Reconnaissance of the Chemical Quality of Surface Waters of the Sabine River Basin Texas and Louisiana

By LEON S. HUGHES *and* DONALD K. LEIFESTE

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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RECONNAISSANCE OF THE CHEMICAL QUALITY OF SURFACE WATERS OF THE SABINE RIVER BASIN, TEXAS AND LOUISIANA

By LEON S. HUGHES and DONALD K. LEIFESTE

ABSTRACT

The Sabine River basin has an abundant supply of surface water of excellent quality. The basin area of 9,700 square miles receives an average of about 48 inches of rainfall per year, of which about 13 inches flows to the Gulf of Mexico.

Variations in the chemical quality of the surface waters in the Sabine River basin are caused principally by areal differences in geology and runoff; but industrial influences, particularly the disposal of oil-field brines, affect the quality in limited areas. Water having the least dissolved solids is found in the lower part of the basin, where rainfall is greatest. Water having higher values of hardness are found in the area of Cretaceous limestone, chalk, and marl in the northwestern part of the basin. Chloride concentrations are generally low except where streams are polluted by oil-field brines and localized natural saline inflow.

Existing reservoirs in the basin contain water of excellent quality, and water to be stored in proposed reservoirs should be excellent.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

Knowledge of the quality of the water that will be available is essential in planning for any water-use project, because the suitability of a water for household or domestic purposes, for agricultural purposes or for industrial processes, depends upon its chemical quality. For a public supply, a water that meets the requirements of all three main types of utilization is needed. If a raw water is not satisfactory for a specific use, chemical analyses are necessary to determine the type and cost of treatment needed to make it satisfactory.

In addition to the determination of the suitability of water for specific purposes, chemical-quality data are needed for (1) the inventory of the water resources, (2) the detection and control of manmade pollution of water supplies, (3) the study of salt-water encroachment into coastal streams and aquifers, (4) planning for reuse of water, and (5) demineralization of water.

A network of daily chemical-quality stations on principal streams in Texas is operated by the U.S. Geological Survey in cooperation with the Texas Water Commission (before 1962, Texas Board of Water Engineers) and with Federal and local agencies. However, the network never has been adequate to inventory completely the chemical quality of the surface waters of the State.

To supplement the information being obtained by the network, a statewide reconnaissance study was begun in September 1961 and carried on cooperatively by the Geological Survey and the Texas Board of Water Engineers (since 1962, the Texas Water Commission). The study includes the analysis of water samples collected periodically at numerous sites throughout the State; it will insure that some quality-of-water information is available at most locations where water-development projects are likely to be built. The study will also aid in the delineation of water-quality problem areas and the identification of probable sources of pollution, thus indicating areas where more detailed investigations are needed.

Water-quality data were collected for the principal streams in each basin and at the sites of numerous proposed reservoirs. Included were all the reservoirs proposed in the Texas Water Commission's plan for meeting 1980 water requirements (Texas Board of Water Engineers, 1961), as well as several other reservoirs that are listed in master-plan reports of various river authorities. Data were collected also for many existing reservoirs.

Data were collected over a wide range of water-discharge rates. At low flows, concentrations of dissolved minerals are likely to be highest, and the analyses of low-flow samples indicate where pollution and salinity problems exist. Data representative of medium and high flows indicate the probable quality of the water that will be stored in reservoirs. Sampling sites selected were at streamflow stations wherever possible, in order that chemical analyses could be considered in relation to water discharge. At sites other than streamflow stations, the water discharge was usually measured when the samples were collected.

ACKNOWLEDGMENTS

The Texas State Department of Health has made available the water-quality data collected in the Sabine River basin by its Water Pollution Control Division.

A report presenting the results of the reconnaissance study and summarizing all available chemical-quality data is planned for each major river basin in Texas. This report on the Sabine River basin is the first of the planned series.

Chemical analyses of streams in the Sabine River basin in Louisiana, made by the U.S. Geological Survey in cooperation with the Louisiana Department of Public Works, are also included in this report, and the surface-water resources of the Louisiana part of the basin are discussed in a general way. However, the report is concerned principally with the Texas part of the Sabine River basin.

SUMMARY

The Sabine River basin has an abundant supply of surface water of excellent quality, but uneven distribution of runoff makes storage projects necessary to provide dependable supplies.

Average annual rainfall in the basin ranges from 40 inches in the northwest to more than 56 inches in the southeast, and annual runoff from the basin has averaged 13 inches. However, runoff rates vary widely with time. The yearly mean discharge of the Sabine River near Ruliff has ranged from 1,760 cfs (cubic feet per second) to 17,210 cfs, and instantaneous flows have varied from a low of 270 cfs to a high of 121,000 cfs.

Until recent years, water development projects have been comparatively small ones, built by cities and private businesses for municipal and industrial use, and much of the surface-water resource is undeveloped. In 1959, 42,060 acre-feet of surface water was used consumptively in the Sabine River basin. Requirements for surface water for municipal and industrial use in the basin in 1980 are estimated by the Texas Water Commission to be 298,000 acre-feet, plus 114,200 acre-feet to be exported to the Trinity River basin and 4,400 acre-feet to the Neches River basin.

The kinds and quantities of minerals dissolved in surface water are the result of many environmental factors, including geology, patterns and characteristics of streamflow, and cultural influences. Rainfall has a great influence on the chemical quality of waters in the Sabine River basin, and much of the soluble materials has been leached from the surface rocks and soils. Consequently, the water in streams is usually low in concentration of dissolved minerals.

Municipal use of water has caused only local changes in the chemical quality of surface water in the Sabine basin, and flow in streams is usually adequate to dilute municipal wastes. Oil-field brine, however, is polluting streams in Lake Fork Creek subbasin, and probably in Socagee Creek.

Natural pollution of surface water is occurring at Grand Saline, in Van Zandt County, Tex., where a small amount of highly saline ground water enters Grand Saline Creek.

Surface water of the Sabine River basin is generally of excellent chemical quality, and meets U.S. Public Health Service Drinking-Water Standards. The concentration of dissolved solids in the water in most streams is less than 250 ppm (parts per million). Runoff from the outcrop areas of the older geologic formations in the upper part of the basin generally has concentrations ranging from 100 to 200 ppm, and water from the outcrops of younger formations in the lower basin has concentrations less than 100 ppm.

The water from much of the basin is soft, having less than 60 ppm hardness, but water from drainage areas where Cretaceous rocks crop out is moderately hard (60–120 ppm).

The chloride concentration is less than 20 ppm in surface water from about two-thirds of the Sabine River basin. Concentrations greater than 100 ppm are found only where pollution is occurring.

The principal existing reservoirs contain water of excellent quality. Water to be stored in proposed reservoirs should also be excellent, although further evaluation of pollution in Lake Fork Creek should be made before the planned reservoir is built.

SABINE RIVER DRAINAGE BASIN

LOCATION AND EXTENT

The Sabine River drains an area of about 7,400 square miles in eastern Texas and 2,300 square miles in western Louisiana (fig. 1). The drainage basin is crescent shaped, is about 300 miles long and averages about 30 miles wide, and includes all or part of 20 counties in Texas and 6 parishes in Louisiana.

TOPOGRAPHY, SOILS, AND VEGETATION

The Sabine River slopes from an altitude of about 750 feet to sea level. In the northwest one-fourth of the basin are rolling plains, extending into eastern Smith and Wood Counties. Southward to northern Orange County are low hills and stream divides; along the Sabine River and its major tributaries are flat flood plains. Central and southern Orange County has relatively open prairie and poorly drained flat lands.

Except for the black waxy soils in the extreme northwest, soils are mostly light-colored fine sandy loams, with subsoils that range from loamy sand to plastic clay in texture and from yellow to red in color.

Much of the basin is forested, and a large part of Texas' commercial timber is grown there. Extensive areas of the forests have been cleared and used for cropland, but as timber has become more

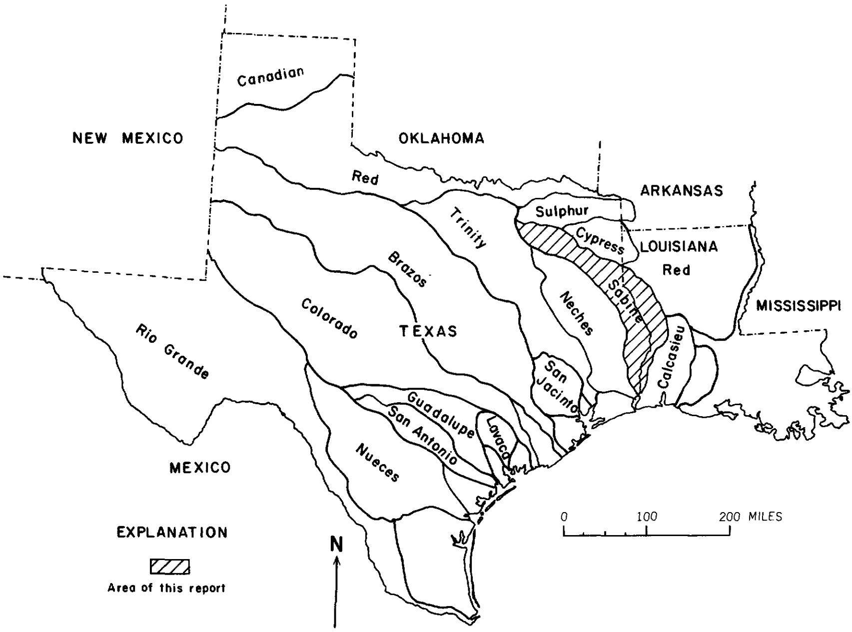

FIGURE 1.—Index map of Texas and Louisiana showing river basins.

important commercially, much of this cropland has been allowed to return to forest.

GEOLOGY

The rocks exposed in the Sabine River basin are a thick series of sedimentary strata that range in age from Cretaceous to Recent. Plate 1 is a generalized map of the geology of the basin. The oldest rocks are exposed in the upper, northwestern part of the basin and dip toward the southeast. In general, successively younger rocks crop out toward the gulf coast, but this stratigraphic sequence is interrupted in the central part of the basin by the Sabine Uplift, a large dome-shaped structural high centered in Panola County. From the north-west flank of the uplift, the formations dip to the northwest; from the southern flank they dip to the south towards the Gulf of Mexico, being overlain by successively younger rocks. Much of the area of the Sabine Uplift is covered by an outcrop of the Wilcox Group of Tertiary age. The stratigraphic succession of formations in the Texas part of the Sabine River basin, with brief descriptions of the rock units, is given in table 1.

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TABLE 1.—*Stratigraphic units in the Sabine River basin, Texas*

System	Series	Group	Stratigraphic unit	Character of rocks
Quaternary	Recent		Alluvium, beach sand, and terrace deposits	Unconsolidated gravel, sand, silt, and clay.
	Pleistocene		Beaumont Clay	Calcareous clay, silt, sand, and gravel.
			Lissie Formation	Beds of sand, gravel, silt, and clay.
Tertiary(?)	Pliocene(?)		Willis Sand	Gravel, calcareous sand, silt, and clay.
Tertiary	Miocene(?) and Miocene		Lagarto Clay and Oakville Sandstone, undifferentiated	Gravel, calcareous sand, silt, and clay.
	Miocene(?)		Catahoula Sandstone	Sand and clay; some volcanic ash and fuller's earth.
	Eocene	Jackson	Undifferentiated	Sand, sandy clay, clay, and volcanic ash.
		Claiborne	Yegua Formation	Sand, sandy shale, clay, and lignite.
			Cook Mountain Formation	Clay and shale containing small amounts of sand, silt, limestone, glauconite, and selenite.
			Sparta Sand	Sand interbedded with shale and clay.
			Mount Selman Formation: Weches Greensand Member	Glauconitic sandstone and shale.
			Mount Selman Formation: Queen City Sand Member	Medium to fine sand, silt, and clay.
			Mount Selman Formation: Reklaw Member	Shale, with thin sand layers.
			Carrizo Sand	Medium to fine sand, interbedded with thin shales.
		Wilcox	Undifferentiated	Silt, clay, fine- to medium-grained sandstone, sandy shale and clay, and thin beds of lignite.
	Paleocene	Midway	Undifferentiated	Shale, clay, and silt.
Cretaceous	Upper Cretaceous	Navarro	Kemp Clay	Clay and sandy clay.
			Nacatoch Sand	Sand and sandy clay.
			Neylandville Marl	Shaly marl and clay.
			Taylor Marl	Marl, chalk, and limestone; some clay, sand, and sandy clay.

DRAINAGE

The Sabine River basin is about 300 miles long, averages 30 miles wide, and is only about 45 miles across at the widest point (pl. 1). The river has many tributaries, all of them small when compared to the Sabine River. Most of the streams are less than 30 miles long and drain less than 200 square miles. Lake Fork Creek in Texas and Bayou Anacoco in Louisiana drain 685 and 431 square miles, respectively; none of the other tributaries drain more than 400 square miles.

PRECIPITATION AND RUNOFF

The climate of the Sabine River basin ranges from moist subhumid to humid (Thornthwaite, 1952, p. 32). The average annual precipitation is about 48 inches, which exceeds the average for the State of Texas by about 60 percent. Within the basin, the annual average precipitation ranges from about 40 inches in the northwest to more than 56 inches in the southeast. Mean annual precipitation in the basin, average (normal) monthly precipitation at four Weather Bureau stations, and annual precipitation for 1889–1962 at one station are shown in figure 2.

Because of the topography and vegetal cover, the rate of runoff from the Sabine River basin is much slower than from most river basins in Texas. The long narrow shape of the basin and the lack of large tributary streams prevent the rapid accumulation of flood waters. Stream bed gradients are very low—for much of its length the Sabine River has a slope of less than 0.8 foot per mile. The river meanders through its flood plain, with numerous sloughs, overflow channels, and marshes. The heavy forest cover of pines and hardwoods slows the runoff even from the rolling hills, and the dense underbrush and timber growing on the flood plains further retards movement of the water.

About 25 percent of the precipitation in the Sabine River basin appears in the streams as runoff. Runoff data plotted on the map in figure 2 show that average runoff from subbasins has ranged from 9.0 inches annually in the upper part of the basin to 18.5 inches in a Louisiana subbasin in the lower part. Runoff from the entire basin, as measured at the lowermost gaging station, Sabine River near Ruliff, averaged 13.0 inches annually for the period 1925–62. Annual runoff at the Ruliff station, expressed as mean discharge in cubic feet per second and as inches per year, is shown for the period of record in a graph on figure 2.

Precipitation and runoff in the Sabine River basin are subject to much greater variations than are indicated by the annual and monthly averages. The yearly mean discharge of the Sabine River near Ruliff has ranged from 1,760 to 17,210 cfs (fig. 2), but instantaneous flows have varied much more widely, from a low of 270 cfs to a high of 121,000 cfs. Similarly, normal monthly rainfall at Longview ranges from 2.56 inches for August to 5.72 inches for May (see fig. 2), but in 1962 the monthly totals ranged from only 0.30 inch in August to 6.28 inches in April. Thus, in spite of relatively high averages, precipitation so unevenly distributed in time does not sustain streamflow, and storage projects are required to make surface water available in dependable quantities for municipal or industrial use.

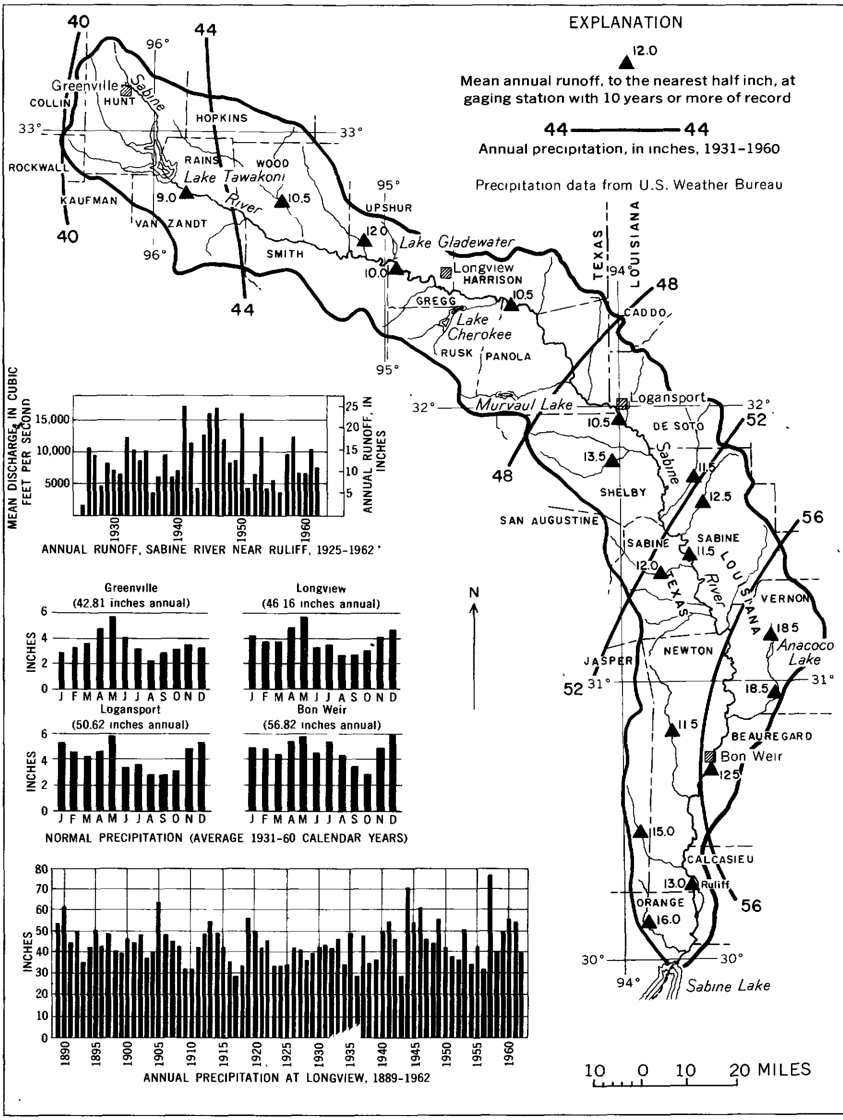

FIGURE 2.—Map of the Sabine River basin showing precipitation and runoff.

AGRICULTURAL AND INDUSTRIAL DEVELOPMENT

The economy of the Sabine River basin is based on agriculture, lumbering, and oil production. General diversified farming is practiced, but dairy farming and the raising of beef cattle and poultry are becoming increasingly important. The central and southern parts of the basin are in the great tree-producing section of Texas, and southern yellow-pine and hardwood lumber is produced in large quantities. The production of oil and gas (fig. 3) has been of utmost importance to the economy of the basin, beginning in 1930. In addition to oil-field maintenance and production-equipment businesses, steel mills, manufacturing plants, fertilizer plants, feed and flour mills, and textile factories help form a broad economic base.

At Grand Saline, Van Zandt County, salt is mined from a salt dome by conventional shaft-and-tunnel methods. Large deposits of clay, lignite, and iron are found in the northern and north-central part of the basin, but these minerals have not been extensively developed.

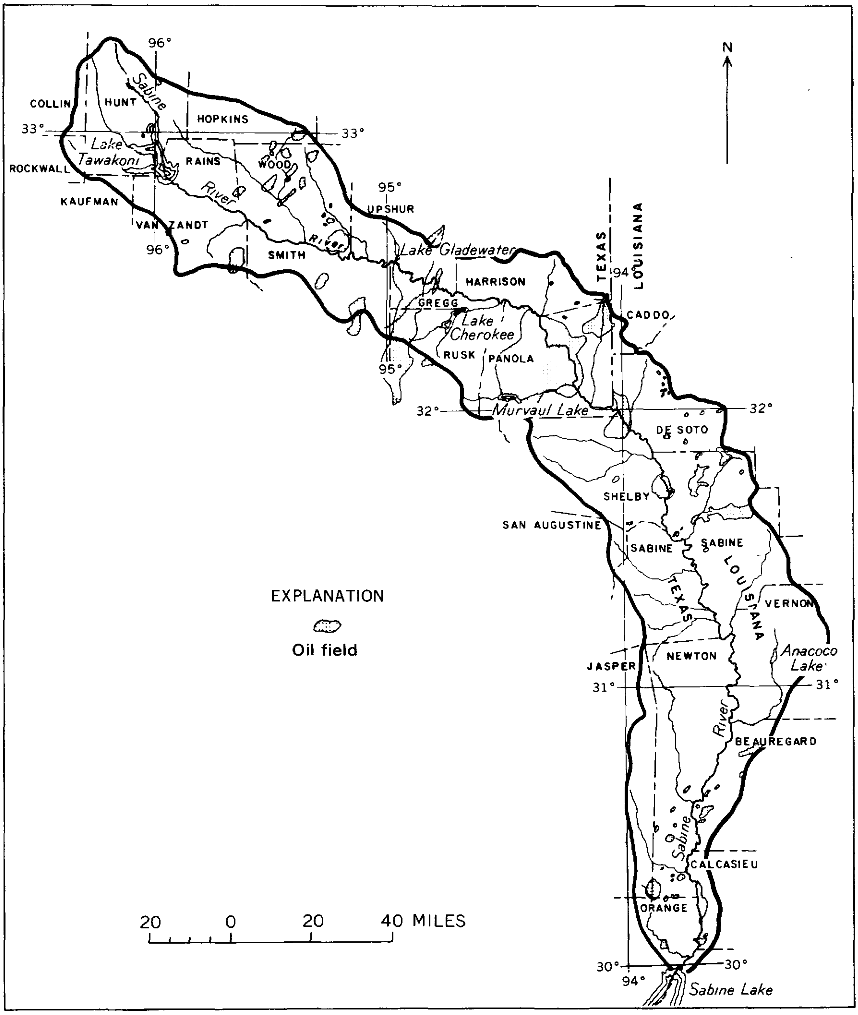

FIGURE 3.—Generalized map of oil fields in the Sabine River basin.

SURFACE-WATER RESOURCES DEVELOPMENT

The average runoff in the Sabine River basin is about 13 inches per year, and the Texas part of the basin contributes about 13 percent of the total runoff for the State (fig. 4). As the basin has less than 3 percent of the State's total area and only 3.2 percent of the population, the quantity of surface water available for development is considerably above the average for the State. Much of the surface-water resource is undeveloped. Until recent years, water-development projects were comparatively small, built by cities and private businesses to provide water supplies for municipal and industrial use. Lake Gladewater, shown in figure 5, is typical of the small reservoirs in the basin. Table 2 lists the capacity, owner, location, and use of the principal reservoirs existing or under construction in January 1963.

Toledo Bend Reservoir, now under construction, is the largest water-development project planned in the basin. It is being built jointly by the States of Texas and Louisiana, and will supply water and hydroelectric power for both States. The dependable yield of Toledo Bend Reservoir is expected to exceed by a million acre-feet annually the estimated 1980 needs of the southern part of the basin.

TABLE 2.—*Reservoirs in the Sabine River basin in Texas completed or under construction as of Jan. 1, 1963, having a capacity of 5,000 acre-feet or more*

[The purpose for which the impounded waters are used is indicated by the following symbols: F, flood control; I, irrigation; M, municipal; P, hydroelectric power; R, recreation; W, industrial]

Name of reservoir	Date completed	Stream	Capacity (ac-ft)	Owner	County	Use
Lake Tawakoni	1960	Sabine River	936,200	Sabine River Authority.	Hunt, Rains, Van Zandt.	MW
Lake Holbrook	1962	Keys Creek	7,990	Wood County	Wood	FR
Lake Hawkins	1962	Little Sandy Creek.	10,340	do	do	FR
Lake Quitman	1962	Dry Creek	7,440	do	do	FR
Lake Winnsboro	1962	Big Sandy Creek	6,580	do	do	FR
Lake Gladewater	1951	Glade Creek	6,950	City of Gladewater.	Upshur	M
Lake Cherokee	1948	Cherokee Bayou	46,700	Cherokee Water Co.	Gregg, Rusk	MR
Murvaul Lake	1957	Murvaul Bayou	45,840	Panola County Fresh Water-Supply District 1.	Panola	MR
Toledo Bend Reservoir.	(1)	Sabine River	(2) 4,661,000	Sabine River Authorities, Texas and Louisiana.	Newton	IMPW

[1] Under construction.
[2] Texas' share of storage capacity is 2,330,500 acre-feet.

Additional reservoirs planned for construction in the Sabine River basin are listed in table 3, and the locations are shown in figure 6.

In 1959, 74,770 acre-feet of water was used for municipal, industrial, and irrigation purposes in the Texas part of the Sabine River basin. Of this total, 42,060 acre-feet was derived from surface-water sources.

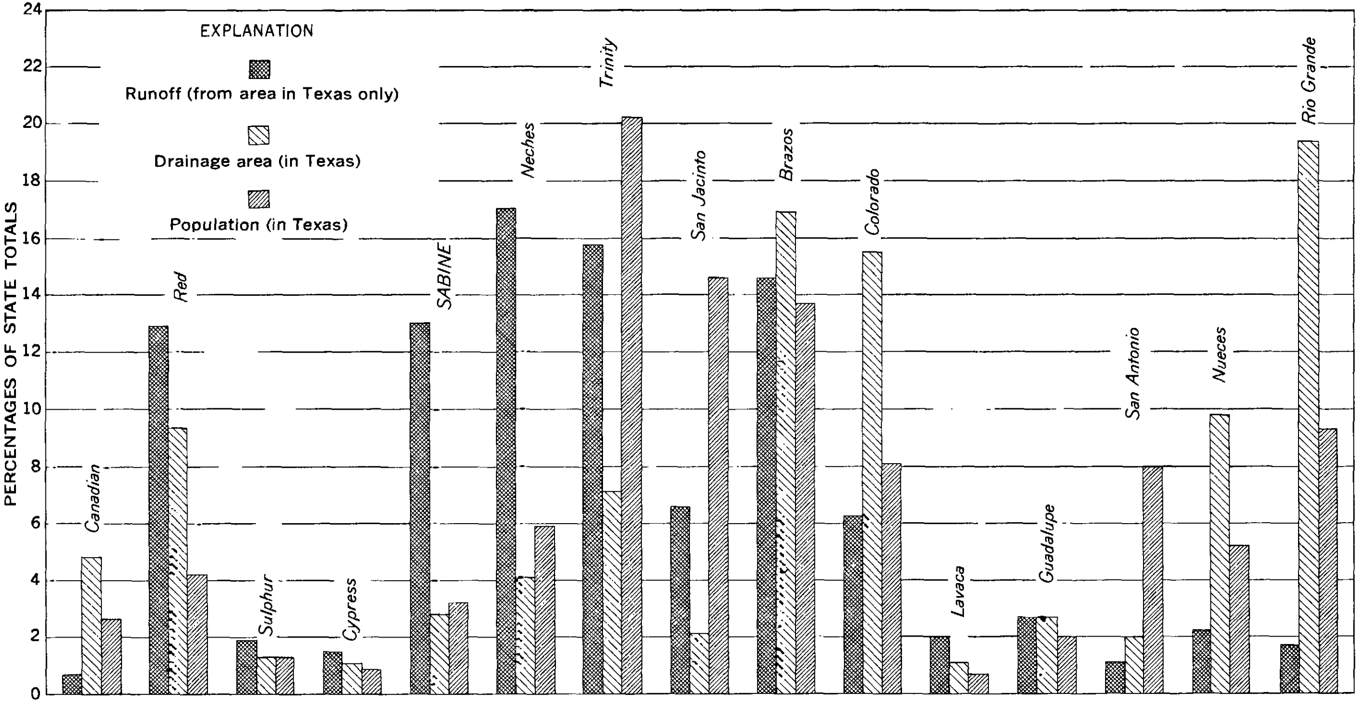

FIGURE 4.—Graph showing average annual runoff, drainage area, and 1960 population of major river basins in Texas, as percentages of State totals.

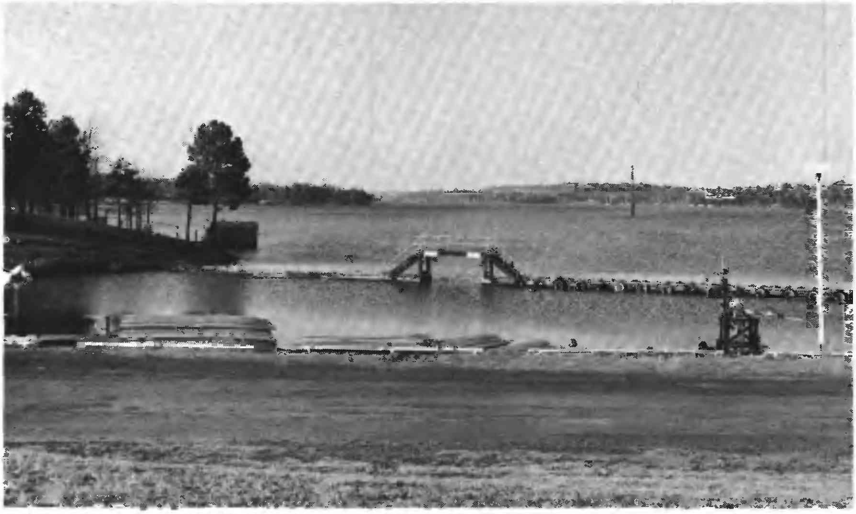

FIGURE 5.—View of Lake Gladewater, Upshur County, Tex.

The 1980 municipal and industrial requirements are estimated by the Texas Water Commission (Texas Board of Water Engineers, 1961) to be 307,900 acre-feet, of which 298,000 acre-feet would be supplied from surface-water sources.

Optimum development and use of the water resources of Texas may require the diversion of excess water from the Sabine River basin to areas of water deficiency. The U.S. Bureau of Reclamation (1953) has a plan for the distribution of excess supplies by an aqueduct which would generally parallel the gulf coast. The aqueduct would be a part of an integrated system of interbasin water exchange aimed at development of the full economic potential of water-deficient areas to the southwest along the Texas gulf coast.

STREAMFLOW RECORDS

Streamflow records in the Sabine River basin date from 1903, when the U.S. Weather Bureau installed a chain gage on the Sabine River at Logansport. The U.S. Geological Survey established a gaging station at Longview in 1904 and at Logansport in 1905. The two stations were operated through 1906 and reestablished in 1923. For the period 1903–05 and 1907–23 monthly records of discharge based on gage-height records obtained by the U.S. Weather Bureau are available for Sabine River at Logansport. More than 20 years of continuous discharge records are available for several stations on the main stem of the Sabine River, and records for more than 10 years are

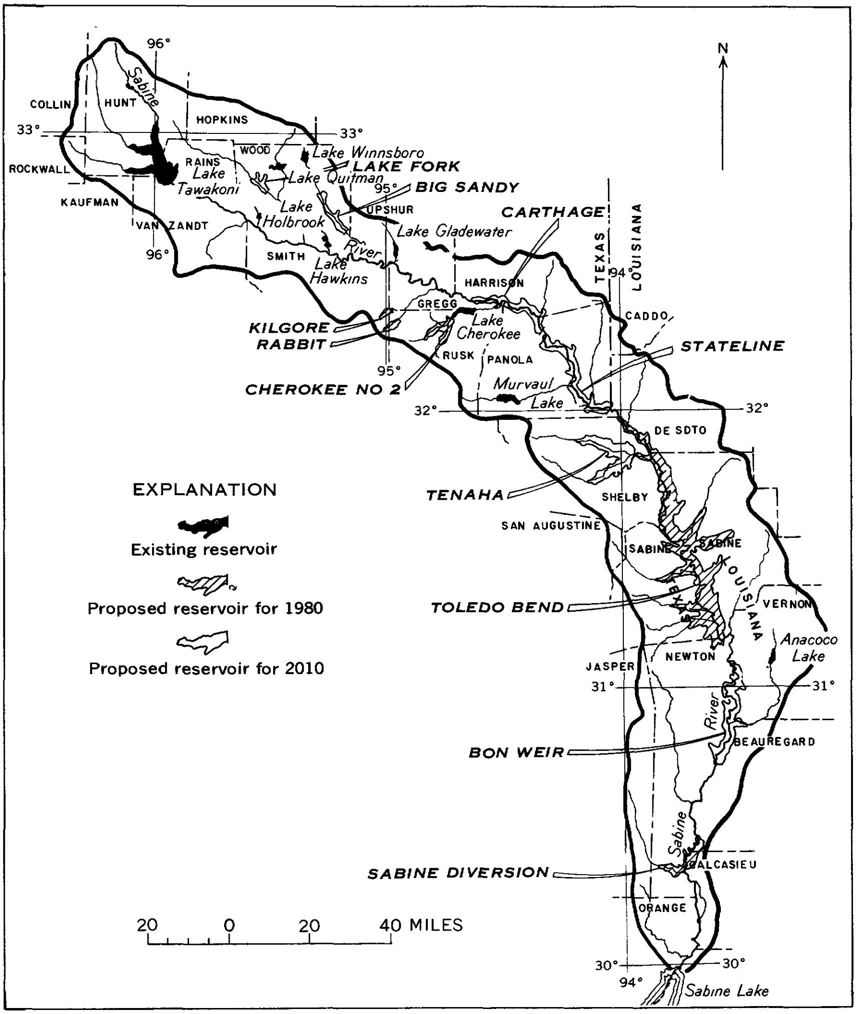

FIGURE 6.—Map of the Sabine River basin showing principal existing and proposed reservoirs.

available for many of the principal tributaries. In 1962 the Geological Survey in Texas operated 9 streamflow stations on the Sabine River and 10 stations on tributaries, 3 reservoir-content stations, and 26 low-flow partial-record stations. In addition, discharge measurements were made at other sites where samples were collected for chemical analysis.

In Louisiana, 12 streamflow stations and many low-flow and crest-stage partial-record stations are operated.

TABLE 3.—*Reservoirs proposed for construction in the Sabine River basin, Texas*

Reservoir	Stream	Capacity (acre-feet)	County
To meet 1980 requirements			
Kilgore	Wilds Creek	16, 270	Rusk
Cherokee 2	Cherokee Bayou	112, 320	Do.
Toledo Bend [1]	Sabine River	4, 661, 000	Newton
Sabine Diversion	do	35, 000	Do.
To meet 2010 requirements			
Lake Fork	Lake Fork Creek	526, 000	Wood
Big Sandy	Big Sandy Creek	174, 000	Do.
Rabbit	Rabbit Creek	18, 000	Rusk
Carthage	Sabine River	652, 000	Panola
Stateline	do	268, 000	Do.
Tenaha	Tenaha Bayou	900, 000	Shelby
Bon Weir	Sabine River	354, 000	Newton

[1] Under construction, 1963.

The periods of record for all the streamflow stations in Texas and Louisiana are given in table 4, and the locations are shown on plate 1. Records of discharge and stage of streams and contents and stage of lakes or reservoirs from 1903 to 1907 and from 1924 to 1960 have been published in the annual series of U.S. Geological Survey water-supply papers. (See list of references.) Beginning with the 1961 water year, streamflow records have been released by the Geological Survey in annual reports on a State-boundary basis (U.S. Geol. Survey, 1961a, b; 1962a, b). Summaries of discharge records giving monthly and annual totals have been published (U.S. Geol. Survey, 1939, 1960; Texas Board Water Engineers, 1958).

CHEMICAL-QUALITY RECORDS

The U.S. Geological Survey began the collection of chemical-quality data on surface waters of the Sabine River basin in 1939 when a sampling station was established on the Sabine River at Logansport. Data, obtained for intermittent periods until August 1945, consisted of chemical analyses of the filtrate from samples collected by the Soil Conservation Service for the determination of suspended matter. Usually only specific conductance and chloride determinations were made on these filtered samples.

A daily sampling station was established near Ruliff in October 1945, was discontinued in September 1946, and reestablished in October 1947. The station near Ruliff, and one on the Sabine River near Tatum, established in February 1952, are still in operation. Daily sampling stations were also operated on the Sabine River near Emory from July 1952 to September 1954 and on Cow Bayou near Mauriceville from March 1952 to December 1955. The chemical-quality data for the daily stations are summarized in table 5, and the complete records are published in an annual series of U.S. Geological Survey water-supply papers and in bulletins of the Texas Water Commission. (See list of references.)

Collection of chemical-quality data for the Sabine River basin reconnaissance study began in 1961. Two to twelve samples were collected and analyzed from each of 17 tributary streams and 5 reservoirs. Most of the sampling sites were at gaging stations, and at other sites discharge measurements were usually made when samples were collected. Single samples were also collected during the study at many additional sites. Numerous miscellaneous samples have been collected by the Geological Survey in the Sabine River basin since 1940, and the results of the analyses of these samples have been included in this report. Analyses for all the periodic and miscellaneous samples collected from streams in the Texas part of the basin are given in table 6.

In Louisiana, water-quality data have been collected for the principal tributaries by the Geological Survey in cooperation with the Louisiana Department of Public Works. The analyses of streams in Louisiana are given in table 7.

The location of all the sampling sites for which analyses are given are shown on plate 1.

Table 4—*Index of surface-water*

[Discharge \\\\\\\\ Gage heights only |||||||||||| Gage heights and discharge measurements
Daily chemical quality ▬ Periodic chemi-

Reference No.	Stream and location	Drainage area (sq mi)	Calendar 1901–10	1911–20
1	Greenville Reservoir at Greenville, Tex	---------		
2	Sabine River at Greenville	77.7		
3	Sabine River near Lone Oak	---------		
4	South Fork Sabine River near Quinlan	78.7		
5	Lake Tawakoni near Wills Point	756		
6	Sabine River near Emory	888		
7	Mill Creek near Edgewood	---------		
8	Grand Saline Creek at FM Road 857 near Grand Saline	---------		
9	Salt Flat at Grand Saline	---------		
10	Grand Saline Creek at U.S. Highway 80 near Grand Saline	---------		
11	Sabine River near Golden	1,123		
12	Sabine River near Mineola	1,357		
13	Duck Creek near Lindale	---------		
14	Lake Fork Creek near Point	---------		
15	Caney Creek near Quitman	---------		
16	Lake Fork Creek near Alba	---------		
17	Dry Creek at FM Road 69 near Quitman	---------		
18	Unnamed creek at Myrtle Springs	---------		
19	Dry Creek near Quitman	---------		
20	Lake Fork Creek near Quitman	585		
21	Big Sandy Creek near Big Sandy	231		
22	Sabine River near Gladewater	2,791		
23	Lake Gladewater near Gladewater	---------		

records in the Sabine River basin

Reservoir contents Periodic discharge measurements
cal quality Water temperature]

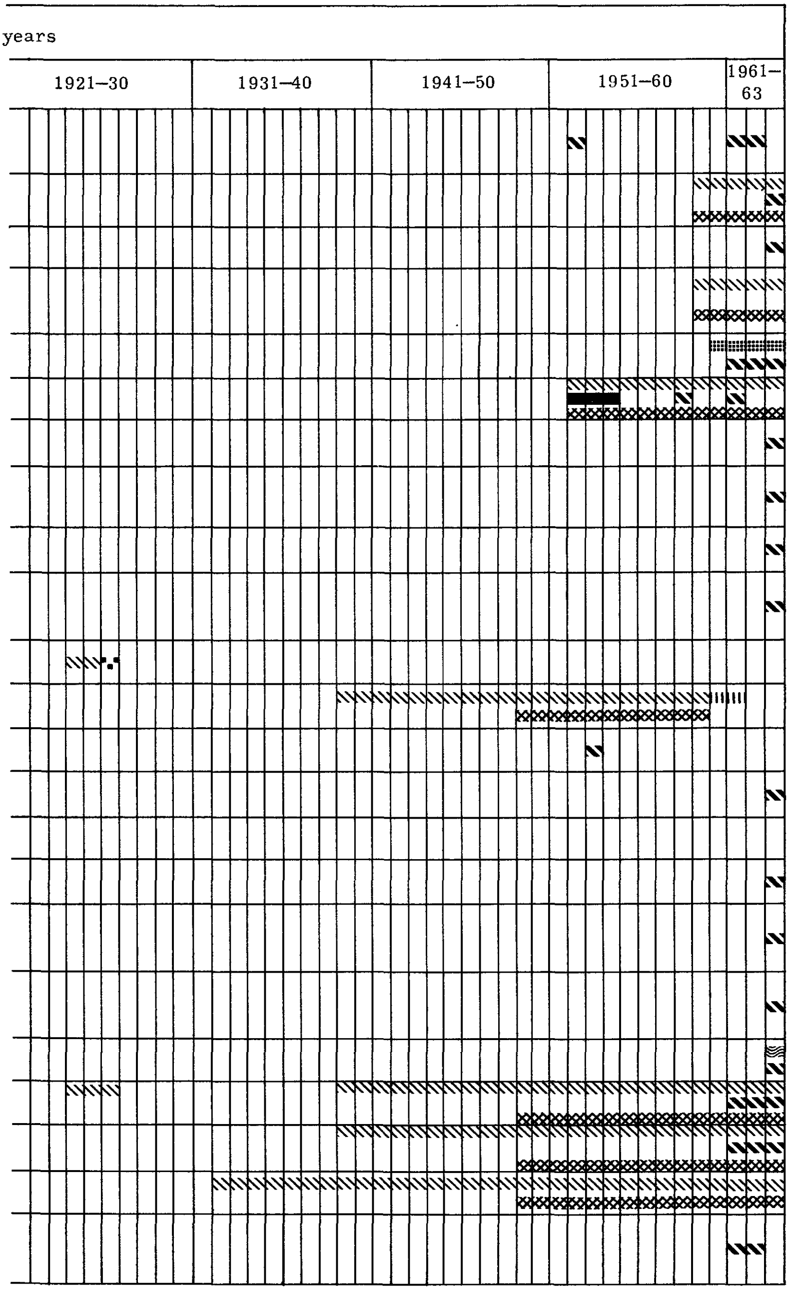

Table 4.—*Index of surface-water records*

Reference No.	Stream and location	Drainage area (sq mi)	Calendar																			
			1901–10										1911–20									
24	Sabine River near Longview, Tex	2,947				▨	▨	▨														
25	Wilds Creek near Laird Hill	--------																				
26	Cherokee Bayou near Oak Hill	--------																				
27	Cherokee Bayou near Elderville	120																				
28	Lake Cherokee near Longview	158																				
29	Cherokee Bayou near Longview	--------																				
30	Cherokee Bayou near Tatum	--------																				
31	Sabine River near Tatum	3,493																				
32	Potters Creek near Marshall	50.5																				
33	Eight Mile Creek near Tatum	106																				
34	Martin Creek near Beckville	192																				
35	Irons Bayou near Carthage	104																				
36	Six Mile Creek near Carthage	33.9																				
37	Murvaul Lake near Gary	115																				
38	Murvaul Bayou near Gary	134																				
39	Murvaul Bayou near Carthage	231																				
40	Socagee Creek near Carthage	82.6																				
41	Socagee Creek near Deadwood	201																				
42	Sabine River at Logansport, La	39			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
43	Bayou Castor near Longstreet	27.7																				
44	Bushneck Bayou at Longstreet	26.9																				
45	Bayou Castor near Logansport	96.5																				
46	Bayou Grand Cane near Logansport	76.5																				
47	Clarke Branch tributary at Stanley	--------																				
48	Clement Creek near Hunter	44.6																				
49	Flat Fork Creek near Center, Tex	--------																				
50	Tenaha Creek near Shelbyville	97.8																				

in the Sabine River basin—Continued

years

1921–30	1931–40	1941–50	1951–60	1961–63

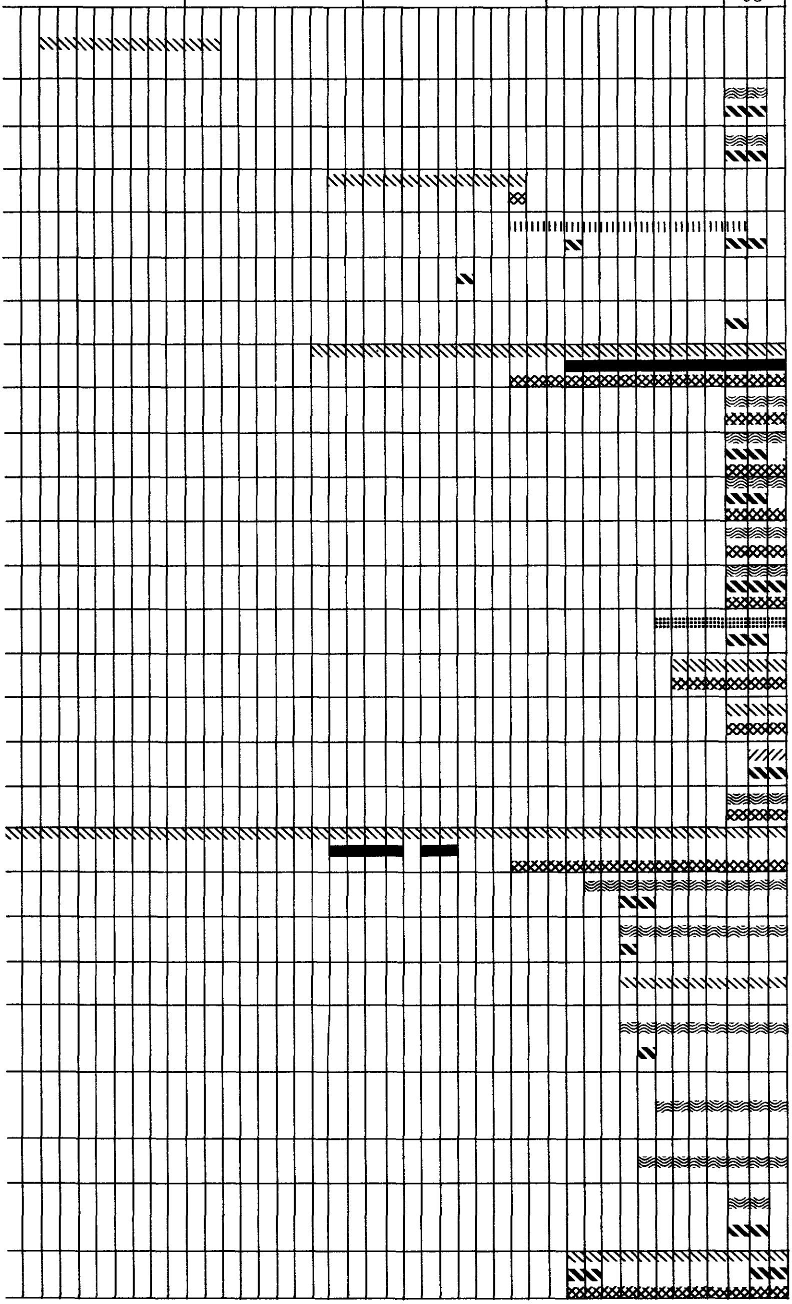

Table 4.—*Index of surface-water records*

Reference No.	Stream and location	Drainage area (sq mi)	Calendar 1901–10	1911–20
51	Tenaha Creek near mouth near Shelbyville, Tex	371		
52	Cow Bayou near Hunter, La	29.2		
53	Bayou Siep near Patroon, Tex	56.0		
54	Chatman Bayou tributary near Mansfield, La	--------		
55	Bayou San Patricio near Benson	80.2		
56	Bayou San Patricio near Noble	154		
57	Bayou San Miguel near Mitchell	29.3		
58	Little Bayou San Miguel near Mitchell	33.4		
59	Bayou San Miguel near Zwolle	111		
60	Bayou Scie at Zwolle	45.9		
61	Harpoon Bayou at Many	22.7		
62	Blackwell Creek at Many	3.16		
63	Lewis Creek near Many	12.5		
64	Edmonson Creek tributary near Many	--------		
65	Hurricane Creek tributary at Loring Lake near Zwolle	1.0		
66	Bayou La Nana near Zwolle	130		
67	Patroon Bayou near Milam, Tex	130		
68	Sabine River near Milam	6,508		
69	Palo Gaucho Bayou near Hemphill	123		
70	Palo Gaucho Bayou near Sabinetown	176		
71	Palo Gaucho Bayou near Milam	--------		
72	Bayou Negreet near Negreet, La	52.1		
73	Housen Bayou near Yellowpine, Tex	92.1		

in the Sabine River basin—Continued

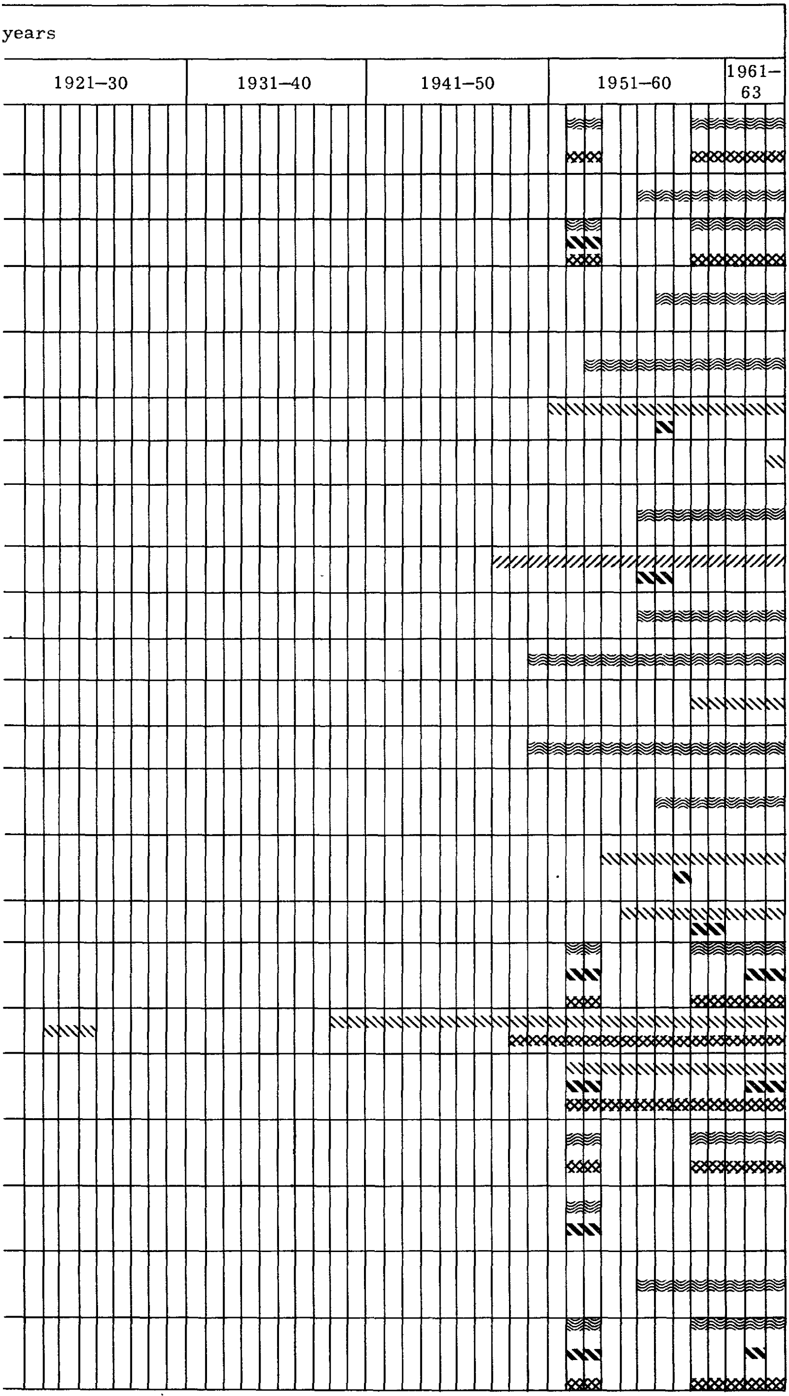

Table 4.—*Index of surface-water records*

Reference No.	Stream and location	Drainage area (sq mi)	Calendar 1901–10	1911–20
74	Sandy Creek near Yellowpine, Tex	135		
75	Mill Creek near Yellowpine	--------		
76	Buck Creek near Burkeville	--------		
77	Indian Creek near Burkeville	--------		
78	Bayou Toro near Florien, La	74.1		
79	Bayou Toro near Toro	144		
80	Bayou Toro south of Toro	187		
81	Sandy Creek near Burr Ferry	33.7		
82	Pearl Creek at Burr Ferry	18.0		
83	Sabine River below Toledo Bend near Burkeville, Tex	7,482		
84	Hickman Creek near Burkeville	--------		
85	Red Bank Creek at Evans, La	17.2		
86	Little Cow Creek above McGraw Creek near Burkeville, Tex	--------		
87	McGraw Creek near Burkeville	--------		
88	Little Cow Creek below McGraw Creek near Burkeville	112		
89	Little Cow Creek near mouth near Burkeville	128		
90	West Anacoco Creek near Hornbeck, La	26.9		
91	East Anacoco Creek near Anacoco	40.6		
92	Bayou Anacoco near Leesville	118		
93	Prairie Creek near Leesville	33.5		
94	Wyatt Creek tributary at Lewis and Killian Lake near Leesville	.2		
95	Anacoco Lake near Leesville	199		
96	Bayou Anacoco near Rosepine	355		
97	Bayou Anacoco near Knight	415		

in the Sabine River basin—Continued

years

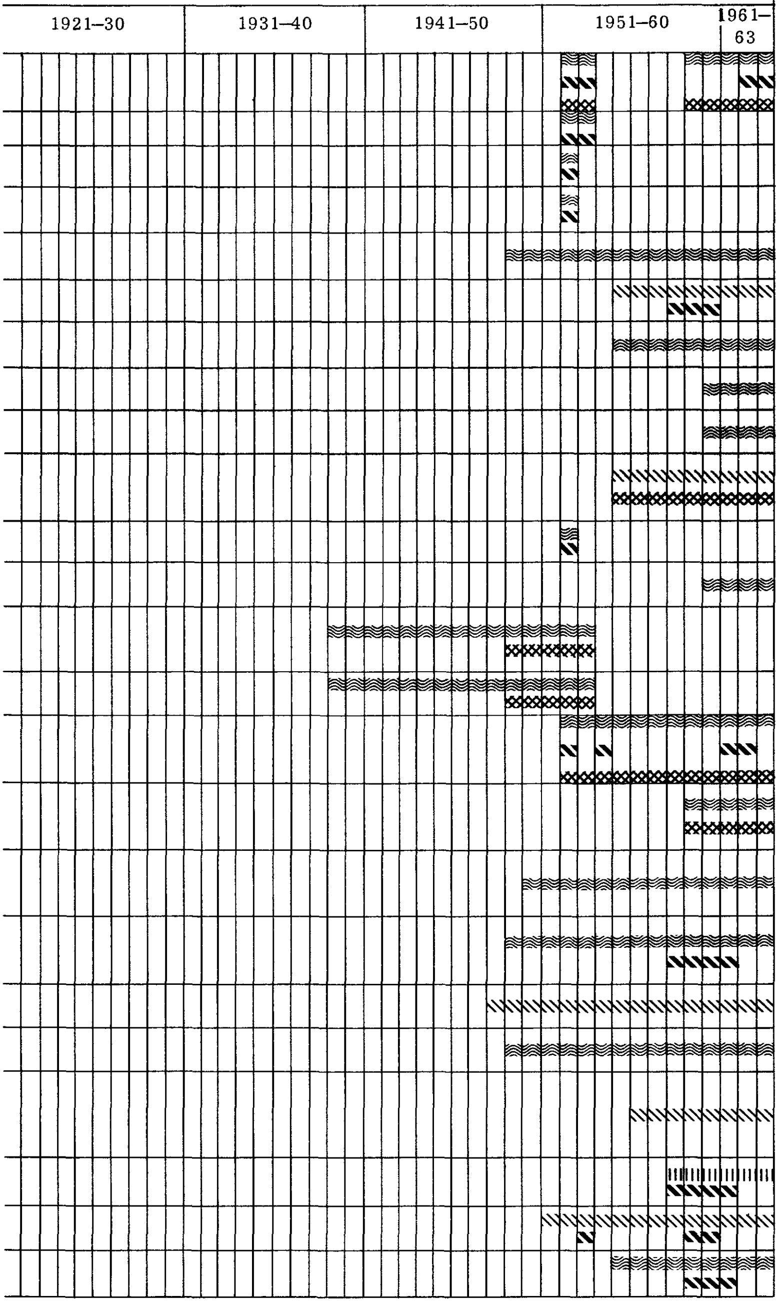

Table 4.—Index of surface-water records

Reference No.	Stream and location	Drainage area (sq mi)	Calendar 1901–10										1911–20									
98	Trout Creek near Merryville, La	16.9																				
99	Sabine River near Bon Weir, Tex	8,229													IIII	IIII	IIII	IIII	III	III	III	IIII
100	Quicksand Creek near Bon Weir	65.1																				
101	Caney Creek near Bon Weir	46.2																				
102	Davis Creek near Bon Weir	27.1																				
103	Dempsey Creek near Bon Weir	--------																				
104	Donahoe Creek near Bon Weir	--------																				
105	Hoosier Creek near Merryville, La	13.1																				
106	Cypress Creek near Bivens	15.4																				
107	Big Cow Creek at Farrsville, Tex	19.9																				
108	Hunters Creek near Farrsville	12.9																				
109	Melhomes Creek near Jasper	15.8																				
110	Bishop Creek near Jasper	3.0																				
111	Big Cow Creek at Dam Site near Newton	122																				
112	Big Cow Creek near Newton	128																				
113	Big Cow Creek near Bleakwood	--------																				
114	Big Cow Creek near Call	--------																				
115	Big Cow Creek near Belgrade	342																				
116	Brushy Creek at Bancroft, La	25.9																				
117	Trout Creek near Call, Tex	--------																				
118	Nichols Creek near Buna	54.4																				
119	Cypress Creek near Buna	69.2																				
120	Cypress Creek near Deweyville	146																				
121	Sabine River near Ruliff	9,329																				
122	Cow Bayou near Mauriceville	83.3																				

in the Sabine River basin—Continued

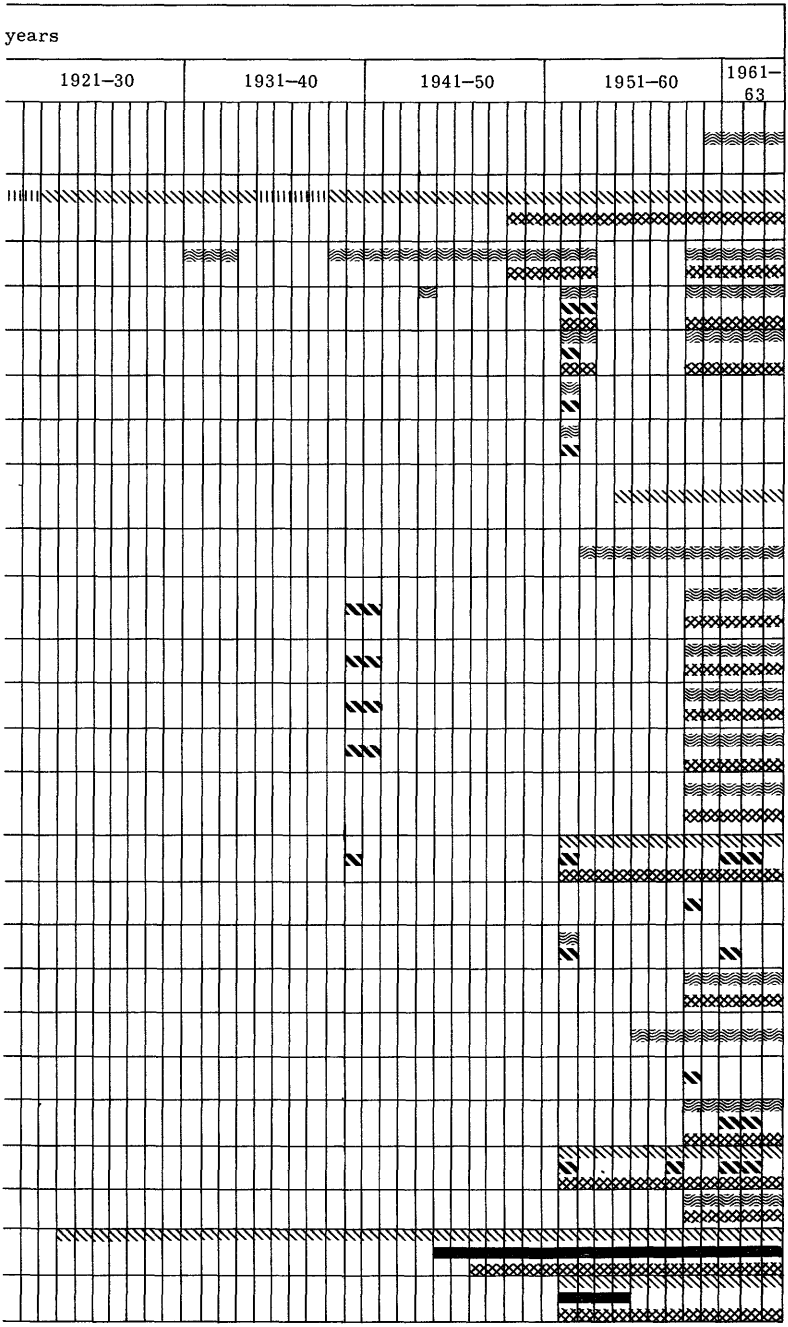

TABLE 5.—*Summary of chemical analyses at daily stations on streams in the Sabine River basin in Texas*

[Analyses listed as maximum and minimum were classified on the basis of the values for dissolved solids only; values of other constituents may not be extremes. Results in parts per million except as indicated]

Water year and date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	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	Sodium-adsorption-ratio	Specific conductance (micromhos at 25° C)	pH
6. Sabine River near Emory, Tex.																			
1953																			
Maximum, June 11–21, 1953	0.25	12	49	6.6	25		180	30	16	2.0	230	0.31	0.16	149	2	26	0.9	397	8.0
Minimum, Apr. 24, 29–30	13,340	5.0	6.6	1.3	4.4	2.9	28	6.9	4.0	1.5	47	.06	1,690	27	4	27	.4	70	6.9
Weighted average	575	8.9	17	2.6	9.7		63	11	5.1	2.5	88	.12	137	53	2	28	.6	145	------
1954																			
Maximum, July 2–7, 1954	.01	14	48	6.4	21		187	21	11	2.2	236	.32	.01	146	0	24	.8	373	7.8
Minimum, Jan. 11–12, 14–19	3,256	8.8	11	2.1	6.5	3.1	44	10	4.2	3.0	71	.10	624	36	0	26	.5	114	7.7
Weighted average	248	11	21	2.8	14		78	15	7.5	3.6	134	.18	89.7	64	0	32	.8	191	------
31. Sabine River near Tatum, Tex.																			
1952																			
Maximum, July 14–17, 19, 21–26, 1952	173	18	22	8.0	147		59	22	238	1.5	532	0.72	248	88	40	78	6.8	942	6.7
Minimum, May 1–6, 8, 27–29	9,575	12	9.6	3.6	21		30	18	27	2.4	115	.16	2,970	39	14	54	1.4	175	6.4
Weighted average	2,134	14	13	4.8	34		31	24	51	2.1	169	.23	974	52	27	59	2.0	277	------
1953																			
Maximum, July 5–6, 8–9, 1953	152	23	22	8.7	186		37	22	312	1.8	667	.91	274	91	60	82	8.5	1,160	7.3
Minimum, May 10–20	16,550	7.8	10	3.3	13		34	11	18	1.5	82	.11	3,660	38	11	42	.9	148	7.1
Weighted average	2,420	11	12	4.2	31		31	19	48	1.6	157	.21	1,030	48	22	59	2.0	260	------
1954																			
Maximum, Dec. 7–10, 13, 1953	1,956	18	20	4.9	207		18	38	330	.8	682	.93	3,600	70	56	87	11	1,200	6.6
Minimum, Jan. 22–31, 1954	4,639	17	11	3.2	28		26	21	40	1.5	178	.24	2,230	41	19	60	1.9	225	7.2

Weighted average	1,004	19	15	4.6	55	32	27	85	1.9	252	.34	683	56	30	68	3.2	398	------
1955																		
Maximum, Oct. 16–25, 1954	80.0	7.8	24	8.4	262	69	20	415	1.0	823	1.12	178	94	38	86	12	1,510	7.8
Minimum, Oct. 31, Nov. 1–8, 12–15	3,200	11	13	2.1	25	37	15	33	2.0	119	.16	1,030	40	10	57	1.7	211	7.2
Weighted average	1,291	14	14	4.1	51	29	26	79	1.6	226	.31	788	52	28	68	3.1	370	------
1956																		
Maximum, Aug. 21–31, 1956	14.2	8.8	26	10	315	120	19	475	1.1	936	1.27	35.9	105	6	87	13	1,750	7.8
Minimum, May 1–7, 10–16	4,697	11	11	2.7	28	33	15	40	1.8	126	.17	1,600	39	12	61	2.0	230	7.2
Weighted average	516	14	13	4.4	60	30	23	95	1.4	229	.31	319	50	26	72	3.7	420	------
1957																		
Maximum, Oct. 21–31, 1956	32.5	4.4	24	9.0	273	148	26	385	.0	805	1.09	70.6	98	0	86	12	1,480	7.3
Minimum, Apr. 24–30, 1957	18,580	8.2	4.7	2.5	16	14	12	23	.8	74	.10	3,710	22	11	61	1.5	133	5.8
Weighted average	3,968	11	13	3.2	25	41	13	37	1.4	126	.17	1,350	46	12	54	1.6	226	------
1958																		
Maximum, Sept. 1–15, 1958	165	17	18	5.5	131	42	18	212	1.5	424	.58	189	68	33	81	6.9	815	7.4
Minimum, May 1–13	38,130	7.8	9.0	1.9	16	30	12	19	.8	82	.11	8,440	30	6	53	1.3	139	6.5
Weighted average	4,291	10	12	3.1	30	31	19	43	.8	134	.18	1,550	43	17	60	2.0	241	------
1959																		
Maximum, Oct. 20, 1958	472	--------	-------	-------	------------	39	------	485	--------	883	1.20	1,130	121	89	------	--------	1,680	7.4
Minimum, May 1–6, 1959	14,200	8.0	9.0	2.5	19	23	14	28	1.0	92	.13	3,530	33	14	56	1.4	172	7.0
Weighted average	1,683	13	13	4.1	46	25	24	73	1.0	188	.26	854	49	29	67	2.9	343	------
1960																		
Maximum, Aug. 17, 19–21, 1960	124	17	23	7.0	159	67	20	251	2.8	513	.70	172	86	32	80	7.5	957	7.2
Minimum, Oct. 12–21, 1959	4,298	14	10	2.9	17	46	10	18	1.2	96	.13	1,110	37	0	51	1.2	160	6.8
Weighted average	2,527	13	13	4.1	39	32	25	57	.7	170	.23	1,160	49	23	63	2.4	303	------
1961																		
Maximum, Oct. 21–31, 1960	441	15	16	5.8	87	40	19	142	.8	334	.45	398	64	31	75	4.7	585	6.6
Minimum, Dec. 8–25	14,200	7.4	6.5	2.5	20	12	13	32	.8	88	.12	3,370	26	17	62	1.7	163	5.6
Weighted average	3,104	11	10	4.0	34	19	23	53	.6	146	.20	1,220	41	26	64	2.3	266	------
1962																		
Maximum, July 16–26, 1962	168	16	16	6.7	120	46	24	188	1.2	395	.54	179	68	30	79	6.3	735	6.3
Minimum, Nov. 23, 1961	4,970	--------	-------	-------	------------	12	8.4	18	--------	65	.09	872	15	5	------	--------	104	6.4
Weighted average	1,802	14	11	4.9	41	19	28	66	.8	177	.24	861	48	32	65	2.6	320	------

TABLE 5.—*Summary of chemical analyses at daily stations on streams in the Sabine River basin in Texas*—Continued

Water year and date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	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	Sodium-adsorption-ratio	Specific conductance (micromhos at 25° C)	pH
121. Sabine River near Ruliff, Tex.																			
1948																			
Maximum, Oct. 1, 7–10, 1947	1,104	--------	13	5.4	106		44	16	164	0.8	364	0.50	1,090	54	2	81	6.3	647	------
Minimum, Feb. 11–20, 1948	22,910	12	6.9	2.9	17		15	19	24	.5	100	.14	6,190	29	17	56	1.4	141	------
Weighted average	8,193	--------	8.0	3.7	23		24	17	34	.2	139	.19	3,070	35	16	59	1.7	191	------
1949																			
Maximum, Dec. 26–27, 1948	2,620	18	14	2.0	122		20	32	183	.5	411	.56	2,910	43	27	86	8.1	695	------
Minimum, Nov. 21–25, 29–30, Dec. 1	11,380	6.2	3.4	1.4	15		9	7.1	22	.2	67	.09	2,060	14	7	69	1.7	102	------
Weighted average	8,636	11	6.0	3.1	18		21	12	27	.9	113	.15	2,630	28	10	59	1.5	147	------
1950																			
Maximum, Oct. 2, 12, 21–24, 1949	7,687	13	8.8	3.2	52		36	16	72	1.2	184	.25	3,820	35	6	76	3.8	311	7.6
Minimum, June 5–11, 1950	74,760	4.7	2.6	1.5	5.8		10	7	5.2	3.0	35	.05	7,060	13	4	50	.1	48	6.5
Weighted average	15,940	12	6.0	2.9	15		19	11	21	1.4	89	.12	3,830	27	11	55	1.3	117	------
1951																			
Maximum, May 21–31, 1951	2,924	18	14	5.5	48		41	29	68	1.5	204	.28	1,610	58	24	64	2.7	360	7.4
Minimum, Jan. 4–10	13,030	7.5	2.5	2.2	12		10	9.0	17	.8	56	.08	1,970	15	7	64	1.3	94	6.7
Weighted average	4,374	14	8.4	3.8	29		26	19	40	1.1	133	.18	1,570	37	15	64	2.1	216	------
1952																			
Maximum, Nov. 1–15, 21–25, 1951	980	16	12	4.4	75		43	15	114	.5	258	.35	683	48	13	77	4.8	472	6.8
Minimum, Apr. 22–30, 1952	34,780	6.4	3.1	1.9	10		10	11	12	1.8	59	.08	5,540	16	7	59	1.1	82	6.2
Weighted average	6,415	12	6.9	3.2	23		21	16	32	1.8	112	.15	1,940	30	13	62	1.8	178	------
1953																			
Maximum, Feb. 3–5, 1953	5,427	15	------	------	55		15	36	85	1.2	232	.32	3,400	52	40	70	3.3	396	6.7
Minimum, Mar. 1–2, 14–26	25,660	7.8	3.1	1.4	8.3	2.2	10	10	11	1.0	50	.07	3,460	14	6	51	1.0	82	6.5
Weighted average	12,340	8.7	5.3	2.1	13		18	9.5	18	1.3	81	.11	2,700	22	7	57	1.2	119	------

1954																	
Maximum, Dec. 16–22, 1953	4,977	14	13	4.9	86	18	25	141	1.0	326	.44	4,380	52	38	78	5.2	543	6.6
Minimum, May 4–10, 15, 1954	20,380	9.6	3.8	1.7	11	12	6.4	16	2.5	57	.08	3,140	16	6	60	1.2	84	6.4
Weighted average	4,097	14	8.3	2.9	26	22	14	38	1.6	121	.16	1,340	32	14	63	2.0	202	------
1955																	
Maximum, Dec. 21–22, 1954	2,940	19	19	4.0	80	32	30	128	1.0	318	.43	2,520	65	39	73	4.3	534	7.4
Minimum, Aug. 5–13, 1955	22,280	6.2	3.2	.7	5.7 2.0	10	3.2	10	1.0	37	.05	2,230	11	3	48	.8	57	6.5
Weighted average	5,574	11	6.9	2.3	22	19	13	32	1.4	104	.14	1,570	26	11	64	1.9	174	------
1956																	
Maximum, July 11–20, 1956	607	22	11	3.6	50	51	8.3	70	1.0	193	.26	316	42	0	72	3.3	332	7.3
Minimum, Feb. 6–16	19,400	8.8	4.0	1.4	14	8	9.9	20	.5	63	.09	3,300	16	10	65	1.5	110	6.3
Weighted average	3,421	13	6.8	2.4	23	21	12	33	.9	103	.14	951	27	10	65	1.9	176	------
1957																	
Maximum, Dec. 1–12, 1956	561	15	10	4.0	76	56	12	105	.5	250	.34	379	42	0	80	5.1	472	7.6
Minimum, Dec. 22–26, 28	10,520	7.8	3.2	1.0	10	11	6.8	13	.2	47	.06	1,330	12	3	65	1.3	72	6.3
Weighted average	9,645	11	8.0	2.5	17	27	10	24	1.2	88	.12	2,280	30	8	55	1.3	151	------
1958																	
Maximum, Oct. 7–15, 1957	2,108	13	12	2.7	74	40	14	109	.5	261	.35	1,490	41	8	80	5.0	457	7.4
Minimum, Sept. 23–26, 28–30, 1958.	34,700	4.6	2.2	.8	5.3 2.0	10	3.4	7.5	.8	32	.04	3,000	9	1	50	.8	52	6.8
Weighted average	12,290	9.7	7.2	2.1	18	21	13	24	.7	85	.12	2,820	26	10	60	1.5	146	------
1959																	
Maximum, Sept. 9, 16–24, 1959	1,271	15	14	4.9	55	56	12	82	.8	212	.29	728	55	9	68	3.2	377	7.0
Minimum, Jan. 31	9,730	5.8	7.4	1.1	4.4	6	5.8	15	.5	43	.06	1,130	23	18	29	.4	76	6.7
Weighted average	6,723	12	7.6	2.7	24	21	15	35	.7	109	.15	1,980	30	13	63	1.9	192	------
1960																	
Maximum, May 13–24, 1960	2,838	13	15	5.8	50	44	32	71	1.0	217	.30	1,660	62	26	64	2.8	380	6.3
Minimum, Dec. 16–31, 1959	12,860	7.8	7.5	2.1	14	23	9.0	20	.8	72	.10	2,500	27	8	53	1.2	126	6.9
Weighted average	6,545	11	9.0	3.3	25	23	19	36	1.3	117	.16	2,070	36	17	60	1.8	202	------
1961																	
Maximum, Oct. 2–3, 5, 1960	2,540	12	10	3.9	63	35	16	94	.2	216	.29	1,480	41	12	77	4.3	402	6.8
Minimum, Sept. 15–18, 1961	23,850	8.1	3.0	.5	6.4 1.9	12	3.8	9.0	.8	40	.05	2,580	10	0	54	.9	59	5.5
Weighted average	12,410	16	6.3	2.4	18	21	12	24	.6	90	.12	3,020	26	8	60	1.5	144	------
1962																	
Maximum, July 11–16, 1962	2,228	14	14	5.9	63	34	23	103	.2	261	.35	1,570	60	32	70	3.5	422	6.1
Minimum, Dec. 11–23, 1961	25,040	11	3.5	1.2	9.4	8	8.0	13	.5	51	.07	3,450	14	7	60	1.1	75	5.7
Weighted average	7,500	12	7.1	2.9	22	20	15	32	.9	103	.14	2,090	30	13	62	1.7	175	------

TABLE 5.—*Summary of chemical analyses at daily stations on streams in the Sabine River basin in Texas*—Continued

Water year and date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	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	Sodium-adsorption-ratio	Specific conductance (micromhos at 25° C)	pH
123. Cow Bayou near Mauriceville, Tex.																			
1952																			
Maximum, Sept. 21–30, 1952	0.01	27	36	20	173		109	23	308	0.8	692	0.94	0.02	172	82	69	5.7	1,210	7.9
Minimum, Apr. 23–30	1,541	3.5	1.8	1.3	3.6		7	5	4.2	1.0	23	.03	95.7	10	4	44	.5	28	6.0
Weighted average	112	5.0	2.2	1.7	6.2		7	6.4	8.4	1.1	37	.05	11.2	12	7	52	.8	46	------
1953																			
Maximum, July 29–31, 1953	2.63	8.3	43	17	325	5.3	8	5.4	620	1.0	1,030	1.40	7.31	178	171	79	11	2,110	6.4
Minimum, Dec. 4–5, 19–23, 30–31, 1952	27.7	4.6	1.8	1.1	4.0	------	8	4.7	6.0	1.0	27	.04	2.02	9	2	49	.6	46	6.5
Weighted average	78.6	4.8	2.6	1.3	10		8	3.5	15	1.3	43	.06	.91	12	5	65	1.3	78	------
1954																			
Maximum, Oct. 14–25, 1953	.09	30	36	18	163		108	21	288	1.0	639	.87	.16	164	76	68	5.5	1,120	7.5
Minimum, May 14–22, 25–29, 1954	181	5.4	2.0	.9	5.7		8	2.2	7.8	1.5	30	.04	14.7	9	2	59	.8	46	6.5
Weighted average	32.5	7.1	3.0	1.3	11		8	3.6	18	1.3	49	.07	4.3	13	6	65	1.3	83	------
1955																			
Maximum, Nov. 18–22, 1954	1.06	6.4	33	12	304		9	4.7	552	1.0	917	1.25	2.62	132	124	83	11	1,780	6.3
Minimum, Feb. 8–19, 1955	385	5.6	2.2	1.2	4.7	.7	7	3.6	8.0	.8	30	.04	31.2	10	5	47	.6	49	6.3
Weighted average	66.0	7.0	2.7	1.5	9.2		8	4.1	15	1.3	50	.07	8.91	13	6	61	1.1	76	------

TABLE 6.—*Chemical analyses of streams and reservoirs in the Sabine River basin in Texas*

[Results in parts per million except as indicated]

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (calculated): Parts per million	Dissolved solids (calculated): Tons per acre-foot	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25° C)	pH
1. Greenville Reservoir at Greenville																				
Mar. 25, 1952	------	2.4	0.01	38	6.5	21	0.8	142	32	13	0.3	0.0	[1]205	0.28	122	5	27	0.8	347	7.9
Nov. 28, 1961	------	3.9	------	38	3.7	19		138	19	12	.5	.0	[1]175	.24	110	0	27	.8	295	7.2
Feb. 5, 1962	------	2.9	------	35	3.7	18		128	21	9.6	.4	.0	154	.21	102	0	27	.8	285	7.1
2. Sabine River at Greenville																				
Feb. 27, 1963	0.8	------	------	------	------	------		180	------	49	------	------	------	------	160	12	------	------	508	7.1
3. Sabine River near Lone Oak																				
Feb. 26, 1963	[2]5	------	------	------	------	------		186	------	43	------	------	------	------	171	18	------	------	575	6.4
5. Lake Tawakoni near Wills Point																				
Dec. 5, 1961	------	2.9	------	29	3.7	11		108	12	6.0	0.3	0.2	118	0.16	88	0	21	0.5	220	7.0
Jan. 12, 1962	------	2.4	------	28	3.6	9.3	4.5	108	12	6.0	.3	.5	120	.16	85	0	18	.4	219	7.0
Jan. 17	------	2.1	------	28	4.1	12		106	12	9.0	.3	.0	120	.16	87	0	23	.6	218	7.0
Apr. 16	------	1.2	------	29	3.7	14		114	12	7.0	.3	.8	[1]134	.18	88	0	25	.6	229	7.2
July 12	------	.6	------	30	3.9	10		110	12	7.2	.3	.0	[1]128	.17	91	1	20	.5	224	7.1
6. Sabine River near Emory																				
Sept. 26, 1958	------	12	------	34	3.1	18		113	28	8.0	------	3.5	[1]176	0.24	98	5	28	0.8	271	7.8
Mar. 1, 1961	------	8.2	------	19	4.0	16		68	25	12	0.2	.2	118	.16	64	8	36	.9	210	6.7

[1] Residue on evaporation at 180° C.

[2] Field estimate.

TABLE 6.—*Chemical analyses of streams and reservoirs in the Sabine River basin in Texas*—Continued

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (calculated)		Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25° C)	pH
													Parts per million	Tons per acre-foot	Calcium, magnesium	Noncarbonate				
7. Mill Creek near Edgewood																				
Feb. 26, 1963	[2] 3	22	------	45	21	65		48	133	115	0.2	0.2	[1] 464	0.63	199	160	42	2.0	737	6.5
8. Grand Saline Creek at FM Road 857 Near Grand Saline																				
Feb. 26, 1963	----------	20	------	50	23	70		20	201	100	0.1	0.2	474	0.64	220	203	42	2.1	792	6.3
9. Salt Flat at Grand Saline																				
Feb. 26, 1963	[2] 0.1	9.2	------	315	51	25,500		99	1,100	39,200	------	--------	66,200	94.3	996	915	98	352	71,100	7.0
10. Grand Saline Creek at U.S. Highway 80 near Grand Saline																				
Feb. 26, 1963	[2] 7	--------	------	------	------	-------------		38	------	1,350	------	--------	--------	------	287	256	------	--------	4,630	6.2
Feb. 27	6.8	17	------	64	29	786		40	251	1,200	0.2	1.0	2,370	3.22	279	246	86	20	4,160	6.7
13. Duck Creek near Lindale																				
Apr. 2, 1953	----------	21	0.42	5.5	3.5	6.8	2.1	14	18	11	0.3	0.2	76	0.10	29	17	32	0.6	105	6.4

14. Lake Fork Creek near Point																			
Feb. 27, 1963	[2] 0.2	------	------	------	------	------	316	------	42	------	------	------	------	284	25	------	------	779	7.1
15. Caney Creek near Quitman																			
Feb. 26, 1963	[2] 5	17	------	39	19	92	52	102	160	0.2	0.0	[1] 475	0.65	176	133	53	3.0	823	6.8
16. Lake Fork Creek near Alba																			
Feb. 27, 1963	[2] 15	------	------	------	------	------	54	------	155	------	------	------	------	231	186	------	------	948	6.8
17. Dry Creek at FM Road 69 near Quitman																			
Feb. 26, 1963	[2] 3	27	------	25	8.8	96	0	71	175	0.2	0.2	413	0.56	98	98	65	4.2	766	[3] 3.8
18. Unnamed Creek at Myrtle Springs																			
Feb. 26, 1963	[2] 0.05	43	------	114	41	505	0	172	1,020	0.7	1.0	1,900	2.58	453	453	68	10	3,470	[4] 3.8
19. Dry Creek near Quitman																			
Feb. 26, 1963	3.8	31	------	82	29	340	0	158	650	0.4	0.5	1,290	1.75	324	324	68	8.2	2,350	[5] 4.3
20. Lake Fork Creek near Quitman																			
Dec. 5, 1961	43.2	20	------	31	13	101	20	78	179	0.2	0.0	[1] 471	0.64	131	114	63	3.8	787	6.1
Jan. 11, 1962	85	20	------	37	18	103	19	127	172	.2	.2	[1] 495	.67	166	151	57	3.5	842	6.1
Jan. 17	480	13	------	25	11	60	18	80	99	.2	.2	297	.40	108	93	55	2.5	534	6.0
Feb. 11	69.7	21	------	43	20	115	24	133	200	.2	.0	544	.74	190	170	57	3.6	952	6.3
Mar. 13	1,800	10	------	19	7.5	52	13	46	94	.2	.0	235	.32	78	68	59	2.6	442	6.2
Apr. 17	52.1	14	------	42	19	119	50	121	194	.3	.0	534	.73	183	142	59	3.8	950	7.4
May 22	16.8	14	------	32	14	84	63	74	135	.3	.1	384	.52	138	86	57	3.1	679	7.5
July 11	8.04	14	------	26	10	58	54	44	101	.2	.0	[1] 302	.41	106	62	55	2.4	527	6.0
Aug. 3	47.3	11	------	15	5.9	31	44	23	49	.3	.2	157	.21	62	26	53	1.7	283	6.1
Sept. 20	23.0	11	------	19	6.5	38	49	29	60	.2	.2	[1] 194	.26	74	34	52	1.9	336	6.8
Jan. 20, 1963	69.4	20	------	43	19	109	36	130	182	.2	.2	[1] 558	.76	186	156	56	3.5	881	6.6
Feb. 24	32.6	19	------	58	27	148	42	183	248	.2	1.5	[1] 745	1.01	256	221	56	4.0	1,210	6.5
Feb. 26	[2] 30	------	------	------	------	------	40	------	235	------	------	------	------	250	217	------	------	1,190	6.6

[1] Residue on evaporation at 180° C.
[2] Field estimate.
[3] Contains 1.4 ppm total acidity as H^{+1}.
[4] Contains 0.4 ppm total acidity as H^{+1}.
[5] Contains 0.3 ppm total acidity as H^{+1}.

TABLE 6.—*Chemical analyses of streams and reservoirs in the Sabine River basin in Texas*—Continued

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (calculated): Parts per million	Dissolved solids (calculated): Tons per acre-foot	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25° C)	pH
21. Big Sandy Creek near Big Sandy																				
Mar. 1, 1961	------	14	------	8.5	3.7	23		6	33	33	0.1	0.5	119	0.16	36	32	58	1.7	207	6.0
Dec. 4	131	16	------	9.0	4.3	31		7	27	52	.2	.2	143	.19	40	34	63	2.1	252	6.1
Jan. 11, 1962	194	18	------	12	5.4	35		5	45	54	.1	.2	172	.23	52	48	59	2.1	296	5.8
Jan. 17	200	18	------	10	5.2	43		4	35	70	.1	.2	184	.25	46	43	67	2.8	330	5.5
Feb. 10	142	17	------	10	5.3	36		5	35	59	.1	.0	164	.22	47	43	62	2.3	291	5.4
Mar. 13	458	12	------	8.0	3.7	30		7	26	47	.1	.0	130	.18	35	29	65	2.2	231	5.6
Apr. 17	114	15	------	9.5	4.6	34		18	27	51	.2	.1	[1]162	.22	43	28	63	2.3	250	6.9
July 11	36.0	15	------	6.2	2.8	21		15	8.4	36	.1	.2	97	.13	27	15	63	1.8	165	5.9
Aug. 3	40.8	16	------	5.0	2.4	18		14	8.8	28	.1	.1	85	.12	22	11	63	1.7	133	6.1
Sept. 20	29.0	15	------	6.2	2.6	19		8	16	30	.1	.8	94	.13	26	20	61	1.6	150	6.1
Jan. 19, 1963	83.5	17	------	8.5	3.9	26		5	24	46	.1	.2	128	.17	37	33	61	1.9	227	5.8
Feb. 23	71.6	------	------	------	------	------		6	------	52	------	------	------	------	36	31	------	------	237	5.7
23. Lake Gladewater near Gladewater																				
Dec. 4, 1961	------	16	------	4.8	2.4	12		14	7.4	20	0.1	0.2	70	0.10	22	10	54	1.1	113	6.0
Feb. 10, 1962	------	16	------	3.0	2.1	9.6	1.6	6	9.6	15	.1	.2	60	.08	16	11	53	1.0	93	5.5
25. Wilds Creek near Laird Hill																				
Dec. 3, 1961	7.2	30	------	5.0	3.0	6.8	1.8	20	12	8.5	0.1	0.2	77	0.10	25	8	35	0.6	94	6.1
Jan. 17, 1962	15.2	26	------	4.8	2.8	6.3	1.2	15	13	10	.1	.0	71	.10	24	11	35	.6	85	6.3
Feb. 10	9.75	28	------	4.8	2.5	6.4	1.5	16	11	7.2	.1	.2	70	.10	22	9	36	.6	82	6.0
Apr. 18	7.28	29	------	4.5	2.4	6.6	1.7	15	11	10	.1	.1	72	.10	21	9	38	.6	78	7.7

For Big Sandy Creek and for Lake Gladewater on Dec. 4, 1961, sodium and potassium are printed as one combined value under both columns; here that value sits in the Sodium column.

26. Cherokee Bayou near Oak Hill

Dec. 3, 1961	22.3	19	------	16	4.4	50		8	7.2	108	0.2	0.2	209	0.28	58	51	65	2.9	392	6.0
Jan. 17, 1962	57	17	------	10	3.7	30		7	13	60	.1	.2	137	.19	40	34	62	2.1	252	5.7
Feb. 9	38.6	17	------	14	3.7	38		7	8.8	83	.2	.2	168	.23	50	44	62	2.3	315	5.9
Apr. 18	24.4	17	------	17	4.1	47		13	7.2	102	.1	.1	200	.27	59	49	64	2.7	365	6.4

28. Lake Cherokee near Longview

Feb. 27, 1952	----------	7.8	0.70	3.5	2.3	8.7		14	13	7.8	0.2	0.5	52	0.07	18	7	51	0.9	81	6.6
Dec. 3, 1961	----------	11	------	4.5	3.0	14		14	9.6	23	.2	.2	72	.10	24	12	57	1.2	122	6.1
Jan. 8, 1962	----------	12	------	5.2	2.4	13		8	13	22	.1	.2	72	.10	23	16	56	1.2	120	6.1
Jan. 17	----------	13	------	5.0	2.5	12		8	12	21	.1	.2	70	.10	23	16	54	1.1	115	5.7

29. Cherokee Bayou near Longview

July 18, 1946	----------	25	------	8.0	4.0	10		43	8.0	11	0.4	----------	[1] 90	0.12	36	1	34	0.7	----------	7.7

30. Cherokee Bayou near Tatum

Mar. 1, 1961	----------	10	------	5.0	2.2	10		6	16	15	0.2	0.1	62	0.08	22	17	50	0.9	106	5.8

33. Eight Mile Creek near Tatum

Nov. 28, 1961	49.5	17	------	9.0	4.6	19		23	22	28	0.2	1.8	113	0.15	41	22	50	1.3	183	6.0
Jan. 17, 1962	----------	8.9	------	4.5	2.6	8.9	2.3	12	12	15	.1	.8	61	.08	22	12	44	.8	100	5.6
May 29	7.91	18	------	13	5.3	33		48	23	38	.5	11	166	.23	54	15	57	2.0	282	6.8
July 4	6.76	19	------	12	4.0	24		42	18	26	.4	8.4	133	.18	46	12	52	1.5	223	6.1

34. Martin Creek near Beckville

Nov. 28, 1961	278	11	------	5.2	4.1	13		16	20	17	0.2	0.1	79	0.11	30	17	49	1.0	131	5.8
Jan. 17, 1962	[2] 500	8.1	------	4.5	3.5	13		11	21	16	.2	.8	72	.10	26	17	53	1.1	126	5.8
May 29	24.6	16	------	6.0	4.5	14		30	13	18	.2	.2	87	.12	33	9	48	1.1	136	6.4
July 4	92.3	12	------	6.2	4.6	12		16	23	16	.2	.0	82	.11	34	21	43	.9	147	5.7

36. Six Mile Creek near Carthage

Nov. 28, 1961	7.41	15	------	20	8.8	69		44	37	114	0.3	0.2	286	0.39	86	50	64	3.2	522	6.3

[1] Residue on evaporation at 180° C.

[2] Field estimate.

TABLE 6.—*Chemical analyses of streams and reservoirs in the Sabine River basin in Texas*—Continued

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (calculated): Parts per million	Dissolved solids (calculated): Tons per acre foot	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25° C)	pH
37. Murvaul Lake near Gary																				
Dec. 3, 1961	----------	5.1	------	7.8	6.5	21		37	22	27	0.2	0.5	108	0.15	46	16	50	1.3	196	6.3
Feb. 9, 1962	----------	6.7	------	8.8	5.9	19		22	28	28	.2	.8	108	.15	46	28	47	1.2	197	6.4
40. Socagee Creek near Carthage																				
May 29, 1962	1.41	16	------	22	9.0	104		42	8.4	195	0.2	0.8	376	0.51	92	58	71	4.7	755	6.8
July 4	3.40	11	------	16	5.0	52		32	6.4	99	.2	.0	206	.28	60	34	65	2.9	405	6.9
Oct. 16	.03	9.0	------	18	6.5	51		38	22	90	.2	.2	216	.29	72	40	61	2.6	404	5.8
Nov. 20	.23	15	------	14	5.2	49		38	6.0	88	.3	.2	197	.27	56	25	65	2.8	370	5.7
Dec. 18	.14	19	------	25	8.6	131		18	12	252	.2	.2	457	.62	98	83	74	5.8	883	5.9
Jan. 29, 1963	3.23	19	------	21	8.6	95		26	18	180	.2	.0	355	.48	88	66	70	4.4	675	6.0
Feb. 20	85.8	12	------	18	8.1	89		26	21	162	.2	.8	324	.44	78	57	71	4.4	610	6.1
Mar. 5	21.6	9.9	------	16	6.8	64		28	23	113	.2	.8	248	.34	68	45	67	3.4	464	6.1
49. Flat Fork Creek near Center																				
Nov. 29, 1961	54.8	14	------	12	8.8	36		39	46	46	0.2	0.2	182	0.25	66	34	55	1.9	317	6.4
Dec. 10	6,100	4.0	------	2.5	1.6	5.8	2.4	10	8.4	7.5	.2	.2	38	.05	13	5	44	.7	64	6.3
Dec. 12	1,400	7.4	------	3.5	2.0	7.2	2.1	11	11	9.5	.2	.5	48	.07	17	8	44	.8	79	6.1
Jan. 16, 1962	[2]1,200	6.3	------	6.0	3.3	18		16	25	20	.2	.5	87	.12	28	15	58	1.5	152	5.8
Oct. 16	.21	9.4	------	14	8.2	53		131	23	36	.3	.2	208	.28	69	0	62	2.8	365	6.3

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50. Tenaha Creek near Shelbyville

June 12, 1952	9.20	19	------	------	------	24		53	26	18	------	------	[1]139	0.19	44	1	54	1.6	198	7.9
Jan. 21, 1953	35.4	16	------	9.0	7.9	29		29	49	30	------	1.2	156	.24	55	31	53	1.7	273	6.7
June 11	24.4	16	------	------	------	19		46	16	16	------	2.0	[1]132	.18	38	0	52	1.3	164	7.1
Nov. 29, 1961	25.3	16	------	8.5	6.9	24		25	40	27	0.2	.1	135	.18	50	29	51	1.5	217	6.2
Dec. 10	4,480	3.6	------	1.8	1.3	3.4	2.6	8	7.0	4.0	.2	.2	28	.04	10	3	36	.5	44	6.2
Dec. 11	1,110	4.7	------	2.5	1.8	4.3	2.4	10	9.6	5.0	.2	.2	36	.05	14	5	36	.5	58	5.8
Dec. 12	1,800	7.0	------	3.0	2.1	5.7	2.4	10	13	6.5	.2	.2	45	.06	16	8	39	.6	71	6.3
Jan. 16, 1962	320	9.4	------	4.5	3.7	15		10	28	15	.2	.8	82	.11	26	18	56	1.3	137	5.6
July 4	7.95	12	------	5.5	3.7	10		26	15	9.2	.1	1.2	70	.10	29	8	43	.8	118	5.8
Aug. 7	.74	12	------	9.2	6.0	23		54	26	18	.2	.2	122	.17	48	3	51	1.4	201	6.5
Oct. 15	4.05	12	------	6.5	5.4	10		34	16	11	.2	.0	78	.11	38	11	37	.7	133	5.9

53. Bayou Siep near Patroon

Oct. 13, 1952	0.4	40	------	------	------	20		65	3.9	22	------	0.2	[1]141	0.19	47	0	49	1.3	191	7.2
Jan. 21, 1953	2.88	34	------	7.0	5.4	17		48	11	18	------	.2	117	.16	40	0	48	1.2	165	6.9
June 11	3.55	30	------	------	------	17		57	6.5	15	------	1.5	[1]132	.18	38	0	50	1.2	153	7.1

67. Patroon Bayou near Milam

June 12, 1952	18.7	17	------	------	------	22		53	31	18	------	------	[1]135	0.18	54	11	47	1.3	217	7.0
Jan. 21, 1953	10.5	18	------	11	8.5	18		42	40	18	------	0.2	[1]133	.18	62	28	39	1.0	226	7.2
June 11	17.3	18	------	------	------	14		44	18	11	------	.5	[1]110	.15	40	4	43	1.0	152	7.6
Nov. 29 1961	23.1	16	------	10	7.3	20		30	42	21	0.2	.0	132	.18	55	30	44	1.2	207	6.2
May 30, 1962	42.0	9.6	------	5.2	3.5	10		20	19	9.5	.2	.0	67	.09	27	11	45	.8	108	6.3
Oct. 17	1.67	13	------	11	7.4	21		66	23	18	.2	.0	126	.17	58	4	44	1.2	210	6.2

69. Palo Gaucho Bayou near Hemphill

May 15, 1952	25.6	19	------	------	------	7.5		28	8.0	7.8	------	------	[1]75	0.10	26	3	38	0.6	89	6.8
Nov. 29, 1961	43.6	17	------	7.8	3.7	5.3	1.9	28	12	9.0	0.1	0.0	71	.10	35	12	24	.4	99	6.2
Dec. 11	975	9.1	------	3.5	2.1	2.8	2.8	12	10	4.5	.1	.5	41	.06	17	8	23	.3	55	6.6
Jan. 16, 1962	242	14	------	6.0	3.0	5.1	1.8	14	15	9.0	.2	.8	62	.08	27	16	27	.4	89	5.8
May 30	67.4	14	------	6.5	2.9	5.3	1.9	25	9.2	7.8	.1	.8	60	.08	28	8	27	.4	89	6.0
July 6	15.7	16	------	6.5	2.9	4.6	1.5	25	8.8	6.7	.1	.0	59	.08	28	8	25	.4	84	6.0
Aug. 8	.69	16	------	10	4.5	10		52	8.0	10	.1	.2	85	.12	43	1	34	.7	128	6.5
Oct. 17	3.59	15	------	8.0	3.9	5.7	2.3	30	14	8.2	.2	.2	72	.10	36	11	24	.4	110	5.8

[1] Residue on evaporation at 180° C.

[2] Field estimate.

TABLE 6.—*Chemical analyses of streams and reservoirs in the Sabine River basin in Texas*—Continued

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (calculated) Parts per million	Dissolved solids (calculated) Tons per acre-foot	Hardness as $CaCO_3$ Calcium, magnesium	Hardness as $CaCO_3$ Noncarbonate	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25° C)	pH
71. Palo Gaucho Bayou near Milam																				
May 16, 1952	39.9	18	------	------	------	10		31	11	8	------	------	[1] 79	0.11	26	1	46	0.9	91	7.0
Oct. 14	.2	13	------	------	------	20		80	6.3	8.0	------	0.8	[1] 105	.14	41	0	51	1.3	171	7.7
Apr. 17, 1953	64.4	18	------	------	------	5.5	1.4	26	10	6.5	------	.5	[1] 79	.11	26	5	30	.5	88	7.5
73. Housen Bayou near Yellowpine																				
June 13, 1952	7.87	29	------	------	------	19		36	22	17	------	------	[1] 135	0.18	34	4	55	1.5	172	7.1
Apr. 17, 1953	11.0	25	------	------	------	20		33	27	16	------	0.2	[1] 137	.19	35	8	55	1.4	175	7.5
Nov. 30, 1961	4.77	22	------	7.2	4.4	26		36	30	21	0.3	.5	129	.18	36	7	61	1.9	199	6.2
Jan. 16, 1962	[2] 400	16	------	4.8	2.3	13		7	25	12	.3	.8	77	.10	21	16	57	1.2	116	5.5
May 31	14.9	25	------	8.0	3.7	23		43	20	20	.2	.5	121	.16	35	0	59	1.7	184	6.0
Aug. 8	.04	13	------	8.0	3.9	31		67	10	26	.3	.5	126	.17	36	0	65	2.2	206	6.4
74. Sandy Creek near Yellowpine																				
June 13, 1952	24.7	23	------	------	------	7.7		16	6.2	7.2	------	------	[1] 64	0.09	13	0	56	0.9	60	6.6
Oct. 14	1.2	21	------	------	------	6.0		15	3.9	5.0	------	0.8	[1] 54	.07	11	0	54	.8	57	6.5
Apr. 17, 1953	36.6	20	------	------	------	------	------	15	------	6.0	------	.2	[1] 63	.09	15	3	------	------	60	7.0
Nov. 30, 1961	30.8	22	------	2.5	1.2	4.6	1.3	8	4.4	8.0	0.1	.1	48	.07	11	5	44	.6	49	5.8
Jan. 16, 1962	246	15	------	3.0	1.0	5.8	1.4	4	12	7.0	.2	.2	48	.07	12	8	48	.7	63	5.3
May 31	33.5	13	------	2.0	1.1	4.5	1.4	8	5.6	5.6	.1	.5	38	.05	10	3	46	.6	48	5.5
Aug. 8	1.90	17	------	4.0	1.5	5.3	1.8	21	3.8	6.0	.0	.5	50	.07	16	0	38	.6	61	6.3

75. Mill Creek near Yellowpine

June 13, 1952	13.1	20	------	------	------	5.7		12	2.6	5.5	------	--------	[1] 44	0.06	18	0	60	0.9	41	6.7
Oct. 14	4.85	18	------	------	------	5.0		10	2.6	4.0	------	0.5	[1] 36	.05	6	0	65	.9	38	6.6
Apr. 17, 1953	17.1	20	------	------	------	3.2	1.0	10	2.9	4.5	------	.2	[1] 47	.06	8	0	43	.5	41	6.6

76. Buck Creek near Burkeville

Oct. 14, 1952	4.21	22	------	------	------	6.1		7	3.7	4.5	------	0.5	[1] 35	0.05	3	0	82	1.5	26	6.5

77. Indian Creek near Burkeville

Oct. 14, 1952	4.04	30	------	------	------	5.7		12	3.6	4.0	------	0.2	[1] 53	0.07	7	0	64	0.9	44	6.6

84. Hickman Creek near Burkeville

Oct. 16, 1952	4.30	23	------	------	------	3.9		9	0.7	3.5	------	0.5	[1] 37	0.05	5	0	63	0.8	30	6.5

88. Little Cow Creek below McGraw Creek near Burkeville

Feb. 13, 1952	[2] 30	12	------	------	------	------------		9	------	9	------	0.2	--------	------	21	------	------	--------	60	7.7
Oct. 16	46.2	19	------	------	------	4.6		12	2.6	4.5	------	.2	[1] 40	0.05	9	0	53	0.7	43	6.7
Sept. 14, 1954	43.3	19	------	1.9	0.8	6.2		14	2.5	5.2	------	.2	43	.06	8	0	63	1.0	46	6.6
Nov. 30, 1961	91.5	15	------	4.0	1.2	3.1	1.3	17	1.6	5.5	0.1	.2	40	.05	15	1	29	.3	57	5.9
Jan. 16, 1962	158	13	------	6.0	.7	3.1	1.2	18	3.0	5.2	.1	.5	42	.06	18	3	26	.3	58	6.0
May 31	73	14	------	3.0	.8	2.9	1.6	11	2.8	4.9	.1	.1	35	.05	11	3	33	.4	43	5.6
July 6	54.6	17	------	3.5	1.0	2.9	1.5	13	2.0	5.6	.1	.0	40	.05	13	2	30	.3	44	6.1

101. Caney Creek near Bon Wier

May 13, 1952	19.5	16	------	------	------	6.0		21	1.6	7.2	------	--------	[1] 53	0.07	16	0	45	0.7	62	6.5
Oct. 17	4.66	18	------	------	------	5.8		17	1.8	6.0	------	0.5	[1] 45	.06	12	0	51	.7	58	6.6
Apr. 16, 1953	15.0	17	------	------	------	4.1	1.6	22	2.0	6.5	------	.5	[1] 58	.08	17	0	32	.4	65	7.3

102. Davis Creek near Bon Wier

Oct. 17, 1952	0.50	13	------	------	------	3.9		8	2.6	4.2	------	2.8	[1] 33	0.04	9	2	48	0.6	41	6.4

[1] Residue on evaporation at 180° C.

[2] Field estimate.

TABLE 6.—*Chemical analyses of streams and reservoirs in the Sabine River basin in Texas*—Continued

Date of collection	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (calculated): Parts per million	Dissolved solids (calculated): Tons per acre-foot	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25° C)	pH
103. Dempsey Creek near Bon Wier																				
June 20, 1952	5.11	28	------	1.9	0.8	5.9		18	1.2	6.2	0.3	0.5	54	0.07	8	0	61	0.9	52	6.5
Oct. 17	.81	30	------	------	------	7.9		18	1.5	6.0	------	.5	[1] 58	.08	8	0	68	1.2	52	6.9
104. Donahoe Creek near Bon Wier																				
June 20, 1952	6.52	24	------	3.2	1.3	6.4	------	14	2	7.2	------	1.0	52	0.07	13	2	51	0.8	58	6.3
107. Big Cow Creek at Farrsville																				
Oct. 5, 1940	[2] 14	------	------	------	------	------		10	2	5.0	------	0.0	------	------	9	------	------	------	------	------
Apr. 10, 1941	------	9.4	0.48	2.0	0.8	2.8		7	2.5	4.2	------	.2	26	0.04	8	3	43	0.4	------	5.8
108. Hunters Creek near Farrsville																				
Oct. 5, 1940	[2] 5	------	------	------	------	------		9	2	5.0	------	0.2	------	------	9	------	------	------	------	------
Apr. 10, 1941	------	8.8	0.50	2.0	0.8	2.8		7	2.1	4.4	------	.3	25	0.03	8	3	43	0.4	------	6.0
109. Melhomes Creek near Jasper																				
Oct. 5, 1940	[2] 9	------	------	------	------	------		10	1.5	4.5	------	0.0	------	------	8	------	------	------	------	------
Apr. 10, 1941	------	8.8	0.62	1.6	0.8	3.1		7	2.5	3.9	------	.2	25	0.03	7	0	48	0.5	------	5.9

110. Bishop Creek near Jasper

Oct. 5, 1940	------	------	------	------	------	------		13	2	5.0	------	0.2	------	------	10	------	------	------	------	------
Apr. 10, 1941	------	8.3	2.0	1.9	0.9	3.2		9	2.5	3.8	------	.2	27	0.04	8	1	46	0.5	------	6.0

112. Big Cow Creek near Newton

Oct. 17, 1940	------	------	------	------	------	------		12	2	4.0	------	0.1	------	------	10	------	------	------	------	6.5
May 9, 1952	53.8	13	------	------	------	5.8		14	1.6	6.0	------	------	[1] 38	0.05	9	0	58	0.8	41	6.5
Nov. 30, 1961	84.0	12	------	1.5	1.2	3.2	1.0	10	.2	6.2	0.2	.2	31	.04	9	0	41	.5	42	5.9
Jan. 16, 1962	204	11	------	4.0	.7	3.5	.8	9	2.8	7.2	.1	.5	35	.05	13	6	35	.4	52	5.6
July 11	41.9	13	------	2.2	.7	2.9	.8	8	.4	6.0	.1	.0	30	.04	8	2	40	.4	36	5.6
Aug. 9	31.7	12	------	2.2	.6	3.1	1.0	8	.8	5.5	.1	.8	30	.04	8	1	42	.5	34	5.9
Oct. 18	36.5	13	------	1.5	.8	2.9	.7	8	.0	5.5	.1	.2	25	.03	7	0	44	.5	32	5.6
Nov. 21	168	12	------	2.2	1.2	3.5	1.7	4	4.6	8.0	.2	.5	36	.05	10	7	38	.5	43	5.5

113. Big Cow Creek near Bleakwood

Mar. 19, 1959	[2] 140	12	------	3.0	0.9	3.9	0.7	12	1.4	6.8	0.0	0.0	35	0.05	11	1	41	0.5	47	6.8

114. Big Cow Creek near Call

Oct. 17, 1952	38.6	20	------	------	------	5.0		12	1.4	5.2	------	0.2	46	0.07	8	0	57	0.8	48	6.5
Feb. 28, 1961	------	11	------	2.2	0.8	3.6	0.5	7	1.4	6.5	0.1	.5	30	.04	9	3	45	.5	40	5.3

117. Trout Creek near Call

Mar. 19, 1959	[2] 20	24	------	2.8	1.1	8.0	1.0	18	1.8	9.8	0.1	0.2	58	0.08	12	0	58	1.0	67	6.1

118. Nichols Creek near Buna

Nov. 29, 1961	35.5	7.2	------	0.5	1.8	15		1	0.4	28	0.2	0.5	54	0.07	9	8	79	2.2	103	4.7
Jan. 15, 1962	70.3	8.0	------	1.5	1.1	16		1	3.0	28	.1	.5	58	.08	8	7	81	2.5	112	4.7

119. Cypress Creek near Buna

June 4, 1952	5.15	7.9	------	------	------	6.0		10	1.3	8.8	------	------	[1] 56	0.08	9	0	59	0.9	58	6.8
Mar. 19, 1959	4.0	8.4	------	1.5	1.2	7.2	0.5	10	1.8	9.8	0.2	0.2	36	.05	9	0	63	1.1	56	6.0
Nov. 29, 1961	19.9	6.1	------	.5	1.3	5.9	.7	3	3.0	10	.1	.5	29	.04	7	4	63	1.0	52	5.0
Jan. 15, 1962	180	5.7	------	1.5	1.0	5.9	.8	1	4.6	11	.1	.5	31	.04	8	7	59	.9	55	4.8
Jan. 16	133	4.6	------	1.5	1.0	5.6	.5	2	4.6	9.8	.1	.2	29	.04	8	6	59	.9	55	5.0
July 9	.24	9.6	------	2.5	1.5	8.0	.4	12	2.0	12	.1	.8	43	.06	12	3	57	1.0	69	5.5

[1] Residue on evaporation at 180°C.

[2] Field estimate.

TABLE 7.—*Chemical analyses of streams and reservoirs in the Sabine River basin in Louisiana*

[Results in parts per million except as indicated]

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (calculated): Parts per million	Dissolved solids (calculated): Tons per acre-foot	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25° C)	pH
42. Sabine River at Logansport																				
Oct. 21–28, 1941	1,450	--	--	22	6.6	124		43	14	214	--	0.2	402	0.55	82	47	77	6.0	820	--
Oct. 30–31	2,310	--	--	6.4	3.0	13		20	4.0	26	--	.0	62	.08	28	12	51	1.1	126	--
Nov. 1–4	10,100	--	--	10	4.4	27		26	11	49	--	.5	115	.16	42	22	58	1.8	236	--
Nov. 5–9	7,900	--	--	22	6.5	109		44	19	186	--	.5	365	.50	82	46	74	5.2	740	--
Nov. 12–18	1,000	--	--	24	7.0	130		52	31	218	--	--	426	.58	89	46	76	6.0	856	--
Dec. 21–24, 26–31	5,640	--	--	20	4.9	88		45	26	139	--	.5	301	.41	70	33	73	4.6	592	--
Jan. 1–10, 1942	4,880	--	--	20	8.4	107		42	34	176	--	.0	366	.50	84	50	73	5.1	749	--
Jan. 21–31	1,430	20	0.21	26	9.1	179		37	41	295	0.5	.8	590	.80	102	72	79	7.7	1,120	--
Mar. 1–10	6,540	--	--	16	6.4	73		32	25	122	--	.5	259	.35	66	40	71	3.9	525	--
Mar. 11–20	5,800	--	--	21	7.9	118		44	40	186	--	1.2	396	.54	85	49	75	5.6	775	--
Apr. 7	1,270	--	--	19	9.2	142		40	28	235	--	.5	453	.62	86	52	78	6.7	915	--
July 21–31	330	--	--	34	9.3	281		75	17	465	--	.2	843	1.15	123	62	83	11	1,630	--
Sept. 11–12, 14–20	3,480	--	--	20	5.7	136		42	20	222	--	2.0	426	.58	74	39	80	6.9	836	--
Sept. 21–25, 30	1,070	--	--	26	7.2	166		50	21	275	--	4.5	524	.71	94	54	79	7.4	1,040	--
Jan. 1–5, 1944	2,900	--	--	21	7.5	120		30	50	189	--	1.5	404	.55	84	59	76	5.7	752	--
Jan. 11–12, 14–20	8,410	--	--	13	4.5	43		48	21	58	--	.5	164	.22	51	12	64	2.6	325	--
Jan. 21–31	7,300	--	--	17	6.5	69		25	42	109	--	.8	257	.35	69	49	68	3.6	484	--
Feb. 1–10	3,570	--	--	22	7.7	95		27	34	165	--	2.2	339	.46	86	64	70	4.5	705	--
43. Bayou Castor near Longstreet																				
Oct. 17, 1955	[1] 0.16	32	0.73	7.5	2.5	16		46	2.0	16	--	1.0	101	0.14	29	0	54	1.3	141	6.9
Dec. 9	[1] .31	24	.70	8.6	3.3	17		57	1.5	16	--	.5	100	.14	35	0	51	1.2	154	7.0
Apr. 4, 1956	[1] 2.98	20	.58	16	8.5	43		60	30	62	--	.6	211	.29	75	26	56	2.2	359	7.0

44. Bushneck Bayou at Longstreet

Oct. 17, 1955	[1] 0.045	14	0.19	23	8.3	39		122	3.7	51	------	0.8	[2] 202	0.27	92	0	48	1.8	364	7.2
Dec. 9	[1] .06	22	.33	28	11	39		136	2.3	62	------	.2	[2] 246	.33	116	5	42	1.6	414	7.2

46. Bayou Grand Cane near Logansport

Apr. 3, 1956	[1] 6.24	10	0.32	18	11	54		49	57	76	------	0.5	251	0.34	90	50	56	2.5	450	7.3

56. Bayou San Patricio near Noble

Apr. 19, 1957	66	15	0.87	6.0	3.2	21		19	18	28	------	0.8	102	0.14	28	13	62	1.8	172	6.5
May 15	62	16	.89	7.3	3.5	30		28	9.4	45	------	1.5	128	.17	33	10	67	2.3	223	6.2
June 14	29	16	2.1	7.3	2.8	31		24	10	46	------	2.2	129	.18	30	10	69	2.5	229	5.9
July 8	5.8	18	3.0	9.5	4.1	38		40	11	55	------	2.2	161	.22	41	8	67	2.6	280	6.2
Sept. 3	.5	5.4	.20	13	6.4	29		77	.4	41	------	1.0	134	.18	59	0	52	1.6	295	7.2

59. Bayou San Miguel near Zwolle

June 20, 1956	0.0	7.0	0.06	11	6.1	21		78	3.8	21	------	1.2	109	0.15	53	0	46	1.2	205	7.4
Jan. 31, 1957	268	64	.50	1.8	1.5	4.0	2.9	6	7.6	5.5	0.7	.8	35	.05	11	6	38	.5	49	6.4
Mar. 1	24	15	.81	5.5	3.0	15		14	24	16	------	.5	87	.12	26	15	56	1.3	140	6.3

65. Hurricane Creek tributary at Loring Lake Near Zwolle

Apr. 11, 1958	------------	2.0	0.14	2.4	0.7	3.2	1.6	11	1.2	4.2	0.6	0.3	21	0.03	9	0	39	0.5	44	6.3

66. Bayou La Nana near Zwolle

Oct. 29, 1959	1.1	12	0.77	10	6.1	21	3.4	63	25	16	0.4	1.1	127	0.17	50	0	46	1.3	183	6.6
Nov. 11	1.2	14	.16	13	5.7	24	3.4	84	16	18	.3	.6	136	.18	56	0	46	1.4	219	6.7
Dec. 9	2.5	16	.31	16	6.6	31	4.3	102	14	30	.3	.3	169	.23	67	0	48	1.7	286	7.2
Feb. 3, 1960	80	13	.45	13	5.7	33	2.5	32	46	40	.2	.5	170	.23	56	30	55	1.9	293	6.6
Mar. 1	122	14	.42	8.4	3.7	18	1.7	18	32	20	.1	.5	108	.15	36	21	51	1.3	175	6.0
Apr. 6	20	12	.22	14	8.6	39	1.8	58	48	44	.3	.2	197	.29	70	22	54	2.0	340	7.1
May 3	8.9	13	2.7	17	8.2	54	2.4	114	1.0	70	.3	.7	225	.31	76	0	60	2.7	431	4.6
June 2	2.2	13	.32	20	6.1	48	2.1	95	23	56	.3	.0	216	.29	75	0	57	2.4	404	6.5
July 5	5.9	15	.43	8.8	4.9	20	2.3	44	15	25	.2	.9	115	.16	42	6	49	1.3	193	6.1
Aug. 3	1.8	11	.28	9.6	4.4	23	2.6	58	11	24	.3	.9	116	.16	42	0	52	1.5	208	6.2
Sept. 7	1.7	14	.39	15	4.5	32	2.0	93	12	28	.2	.3	154	.21	56	0	54	1.9	263	6.7

[1] Discharge at time of sampling

[2] Residue on evaporation at 180°C.

TABLE 7.—*Chemical analyses of streams and reservoirs in the Sabine River basin in Louisiana*—Continued

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (calculated)		Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25° C)	pH
													Parts per million	Tons per acre-foot	Calcium, magnesium	Noncarbonate				
79. Bayou Toro near Toro																				
Sept. 10, 1958	52	17	0.62	3	0.5	3.9	1.5	9	4.2	4.6	0.4	0.7	40	0.05	10	2	43	0.6	42	6.2
Nov. 6, 1959	10	23	.24	3.7	1.2	5.3	.8	16	5.0	5.2	.1	.4	53	.07	14	1	43	.6	64	6.3
Dec. 10	9.0	25	.15	3.8	.6	7.4	2.3	17	8.6	6.0	.2	.1	62	.08	12	0	52	.9	67	6.2
Feb. 4, 1960	650	13	.37	4.5	.9	6.7	2.2	6	14	8.3	.1	1.0	54	.07	15	10	45	.7	82	5.5
Mar. 1	150	17	.37	4.4	1.7	6.4	1.4	8	15	8.0	.2	.5	59	.08	18	12	41	.7	74	6.6
Apr. 6	45	19	.35	5.1	1.8	8.7	1.8	19	12	9.2	.1	.3	67	.09	20	4	46	.8	82	6.6
May 3	24	21	.40	5.9	1.3	8.0	1.7	19	10	9.4	.2	.4	67	.09	20	4	44	.8	82	5.7
May 31	7.2	22	.83	5.4	1.1	8.5	1.9	25	7.6	7.2	.1	.0	67	.09	18	0	47	.9	84	6.6
July 6	26	20	.40	7.0	1.6	5.1	2.4	19	7.8	9.4	.1	.5	63	.09	24	8	29	.4	81	5.7
Aug. 3	7.0	18	.47	7.6	1.2	4.8	1.2	18	7.8	9.0	.1	.6	60	.08	24	9	29	.4	87	6.1
Sept. 6	5.0	20	.14	5.6	.5	4.6	.8	17	5.0	5.5	.0	.4	50	.07	16	2	37	.5	64	5.9
91. East Anacoco Creek near Anacoco																				
Sept. 10, 1958	------------	22	0.16	2.4	0.2	3.9	0.9	9	0.6	5.8	0.2	0.4	41	0.06	7	0	51	0.6	35	5.9
Dec. 10, 1959	[1]5.2	21	.07	2.1	.2	3.7	1.4	10	.6	4.9	.1	.1	39	.05	6	0	51	.7	38	6.0
May 18, 1960	[1]4.5	20	.17	3.0	.4	3.7	1.1	9	4.6	4.0	.1	.3	42	.06	9	2	43	.5	42	6.1
May 11, 1961	[1]13.4	15	.14	.9	.7	3.0	.8	8	.2	4.0	.0	.4	29	.04	5	0	52	.6	36	6.0
Sept. 6	[1]8.21	16	.02	2.3	.3	2.8	.9	10	.0	4.0	.1	.2	32	.04	7	0	42	.5	34	5.4
95. Anacoco Lake near Leesville																				
Sept. 10, 1958	------------	7.4	0.06	2.8	1.0	1.7	1.8	12	0	3	0.8	0.8	25	0.03	11	1	22	0.2	35	6.1
Nov. 6, 1959	------------	6.6	.01	4.7	.8	2.8	1.0	18	.0	3.6	.2	1.3	30	.04	15	0	27	.3	58	6.2
May 18, 1960	------------	6.5	.08	5.0	.9	2.8	.9	13	6.0	4.3	.1	.2	33	.04	16	5	26	.3	49	5.7
Nov. 2	------------	6.9	.02	5.4	1.4	2.3	1.4	17	1.2	7.0	.1	.4	34	.05	19	5	19	.2	51	6.2
May 11, 1961	------------	7.1	.12	3.0	.6	1.6	.9	10	1.2	3.0	.1	.7	23	.03	10	2	24	.2	40	5.6
Aug. 15	------------	3.9	.00	2.2	.8	2.3	1.0	12	1.4	2.8	.1	.6	21	.03	9	0	32	.3	29	6.5

96. Bayou Anacoco near Rosepine

Aug. 22, 1952	28	16	0.08	4.9	1.8	5.5	2.8	26	2.4	7.0	0.1	0.2	54	0.07	20	0	34	0.5	80	6.4
Sept. 24	53	20	.12	2.2	1.0	4.1	1.6	14	2.3	5.5	.4	.5	[3] 45	.06	10	0	43	.6	42	6.6
Oct. 29	27	11	.44	5.2	1.2	4.5	2.0	24	1.2	5.7	.2	.5	44	.06	18	0	32	.5	63	6.6
Dec. 17	145	9.8	.40	4.2	1.0	4.5	------	20	1.7	4.2	------	1.2	37	.05	15	0	40	.5	53	6.3
Mar. 5, 1953	561	20	.44	2.2	1.0	4.3	------	9	3.7	4.8	------	.8	41	.06	10	2	49	.6	43	6.0
Apr. 8	227	9.0	.33	3.9	1.2	3.3	------	16	2.6	3.8	------	1.0	33	.04	15	2	33	.4	48	6.3
July 9	86	8.8	.23	4.0	.9	2.7	1.4	19	1.8	3.5	------	.5	33	.04	14	0	27	.3	47	6.5
Aug. 5	244	9.5	.35	3.4	.8	2.6	1.2	17	1.4	3.5	------	.5	31	.04	12	0	29	.3	43	6.5
Sept. 8	96	12	.18	3.9	1.2	4.0	1.3	20	1.1	4.5	------	1.2	39	.05	15	0	35	.5	47	7.1
Nov. 14, 1959	24	13	.06	5.4	.9	3.7	1.4	10	1.4	9.9	.1	3.5	44	.06	17	9	30	.4	65	6.4
Jan. 4, 1960	670	8.6	.19	2.8	.2	2.3	.7	6	1.8	4.2	.1	.5	24	.03	8	3	36	.4	36	6.0
Mar. 14	300	11	.19	4.1	.4	4.8	1.7	12	2.4	7.0	.1	1.6	40	.05	12	2	43	.6	54	6.1
May 3	91	13	.17	3.6	.7	4.6	1.7	9	2.2	9.0	.1	2.0	41	.06	12	5	41	.6	55	5.2
July 6	68.5	13	.01	6.0	.3	2.1	1.1	18	1.0	4.2	.1	.0	37	.05	16	1	21	.2	53	6.3

97. Bayou Anacoco near Knight

Sept. 21, 1959	[1] 61.7	15	0.11	4.3	1.0	3.0	0.9	20	4.0	4.0	0.1	0.3	39	0.05	15	0	29	0.3	53	6.6
May 18, 1960	[1] 87.5	13	.08	5.5	.6	3.9	1.0	16	4.8	5.0	.1	.2	42	.06	16	3	33	.4	55	5.7
Apr. 24, 1961	[1] 243	8.8	.1	4.7	.1	3.9	1.2	14	.8	5.7	.0	1.2	34	.05	12	1	39	.5	51	5.9
Aug. 28	[1] 258	11	.01	4.0	.5	2.8	.9	14	.6	4.0	.1	.2	31	.04	12	1	31	.3	42	5.9

[1] Discharge at time of sampling.

[3] Contains 0.02 ppm boron (B).

The Water Pollution Control Division of the Texas State Department of Health since 1957 has had a state-wide stream-sampling program, which has included the collection of data at 15 sites in the Sabine River basin—12 on the main stem and 3 on tributaries. The analyses have included the determination of pH, biochemical oxygen demand, total solids, dissolved oxygen, chloride, chlorine demand, and sulfate. Data from this program were made available to the Geological Survey and have been studied during the preparation of this report. The data-collection sites of the State Department of Health are listed below. Most of them are at Geological Survey gaging stations, and the numbers below refer to locations shown in figure 2.

Reference No.	*Data-collection site*
6	Sabine River, near Emory
12	near Mineola
20	Lake Fork Creek near Quitman
	Sabine River near Big Sandy
21	Big Sandy Creek near Big Sandy
22	Sabine River, near Gladewater
24	near Longview
31	near Tatum
42	at Logansport
68	near Milam
83	below Toledo Bend near Burkeville
99	near Bon Weir
121	near Ruliff
	at Orange
122	Cow Bayou near Mauriceville

RELATION OF QUALITY OF WATER TO USE

Quality-of-water studies usually are concerned with the suitability of the water for a proposed use, judged by the chemical, physical, and sanitary characteristics of the water. In the Sabine River basin, surface water is being used, and developments are planned primarily for municipal and industrial use. Water of suitable quality for public supply will be satisfactory also for irrigation and recreation purposes.

This report considers principally the chemical character of the water and its relation to the principal types of utilization. Other water-quality considerations, including color, turbidity, taste, and presence of micro-organisms and organic substances, are not considered in this report.

Most mineral matter dissolved in water is in the form of ions. An ion is an atom or group of atoms having an electric charge. Principal cations (positive charge) found in natural waters are calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and iron (Fe). The principal anions (negative charge) are carbonate (CO_3), bicarbonate

(HCO_3), sulfate (SO_4), chloride (Cl), fluoride (F), and nitrate (NO_3). Other constituents and properties are often determined to aid in the definition of the chemical and physical quality of water. Table 8 lists constituents and properties determined by the U.S. Geological Survey and includes a résumé of their sources and significance.

TABLE 8.—*Source and significance of dissolved mineral constituents and properties of water*

Constituent or property	Source or cause	Significance
Silica (SiO_2)	Dissolved from practically all rocks and soils, commonly less than 30 ppm. High concentrations, as much as 100 ppm, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high-pressure boilers to form deposits on blades of turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment. More than 1 or 2 ppm of iron in surface waters generally indicate acid wastes from mine drainage or other sources.	On exposure to air, iron in ground water oxidizes to reddish-brown precipitate. More than about 0.3 ppm stain laundry and utensils reddish-brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. U.S. Public Health Service (1962) drinking-water standards state that iron should not exceed 0.3 ppm. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
Calcium (Ca) and Magnesium (Mg).	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming (see hardness). Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and textile manufacturing.
Sodium (Na) and potassium (K)	Dissolved from practically all rocks and soils. Found also in ancient brines, sea water, industrial brines, and sewage.	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high sodium content may limit the use of water for irrigation.
Bicarbonate (HCO_3) and carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks, such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot water facilities to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium, cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in mine waters and in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. U.S. Public Health Service (1962) drinking-water standards recommend that the sulfate content should not exceed 250 ppm.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial brines.	In large amounts in combination with sodium, gives salty taste to drinking water. In large quantities, increases the corrosiveness of water. U.S. Public Health Service (1962) drinking-water standards recommend that the chloride content should not exceed 250 ppm.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Added to many waters by fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth, depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptibility of the individual. (Maier, 1950.)
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentration much greater than the local average may suggest pollution. U.S. Public Health Service (1962) drinking-water standards suggest a limit of 45 ppm. Waters of high nitrate content have been reported to be the cause of methemoglobinemia (an often fatal disease in infants) and therefore should not be used in infant feeding. Nitrate has been shown to be helpful in reducing intercrystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.

TABLE 8.—*Source and significance of dissolved mineral constituents and properties of water*—Continued

Constituent or property	Source or cause	Significance
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Includes some water of crystallization.	U.S. Public Health Service (1962) drinking-water standards recommend that waters containing more than 500 ppm dissolved solids not be used if other less mineralized supplies are available. Waters containing more than 1,000 ppm dissolved solids are unsuitable for many purposes.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called noncarbonate hardness. Waters of hardness as much as 60 ppm are considered soft; 61–120 ppm, moderately hard; 121–180 ppm, hard; more than 180 ppm, very hard.
Specific conductance (micromhos at 25° C)	Mineral content of the water.	Indicates degree of mineralization. Specific conductance is a measure of the capacity of the water to conduct an electric current. Varies with concentration and degree of ionization of the constituents.
Hydrogen-ion concentration (pH)	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, and phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals.

DOMESTIC PURPOSES

The safe limits for the mineral components usually found in water vary with individuals, with different amounts of water used, and with other factors. The limits usually quoted in the United States for drinking water are based on the U.S. Public Health Service drinking-water standards. These standards were established first in 1914 to control the quality of water used on interstate carriers for drinking and for culinary purposes. They have been revised several times; the latest revision was in 1962 (U.S. Public Health Service, 1962). These standards have been endorsed by the American Water Works Association as minimum standards for all public water supplies.

The limits specified by the drinking-water standards for the various constituents are included in the statements under "Significance" in table 8. The concentration of fluoride should not average more than the appropriate upper limit in the following table.

Annual average of maximum daily air temperatures [1] (°F)	Recommended control limits—Fluoride concentrations in parts per million		
	Lower	Optimum	Upper
50.0–53.7	0.9	1.2	1.7
53.8–58.3	.8	1.1	1.5
58.4–63.8	.8	1.0	1.3
63.9–70.6	.7	.9	1.2
70.7–79.2	.7	.8	1.0
79.3–90.5	.6	.7	.8

[1] Based on temperature data obtained for a minimum of 5 years.

IRRIGATION

The chemical composition of a water supply is an important factor in evaluating its usefulness for irrigation. The extent to which chemical quality limits the suitability of a water depends on a number of factors. These include the nature and composition of the soil and subsoil, the topography of the land, the amounts of water used and methods of applying it, the kind of crops grown, and the climate of the region, including the amounts and distribution of rainfall.

The characteristics of an irrigation water that are most important in determining its quality, according to the U.S. Salinity Laboratory Staff (1954, p. 69), are (1) total concentration of soluble salts; (2) relative proportion of sodium to other cations; (3) concentration of boron or other elements that may be toxic; and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium.

The U.S. Salinity Laboratory Staff introduced the term "sodium-adsorption-ratio" (SAR) to express the relative activity of sodium ions in exchange reactions with the soil. This ratio is expressed by the equation:

$$SAR=\frac{Na^{+}}{\sqrt{\frac{Ca^{++}+Mg^{++}}{2}}}$$

where the concentration of the ions are expressed in equivalents per million.

The U.S. Salinity Laboratory Staff has prepared a system for classifying irrigation waters in terms of salinity and sodium hazards. Empirical equations were used in developing a diagram which uses SAR and specific conductance in evaluating irrigation water. The diagram is reproduced in modified form as figure 7. Although the classification embodies both research and field observations, it is tentative and should be used for general guidance only.

With respect to salinity hazard, waters are divided into four classes: low salinity, medium salinity, high salinity, and very high salinity; the dividing points between classes are 250, 750, and 2,250 micromhos per centimeter. They range from water that can be used for irrigation of most crops on most soils to that which is not usually suitable for irrigation.

Waters are divided into four classes with respect to sodium or alkali hazard: low, medium, high, and very high, depending on the SAR value and the specific conductance. The classification covers waters that range from those which can be used for irrigation on almost all soils to those which are generally unsatisfactory for irrigation.

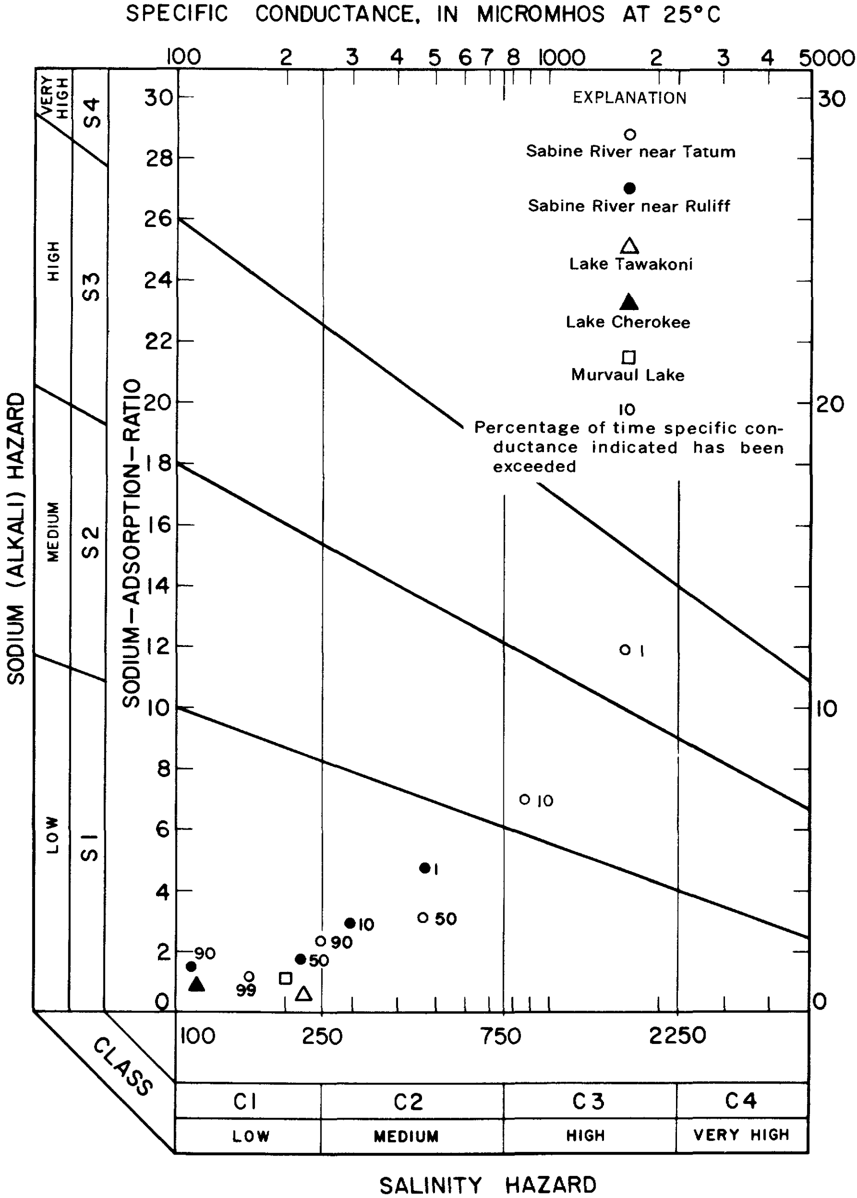

FIGURE 7.—Diagram for the classification of irrigation waters, Sabine River basin. Adapted from U.S. Salinity Laboratory Staff, 1954, p. 80.

Representative data from analysis of water from three reservoirs and the Sabine River at the chemical quality stations near Tatum and near Ruliff are plotted on figure 7. For the river stations the percentage of time that the specific conductance exceeded the indicated value during the period 1953–62 is shown. The data show that the water of the Sabine River basin is generally low with respect to salinity and sodium hazards.

The principal use of surface water for irrigation in the Sabine River basin in Texas is for growing rice in the lower part of the basin. The concentration of chemical constituents tolerated by rice varies with the stage of growth, but investigators generally agree that water containing less than 600 ppm sodium chloride (350 ppm chloride) is not harmful to rice at any stage of growth (Irelan, 1956, p. 330). Water of the Sabine River basin, except at a few points where gross pollution occurs, meets all quality requirements for rice irrigation.

Surface water is also used for supplemental irrigation of field crops and truck gardens, principally in the upper half of the basin. For supplemental irrigation in humid and subhumid areas, water-quality requirements are not rigid, and water of the Sabine River and its tributaries would generally be classified as excellent for irrigation.

INDUSTRIAL USE

Industry is one of the major water users in the Sabine River basin, and the economic feasibility of a water-development project may depend on the acceptability of the water for industrial use.

The quality requirements for industrial water vary widely from industry to industry. For some purposes, such as cooling, water of almost any quality can be used, whereas in some manufacturing processes and in high-pressure steam boilers, water approaching the quality of distilled water may be required. The requirements of water quality for many types of industry and processes are given in table 9.

Hardness is a property which receives great attention in industrial water supplies. It is objectionable because of the formation of scale in boilers, pipes, water heaters, and radiators, with the resultant loss in heat transfer, boiler failure, and loss of flow. However, calcium carbonate sometimes forms protective coatings on pipe and other equipment, thus reducing corrosion. A certain amount of calcium salts are desirable in water used by the brewing industry.

High dissolved-solids concentration may be closely associated with the corrosive property of a water, particularly if chloride is present in appreciable quantities. Water containing high concentrations of magnesium chloride may be very corrosive, because the hydrolysis of this unstable salt yields hydrochloric acid.

TABLE 9.—*Water-quality tolerances for industrial applications* [1]

[Allowable limits in parts per million except as indicated]

Industry	Turbidity	Color	Color $+O_2$ consumed	D.C. (ml/l)	Odor	Hardness	Alkalinity (as $CaCO_3$)	pH	Total solids	Ca	Fe	Mn	Fe+ Mn	Al_2O_3	SiO_2	Cu	F	CO_3	HCO_3	OH $CaSO_4$	Na_2SO_4 to Na_2SO_3 ratio	General [2]
Air conditioning [3]											0.5	0.5	0.5									A, B
Baking	10	10				(4)					.2	.2	.2									C
Boiler feed:																						
0–150 psi	20	80	100	2		75		8.0+	3,000–1,000					5	40			200	50	50	1 to 1	
150–250 psi	10	40	50	.2		40		8.5+	2,500–500					.5	20			100	30	40	2 to 1	
250 psi and up	5	5	10	0		8		9.0+	1,500–100					.05	5			40	5	30	3 to 1	
Brewing: [5]																						
Light	10				Low		75	6.5–7.0	500	100–200	.1	.1	.1				1			100–200		C, D
Dark	10				Low		150	7.0 ⟶	1,000	200–500	.1	.1	.1				1			200–500		C, D
Canning:																						
Legumes	10				Low	25–75					.2	.2	.2									C
General	10				Low						.2	.2	.2				1					C
Carbonated beverages [6]	2	10	10		0	250	50		850		.2	.2	.3				.2					C
Confectionary					Low			(7)	100		.2	.2	.2									
Cooling [8]	50					50					.5	.5	.5									A, B
Food, general	10				Low						.2	.2	.2									C
Ice (raw water) [9]	1–5	5					30–50		300		.2	.2	.2		10							C
Laundering						50					.2	.2	.2									
Plastics, clear, undercolored	2	2							200		.02	.02	.02									

Paper and pulp: [10]																						
Groundwood	50	20				180					1.0	.5	1.0									A
Kraft pulp	25	15				100			300		.2	.1	.2									
Soda and sulfite	15	10				100			200		.1	.05	.1									
Light paper, HL-Grade	5	5				50			200		.1	.05	.1									B
Rayon (viscose) pulp:																						
Production	5	5				8	50		100		.05	.03	.05	<8.0	<25	<5						
Manufacture	.3					55		7.8-8.3			.0	.0	.0									
Tanning [11]	20	10-100				50-135	135	8.0			.2	.2	.2									
Textiles:																						
General	5	20				20					.25	.25										
Dyeing [12]	5	5-20				20					.25	.25	.25									
Wool scouring [13]		70				20					1.0	1.0	1.0									
Cotton bandage [13]	5	5			Low	20					.2	.2	.2									

[1] American Water Works Association, 1950.

[2] A, No corrosiveness; B, No slime formation; C, Conformance to Federal drinking-water standards necessary; D, NaCl, 275 ppm.

[3] Waters with algae and hydrogen sulfide odors are most unsuitable for air conditioning.

[4] Some hardness desirable.

5 Water for distilling must meet the same general requirements as for brewing (gin and spirits mashing water of light-beer quality; whiskey mashing water of dark-beer quality).

6 Clear, odorless, sterile water for syrup and carbonization. Water consistent in character. Most high quality filtered municipal water not satisfactory for beverages.

[7] Hard candy requires pH of 7.0 or greater, as low value favors inversion of sucrose, causing sticky product.

[8] Control of corrosiveness is necessary as is also control of organisms, such as sulfur and iron bacteria, which tend to form slimes.

[9] $Ca(HCO_3)_2$ particularly troublesome. $Mg(HCO_3)_2$ tends to greenish color. CO_2 assists to prevent cracking. Sulfates and chlorides of Ca, Mg, Na should each be less than 300 ppm (white butts).

[10] Uniformity of composition and temperature desirable. Iron objectionable as cellulose adsorbs iron from dilute solutions. Manganese very objectionable, clogs pipelines and is oxidized to permanganates by chlorine, causing reddish color.

[11] Excessive iron, manganese, or turbidity creates spots and discoloration in tanning of hides and leather goods.

[12] Constant composition; residual alumina 0.5 ppm.

[13] Calcium, magnesium, iron, manganese, suspended matter, and soluble organic matter may be objectionable.

RECREATION

The use of waters for recreation, including swimming, boating, and fishing, is an increasingly valuable bonus associated with the development of surface-water resources for municipal and industrial supplies.

Waters used for swimming and bathing should be reasonably free from pathogenic organisms and should be esthetically enjoyable, being free from objectionable floating or suspended substances and free of foul tastes and odors. They should contain no substance that is toxic on ingestion or is irritating to the skin. Water used for boating and associated water sports should meet these same requirements, because the users are subjected to sprays and other contact with the water.

Probably the greatest recreational use of water is for fishing. Although there is considerable published material on the effect of water quality on fish life, limits have not been established for a multitude of elements and compounds that may be toxic to fish. Recent research indicates that fish are extremely sensitive to certain insecticides and commercial poisons.

FACTORS AFFECTING CHEMICAL QUALITY OF WATER

The kinds and quantities of minerals dissolved in surface water are the result of a number of environmental factors, including geology, patterns and characteristics of streamflow, and cultural influences.

GEOLOGY

In areas where cultural influences are small, the amount of dissolved solids carried by streams depends principally on the types of rocks and soils in the drainage basin. The physical and chemical properties of the rocks and soils depend not only on the environment in which the rocks were formed but also on the post depositional environment. In some areas of high rainfall, rocks that originally contained large quantities of easily soluble minerals have been leached by circulating water until the mantle rock and residual soil contain relatively small amounts of readily soluble minerals. Conversely, in arid or semiarid regions the rocks and soils may contain large amounts of soluble material. Surface rocks and soils of the Sabine River basin have been leached as a result of high rainfall, and over much of the basin the dissolved-mineral content of surface runoff and ground-water inflow is exceptionally low.

The relation of the geology to the concentration of the various dissolved constituents in the water of the Sabine River basin is discussed in the section on "Chemical quality of the water."

STREAMFLOW

The patterns and characteristics of streamflow usually affect the chemical character of the water in streams. Water discharge of any stream not regulated by upstream reservoirs varies from day to day and even from hour to hour. The variation may be large, such as for streams that flow mostly in response to storms, or small, if the flow is mostly from ground water. Usually the dissolved-solids concentration of the water is highest during periods of low flow, when the flow is mostly from ground water that has been in contact with rock and soil particles for a sufficient time to dissolve part of the soluble minerals, and lowest when the flow is from flood runoff. The effect of rates of streamflow on the dissolved-solids concentration of streams is usually greatest in streams whose low-flow waters have high concentrations of dissolved solids.

In the Sabine River basin the water in streams is derived mostly from surface runoff, but review of streamflow records show that the base flow of many streams is maintained by ground-water inflow. In much of the basin the ground water reaching the streams is low in dissolved material, because heavy rainfall has already leached the soluble minerals from the exposed rocks and soils. Therefore, in many of the streams the dissolved-solids concentration varies only slightly with changes in water discharge. Figure 8 shows the relation of the concentration of dissolved solids to water discharge in three tributary streams. Palo Gaucho Bayou and Martin Creek have dissolved-solids concentrations less than 100 ppm even at lowest rates of discharge, and at flood flows they have only slightly lower concentrations. Lake Fork Creek shows evidence of pollution. During periods of low flow, dissolved-solids concentrations have ranged widely indicating that pollution occurs intermittently. During periods of high flow, the effects of pollution are minimized as surface runoff of low-concentration dilutes the small quantities of more saline waters. Samples of low flow, collected soon after high flow has subsided, have also contained low concentrations of dissolved solids.

Figure 9 shows the relation of the annual weighted-average concentration of dissolved solids to the annual mean discharge of the Sabine River near Tatum and near Ruliff. The plots for both stations show decreases in dissolved solids with increases in discharge, but the effect is much greater at Tatum. That part of the basin above Tatum has the lowest rainfall, and the dissolved-solids concentrations of the water vary over a wide range. The quality of water at the Ruliff station shows the effect of inflow from the high-rainfall area where dissolved solids are always low and subject to only slight variations.

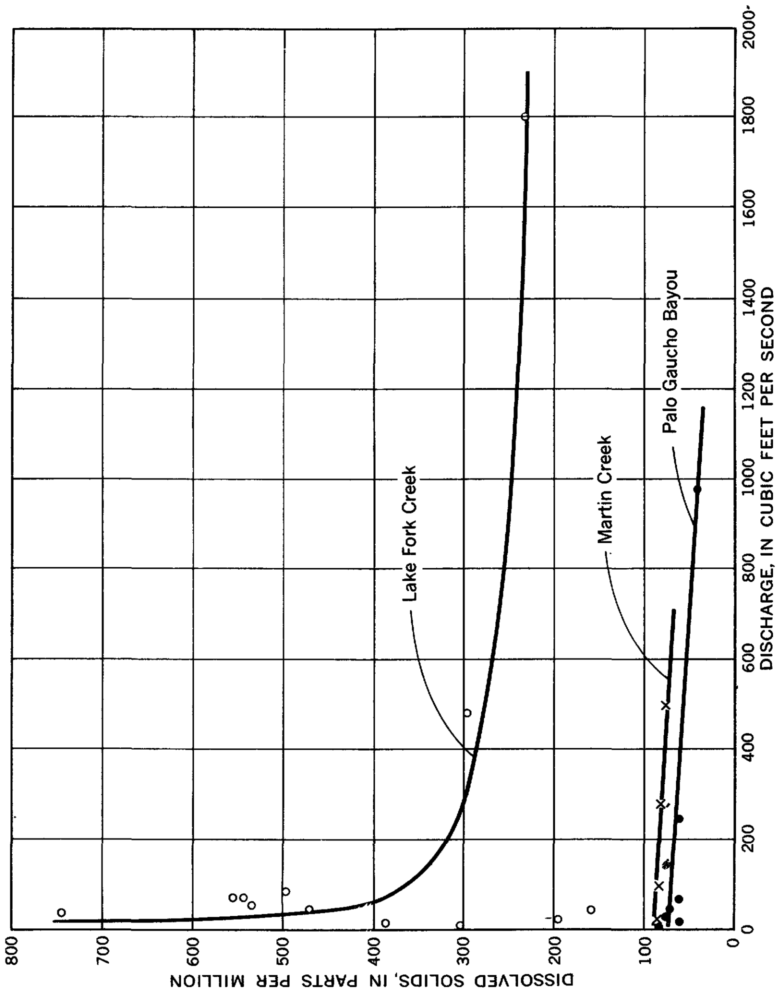

FIGURE 8.—Graph showing relation of concentration of dissolved solids to water discharge in three tributaries of the Sabine River.

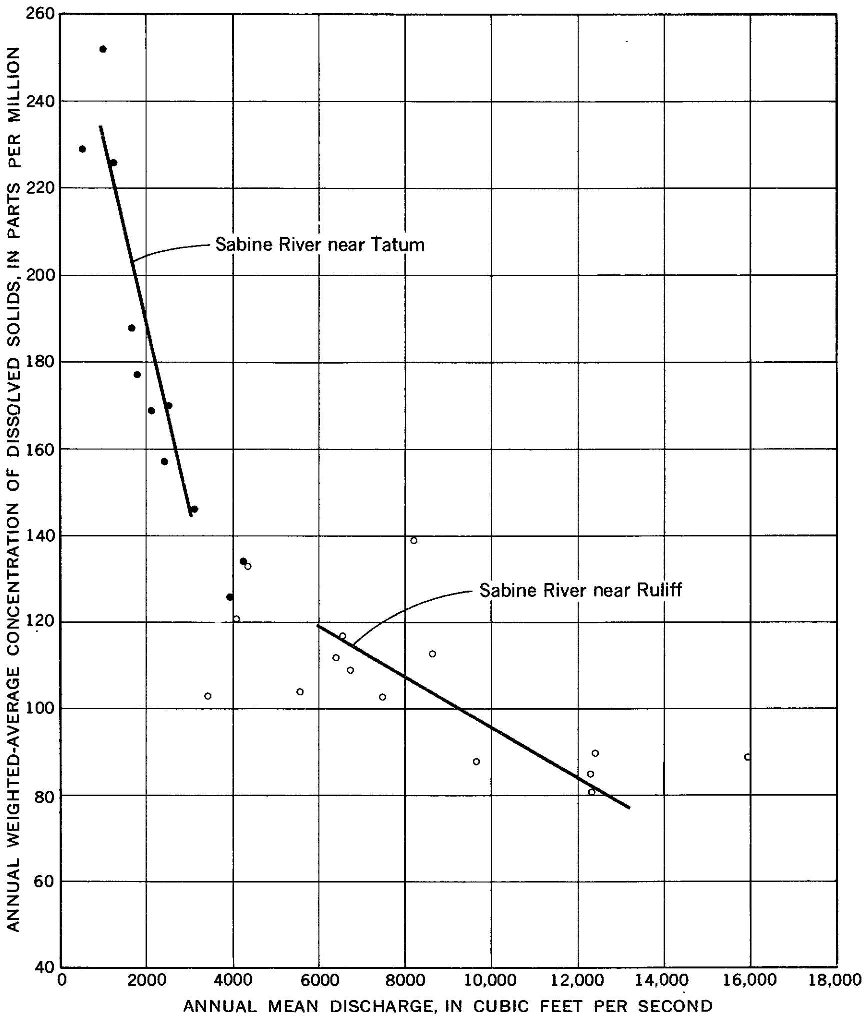

FIGURE 9.—Graph showing relation of annual weighted-average concentration of dissolved solids to water discharge, Sabine River near Tatum and near Ruliff.

INDUSTRIAL INFLUENCES

The activities of man often have a significant effect on the chemical quality of surface water. The disposition of oil-field brines and municipal and industrial wastes and the depletion of streamflow by diversion for municipal and industrial use all produce changes in water quality.

Brine is produced in nearly all oil fields, and if improperly handled, eventually reaches the streams. The composition of oil-field brines varies, but the principal chemical constituents, in order of magnitude of their concentrations (in ppm), are generally chloride, sodium, calcium, and sulfate. Pollution of the surface streams by oil-field brines can be a major problem in areas where oil production is extensive. Although oil is produced in many areas in the Sabine River basin (fig. 3), most of the brine is reinjected into wells, and pollution of surface water has been kept at a low level. Some brines appear to be reaching the surface waters in the Lake Fork Creek and Socagee Creek subbasins and causing deterioration of water quality in these streams. The effect on the main stem of the Sabine has been minor.

Injected brine may sometimes move upward along fault zones or as a result of leakage into other wells, thus polluting fresh ground water, and even eventually reaching the surface. Pollution of fresh ground water in city wells at Hawkins, Wood County, has been reported (Burnitt, 1963).

Municipal use of water tends to increase the concentration of dissolved solids in a stream system. The depletion of flow by diversion and consumptive use, the loss of water because of increased evaporation, and the disposal of municipal wastes into a stream result in higher average concentrations of dissolved solids in the remaining water. The municipal use of water from the Sabine River has caused only local changes in water quality. There are no large diversions downstream from Lake Tawakoni, and the flow is adequate to dilute the municipal wastes that are introduced.

The diversion of the water of Lake Tawakoni from the Sabine River basin will have little effect on the average quality of the main stem of the Sabine River. The quantity of water diverted is small in comparison with the total flow of the Sabine, and the dissolved-solids content of the water to be diverted is near the average for the basin as a whole.

CHEMICAL QUALITY OF THE WATER

Surface water of the Sabine River basin generally is of good chemical quality, meeting U.S. Public Health Service Drinking-Water Standards. Variations in concentrations of dissolved constituents are influenced principally by the geology of the runoff area and by cultural influences, but also by rainfall and streamflow characteristics.

The geographic variations of dissolved solids, hardness, and chloride are shown on figures 10, 13, and 14. These maps are based on the discharge-weighted average concentrations, as estimated from all available chemical-quality records. All the streams will at times have concentrations exceeding those shown for their respective areas, but the averages shown on the maps are indicative of the type of water that would be stored in reservoirs. For many of the streams the data were limited, particularly on the chemical quality of flood flows, and the boundaries of the areas are necessarily generalized. Comparison of these maps with the geologic map (pl. 1) shows that the quality of the water contributed by the different sections of the basin is related to the surface geology.

DISSOLVED SOLIDS

The concentration of dissolved solids in surface water of the Sabine River basin is generally less than 250 ppm (fig. 10). Water from the

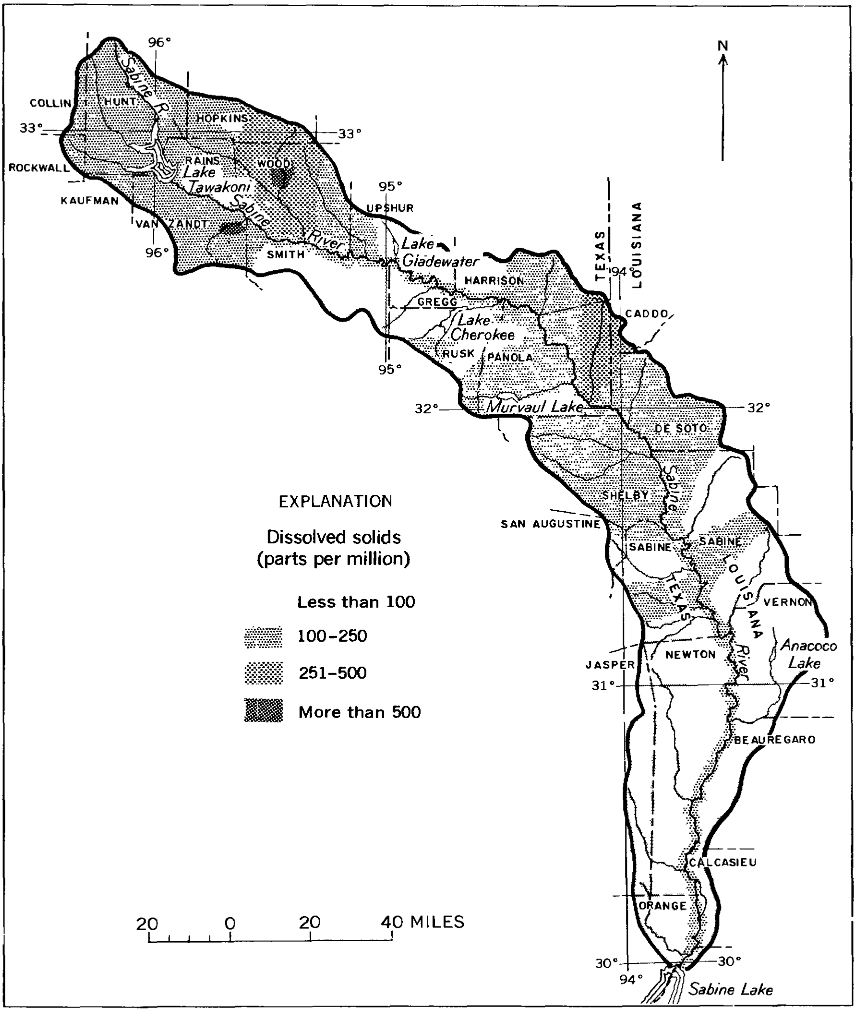

FIGURE 10.—Map of the Sabine River basin showing concentration of dissolved solids in surface water.

outcrop areas of the Taylor Marl and the Navarro Group, the Midway and Wilcox Groups, and the older formations of the Claiborne Group, generally has dissolved-solids concentrations ranging from 100 to 250 ppm. Water from the outcrops of younger formations has concentrations less than 100 ppm. Exceptions to these general relationships were observed in two areas (Lake Fork Creek and Socagee Creek subbasins) where dissolved-solids concentrations are higher than 250 ppm, apparently because of oil-field pollution.

One area where natural pollution of surface water is occurring is at Grand Saline, in Van Zandt County. Here a salt dome lying close beneath the surface is overlain by a salt flat, or "saline" (fig. 11). A small flow of highly saline ground water emerges here and flows from the flat into Grand Saline Creek. A sample of the brine in one of the small streams draining the flat contained 39,200 ppm chloride and 66,200 ppm dissolved solids. Comparison of the chloride content of Grand Saline Creek at sites above and below the salt flat indicates that in February 1963 the brine effluent was contributing about 25 tons of chloride per day to the creek and thence to the Sabine River. (See analyses for sites 8, 9, and 10 in table 6.)

The discharge-weighted average concentration of dissolved solids in the main stem of the Sabine River falls within the 101–250 ppm range throughout most of the river's length. For the ten-year period from October 1952 to September 1962, for which concurrent records are available, the weighted-average concentrations at Tatum and Ruliff were 161 and 96 ppm, respectively. The analyses showing annual maximum and minimum dissolved-solids concentrations and the annual weighted averages for the daily sampling stations are given in table 5.

FIGURE 11.—View of salt flat at Grand Saline, Van Zandt County, Tex.

Time-weighted averages are much higher than discharge-weighted averages. Duration curves for concentrations of dissolved solids for the Tatum and Ruliff stations, given on figure 12, show that at

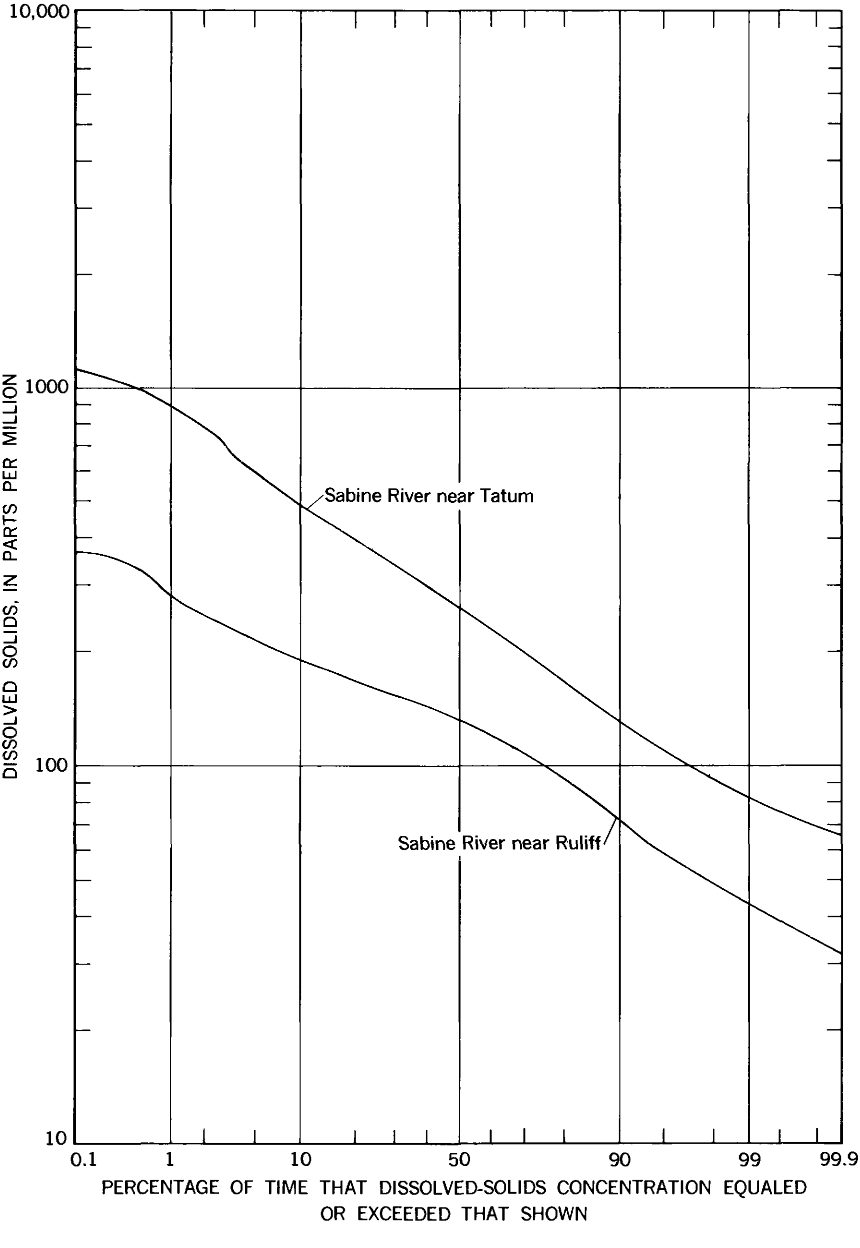

FIGURE 12.—Duration curves for dissolved solids for Sabine River near Tatum and near Ruliff, water years 1953–62.

Tatum, 260 ppm dissolved solids has been equaled or exceeded 50 percent of the time, and at Ruliff, 120 ppm has been equaled or exceeded 50 percent of the time. After Toledo Bend Reservoir is completed and in operation, the water at Ruliff will be more uniform in quality and will seldom exceed 150 ppm in dissolved-solids concentration.

HARDNESS

Surface water of much of the Sabine River basin is soft, having less than 60 ppm hardness (fig. 13). In the southern one-third of the basin the water is very soft, with less than 30 ppm hardness.

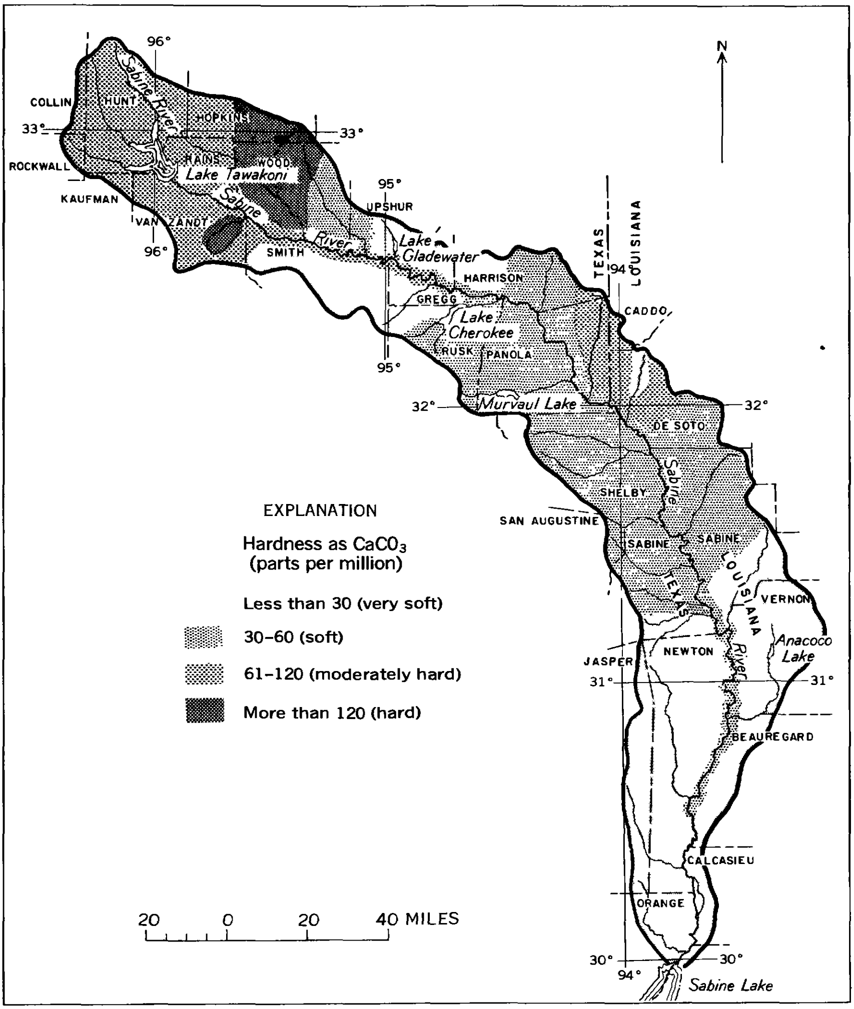

FIGURE 13.—Map of the Sabine River basin showing hardness of surface water.

Water draining from the northwest end of the basin, where limestone, chalk, and marl of Cretaceous age crop out, is moderately hard (61–120 ppm). The principal dissolved constituents in the water from this area are calcium and bicarbonate, as shown by the analyses for Greenville Reservoir and Lake Tawakoni (sites 1 and 5, table 6).

Hard water is typical of the Grand Saline Creek and Lake Fork Creek subbasins where natural and manmade pollution is occurring.

Water of the upper one-third of the length of the main stem of the Sabine River is moderately hard. Inflow of softer water in the lower part of the basin decreases the hardness to less than 30 ppm (very soft) at the Ruliff station.

Nearly all the hardness of the water of the basin is due to calcium and magnesium. In the moderately hard water draining from the area where Cretaceous rocks crop out, calcium is present in a ratio of about 8 parts to 1 of magnesium; whereas in the softer waters, the ratio may be less than 2 to 1.

CHLORIDE

The chloride concentration is less than 20 ppm in surface water from about two-thirds of the Sabine River basin (fig. 14). Low-chloride water is in streams draining areas where rocks of the Taylor Marl, Navarro Group, and Midway Group crop out at the upper end of the basin, areas where rocks of the Claiborne Group crop out in the north-central part, and the entire southern half of the basin, which is underlain by Quaternary and upper Tertiary rocks. Water containing 21–100 ppm chloride is typical of streams draining areas underlain by rocks of the Wilcox Group and the older formations of the Claiborne Group. Chloride concentrations exceeding 100 ppm occur in water of Lake Fork and Socagee Creeks which drain oil fields. The relation of oil fields to the chloride concentration in the water of Socagee Creek was not determined in this study, but in the Lake Fork Creek subbasin, streams draining the Quitman oil field were found to have chloride concentrations as high as 1,020 ppm (sites 17 and 19, table 6). Water draining from the salt flat at Grand Saline contained 39,200 ppm chloride on February 26, 1963; this inflow of high-chloride water raised the chloride concentration of base flow of Grand Saline Creek downstream from the salt flat to 1,200 and 1,300 ppm on February 26 and 27, respectively. Upstream from the salt-flat inflow Grand Saline Creek contained only 100 ppm of chloride. (See sites 8–10, table 6.)

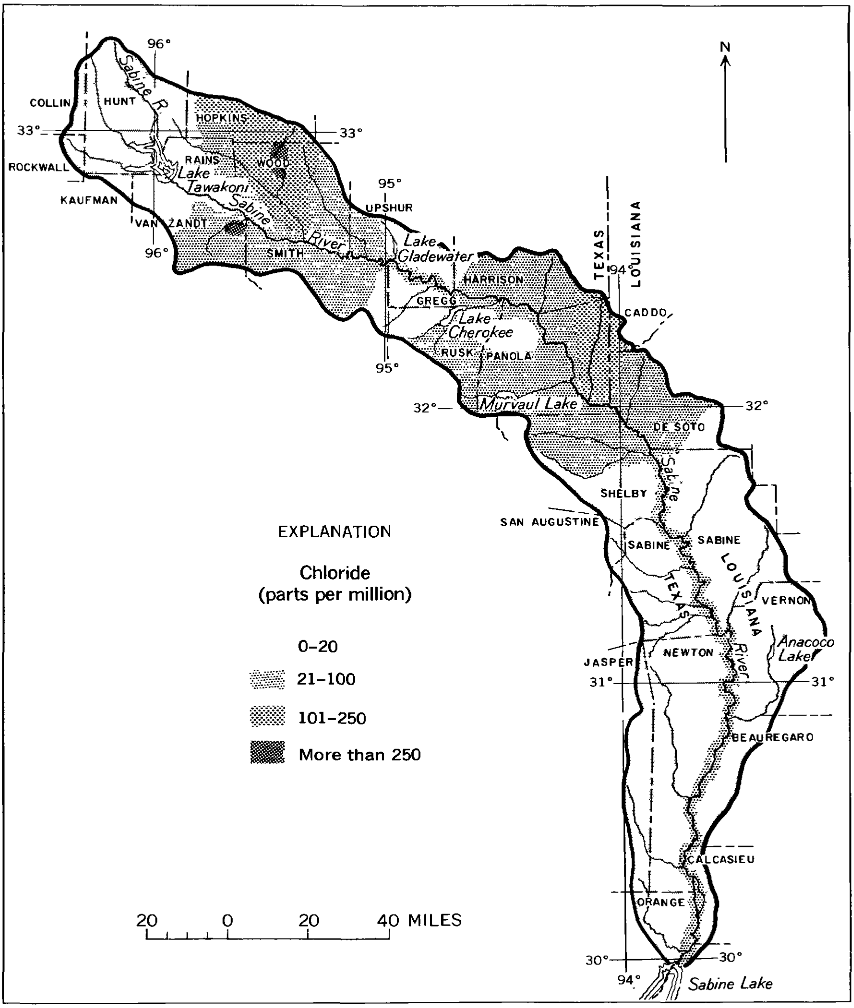

FIGURE 14.—Map of the Sabine River basin showing concentration of chloride in surface water.

OTHER CONSTITUENTS

Other constituents of importance in the evaluation of the quality of a water include silica, iron, sodium, bicarbonate, sulfate, fluoride, and nitrate.

Many streams in the Sabine River basin contain from 10 to 30 ppm silica, and the weighted-average concentration in the Sabine River near Ruliff is about 12 ppm. In some streams having low dissolved-solids concentrations, silica may constitute as much as

40 percent of the dissolved material present. Water draining rocks of Cretaceous age is very low in silica, containing only about 3 ppm.

The occurrence of iron in surface waters was not studied during this reconnaissance, but data on iron concentrations are available for the Sabine River near Ruliff and for the sampling points in Louisiana. In surface waters, the sediment normally present often includes some iron oxides that are carried in colloidal suspension or as very fine sediment particles. High values for "dissolved" iron frequently are the result of the presence of these finely divided particles in suspension. Usual public water-supply treatment and filtration practices effectively remove both dissolved and suspended iron from surface waters.

Sodium is the principal cation in the waters of the Sabine River basin, except that calcium predominates in the area where Cretaceous rocks crop out. In those waters having high chloride concentrations, sodium occurs in quantities approximately equivalent to the chloride. It is therefore present in highest concentrations in Grand Saline, Lake Fork, and Socagee Creeks. In unpolluted streams, the sodium concentration seldom exceeds 50 ppm.

In water draining from rocks of Cretaceous age, bicarbonate is the principal anion, and occurs in quantities approximately equivalent to the calcium and magnesium. In the remainder of the Sabine River basin, it is present in smaller concentrations.

Sulfate concentrations are generally less than 30 ppm in most streams of the basin. The weighted-average concentration for the Sabine River near Tatum ranged from 13 to 28 ppm, and near Ruliff from 9.5 to 19 ppm. Higher concentrations are found in the polluted streams. Concentrations of fluoride and nitrate are low in all surface waters in the Sabine River basin. Fluoride concentrations range generally from 0.1 to 0.5 ppm, and nitrate from 0.0 to 2 ppm.

WATER QUALITY IN RESERVOIRS

The principal reservoirs in the Sabine River basin in Texas were sampled during the reconnaissance study, and the chemical analyses are given in table 6. Analyses are also available for many of the small reservoirs used for public supply (Sundstrom and others, 1948; Texas State Department of Health, 1960). The water in all the reservoirs is satisfactory for public supply, except that softening the water of Greenville Reservoir and Lake Tawakoni might be desirable.

Greenville Reservoir.—The water in the Greenville Reservoir is calcium bicarbonate in type and is moderately hard. Dissolved-solids concentrations have ranged from 154 to 205 ppm. Analyses have shown maximum chloride and sulfate concentrations of 13 and 32 ppm, respectively.

Lake Tawakoni.—This new reservoir was filling for the first time during the course of the investigation. The water of Lake Tawakoni is also calcium bicarbonate in type and moderately hard, but the concentrations of most constituents are less than in Greenville Reservoir. Although dissolved-solids concentrations ranged from 118 to 134 ppm during the 8-month period from December 1961 to July 1962, the chemical composition of stored water remained remarkably uniform.

Lake Gladewater.—Very soft water, containing only 60 to 70 ppm dissolved solids, is stored in Lake Gladwater. The principal dissolved constituents are silica, 16 ppm, and chloride, 15 to 20 ppm.

Lake Cherokee.—Water in Lake Cherokee, similar to that in Lake Gladewater, is very soft and low in all dissolved constituents.

Murvaul Lake.—The water of Murvaul Lake is soft, and in the winter of 1961–62 it contained only 108 ppm dissolved solids.

WATER QUALITY AT PROPOSED RESERVOIR SITES

One of the principal purposes of the Sabine River basin reconnaissance study was to appraise the quality of the water which will be available for storage in proposed reservoirs. Streams were sampled periodically at or near all the reservoir sites, except those on the main stem where quality can be inferred from the daily-station records. An evaluation of water quality follows for each of the reservoirs proposed in the Texas Water Commission's Plan for 1980 (Texas Board Water Engineers, 1961) and in the Sabine River Authority's Master Plan (Sabine River Authority, 1960) to meet requirements for 2010. These evaluations are based on present conditions; cultural influences in the basin may cause significant changes in water quality before some of the reservoirs are built.

Kilgore Reservoir.—Only low-flow samples were collected from Wilds Creek, but the highest dissolved-solids concentration observed was 77 ppm. All constituents were present in very low concentrations, except silica which ranged from 26 to 30 ppm. Higher flows would probably have a lower silica content, and the dissolved-solids content of water to be stored in Kilgore Reservoir should not exceed 70 ppm.

Cherokee Reservoir 2.—Analyses of samples from Cherokee Bayou near Oak Hill, above Lake Cherokee, indicate that the upstream reservoir might contain water having slightly higher concentrations of dissolved constituents, principally sodium and chloride, than does the existing reservoir. However, dissolved-solids concentrations in the upstream reservoir should not exceed 150 ppm.

Toledo Bend Reservoir.—Although this main-stem reservoir is under construction in the lower one-third of the basin, much of the area of highest rainfall and lowest dissolved-solids content of the water is below the damsite. The concentration of dissolved constituents in water which will be stored in Toledo Bend Reservoir will probably be about midway between that measured at the Tatum and Ruliff stations. Thus, if the reservoir fills during a period of average rainfall and runoff, the stored water would contain about 150 ppm dissolved solids and would be soft.

Lake Fork Reservoir.—The pollution of Lake Fork Creek by oil-field brines has been mentioned. In February 1963 the effects of this pollution were greatest in the lower part of the Dry Creek subbasin, but chloride concentrations were also high in other streams (table 6). The Lake Fork damsite is above the mouth of Dry Creek, whereas the gaging station on Lake Fork Creek near Quitman, where the periodic sampling was done, is below Dry Creek. Thus, the chemical-quality records obtained are not strictly applicable to the damsite. Additional study should be given to this area before a reservoir is built.

Big Sandy Reservoir.—The chemical analyses in table 6 indicate that oil-field activities may influence slightly the quality of the water of Big Sandy Creek near Big Sandy; but even so, the maximum chloride concentration observed during March 1961 to February 1963 was 70 ppm, and the maximum dissolved solids was 184 ppm. Water stored in a reservoir on Big Sandy Creek would be of excellent quality, would be soft, and would have a dissolved-solids concentration probably not exceeding 150 ppm.

Rabbit Reservoir.—The quality of water in Rabbit Creek at the reservoir site can be inferred from the analyses for nearby Wilds Creek (see site 25, table 6). If oil-field pollution is prevented, the reservoir should store soft water having a dissolved-solids content less than 100 ppm.

Carthage and Stateline Reservoirs.—The quality of the water at the sites of these two main stem reservoirs probably is similar to that determined for Sabine River near Tatum (see table 5). Stateline Reservoir would receive additional inflow from several tributaries carrying water having low concentrations of dissolved solids, but it would also receive water from Socagee Creek, whose water quality appears to be affected by oil fields. (See data for site 40, table 6.) Dissolved-solids concentrations of the water in the 2 reservoirs will probably range between 150 and 200 ppm.

Tenaha Reservoir.—Floodwater of Tenaha Creek is very low in concentrations of dissolved constituents, and the water which will be stored in Tenaha Reservoir should contain less than 100 ppm dissolved solids.

Bon Weir and Sabine Diversion Reservoirs.—Water available for storage in Bon Weir and Sabine Diversion Reservoirs will consist of inflow from a number of tributaries below Toledo Bend Dam and releases from Toledo Bend Reservoir. The tributaries yield water containing only about 50 ppm dissolved solids, and the releases from Toledo Bend will probably contain about 150 ppm.

PROBLEMS NEEDING ADDITIONAL INVESTIGATION

The Sabine River basin has an abundance of water of good quality, and is remarkably free of water-quality problems. However, three areas were noted during this reconnaissance where further study should be made, and the wide-spread practices of water-flooding in oil fields and the reinjection of oil-field brines should be watched carefully.

Lake Fork Creek subbasin is an area where oil-field brine pollution is occurring. Further study will be needed to determine whether the brine is reaching the streams by seepage from disposal pits or is leaking back to the surface after being injected into wells.

Oil fields in the Socagee Creek subbasin may be contributing brine to surface waters as the high chloride concentrations (88–252 ppm) observed at the sampling site near Carthage indicate.

The brine discharge from the salt flat at Grand Saline may have an increasing effect on the quality of the water of the Sabine River. In February 1963 the effluent from the salt flat was contributing about 25 tons of chloride per day to Grand Saline Creek and thence to the River. If the additional dams being built in the upper basin tend to decrease the base flow of the Sabine, such a saline inflow may become significant.

Large quantities of oil-field brines are reinjected into wells in the Sabine River basin. If geologic conditions are suitable, if the wells are properly constructed, if excessive pressures are not used, and if nearby oil wells are properly cased and abandoned wells properly plugged, this method of disposing of brine poses little danger of polluting fresh ground- and surface-water supplies. That oil-field operation can be a hazard to water quality is evident in other areas of Texas. Conselman, Jenke, and Tice, Consultants (written commun., 1962) report that pollution in the Hubbard Creek drainage area in the Brazos River basin is partly due to leakage from waterflood injection wells and salt-water disposal wells. They state:

> Industrial brines have reached the watershed from (1) surface leakage of salt water pits, producing wells, water injection wells, lease lines, tanks, heaters, treaters and abandoned dry holes; (2) leaching of salt-impregnated areas by run-off; (3) seepage of salt-water pits into the shallow subsurface; (4) subsurface seepage from salt water disposal wells pumping brine into the annulus, with pressures and volumes in excess of the capacity of subsurface resevoirs; (5) waterflood in-

jection wells which unintentionally inject brine into reservoirs other than those to be re-pressured; (6) abandoned shot-holes and core-holes which receive lateral salt water migration from other sources; * * *.

Similar pollution of surface waters may occur in the Sabine River basin as a result of salt-water disposal wells and waterflooding activities and, if so, could cause deterioration of water quality.

Continued municipal and industrial growth in the Sabine River basin will increase the waste-disposal burdens of the stream system and will require continuous effort by water-pollution control agencies to keep deterioration of water quality at a minimum.

The encroachment of sea water from the Gulf of Mexico through Sabine Lake may make the water of the lower reach of the river unsuitable for use. Depletion of flow as a result of increased consumptive use and upstream storage will permit a wedge of salt water to travel increased distances up the river. A study of the water-quality characteristics of the tidal reach of the river should be made before diversions from potentially affected reaches are planned.

The quality of water may be improved or degraded by impoundment. Beneficial effects include the reduction of turbidity, silica, color, and coliform bacteria, the evening out of sharp variations in chemical quality, the entrapment of sediment, and reductions in temperature. Detrimental effects of impoundment include increased growth of algae, reduction of dissolved oxygen, and increases in dissolved solids and hardness as a result of evaporation. The significance of these changes in water quality and their relations to the intended uses of the water are subjects on which further study is needed.

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Water Year	Water-Supply Paper	Texas Water Commission Bulletin	Water Year	Water-Supply Paper	Texas Water Commission Bulletin
1940–45		[1] 1938–45	1954	1352	[1] 1954
1946	1050	[1] 1946	1955	1402	[1] 1955
1947	1102	[1] 1947	1956	1452	5905
1948	1133	[1] 1948	1957	1522	5915
1949	1163	[1] 1949	1958	1573	6104
1950	1188	[1] 1950	1959		6205
1951	1199	[1] 1951	1960		6215
1952	1252	[1] 1952	1961		6304
1953	1292	[1] 1953			

[1] "Chemical Composition of Texas Surface Waters" was designated only by water year from 1938 through 1955.

Numbers of U.S. Geological Survey water-supply papers containing results of stream measurements in Sabine River basin, 1903–60

Year	WSP	Year	WSP	Year	WSP	Year	WSP
1903	99	1930	730	1940	898	1950	1178
1904	132	1931	718	1941	928	1951	1212
1905	174	1932	733	1942	958	1952	1242
1906	210	1933	748	1943	978	1953	1282
1924	588	1934	763	1944	1008	1954	1342
1925	608	1935	788	1945	1038	1955	1392
1926	628	1936	808	1946	1058	1956	1442
1927	648	1937	828	1947	1088	1957	1512
1928	668	1938	858	1948	1118	1958	1562
1929	688	1939	878	1949	1148	1959	1632
						1960	1712

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