, by far the greater part of the precipitation is the rain of the summer storms.

In reports to the Bureau of Reclamation and in the proposed Pecos River compact the river basin is divided into three parts, defined in the compact as follows:

The term "upper basin" means that part of the Pecos River basin above and north from a due east and west line crossing the Pecos River on the boundary between Tps. 6 and 7 N., R. 22 E. New Mexico principal meridian.

[1] Follansbee, Robert, and Dean, H. J., Water resources of the Rio Grande basin, 1888–1913: U. S. Geol. Survey Water-Supply Paper 358, pp. 452–453, 1915.

The term "middle basin" means that part of the Pecos River basin below and south from a prolongation of the boundary line between Tps. 6 and 7 N., R. 22 E. New Mexico principal meridian, to the Texas-New Mexico State line.

The term "lower basin" means that part of the Pecos River basin within the State of Texas lying above and northwest of the Kansas City, Mexico & Orient Railroad.

The analyses made for this report relate only to the lower basin, but the composition of the water in the river at the sampling points is affected by regulation of the discharge and use of the water in the upper and middle basins.

CONSTITUENTS OF NATURAL WATERS

The mineral matter dissolved in natural waters is derived from the rocks and soils. The main constituents of most fresh waters are the bicarbonates of calcium and magnesium. Such waters contain minor quantities of sulphate, chloride, and sodium. Small quantities of potassium and nitrate are generally present, but the quantities of these substances are so small that in discussions of analyses potassium is usually included with the sodium, and sometimes the nitrate is included with the chloride.

Waters that pass over or through beds of gypsum dissolve comparatively large quantities of calcium and sulphate, the constituents of gypsum. When normal water evaporates from the soil the carbonates of calcium and magnesium become insoluble; calcium sulphate is slightly soluble; but sodium chloride and sodium sulphate are easily soluble and will be taken up at once by water which may chance to flow where the concentration by evaporation has taken place. Thus the waters flowing through regions where rainfall is slight and evaporation is rapid will carry much larger proportions of sodium chloride and sodium sulphate than the waters of humid, cool regions.

USES OF WATER

DOMESTIC AND INDUSTRIAL

The water of Pecos River at the points in Texas represented by analyses in this report contains so much dissolved mineral matter that it would generally be classed as unfit for domestic or industrial use.

IRRIGATION

A memorandum by C. T. Pease on the Pecos drainage basin in New Mexico and Texas, prepared in October, 1923, gives on page 51 a tabulation of areas irrigated from Pecos River in Texas, which shows a total of 33,577 acres. The figures are stated to be only approximate, but it is evident that large use in irrigation is now made or is planned for the water of Pecos River. The water generally carries more dissolved mineral matter than is considered desirable in irrigation, but this condition is offset by the porous character of the soil, which favors prompt drainage after the use of large volumes of water, and by the high proportion of calcium in the water, which helps the physical condition of the soil.

In a paper on the movement of water in irrigated soils Scofield[2] notes chemical reactions between soils and waters as determining factors in the movement of the waters. These reactions are also referred to by Harris[3] in his discussion of soil alkali. Both of the authors named emphasize the importance of drainage as a primary requisite for successful irrigation, regardless of the quality of the water used. Natural drainage may be sufficient to prevent the accumulation of harmful quantities of alkali, but many irrigated areas require artificial drainage. Scofield and Harris give many references to articles dealing with specific instances of irrigation practice and with laboratory experiments.

It is not possible to set any close limits for permissible concentration of salts in water to be used for irrigation. Reports of experiences on irrigation projects referred to by Scofield and by Harris suggest that 1,000 parts per million of dissolved solids is near the limit for satisfactory irrigation water and that water with 3,000 parts per million of dissolved solids requires the greatest care in its use to prevent accumulation of alkali in the soil. Scofield[4] states:

> While many crop plants may obtain water from a soil solution which contains more than 1 per cent of dissolved mineral matter, it would appear to be advisable generally to keep the solution below that degree of concentration. In order to do this it follows that in applying irrigation water it should be the aim to use enough so that the proportion lost by percolation is large enough to offset the concentration due to evaporation and transpiration. Thus if the irrigation water contains 1,000 parts per million of salt, enough should be used so that 10 per cent of the quantity applied may percolate below the root zone.

On this principle a water with 3,000 parts per million of dissolved solids should be used in sufficient quantity to permit 30 per cent to percolate below the root zone, and with water containing 5,000 parts per million 50 per cent should be drained away.

The effect of the proportions of the different basic constituents in irrigation waters has been noted by many writers and has been emphasized by Scofield in his discussion of the permeability of soils. From field studies and experiments and from the results reported by other workers he concludes:[5]

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[2] Scofield, C. S., Jour. Agr. Research, vol. 27, pp. 617–694, 1924.

[3] Harris, F. S., Soil alkali, its origin, nature, and treatment., New York, John Wiley & Sons, 1920.

[4] Op. cit., pp. 681–682.

[5] Op. cit., p. 692.

> The injurious effects that have been ascribed to sodium carbonate, or "black alkali," in irrigated soils appear to be due to the sodium rather than to the carbonate, and sodium in solution, even when associated with the stronger acids, combines with the soil and ultimately causes deflocculation and impermeability.
>
> The readjustment of the relative proportions of sodium and other bases in an impermeable soil, to the end of improving the physical condition, depends upon replacing the sodium with another base, such as calcium or aluminum, which when combined with the soil brings about a flocculated and permeable condition.

Gypsum has long been recognized as beneficial in the treatment of soils injured or likely to be injured by alkali. Its application has not been so generally recognized as serving to prevent the replacement of calcium in the soil by sodium in the applied water that occurs when the ratio of calcium to sodium in the soil solution drops too low. Obviously the prevention of this reaction in the soil is much easier than its reversal, because before the replacement the soil is permeable, whereas after it the soil is relatively impermeable and therefore not so easily acted on by solutions that will give up calcium for the sodium. There is so much gypsum in the soil throughout the Pecos River basin that most of the ground and surface waters carry practically all they can hold in solution with the other salts they contain. Thus they generally have little tendency to make the soils impermeable through replacement of calcium by sodium.

COLLECTION OF SAMPLES

The samples analyzed for this report were nearly all collected from Pecos River at gaging stations maintained by the United States Geological Survey and the Board of Water Engineers of Texas at Angeles, Porterville, Barstow, Grandfalls, Buenavista, and Sheffield. The collections were made by the engineers who were making measurements of discharge of the river at the gaging stations. A few samples were collected from tributaries, from drainage ditches, and from Pecos River in New Mexico.

On account of the high mineral content of the waters it was possible to make a satisfactory examination of a small sample. Two 4-ounce bottles of water were used for most of the samples. When a more complete analysis was to be made, four or eight bottles were used for each sample.

METHODS OF ANALYSIS

The analyses of some samples included determinations of total solids, silica, iron, calcium, magnesium, sodium and potassium, bicarbonate, sulphate, chloride, and nitrate. These analyses were made by methods practically the same as are described in "Standard methods of water analysis," published by the American Public Health

Association. In some of the otherwise complete analyses the potassium was not separated and the total quantity of mixed chlorides was calculated to sodium; in others sodium and potassium were not determined, but sodium was reported in sufficient quantity to balance the analysis. Such results are indicated as "calculated" in the table of analyses.

The quantities of silica, iron, and nitrate found made up so small a proportion of the total quantity of salts that their determination was omitted from most of the analyses. In the partial analyses a small portion of the water, usually 50 cubic centimeters, was evaporated for the determination of total solids. The residue was heated to approximately constant weight at 180° C. A second portion of 50 cubic centimeters or less was diluted and used for the determination of sulphate by the usual gravimetric method. Another portion of 50 cubic centimeters or less was diluted and used for the determination of calcium and magnesium without evaporation. Bicarbonate and chloride were determined by titration.

Most of the samples contained so much calcium and sulphate that the weight of the residue after long heating at 180° C. was somewhat greater than the sum of the constituents as determined by analysis. In general this excess was 1 to 5 per cent of the sum.

The analyses are reported as radicles in parts per million. The errors involved in reporting as parts per million the results obtained with measured portions of the sample are well within the probable inevitable errors of analysis.

QUALITY OF WATER

UPPER BASIN

No samples of water from the upper basin of Pecos River were collected for this report. Published analyses[6] of samples from Gallinas River near Las Vegas, N. Mex., and from Pecos River at Santa Rosa, N. Mex., have been used.

Gallinas River at the sampling point drains an area of 89 square miles. The mean weekly discharge from March 19, 1905, to March 31, 1906, was from 2 to 327 second-feet. The mean discharge for the years 1905 to 1908 was 35 second-feet. The average of analyses of monthly composite samples is given in Table 1 (No. 1). The total dissolved solids in weekly composite samples ranged from 120 to 386 parts per million. This water is rather better than the average hard water found over the greater part of the United States. On the basis of its dissolved mineral constituents it would be classed as good for all ordinary uses. It is probable that other headwaters of Pecos River are of the same quality.

[6] U. S. Geol. Survey Water-Supply Paper 274, pp. 139, 140.

TABLE 1.—*Analyses of water from Pecos River and tributaries in New Mexico, 1905–1907*

[Averages of analyses of monthly composites of daily samples in parts per million (milligrams per liter). From U. S. Geological Survey Water-Supply Paper 274, pp. 139–140]

No.	Source	Total dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)
1	Gallinas River at Las Vegas, N. Mex	204	41	5.9	29	150	24	22	0.12
2	Pecos River at Santa Rosa, N. Mex	1,220	270	37	45	180	620	43	.28
3	Hondo River at Roswell, N. Mex	782	150	30	39	150	350	39	1.2
4	Pecos River at Dayton, N. Mex	3,110	440	100	400	170	1,200	620	.06
5	Pecos River at Carlsbad, N. Mex	2,720	380	95	300	160	1,200	460	.03

Pecos River at Santa Rosa, N. Mex., drains an area of 2,780 square miles. The mean monthly discharge was 181 second-feet in 1906 and 92 second-feet in the year ending September 30, 1913. The daily discharge ranged from 5 to 2,930 second-feet between 1910 and 1913.

The average of analyses of monthly composites of samples taken daily from October 6, 1905, to December 29, 1906, is given in Table 1 (No. 2). The total dissolved solids in weekly composite samples ranged from 174 to 2,320 parts per million. Most of the time this water would be classed as suitable for irrigation but not wholly satisfactory for domestic use. The outstanding difference between the water of Gallinas River at Las Vegas and Pecos River at Santa Rosa is in the increased content of calcium and sulphate—the constituents of gypsum. The increase in these two constituents is 825 parts per million out of the total of 1,016 parts per million increase in total solids. The water changes from a typical calcium bicarbonate water to a calcium sulphate water.

MIDDLE BASIN

An attempt was made in September, 1924, to collect a series of samples from Pecos River and its tributaries in the middle and lower basins, from Carlsbad, N. Mex., to Sheffield, Tex. The series was not completed because rains on the drainage basin changed the character of the water so that the later samples were not comparable with those taken earlier. Analyses of samples collected at this time from points other than the regular gaging stations in Texas are given in Table 2 (Nos. 7–11). In January, 1925, a series of samples was completed without rain, so that the analyses are comparable; these analyses are given in Table 2 (Nos. 12–238). Six of these samples (Nos. 55, 99, 131, 171, 211, 238) were the final samples at the regular stations in Texas, and their analyses are given also in Table 3 under the same numbers.

TABLE 2.—*Analyses of water from Pecos River and tributaries between Carlsbad, N. Mex., and Sheffield, Tex., 1924–25*

[Analyses by H. B. Riffenburg; parts per million. Discharge measurements by S. D. Breeding]

No.	Station	Date	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (determined)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Discharge (second feet)
		1924											
6	Irving Springs near Pecos, Tex	July 29	2,794			304	87	[a] 504	266	831	800		1.0
7	Pecos River at Carlsbad, N. Mex	Sept. 9	2,754	31	0.25	372	107	324	207	1,174	480	5.0	76
8	Pecos River near Malaga, N. Mex	do	4,172	21	.60	480	180	574	176	1,605	950	10	150
9	Delaware Creek near Angeles, N. Mex	do	3,700	39	.70	668	121	210	81	2,082	265	5.0	.2
10	Drain ditch 4 miles south of Barstow, Tex	Sept. 13	6,920	33	.25	684	245	1,245	166	2,476	1,920	17	9.0
11	Barstow drain ditch 3 miles southeast of Barstow, Tex	Oct. 16	6,100			600	221	[a] 1,097	151	2,126	1,740		31
		1925											
12	Pecos River at United States gaging station at Carlsbad, N. Mex.	Jan. 15	2,880	28	.25	400	131	Na 299 K 26	185	1,317	480	5.0	88.3
13	Drain ditch A, sec. 14, T. 22 S., R. 27 E., 4 miles below Carlsbad, N. Mex.	do	4,264	56	.45	496	245	Na 472 K 22	222	1,860	820	10	1.28
14	Drain ditch E, sec. 30, T. 22 S., R. 28 E., 7 miles below Carlsbad, N. Mex.	do	5,160	32	.25	500	349	Na 592 K 16	281	2,222	1,020	7.5	1.58
15	Cass Draw drain, sec. 5, T. 23 S., R. 28 E., 9 miles below Carlsbad, N. Mex.	do	4,744	38	.38	616	253	Na 565 K 13	217	2,044	1,060	9.2	3.5
16	Black River near Malaga, N. Mex	Jan. 16	3,909	28	.30	576	149	Na 400 K 13	137	1,821	680	3.3	10.0
17	Pecos River, sec. 18, T. 24 S., R. 28 E., near Malaga, N. Mex	Jan. 15	3,800	28	.25	472	166	Na 488 K 14	188	1,532	830	5.0	142
18	Delaware Creek at mouth, near Angeles, Tex	Jan. 16	2,960	13	.21	580	87	Na 170 K 11	83	1,812	160	2.5	2.0
55	Pecos River at United States gaging station near Angeles, Tex	do	4,620	25	.25	492	170	Na 771 K 16	173	1,597	1,280	6.7	144
99	Pecos River at United States gaging station near Porterville, Tex.	Jan. 19	4,560	28	.33	492	169	Na 729 K 48	166	1,646	1,200	7.5	154
131	Pecos River at United States gaging station above Barstow, Tex.	Jan. 20	4,680	16	.25	500	175	Na 787 K 37	161	1,646	1,320	6.7	31
19	Barstow drain ditch, 3 miles southeast of Barstow, Tex	do	5,800	38	1.0	600	205	Na 995 K 40	181	2,041	1,600	8.6	38.2
171	Pecos River at United States gaging station near Grandfalls, Tex.	Jan. 21	13,080	28	.75	800	446	Na 3,135 K 74	256	3,407	4,940	9.0	1.3
211	Pecos River at United States gaging station near Buenavista, Tex.	do	12,300	35	.38	788	384	Na 2,912 K 48	200	3,160	4,600	7.3	24
238	Pecos River at United States gaging station near Sheffield, Tex.	Jan. 22	9,260	25	.25	592	341	Na 2,029 K 128	254	2,423	3,340	10	55

[a] Calculated.

In 1905–6 samples were collected from Hondo River at Roswell, N. Mex., and from Pecos River at Dayton and Carlsbad, N. Mex. Averages of analyses of samples from these points are given in Table 1 (Nos. 3–5).

Hondo River near Roswell has a drainage area of 1,040 square miles. In 1906 the river was dry for about one-third of the time and flowed 200 second-feet for one day in January. The average discharge was about 13 second-feet. The quantity of dissolved solids in weekly composite samples from March 26 to August 4, 1905, ranged from 546 to 986 parts per million. The predominating mineral constituents are calcium and sulphate, as in Pecos River at Santa Rosa.

Pecos River near Dayton has a drainage area of about 22,000 square miles. The yearly average discharge from 1905–6 to 1912–13

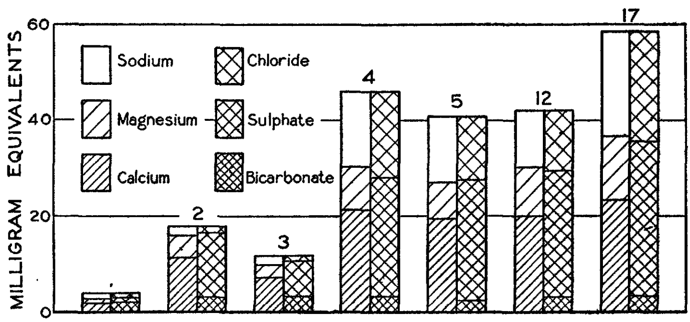


Figure 12.—Composition of water from Pecos River and tributaries in New Mexico. Numbers refer to analyses in Tables 1 and 2

ranged from 276 to 416 second-feet and the daily discharge from 32 to 50,000 second-feet. Samples were collected for analysis in 1905–6 below the Rio Penasco near Dayton.

The average of analyses of monthly composites of daily samples from October 6, 1905, to December 29, 1906, is given in Table 1 (No. 4) and is shown graphically in Figure 12. The quantity of total dissolved solids in weekly composites ranged from 748 to 5,120 parts per million. As compared with the river water at Santa Rosa there is an increase in calcium and sulphate and a much greater increase in sodium and chloride.

Samples were collected from Pecos River at Carlsbad, N. Mex., from May 22, 1905, to April 30, 1907. The average of analyses of monthly composites of daily samples is given in Table 1 (No. 5) and is shown graphically in Figure 12. The quantity of total dissolved solids in weekly composites ranged from 1,240 to 3,810 parts per million.

Other samples were collected from Pecos River at Carlsbad, N. Mex., September 9, 1924, and January 15, 1925. Analyses of these samples are given in Table 2 (Nos. 7 and 12). Analysis 12 is shown graphically in Figure 12. These analyses are not very different from the average of the analyses for 1905–1907.

Samples were collected January 15, 1925, from drain ditch A, 4 miles below Carlsbad; drain ditch E, 7 miles below Carlsbad; and Cass Draw drain, 9 miles below Carlsbad. Analyses of these samples are given in Table 2 (Nos. 13, 14, 15). These waters are somewhat like the river water at Carlsbad as shown by analysis 12, Table 2, but they contain nearly twice as much dissolved mineral matter. The increase is chiefly in the more easily soluble constituents—sulphate and chloride of sodium and magnesium. The proportional increase in calcium is much less.

The analysis of a sample collected January 16, 1925, from Black River near Malaga, N. Mex., is given in Table 2 (No. 16). This sample was better than the samples from the drain ditches but poorer than the river water at Carlsbad. Its general characteristics are the same as those of the drain waters.

Samples were collected from Pecos River near Malaga, N. Mex., September 9, 1924, and January 15, 1925. Analyses of these samples are given in Table 2 (Nos. 8 and 17). Analysis 17 is shown graphically in Figure 12. The sample collected in 1925 was similar to the sample from Black River, but it contained more sodium and chloride and less calcium and sulphate. The sample collected in 1924 differed from that collected in 1925 chiefly in concentration; the proportions of the different salts were about the same.

The changes in composition of the water of Pecos River and its tributaries are shown graphically in Figure 12. The heights of the different sections are proportional to the number of milligram equivalents of the different constituents in 1 kilogram of water. The number of milligram equivalents is calculated from the parts per million by dividing by the combining weights of the different radicles as follows: Calcium 20, magnesium 12.16, sodium 23, bicarbonate 61, sulphate 48, chloride 35.45.

The diagrams make plain the almost constant quantity of bicarbonate from the headwaters to the Texas line, and the preponderance of calcium, magnesium, and sulphate in all the analyses except No. 1. Nos. 4, 5, 12, and 17 show the results of the solution from the soil of sodium chloride and sulphates of calcium and magnesium beyond the quantities in the water of Pecos River at Santa Rosa (No. 2) and Hondo River at Roswell (No. 3).

LOWER BASIN

Practically all the work done for this report relates to the lower basin of Pecos River, and nearly all the samples analyzed were collected at six stations where gages were maintained and frequent discharge measurements made. Analyses for these stations are given in Table 3, with discharge data corresponding to the analyses. The series of samples mentioned in the section on the middle basin includes several from the lower basin. Six of these (Nos. 55, 99, 131, 171, 211, 238) are given in Table 2 and also at their proper places in Table 3.

Samples were collected September 9, 1924, and January 16, 1925, from Delaware Creek near Angeles, Tex. Analyses are given in Table 2 (Nos. 9 and 18). The two analyses differ considerably in their quantities of dissolved solids, but the proportions of the constituents are about the same. The water is decidedly better than the river water at Malaga, N. Mex., or at Angeles, as shown by analysis 55 in Table 2 and analysis 51 in Table 3, which is comparable with analysis 9 in Table 2. The water of Delaware Creek is not only lower in total solids than the Pecos River water, but it has a much higher ratio of calcium to sodium, which is possibly of more value in irrigation than the smaller total quantity of dissolved material.

Analyses of samples from Pecos River at Angeles, Tex., September 9, 1924, and January 16, 1925, are given in Table 3 (Nos. 51 and 55) and Table 2 (No. 55). Analysis 55 is shown graphically in Figure 13. Analyses of samples collected January 19, 1925, from Pecos River at Porterville, Tex., and January 20, 1925, from the river above Barstow, Tex., are given in Table 2 (Nos. 99 and 131) and are shown graphically in Figure 13. These analyses show comparatively little change in composition of the river water from Angeles to Barstow. Analysis 6 in Table 2 represents a sample collected July 7, 1924, from Irving Springs, near Pecos, Tex. The composition of the water is similar to that of Pecos River at Carlsbad, N. Mex., but the ratio of calcium to sodium is lower. The water is much better than samples collected from the river at Angeles and at Porterville in July, 1924.

Analyses 10, 11, and 19 in Table 2 represent samples collected from the Barstow drain ditch September 13 and October 16, 1924, and January 20, 1925. These samples all contained more dissolved mineral matter than the river water at Barstow at corresponding times. The increase is mainly in sodium, sulphate, and chloride, although some calcium has also been taken up from the soil.

Analyses of samples from Pecos River collected January 21, 1925, near Grandfalls, Buenavista, and Sheffield, Tex., are given in Tables

2 and 3 (Nos. 171, 211, 238). These analyses are shown graphically in Figure 13. The waters are much more concentrated than any of the samples from stations farther upstream. The increase in dissolved solids is mainly in the sodium, sulphate, and chloride.

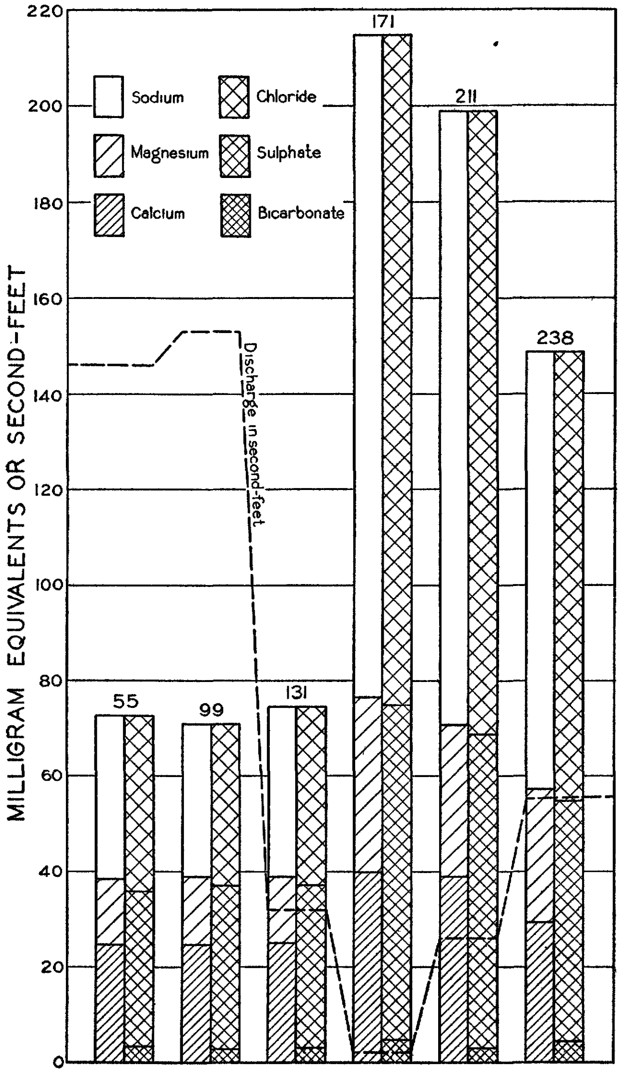


FIGURE 13.—Composition of water from Pecos River in Texas. Numbers refer to analyses in Tables 2 and 3

ANGELES

From March 23, 1922, to January 16, 1925, 36 samples of water were collected from Pecos River at the gaging station near Angeles, Tex. Analyses of these samples are given in Table 3 (Nos. 20–55).

These analyses are shown graphically in Figure 14, and No. 55 is shown also in Figure 13.

The total dissolved material for these analyses is shown along with the discharge of the river in Plate 9. On account of the great difficulty of making satisfactory determinations of total dissolved solids in waters of such concentration the sum of the determined constituents has been plotted rather than the determined solids.

The results given in the table and shown in Figure 14 make plain the considerable range in concentration of the dissolved solids. The most concentrated sample contained somewhat less than twice the quantity of dissolved solids found in the least concentrated sample. Figure 2 shows that the changes in composition of the water are almost entirely in the amounts of sodium, sulphate, and chloride. Plate 9 shows a general tendency toward greater concentration of dissolved material with lower discharges, but the changes are not very marked.

PORTERVILLE

From March 24, 1922, to January 19, 1925, 44 samples of water were collected from Pecos River at the gaging station near Porterville, Tex. Analyses of these samples are given in Table 3 (Nos. 56–99). No. 99 is shown graphically in Figure 13. The table shows that the samples collected at Porterville covered a wider range of concentration than those for Angeles. Both lower and higher concentrations were found at Porterville, and the most concentrated sample contained over three times the quantity of total solids found at Angeles. All the changes in composition were, however, almost wholly in the content of sodium, sulphate, and chloride.

BARSTOW

From March 25, 1922, to January 20, 1925, 32 samples of water were collected from Pecos

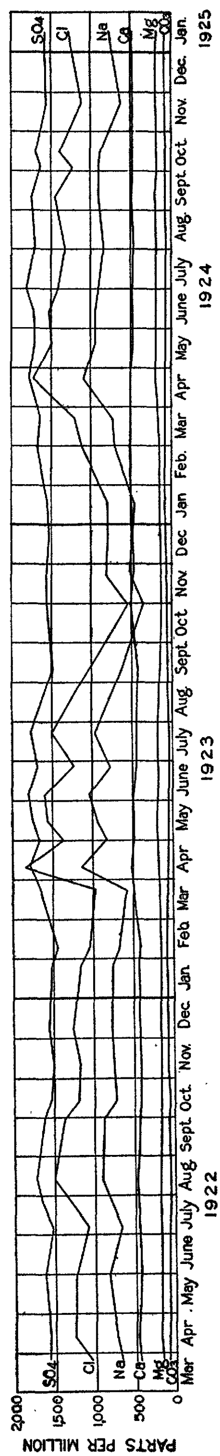


FIGURE 14.—Analyses of water from Pecos River at Angeles, Tex.

River at the gaging station above Barstow, Tex. Analyses of these samples are given in Table 3 (Nos. 100–131). No. 131 is shown graphically in Figure 13.

The analyses are similar to those for Angeles and Porterville, but the range in composition is more like that at Porterville. Both low and high limits of concentration are around 200 parts per million less than at Porterville; the highest quantity of total solids is more than three times the lowest.

GRANDFALLS

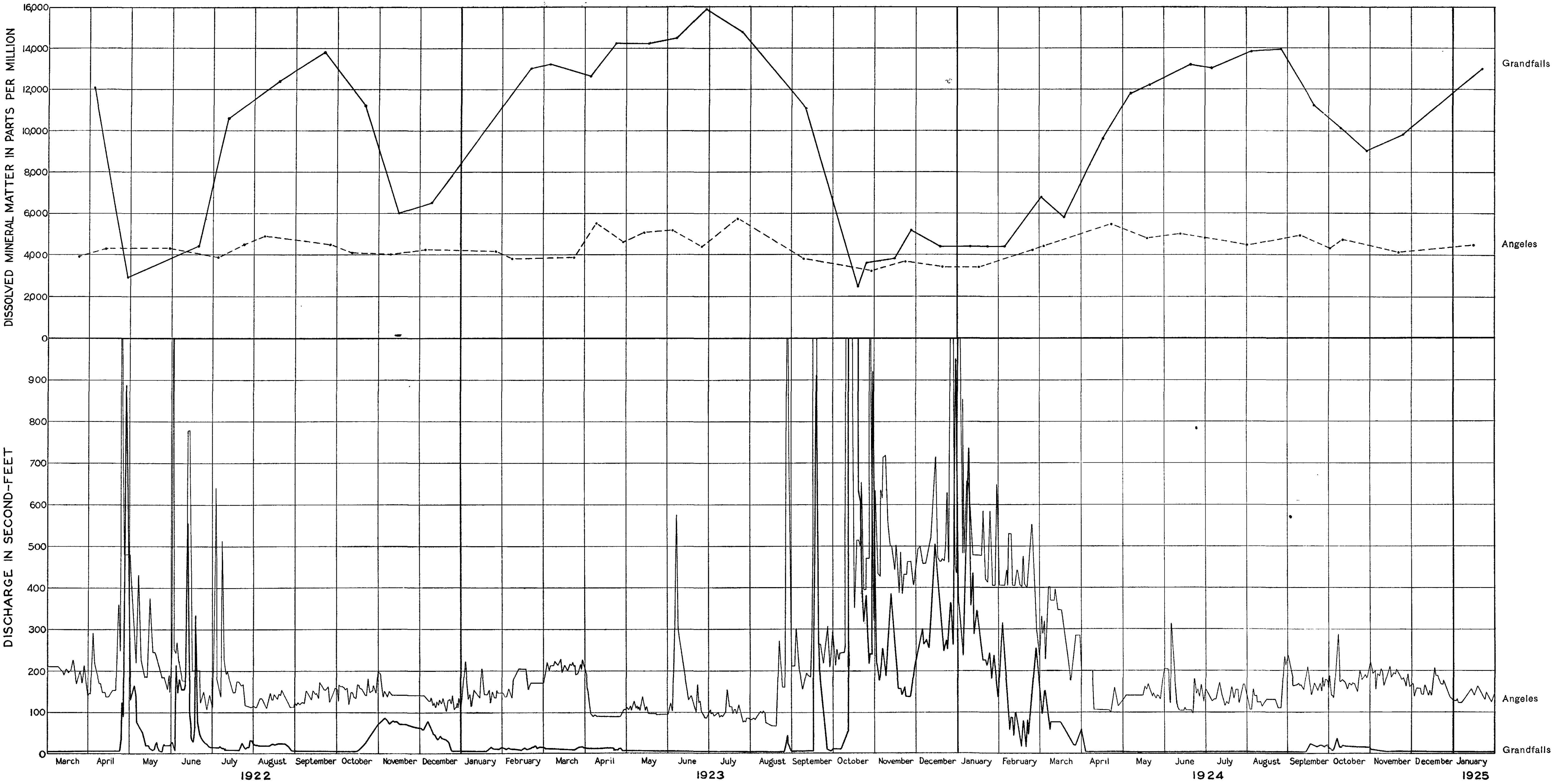
From April 4, 1922, to January 21, 1925, 40 samples of water were collected from Pecos River at the gaging station near Grandfalls, Tex. Analyses of these samples are given in Table 3 (Nos. 132–171) and are plotted in Figure 15. Analysis 171 is shown graphically in Figure 13. The sums of the determined constituents are shown with daily discharges in Plate 9.

The analyses show that the character of the water changes greatly between Barstow and Grandfalls. Discharge measurements indicate that nearly the whole flow of the river is diverted at Barstow. The small flow at Grandfalls must consist largely of return water from irrigation projects. This water naturally brings in large quantities of soluble salts from the soil, where they have been concentrated by evaporation of the irrigation water. Most of the time the concentration of dissolved solids at Grandfalls is about double the quantity at Barstow. The range in the samples examined was from about one and one-half times the minimum at Barstow to over two and one-half times the maximum. The maximum at Grandfalls was over six times the minimum.

Figure 15 and Table 3 show that the variation in concentration at Grandfalls was almost entirely in the sodium, sulphate, and chloride, as at the other stations. The bicarbonate is the most constant constituent; its quantity is practically the same throughout the river in Texas. The calcium and magnesium vary slightly in concentration with the sodium, but they are fairly uniform all the time throughout the length of the river.

BUENAVISTA

From April 5, 1922, to January 21, 1925, 40 samples of water were collected from Pecos River at the gaging station near Buenavista, Tex. Analyses of these samples are given in Table 3 (Nos. 172–211). Analysis 211 is shown graphically in Figure 13. The analyses for Buenavista show the same characteristics as those for Grandfalls. The range in concentration of dissolved solids is from about the same



DISSOLVED MINERAL MATTER AND DISCHARGE OF PECOS RIVER AT ANGELES AND GRANDFALLS, TEX.

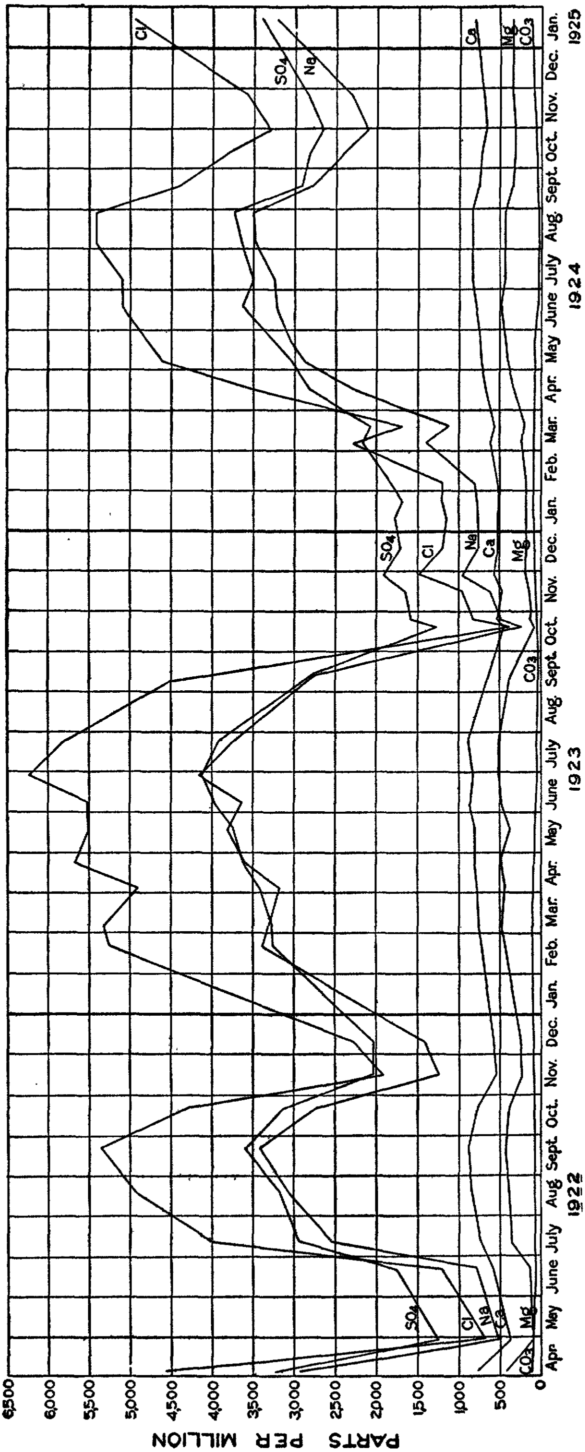


FIGURE 15.—Analyses of water from Pecos River at Grandfalls, Tex.

minimum to a maximum about 2,600 parts less than the maximum for Grandfalls. The discharge is usually greater at Buenavista. The water reaching the river between Grandfalls and Buenavista must be slightly better than the river water at Grandfalls but still highly concentrated and carrying much larger quantities of sodium salts than of calcium and magnesium salts.

SHEFFIELD

From April 6, 1922, to January 22, 1925, 27 samples of water were collected from Pecos River at the gaging station near Sheffield, Tex. Analyses of these samples are given in Table 3 (Nos. 212–238). No. 238 is shown graphically in Figure 13. The concentration of salts in the water is generally less than at Buenavista, but the character of the water is essentially the same as at Buenavista and Grandfalls. The range in quantity of dissolved solids is from a minimum practically the same as at the two stations above to a maximum 2,300 parts per million less than at Buenavista and 4,900 parts per million less than the maximum at Grandfalls. The maximum at Sheffield is about four and one-half times the minimum. The discharge at Sheffield is usually greater than at Buenavista but still considerably lower than at Barstow. It is evident that the water reaching the river between Buenavista and Sheffield is less concentrated than the river water at Buenavista, but that it nevertheless carries large quantities of sodium, sulphate, and chloride.

SUMMARY

The extreme headwaters of Pecos River in New Mexico are shown by older analyses to be originally normal calcium carbonate waters. Early in the course of the river it receives large quantities of calcium and sulphate through the solution of gypsum from the soil. Sodium and chloride (common salt) appear in increasing quantities to the Texas line, but the alkaline earth (calcium and magnesium) salts are appreciably in excess over the alkali (sodium) salts.

In Texas the river water carries about equal quantities of alkali (sodium) salts and alkaline earth (calcium and magnesium) salts, as far as Barstow. From Grandfalls down the quantity of alkali salts is generally double the quantity of alkaline earth salts. The total quantity of dissolved solids from Grandfalls down is usually two or three times the quantity carried above Barstow, which is in turn from one and one-half to two times the quantity at Carlsbad, N. Mex.

In times of high water the quantity of dissolved solids at all points in Texas drops to about the average quantity in the water at Carlsbad, N. Mex.

TABLE 3.—*Analyses of water from Pecos River at gaging stations in Texas, 1922–1925*

[Analyses by H. B. Riffenburg, except Nos. 20, 56, 100, 132, 172, and 212, by Margaret D. Foster; parts per million. Samples collected at United States gaging stations by engineers making discharge measurements]

Angeles

No.	Date	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (calculated)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Discharge (second-feet)
	1922											
20	Mar. 23	4,128	18	0.15	442	157	677	[a] 146	1,556	1,050	1.2	173
21	Apr. 12	4,750			464	175	742	139	1,551	1,250		151
22	May 29	4,600	19		434	170	816	122	1,640	1,240		147
23	July 5	4,068			454	154	672	120	1,542	1,080		160
24	July 25	4,800			468	183	801	112	1,667	1,300		119
25	Aug. 11	4,944			488	197	912	117	1,728	1,500		122
26	Sept. 28	4,780			444	166	891	134	1,613	1,375		148
27	Oct. 12	4,352			444	175	726	134	1,541	1,200		148
28	Nov. 9	4,520			430	155	754	149	1,508	1,175		143
29	Dec. 5	4,440			440	175	782	137	1,564	1,260		143
	1923											
30	Jan. 25	4,230			428	158	773	159	1,547	1,175		148
31	Feb. 8	3,920			416	151	681	163	1,465	1,050		132
32	Mar. 22	4,130			500	164	590	142	1,666	960		212
33	Apr. 9	5,920			524	190	1,151	134	1,811	1,840		86
34	Apr. 29	4,960			484	189	835	112	1,679	1,390		109
35	May 13	5,400			496	201	947	110	1,761	1,560		117
36	June 4	5,620			480	184	1,045	102	1,811	1,600		122
37	June 25	4,728			460	187	783	98	1,705	1,250		102
38	July 21	5,280			456	195	974	93	1,778	1,510		105
39	Sept. 9	3,980			428	158	654	127	1,506	1,040		160
40	Oct. 29	3,370			512	118	358	134	1,564	570		[b] 1,265
41	Nov. 22	3,800			496	140	527	146	1,583	810		406
42	Dec. 20	3,800			488	143	488	166	1,539	800		470
	1924											
43	Jan. 16	3,864			496	145	478	159	1,550	800		478
44	Feb. 28	4,300			516	149	698	137	1,671	1,110		232
45	Mar. 21	4,640			520	155	737	137	1,638	1,220		174
46	Apr. 22	5,700			504	197	1,077	137	1,783	1,730		99
47	May 18	5,180			468	184	954	132	1,704	1,500		161
48	June 12	5,216			492	179	953	100	1,725	1,530		110
49	July 1	4,954			480	194	906	110	1,811	1,410		153
50	Aug. 1	4,820			464	188	822	98	1,704	1,321		153
51	Sept. 9	5,100	29	.40	480	197	[c] 905	117	1,737	1,450	10	165
52	Oct. 2	4,560	32	.10	458	175	Na [c] 767 K [c] 26	146	1,624	1,230	5.0	165
53	Oct. 14	4,920	21	.20	466	185	Na [c] 850 K [c] 28	129	1,674	1,380	5.0	157
54	Nov. 21	4,200			468	192	627	156	1,564	1,110		192
	1925											
55	Jan. 16	4,620	25	.25	492	170	Na [c] 771 K [c] 16	173	1,597	1,280	6.7	144

[a] Includes equivalent of a small amount of carbonate (CO_3).
[b] Flood of several days.
[c] Determined.

TABLE 3.—*Analyses of water from Pecos River at gaging stations in Texas, 1922–1925*—Continued

Porterville

No.	Date	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (calculated)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Discharge (second-feet)
	1922											
56	Mar. 24	4,136	21	0.17	473	155	633	[a] 130	1,627	987	2.3	157
57	Apr. 11	4,720			452	172	770	98	1,723	1,160		143
58	Apr. 26	2,044			366	40	208	146	1,057	220		[b] 1,560
59	May 18	3,374			396	110	480	127	1,310	720		314
60	June 7	3,264	24		408	109	477	146	1,288	740		240
61	June 26	5,334			500	179	926	83	1,794	1,462		136
62	July 12	2,480			338	74	316	105	1,037	475		180
63	Aug. 5	6,000			526	214	1,095	102	1,942	1,750		90
64	Aug. 26	5,560			508	206	984	[a] 78	1,860	1,600		119
65	Sept. 13	5,108			460	183	966	[a] 87	1,687	1,540		130
66	Sept. 27	4,752			444	180	847	[a] 82	1,663	1,340		130
67	Oct. 14	5,140			472	175	886	122	1,646	1,425		136
	1923											
68	Jan. 26	4,440			420	167	852	163	1,523	1,325		120
69	Mar. 21	4,420			524	168	614	139	1,737	1,000		196
70	Apr. 2	4,600			536	166	666	122	1,745	1,100		182
71	May 3	5,620			524	210	939	112	1,844	1,560		99
72	May 20	5,740			560	201	1,012	98	2,058	1,560		76
73	June 9	3,440			576	76	349	105	1,649	500		408
74	June 22	5,280			496	181	962	85	1,786	1,520		99
75	July 11	5,700			552	201	937	78	1,844	1,600		128
76	Sept. 9	3,840			440	140	588	105	1,465	950		173
77	Oct. 11	2,700			332	70	405	107	1,360	350		[b] 4,050
78	Oct. 28	3,634			492	137	443	134	1,564	720		521
79	Nov. 7	3,640			504	133	432	122	1,564	720		766
80	Nov. 21	3,740			500	128	503	139	1,588	780		521
81	Dec. 7	3,860			496	144	495	137	1,600	800		442
	1924											
82	Jan. 4	3,540			488	135	505	163	1,560	790		836
83	Jan. 16	3,988			492	143	570	171	1,580	900		468
84	Jan. 28	3,910			500	149	511	161	1,576	850		370
85	Feb. 13	3,890			488	144	511	156	1,572	820		326
86	Feb. 26	3,834			504	142	488	124	1,580	820		348
87	Mar. 17	4,140			520	157	564	124	1,646	960		326
88	Mar. 27	4,260			508	166	606	129	1,683	1,000		283
89	Apr. 10	5,040			520	168	883	117	1,712	1,440		123
90	Apr. 23	6,670			532	222	1,363	110	1,959	2,180		101
91	May 3	5,560			496	192	988	117	1,750	1,600		123
92	May 16	5,400			464	187	1,001	122	1,731	1,560		144
93	June 5	5,034			500	192	794	107	1,728	1,330		154
94	July 25	4,856			480	186	826	98	1,671	1,375		134
95	Aug. 14	5,812			504	265	1,024	88	1,926	1,770		93
96	Oct. 1	5,000			508	162	942	134	1,728	1,470		144
97	Oct. 18	4,980			504	192	849	115	1,753	1,400		144
98	Nov. 22	4,416			468	135	807	132	1,610	1,200		172
	1925											
99	Jan. 19	4,560	28	.33	492	169	Na [c] 729; K [c] 48	166	1,646	1,200	7.5	154

[a] Includes equivalent of a small amount of carbonate (CO_3).
[b] Flood of several days.
[c] Determined.

TABLE 3.—*Analyses of water from Pecos River at gaging stations in Texas, 1922–1925*—Continued

Barstow

No.	Date	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (calculated)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Discharge (second-feet)
	1922											
100	Mar. 25	4,282	16	0.15	496	159	640	[a] 131	1,670	1,018	2.0	5.1
101	May 8	1,854	------	------	314	42	216	159	905	250	------	102
102	June 16	3,596	------	------	510	92	437	90	1,514	675	------	5
103	June 27	5,536	------	------	546	188	1,093	142	1,918	1,700	------	.7
104	July 24	5,612	------	------	576	197	924	146	1,942	1,500	------	.7
105	Aug. 25	6,440	------	------	680	219	1,020	171	2,206	1,760	------	.3
106	Sept. 9	6,292	------	------	608	227	1,122	120	2,128	1,820	------	.5
107	Oct. 20	4,770	------	------	456	175	856	122	1,613	1,375	------	20
108	Nov. 10	4,680	------	------	448	181	839	127	1,761	1,240	------	110
	1923											
109	Jan. 24	4,280	------	------	430	159	753	137	1,531	1,175	------	55
110	Feb. 7	4,174	------	------	416	162	747	146	1,490	1,175	------	72
111	Mar. 24	4,520	------	------	530	175	666	142	1,778	1,080	------	5.1
112	Apr. 7	5,080	------	------	576	184	794	137	1,951	1,260	------	2.1
113	Apr. 21	5,920	------	------	556	196	1,070	142	1,926	1,700	------	.8
114	May 5	5,980	------	------	592	223	1,010	134	2,000	1,700	------	.5
115	May 19	6,240	------	------	624	210	1,068	144	2,140	1,700	------	.4
116	June 9	5,020	------	------	480	162	787	117	1,485	1,370	------	27
117	Oct. 11	3,400	------	------	436	131	446	146	1,295	800	------	[b] 2,110
118	Nov. 3	3,560	------	------	524	128	391	129	1,556	680	------	591
119	Nov. 23	3,860	------	------	496	135	502	137	1,605	780	------	331
120	Dec. 13	3,740	------	------	488	131	488	144	1,564	760	------	540
	1924											
121	Jan. 4	3,676	------	------	464	144	494	151	1,509	800	------	904
122	Jan. 18	4,060	------	------	496	153	566	163	1,588	930	------	385
123	Feb. 15	4,080	------	------	500	149	564	146	1,630	900	------	205
124	Mar. 1	4,620	------	------	520	157	747	144	1,687	1,200	------	108
125	Mar. 22	4,460	------	------	540	162	651	142	1,745	1,060	------	21
126	Apr. 12	5,330	------	------	560	192	929	139	1,899	1,500	------	1.5
127	May 12	5,740	------	------	532	197	1,013	112	1,913	1,600	------	1.4
128	Oct. 3	6,320	------	------	616	218	1,156	159	2,189	1,800	------	.4
129	Oct. 20	5,224	------	------	500	194	955	127	1,827	1,500	------	3.6
130	Nov. 20	4,420	------	------	480	178	699	122	1,646	1,160	------	48
	1925											
131	Jan. 20	4,680	16	.25	500	175	Na [c] 787; K [c] 37	161	1,646	1,320	6.7	31

[a] Includes equivalent of small amount of carbonate (CO_3).
[b] Flood of several days.
[c] Determined.

TABLE 3.—*Analyses of water from Pecos River at gaging stations in Texas, 1922–1925*—Continued

Grandfalls

No.	Date	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (calculated)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Discharge (second-feet)
	1922											
132	Apr. 4	12,812	------	------	764	417	2,943	[a] 216	3,243	4,585	------	4.4
133	Apr. 28	3,140	------	------	376	92	505	185	1,253	680	------	740
134	June 20	4,737	22	1.5	556	129	788	129	1,760	1,200	------	102
135	July 11	10,748	------	------	740	352	2,544	161	2,930	4,000	------	9.0
136	Aug. 18	13,460	------	------	840	390	3,052	115	3,165	4,925	------	23
137	Sept. 21	14,456	------	------	872	437	3,414	142	3,572	5,360	------	9.0
138	Oct. 21	12,430	------	------	760	380	2,738	134	3,144	4,275	------	23
139	Nov. 15	6,188	------	------	532	221	1,242	139	2,031	1,920	------	75
140	Dec. 9	6,920	------	------	560	236	1,409	149	2,025	2,270	------	48
	1923											
141	Feb. 21	13,260	------	------	722	432	3,393	203	3,251	5,250	------	10
142	Mar. 5	14,330	------	------	764	476	3,306	195	3,254	5,320	------	13
143	Apr. 4	13,670	------	------	768	438	3,174	195	3,407	4,900	------	12
144	Apr. 23	15,210	------	------	808	494	3,612	171	3,608	5,675	------	9.0
145	May 17	15,308	------	------	792	363	3,817	146	3,737	5,500	------	6.5
146	June 7	15,240	------	------	856	481	3,633	117	3,967	5,520	------	6.0
147	June 28	16,940	------	------	820	515	4,153	[a] 103	4,123	6,250	------	3.5
148	July 24	15,440	------	------	880	508	3,714	[a] 116	3,922	5,800	------	3.5
149	Sept. 11	11,930	------	------	648	384	2,818	[a] 68	2,831	4,480	------	5.5
150	Oct. 18	2,610	------	------	448	74	234	110	1,267	370	------	[b] 2,960
151	Oct. 24	3,810	------	------	532	128	475	127	1,576	810	------	378
152	Nov. 15	3,950	------	------	496	140	631	122	1,664	960	------	224
153	Nov. 27	5,536	------	------	556	192	927	144	1,909	1,480	------	153
154	Dec. 17	4,548	------	------	512	166	754	151	1,712	1,200	------	362
	1924											
155	Jan. 10	4,920	------	------	520	162	757	173	1,773	1,150	------	292
156	Jan. 22	4,580	------	------	500	166	752	151	1,680	1,200	------	241
157	Feb. 5	4,880	------	------	520	162	805	151	1,823	1,200	------	118
158	Mar. 5	7,160	------	------	608	241	1,419	161	2,156	2,280	------	150
159	Mar. 18	5,820	------	------	564	201	1,129	156	2,077	1,700	------	73
160	Apr. 16	10,190	------	------	680	349	2,272	161	2,831	3,540	------	3.1
161	May 6	12,800	------	------	728	415	2,878	181	3,020	4,600	------	2.8
162	May 20	13,300	------	------	740	437	3,026	161	3,243	4,760	------	2.1
163	June 17	13,718	------	------	792	493	3,221	78	3,628	5,080	------	2.1
164	July 8	13,640	------	------	840	428	3,239	[a] 73	3,506	5,097	------	6.4
165	Aug. 5	14,344	------	------	844	437	3,482	[a] 51	3,646	5,413	------	3.4
166	Aug. 27	14,570	------	------	840	446	3,500	46	3,741	5,400	------	2.1
167	Sept. 17	11,860	------	------	752	343	2,770	85	2,914	4,400	------	26
168	Oct. 10	10,500	------	------	724	328	2,410	105	2,806	3,820	------	14
169	Oct. 28	9,560	------	------	664	314	2,104	132	2,650	3,300	------	11
170	Nov. 24	10,360	------	------	692	341	2,293	168	2,839	3,560	------	2.8
	1925											
171	Jan. 21	13,080	28	.75	800	446	Na [c] 3,135; K [c] 74	256	3,407	4,940	9.0	1.3

[a] Includes equivalent of small amount of carbonate (CO_3).
[b] Flood of several days.
[c] Determined.

TABLE 3.—*Analyses of water from Pecos River at gaging stations in Texas, 1922–1925*—Continued

Buenavista

No.	Date	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (calculated)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Discharge (second-feet)
	1922											
172	Apr. 5	11,736			782	356	2,663	[a] 184	2,968	4,230		64
173	Apr. 28	5,724			484	178	1,140	156	1,872	1,660		682
174	June 19	9,020	29	0.16	604	280	2,032	154	2,561	3,038		116
175	July 10	12,004			810	374	2,907	178	3,118	4,600		46
176	July 29	12,080			826	400	2,900	178	3,243	4,600		38
177	Aug. 17	13,460			824	420	3,027	137	3,243	4,875		34
178	Sept. 6	13,580			832	382	3,094	142	3,350	4,800		31
179	Sept. 21	13,206			812	407	3,108	161	3,251	4,920		30
	1923											
180	Jan. 19	12,320			764	389	2,893	185	3,134	4,525		34
181	Feb. 21	12,680			770	400	3,051	195	3,209	4,750		34
182	Mar. 5	13,120			800	415	3,101	195	3,350	4,820		39
183	Apr. 5	11,280			754	361	2,520	185	2,930	4,000		31
184	Apr. 23	13,120			840	415	3,035	195	3,267	4,850		37
185	May 17	13,200			800	411	2,996	188	3,309	4,680		30
186	June 7	13,920			836	437	3,372	190	3,523	5,240		28
187	June 28	14,260			828	428	3,316	154	3,536	5,125		24
188	July 24	14,230			832	437	3,297	115	3,572	5,125		18
189	Aug. 15	14,350			824	460	3,423	151	3,613	5,320		20
190	Oct. 19	2,640			468	73	253	102	1,317	400		[b] 2,000
191	Nov. 16	4,760			544	163	738	142	1,751	1,200		231
192	Nov. 28	6,780			612	218	1,289	161	2,129	2,040		96
193	Dec. 17	4,740			480	163	843	146	1,761	1,240		400
	1924											
194	Jan. 8	4,544			512	161	725	176	1,680	1,150		386
195	Jan. 23	5,800			572	192	1,041	171	1,934	1,650		227
196	Feb. 6	6,580			588	218	1,277	166	2,070	2,020		97
197	Feb. 20	8,580			648	280	1,853	183	2,428	2,920		77
198	Mar. 6	7,420			628	247	1,505	163	2,325	2,340		197
199	Mar. 19	7,660			632	253	1,584	171	2,354	2,460		119
200	Apr. 17	11,600			784	354	2,708	181	2,991	4,280		62
201	May 7	12,030			744	369	2,724	176	2,992	4,280		51
202	May 21	12,150			760	370	2,739	181	3,062	4,280		49
203	June 18	12,468			784	406	2,978	144	3,276	4,660		26
204	July 8	12,256			784	402	2,852	107	3,160	4,560		27
205	Aug. 5	12,812			800	382	3,062	100	3,328	4,735		27
206	Aug. 27	13,028			808	419	3,070	98	3,425	4,800		22
207	Sept. 17	12,620			772	402	2,877	100	3,190	4,560		27
208	Oct. 10	12,024			760	379	2,835	124	3,099	4,460		26
209	Oct. 29	11,960			780	376	2,721	171	3,103	4,280		28
210	Nov. 25	8,220			636	271	1,767	146	2,403	2,780		60
	1925											
211	Jan. 21	12,300	35	.38	788	384	Na [c] 2,912; K [c] 48	200	3,160	4,600	7.3	24

[a] Includes equivalent of small amount of carbonate (CO_3).
[b] Flood of several days.
[c] Determined.

TABLE 3.—*Analyses of water from Pecos River at gaging stations in Texas, 1922–1925*—Continued

Sheffield

No.	Date	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (calculated)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Discharge (second-feet)
	1922											
212	Apr. 6	5,516			355	184	1,250	[a] 159	1,445	1,934		108
213	Apr. 30	5,668			430	168	1,236	151	1,556	1,920		672
214	June 19	8,380	24	0.25	536	277	1,875	154	2,211	2,925		172
215	July 19	10,176			626	350	2,341	161	2,683	3,662		66
216	Aug. 15	11,220			608	380	2,533	107	2,744	4,000		46
217	Sept. 20	9,520			540	323	2,209	[a] 103	2,387	3,480		54
	1923											
218	Apr. 6	10,780			620	376	2,114	156	2,650	3,760		60
219	May 18	10,614			592	374	2,497	107	2,716	3,920		50
220	July 2	11,710			612	384	2,704	[a] 69	2,853	4,225		38
221	July 25	12,020			632	402	2,859	85	3,012	4,425		31
222	Aug. 16	10,760			592	376	2,569	122	2,753	4,000		24
223	Sept. 18	8,320			484	280	1,893	[a] 70	2,099	3,000		72
224	Oct. 21	2,650			332	67	421	105	1,383	350		[b] 1,520
225	Dec. 28	6,020			560	205	1,086	156	1,967	1,720		330
	1924											
226	Jan. 9	5,000			548	166	820	156	1,821	1,280		539
227	Feb. 7	7,460			572	266	1,548	190	2,280	2,380		265
228	Mar. 6	6,430			492	227	1,339	120	2,068	2,000		207
229	Apr. 17	9,110			600	313	2,062	159	2,411	3,280		104
230	May 21	11,420			620	384	2,652	132	2,856	4,120		79
231	June 18	9,464			516	345	2,211	110	2,469	3,440		42
232	July 9	11,234			660	384	2,527	122	2,535	4,240		36
233	Aug. 6	10,660			608	360	2,425	107	2,683	3,820		30
234	Aug. 28	11,470			668	396	2,668	100	2,963	4,200		40
235	Sept. 27	7,240			440	249	1,679	115	1,877	2,640		45
236	Oct. 29	10,320			572	367	2,609	112	2,654	4,080		45
237	Nov. 25	11,720			640	402	2,790	90	2,971	4,360		82
	1925											
238	Jan. 22	9,260	25	.25	592	341	Na [c] 2,029; K [c] 128	254	2,423	3,340	10	55

[a] Includes equivalent of small amount of carbonate (CO_3).
[b] Flood of several days.
[c] Determined.