TEXAS WATER DEVELOPMENT BOARD

REPORT 87

RECONNAISSANCE OF THE CHEMICAL QUALITY OF SURFACE WATERS OF THE SULPHUR RIVER AND CYPRESS CREEK BASINS, TEXAS

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RECONNAISSANCE OF THE CHEMICAL QUALITY OF SURFACE WATERS OF THE SULPHUR RIVER AND CYPRESS CREEK BASINS, TEXAS

ABSTRACT

The Sulphur River and Cypress Creek basins are adjacent basins in the northeast corner of Texas. The combined drainage area in Texas is 6,370 square miles. Both basins are completely within the West Gulf Coastal Plain section of the Coastal Plain physiographic province. The topography is characterized by irregular rolling and hilly uplands and flat flood plains.

The climate of the study basins ranges from moist subhumid to humid. The average annual precipitation ranges from 42 inches in the west to 48 inches in the east and averages about 45 inches. About one-fourth of the precipitation appears in the streams as runoff.

Surface water in the Sulphur River and Cypress Creek basins is generally of good chemical quality and is suitable for most municipal, industrial, and agricultural purposes.

The kinds and quantities of minerals dissolved in surface waters of the basins are related principally to the geology of the runoff area and to rainfall and streamflow characteristics, but is also affected by industrial activities.

The rocks exposed in the basins are sedimentary deposits of Cretaceous and Tertiary age, composed mainly of sand, marl, chalk, limestone, and clay. Throughout much of the basins, abundant rainfall has leached much of the readily soluble material from the exposed rocks and soils, and the water in streams is usually low in concentration of dissolved materials. Water from the Cretaceous and Tertiary rocks in the Sulphur River basin is generally of a mixed type containing less than 250 ppm (parts per million) dissolved solids, except in the White Oak Creek subbasin where oil-field drainage intermittently degrades the quality of the water. In the Cypress Creek basin, the Cretaceous rocks contribute a sodium chloride type water that generally contains less than 250 ppm dissolved solids.

The chloride content of the surface waters is generally less than 25 ppm. Higher concentrations are found in White Oak Creek near the Talco oil field and in Glade Creek, a tributary to Little Cypress Creek, where oil-field drainage is affecting the quality of the water.

Surface water of the basins ranges from soft to hard. The South Sulphur, North Sulphur, and Sulphur Rivers usually contain moderately hard water and White Oak Creek has hard water. Cypress Creek has moderately hard water in its upper reaches and soft water downstream.

All the reservoirs in the basins contain water of very good quality. The dissolved-solids concentration is usually less than 150 ppm. Water available for storage at potential reservoirs is also of very good quality.

The Sulphur River and Cypress Creek basins are free of serious water-quality problems. Continued municipal and industrial growth will increase the waste-disposal burdens of the streams, and planned impoundments will cause a reduction in the streamflow which now aids in waste assimilation. As the water resources of the basins are developed, the magnitude and significance of the probable changes in water quality will necessitate studies of the resulting problems.

RECONNAISSANCE OF THE CHEMICAL QUALITY OF SURFACE WATERS OF THE SULPHUR RIVER AND CYPRESS CREEK BASINS, TEXAS

INTRODUCTION

The investigation of the chemical quality of the surface waters of the Sulphur River and Cypress Creek basins is part of a statewide reconnaissance study. Each major river basin in the State is being studied and a report prepared presenting the results of the study and a summary of all available chemical-quality data. The area of this report and the river basins for which reports are published are shown on Figure 1.

The purpose of this report is to present the available information on the water quality of the Sulphur River and Cypress Creek basins that will further proper development, control, and use of the water resources of the area. In the study the following items were considered: the nature and amounts of mineral constituents in solution; the geologic, hydrologic, and cultural influences that determine water quality; the amount and probable source of the salt discharged by the streams; and the suitability of the water for domestic, industrial, and irrigation use.

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 Development Board and with other federal and local agencies. This network has not 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 cooperative statewide reconnaissance by the U.S. Geological Survey and the Texas Water Development Board was begun in September 1961. In this reconnaissance, samples for chemical analysis are collected periodically at numerous sites throughout Texas so that some quality-of-water information will be available for locations where water-development projects are likely to be built. These data aid in the delineation of areas having water-quality problems and in the identification of probable sources of pollution, thus indicating areas where more detailed investigations are needed.

SULPHUR RIVER AND CYPRESS CREEK DRAINAGE BASINS

General Description

The Sulphur River and Cypress Creek basins are adjacent basins in the northeast corner of Texas. The combined area is bordered on the east by the states of Arkansas and Louisiana, on the south and west by the Sabine River basin, and on the north by the Red River basin (Figure 1).

The Sulphur River is formed at the extreme eastern edge of Delta County by the junction of the North and South Sulphur Rivers. The South Sulphur River has its source in south-central Fannin County and flows eastward about 60 miles to its junction with the North Sulphur River. The North Sulphur River has its source in southeastern Fannin County and flows eastward about 50 miles to its junction with the South Sulphur River.

The Sulphur River, thus formed, flows eastward about 75 miles and crosses the Arkansas boundary at the Cass-Bowie County line, joining the Red River about 15 miles southeast of the Texas-Arkansas boundary. The Sulphur River, which drains 3,558 square miles in Texas, has two major tributaries, Cuthand Creek and White Oak Creek.

Cypress Creek has its source in southeastern Hopkins County and flows eastward into Caddo Lake at the Louisiana boundary. Little Cypress Creek, the major tributary, rises in northeastern Wood County and flows eastward about 70 miles before joining Cypress Creek about 12 miles west of the Texas-Louisiana boundary. Of the many small tributaries, Black Cypress Bayou, Frazier Creek, and Black Bayou are the most significant. The drainage area in Texas of the Cypress Creek basin totals 2,812 square miles.

The study area is completely within the West Gulf Coastal Plain section of the Coastal Plain physiographic province. Low relief and a gentle gulfward slope of the land surface characterize this section. Local topographic

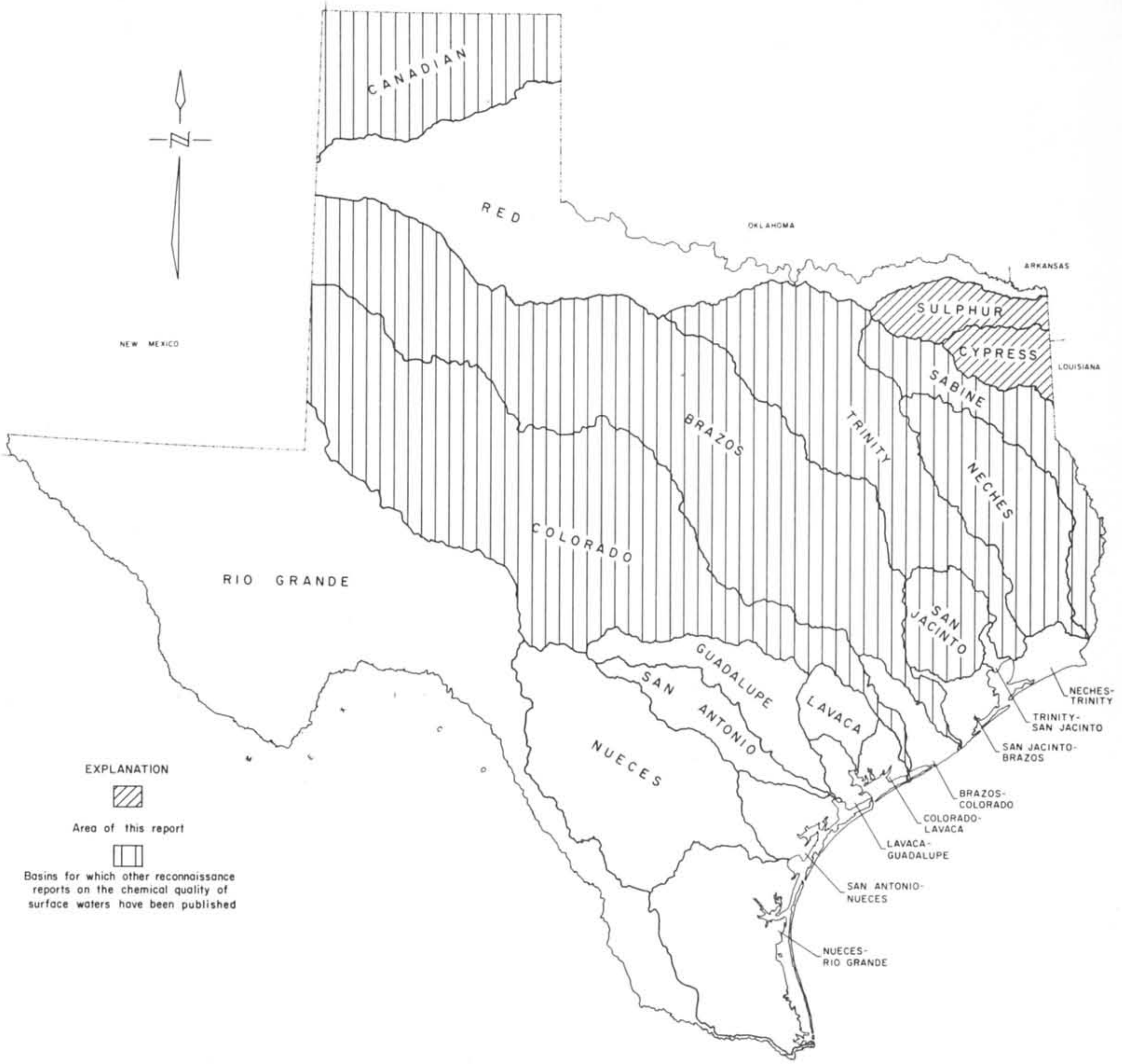

Figure 1.--Index Map Showing River Basins and Coastal Areas

features are irregular rolling and hilly uplands and flat flood plains and terraces. The streams have wide, nearly flat flood plains bounded by a series of terraces, which may be more than 100 feet higher than the stream channel.

The climate of the study basins ranges from moist subhumid to humid (Thornthwaite, 1952, p. 32). The boundary between the moist subhumid and humid belts extends across Camp and Titus Counties; east of the boundary the climate is humid. The average annual precipitation ranges from 42 inches in the west to 48 inches in the east and averages about 45 inches. Mean annual precipitation in the study basins and average (normal) monthly precipitation at two U.S. Weather Bureau stations are shown on Figure 2. Precipitation is fairly evenly distributed throughout the year with April and May usually the wettest months and August, September, and October the driest.

Runoff is defined as that part of the precipitation appearing in surface streams, and is the same as streamflow unaffected by artificial storage or diversion (Langbein and Iseri, 1960, p. 17). Temperature, seasonal distribution of rainfall, storm intensity, infiltration rates, channel configuration, and types and density of vegetation affect the amount of runoff from a drainage basin.

About one-fourth of the precipitation in the Sulphur River and Cypress Creek basins appears in the streams as runoff. The average annual runoff in the Sulphur River basin ranges from about 9 inches at the headwaters in Fannin County to about 13 inches at the Texas-Arkansas line. Annual runoff measured at the former gaging station Sulphur River near Darden for the 33-year period 1924-56 is given on Figure 2 as mean discharge in cubic feet per second and as inches per year. The average annual runoff was 1,670,000 acre-feet (11.2 inches) and ranged from a minimum of 353,100 acre-feet (2.4 inches) in 1925 to a maximum of 4,025,000 acre-feet (27.2 inches) in 1945.

The average annual runoff in the Cypress Creek basin ranges from about 11 to 16 inches but due to differences in physiography and surface geology does not vary in proportion to annual average rainfall. Annual runoff measured at the former gaging station Cypress Creek near Jefferson for the 35-year period 1925-59 is given on Figure 2 as mean discharge in cubic feet per second and as inches per year. The average annual runoff was 501,600 acre-feet (11.1 inches) and ranged from a minimum of 110,000 acre-feet (2.4 inches) in 1925 to a maximum of 1,346,000 acre-feet (29.7 inches) in 1958.

Population and Municipalities

The Sulphur River and Cypress Creek basins constitute about 2.4 percent of the area of Texas and have about 2.2 percent of the State's population. The population of the study basins in 1965 was about 222,000; 130,000 in the Sulphur River basin and 92,000 in the Cypress Creek basin. More than half of the people in the basins live in urban areas. The cities in the basin with populations of more than 2,500 are listed in the following table.

Sulphur River basin

CITY	POPULATION*	CITY	POPULATION*
Texarkana, Texas	31,490	New Boston	3,750
Sulphur Springs	10,400	Clarksville	3,700
Commerce	6,200		

Cypress Creek basin

CITY	POPULATION*	CITY	POPULATION*
Mt. Pleasant	10,450	Atlanta	4,100
Gilmer	4,560	Daingerfield	3,600
Pittsburg	4,120	Jefferson	2,900

* Population estimates for 1965, from Texas Almanac, 1966-67 edition.

Economic Development

Agriculture in the Sulphur River and Cypress Creek basins is limited chiefly to livestock raising and truck farming. Some cotton, grain, and livestock feed is grown mainly in the extreme western part of the Sulphur River basin.

Oil production and processing, lumbering and associated lumber processing plants, and various light manufacturing plants form the economic base in the central and eastern parts of the study basin. Hunting, fishing, and associated recreational activities have developed into substantial income producing activities, especially in the vicinity of Texarkana Reservoir, Lake O' the Pines, and Caddo Lake.

Development of Surface-Water Resources

The Sulphur River and Cypress Creek basins constitute only 2.4 percent of the total area of Texas but have 10 percent of the total runoff for the State. Figure 3 gives the average annual runoff, drainage area, and population of each major river basin in Texas, as percentages of the State totals. Only the Sabine and

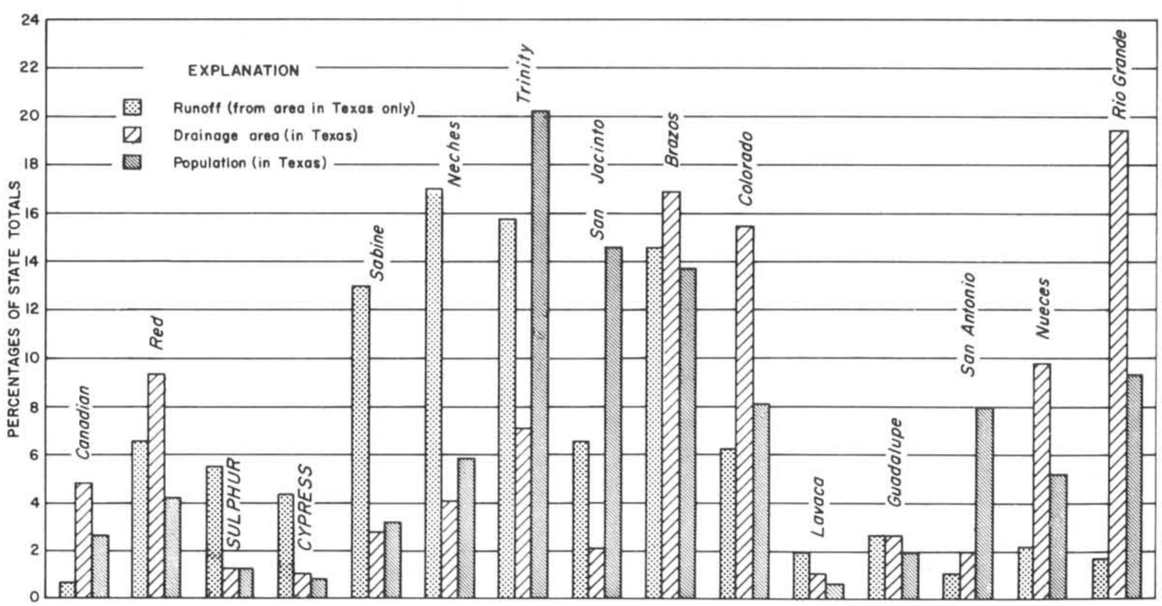

Figure 3.--Average Annual Runoff, Drainage Area, and 1960 Populations of Major River Basins in Texas, as Percentages of State Totals

Neches River basins have runoff-population ratios as favorable as the Sulphur River and Cypress Creek basins.

The surface-water resources of the study basins, especially the Sulphur River basin, are to a great extent undeveloped. Texarkana Reservoir, owned by the U.S. Army Corps of Engineers, is the largest reservoir in the area. Although the 2,654,300 acre-feet capacity reservoir was built primarily for flood control, it serves as a source of municipal supply for the cities of Texarkana, Texas, and Texarkana, Arkansas. Lake O' the Pines and Caddo Lake, both on Cypress Creek, are the only other large reservoirs. Table 1 lists all the reservoirs with more than 5,000 acre-feet capacity and gives their capacities and uses. Figure 4 shows the locations of the existing reservoirs, of Cooper Reservoir which Congress has authorized for construction, and a number of potential damsites which have been considered by various agencies.

The Soil Conservation Service of the U.S. Department of Agriculture administers a program designed to develop flood-prevention and land-treatment measures on subwatersheds having less than 250,000 acres in drainage area. In the Sulphur River basin, 24 floodwater-retarding structures partly controlling runoff from 56,700 acres have been constructed. Because of the small direct monetary damage from flooding, no floodwater-retarding structures have been constructed in the Cypress Creek basin.

CHEMICAL QUALITY OF THE WATER

Chemical-Quality Records

The collection of chemical-quality data on surface water of the Sulphur River and Cypress Creek basins by the U.S. Geological Survey began in 1947 when a sampling station was established on the Sulphur River near Darden. This station was discontinued in 1950, and no daily stations were operated until 1957 when a station was established on the South Sulphur River near Cooper. The Cooper station was discontinued in September 1966 and a new station, Sulphur River near Talco, was established.

Collection of chemical-quality data for this reconnaissance began in 1964 and continued through July 1967. Samples were collected periodically from most of the principal streams and reservoirs. Numerous miscellaneous samples have been collected by the U.S. Geological Survey in earlier years and the results of the analyses of these samples are included in this report. Discharge measurements were usually made when a sample was collected.

The periods of record of all data-collection sites are shown in Table 4 and the locations are shown on Figure 10. 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 reports of

Table 1.--Reservoirs with Capacities of 5,000 Acre-Feet or More in the Sulphur River and Cypress Creek Basins, December 31, 1967

(The purpose for which the impounded waters are used is indicated by the following symbols: M, municipal; I, industrial; FC, flood control; R, recreation.)

RESERVOIR	DATE COMPLETED	STREAM	CAPACITY[a] (ACRE-FEET)	OWNER	COUNTY	USE
River Crest	1953	Sulphur (off channel)	7,200	Texas Power & Light Co.	Red River	I
Texarkana	1957	Sulphur River	2,654,300	U.S. Army Corps of Engineers	Bowie, Cass, Morris, Titus, Red River	M,FC
Ellison Creek	1943	Ellison Creek	24,700	Lone Star Steel Co.	Morris	I
Johnson Creek	1961	Johnson Creek	10,100	Southwestern Electric Power Co.	Marion	I,R
Lake O' the Pines	1959	Cypress Creek	842,100	U.S. Army Corps of Engineers	Marion, Camp, Morris, Upshur, Harrison	M,I, FC,R
Caddo Lake	1914	Cypress Creek	175,000	do	Harrison, Marion	R

[a] Total capacity is that capacity below the lowest uncontrolled outlet or spillway and is based on the most recent reservoir survey available.

the Texas Water Development Board (see table in references). Results of all the periodic and miscellaneous analyses are given in Table 6.

The Texas State Department of Health makes available to the U.S. Geological Survey the data collected in its statewide stream-sampling program. The data-collection sites are listed in the following table. Most of them are at U.S. Geological Survey gaging stations and the numbers refer to locations on Figure 10.

REFERENCE NO.	TEXAS STATE DEPARTMENT OF HEALTH DATA-COLLECTION SITE
3	Sulphur River near Talco
10	White Oak Creek near Omaha
11	Sulphur River near Darden
..	Sulphur River near Maud
17	Cypress Creek near Pittsburg
21	Cypress Creek near Jefferson
..	Cypress Creek at Jefferson
24	Black Cypress Bayou near Jefferson
27	Little Cypress Creek near Jefferson

Streamflow Records

Streamflow in the Sulphur River and Cypress Creek basins was measured as early as 1924 when the U.S. Geological Survey established streamflow stations on the Sulphur River near Darden and on Cypress Creek near Jefferson. Over 30 years of continuous record was collected at both sites before the construction of reservoirs forced the discontinuance of both stations. In 1966 the Geological Survey operated 9 streamflow stations in the study basins, 5 of which have been operated for over 15 years. The U.S. Army Corps of Engineers maintains reservoir-content gages on Texarkana Reservoir and Lake O' the Pines and has made numerous discharge measurements at various sites in the study basins.

The periods of record for all the streamflow stations are given in Table 4 and the locations are shown on Figure 10. Records of discharge and stage of streams, and stage and contents of lakes and reservoirs from 1924 to 1960 have been published in the annual series of U.S. Geological Survey Water-Supply Papers (see table in references). Beginning with the 1960 water year, streamflow records have been released by the Geological Survey in annual reports on a State boundary basis (U.S. Geological Survey, 1961, 1962, 1963, 1964b, 1965, 1966). Summaries of discharge records giving monthly and annual totals have been published (U.S. Geological Survey, 1960, 1964a; Texas Board of Water Engineers, 1958).

Environmental Factors and Their Effects on the Chemical Quality of the Water

All water from natural sources contains mineral constituents dissolved from the rocks and minerals of the earth's crust. The water may run into streams quickly and dissolve only a small amount of material, or infiltrate to ground-water reservoirs and eventually be discharged to a stream and thereby be more mineralized. Many environmental factors determine the chemical quality of a water, the most important of which are geology, patterns and characteristics of streamflow, and the activities of man.

Waters usually are classified in various ways to illustrate similarities and differences in composition. In the following discussions which relate chemical quality of water to environmental factors, water is classified on the basis of geochemical type (principal chemical constituents) and hardness.

Waters are classified as to geochemical type on the basis of the predominant cations and anions in equivalents per million. For example, water is referred to as a sodium chloride type if the sodium ion constitutes 50 percent or more of the cations (positively charged ions) and the chloride ion constitutes 50 percent or more of the anions (negatively charged ions). Waters in which one cation and one anion are not clearly predominant are classified as mixed types and are identified by the names of all the major ions.

On the basis of hardness, waters are classified as follows: Soft, 0 to 60 ppm (parts per million) hardness; moderately hard, 61 to 120 ppm; hard, 121 to 180 ppm; and very hard, more than 180 ppm.

Geology

When industrial and municipal influences are small, the chemical character of a river water is dependent primarily on the mineral and physical properties of the geologic formations that are traversed and the time the water is in contact with the rocks.

The amount of minerals in the rocks and soils available for solution is decreased by leaching; therefore, in areas of high rainfall such as the Sulphur River and Cypress Creek basins, much of the readily soluble materials have been removed from the surface rocks and soils, and surface runoff usually contains less than 250 ppm dissolved solids. Ground-water inflow is more highly mineralized than surface runoff, but the base flow of most streams in the Sulphur River and Cypress Creek basins seldom exceeds 500 ppm dissolved solids.

Some streams in the Sulphur River and Cypress Creek basins drain outcrops of more than one geologic formation and the water is therefore a composite of several geochemical types. Also the mineral composition of a particular formation may differ from area to area.

Figure 5 shows the geochemical character and ionic concentration of some surface waters in the study basins. The equiaxial quadrilaterals depict the concentration of the ions in solution. The total ionic concentration in equivalents per million is equal to twice the length of either the vertical or horizontal axis. If the major part of the quadrilateral is in the lower left quarter, sulfate or chloride predominate among the anions and sodium or potassium among the cations. If the major part is in the upper right quarter, calcium or magnesium and carbonate or bicarbonate are predominant.

The North Sulphur River rises on sedimentary rocks of Late Cretaceous age composed mainly of fossiliferous sand, marl, and chalk. Water from this area is generally dilute and of a mixed type; calcium, sodium, bicarbonate, and sulfate are the principal ions and dissolved-solids content is usually near 250 ppm. The South Sulphur River rises on sedimentary rocks of Late Cretaceous age composed mainly of calcareous clay and limestone. Runoff from these rocks is a dilute, calcium bicarbonate type water. Downstream from the confluence of the North and South Forks, the Sulphur River drains Cretaceous and Tertiary rocks similar to those in the headwater reaches. Near Talco (site 3) the water is a mixed type, with calcium and bicarbonate the principal ions. Between Talco (site 3) and Darden (site 11) two large tributaries, Cuthand Creek and White Oak Creek, enter the river. Cuthand Creek drains Cretaceous and Tertiary rocks and contributes a relatively dilute water of a mixed type. White Oak Creek, which also drains Cretaceous and Tertiary rocks, is highly variable in quality, probably because of oil-field waste disposal in the watershed. The quality of the water in Texarkana Reservoir, however, has not been seriously affected by the sometimes poor-quality water from White Oak Creek.

Cypress Creek rises on Tertiary rocks composed mainly of sand, silt, clay, lignite, and glauconite. Limited data for Cypress Creek north of Pittsburg (site 16) indicate that the low flow is a sodium chloride type water usually containing near 250 ppm dissolved solids. Little Cypress Creek, which drains Tertiary rocks similar to those drained by Cypress Creek, contributes water that is lower in dissolved-solids content, but also of the sodium chloride type.

Streamflow

The patterns and characteristics of streamflow usually affect the chemical character of water in streams. In most streams where the flow is not regulated by upstream reservoirs, the concentrations of dissolved-mineral constituents vary inversely with the stage of the stream. The base flow, or sustained low flow, of a stream is predominantly water that has entered as ground-water effluent. Usually this water has been in contact with rocks and soils for a sufficient time to dissolve part of their soluble materials. Conversely, at high stages most of the flow of a stream consists of surface runoff that has been in contact with exposed rocks and soils for only a short time. Therefore, the dissolved-solids content of a stream is usually lowest during periods of high flow. This relationship is generally applicable to the water of the Sulphur River and Cypress Creek basins. Figure 6 shows the relationship of dissolved solids to water

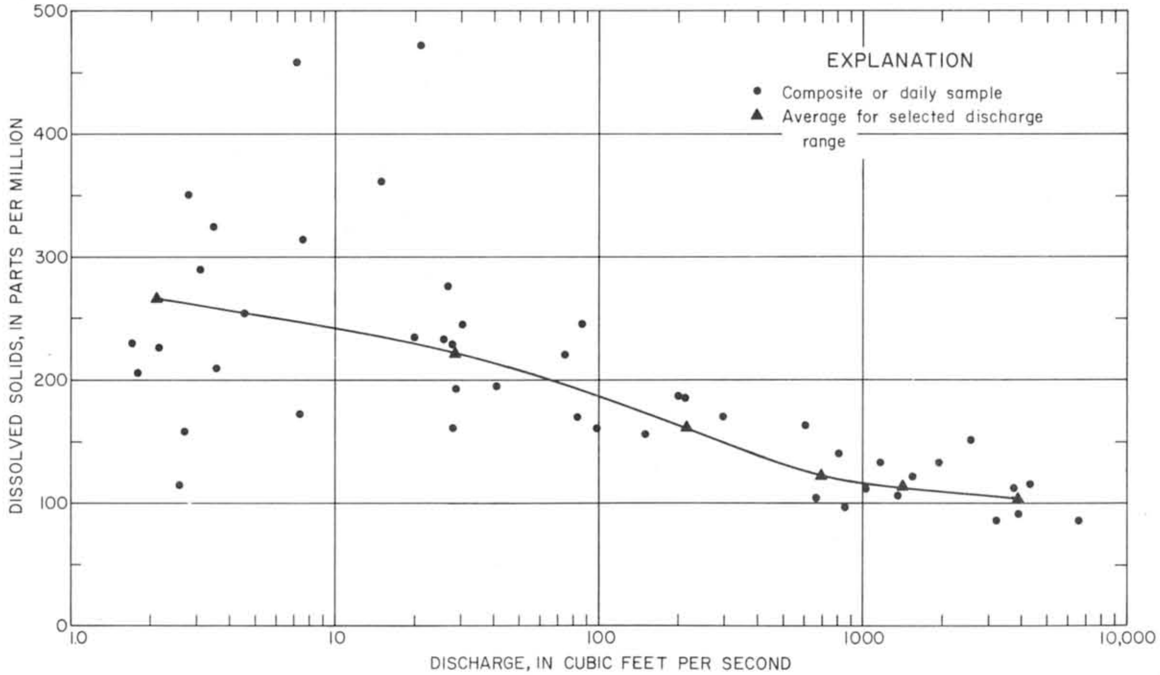

Figure 6.--Relation of Dissolved Solids to Water Discharge for South Sulphur River Near Cooper

discharge for the South Sulphur River near Cooper (site 1). Obviously the salt content has varied over relatively wide ranges, and the probability of accurately estimating chemical quality from water discharge is poor. However, the mean concentration within selected discharge ranges shows a definite trend in quality. Because ground-water inflow is small and the stream is subject to periods of no flow, the points are very scattered during low flows. Many of the low-flow values plotted occurred after a rise and do not represent ground-water inflow. Figure 7 shows duration curves of dissolved solids and water discharge for the same site (site 1). The duration curves are cumulative frequency curves that show percent of time which specified concentrations were equaled or exceeded and percent of time that water discharge was equal to or less than a specified discharge during a specified period. The steep slope of the flow-duration curve denotes a highly variable stream whose flow is largely from direct runoff. The curves also show the inverse relationship of rates of water discharge to the concentration of dissolved solids.

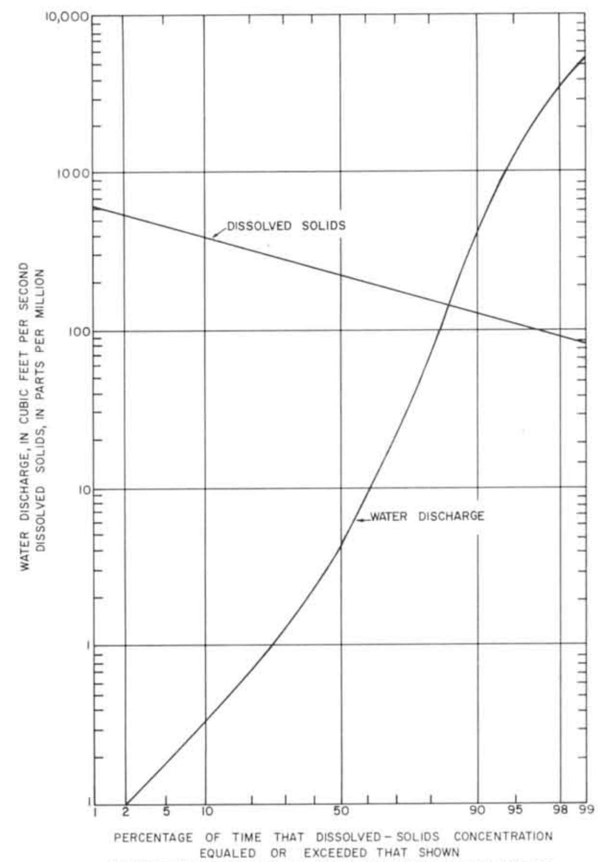

Figure 7.--Duration Curves for Dissolved Solids and Water Discharge for South Sulphur River Near Cooper Water Years 1959-66

Activities of Man

The activities of man often have a deteriorative effect on the chemical quality of water. Oil-field brine, municipal and industrial wastes, and irrigation return flows increase the concentration of dissolved materials in streams.

Brine is produced in nearly all oil fields and it may, if improperly handled, eventually reach the streams. The composition of oil-field brine varies; but the principal chemical constituents in order of magnitude of their concentration (in ppm) are generally chloride, sodium, calcium, and sulfate. The Texas Water Commission and Texas Water Pollution Control Board (1963) compiled an inventory conducted by the Texas Railroad Commission which showed that approximately 80 million barrels (10,800 acre-feet) of brine was produced in 1961 in the Sulphur River and Cypress Creek basins. Oil is produced in several areas in the study basins (see Figure 10), but most of the brine reported by the Texas Water Commission was produced in the Talco field in northern Franklin and Titus Counties and in the East Texas field in southeastern Upshur County. Although almost 99 percent of the brine in both fields is reinjected into the subsurface, some deterioration of water quality is occurring in both areas. Chemical analyses of samples from White Oak Creek near Mount Vernon (site 8) and near Omaha (site 10) strongly indicate that oil-field brines are reaching that stream. The Sulphur River also receives runoff from the Talco field but is not affected as seriously as White Oak Creek. Smith, Montgomery, and Blakey (1966) reported that saline inflows to Little Cypress Creek apparently resulted from oil-field activity in that watershed. The photographs in Figure 8 show the effects of oil-field brines in the Glade Creek subbasin. Glade Creek empties into Little Cypress Creek just downstream from the Ore City streamflow station (site 25).

Relation of Quality of Water to Use

Quality-of-water studies usually are concerned with determining the suitability of water—judged by the chemical, physical, and biological characteristics—for its proposed use. In the Sulphur River and Cypress Creek basins, surface water is used primarily for municipal and industrial supplies and a limited amount is used for irrigation. This report considers only the chemical character of the water and its relation to the principal uses.

All natural water contains dissolved-mineral matter. Most of this mineral matter in water is dissociated into charged particles, or ions. Principal cations (positive charged) in natural water are calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), and iron (Fe). The principal anions (negative charged) are carbonate (CO_3), bicarbonate (HCO_3), sulfate (SO_4), chloride (Cl),

Oil-well site showing brine pollution which is killing vegetation and contributing to soil erosion.

Brine disposal pond adjacent to Glade Creek showing the devastating effects of polluted surface water.

Figure 8.--Effects of Oil-Field Pollution in the Little Cypress Creek Watershed

fluoride (F), and nitrate (NO_3). Other constituents and properties are often determined to help define the chemical and physical quality of water. Table 2 lists the constituents and properties commonly determined by the U.S. Geological Survey, and includes a résumé of their sources and significance.

Domestic Purposes

Because of differences in individuals, varying amounts of water used, and other factors, it is difficult to define the safe limits for the mineral constituents usually found in water. The limits usually accepted in the United States for drinking water are the drinking-water standards established by the U.S. Public Health Service. Originally established in 1914 to control the quality of water used on interstate carriers for drinking and culinary purposes, these standards have been revised several times. The latest revision was in 1962 (U.S. Public Health Service, 1962). These standards have been accepted by the American Water Works Association and by most of the state departments of public health as minimum standards for all public water supplies.

The maximum concentrations permitted by these standards are given for selected constituents in the following table:

CONSTITUENT	MAXIMUM CONCENTRATION (PPM)
Sulfate	250
Chloride	250
Nitrate	45
Fluoride	.9[a]
Dissolved solids	500

[a] Based on temperature records for Clarksville.

In the Sulphur River and Cypress Creek basins the concentrations of these constituents are considerably lower than the maximum concentrations recommended.

Industrial Use

The quality requirements vary greatly for almost every industrial application, as is indicated by the water-quality tolerances given in Table 3. One requirement of most industries is that the concentrations of the various constituents in the water remain relatively constant. When concentrations of undesirable substances in water vary, constant monitoring is required.

Hardness is one of the more important properties of water that affects its utility for industrial purposes. Excessive hardness is objectionable because it contributes to the formation of scale in steam boilers, pipes, water heaters, radiators, and various other equipment where water is heated, evaporated, or treated with alkaline materials. The accumulation of scale increases costs for fuel, labor, repairs, and replacement, and lowers the quality of many wet-processed products. However, some calcium hardness may be desirable because calcium carbonate sometimes forms protective coatings on pipes and other equipment and reduces corrosion.

The corrosive property of a water receives considerable attention in industrial water supplies. A high concentration of dissolved solids in a water may be closely associated with the corrosive property of the water especially if chloride is present in appreciable quantities. Water that contains a high concentration of magnesium chloride may be highly corrosive because the hydrolysis of this salt yields hydrochloric acid.

Surface water of the Sulphur River and Cypress Creek basins is relatively low in dissolved solids and only moderately hard, therefore very little treatment is necessary to make it suitable for use by many industries.

Irrigation

The chemical composition of a water is an important factor in determining its usefulness for irrigation because the irrigation water should not adversely affect the productivity of the land. The extent to which chemical quality limits the suitability of a water for irrigation depends on factors such as: the nature, composition, and drainage of the soil and subsoil; the amounts of water used and the methods of application; the kind of crops grown; and the climate of the region, including the amounts and distribution of rainfall. Because these factors are highly variable, every method of classifying water for irrigation is somewhat arbitrary.

The most important characteristics in determining the quality of irrigation water, 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) the excess of equivalents of bicarbonate over equivalents of calcium plus magnesium.

High concentration of dissolved salts in irrigation water may cause a buildup of salts in the soil solution, and may make the soil saline. The increased salinity of the soil may drastically reduce crop yields by decreasing the ability of the plants to take up water and essential plant nutrients from the soil solution. The tendency of irrigation water to cause a high buildup of salts in the soil is called the salinity hazard of the water. The specific conductance of the water is used as an index of the salinity hazard.

Table 2.--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 in 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 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 inter-crystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.
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 non-carbonate 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.

Table 3.--Water-Quality Tolerances for Industrial Applications [1]

[Allowable Limits in Parts per Million Except as Indicated]

INDUSTRY	TUR-BID-ITY	COLOR	COLOR + O_2 CON-SUMED	DIS-SOLVED OXYGEN (ml/l)	ODOR	HARD-NESS	ALKA-LINITY (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	GEN-ERAL [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 [7]	--	--	--	--	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 compositions 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.

High concentrations of sodium relative to the concentrations of calcium and magnesium in irrigation water can adversely affect soil structure. Cations in the soil solution become fixed on the surface of the soil particles; calcium and magnesium tend to flocculate the particles, whereas sodium tends to deflocculate them. This adverse effect on soil structure caused by high sodium concentrations in an irrigation water is called the sodium hazard of the water. An index used for predicting the sodium hazard is the sodium-adsorption ratio (SAR), which is defined by the equation:

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

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

The U.S. Salinity Laboratory Staff has prepared a classification for irrigation waters in terms of salinity and sodium hazards. Empirical equations were used in developing a diagram, reproduced in modified form as Figure 9, which uses SAR and specific conductance in classifying irrigation waters. With respect to salinity and sodium hazards, waters are divided into four classes: low, medium, high, and very high. The classification range encompasses those waters which can be used for irrigation of most crops on most soils as well as those which are generally unsuitable for irrigation.

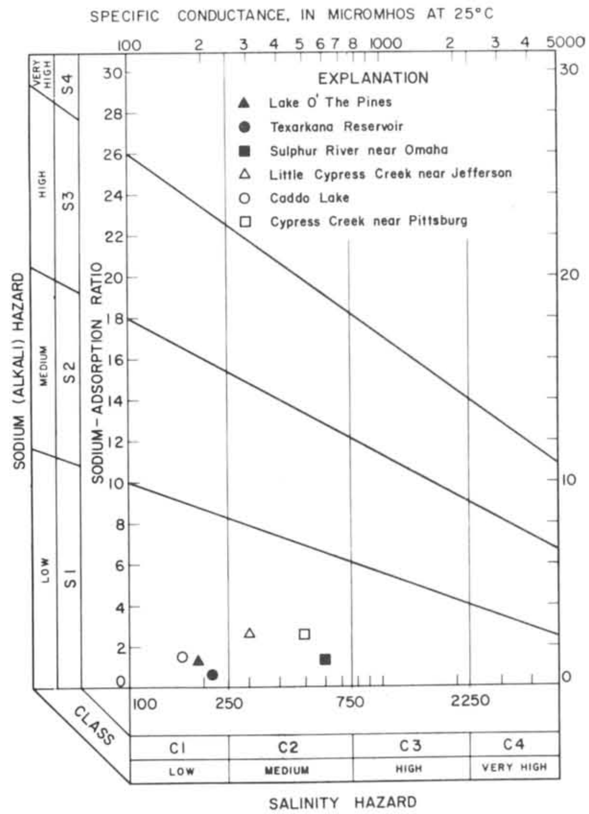

Figure 9.--Classification of Irrigation Waters

Representative data from analyses of water from different sources in the Sulphur River and Cypress Creek basins are plotted in Figure 9. The data show that the sodium and salinity hazards are low or medium for all surface water in the basins.

Geographic Variations in Water Quality

Variations in dissolved solids, hardness, and chloride in the streams in the Sulphur River and Cypress Creek basins are shown in Figures 11, 12, and 13. These values are based on the discharge-weighted average concentrations as calculated from chemical-quality data. The discharge-weighted average represents approximately the chemical character of the water if all the water passing a point in the stream were impounded in a reservoir and mixed, with no adjustments for evaporation, rainfall, or chemical changes that might occur during storage. For many of the streams chemical-quality data are limited, especially data on flood flows. All the streams will at times have concentrations exceeding those shown, but the averages shown on the maps at a potential reservoir site are indicative of the type of water that would be stored in a reservoir.

Dissolved Solids

The concentration of dissolved solids in surface water of the Sulphur River and Cypress Creek basins is generally less than 250 ppm (Figure 11). The North Sulphur River generally has dissolved-solids concentrations of near 250 ppm. The South Sulphur River usually has concentrations of between 100 and 150 ppm. The weighted-average concentration for the period 1959-65 was 140 ppm. Drainage from the Talco oil field slightly degrades the water of the Sulphur River and White Oak Creek, but good-quality inflow downstream from the oil field, and flood runoff, is of sufficient quantity so that the dissolved-solids content of Texarkana Reservoir is usually less than 150 ppm.

In the upper reaches of Cypress Creek, low and moderate flows frequently contain more than 250 ppm dissolved solids. Chemical-quality data on flood flows are lacking, but Lake O' the Pines usually contains about 100 ppm dissolved solids indicating that high flows are of excellent quality. Little Cypress Creek generally contains less than 150 ppm dissolved solids. Oil-field drainage is degrading Little Cypress Creek in northern Gregg County but the effect is minor when considering weighted averages. Tributary inflow in the eastern part of the Cypress Creek basin usually contains less than 100 ppm dissolved solids.

Chloride

The chloride content of surface waters of the Sulphur River and Cypress Creek basins is generally less than 25 ppm (Figure 12). The North Sulphur and Sulphur Rivers contain less than 25 ppm chloride throughout their reach and the South Sulphur River contains less than 10 ppm. White Oak Creek contains less than 25 ppm chloride upstream from the Talco oil field and between 50 and 100 ppm downstream. The headwater reaches of Cypress Creek contain slightly more than 25 ppm chloride but downstream from Pittsburg better quality inflow decreases the concentration to less than 25 ppm. Little Cypress Creek contains less than 25 ppm upstream from the oil field in northern Gregg County and more than 50 ppm downstream. Tributary streams in the eastern part of the basin generally contain less than 25 ppm chloride.

Hardness

Surface water of the study basins generally ranges from soft to hard (Figure 13). The South Sulphur, North Sulphur, and Sulphur Rivers are moderately hard throughout most of their course. White Oak Creek contains hard water throughout its course. Cypress Creek has moderately hard water in its upper reaches, but downstream from Pittsburg, Cypress Creek and all its tributaries have soft water.

Other Constituents

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

Most of the streams in the Sulphur River basin contain less than 10 ppm silica and most of the streams in the Cypress Creek basin contain less than 20 ppm.

Sodium concentrations are generally less than 50 ppm in most of the streams. In those waters having high chloride concentrations, sodium occurs in larger quantities. It is, therefore, present in highest concentrations in those areas affected by oil-field brine.

Bicarbonate is the principal anion in most waters of the Sulphur River basin. Bicarbonate concentrations are subject to considerable variation and although concentrations of over 200 ppm are not uncommon, the weighted-average concentration is usually less than 150 ppm. In the Cypress Creek basin, bicarbonate concentrations are much lower, always averaging less than 50 ppm.

Sulfate concentrations are generally less than 50 ppm in both basins, although higher concentrations are found in those streams receiving oil-field drainage. Tributary inflow in the eastern part of the basins usually contains less than 10 ppm sulfate.

Fluoride and nitrate concentrations are low throughout the study basins; fluoride concentrations seldom exceed 0.5 ppm, and nitrate concentrations are generally less than 2.0 ppm.

Water Quality in Reservoirs

The principal reservoirs in the basins were sampled during the reconnaissance and the chemical analyses are given in Table 6. Analyses are also available for some of the small reservoirs used for public supply (Sundstrom and others, 1948).

Texarkana Reservoir.—Texarkana Reservoir was built primarily for flood-control purposes, but also provides municipal water for the cities of Texarkana, Texas, and Texarkana, Arkansas. Three analyses during 1966 show that the water usually contains between 100 and 150 ppm dissolved solids, is moderately hard (61 to 120 ppm), and usually contains about 15 to 20 ppm chloride and about 20 ppm sulfate.

Ellison Creek and Johnson Creek Reservoirs.—These privately owned reservoirs supply industrial water for the Lone Star Steel plant and cooling water for two steam-electric plants. Chemical analyses of the stored water are not available, but the water should be similar to that stored in Lake O' the Pines.

Lake O' the Pines.—The water in Lake O' the Pines is of good quality as shown in one analysis in 1965 and two in 1966. In August 1965 and January 1966, the water contained about 100 ppm dissolved solids, but in July 1966, the dissolved-solids content was 60 ppm and most constituents were only about half the January concentrations.

Water Quality at Potential Reservoir Sites

One of the purposes of the reconnaissance was to appraise the quality of the water which will be available for storage in future reservoirs. These evaluations are based on present conditions. Population growth, industrial expansion, and the continuing development of water resources will cause significant changes in the quality of the water that can be impounded.

Cooper.—A reservoir on the South Sulphur River at the Cooper site would impound water of excellent quality. Records for the daily sampling station South Sulphur River near Cooper indicate that the impounded water would be a calcium bicarbonate type and contain less than 150 ppm dissolved solids, less than 10 ppm chloride, less than 20 ppm sulfate, and be moderately hard.

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Sulphur Bluff 1.—Sulphur Bluff 1 would be immediately downstream from Cooper Reservoir and should store water of generally the same quality as that impounded in Cooper Reservoir.

Sulphur Bluff 2.—The waters of the North Sulphur River impounded at Sulphur Bluff 2 would be moderately hard and contain about 250 ppm dissolved solids.

Naples 1.—A reservoir on the Sulphur River at the Naples 1 site would store water containing less than 250 ppm dissolved solids. The water would be hard and of a mixed type.

Naples 2.—The Naples 2 site is on White Oak Creek which is receiving oil-field drainage. Water stored at this site would be of acceptable quality for municipal uses if natural runoff from the area continues to be of sufficient quantity to dilute the oil-field wastes.

Texarkana Enlargement.—The enlargement of Texarkana Reservoir should not cause significant change in the quality of the water stored. The water should still be moderately hard and contain less than 150 ppm dissolved solids.

Franklin County and Titus County.—These adjoining reservoirs on Cypress Creek would store a sodium sulfate chloride type water containing less than 250 ppm dissolved solids.

Marshall.—A reservoir on Little Cypress Creek at the Marshall site would store a sodium chloride type water containing less than 150 ppm dissolved solids.

Black Cypress.—According to periodic chemical-quality data for Black Cypress Bayou near Jefferson, water impounded at the Black Cypress site would be low in all dissolved constituents and contain less than 100 ppm dissolved solids.

Problems Needing Additional Investigation

This reconnaissance of the chemical quality of surface water in the Sulphur River and Cypress Creek basins has shown that, in general, the basins are remarkably free of water-quality problems. Specifically, two streams—White Oak Creek near Talco, and Little Cypress Creek downstream from the Ore City streamflow station—show indications of pollution. High chloride concentrations in low-flow waters in these streams indicate that oil fields may be contributing brine to the watersheds.

Most of the brine produced in the Sulphur River and Cypress Creek basins is reportedly reinjected into wells. Waterflooding in oil fields and reinjection of brines should be carefully watched to ensure that brine does not enter fresh ground-water supplies or surface streams.

Continued municipal and industrial use in the larger cities in the basins will cause an increase in the waste-disposal burdens of the streams and impoundment of water in reservoirs will cause a reduction of streamflow now utilized for the assimilation of wastes.

Impoundment of water will result in some changes of water quality. Beneficial effects will include: the reduction of turbidity, silica, color, and coliform bacteria; the evening out of sharp variations in chemical quality; the entrapment of sediment; and a reduction in temperature. On the other hand, detrimental effects will include an increased growth of algae and a reduction of dissolved oxygen. As the water resources of the basins are extensively developed, the magnitude and significance of the probable changes in water quality will necessitate studies of the resulting problems.

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YEAR	WATER-SUPPLY PAPER NO.
1924	587
1925	607
1926	627
1927	647
1928	667
1929	687
1930	702
1931	717
1932	732
1933	747
1934	762
1935	787
1936	807
1937	827
1938	857
1939	877
1940	897
1941	927
1942	957
1943	977
1944	1007
1945	1037
1946	1057
1947	1087
1948	1117
1949	1147
1950	1177
1951	1211
1952	1241
1953	1281
1954	1341
1955	1391
1956	1441
1957	1511
1958	1561
1959	1631
1960	1711

Quality-of-water records for the Sulphur River and Cypress Creek basins are published in the following U.S. Geological Survey Water-Supply Papers and Texas Water Development Board reports (including reports formerly published by the Texas Water Commission and Texas Board of Water Engineers):

WATER YEAR	U.S.G.S. WATER-SUPPLY PAPER NO.	TWDB REPORT NO.
1947	1102	*1947
1948	1133	*1948
1949	1163	*1949
1950	1188	*1950
1951	1199	*1951
1952	1252	*1952
1953	1292	*1953
1954	1352	*1954
1955	1402	*1955
1956	1452	Bull. 5905
1957	1522	Bull. 5915
1958	1573	Bull. 6104
1959	1644	Bull. 6205
1960	1744	Bull. 6215
1961	1884	Bull. 6304
1962	1944	Bull. 6501
1963	1950	Rept. 7

* "Chemical Composition of Texas Surface Waters" was designated only by water year prior to 1956.

Table 4.--Index of Surface-Water Records in the Sulphur River and Cypress Creek Basins

Reference No.	Stream and Location	Drainage area (Sq. miles)	Type and period of record					
			Daily chemical quality	Discharge	Periodic chemical quality	Periodic discharge measurements	Reservoir contents	Water temperature
	SULPHUR RIVER BASIN							
1	South Sulphur River near Cooper	527	1958-66	1942-66				1949-66
2	North Sulphur River near Cooper	276		1949-66	1950, 1958			1949-66
3	Sulphur River near Talco	1,365		1956-66	1965-66			1956-66
4	Cuthand Creek near Bogata	69		1963-66				1963-66
5	Cuthand Creek south of Clarksville	--			1965-66	1965-66		
6	Kickapoo Creek south of Clarksville	--			1965-66	1965-66		
7	Sulphur River north of Omaha	--			1960, 1965-66	1965-66		
8	White Oak Creek near Mount Vernon	--			1965-66	1965-66		
9	White Oak Creek near Talco	494		1949-66				1949-66
10	White Oak Creek near Omaha	--			1965-66	1965-66		
11	Sulphur River near Darden	2,774	1947-50	1923-54				1949-54
12	Caney Creek Reservoir near Redwater	--			1952, 1962 1964-65			
13	Caney Creek near Redwater	18.0			1961-62	1958-62		
14	Texarkana Reservoir near Texarkana	3,443			1957, 1966		1953-66	
15	Aiken Creek near Texarkana	12.2				1958-61		
	CYPRESS CREEK BASIN							
16	Cypress Creek north of Pittsburg	--			1965-66	1965-66		
17	Cypress Creek near Pittsburg	366		1943-63				1949-63
18	Boggy Creek near Daingerfield	72		1943-66				1949-66
19	Ellison Creek Reservoir near Daingerfield	37					1943-62	
20	Lake O' the Pines near Jefferson	850			1965-66		1957-66	
21	Cypress Creek near Jefferson	850		1924-61				
22	Kelly Creek near Marietta	50.5			1942 1961-62	1958-62		
23	Hughes Creek near Avinger	49			1961-62	1958-62		
24	Black Cypress Bayou near Jefferson	365			1965-66	1964-66		
25	Little Cypress Creek near Ore City	383		1962-66	1965-66			
26	Moccasin Creek near Harleton	30			1961-62	1958-62		
27	Little Cypress Creek near Jefferson	675		1946-66	1964-66			1949-66
28	Prewitt Creek near Karnack	19			1961-62	1958-62		
29	Kitchens Creek near Smithland	27				1958-62		
30	Jims Bayou near Kildare	82.9				1958-62		
31	Frazier Creek near Linden	47.9				1958-62		
32	Frazier Creek near McLeod	199				1964-65		
33	Black Bayou near Atlanta	52.1			1961-62	1958-62		
34	Caddo Lake	--			1952-56 1958-63			

Table 5.--Summary of Chemical Analyses at Daily Stations on Streams in the Sulphur River and Cypress Creek Basins

(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.)

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)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25° C)	pH
1. SOUTH SULPHUR RIVER NEAR COOPER																						
Water year 1959																						
Maximum, Nov. 18-20,1958.	11.7	10		55	6.7	103		139	60	148	0.6	1.2		452	0.61	14.3	164	50	58	3.5	815	7.6
Minimum, Apr. 17-21,1959.	583	12		23	2.9	15		78	23	7.5	.4	3.2		125	.17	197	69	5	32	.8	208	7.6
Weighted average..	91.2	13		32	3.2	21		106	26	14	.5	3.7		167	.23	41.1	93	6	33	.9	285	--
Water year 1960																						
Maximum, Nov. 1, 1959............	19.0	16		88	9.1	328		182	36	555	--	2.2		1120	1.52	57.5	257	108	74	8.9	2040	8.2
Minimum, Jan. 6-8, 1960..	3396	9.4		19	2.4	12		75	13	4.0	.6	1.0		98	.13	899	57	0	31	.7	164	7.4
Weighted average..	339	11		28	2.9	17		98	21	9.7	.4	3.1		143	.19	131	82	1	31	.8	236	--
Water year 1961																						
Maximum, Feb. 1-5, 1961..	18.2	12		113	14	75		361	112	61	.3	2.5		592	.81	29.1	340	44	32	1.8	911	7.6
Minimum, Dec. 8-14,1960..	6225	8.8		18	2.3	6.9	2.9	64	9.2	4.0	.4	1.0		84	.11	1410	54	2	21	.4	141	7.0
Weighted average..	387	9.7		27	2.8	14		92	18	8.9	.4	1.4		129	.18	135	79	3	28	.7	220	--
Water year 1962																						
Maximum, Nov. 11-21,1961.	.4	9.4		54	6.7	127		240	110	88	.6	1.5		529	.72	.57	162	0	63	4.3	877	6.9
Minimum, June 28-30,1962.	3603	14		17	1.1	8.2		61	8.2	2.8	--	2.8		84	.11	817	47	0	28	.5	124	7.2
Weighted average..	331	13		27	2.8	14		93	18	8.1	--	3.2		134	.18	120	79	6	28	.7	220	7.0
Water year 1963																						
Maximum, Nov. 9, 1962....	7.3	12		100	10	326		168	41	580	--	.8		1150	1.56	22.7	290	153	71	8.3	2130	7.6
Minimum, Nov. 26-30.	3668	11		26	2.2	11		85	17	6.5	--	2.0		118	.16	1170	74	4	25	.6	204	6.4
Weighted average..	156	12		32	3.2	17		103	26	12	--	3.2		159	.22	77.0	92	8	30	.8	258	6.7
Water year 1964																						
Maximum, May 9, 1964.....	166	11		103	8.5	175		184	46	335	--	1.8		770	1.05	345	292	141	57	4.4	1400	7.7
Minimum, May 30-31.	3945	6.1		21	2.8	11		70	17	7.4	--	2.0		101	.14	1076	64	7	27	.6	176	6.8
Weighted average..	134	9.9		28	3.3	14		93	19	7.9	--	1.3		134	.18	82.0	84	3	38	.7	227	7.2
Water year 1965																						
Maximum, Mar. 10-31,1965.	21.2	9.2		100	14	56		340	78	48	--	1.0		473	.64	27.1	307	28	28	1.4	781	7.7
Minimum, Feb. 8-14	6717	7.9		18	2.7	6.3	2.5	66	10	2.8	--	3.8		86	.12	1560	56	2	22	.4	144	7.6
Weighted average..	430	9.0		24	2.8	82		82	15	5.0	--	2.8		111	.15	142	70	2	23	.5	188	6.9
11. SULPHUR RIVER NEAR DARDEN																						
Water year 1948																						
Maximum, Aug. 1, 1948	152	10		111	33	1150		76	477	1670		4.0		3570	4.75	1430	412	350	86		5910	--
Minimum, Dec. 16-27,1947.	11940	--		20	4.1	13		64	30	7.0		1.2		107	.15	3450	67	14	29		160	--
Weighted average..	2905	--		27	3.8	21		81	26	22		1.9		171	.23	1340	83	17	35		253	--
Water year 1949																						
Maximum, Oct. 24, 27-31, 1948.....	23.7	7.5		194	52	1970		158	733	2900		--		5930	8.06	379	698	568	86		10000	--
Minimum, Jan. 26-31......	28750	5.8		17	1.5	14		66	10	10		1.0		122	.17	9470	49	0	39		150	--
Weighted average..	2225	7.3		24	3.5	22		81	20	25		1.1		168	.23	1010	74	8	39		252	--

Table 6.--Chemical Analyses of Streams and Reservoirs for Locations Other Than Daily Stations

(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)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25° C)	pH
2. NORTH SULPHUR RIVER NEAR COOPER																						
July 20, 1950	2.6	6.4	--	41	3.8	32		94	77	21	--	0.0		244	0.33		118	41	37	1.3	390	7.8
July 22	1820	9.8	--	41	2.0	23		120	41	13	--	1.5		209	.28		110	12	31	1.0	322	7.7
July 27	3770	11	--	53	4.2	26		158	61	8.0	--	3.0		252	.34		150	20	28	.9	391	7.8
Aug. 7	5.6	11	--	53	5.2	42		146	79	30	--	.0		296	.40		154	34	37	1.5	485	7.9
Sept. 26, 1958	.8	13	--	70	8.1	73		81	210	57	--	.5		472	.64		208	142	43	2.2	751	7.8
Jan. 16, 1967	2.73	3.9	--	95	9.4	75	2.6	196	190	62	0.3	.0		534	.73		276	115	37	2.0	853	7.2
Feb. 21	6.33	6.2	--	84	7.4	60	2.5	162	171	43	.5	1.0		456	.62		240	107	35	1.7	724	7.2
Apr. 7	3.56	3.1	--	61	6.5	60	2.8	126	140	42	.3	.0		378	.51		178	75	42	2.0	622	7.3
May 5	139	10	--	67	4.0	25	2.8	182	64	16	.6	1.2		280	.38		184	34	23	.8	456	8.0
3. SULPHUR RIVER NEAR TALCO																						
Jan. 6, 1965	62.5	7.7	--	52	7.4	23		149	58	19	0.4	0.2		241	0.33		160	38	24	0.8	410	7.9
Mar. 17	60	6.5	--	90	9.6	51		230	121	41	.4	1.0		434	.59		264	76	30	1.4	742	7.2
Apr. 22	13.6	4.9	--	100	9.4	63		264	133	49	.4	.0		490	.67		288	72	32	1.6	828	7.2
May 26	63.8	11	--	68	6.0	33		199	69	21	.3	.2		306	.42		194	31	27	1.0	526	6.8
July 8	2.2	10	--	73	5.6	44		220	72	31	.5	.2		344	.47		205	24	32	1.3	585	7.2
Sept. 25	843	7.8	--	37	2.1	13		118	22	5.3	.3	1.2		147	.20		101	4	22	.6	255	6.6
Nov. 30	1.0	8.0	--	88	8.9	60	3.8	270	104	46	.4	.0		452	.61		256	34	33	1.6	758	7.1
Jan. 5, 1966	11.4	2.7	--	98	9.1	100	3.6	230	191	80	.4	.0		598	.81		282	91	43	2.6	986	7.6
Feb. 15	193	6.6	--	40	3.6	14	3.3	126	31	7.7	.2	2.0		170	.23		115	11	20	.6	299	6.8
Mar. 16	33.1	6.8	--	76	6.5	51	3.9	196	113	33	.5	.8		388	.53		216	56	33	1.5	634	8.0
5. CUTHAND CREEK SOUTH OF CLARKSVILLE																						
July 7, 1965	.1	11	--	90	5.5	39		203	99	43	0.4	0.2		388	0.53		247	80	25	1.1	646	7.3
Sept 23	27.3	5.1	--	21	.9	6.6	2.9	59	17	5.3	.1	.2		88	.12		56	8	19	.4	154	6.3
Jan. 4, 1966	3.2	9.3	--	27	1.9	65	4.9	130	45	43	.3	11		271	.37		75	0	63	3.3	480	6.7
Feb. 8	3.1	2.5	--	41	3.1	38	2.9	141	45	27	.3	.2		229	.31		115	0	41	1.5	409	7.5
Apr. 19	1.6	5.7	--	119	6.6	167	4.0	418	159	134	.7	.8		803	1.09		324	0	52	4.0	1340	7.2
July 20	.1	12	--	122	8.6	116	3.3	196	230	130	.3	.0		718	.98		340	180	42	2.7	1140	7.4
Jan. 17, 1967	1.75	10	--	93	5.2	53	4.4	198	125	54	.2	.2		442	.60		254	91	31	1.4	719	7.0
Apr. 8	1.87	7.5	--	99	6.2	92	5.0	306	114	70	.6	.2		544	.74		272	22	42	2.4	885	7.5
6. KICKAPOO CREEK SOUTH OF CLARKSVILLE																						
July 7, 1965	9.2	13	--	43	2.6	25		137	26	22	0.3	0.5		199	0.27		118	6	31	1.0	329	7.3
Sept. 24	.8	8.6	--	25	1.4	23		60	21	33	.1	.5		143	.19		68	19	42	1.2	258	6.3
Jan. 4, 1966	7.0	6.9	--	17	1.6	13	4.2	48	13	20	.5	.5		101	.14		49	10	34	.8	188	6.4
Feb. 8	.1	8.6	--	32	2.6	17	3.2	75	33	24	.1	.8		158	.21		91	29	28	.8	278	6.5
Apr. 19	.4	10	--	64	4.7	42	3.8	122	86	58	.3	.8		330	.45		179	79	33	1.4	564	6.9
Nov. 8	.11	8.4	--	72	4.6	39	5.2	174	60	58	.1	.5		334	.45		198	56	29	1.2	570	7.3
Jan. 17, 1967	1.48	17	--	48	4.0	28	4.5	102	61	38	.1	.2		251	.34		136	53	30	1.0	417	6.8
Apr. 8	.74	15	--	65	5.8	47	4.3	162	64	64	.3	.2		346	.47		186	53	35	1.5	591	7.1
Apr. 27	219	8.2	--	22	1.6	5.3	3.0	68	10	5.8	.1	.5		90	.12		62	6	15	.3	154	6.6

Table 6.--Chemical Analyses of Streams and Reservoirs for Locations Other Than Daily Stations--Continued

(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)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25° C)	pH
7. SULPHUR RIVER NORTH OF OMAHA																						
Mar. 18, 1960	--	6.8	--	41	4.0	22		115	45	17	0.2	0.8		194	0.26		119	24	29	0.9	324	7.2
Jan. 12, 1965	3420	7.3	--	32	4.4	10		108	17	9.2	.4	.2		134	.18		98	9	19	.4	233	7.8
Mar. 18	304	7.2	--	64	4.7	29		164	68	25	.3	.8		280	.38		179	45	26	.9	490	7.0
Apr. 23	32.1	4.9	--	89	7.3	50		237	102	42	.4	.2		413	.56		252	58	30	1.4	711	7.3
May 27	282	12	--	52	4.2	17		167	30	11	.3	.2		209	.28		147	10	20	.6	365	6.7
Sept. 26	1630	7.9	--	41	2.4	20		128	33	9.9	.4	1.8		179	.24		112	7	28	.8	315	6.5
Jan. 6, 1966	50.0	6.1	--	30	.8	29	4.0	84	16	41	.3	1.0		169	.23		78	9	43	1.4	310	6.7
Apr. 21	18.4	2.8	--	92	7.1	59	4.2	234	114	54	.4	.0		448	.61		258	66	33	1.6	763	7.3
June 17	--	9.8	--	60	3.4	10	3.6	199	13	7.0	.4	1.0		206	.28		164	1	11	.3	361	7.4
July 22	10.4	3.8	--	69	3.2	52	3.3	158	112	41	.0	1.0		364	.50		194	64	36	1.6	621	7.0
Aug. 25	25.4	6.5	--	46	2.7	13	3.4	146	24	7.2	.4	1.8		177	.24		126	6	18	.5	311	6.9
Jan. 20, 1967	13.9	7.9	--	67	5.4	79	4.7	152	58	126	.2	.0		423	.58		189	64	47	2.5	751	7.5
8. WHITE OAK CREEK NEAR MOUNT VERNON																						
Feb. 25, 1965	10.8	7.3	--	13	4.8	22		34	31	24	1.0	3.2		123	.17		52	24	47	1.3	223	6.7
Mar. 18	43.9	1.3	--	22	10	42		42	83	46	.6	.8		227	.31		96	62	49	1.9	422	6.3
Apr. 23	22.1	7.3	--	22	9.0	44		59	66	40	2.0	10		299	.41		92	44	51	2.0	407	6.4
May 27	46.7	16	--	25	12	42		57	85	46	.7	1.2		256	.35		112	65	45	1.7	448	6.3
Sept. 26	62.8	7.9	--	6.8	2.7	14		23	18	14	.5	1.0		76	.24		28	9	53	1.2	133	6.2
Oct. 29	.2	6.6	--	14	6.8	26		58	34	25	.9	.0		142	.19		63	15	--	1.4	270	6.5
10. WHITE OAK CREEK NEAR OMAHA																						
July 20, 1950	23.9	6.8	--	17	6.2	171		37	81	230	--	0.5		558	0.76		68	38	85	9.0	1010	7.1
Aug. 7	20.2	11	--	14	6.5	97		45	48	132	--	.0		360	.49		62	25	77	5.4	616	7.3
Mar. 18, 1960	--	6.4	--	14	5.9	42		27	58	48	0.1	.2		188	.26		59	37	61	2.4	323	6.5
Feb. 4, 1965	38.8	8.8	--	16	7.6	51		35	71	56	.3	.8		228	.31		71	42	61	2.6	378	6.8
Mar. 18	414	8.5	--	18	10	41		32	67	56	.3	.2		217	.30		86	60	51	1.9	407	6.8
Apr. 23	29.8	6.6	--	35	17	106		69	126	140	.8	.2		466	.63		158	101	59	3.7	850	6.5
May 27	891	9.9	--	13	4.8	21		51	21	23	.3	.8		119	.16		52	10	46	1.3	212	6.5
Sept. 26	129	4.9	--	41	12	351		38	150	515	.2	1.0		1090	1.48		152	121	83	12	2050	6.1
Oct. 28	.9	7.6	--	17	6.5	77		69	41	96	.4	.2		280	.38		69	12	71	4.0	533	6.8
Dec. 1	1.6	7.0	--	25	7.9	146	4.9	80	62	208	.4	.2		500	.68		95	30	76	6.5	953	6.9
Jan. 6, 1966	225	5.4	--	36	14	270	6.8	43	122	418	.7	.2		894	1.22		148	112	79	9.6	1700	6.2
Apr. 21	41.5	6.0	--	42	17	150	5.1	68	141	223	.0	1.0		618	.84		175	120	64	4.9	1120	6.8
June 17	--	--	--	--	--	--		59	--	64	--	--		--	--		80	32	--	--	425	6.4
June 22	26.3	1.0	--	24	8.9	62	4.7	88	53	78	.4	.2		275	.37		96	24	57	2.8	513	6.9
Jan. 20, 1967	29.4	14	--	30	13	78	5.6	28	114	114	.1	.0		383	.52		128	106	56	3.0	674	6.2
12. CANEY CREEK RESERVOIR NEAR REDWATER																						
July 11, 1952	--	7.4	0.09	3.6	2.5	9.8		28	8.7	5.2	0.2	0.8		52	0.07		19	0	52	1.0	70	7.2
Apr. 20, 1962	--	4.7	.51	2.2	1.2	3.6		9	6.2	3.0	.1	.0		25	.03		10	3	43	.5	43	5.6
Mar. 3, 1964	--	8.3	.70	3.5	1.5	6.6		12	11	4.7	.4	.2		42	.06		15	5	49	.7	67	6.8
Apr. 8, 1965	--	6.1	.62	3.0	.9	5.4		11	8.6	3.0	.2	.2		33	.04		11	2	51	.7	47	6.2

Table 6.--Chemical Analyses of Streams and Reservoirs for Locations Other Than Daily Stations--Continued

(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)	Boron (B)	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
13. CANEY CREEK NEAR REDWATER																						
May 23, 1961	3.9	17	0.00	5.2	3.0	13	1.2	40	4.0	12	0.2	0.9		76	0.10		26	0		1.1	113	6.5
Sept. 18, 1962	.6	22	.03	9.0	2.9	9.4	1.9	45	5.4	10	.2	.0		83	.11		34	0	36	.7	114	6.3
14. TEXARKANA RESERVOIR NEAR TEXARKANA																						
Dec. 20, 1957 a/	--	6.4	0.55	20	1.6	7.4	3.6	66	12	7.5	0.2	0.2		91	0.12		56	0	21	0.4	160	7.3
Jan. 7, 1966	--	4.2	--	32	3.0	17	3.6	105	18	19	.3	.2		149	.20		92	6	28	.8	270	6.8
Apr. 20	--	3.4	--	25	2.4	14	3.0	72	21	16	.3	.2		120	.16		72	13	29	.7	223	6.6
Nov. 6	--	5.8	--	24	2.3	12	3.4	76	16	13	.1	1.0		115	.16		69	7	26	.6	199	7.7
Apr. 9, 1967	--	.0	--	25	3.0	24	3.4	55	38	34	.1	.5		155	.21		75	30	40	1.2	286	6.4
16. CYPRESS CREEK NORTH OF PITTSBURG																						
Mar. 18, 1965	309	10	--	15	8.7	31		22	56	45	0.2	0.5		177	0.24		73	55	48	1.6	331	5.9
Apr. 23	20.1	15	--	22	12	55		42	71	79	.3	3.2		278	.38		104	70	53	2.3	500	6.0
May 27	72.4	18	--	19	9.6	39		33	61	56	.3	1.8		221	.30		87	60	49	1.8	393	6.1
July 9	5.8	17	--	22	8.5	86		52	52	116	.4	20		348	.47		90	48	68	3.9	640	6.4
Sept. 26	10.9	12	--	10	4.4	24		17	36	27	.2	5.0		127	.17		43	29	54	1.6	223	5.8
Oct. 28	2.9	15	--	25	8.4	159		37	56	230	.5	34		546	.74		97	66	78	7.0	1050	6.0
Dec. 1	4.6	17	--	15	3.4	70	5.3	33	36	97	.7	14		274	.37		51	24	72	4.3	511	6.2
Apr. 21, 1966	29.2	11	--	22	11	45	3.6	28	66	80	.3	.0		253	.34		100	77	48	2.0	462	6.4
June 15	10.7	19	--	19	8.1	45	3.1	40	47	68	.5	2.8		232	.32		81	48	54	2.2	411	7.0
Feb. 28, 1967	44.6	12	--	24	12	46	2.7	24	87	70	.1	2.0		268	.36		109	90	47	1.9	480	6.2
May 9	260	12	--	15	6.9	24	3.4	31	43	36	.4	1.2		157	.21		66	40	43	1.3	271	7.0
20. LAKE O' THE PINES NEAR JEFFERSON																						
Aug. 18, 1965	--	6.4	--	12	3.4	19		32	24	24	0.2	0.2		105	0.14		44	18	49	1.2	196	6.4
Jan. 7, 1966	--	7.5	--	12	3.9	18	3.7	34	22	25	.3	.0		109	.15		46	18	44	1.2	198	6.8
July 7	--	1.4	--	8.5	1.9	7.6	3.3	24	13	11	.0	.8		60	.08		29	9	33	.6	117	6.8
Mar. 7, 1967	--	4.3	--	9.0	2.7	8.8	3.2	28	14	12	.3	.5		69	.09		34	11	34	.7	122	6.9
22. KELLY CREEK NEAR MARIETTA																						
Mar. 17, 1942	--	--	1.6	5.4	3.1	8.1		21	12	10	--	--		78	0.11		26	9	--	0.7	93	--
May 23, 1961	6.2	14	.00	2.9	1.6	3.7	1.3	12	5.6	3.5	0.2	2.6		40	.05		14	4	--	.4	49	6.1
Sept. 18, 1962	.4	29	.01	6.2	2.5	4.9	2.8	2	28	6.0	.1	.0		81	.11		26	24	27	.4	93	5.4
23. HUGHES CREEK NEAR AVINGER																						
May 23, 1961	9.9	10	0.00	2.5	1.5	3.7	1.2	10	5.0	5.0	0.0	1.5		35	0.05		12	4		0.5	47	5.8
Sept. 18, 1962	8.0	22	.02	2.5	2.0	5.3	2.3	15	6.4	7.2	.1	.0		55	.07		14	2	40	.6	62	5.8

a/ Boron 0.05 ppm.

Table 6.--Chemical Analyses of Streams and Reservoirs for Locations Other Than Daily Stations--Continued

(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)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25° C)	pH
24. BLACK CYPRESS BAYOU NEAR JEFFERSON																						
Mar. 22, 1965	355	12	--	2.0	2.4	4.1	1.4	8	9.0	6.5	0.2	0.2		42	0.06		15	8	35	0.5	59	6.2
Apr. 24	99.8	13	--	4.8	2.4	5.9	1.1	21	6.0	8.7	.2	.8		53	.07		22	5	36	.5	78	6.7
May 29	422	17	--	3.5	1.3	4.0	1.5	14	5.2	5.0	.1	.8		45	.06		14	3	35	.5	55	6.1
July 10	16.4	22	--	5.2	1.7	5.8	1.8	21	4.6	8.2	.1	.8		60	.08		20	3	36	.6	77	6.4
Sept. 27	2.2	12	--	8.8	2.9	19		15	5.6	41	.0	.2		96	.13		34	22	55	1.4	180	6.0
Oct. 29	.1	13	--	11	4.0	35		18	5.0	70	.2	.3		147	.20		44	29	63	2.3	285	6.0
Dec. 2	3.2	18	--	6.0	2.2	9.6	3.1	10	17	16	.1	.2		77	.10		24	16	43	.9	123	6.1
July 7, 1966	6.9	16	--	6.8	1.4	6.0	2.1	20	6.4	10	.2	.2		59	.08		23	6	34	.5	109	6.5
Aug. 2	1.6	--	--	--	--	11	2.4	--	1.6	21	.1	1.2		--	--		--	--	--	--	137	--
Sept. 8	11.5	17	--	4.8	1.4	4.2	1.8	14	6.8	7.2	.1	.5		51	.07		18	6	31	.4	62	6.6
Jan. 26, 1967	136	18	--	3.5	1.3	5.2	1.6	7	9.0	8.3	.0	.2		50	.07		14	8	41	.6	63	5.9
May 17	366	17	--	4.5	1.7	3.9	2.0	18	4.4	5.6	.4	.8		49	.07		18	4	29	.4	62	6.1
25. LITTLE CYPRESS CREEK NEAR ORE CITY																						
Sept. 12, 1964	0.1	11	--	9.2	3.4	40		14	38	51	0.2	0.2		160	0.22		37	26	70	2.9	298	6.4
Oct. 27	5.4	19	--	11	3.8	70		8	29	111	.2	.8		249	.34		43	37	78	4.6	444	6.4
Feb. 13, 1965	1600	11	--	4.2	1.8	15		8	10	24	.1	.5		71	.10		18	11	65	1.5	137	5.7
Apr. 24	110	24	--	10	4.1	35		20	24	54	.2	.5		162	.22		42	25	65	2.3	279	6.0
May 30	1260	17	--	7.0	2.8	15		18	15	21	.2	.5		88	.12		29	14	52	1.2	141	6.0
Sept. 27	3.4	11	--	9.5	3.7	55		53	17	68	.1	1.8		192	.26		39	0	75	3.8	356	6.3
Dec. 2	1.6	16	--	10	2.2	48	4.3	4	93	31	.1	.5		207	.28		34	31	73	3.6	352	5.6
Jan. 9, 1966	20.8	21	--	9.3	2.6	19	3.0	0	52	19	.0	.2		126	.17		34	34	52	1.4	216	4.4
Feb. 15	56.3	19	--	6.7	3.0	22	2.7	6	25	32	.0	.2		114	.16		29	24	60	1.8	190	6.0
Mar. 20	39.1	13	--	8.5	2.9	17	2.8	13	30	22	.2	.5		103	.14		33	22	50	1.3	176	6.3
Jan. 28, 1967	63.2	23	--	6.0	2.4	14	2.4	6	28	17	.0	.2		96	.13		25	20	52	1.2	142	5.7
Mar. 6	--	13	--	8.0	2.8	22	2.5	11	30	28	.2	.4		112	.15		31	22	58	1.7	187	6.1
Apr. 20	295	17	--	7.5	2.9	9.0	4.4	7	31	12	.2	.5		88	.12		31	25	35	.7	129	5.4
May 18	89.2	25	--	8.0	3.2	17	2.9	16	26	23	.4	.8		114	.16		33	20	50	1.3	172	6.0
26. MOCCASIN CREEK NEAR HARLETON																						
May 23, 1961	1.4	19	0.00	3.8	1.8	8.8	1.4	10	7.2	14	0.1	1.3		62	0.08		17	9	--	0.9	87	5.8
Sept. 19, 1962	.6	34	.02	4.5	2.2	7.3	3.7	10	17	10	.2	.2		84	.11		20	12	39	.7	95	5.7
June 10, 1964	.03	--	--	--	--	--	--	24	--	12	--	--		--	--		24	4	--	--	108	5.7
27. LITTLE CYPRESS CREEK NEAR JEFFERSON																						
June 12, 1962	10.6	22	--	12	3.7	52		20	22	83	0.2	0.5		205	0.28		45	29	71	3.4	373	5.8
Sept. 13, 1964	.5	14	--	21	10	165		2	45	285	.1	.8		542	.74		94	92	79	7.4	1040	5.8
Oct. 22	2.0	16	--	9.5	3.7	56		6	46	76	.1	.0		210	.29		39	34	76	3.9	378	5.9
Feb. 14, 1965	643	11	--	4.2	1.8	11		10	18	9.4	.1	.8		61	.08		18	10	56	1.1	100	5.8
Apr. 26	38.8	15	--	9.5	4.4	39		14	32	57	.2	1.5		166	.23		42	30	67	2.6	292	5.9
May 31	636	16	--	5.5	2.3	11		16	17	11	.5	.2		72	.10		23	10	52	1.0	106	5.9
Sept. 29	1.2	14	--	14	3.2	34		0	82	24	.0	2.2		173	.24		48	48	60	2.1	303	4.6
Dec. 2	2.0	6.1	--	10	2.9	53	4.1	28	41	67	.2	.2		198	.27		37	14	73	3.8	379	6.7
Jan. 7, 1966	70.7	20	--	9.8	2.8	52	3.3	5	22	89	.0	.0		201	.27		36	32	74	3.8	370	6.4
Feb. 13	214	19	--	9.8	3.4	38	2.8	4	17	75	.1	.2		167	.23		38	35	66	2.7	303	5.6

Table 6.--Chemical Analyses of Streams and Reservoirs for Locations Other Than Daily Stations--Continued

(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)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25° C)	pH
27. LITTLE CYPRESS CREEK NEAR JEFFERSON--Continued																						
Mar. 18, 1966	122	16	--	10	3.2	42	2.8	8	23	75	.2	.8		177	0.24		38	32	69	3.0	332	6.6
Apr. 27	--	2.7	--	2.0	.2	1.5	1.9	6	4.0	1.3	.1	.2		17	.02		6	1	28	.3	30	5.7
Jan. 25, 1967	88.7	--	--	--	--	53	--	8	27	89	--	--		--	--		40	33	--	3.6	373	6.3
Mar. 6	118	14	--	9.8	3.1	40	2.3	10	23	65	.3	.2		163	.22		37	29	68	2.9	299	6.1
Apr. 19	454	14	--	7.2	2.6	28	3.6	8	16	51	.2	.4		127	.17		29	22	65	2.3	225	5.5
May 17	508	18	--	8.5	3.1	18	3.2	18	19	30	.5	.5		110	.15		34	19	51	1.3	180	6.1
28. PREWITT CREEK NEAR KARNAK																						
May 23, 1961	3.2	12	0.00	2.7	1.5	3.7	0.7	12	5.2	4.0	0.2	1.3		32	0.04		12	2		0.5	47	6.2
Sept. 19, 1962	.5	18	.04	3.0	1.9	3.3	1.2	13	4.8	5.5	.1	.0		44	.06		15	5	30	.4	48	6.2
33. BLACK BAYOU NEAR ATLANTA																						
May 23, 1961	8.1	10	0.00	3.0	1.9	19	1.7	36	3.8	15	0.3	2.9		76	0.10		16	0	--	2.1	121	6.7
Sept. 18, 1962	4.9	19	.05	4.2	1.8	31	2.9	53	3.4	27	.2	4.0		120	.16		18	0	76	3.2	189	6.2
34. CADDO LAKE																						
Feb. 26, 1952	--	15	0.76	6.9	3.4	17	3.6	16	20	27	0.3	0.5		127	0.17		31	18	51	1.3	168	6.4
June 21	--	28	5.2	6.2	3.9	22		23	19	27	.2	1.5		119	.16		32	13	60	1.7	172	7.1
Aug. 25, 1953	--	22	.94	7.0	3.0	23		25	14	31	.2	.2		125	.17		30	9	62	1.7	178	6.9
Nov. 2, 1954	--	15	.54	7.4	3.7	24		39	13	28	.3	.2		120	.16		34	2	61	1.8	185	7.1
Aug. 20, 1956	--	14	.16	6.2	4.0	28		33	11	38	.4	.2		118	.16		32	5	66	2.2	203	6.8
July 22, 1959	--	15	.13	8.0	2.7	23		26	14	31	.2	.2		107	.15		31	10	61	1.8	177	6.2
May 18, 1960	--	18	1.8	5.0	3.7	19		16	12	30	.1	.8		97	.13		28	15	60	1.6	157	6.0
June 14, 1962	--	17	1.8	5.5	2.2	21		12	11	33	.1	1.0		97	.13		23	13	67	1.9	156	5.8
June 23, 1963	--	13	.46	8.0	3.2	24		20	17	36	.2	.2		112	.15		33	17	61	1.8	189	6.0