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SUMMARY OF ANNUAL RECORDS OF CHEMICAL QUALITY OF WATER OF THE ARKANSAS RIVER IN OKLAHOMA AND ARKANSAS

1945–52

A PROGRESS REPORT

Prepared in cooperation with the University of Arkansas Engineering Experiment Station, Oklahoma Planning and Resources Board, Division of Water Resources, and the Oklahoma Agricultural and Mechanical College, Division of Engineering Research.

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary

GEOLOGICAL SURVEY
W. E. Wrather, Director

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ABSTRACT

The Arkansas River is subject to many types of pollution downstream from the Oklahoma-Kansas State line, and its inferior quality together with its erratic flow pattern has caused it to be largely abandoned as a source of municipal and industrial water supply. Currently, the Arkansas River is not directly used as a source of public supply in any part of the basin in either Oklahoma or Arkansas.

In general, the chemical concentration of the river water increases downstream from the Oklahoma-Kansas State line to Tulsa because of tributary inflow from the Salt Fork Arkansas River and the Cimarron River, both streams being sources of large amounts of natural salts and industrial wastes. A decrease in concentration of dissolved solids is noted downstream from Tulsa due to tributary inflow from the Verdigris, Neosho, and Illinois Rivers; another increase in concentration occurs with tributary inflow from the Canadian River, which is largely oilfield wastes. A progressive decrease in concentration is noted as the river flows through Arkansas to the Mississippi River, because all major tributaries below the Canadian River have a dilution effect upon the chemical concentration of the Arkansas River water.

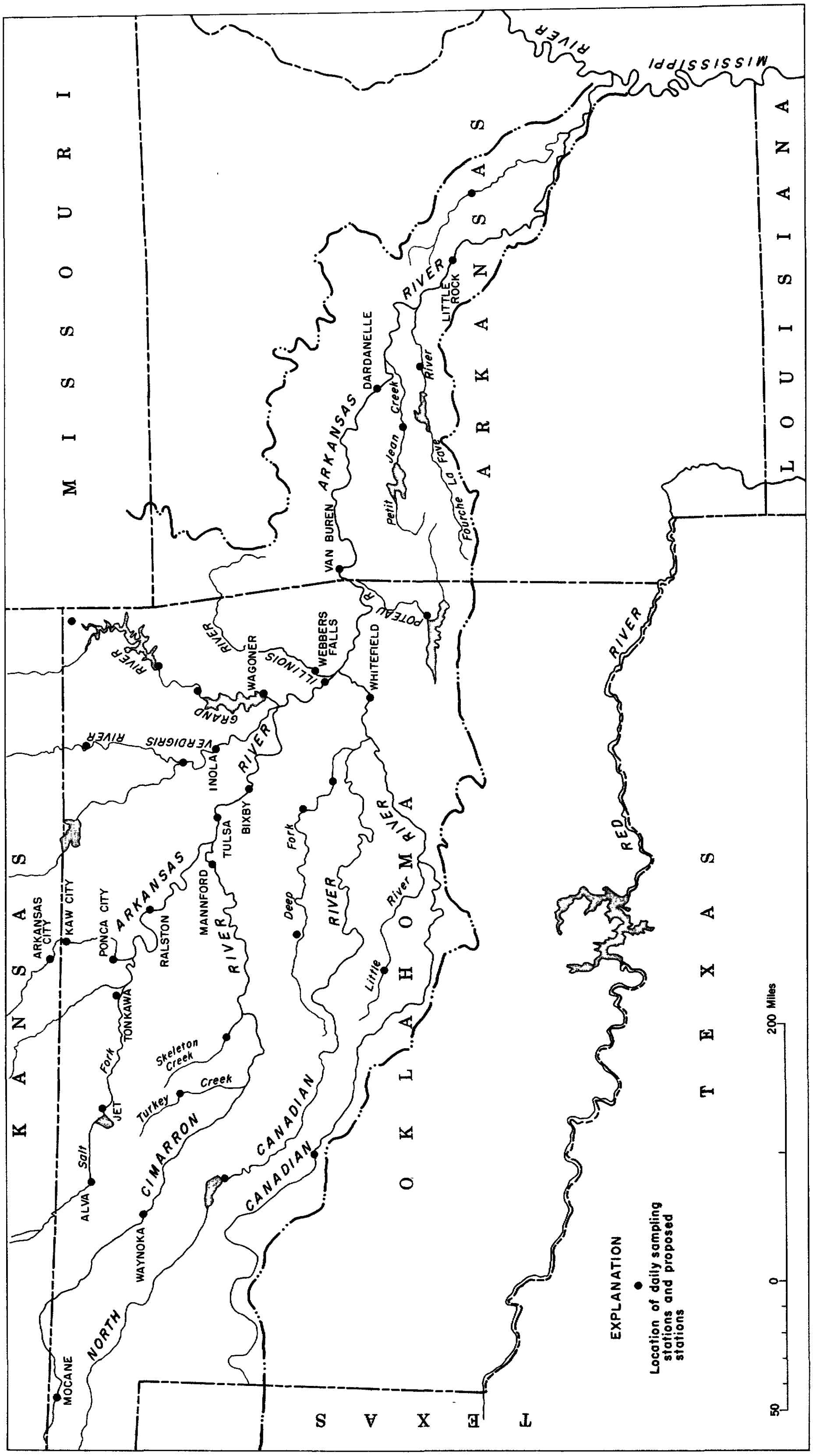


Figure 1.--Map showing location of Arkansas River basin in Oklahoma and Arkansas.

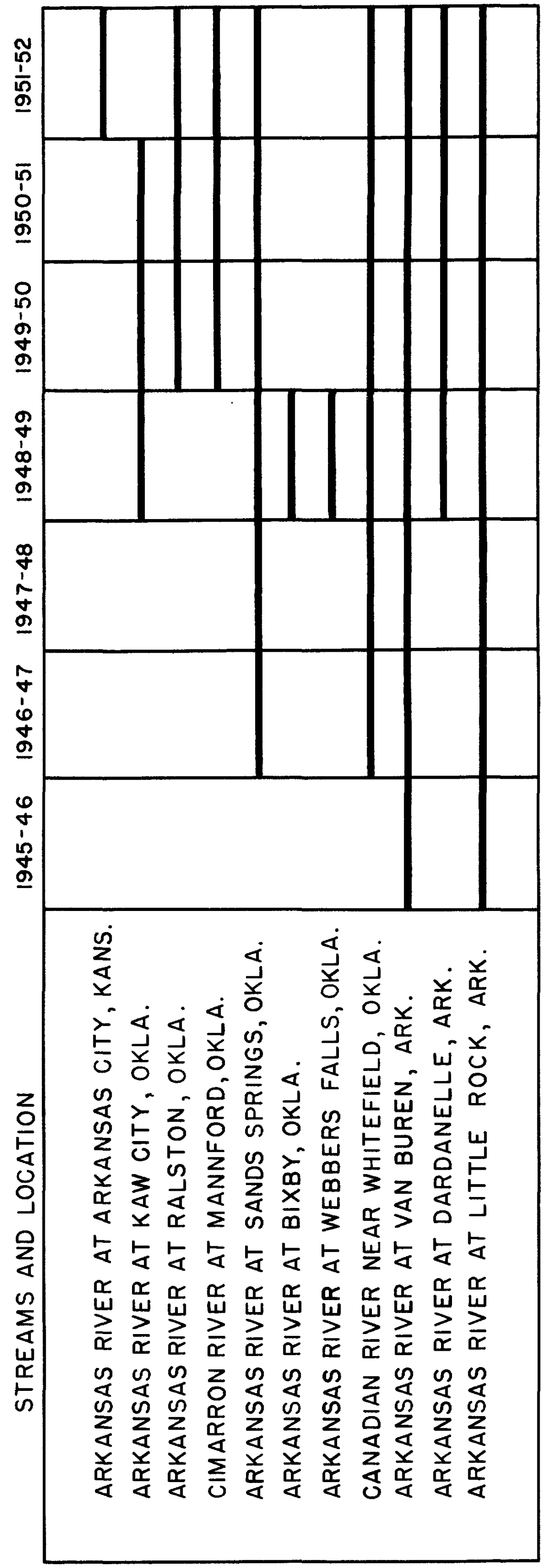


Figure 2.--Years of operation of sampling stations, 1946-52.

Proposals for storage and regulating reservoirs on the Arkansas River in both Oklahoma and Arkansas have been made by the Corps of Engineers and others. Additional proposals are being considered in the present Arkansas-White-Red River Basin Inter-Agency Sub-Committee studies. If constructed, these reservoirs will provide an opportunity for control of flow and beneficial use of Arkansas River water both at and downstream from these sites. Impoundment alone will greatly reduce the extremes in water quality, and by reasonable control of municipal and industrial wastes, the water at some points on the river would be comparable in quality to many existing municipal and industrial supplies in the basin.

INTRODUCTION

Purpose and Scope of Report

The U. S. Geological Survey has carried on a program for the investigation of the quality of water resources in cooperation with the States of Arkansas (since 1945) and Oklahoma (since 1946). This program has included the collection of data in the Arkansas River basin which embraces about two-thirds of the area of Oklahoma and about one-fifth of the area of Arkansas. Results of these investigations in the respective States are published annually by the States of Arkansas and Oklahoma and are also included in the series of annual Water-Supply Papers of the U. S. Geological Survey, "Quality of surface waters of the United States." This report presents a summation of data collected under these cooperative programs in the Arkansas River basin and an evaluation of the effect of tributary inflow on chemical quality of the Arkansas River.

In Oklahoma, during the period from October 1946 to September 1952, daily records of chemical quality were collected at six locations on the Arkansas River and at 22 locations on its tributaries. In Arkansas, during the period from October 1945 to September 1952, daily records were collected at three locations on the Arkansas River and at three locations on its tributaries. Figure 1 indicates the locations of these 34 daily sampling stations. Figure 2 indicates the years of available records for the nine stations on the Arkansas River and on the Cimarron and Canadian Rivers, the two most important tributaries insofar as the effect on the chemical quality of the water in the Arkansas River is concerned. It is important to note that these records were not collected for the specific purpose of evaluating the quality of water of the Arkansas River, but rather as part of a general evaluation of the quality of water resources of Oklahoma and Arkansas. Hence, there are current deficiencies in records necessary for full evaluation of the quality of the Arkansas River. These areas where further study seems to be worthwhile will be pointed out along with the areas where present information seems adequate to support reasonable conclusions.

Personnel and Acknowledgments

The cooperative investigations of water resources in the States of Arkansas and Oklahoma on which this report is based were conducted by the Water Resources Division of the U. S. Geological Survey, Carl G. Paulsen, Chief Hydraulic Engineer. Investigations of water quality were under the general supervision of S. K. Love, Chief, Quality of Water Branch.

The program in Arkansas was carried on in cooperation with the University of Arkansas Engineering Experiment Station, Dr. W. W. Grigorieff, Director; the program in Oklahoma was in cooperation with the Division of Water Resources of the Oklahoma Planning and Resources Board, Ira C. Husky, Director, and the Oklahoma Agricultural and Mechanical College, Division of Engineering Research, Dr. Clark A. Dunn, Executive Director.

Geological Survey offices contributed information used in parts of the report and the assistance is acknowledged of S. K. Jackson, District Engineer, Oklahoma City, Okla.; John L. Saunders, District Engineer, Fort Smith, Ark.; S. L. Schoff, District Geologist, Norman, Okla.; and Roger C. Baker, District Geologist, Little Rock, Ark.

ARKANSAS RIVER DRAINAGE BASIN

Location and Extent

The Arkansas River and its tributaries drain an area of 160,640 square miles in parts of Colorado, Kansas, New Mexico, Texas, Missouri, Oklahoma, and Arkansas. Of this total, about 44,800 square miles lie in Oklahoma and about 12,100 square miles in Arkansas. Thus, the area included in this report comprises about 35 percent of the drainage area of the Arkansas River.

The principal tributaries of the Arkansas River downstream from the Oklahoma-Kansas State line are the Salt Fork Arkansas, Cimarron, Verdigris, Neosho, Illinois, Canadian, and Poteau Rivers in Oklahoma and Mulberry River, Illinois Bayou, Petit Jean Creek, Fourche La Fave River, and Bayou Meto in Arkansas. The following table lists the drainage area and average discharge for these tributaries, during the period October 1946 to September 1952, at locations near their junction with the Arkansas River.

Drainage area and average discharge of principal tributaries to the Arkansas River in Oklahoma and Arkansas, October 1946 to September 1952

Stream and location of measurements	Drainage area (sq mi)	Average discharge for water year (acre-feet)					
		1947	1948	1949	1950	1951	1952
Salt Fork Arkansas River at Tonkawa, Okla	4,528	1,720	1,510	4,640	1,120	3,560	1,040
Cimarron River at Mannford, Okla	18,849	3,460	2,410	5,210	3,390	....	....
Verdigris River near Inola, Okla	7,911	8,920	10,120	11,330	8,400	12,880	7,220
Neosho River near Wagoner, Okla	12,307	16,930	18,870	....	....	27,960	14,850
Illinois River near Gore, Okla	1,622	3,810	3,510	4,370	5,080	2,870	2,320
Canadian River near Whitefield, Okla	47,576	17,850	12,700	15,840	19,760	9,110	5,200
Poteau River near Wister, Okla	1,012	3,270	2,070	2,900	3,210	1,710	2,180
Mulberry River near Mulberry, Ark	372	1,330	831	1,540	1,730	1,050	1,480
Illinois Bayou near Scottsville, Ark	242	....	668	1,020	1,370	607	1,070
Petit Jean Creek at Danville, Ark	741	1,230	1,690	2,130	2,910	1,110	2,230
Fourche La Fave River near Nimrod, Ark	680	1,190	1,780	2,340	3,160	1,140	2,460
Bayou Meto near Stuttgart, Ark	560	664	1,440	1,550	2,530	1,070	994

Physical and Geologic Features

The Arkansas River enters Oklahoma at the northern boundary near Newkirk, just east of the 97th meridian, crosses the State in a southeasterly direction, flows past Tulsa, and enters Arkansas at its western boundary near Fort Smith, north of the 35th parallel. The river flows in a southeasterly direction past Little Rock near the center of the State, and empties into the Mississippi River east of Dumas, Ark., west of the 91st meridian.

Oklahoma

The Arkansas River flows across alternating beds of sandstone and shale of Pennsylvanian age totaling several thousand feet in thickness. The shale beds predominate and generally are dark in color. The sandstone beds are fine to medium in texture and brown in color. Most of these rocks are carboniferous to a degree. Included are at least seven beds of workable coal, ranging in thickness from 2 to 6 feet, and ranging in character from bituminous to semianthracite. Petroleum and natural gas are found throughout the basin, except in the northeastern part.

From about the longitude of Muskogee eastward, the river flows through the major physiographic division known as the Interior Highlands, which is divided into the Ouachita province on the south and the Ozark Plateaus on the north. The river is in the Arkansas Valley section of the Ouachita province. The highest ridges rise more than 2,000 feet above sea level and as much as 1,500 feet above the valleys. The bedrock is of Pennsylvanian age; well-indurated sandstone forms the ridges and gray shale forms the valleys.

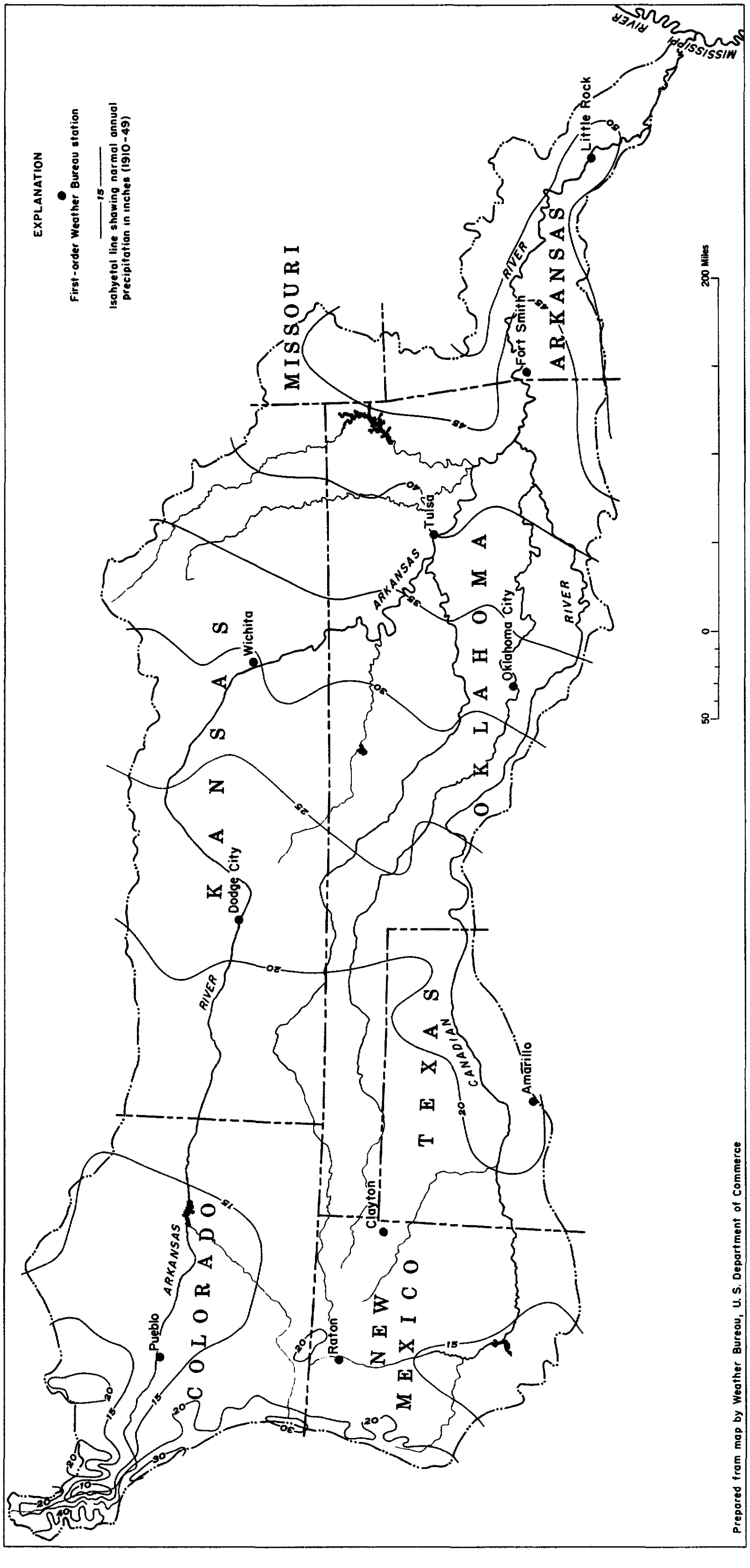
North of the Arkansas Valley section lies the Springfield-Salem plateaus of the Ozark Plateaus province. The rocks underlying this portion of the State belong principally to the Boone formation, a series of chert and limestone beds of Mississippian age. The maximum height of the hills above their bases is about 400 feet, and the average is about 250 feet. Solution of the limestone bedrock has resulted in an underground drainage system, and springs abound in the valleys.

From about the longitude of Muskogee westward to the Oklahoma Panhandle, the drainage basin of the Arkansas River lies in the Central Lowland province of the major physiographic division known as the Interior Plains. In Oklahoma this province includes the Osage Plains section. From about the longitude of Shawnee eastward, bedrocks of the Osage Plains consist principally of shale and sandstonewith a few limestone beds. The average dip is westward and ranges from about 30 feet to the mile near the Kansas border to about 60 feet to the mile in the southern part of the region. The surface slope is southeastward, and the relief is rarely more than 300 feet. Extending westward from Shawnee for a distance of approximately 100 miles is the part of the Osage Plains known as the redbeds plains region, which consists of soft red shale and red sandstone. Over most of this area the height of the hills above the streams is not more than 100 feet. West of the redbeds plains region and extending almost to the Oklahoma Panhandle is the Gypsum Hills region of the Osage Plains. This region is similar to the redbeds plains region except that the weathering of gypsum beds has produced a somewhat more rugged topography.

The major part of the Oklahoma Panhandle is in the High Plains section of the Great Plains Province, and is on the monocline sloping eastward from the Rocky Mountains. The extreme eastern part of the Panhandle is in the Plains Border section, which is transitional between the High Plains and the Central Lowland. The High Plains consist mostly of loose sand, clay, and gravel of Tertiary age.

Arkansas

The part of the Arkansas River basin from Fort Smith to Little Rock lies in a major physiographic



Prepared from map by Weather Bureau, U. S. Department of Commerce

Figure 3. --Normal annual isohyetal map of Arkansas River basin.

province known as the Interior Highlands and the part below Little Rock is in the West Gulf Coastal Plain.

In the West Gulf Coastal Plain area the Arkansas basin is less than 30 miles wide and generally less than 250 feet above sea level. The relief is low with with indistinct stream divides. The unconsolidated deposits immediately underlying the basin consist of clay, silt, sand, and gravel of Tertiary and Quaternary age.

In the Interior Highlands area, the Arkansas River basin is as much as 85 miles wide, and it lies in the three subdivisions of the area. The northern part of the basin is in the Boston Mountains. The Boston Mountains consist of a dissected plateau with mountain summits standing from 1, 850 to 2, 250 feet above sea level and rising from 500 to 1, 300 feet above the adjacent valley areas. The southern part of the Arkansas River basin is in the Ouachita Mountains. These mountains consist of long, generally eastward-trending ridges having altitudes of 1, 500 to 2, 000 feet above sea level with linear valleys having altitudes from 400 to 1, 100 feet. The bedrock of the Interior Highlands province consists of shale, siltstone, sandstone, and some coal of Paleozoic age. In the Interior Highlands area the Arkansas River flows through a broad valley known as the Arkansas Valley. The Arkansas Valley trends eastward and is from 30 to 40 miles wide. The valley consists of: flat alluvial areas which border the Arkansas River and are only a few feet above it; terraces with flat to gently rolling surfaces that make up a considerable part of the valley area; asymmetrical, generally eastward-trending ridges that stand from 600 to 1, 000 feet above sea level; and flat-topped mountains, 1, 800 to 2, 800 feet above sea level. The alluvial material in the bottom lands bordering the Arkansas River consists of clay, silt, and sand. The terrace deposits mostly consist of a drab loesslike silt, although sand and gravel deposits occur at some places, particularly on the terraces along the tributary streams near the mountainous areas.

Climate

The Arkansas River basin has many local variations in climate with an increase in precipitation in downstream areas and with large ranges between annual maximum and minimum temperatures and amounts of precipitation. For the period 1910 to 1949, U. S. Weather Bureau records show that the average annual rainfall ranges from about 15 inches in the extreme western parts of the basin to about 50 inches near the mouth of the Arkansas River. Figure 3 indicates an average annual rainfall range on the Arkansas River in Oklahoma and Arkansas of from about 30 inches along the Oklahoma-Kansas border to slightly over 50 inches at the mouth. The following table, taken from U. S. Weather Bureau records, shows climatic conditions at some locations along the Arkansas River in Oklahoma and Arkansas.

Climate records of four towns in the Arkansas River basin

Town	Altitude (feet above mean sea level)	Air temperature (°F)				Rainfall (inches)			
		Years of record	Max daily	Min daily	Average annual	Years of record	Max annual	Min annual	Average annual
Wichita, Kans.[1]	1, 372	62	114	-22	56.6	51	43.53	15.58	30.33
Tulsa, Okla...............	672	15	109	-8	60.3	51	62.82	24.07	37.86
Fort Smith, Ark.........	461	69	113	-15	61.6	51	71.81	19.80	39.83
Little Rock, Ark........	257	71	110	-12	62.7	51	66.40	31.57	48.25

[1] Located about 50 miles north of Oklahoma-Kansas State line.

Streamflow Records

During the period from October 1946 to September 1952, the records collected by the U. S. Geological Survey for the Arkansas River show a wide range in streamflow characteristics as indicated in the following table.

Discharge at some gaging stations on the Arkansas River below the Oklahoma-Kansas State line during the period 1946-52

Location	Drainage area (sq. miles)	Daily discharge (acre-feet)		
		Maximum	Minimum	Mean
Arkansas City, Kans.[1]........	43,713	119,800	397	6,640
Ralston, Okla.....................	54,465	255,900	555	14,800
Tulsa, Okla........................	74,615	295,500	647	19,150
Van Buren, Ark..................	150,483	765,600	4,721	77,060
Dardanelle, Ark..................	153,707	753,700	6,050	87,290
Little Rock, Ark.................	158,201	704,100	6,426	99,390

[1] This gaging station location is just above the Oklahoma-Kansas State line in Kansas.

The average annual runoff[1] for Oklahoma for the period 1921-45 was 18,700,000 acre-feet of which, 11,100,000 acre-feet was contributed by the Arkansas River drainage basin in Oklahoma. For Arkansas during the same period the average annual runoff was 46,300,000 acre-feet of which 8,600,000 acre-feet was contributed by the Arkansas River drainage basin in Arkansas.

CHEMICAL QUALITY

The changes in chemical quality of the Arkansas River are discussed on the basis of arbitrary division of the river into three segments: Oklahoma-Kansas State line to Tulsa, Tulsa to Van Buren, and Van Buren to Little Rock. These divisions correspond roughly to the major changes in chemical quality as influenced by tributary inflow.

Definition of Terms

The units in which data are presented and other terms used in this report are defined as follows:

Cubic foot per second (cfs) is the rate of discharge of a stream whose channel is 1 square foot in cross-sectional area and whose average velocity is 1 foot per second.

An acre-foot is the quantity of water required to cover an acre of land surface to the depth of 1 foot and is equivalent to 43,560 cubic feet. The term is commonly used in connection with storage for irrigation.

Drainage area of a stream at a specified location is that area measured in a horizontal plane which is enclosed by a topographic divide such that direct surface runoff from precipitation normally would drain by gravity into the river basin that lies above the specified location. Areas of drainage basins given herein include all closed basins or noncontributing areas within the area.

A part per million (ppm) is a unit weight of a constituent in a million unit weights of water. One part per million equals one ten-thousandth of one percent (0.0001).

An equivalent per million is a unit chemical combining weight of a constituent in a million unit weights of water and is calculated by dividing the concentration in parts per million by the chemical combining weight of the constituent.

Percent sodium is computed by dividing the equivalent per million of sodium by the sum of the equivalents per million of the cations (calcium, magnesium, sodium, and potassium) and multiplying the quotient by 100.

A weighted average analysis represents approximately the composition of water that would be found in a reservoir that contains all the water passing a given station during the year after thoroughly mixing in the reservoir.

The Geological Survey's water year is the period from October 1 to September 30 of the succeeding year. Water year 1952 is the period from October 1, 1951, to September 30, 1952.

Pollution, as used in this report, defines conditions in which the mineral concentration of water exceeds acceptable limits for a particular use. Artificial pollution refers to conditions which have been manmade, and natural pollution refers to conditions over which man has no control, such as natural salt deposits.

Collection and Examination of Samples

Samples of water for chemical analysis were collected daily at sampling stations shown in table 1. Specific

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[1] Langbein, W. B., and others, 1949, Annual runoff in the United States: U. S. Geol. Survey Circ. 52.

Table 1.—Summary of analyses, 1945-52.

[Chemical analyses in parts per million]

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25°C)	pH
														Parts per million	Tons per acre-foot	Tons per day	Calcium, magnesium	Noncarbonate			
Arkansas River at Arkansas City, Kans., water year 1952																					
Maximum, Dec. 22-23, 1951	1,255	......	......	154	43	373		0	323	313	550	......	7.6	[1]1,600	2.18	5,420	561	296	59	2,680	8.2
Minimum, Oct. 1-10, 1951	3,756	......	......	52	12	112		0	152	100	135	......	3.6	501	.68	5,080	180	55	57	862	7.5
Weighted average	1,907	......	......	100	28	243		......	234	242	316	......	5.3	1,090	1.48	5,610	364	173	59	1,790	......
Arkansas River at Kaw City, Okla., water year 1949																					
Maximum, Jan. 11-13, 1949	......	......	......	146	38	388		7	241	216	655	......	8.0	1,580	2.15	......	520	311	62	2,670	......
Minimum, Jan. 14-20, 1949	......	......	......	33	6.7	37		0	94	26	59	......	3.0	241	.33	......	110	33	42	391	......
Arkansas River at Kaw City, Okla., water year 1950																					
Maximum, Apr. 29-30, 1950	......	......	......	133	45	468		0	171	255	795	......	8.4	1,790	2.43	......	517	377	66	3,150	......
Minimum, July 26-31, 1950	......	......	......	29	5.3	18		0	99	14	26	......	2.8	201	.27	......	94	14	30	285	......
Arkansas River at Kaw City, Okla., water year 1951																					
Maximum, Feb. 22-24, 26, 1951	......	......	......	152	45	359		0	239	347	555	......	6.3	1,650	2.24	......	564	368	58	2,670	......
Minimum, Apr. 29-30, 1951	......	......	......	37	6.4	37		0	109	29	54	......	4.2	254	.35	......	119	29	40	418	7.3
Arkansas River at Ralston, Okla., January 1950 to September 1950																					
Maximum, May 1-6, 1950	1,345	......	......	122	41	477		0	165	255	785	......	3.0	1,760	2.39	6,390	473	338	69	3,120	......
Minimum, July 21-22, 1950	23,350	......	......	34	5.2	33		0	105	21	47	......	3.7	240	.33	15,100	106	20	40	388	......
Weighted average	6,819	......	......	66	16	160		......	149	108	240	......	3.1	702	.95	12,900	230	108	60	1,190	......
Arkansas River at Ralston, Okla., water year 1951																					
Maximum, Jan. 5, 1951	1,920	......	......	154	48	667		0	260	281	1,080	......	5.1	2,530	3.44	13,120	582	368	71	4,070	......
Minimum, July 15-17, 1951	102,800	......	......	24	7.2	34		0	82	34	42	......	3.5	208	.28	57,730	90	22	46	345	7.1
Weighted average	12,770	......	......	61	15	123		......	145	111	174	......	3.1	593	.81	20,450	214	94	56	991	......
Arkansas River at Ralston, Okla., water year 1952																					
Maximum, Aug. 11, 1952	1,300	......	......	120	38	536		0	134	212	912	......	5.0	2,000	2.72	7,020	456	346	72	3,420	8.2
Minimum, June 7, 1952	20,100	......	......	40	10	44		0	94	47	76	......	3.6	309	.42	16,770	141	64	40	492	7.8
Weighted average	4,267	......	......	101	29	240		......	219	204	350	......	3.5	1,080	1.47	12,440	371	192	58	1,800	......
Cimarron River at Mannford, Okla., water year 1950																					
Maximum, May 2-8, 1950	137	......	......	460	136	3,390		0	160	392	6,050	......	3.5	10,500	14.28	3,880	1,710	1,580	81	16,800	......
Minimum, July 12, 19, 1950	1,790	......	......	46	11	196		0	92	36	335	......	1.9	739	1.01	3,570	160	84	73	1,160	......
Weighted average	1,707	......	......	126	30	750		......	157	196	1,230	......	5.1	2,420	3.29	11,200	438	310	79	4,160	......
Cimarron River at Mannford, Okla., water year 1951																					
Maximum, Apr. 8, 1951	......	......	......	338	105	4,340		0	215	630	7,000	......	4.1	13,000	17.68	......	1,280	1,100	88	20,200	8.2
Minimum, Sept. 10, 1951	......	......	......	47	11	125		0	84	22	240	......	2.8	568	.77	......	162	93	63	964	7.8
Cimarron River at Mannford, Okla., water year 1952																					
Maximum, Sept. 20, 1952	......	......	......	1,150	282	6,490		0	84	284	12,600	......	......	22,400	30.46	......	4,030	3,960	78	34,200	7.8
Minimum, May 24, 1952	......	......	......	58	15	201		0	129	20	365	......	3.8	858	1.17	......	206	100	68	1,500	8.1

[1] Maximum boron recorded was 0.07 ppm.

Table 1.—Summary of analyses, 1945-52—Continued

Date of collection	Mean discharge (cfs)	Silica (SiO$_2$)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO$_3$)	Bicarbonate (HCO$_3$)	Sulfate (SO$_4$)	Chloride (Cl)	Fluoride (F)	Nitrate (NO$_3$)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as CaCO$_3$: Calcium, magnesium	Hardness as CaCO$_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Arkansas River at Sand Springs bridge near Tulsa, Okla., water year 1947																					
Maximum, Oct. 11, 1946	1,050	......	......	......	......	......		0	79	380	5,030	......	0.5	......	......	......	1,280	......	......	15,300	......
Minimum, July 2, 1947	13,900	......	......	......	......	......		0	50	75	215	......	.0	......	......	......	106	......	......	672	......
Weighted average	8,096	......	......	......	......	......		......	145	166	605	......	3.1	......	......	......	341	......	......	2,370	......
Arkansas River at Sand Springs bridge near Tulsa, Okla., water year 1948																					
Maximum, Feb. 1-4, 1948	870	......	......	227	56	1,220		12	202	276	2,100	......	7.0	4,000	5.44	9,400	796	611	77	6,380	......
Minimum, Aug. 12-13, 1948	17,000	......	......	56	10	135		0	91	88	215	......	7.0	556	.76	25,500	180	106	62	927	......
Arkansas River at Sand Springs bridge near Tulsa, Okla., water year 1949																					
Maximum, Dec. 1-10, 1948	5,295	......	......	153	51	1,000		0	90	259	1,720	......	2.0	3,230	4.39	46,200	592	518	79	5,340	......
Minimum, May 25, 27-28, 1949	60,270	......	......	52	9.5	95		0	129	73	135	......	5.0	442	.60	71,900	169	64	55	771	......
Arkansas River at Sand Springs bridge near Tulsa, Okla., January 1950 to September 1950																					
Maximum, Mar. 1, 1950	3,390	......	......	209	62	1,250		0	180	308	2,150	......	4.5	4,070	5.54	37,300	776	629	78	6,900	......
Minimum, July 18-20, 1950	49,430	......	......	36	5.4	36		0	112	18	55	......	1.8	232	.32	31,000	112	20	41	391	......
Weighted average	9,315	......	......	84	20	329		......	154	132	523	......	3.7	1,200	1.63	30,200	292	166	71	2,080	......
Arkansas River at Sand Springs bridge near Tulsa, Okla., water year 1951																					
Maximum, May 13, 1951	15,000	......	......	175	42	1,030		0	209	214	1,740	......	6.5	3,530	4.80	143,000	609	438	79	5,860	8.0
Minimum, July 17-18, 1951	108,700	......	......	39	9.7	81		0	121	53	112	......	2.7	379	.52	111,200	138	38	56	654	7.4
Weighted average	15,620	......	......	81	20	270		......	156	139	422	......	3.5	1,070	1.46	45,130	284	156	67	1,830	......
Arkansas River at Sand Springs bridge near Tulsa, Okla., water year 1952																					
Maximum, Sept. 4, 1952	860	......	......	151	52	1,020		5	158	279	1,690	......	2.3	3,460	4.71	8,030	590	452	79	5,880	8.3
Minimum, June 5-8, 1952	18,820	......	......	54	14	172		0	133	74	268	......	2.9	696	.95	35,370	192	84	66	1,240	7.7
Weighted average	5,444	......	......	111	32	463		......	203	196	734	......	3.8	1,720	2.34	25,280	408	242	71	2,940	......
Arkansas River at Bixby, Okla., water year 1949																					
Maximum, Dec. 1-3, 10, 1948	......	......	......	172	50	913		0	212	437	1,410	......	4.0	3,090	4.20	......	634	461	76	4,610	......
Minimum, May 22, 25, 27, 1949	......	......	......	57	10	105		0	132	73	158	......	6.0	475	.65	......	183	75	56	838	......
Arkansas River at Webbers Falls, Okla., water year 1949																					
Maximum, Nov. 6, 1948	......	......	......	144	29	377		0	176	133	665	......	3.0	1,410	1.92	......	404	260	67	2,520	......
Minimum, Feb. 21-25, 1949	......	......	......	45	7.8	76		0	116	47	116	......	3.0	352	.48	......	144	50	53	584	......
Canadian River near Whitefield, Okla., water year 1947																					
Maximum, Mar. 21, 1947	1,840	......	......	......	......	......		0	144	96	3,000	......	2.0	......	......	......	184	......	......	......	......
Minimum, June 9-17, 1947	3,188	......	......	33	7.8	37		0	145	20	38	......	3.0	210	0.29	1,810	114	0	42	341	......
Weighted average	8,997	......	......	......	......	......		......	101	44	278	......	2.4	......	......	......	198	......	......	1,100	......
Canadian River near Whitefield, Okla., water year 1948																					
Maximum, Oct. 1, 1947	303	......	......	......	......	......		0	118	77	3,660	......	7.0	......	......	......	1,160	......	......	9,670	......
Minimum, Jan. 2, 5-7, 1948	4,725	......	......	6.4	2.8	10		0	16	13	14	......	4.0	89	0.12	1,140	27	14	45	77.4	......
Weighted average	6,402	......	......	......	......	......		......	102	29	329	......	3.1	......	......	......	......	......	......	......	......

Canadian River near Whitefield, Okla., water year 1949

Maximum, Jan. 21-24, 1949	1,059	......	......	516	127	2,610		0	182	69	5,150	......	6.5	8,570	11.66	24,500	1,810	1,660	76	13,100	......
Minimum, May 19-20, 1949	143,500	......	......	38	7.8	64		0	108	19	110	......	2.5	308	.42	119,000	127	38	52	495	......
Weighted average	7,985	......	......	71	18	196		......	123	49	373	......	3.4	801	1.09	17,300	251	150	63	1,360	......

Canadian River near Whitefield, Okla., water year 1950

Maximum, Dec. 12, 17-19, 1949	820	......	......	408	105	1,960		0	190	53	3,900	......	5.0	6,520	8.87	14,400	1,450	1,290	75	10,900	......
Minimum, Sept. 17-20, 1950	58,850	......	......	30	5.8	40		0	92	18	65	......	1.5	244	.33	38,800	99	24	47	389	......
Weighted average	9,964	......	......	61	16	172		......	113	34	327	......	2.8	731	.99	19,700	218	126	63	1,270	......

Canadian River near Whitefield, Okla., water year 1951

Maximum, Jan. 18, 1950	2,240	......	......	367	97	1,690		0	165	81	3,370	......	13	6,500	8.84	39,310	1,310	1,180	74	10,400	......
Minimum, June 14-15, 17-18, 1951	28,400	......	......	42	9.6	76		0	114	38	124	......	2.2	392	.53	30,060	144	51	53	677	7.9
Weighted average	4,595	......	......	89	26	269		......	146	65	510	......	3.4	1,170	1.59	14,520	329	210	64	1,940	......

Canadian River near Whitefield, Okla., water year 1952

Maximum, July 18, 1952	2,760	......	......	461	127	2,500		0	99	47	4,940	......	......	9,730	13.23	72,510	1,670	1,590	76	13,600	8.1
Minimum, Apr. 23-24, 26, 1952	31,530	......	......	36	9.0	66		0	89	14	128	......	1.6	380	.52	32,350	127	54	53	602	7.7
Weighted average	2,620	......	......	89	26	360		......	108	35	700	......	......	1,420	1.93	10,050	329	240	70	2,390	......

Arkansas River at Van Buren, Ark., water year 1946

Maximum, Dec. 21-31, 1945	6,411	......	......	101	26	311		0	195	69	568	......	1.7	1,170	1.59	20,300	359	199	65	2,220	......
Minimum, May 21, 24-26, 28-30, 1946	91,800	......	......	23	6.2	36		0	73	18	57	......	1.8	217	.30	53,800	83	23	48	344	......
Weighted average	33,790	......	......	43	10	93		......	105	35	161	......	1.9	441	.60	66,200	150	64	54	759	......

Arkansas River at Van Buren, Ark., water year 1947

Maximum, Oct. 21-24, 1946	10,050	......	......	84	17	506		0	157	140	782	......	2.5	1,610	2.19	43,700	280	150	80	3,060	......
Minimum, Dec. 12-19, 1946	141,800	......	......	28	6.2	40		0	82	17	67	......	2.8	239	.33	91,500	95	28	48	390	......
Weighted average	38,660	......	......	48	9.7	108		......	111	54	174	......	2.4	494	.67	107,000	161	69	57	845	......

Arkansas River at Van Buren, Ark., water year 1948

Maximum, Nov. 22-23, 29-30, 1947	5,608	......	......	100	27	376		0	123	55	722	......	2.2	1,340	1.82	20,300	360	260	69	2,620	......
Minimum, July 21-23, 29-31, 1948	136,300	......	......	31	5.2	45		0	100	28	59	......	1.9	243	.33	89,400	99	17	50	402	......
Weighted average	34,910	......	......	43	9.1	104		......	105	42	170	......	2.0	463	.63	95,471	145	59	57	795	......

Arkansas River at Van Buren, Ark., water year 1949

Maximum, Dec. 7-8, 1948	10,080	......	......	100	25	461		0	162	116	778	......	4.1	1,560	2.12	42,460	352	220	......	2,880	......
Minimum, Jan. 29-31, 1949	110,300	......	......	19	5.6	40		0	50	18	67	......	2.2	241	.33	71,770	70	30	......	341	......
Weighted average	45,180	......	......	50	11	116		......	112	63	184	......	3.3	514	.70	62,700	170	78	60	874	......

Arkansas River at Van Buren, Ark., water year 1950

Maximum, Dec. 21-24, 1949	7,630	......	......	120	29	400	......	0	171	121	738	......	3.8	1,500	2.04	30,900	418	278	68	2,670	......
Minimum, May 11-20, 1950	191,700	10	0.06	33	5.7	46	2.0	0	89	19	77	0.1	2.5	264	.36	137,000	106	33	48	443	7.6
Weighted average	41,620	......	......	48	48	95	......	......	110	44	160	......	3.0	452	.62	50,800	160	70	54	770	......

Arkansas River at Van Buren, Ark., water year 1951

Maximum, Jan. 11-13, 1951	7,253	......	......	133	35	484	......	6	191	133	852	......	2.8	1,740	2.37	34,070	476	310	69	3,190	8.4
Minimum, July 18-27, 1951	188,700	......	......	38	6.5	26	......	0	112	31	39	......	2.7	216	.29	110,000	122	30	32	381	7.6
Weighted average	45,960	......	......	53	12	96	......	......	126	59	157	......	3.2	474	.64	58,820	182	78	53	811	......

Table 1. —Summary of analyses, 1945-52—Continued

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25°C)	pH
														Parts per million	Tons per acre-foot	Tons per day	Calcium, magnesium	Non-carbonate			
Arkansas River at Van Buren, Ark., water year 1952																					
Maximum, July 22, 24-25, 1952	6,733	......	......	106	30	398	......	0	139	71	745	......	3.2	1,530	2.08	27,810	388	274	69	2,620	7.8
Minimum, Apr. 13-15, 1952	83,570	......	......	32	8.8	54	......	0	76	32	94	......	1.9	297	.40	67,010	166	54	50	501	7.7
Weighted average	26,750	......	......	56	13	114	......	......	127	61	192	......	2.9	556	.75	40,160	193	89	56	928	......
Arkansas River at Dardanelle, Ark., water year 1949																					
Maximum, Dec. 11-13, 1948	9,900	8.0	0.03	88	22	375	2.8	16	124	105	635	0.4	3.8	1,320	1.80	35,280	310	182	......	2,440	8.2
Minimum, Jan. 23-26, 30, 1949	171,300	7.4	.67	19	3.6	35	1.1	0	54	15	60	.2	2.0	220	.30	101,800	62	18	......	316	7.8
Weighted average	52,120	......	......	44	9.6	95	3.5	......	104	53	159	......	3.0	459	.62	64,590	150	64	57	779	......
Arkansas River at Dardanelle, Ark., water year 1950																					
Maximum, Oct. 17-19, 1949	11,200	6.6	0.03	95	24	318	10	0	116	78	590	0.0	1.2	1,180	1.60	35,700	336	240	66	2,180	7.9
Minimum, Feb. 12-13, 1950	96,000	......	......	15	4.0	29	......	0	40	18	46	......	1.2	160	.22	41,500	54	21	54	245	7.4
Weighted average	48,460	......	......	41	8.7	80	......	......	99	38	134	......	2.3	388	.53	50,800	139	57	53	665	......
Arkansas River at Dardanelle, Ark., water year 1951																					
Maximum, Dec. 20-21, 24-26, 1950	7,452	12	0.06	118	30	378	7.6	0	204	155	648	0.3	2.7	1,450	1.97	29,170	418	251	66	2,530	7.9
Minimum, July 21-29, 1951	167,600	14	.04	38	7.1	28	4.0	0	115	29	44	.2	2.2	226	.31	102,300	124	30	32	357	7.5
Weighted average	48,670	......	......	49	10	88	......	......	119	52	143	......	3.0	441	.60	57,950	163	66	54	744	......
Arkansas River at Dardanelle, Ark., water year 1952																					
Maximum, July 24-30, 1952	6,786	7.2	0.03	90	29	349	8.1	0	112	70	655	0.3	2.0	1,350	1.84	24,730	344	252	68	2,330	8.0
Minimum, Nov. 24-27, 1951	85,480	8.6	.36	25	5.0	27	3.5	0	71	21	43	.3	1.6	194	.26	44,770	83	25	40	294	7.8
Weighted average	32,280	......	......	48	11	91	......	......	112	50	155	......	2.2	457	.62	39,830	165	73	55	768	......
Arkansas River at Little Rock, Ark., water year 1946																					
Maximum, Sept. 6-10, 1946	7,590	......	......	85	22	353		0	120	50	650	......	3.2	1,220	1.66	25,000	302	204	72	2,220	......
Minimum, May 21-31, 1946	124,300	......	......	29	5.0	44		0	79	16	75	......	1.8	232	.32	77,900	93	28	50	382	......
Weighted average	49,240	......	......	33	8.1	71		......	98	28	124	......	1.8	355	.48	76,900	130	51	52	615	......
Arkansas River at Little Rock, Ark., water year 1947																					
Maximum, Oct. 24-29, 1946	10,920	......	......	104	26	514		0	164	186	818	......	1.8	1,730	2.35	51,000	366	232	75	3,340	......
Minimum, Dec. 11-20, 1946	188,300	......	......	23	4.3	28		0	81	15	38	......	.2	187	.25	95,100	75	9	45	294	......
Weighted average	47,590	......	......	39	9.0	91		......	108	47	137	......	2.3	419	.57	92,050	135	49	57	726	......
Arkansas River at Little Rock, Ark., water year 1948																					
Maximum, Nov. 29-30, 1947	8,450	......	......	84	22	367		0	107	91	648	......	1.5	1,270	1.73	29,000	300	213	74	2,280	......
Minimum, Jan. 11-14, 1948	29,880	......	......	12	4.3	53		0	62	17	66	......	2.2	206	.28	16,600	48	0	71	309	......
Weighted average	44,710	......	......	34	7.6	87		......	97	34	134	......	2.4	382	.52	83,900	117	38	60	658	......
Arkansas River at Little Rock, Ark., water year 1949																					
Maximum, Sept. 22-23, 1949	25,550	......	......	104	24	339		0	121	99	630	......	4.3	1,260	1.71	86,920	358	259	......	2,280	......
Minimum, Feb. 1-9, 1949	110,500	......	......	23	5.3	31		0	64	18	52	......	2.3	191	.26	56,980	80	27	......	306	......
Weighted average	58,420	......	......	45	9.2	89		......	105	48	145	......	3.5	424	.58	66,880	150	64	56	732	......
Arkansas River at Little Rock, Ark., water year 1950																					
Maximum, Dec. 3-4, 7-11, 1949	8,219	9.4	0.00	94	26	285	13	0	170	114	485	0.1	3.8	1,110	1.51	24,600	342	202	63	1,780	7.9
Minimum, Jan. 11-13, 18-20, 1950	89,070	......	......	22	5.1	39	......	0	54	20	66	......	1.8	224	.30	53,900	76	32	53	302	7.2
Weighted average	58,740	......	......	41	8.7	70	......	......	98	35	121	......	3.3	363	.49	57,600	137	56	51	619	......

Arkansas River at Little Rock, Ark., water year 1951

Maximum, Dec. 28-29, 1950	8,520	....	......	119	30	379	....	0	216	126	668	....	2.5	1,430	1.94	32,900	420	244	66	2,590	7.9
Minimum, July 21-31, 1951	165,700	12	0.12	39	7.6	28	4.3	0	119	30	41	0.3	3.5	234	.32	104,700	128	31	31	376	7.3
Weighted average	52,490	....	......	48	10	82	....	....	121	49	135	....	3.6	430	.58	60,940	161	62	53	718	......

Arkansas River at Little Rock, Ark., water year 1952

Maximum, July 27, 29-31, 1952	7,270	....	......	94	29	351	....	0	128	64	655	....	1.6	1,400	1.90	27,480	354	248	68	2,410	8.2
Minimum, Nov. 26-30, 1951	94,780	....	......	28	5.3	38	....	0	76	25	57	....	2.0	235	.32	60,140	92	30	47	362	7.5
Weighted average	38,730	....	......	43	9.6	79	....	....	103	43	131	....	3.0	407	.55	42,560	147	62	54	679	......

conductance, expressed as micromhos at 25° C., was determined for each daily sample. Composite samples for chemical analyses were prepared by mixing equal quantities of daily samples based on concentration of dissolved solids as indicated by the specific conductance values.

Samples were analyzed according to methods regularly used by the Geological Survey. These methods are essentially the same as, or are modifications of, methods described in authoritative publications for the mineral analysis of water samples. [2]

The main constituent causing an increase in concentration of the Arkansas River in Oklahoma and Arkansas is the chloride coming from both natural sources and industrial wastes. Other constituents normally found in a natural water may decrease in concentration due to chemical changes occurring as a result of its environment. For example, silica and nitrate content may be reduced by growing plants, and calcium and magnesium may be precipitated as carbonate due to loss of carbon dioxide in the water resulting from temperature changes. Sodium may be removed by a natural ion exchange process, sulfate may be reduced to sulfides or to hydrogen sulfide which is evolved as a gas, but the chloride ion is unchanged by natural processes and is therefore a good basis for comparison of downstream changes in chemical quality.

Table 1 presents a summary of chemical-quality data collected at the nine daily sampling stations on the Arkansas River, and collected on the Canadian River at Whitefield, and the Cimarron River at Mannford.

Oklahoma-Kansas State Line to Tulsa

The Arkansas River shows a substantial increase in chloride concentration downstream from the Oklahoma-Kansas State line to Tulsa. (See table 1, and figs. 4 and 5.) For the water year 1952, the maximum chloride concentration was 685 ppm at Arkansas City, 912 ppm at Ralston, and 1,690 ppm at Tulsa. From October 1946 to September 1952, the maximum chloride concentration was 795 ppm at Kaw City near the Oklahoma-Kansas State line, 1,080 ppm at Ralston, and 5,030 ppm at Tulsa.

Influence of Salt Fork Arkansas River

The increased chloride concentration noted in the Arkansas River downstream toward Tulsa is due to both solution of natural salt deposits and to introduction of industrial wastes from many oilfields and refineries within this portion of the basin. The two main tributaries within this reach of the river, Salt Fork Arkansas River and Cimarron River, contribute much chloride picked up by leaching of salt deposits in flow through natural salt plains. The Salt Fork flows into the Arkansas River at Ponca City, which is about 44 miles upstream from Ralston. This stream is relatively low in chloride concentration until it flows through the Salt Plain area about 20 miles downstream from the city of Alva. During the period October 1950 to September 1951, daily chemical-quality records collected at a sampling station on the Salt Fork Arkansas River near Alva show a maximum chloride concentration of 320 ppm and a weighted-average chloride concentration of 77 ppm. Downstream from this location on the Salt Fork Arkansas River near Jet, which is just below the Great Salt Plains Reservoir, many periodic samples collected during the same time show a maximum chloride concentration of 5,570 ppm and a minimum of 940 ppm. There is no evidence to indicate that this increase in chloride concentration between Alva and Jet is due to any source other than pickup of natural salt.

There are many oilfields and refineries located in the Salt Fork Arkansas River drainage basin downstream from Jet. However, there has been no collection of daily records near Jet that would give an indication of how much of the increased chloride load in the Arkansas River from the Oklahoma-Kansas State line to Ralston is due to pickup of natural salt by the Salt Fork Arkansas River, and how much is due to wastes from these oilfields and refineries.

Influence of Cimarron River

The Cimarron River contributes a large salt load to the Arkansas River. This stream enters Oklahoma at its extreme western boundary and flows in and out of the States of Oklahoma and Kansas twice before entering Oklahoma for the last time, midway between the 99th and 100th meridians. It flows across the State in a southeasterly direction to its junction with the Arkansas River at Keystone, 17 miles upstream from Tulsa. The natural chloride concentration of the Cimarron River increases as it flows through the Salt Plain in the vicinity of Waynoka.

Daily chemical-quality records collected on the Cimarron River near Mocane, during the period from October 1946 to September 1948, show a maximum chloride concentration of 840 ppm and a weighted-average chloride concentration of 387 ppm and 421 ppm for the 1947 and 1948 water years respectively. Periodic samples collected from the Cimarron River upstream from Waynoka indicate that the major part of the increased chloride concentration comes from the Salt Plain northwest of Waynoka. The following table shows chloride concentrations of samples collected downstream from Mocane to Waynoka. These samples were collected February 12, 1953.

Sampling point	Chloride (ppm)
Mocane	540
Rosston	590
Buffalo	1,790
Freedom	8,080
Waynoka	15,600

The sampling site near Buffalo is about 12 miles downstream from the Oklahoma-Kansas State line where the Cimarron River enters Oklahoma for the last time. There is no evidence to indicate that this increase in chloride concentration between Mocane and Waynoka is due to any cause other than pickup of

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[2] American Public Health Association, 1946, Standard methods for examination of water and sewage, 9th ed., and Association of Official Agricultural Chemists, 1950, Methods of analysis of the association of official agricultural chemists, 7th ed.

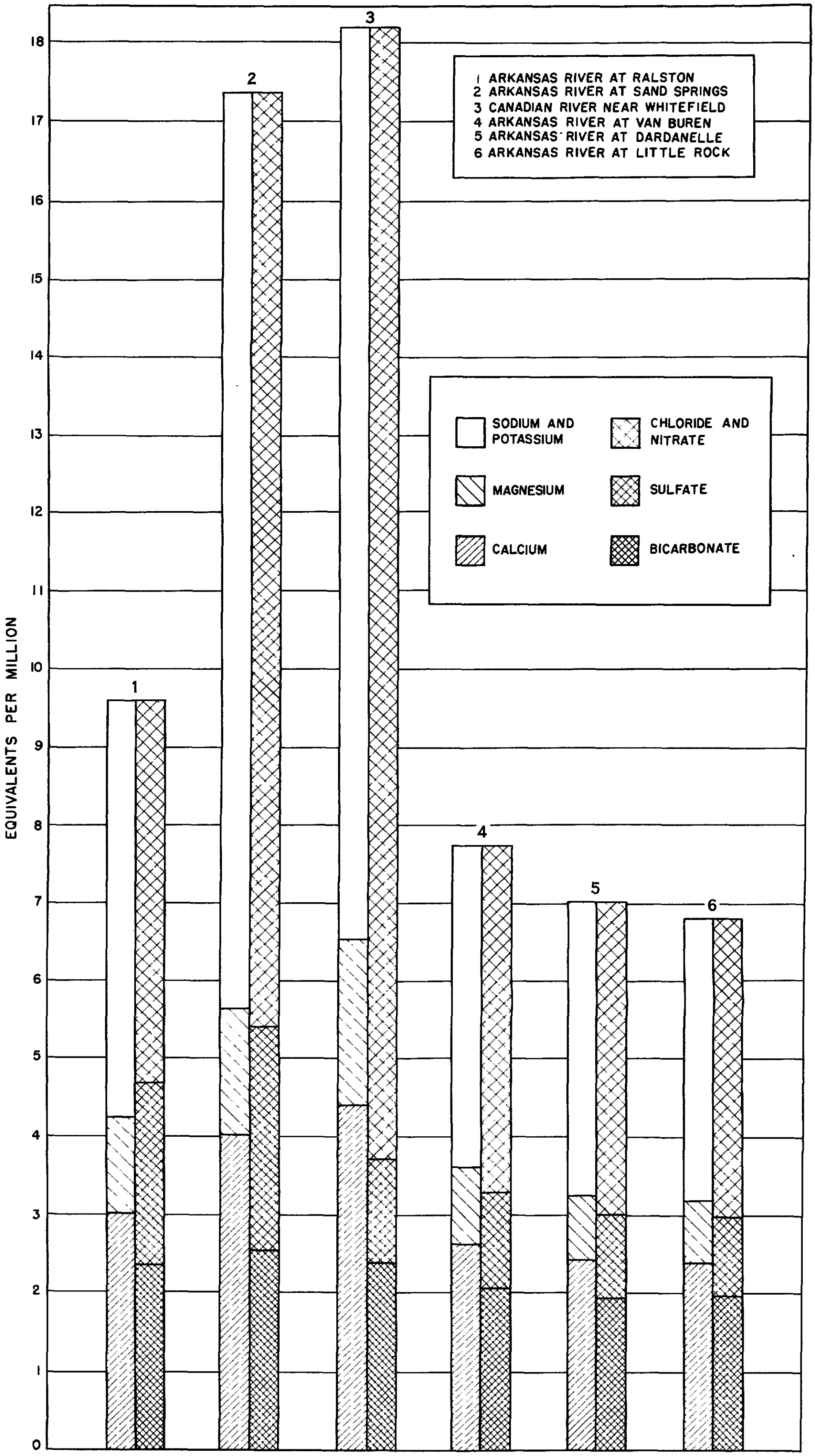

Figure 4. --Weighted average analyses for some streams in the Arkansas River basin, October 1950 to September 1951.

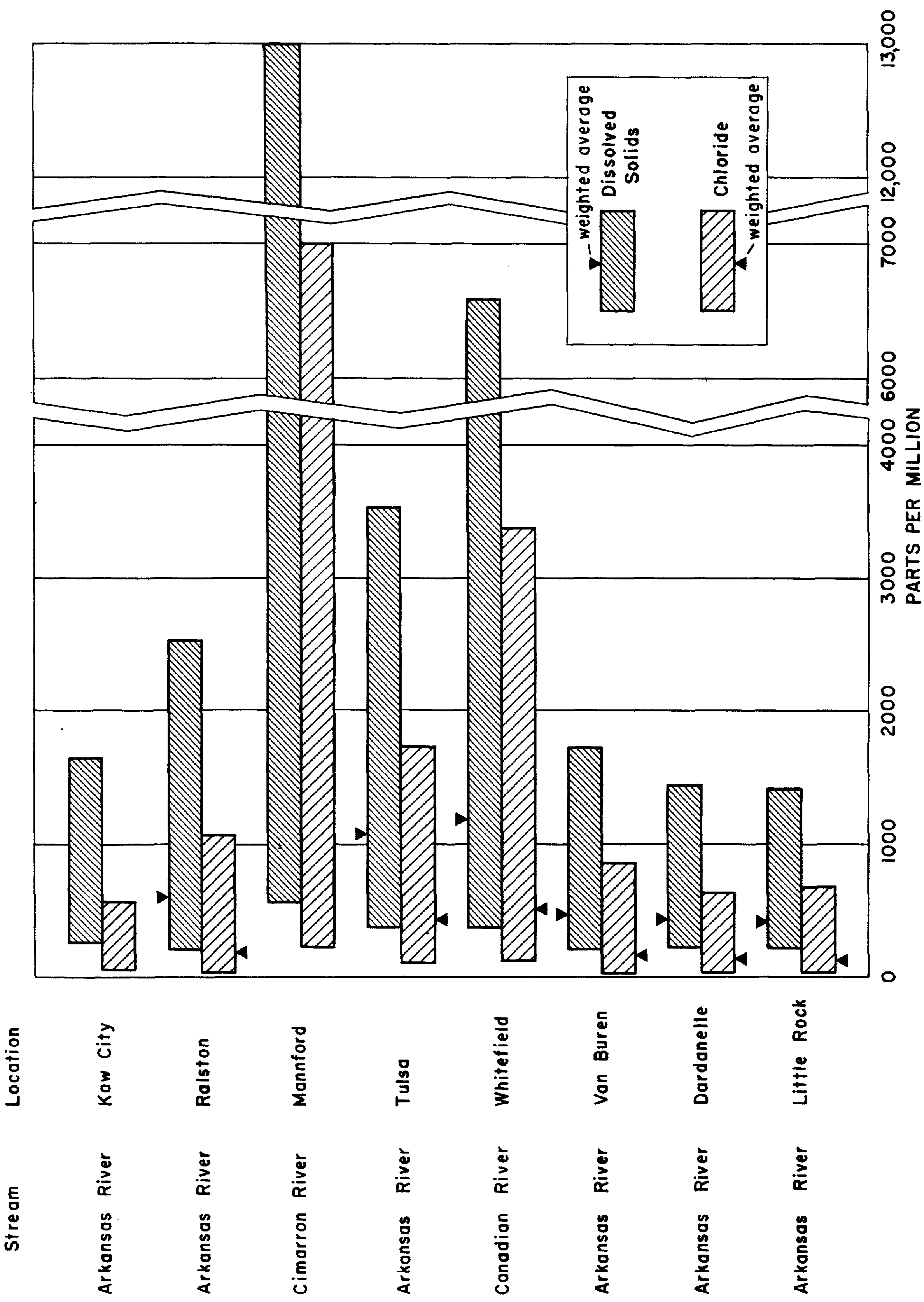

Figure 5. --Range and weighted averages of dissolved solids and chloride, water year 1950.

Table 2.--Runoff, chloride, and dissolved solids for water year 1950 at selected locations in the Arkansas River basin

Stream and location	Runoff (acre-feet)	Chloride (total tons)	Dissolved solids (total tons)
Arkansas River at Ralston, Okla	4,140,000	1,366,000	3,933,000
Cimarron River at Mannford, Okla	1,236,000	2,064,000	4,066,000
Arkansas River near Tulsa, Okla	5,603,000	3,978,000	9,133,000
Canadian River near Whitefield, Okla	7,214,000	3,174,000	7,142,000
Arkansas River at Van Buren, Ark	30,130,000	6,629,000	18,680,000
Arkansas River at Little Rock, Ark	42,520,000	6,803,000	20,830,000

natural salt by the Cimarron River between these two points.

Daily chemical-quality records were collected on the Cimarron River at Mannford for the period from October 1948 to September 1952 and since that time have been collected at a site near Perkins, 67 miles upstream from Mannford. There are many oilfields and refineries located in the Cimarron River drainage basin between Waynoka and Mannford, but to date, no daily records have been collected at the Waynoka location which would give an indication of how much of the chloride load being discharged into the Arkansas River from the Cimarron River is due to natural causes and how much is due to these oilfield operations.

A comparison of data collected for the period October 1949 to September 1950, shown in table 2, gives an indication of the amount of chloride discharged into the Arkansas River by the Cimarron River. During this period the total runoff of the Arkansas River at Tulsa was 5.603 million acre-feet, of which 22 percent or 1.236 million acre-feet was contributed by the Cimarron River. However, the total chloride load for the same period was 3.978 million tons at Tulsa, of which 52 percent or 2.064 million tons was contributed by the Cimarron River. The total runoff of the Arkansas River at Tulsa was only 35 percent higher than the runoff of the Arkansas River upstream at Ralston; yet, the chloride load at Tulsa was 191 percent higher than at Ralston. Of this increased chloride load from Ralston to Tulsa, 79 percent was contributed by the Cimarron River.

The proposed site of the Keystone Reservoir near Tulsa is located on the Arkansas River below its junction with the Cimarron River. Weighted-average analyses for the daily chemical-quality sampling station on the Arkansas River at Sand Springs bridge near Tulsa should be the approximate average analysis of water stored in this reservoir. Even though this proposed reservoir is located below the junction with the Cimarron River, and the resulting chemical quality of the water in storage would reflect the large load of chloride coming from the Cimarron, storage alone would tend to decrease the large variations in daily concentrations. As noted in the summary of analyses, table 1, a maximum chloride concentration of 5,030 ppm was observed during the period October 1946 to September 1952 for the Tulsa station. However, this concentration occurred during a period of relatively low runoff, and it would have had a comparatively small effect on the concentration of the water stored in the proposed reservoir. The weighted-average chloride concentration for the above period at Tulsa ranged from 422 to 705 ppm. The maximum concentrations and fluctuations in concentration of the resulting stored water would depend to a great extent on the amount of stored water, reservoir operation, evaporation, and physical features of the reservoir.

A further evidence of the relation of chloride concentration to runoff is noted by comparing the weighted-average analyses at the Tulsa station for water years 1947, and 1950–52. During these 4 years the maximum weighted-average chloride concentration of 734 ppm occurred during the year of lowest runoff, and the minimum weighted-average chloride concentration of 422 ppm occurred during the period of highest runoff. If this runoff had been equalized by impoundment, the annual variation in concentration of all chemical constituents would have been greatly reduced.

Although the degree of improvement that might be made by the control of industrial wastes in the Arkansas River tributaries cannot be determined from available data, present records should provide an indication of the maximum concentration which would be found in the stored water.

Tulsa to Van Buren

Influence of Verdigris, Neosho, and Illinois Rivers

As the Arkansas River flows downstream from Tulsa, a decrease in dissolved solids and chloride concentration is principally due to tributary inflow from the Verdigris, Neosho, and Illinois Rivers. This dilution effect from the Verdigris and Neosho Rivers is evident from daily records collected on the Arkansas River at Webbers Falls during the period October 1948 to September 1949 when the maximum observed chloride concentration was 665 ppm, while the maximum observed chloride concentration at Tulsa during the same period was 1,720 ppm. The following table

Stream	Runoff (million acre-ft)	Chloride (ppm)		
		Maximum	Minimum	Weighted average
Verdigris River near Inola, Okla	4.134	435	27	55
Neosho River near Wagoner, Okla	1/6.746	12	5.2	8.4
Illinois River near Gore, Okla	1.286	68	1.2	5.9

1/For period October 1948 to July 1949.

gives the chloride concentrations observed at the daily sampling stations on the Verdigris and Neosho Rivers during the period October 1948 to September 1949 and the Illinois River during the period October 1947 to September 1948. Each sampling station is located near the junction of the particular stream with the Arkansas River.

Influence of Canadian River

In the reach of the Arkansas River from Tulsa to Van Buren, the Canadian River is the only stream of any size which does not have a dilution effect upon the Arkansas River water. This stream enters the Arkansas River about 101 miles downstream from Tulsa, and 69 miles upstream from Van Buren.

For the period October 1946 to September 1952 daily chemical-quality records show the maximum chloride concentration of the Canadian River near Whitefield to be 5,150 ppm. Data collected in 1950, table 2, show that 3.174 million tons of chloride was discharged into the Arkansas River from this stream. For the same year, records show that the Canadian River contributed 24 percent of the runoff of the Arkansas River at Van Buren, Ark., and 38 percent of the total chloride load.

Present data indicate no pickup of natural salt of consequence by streams in the Canadian River basin, and practically all the chloride load of the Canadian River results from oilfield and industrial wastes, most of which occur in the drainage basin east of Oklahoma City. The North Canadian River, one of the major tributaries to the Canadian River, is the source of water supply for Oklahoma City, yet periodic samples collected from this stream only 20 miles downstream from the intake of the Oklahoma City water supply show chloride concentrations at times exceeding 10,000 ppm. The State of Oklahoma has initiated steps to eliminate the sources of pollution on the North Canadian River, and, if successful, favorable results and improvement of chemical quality should be noticeable even in the Arkansas River.

Two other tributaries which are responsible for large amounts of chloride pollution in the Canadian River are the Deep Fork River and Little River. Chloride concentrations as much as 2,300 ppm have been observed in Deep Fork River and as much as 38,000 ppm in Little River. Both streams carry large amounts of drainage from oilfield operations. In the newer oilfields of Oklahoma, steps are taken to control these wastes but some fields in the Deep Fork and Little River drainage basins are very old, and up to the present, no corrective measures have been taken to eliminate this source of pollution.

With the exception of the Canadian River, all major tributary streams between Tulsa and Van Buren have a dilution effect upon the Arkansas River. The chloride pollution introduced by the Canadian River is shown by the fact that during the 1949 water year the Arkansas River at Webbers Falls, which is below its junction with the Verdigris and Neosho Rivers but above the Canadian River, had a maximum chloride concentration of 665 ppm. During this same period the Arkansas River at Van Buren had a maximum chloride concentration of 778 ppm, even though all tributary streams between Webbers Falls and Van Buren, with the exception of the Canadian River, usually have chloride concentrations of less than 10 ppm.

The overall dilution effect upon the Arkansas River by tributary inflow between Tulsa and Van Buren is shown by a comparison of the weighted-average chloride concentrations at these two locations. For the period October 1946 to September 1952 the weighted-average chloride concentrations for the Arkansas River at Tulsa ranged from 422 to 734 ppm. The weighted-average chloride concentrations for the same period at Van Buren ranged from 157 to 192 ppm.

Van Buren to Little Rock

Headwaters of the tributaries to the Arkansas River from Van Buren to Little Rock are in the Boston Mountains to the north and in the Ouachita Mountains to the south. These streams are all low in mineral content, and there is no evidence of excessive chloride concentration due to either pickup of natural salt or to industrial wastes.

The two largest tributaries of the Arkansas River in the reach from Van Buren to Dardanelle are Mulberry River and Illinois Bayou. A slight decrease in mineral concentration was observed in this reach of the Arkansas River in the 1950 water year due to tributary inflow from these two streams. The maximum chloride concentration at Van Buren was 738 ppm, while the maximum at Dardanelle for the same period was only 590 ppm, and the weighted-average chloride concentrations for 1950 were 160 ppm at Van Buren, and 134 ppm at Dardanelle. An analysis of the daily chemical-quality records collected on the Arkansas River at Dardanelle during the period October 1948 to September 1952 indicate that with the construction of the proposed Dardanelle Reservoir, the resulting stored water would probably meet qualifications for a municipal supply, so far as mineral content is concerned, dependent on capacity of the reservoir, operation, and physical features. The table below shows a comparison of selected U. S. Public Health Service drinking-water standards with the maximum weighted-average concentrations observed for the Arkansas River at

Comparison of selected U. S. Public Health Service drinking-water standards with constituents for the Arkansas River at Dardanelle, Ark., October 1948 to September 1952

Constituent	U. S. Public Health Service Standards	Arkansas River at Dardanelle
	Should not exceed (ppm)	Maximum weighted-average concentration (ppm)
Nitrate (NO_3).....	44	3.0
Magnesium (Mg).	125	11
Chloride (Cl)......	250	159
Sulfate (SO_4)......	250	53
Dissolved solids.	[1]500	459

[1] 1,000 ppm permitted where water of better quality is not available.

Dardanelle for the period October 1948 to September 1952. The Public Health Service has established no standard for nitrate. Studies[3] indicate that nitrate in excess of 44 ppm in drinking water may be a contributing factor or the cause of a condition in infants known as methemoglobinemia ("blue babies").

As the Arkansas River flows downstream from Dardanelle to Little Rock, the only two tributaries contributing any sizable runoff are Petit Jean Creek and Fourche La Fave River. There is a further slight decrease in mineral concentration of the Arkansas River between Dardanelle and Little Rock due to the dilution effect of the tributaries and direct surface runoff. During the water year 1950 the weighted-average chloride concentration of the Arkansas River at Dardanelle was 134 ppm and at Little Rock was 121 ppm.

The chemical-quality sampling station on the Arkansas River at Little Rock is the farthest point downstream on the river at which daily chemical-quality records have been collected, but daily records have been collected for Bayou Meto, one of the tributaries to the river below Little Rock, and results indicate no highly concentrated waters from this source.

CONCLUSIONS

On the basis of records collected under the cooperative programs in the States of Arkansas and Oklahoma, a comparison of downstream changes or variations in chemical quality of water of the Arkansas River can be made by using the chloride concentrations. The data are incomplete at several places in the basin, but present records are sufficient to make preliminary observations of the downstream changes.

During the 1952 water year, weighted-average chloride concentrations for six daily sampling stations on the Arkansas River point out the extreme fluctuations in chemical concentrations due to tributary inflow between the Oklahoma-Kansas State line and Little Rock, Ark. During this period the weighted-average chloride concentration for the Arkansas City station near the Oklahoma-Kansas State line was 316 ppm. For the same period the weighted-average chloride concentration for the Ralston station, 115 river miles downstream from Arkansas City, was 350 ppm. One of the main factors contributing to this increased chemical concentration was inflow from the Salt Fork Arkansas River. This stream obtains its high chloride content from both pickup of natural salt and from the introduction of oilfield brine and industrial wastes. Additional information is needed to determine the proportion of the salt load contributed by each source. This could be accomplished by the establishment of daily chemical-quality sampling stations to be operated simultaneously on Salt Fork Arkansas River near Jet, to show the salt load carried by the river due to natural sources, and near Ponca City, to show the total salt load contributed to the Arkansas River by pickup of natural salt and by industrial wastes.

The next point on the Arkansas River downstream from Ralston at which a weighted-average chloride value is available for the 1952 water year is the Tulsa station, a distance of 71 river miles downstream from Ralston. At this station the weighted-average chloride concentration increased to 734 ppm. This increase is due principally to inflow from the Cimarron River which carries large amounts of chloride derived from natural salt deposits and oilfield operations and industrial wastes. Present data are not sufficient to differentiate between amounts from each source. Additional information could be supplied by the establishment of daily sampling stations to be operated simultaneously on the Cimarron River near Waynoka, to determine the amount of chloride load due to pickup of natural salt from the salt deposits northwest of Waynoka and at Mannford, to determine approximately the total chloride load carried by the stream from all sources.

The next downstream location from Tulsa at which daily chemical-quality records are available for the 1952 water year is at Van Buren, Ark., a distance of 170 river miles. The weighted-average chloride concentration at this point for the 1952 water year was 192 ppm, a significant decrease in comparison with the value of 734 ppm observed for the station at Tulsa for the same period. The only tributary stream between Tulsa and Van Buren which carries an appreciable chloride concentration is the Canadian River which

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[3] Waring, F. H., 1949, Significance of nitrate in water supplies: Am. Water Works Assoc. Jour., v. 41, no. 2, p. 147-150.

empties into the Arkansas River 101 river miles below Tulsa. The weighted-average chloride concentration for the Canadian River near Whitefield, Okla., for the 1952 water year was 510 ppm. However, other tributary streams between Tulsa and Van Buren, namely the Verdigris, Neosho, Illinois, and Poteau Rivers, were sufficiently low in chloride concentrations to have a significant dilution effect upon the water in the Arkansas River.

All tributary streams between Van Buren and Little Rock are sufficiently low in chloride concentration to produce a steady dilution effect on the Arkansas River water as it flows downstream. During the 1952 water year the weighted-average chloride concentration at the Dardanelle station, a distance of 98 river miles downstream from Van Buren, was 155 ppm, and 90 river miles farther downstream at the Little Rock station the weighted-average chloride concentration showed a further decrease to 131 ppm. At present no information is available on the chemical quality of the Arkansas River water from Little Rock to the Mississippi River. However, miscellaneous analyses from tributary streams in this region indicate that no significant amounts of chloride are introduced into the river.

The data for dissolved solids included in this report have not been used in discussion of variations in the chemical quality of the Arkansas River. There have been certain minor discrepancies in the reconciliation of the total load at various places in the basin. More data are needed for several phases of the program before it is possible to specify causes for these discrepancies. Preliminary studies have been made in some phases in an attempt to determine the sources of error. However, in any region of complex geology, erratic streamflow characteristics, and diversified industrial activity, many factors have a controlling influence on the quality of water of a stream. This is particularly true in the Arkansas River basin of Oklahoma and Arkansas. These factors plus the collecting of only one sample a day from streams with wide variations in daily mineral content indicate that the load values shown in tables 1 and 2 are well within reasonable limits of error.

Data collected under the cooperative programs for Oklahoma and Arkansas were not designed to give a complete evaluation of the quality of water of the Arkansas River in the respective States. With an expanded program designed primarily to satisfy the needs for data, discrepancies such as have been noted would be eliminated.

At the present time there is no place on the Arkansas River from the Oklahoma-Kansas State line to Little Rock, Ark., at which the water would be suitable for daily use for a municipal supply, although some cities along the river in Arkansas use the water at times to supplement their regular supply.

Even if the Arkansas River were impounded at the proposed Keystone Reservoir site near Tulsa, Okla., the resulting stored water would not meet standards desired for a municipal water supply. Because of the large amounts of chloride being introduced into the stream from natural sources over which there is no control, it is doubtful if the chloride concentration could be sufficiently reduced to meet these standards even if major sources of oilfield brine and industrial wastes were substantially abated. However, storage at this reservoir would greatly reduce the daily variation in mineral concentration and would show a definite leveling off in daily variations downstream.

This leveling-off effect plus tributary inflow from less concentrated streams below Tulsa would yield an impounded supply at the proposed Dardanelle Reservoir near Dardanelle, Ark., which would meet standards of mineral content for use as a municipal supply, though cost of treatment of the water probably would be higher than present costs to cities in this vicinity.

It is doubtful that the Arkansas River water upstream from Tulsa would be suitable for irrigation uses even with the construction of the proposed Keystone Reservoir. However, with the leveling-off effect upon daily variation in chemical quality accomplished by this reservoir, it is probable that the water in the river could be used for irrigation anywhere below the junction of the Arkansas River with the Verdigris River, and it should be usable without question downstream from Van Buren, Ark. Arkansas River water is being used for supplemental irrigation at several places in Arkansas between Van Buren and Dardanelle, and with the leveling off in daily variations accomplished by the proposed Keystone and Dardanelle reservoirs, it should be usable at any time and place on the river in Arkansas.

At the present time, industrial use of the Arkansas River water in Oklahoma and Arkansas is confined largely to uses in which chemical quality is no factor, such as gravel washing and cooling water. However, with the elimination of large daily variations in mineral concentrations, it is probable that more beneficial use could be made of the water by industry.

The collection of records at the additional sampling sites mentioned together with studies to determine causes for discrepancies in present data would provide a more complete evaluation of the changes of chemical quality in the Arkansas River in Oklahoma and Arkansas.

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