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BRINE IN SURFACE WATER OF THE LITTLE ARKANSAS RIVER BASIN, KANSAS

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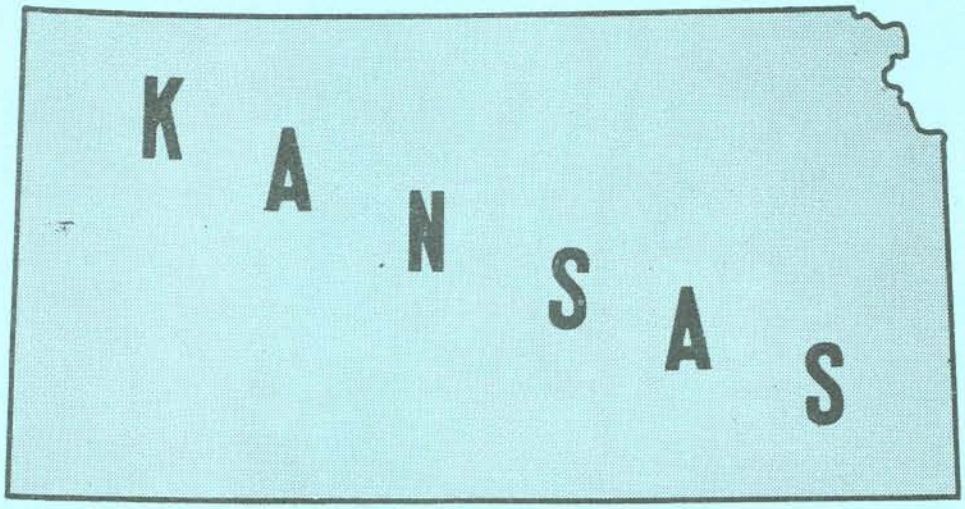

KANSAS STATE DEPARTMENT OF HEALTH
ENVIRONMENTAL HEALTH SERVICES

Topeka, Kansas

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OF THE LITTLE ARKANSAS RIVER BASIN, KANSAS

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Abstract

Observations on the sources and characteristics of brines in the Little Arkansas River basin in Kansas and on the effect of chloride in surface water indicate that residual brine from oil field wastes, brine from solution of natural salts, and possibly brine from industrial waste enter basin streams.

During the period 1945-62, oil field brines that contained about 320,000 tons of chloride were placed in surface storage ponds in the basin. Since 1945, storage of chloride in surface ponds has decreased, as a result of control measures, from an average annual rate of about 19,000 tons during the period 1945-62 to about 1,400 tons during 1962. Ground water from areas having natural salts may affect the water quality of the Little Arkansas River. Contamination by industrial waste is probably minor in the basin.

During periods when specific conductance of the water from the Little Arkansas River is high, chloride is the major constituent. Sodium chloride ratios computed for low flow samples indicate contamination from residual oil field brine.

INTRODUCTION

The natural environment in the Little Arkansas River basin has been altered within the past 40 years by surface storage of oil field brines. The brine from oil field development from solution of natural salts, and possibly from industrial waste, contributes dissolved solids to surface water in the Little Arkansas River basin. Information on the characteristics, amount, sources, and areal distribution of brine is useful in predicting water quality trends and in planning water resources development.

Previous hydrologic investigations in the area include those by Williams and Lohman (1949) on ground water, by Jones (1945, 1950) on oil field pollution control, and by Rall and Wright (1953) on composition of oil field brines. The Wichita Water Department has been collecting water quality data in parts of the basin since 1952, and, in cooperation with the city of Wichita, the U. S. Geological Survey collected data on chlorides in surface water during the 1960-61 water years. An automatic conductivity recorder was installed about June 1961 by the U. S. Department of Health, Education, and Welfare on the Little Arkansas River at Valley Center. Data on brine storage amounts and on the location of storage ponds were furnished by the Kansas State Department of Health.

SOURCES OF BRINE

Oil Field Waste

Major oil production began in 1924 in the Welch-Bornholt pool area of Rice and McPherson counties; since then 16 fields have been developed (Fig. 1). About 274 million barrels of oil was produced from 1924 to 1959 (Table 1). Brines are produced in Kansas at an average rate of about 5 barrels of brine to 1 barrel of oil; however, the ratio depends on area and production period and may vary from 1 to 10 barrels or more of brine to 1 barrel of oil.

Before about 1945, oil field brine was disposed of in established waterways, in evaporation ponds, or rarely in deep injection wells. Brine from evaporation ponds percolated into ground storage or into ground water reservoirs, and subsequent seeps have contributed chloride and other dissolved minerals to surface water. Improperly plugged holes have contributed unknown amounts of brine to fresh

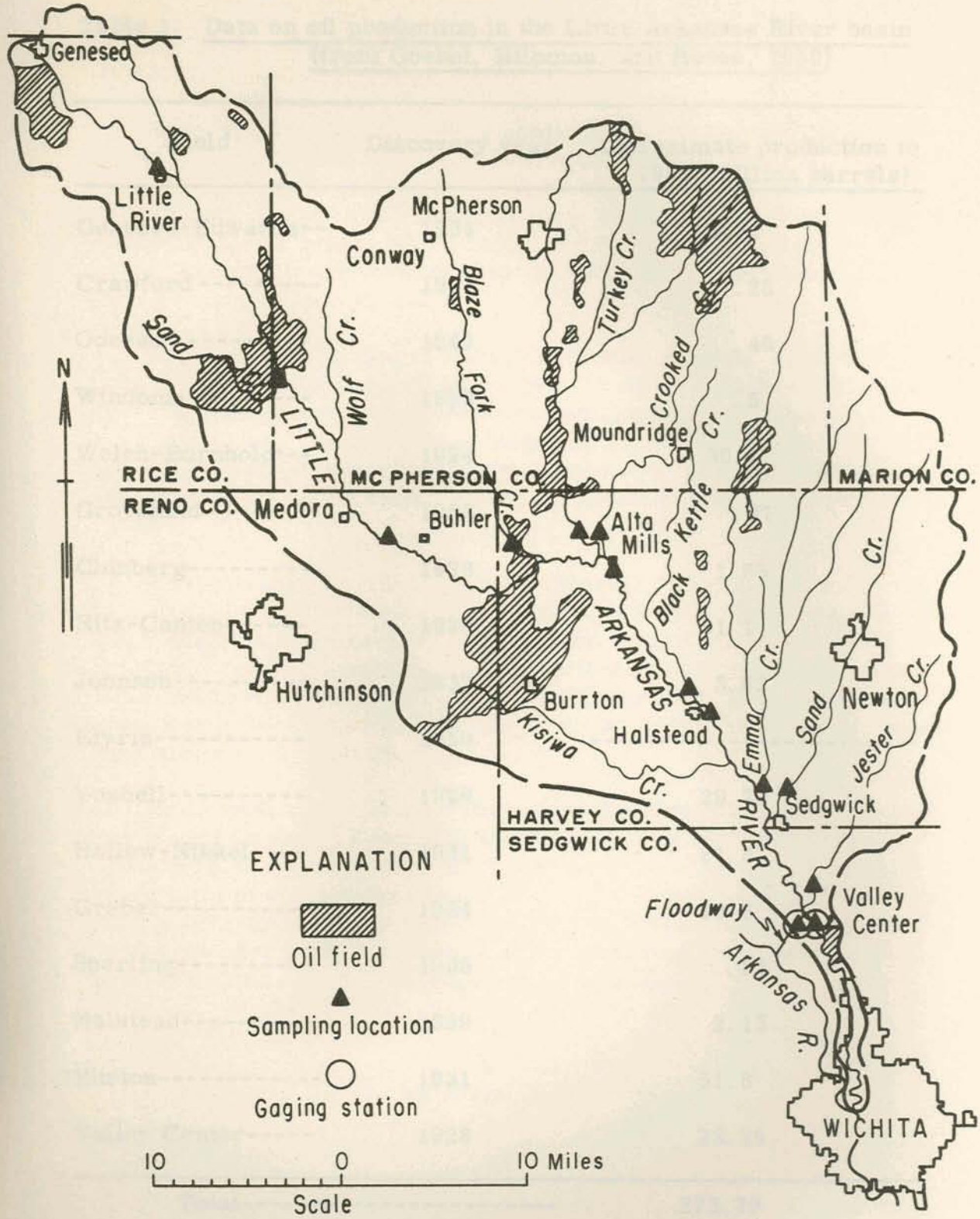

FIGURE 1- LOCATION OF OIL FIELDS, SAMPLING SITES, AND GAGING STATIONS IN THE LITTLE ARKANSAS RIVER BASIN, KANSAS

Table 1. Data on oil production in the Little Arkansas River basin (from Goebel, Hilpman, and Beene, 1959)

Field	Discovery year	Approximate production to 1959 (million barrels)
Geneseo-Edwards--	1934	43.1
Crawford----------	1953	.25
Odessa ----------	1949	.46
Windom----------	1953	.5
Welch-Bornholdt--	1924	30.7
Groveland -------	1953	.37
Chinberg---------	1929	1.85
Ritz-Canton------	1929	51.1
Johnson----------	1932	3.62
Elyria----------	1959	----------
Voshell----------	1929	29.73
Hollow-Nikkel----	1931	21.5
Graber----------	1934	13.6
Sperling----------	1935	.82
Halstead----------	1929	2.13
Burton----------	1931	51.8
Valley Center------	1928	22.26
Total----------		273.79

water aquifers. The total number of holes that have been drilled has not been determined; however, probably only about 10 percent produced oil.

General statutes on oil field abatement were enacted in 1935 by the Kansas Legislature and were revised periodically through 1957. During this period, pollution problems became well defined and brine control methods were developed (Jones, 1945, 1950). The chloride concentration of brine, which can be determined readily by titration in the field and the amount of brine produced were used as a basis for enforcing deep disposal.

Major oil production in the Little Arkansas River basin is from rocks of Mississippian and/or Ordovician Age. The associated brines have high concentrations of dissolved solids, with chloride as the principal anion. Rocks of Mississippian Age produce brine having about 6 percent chloride by weight, whereas total dissolved solids are about 11 to 6 percent by weight, respectively (Rall and Wright, 1953).

An estimated 15 million tons of chloride was pumped to the surface in basin oil operations in the period 1924-62. However, because large amounts were released and flushed during heavy rainfalls, the amount of chlorides retained as evaporites probably was only about 1 million tons. These estimates were made after discussing early operation procedures and disposal methods with various people associated with the oil industry.

Brine monitoring showed that about 320,000 tons of the chloride was placed in surface ponds in the basin during 1945-62 (Table 2). The annual rate of chloride stored in surface ponds has decreased, as a result of control measures, from an average of about 19,000 tons during 1945-62 to about 1,400 tons during 1962. Although control measures have been established and disposal methods have been changed, complete elimination of storage ponds is unlikely.

Industrial Waste

Water pollution from industrial waste is probably minor, although the effect of waste releases into Turkey Creek at McPherson has not been fully investigated. Near Conway (Fig. 1) is a complex of hydrocarbon storage "jugs" (caverns developed in subsurface salt beds by

Table 2. Surface disposal of chloride in the Little Arkansas River basin

Drainage basin	Drainage area (sq. miles)	Number of storage ponds 1/	Chloride: Total stored January 1945 to July 1962 (tons)	Chloride: Maximum annual amount stored January 1945 to July 1962 (tons)	Chloride: Stored 1962 (tons)
Little Arkansas River upstream from Sand Creek (Rice County)--	191	23	8,200	2,280	240
Sand Creek (Rice County) ----	29	28	83,300	9,700	260
Wolf Creek----------	31	0	0	0	0
Blaze Fork Creek----------	166	5	6,600	1,600	0
Turkey Creek ----------	202	45	220,000	29,000	710
Crooked Creek ----------	45	0	0	0	0
Black Kettle Creek----------	42	0	0	0	0
Kisiwa Creek----------	91	1	80	80	80
Emma Creek ----------	183	6	1,700	370	100
Sand Creek (Harvey County)---	95	0	0	0	0
Jester Creek ----------	56	2	970	930	0
Little Arkansas River at Valley Center----------	1,327	110	320,850	--------	1,390
Little Arkansas River at mouth--	1,344	110	320,850	--------	1,390

[1]Surface disposal ponds that were or are in use.

pumped water). Saturated brine solutions are stored in sealed surface pits and are circulated into the "jugs" to force hydrocarbons to the surface. Such pits may be a minor hazard; one failed on May 18, 1960, and allowed brines to flow into Blaze Fork Creek.

Natural Salts

The Wellington formation of Permian Age, which crops out in some areas and underlies much of the basin, contains salt beds. In the western part of the basin these salt beds are now overlain by extensive alluvium but were previously at or near the eroded surface. The water in many domestic wells that are drilled into the shale sections of the Wellington has as much as 700 ppm (parts per million) of chloride. Therefore, the inflow of ground water from the Wellington and runoff from the outcrop of that formation contributes some chloride to the Little Arkansas River.

CHLORIDE FROM BRINE IN SURFACE WATER

During the 1960 and 1961 water years, data on chloride concentration and on specific conductance (a general measure of total dissolved solids) were obtained daily for the Little Arkansas River at Valley Center, periodically for Turkey Creek and Sand Creek, and during low flow periods in selected reaches of the Little Arkansas River. A few samples were analyzed for other dissolved constituents.

Chloride concentrations show a wide range for any given water discharge at Valley Center (Fig. 2); however, concentrations are usually less than 250 ppm, which is the upper limit recommended by the U. S. Department of Health, Education and Welfare (1962). The unusually high concentrations on May 25-26, 1960, resulted from the failure of the brine pit near Conway on May 18. Although a computed load of about 2,700 tons of chloride escaped from the pit, only about 1,600 tons was discharged by the Little Arkansas River at Valley Center during the period May 22-28. Probably the remainder was lost to ground storage or was stored temporarily in pools.

The wide range of chloride concentration in the Little Arkansas River at Valley Center is a result of varying conditions in the basin. The amount and intensity of rainfall, the quantity and chemical quality of ground water inflow, and the availability of chlorides are factors that together determine the specific conductance and chloride content

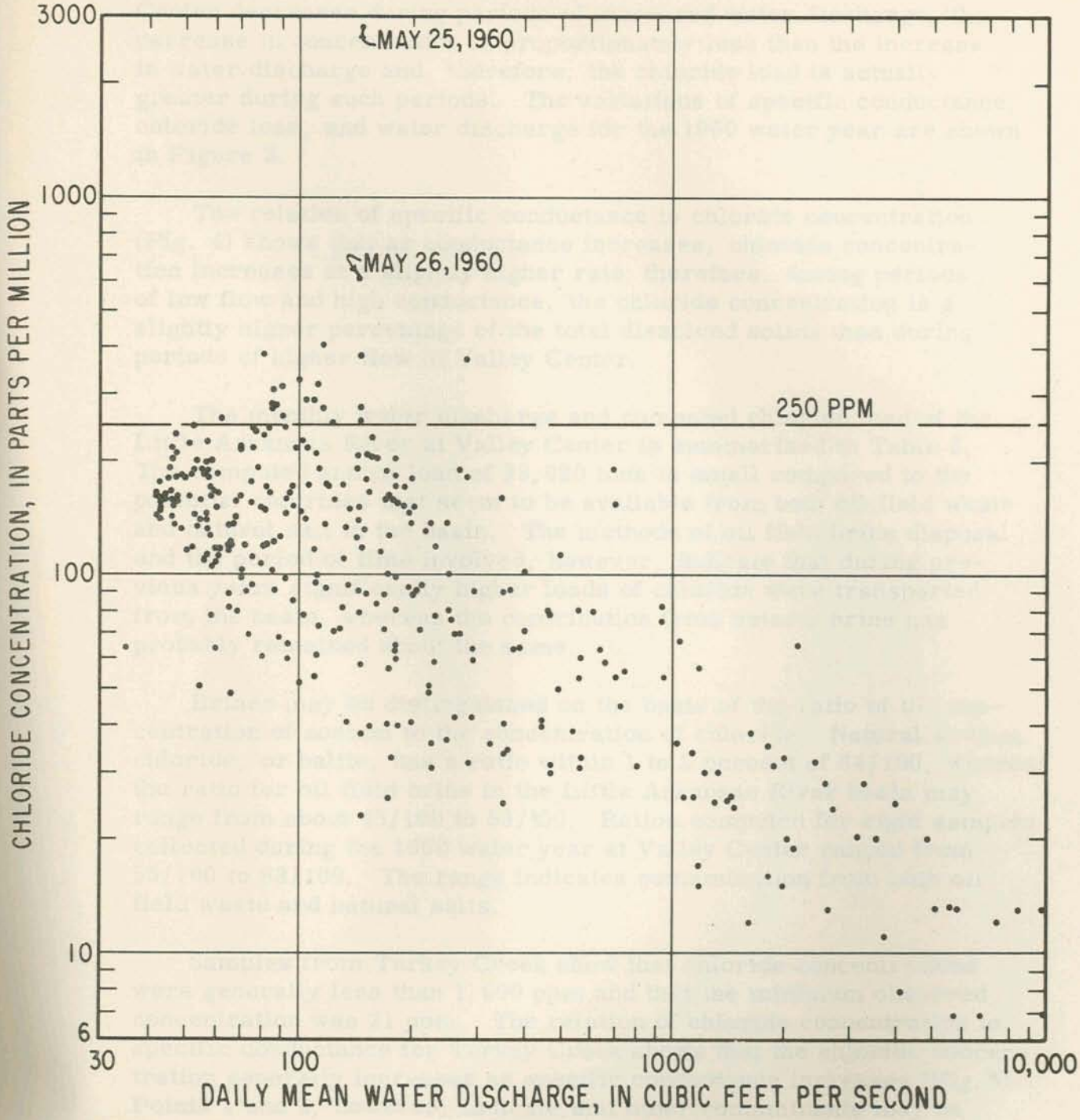

FIGURE 2 – RELATION OF CHLORIDE CONCENTRATION TO WATER DISCHARGE OF LITTLE ARKANSAS RIVER AND FLOODWAY AT VALLEY CENTER, 1960 WATER YEAR.

of the river water. Although the chloride concentration at Valley Center decreases during periods of increased water discharge, the decrease in concentration is proportionately less than the increase in water discharge and, therefore, the chloride load is actually greater during such periods. The variations of specific conductance, chloride load, and water discharge for the 1960 water year are shown in Figure 3.

The relation of specific conductance to chloride concentration (Fig. 4) shows that as conductance increases, chloride concentration increases at a slightly higher rate; therefore, during periods of low flow and high conductance, the chloride concentration is a slightly higher percentage of the total dissolved solids than during periods of higher flow at Valley Center.

The monthly water discharge and computed chloride load of the Little Arkansas River at Valley Center is summarized in Table 3. The computed annual load of 23,020 tons is small compared to the potential chlorides that seem to be available from both oil field waste and natural salt in the basin. The methods of oil field brine disposal and the period of time involved, however, indicate that during previous years significantly higher loads of chloride were transported from the basin, whereas the contribution from natural brine has probably remained about the same.

Brines may be distinguished on the basis of the ratio of the concentration of sodium to the concentration of chloride. Natural sodium chloride, or halite, has a ratio within 1 to 2 percent of 64/100, whereas the ratio for oil field brine in the Little Arkansas River basin may range from about 45/100 to 55/100. Ratios computed for eight samples collected during the 1960 water year at Valley Center ranged from 55/100 to 63/100. The range indicates contamination from both oil field waste and natural salts.

Samples from Turkey Creek show that chloride concentrations were generally less than 1,000 ppm and that the minimum observed concentration was 21 ppm. The relation of chloride concentration to specific conductance for Turkey Creek shows that the chloride concentration generally increases as specific conductance increases (Fig. 5). Points 1 and 2, however, indicate that other contaminants may be present in Turkey Creek. The pH of most samples was about 7.0, but points 1 and 2 had a pH of 6.0 and 6.7, respectively. Some occasional industrial waste, as well as oil field wastes and natural salts, may be providing contaminants to Turkey Creek.

Sand Creek (Rice County) contributes high concentrations of chloride when there is flow and concentrations as high as 5,000 ppm

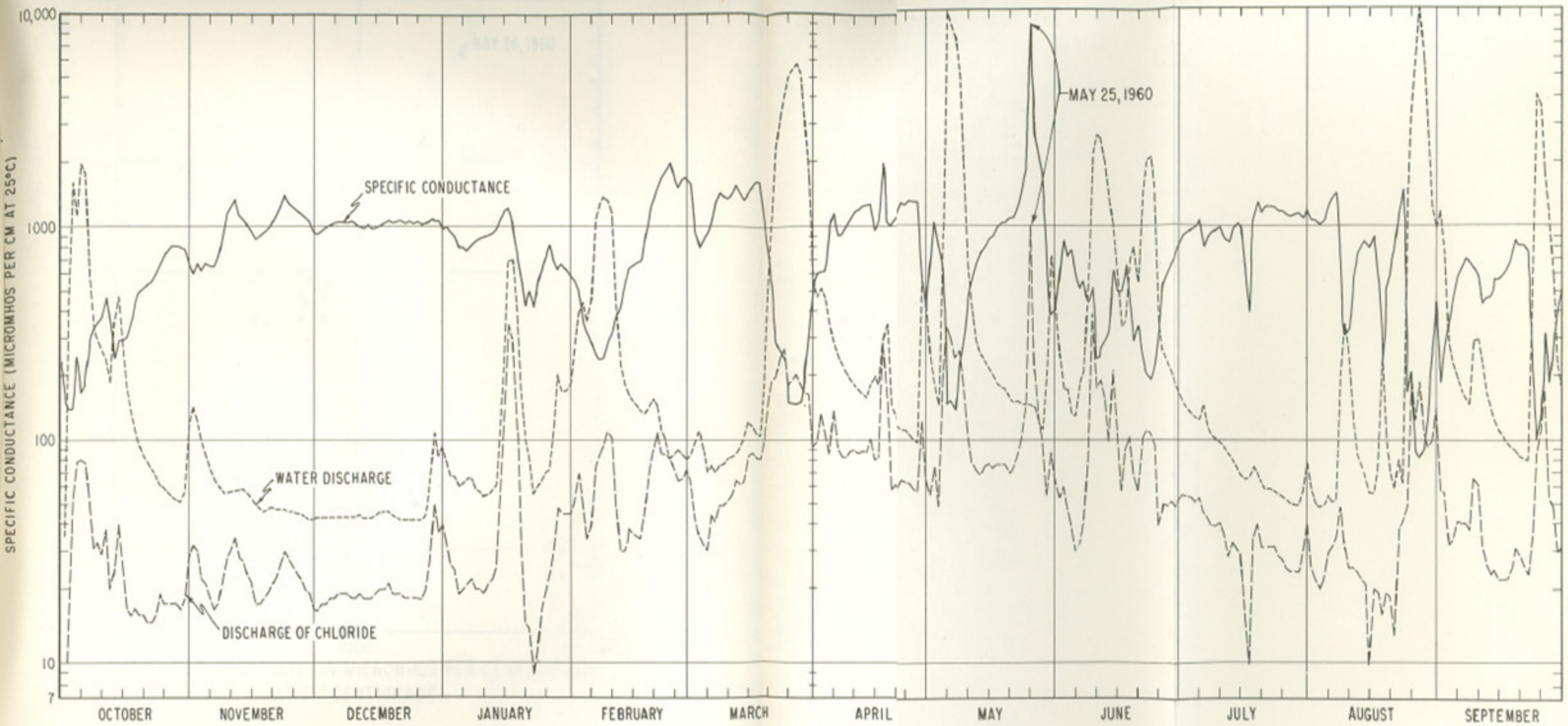

FIGURE 3. - VARIATION OF DAILY MEAN WATER DISCHARGE, SPECIFIC CONDUCTANCE, AND CHLORIDE LOAD OF LITTLE ARKANSAS RIVER AND FLOODWAY AT ALLEY, 1960 WATER YEAR.

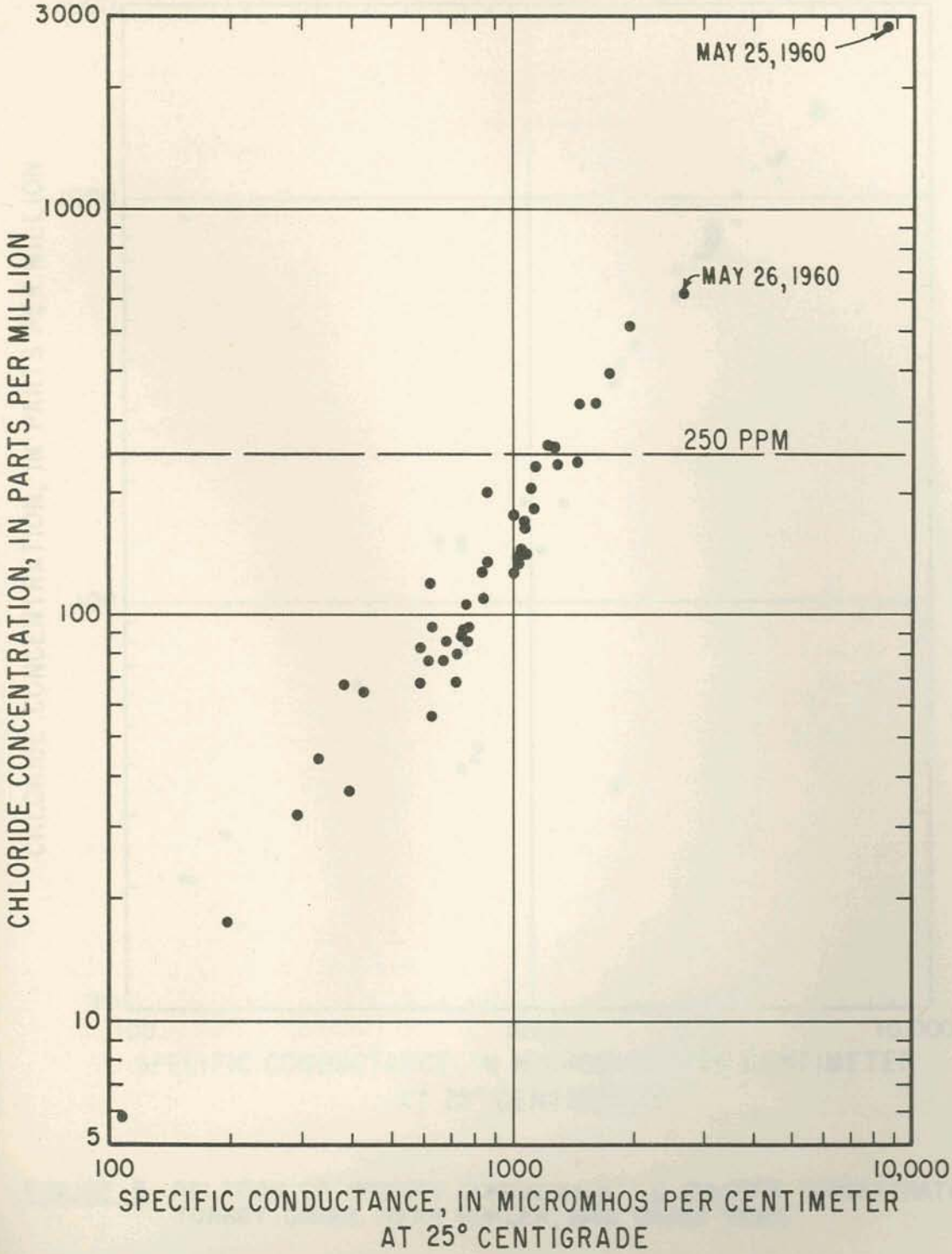

FIGURE 4.– RELATION OF SPECIFIC CONDUCTANCE TO CHLORIDE CONCENTRATION, LITTLE ARKANSAS RIVER AND FLOODWAY AT VALLEY CENTER, 1960 WATER YEAR.

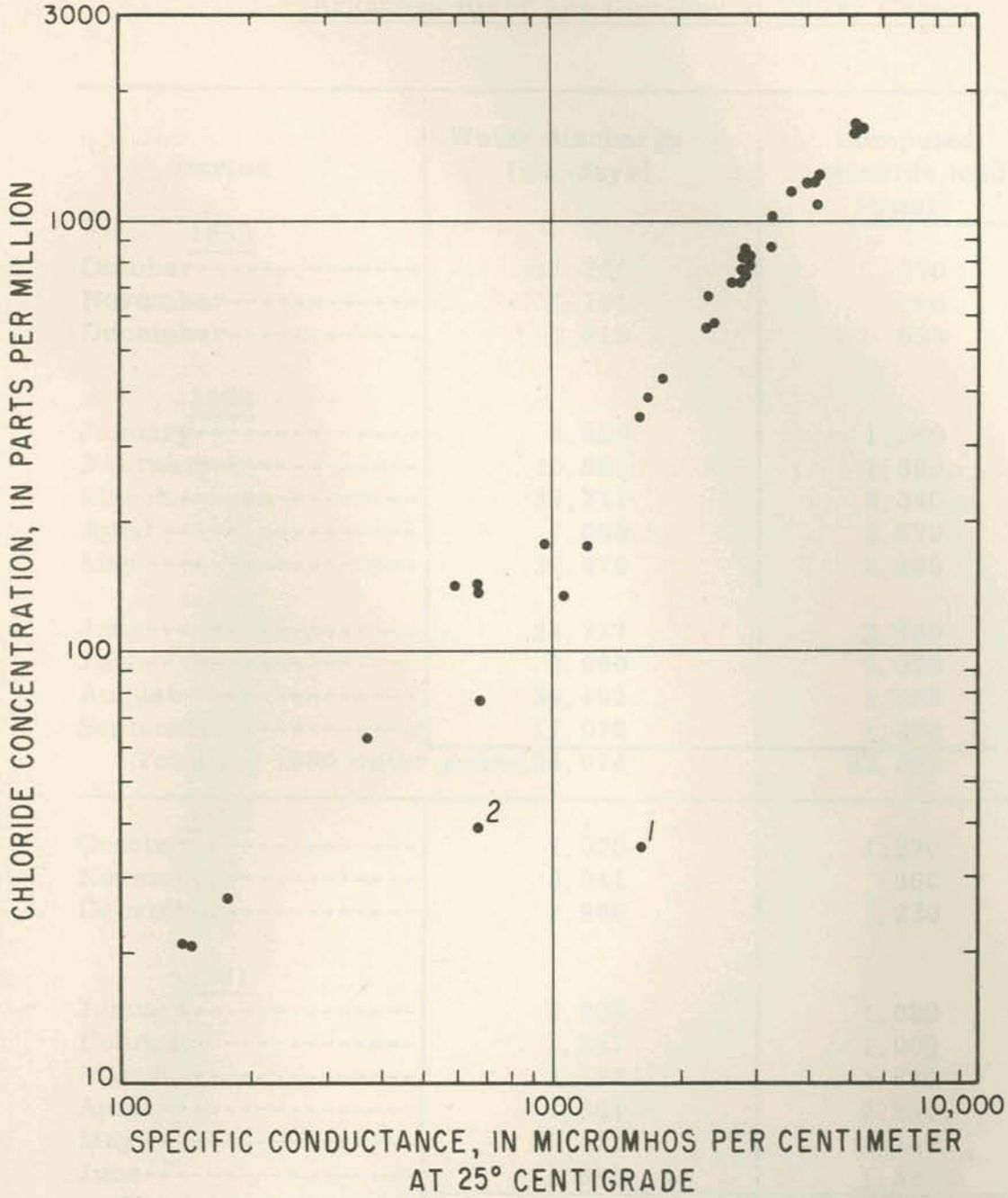

FIGURE 5 - RELATION OF SPECIFIC CONDUCTANCE TO CHLORIDE CONCENTRATION, TURKEY CREEK NEAR BUHLER, 1960 WATER YEAR.

Table 3. Water discharge and chloride load of Little Arkansas River and floodway at Valley Center

Period	Water discharge (cfs-days)	Computed chloride load (tons)
1959		
October	11,244	870
November	1,781	700
December	1,515	650
1960		
January	4,453	1,560
February	10,881	1,880
March	39,711	3,340
April	7,083	2,670
May	39,478	4,590
June	24,777	2,780
July	2,590	1,070
August	34,482	1,590
September	17,079	1,320
Total for 1960 water year	195,074	23,020
1960		
October	7,020	1,270
November	3,041	960
December	2,986	1,230
1961		
January	2,038	1,020
February	3,657	1,000
March	4,182	1,680
April	8,681	2,250
May	48,118	4,140
June	5,660	1,390
Total for October 1960 to June 1961	85,383	14,940
1961		
July	10,413	(1)
August	2,808	----------
September	11,890	----------
Total for 1961 water year	110,494	----------

(1) Automatic conductivity recorder installed by U. S. Health, Education, and Welfare Dept.

have been sampled. The small drainage basin (29 square miles) of Sand Creek has had an average of about one brine storage pond per square mile.

During low flow studies in the Little Arkansas River basin, the water discharge was about 1 cfs (cubic feet per second) at Little River, 12 to 55 cfs on the main stem at Alta Mills, and from 47 to 79 cfs at Valley Center. Chloride concentrations were about 50 ppm at Little River and ranged from 171 to 532 at Alta Mills and from 93 to 170 ppm at Valley Center. The greater concentration at Alta Mills probably reflected the chloride contribution from Sand Creek (Rice County) and Turkey Creek, which have the greater portion of stored oil field brine. Average sodium-chloride ratios for the main stem and for tributaries during low flow are shown in Figure 6.

Chloride concentrations and loads in the Little Arkansas River at Valley Center will decrease further with time as a result of oil field brine control. The contribution of chloride from natural salts, however, probably will remain about the same. Further study will be necessary to determine the relative amounts of contamination from residual brine and from natural salts.

CONCLUSIONS

Data show that chloride in the water of the Little Arkansas River varies with time and place; that the chloride concentration for any given water discharge varies widely at Valley Center; and that chloride is the principal anion, especially during low flow periods. The highest chloride concentrations were observed in Sand Creek (Rice County) and in Turkey Creek. Computed sodium-chloride ratios at low flow indicate pollution from both natural salt and residual oil field brine.

Preliminary data indicate that water from the Little Arkansas River at Valley Center is suitable for municipal use most of the time. Chloride concentrations are usually less than 250 ppm; other contaminants, however, may be present in concentrations that exceed recommended limits.

At Valley Center the chloride concentration generally decreases during periods of increased water discharge. However, the chloride load is much greater during such periods because the decrease in chloride concentration is proportionately less than the increase in water discharge.

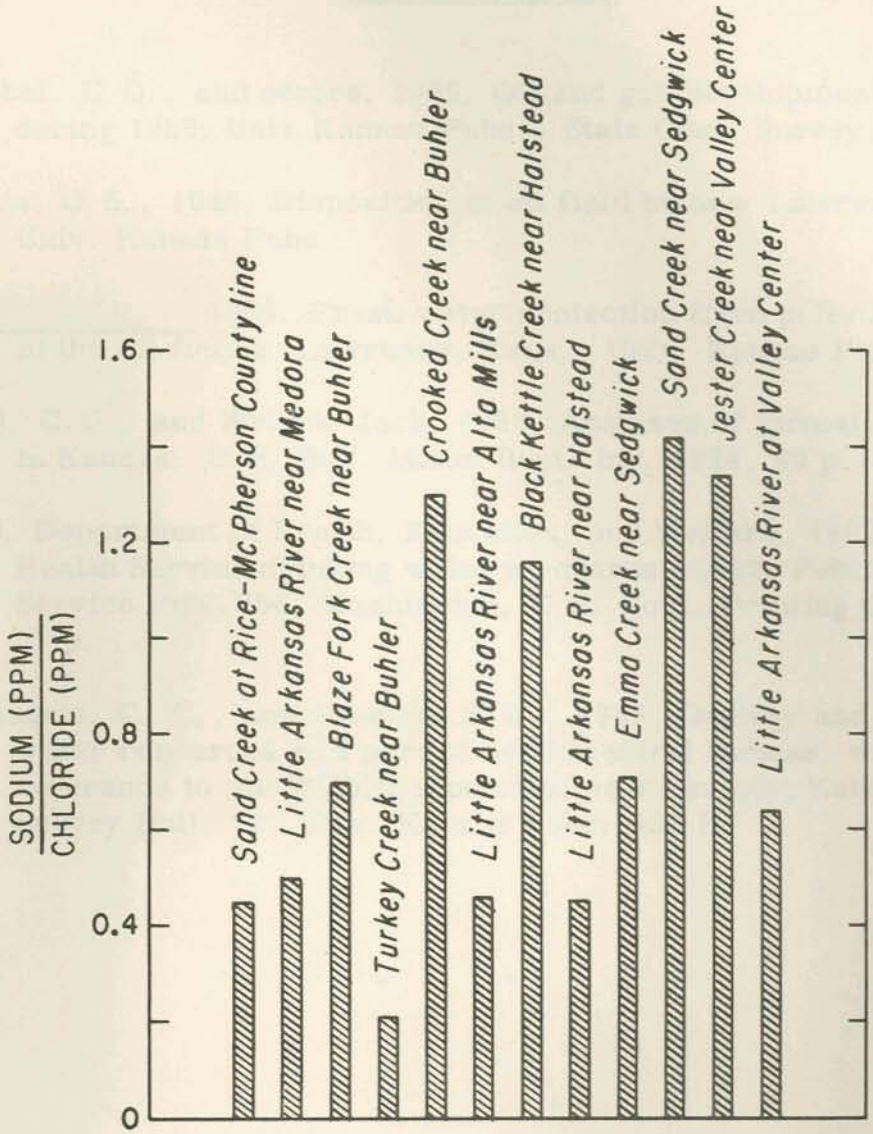

FIGURE 6 – AVERAGE SODIUM-CHLORIDE RATIOS FOR LOW-FLOW SAMPLES FROM THE LITTLE ARKANSAS BASIN, 1960 WATER YEAR.

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