In cooperation with the City of Houston

Characteristics of Water-Quality Data for Lake Houston, Selected Tributary Inflows to Lake Houston, and the Trinity River Near Lake Houston (A Potential Source of Interbasin Transfer), August 1983–September 1990

Water-Resources Investigations Report 99–4129

U.S. Department of the Interior
U.S. Geological Survey

Cover photographs:

Upper right: View of the intake tower from the spillway levee, Lake Houston near Sheldon, Texas, April 16, 1971. Photo by A.M. Miller, U.S. Geological Survey.

Lower left: Lake Houston spillway, October 1994 flood. Photo by J.W. East, U.S. Geological Survey.

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U.S. GEOLOGICAL SURVEY
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Austin, Texas
1999

U.S. DEPARTMENT OF THE INTERIOR

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VERTICAL DATUM AND ABBREVIATIONS

Sea Level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviations:

acre-ft, acre-foot
cols./100 mL, colonies per 100 milliliters
°C, degree Celsius
°F, degree Fahrenheit
ft, foot
in., inch
m, meter
Mgal/d, million gallons per day
mg/L, milligram per liter
mi, mile
mi/hr, mile per hour
mi^2, square mile
µg/L, microgram per liter
µS/cm, microsiemens per centimeter at 25 degrees Celsius
Pt-Co unit, platinum-cobalt unit
TU, nephelometric turbidity unit

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Abstract

Lake Houston, a reservoir completed in 1954 about 25 miles east-northeast of Houston, Texas, is a principal surface-water source for the city of Houston. The increase in water supply to meet future demands is expected to be accommodated by supplementing surface-water inflows to Lake Houston. The Trinity River is considered a potential source for interbasin transfer of water to Lake Houston. Before beginning to supplement inflows, the City needs to better understand the potential effects on Lake Houston water quality from streams that flow into or might contribute water to Lake Houston. During 1983–90, the USGS collected 3,727 water-quality samples from 27 sites in Lake Houston, 6 of the 7 main tributaries to the lake, and the Trinity River at Romayor.

Longitudinal profiles of water temperature, dissolved oxygen, specific conductance, pH, and nutrients from the dam to the East and West Forks of Lake Houston constructed for a winter day and a summer day indicate that in general the lake water is mixed in the winter and stratified in the summer.

The results of Mann-Whitney rank-sum tests to determine whether there were significant differences between summer and non-summer field measurements, 5-day biological oxygen demand, bacteria, physical and aesthetic properties, nutrients, organic carbon, chlorophyll *a,* and trace elements in the lake nearest the dam, the East Fork of the lake, and the West Fork of the lake at the same relative depth showed significant differences between summer and non-summer samples for at least one of the three locations at the same relative depth for all 15 properties and constituents tested except specific conductance. The test results indicate that in general Lake Houston is well mixed in the non-summer period and stratified with respect to selected properties and constituents in the summer.

The results of rank-sum tests to determine whether there were significant differences between field measurements, 5-day biological oxygen demand, physical and aesthetic properties, nutrients, organic carbon, and chlorophyll *a* in the lake nearest the dam, the East Fork of the lake, and the West Fork of the lake for samples collected during the same season at the same relative depth showed that significant differences were common; generally, the West Fork had the largest median concentrations among the three locations. The tests comparing trace element concentrations between the lake nearest the dam and the East Fork showed mixed results—large median dissolved manganese concentrations in lake bottom samples in the summer and in East Fork near-surface samples in the non-summer period.

The results of rank-sum tests comparing selected properties, 5-day biological oxygen demand, bacteria, nutrients, and total organic carbon in the eastern tributaries with those in the western tributaries, in the eastern tributaries with those in the Trinity River, and in the western tributaries with those in the Trinity River during the same season (summer or non-summer) at the same relative streamflow (low-medium or high) showed that significant differences were more common than not. In the comparisons of the eastern tributaries with

the western tributaries that resulted in significant differences, medians of the western tributaries were larger for all properties and constituents except total organic carbon; in the comparisons of the eastern tributaries with the Trinity River that resulted in significant differences, medians were larger for the Trinity River in about 60 percent of the tests; and in the comparisons of the western tributaries with the Trinity River that resulted in significant differences, medians were larger for the western tributaries in about 60 percent of the tests.

In the tests comparing trace elements between the eastern and western tributaries during the same season at the same relative streamflow, five of the eight tests showed no significant differences; between the eastern tributaries and the Trinity River, all eight tests showed significant differences, with eastern tributary medians larger in all tests; and between the western tributaries and the Trinity River, seven of the eight tests showed significant differences, with western tributary medians larger in all seven tests.

The tests comparing selected properties, 5-day biological oxygen demand, nutrients, and total organic carbon between the eastern tributaries and the East Fork of Lake Houston, between the western tributaries and the West Fork of Lake Houston, and between the Trinity River and the lake nearest the dam, the East Fork, and the West Fork during the same season (summer or non-summer) yielded significant differences in about 60 percent of the tests. No discernible pattern emerged to associate significant differences with season.

In the tests comparing trace elements between the tributaries and the respective forks of the lake to which the tributaries drain, iron concentrations were significantly different in three of the four tests, with median concentrations larger in the tributaries. All the tests comparing manganese between the Trinity River and the three locations in the lake yielded significant differences, with larger median concentrations in the lake.

INTRODUCTION

Background

Lake Houston is a reservoir located on the San Jacinto River, east-northeast of downtown Houston, in southeastern Texas (fig. 1). The reservoir was constructed by the City of Houston in 1954 as a public water supply for the city, for the Houston-Baytown area industrial complex, and for local irrigation.

Prior to the completion of Lake Houston, the public water supply for the Houston metropolitan area was from ground water (Wood and Gabrysch, 1965). The population in the metropolitan area increased from about 1.2 million people in 1960 to about 3.3 million people in 1990 (Kingston, 1991). This rapid population growth resulted in increased demands for municipal and industrial water supplies. Water demand in the metropolitan area increased from about 300 Mgal/d in 1960 (Wood and Gabrysch, 1965) to about 779 Mgal/d in 1986 (Harris-Galveston Coastal Subsidence District, 1987). In 1960, about 76 percent of the total water demand was supplied by ground water and 24 percent by surface water. However, increased withdrawals of ground water resulted in declining water levels in the aquifer, which caused pronounced regional land subsidence (Gabrysch, 1984), possible saltwater intrusion (Jorgensen, 1976), and increased fault activity (Holzer, 1984). The Harris-Galveston Coastal Subsidence District was created by the State legislature in 1975 to control regional subsidence by regulating the use of ground water and by formulating plans to convert area water supplies to rely more on surface water (Harris-Galveston Coastal Subsidence District, 1992). Water-supply data from 1986 indicate that 47 percent of the water demand was supplied from ground-water sources, and 53 percent was supplied from surface-water sources (Harris-Galveston Coastal Subsidence District, 1987).

The current (1999) surface-water sources for the Houston metropolitan area are Lake Houston, the main surface-water public water supply, and the Coastal Water Authority canal, the main surface-water industrial water supply (fig. 1). The increase in water supply to meet future demands is expected to be accommodated by supplementing surface-water inflows to Lake Houston. As early as 1972, the City of Houston considered interbasin transfer of water from the Trinity River, through Luce Bayou, into Lake Houston (Turner, Collie, and Braden, Inc., 1972). The city has partial ownership of Lake Livingston (70 percent of the water)

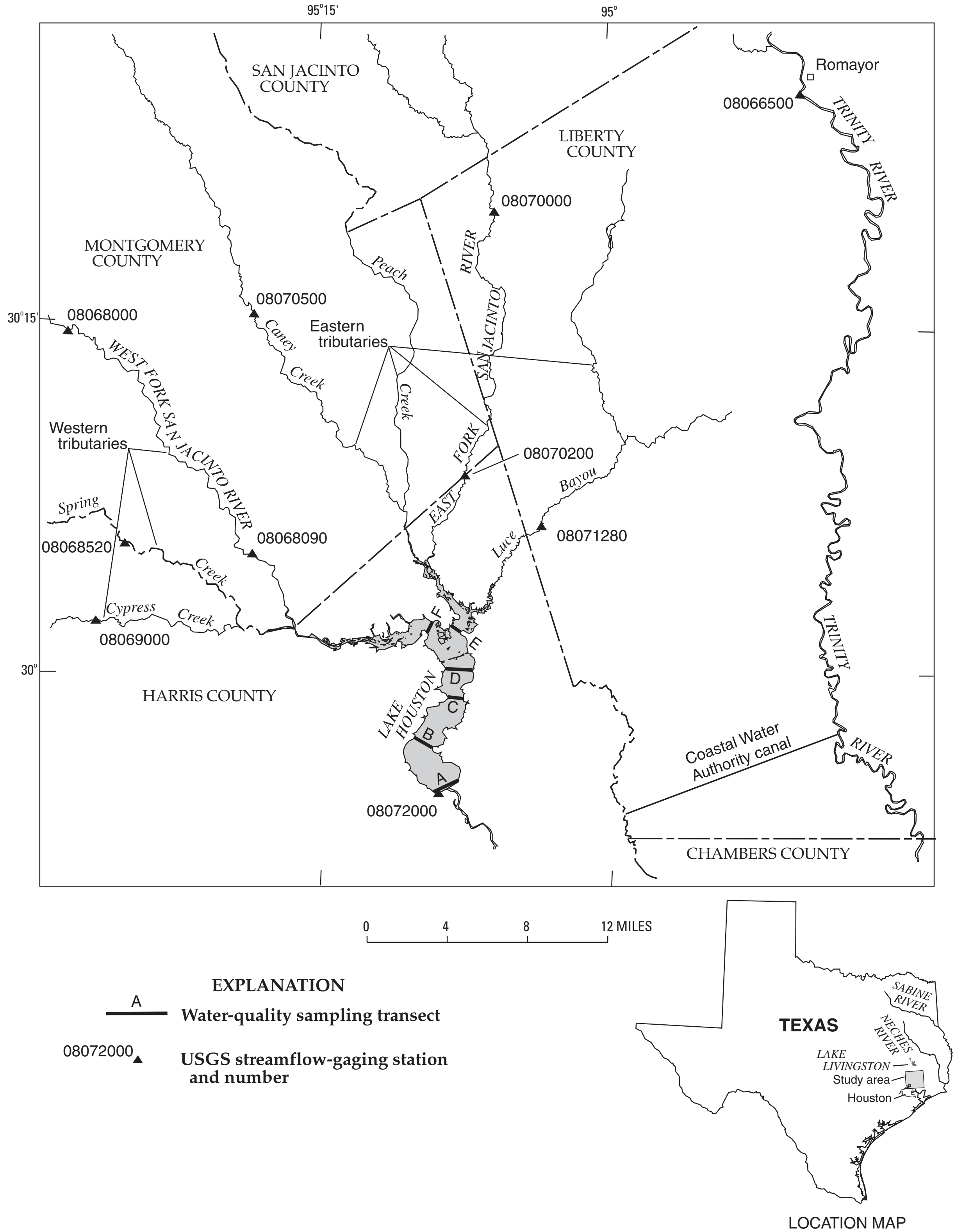

Figure 1. Location of study area and surface-water-quality sampling sites.

on the Trinity River north of the study area (fig. 1). Turner, Collie, and Braden, Inc. (1972) determined that a minimum-conveyance structure could be constructed to connect the Trinity River to Luce Bayou. For this reason, the Trinity River is considered a potential source for interbasin transfer of water into Lake Houston. The Neches and Sabine River Basins, northeast of Lake Houston near the eastern border of Texas (fig. 1), also might be considered for supplementary surface-water inflows to Lake Houston.

The potential effects on Lake Houston water quality from streams that flow into or might contribute water to Lake Houston are of interest to the City of Houston. In 1983, the U.S. Geological Survey (USGS), in cooperation with the City of Houston, began an investigation of the potential effects. The investigation has three phases: Phase I involved the collection of water-quality data in Lake Houston, its tributaries, and the Trinity River. The data were used to characterize the physical properties and chemical constituents to determine whether water quality varies in these waters. Phase II involves the use of simulation to predict the potential effects on the water quality of Lake Houston as water from other sources mixes with water in Lake Houston. Phase III is intended to characterize the water quality in Lake Houston after water actually has been transferred from the Trinity River (or other sources) into Lake Houston.

The USGS gratefully acknowledges the financial support provided by the City of Houston for this investigation.

Purpose and Scope

This report deals only with phase I of the investigation and is a summary of water-quality data collected August 1983–September 1990 in Lake Houston, its major tributaries, and the Trinity River. Data are summarized for the main body of Lake Houston, the lake transect nearest the dam, the East Fork of the lake, the West Fork of the lake, the eastern tributaries (tributaries to East Fork of Lake Houston), the western tributaries (tributaries to West Fork of Lake Houston), and one site on the Trinity River at Romayor, Tex. (about 35 mi downstream of Lake Livingston) (fig. 1). The purpose of this report is to describe the areal and temporal variations of selected physical properties and chemical constituents at these sites. Data collected during this study were published in annual USGS water data reports (U.S. Geological Survey, 1984–91).

The water-quality sampling program for Lake Houston, its contributing tributaries, and the Trinity River is described. Summary statistics of water-quality data collected are presented. Longitudinal profiles through Lake Houston of six selected physical properties and chemical constituents illustrate how water quality varied vertically and along the length of the lake. Seventeen of 59 properties and constituents collected in the sampling program were selected as important factors affecting biological, physical, and chemical processes in water. The 17 properties and constituents were grouped on the basis of six locations representing the study area (the lake nearest the dam, East Fork of the lake, West Fork of the lake, the eastern and western tributaries, and the Trinity River), statistically summarized, and compared to available drinking water standards established by the U.S. Environmental Protection Agency (EPA). The 17 properties and constituent concentrations are presented in boxplots and subsets of 13 to 15 properties and constituent concentrations statistically tested for differences on the basis of combinations of season, depth, location, and streamflow.

Description of the Study Area

Lake Houston is formed by two earthfill embankment sections and a 3,160-ft-long concrete spillway midway between the embankment sections, for a total length of 12,100 ft. The dam closure was completed April 9, 1954. The drainage basin for Lake Houston is 2,828 mi^2. Major tributaries in the drainage basin are the East and West Forks of the San Jacinto River, Luce Bayou, Caney Creek, Peach Creek, Cypress Creek, and Spring Creek.

Lake Houston has a capacity of 146,700 acre-ft and a surface area of 12,240 acres at the spillway crest elevation of 43.8 ft above sea level. The mean depth at the spillway crest is 12 ft, and the maximum depth is about 50 ft. The length of the shoreline is about 36 mi.

Lake Houston is located about 25 mi east-northeast of downtown Houston. The reservoir has two main inflow branches. The eastern branch mainly drains a predominantly rural watershed, and the western branch drains a more urbanized basin. The major eastern-branch inflow tributaries are the East Fork San Jacinto River, Luce Bayou, Caney Creek, and Peach Creek. The major western-branch inflow tributaries are the West Fork San Jacinto River, Cypress Creek, and Spring Creek (fig. 1).

Table 1. Lake Houston subbasin characteristics (modified from Baca and others, 1982)

River or creek	Drainage area (square miles)	Percent of drainage basin
East Fork subbasin (eastern branch)		
East Fork San Jacinto River	371	13
Peach Creek	166	6
Caney Creek	201	7
Luce Bayou	197	7
West Fork subbasin (western branch)		
West Fork San Jacinto	956	34
Spring Creek	446	16
Cypress Creek	323	11
Lake Houston environs[1]	168	6
Totals	2,828	100

[1] That part of the watershed surrounding Lake Houston downstream of tributary inflows.

The Trinity River originates in northeast Texas and flows east of Lake Houston, about 3 mi from the upstream end of Luce Bayou (fig. 1). Lake Livingston is the largest reservoir near the mouth of the Trinity River. The drainage area for the Trinity River at the Lake Livingston dam is 16,583 mi^2. The conservation pool for Lake Livingston is about 1,790,000 acre-ft, more than 10 times that of Lake Houston.

The Lake Houston drainage basin extends into parts of seven counties, but most of the basin is in Harris and Montgomery Counties (fig. 1). The eastern branch drains about 935 mi^2 or about 33 percent of the drainage basin, and the western branch drains about 1,725 mi^2 or about 61 percent of the drainage basin (table 1). The part of the watershed immediately surrounding Lake Houston below the tributary inflows drains about 6 percent of the watershed (table 1).

During the phase of the study documented in this report, about 73 percent of the Lake Houston drainage basin was forested and 14 percent was pasture. The eastern subbasin was predominantly agricultural, and the western subbasin was agricultural and urban (Matty and others, 1987). Other land uses in the western subbasin included the Houston Intercontinental Airport (west of Lake Houston), gravel operations, and highway construction (Bedient and others, 1980). Some oil production also occurred in the Lake Houston watershed. The most active urban development for the study period occurred in the western subbasin along the lower part of the Cypress Creek watershed (fig. 1).

Lake Houston receives direct wastewater discharges from five municipal wastewater-treatment plants. During the study about 31 permitted treatment plants discharged to Cypress Creek, 13 to Spring Creek, and 30 to the West Fork San Jacinto River. Overall, more than 150 municipal wastewater-treatment plants of various capacities were located in the Lake Houston drainage basin during the study (Bedient and others, 1980; Houston-Galveston Area Council, 1984).

The climate of the Houston metropolitan area is characterized by short mild winters, long hot summers, high relative humidity, and prevailing southeasterly winds. Annual precipitation in the Lake Houston drainage basin averages 40 to 47 in. (Kingston, 1991). Temperatures typically range from a mean minimum of about 46 °F in January to a mean maximum of about 93 °F in July (Kingston, 1991). The wind averages about 8 mi/hr and is from the south-southeast nearly the entire year (Baca and others, 1982; Houston-Galveston Area Council, 1984).

DATA COLLECTION

Fifty-nine physical properties and chemical constituents were measured or analyzed from surface-water samples collected August 1983–September 1990 in Lake Houston, its tributaries, and the Trinity River at Romayor. The properties and constituents were categorized into five groups: (1) Field measurements, 5-day biochemical oxygen demand (BOD), and bacteria; (2) physical and aesthetic properties; (3) major inorganic constituents and related physical properties; (4) nutrients, organic carbon, and chlorophyll; (5) trace elements.

Location of Sampling Sites and Frequency of Sampling

Twenty-seven surface-water-quality sampling sites were established on Lake Houston, six of the seven main contributing tributaries, and the Trinity River (table 2). The Lake Houston sampling was done along six transects (A through F) (fig. 1). Three sampling sites were on each transect for a total of 18 sampling sites. Each transect had one sampling site in the old river channel (center of the transect), and one site on either

Table 2. Surface-water-quality sampling sites in Lake Houston, tributaries to Lake Houston, and Trinity River

Station no. or site identification no.	Station or site name (fig. 1)	Latitude	Longitude
	Sampling sites in Lake Houston		
295516095080801	Site AC—Transect A, center at dam	29°55'16"	95°08'08"
295527095074501	Site AL—Transect A, near left bank at dam	29°55'27"	95°07'45"
295505095083101	Site AR—Transect A, near right bank at dam	29°55'05"	95°08'31"
295702095091401	Site BC—Transect B, center	29°57'02"	95°09'14"
295656095090201	Site BL—Transect B, near left bank	29°56'56"	95°09'02"
295708095092901	Site BR—Transect B, near right bank	29°57'08"	95°09'29"
295902095074201	Site CC—Transect C, center	29°59'02"	95°07'42"
295902095073001	Site CL—Transect C, near left bank	29°59'02"	95°07'30"
295902095075301	Site CR—Transect C, near right bank	29°59'02"	95°07'53"
300016095073401	Site DC—Transect D, center	30°00'16"	95°07'34"
300016095072301	Site DL—Transect D, near left bank	30°00'16"	95°07'23"
300016095075601	Site DR—Transect D, near right bank	30°00'16"	95°07'56"
300158095074601	Site EC—Transect E, center at mouth of east fork of reservoir	30°01'58"	95°07'46"
300156095074001	Site EL—Transect E, near left bank at mouth of east fork of reservoir	30°01'56"	95°07'40"
300202095075701	Site ER—Transect E, near right bank at mouth of east fork of reservoir	30°02'02"	95°07'57"
300209095091201	Site FC—Transect F, center at mouth of west fork of reservoir	30°02'09"	95°09'12"
300214095090901	Site FL—Transect F, near left bank at mouth of west fork of reservoir	30°02'14"	95°09'09"
300202095091701	Site FR—Transect F, near right bank at mouth of west fork of reservoir	30°02'02"	95°09'17"
	Trinity River site and tributary inflow sites to Lake Houston		
08066500	Trinity River at Romayor, Tex.	30°25'30"	94°51'02"
08068000	West Fork San Jacinto River near Conroe, Tex.	30°14'40"	95°27'25"
08068090	West Fork San Jacinto River above Lake Houston near Porter, Tex.	30°05'09"	95°17'59"
08068520	Spring Creek at Spring, Tex.	30°05'31"	95°24'21"
08069000	Cypress Creek near Westfield, Tex.	30°02'08"	95°25'43"
08070000	East Fork San Jacinto River near Cleveland, Tex.	30°20'11"	95°06'14"
08070200	East Fork San Jacinto River near New Caney, Tex.	30°08'43"	95°06'14"
08070500	Caney Creek near Splendora, Tex.	30°15'34"	95°18'08"
08071280	Luce Bayou above Lake Houston near Huffman, Tex.	30°06'34"	95°03'35"

side of the center, between the old channel and the shoreline. Samples were collected at all three locations along each transect during low and high streamflows in the winter, spring, and summer during August 1983–May 1987. In May 1987, the frequency of sampling at the center of each transect was increased during the summer, which is the most critical time of the year for adverse water quality in Lake Houston. The center of each transect was sampled approximately biweekly between May and October and was sampled only once during the winter. In February 1988, sampling between the center of the transect and shoreline was decreased to twice a year, once in the winter and once in the summer. Occasional departures from the sampling schedule occurred as a result of inclement weather or equipment failures or both; thus, not all physical properties and chemical constituents were measured or sampled at each site on all sampling dates.

Modification of the sampling program in May 1987 was based on results of the Mann-Whitney rank-sum statistical test (Helsel and Hirsch, 1992, p. 118). The Mann-Whitney, or Wilcoxon, test is done to determine whether two groups (in this application, properties and constituents collected in the center of a transect and those collected between the center and the shoreline) come from the same population (have the same median)—in other words, whether the two groups are not significantly different. Properties and constituents selected for the test were water temperature, specific conductance, dissolved oxygen (DO), percent of saturation for DO, pH, total nitrogen, total ammonia plus organic nitrogen, total nitrite plus nitrate nitrogen, and total phosphorus. The tests did not indicate a significant difference (at the 5-percent level of significance) between the properties and constituents sampled at the same depths (near-surface or bottom) in the center of the transect and those sampled between the center and shoreline.

Eight tributary sampling sites were established—two each on the East Fork San Jacinto River and West Fork San Jacinto River and one each on Spring Creek, Cypress Creek, Caney Creek, and Luce Bayou (table 2). The sites, either existing USGS streamflow-gaging stations or new sites, represent all but one of the major tributary inflows. Peach Creek was not selected because the stream has not been gaged since the 1970s, and the stream is hydrologically similar to Caney Creek (fig. 1). Peach Creek has about the same drainage area and land use as Caney Creek. All tributary sampling sites were located to minimize possible backwater effects from flood flows into the reservoir.

During August 1983–May 1987, tributary samples were collected within a week of when samples were collected in Lake Houston. During May 1987–September 1990, non-storm-event sampling at tributary sites was decreased to three times per year, once each during the winter, spring, and summer. Additional samples were collected during storm events at each of the six tributaries (at the downstream sites on the East Fork San Jacinto and West Fork San Jacinto Rivers). Three storm-event samples per year were collected—one each during winter, spring, and summer. The sampling program was less complete at some sampling sites because of equipment failures and vandalism.

Except for some intensive sampling associated with Hurricane Alicia in August 1983, samples were collected for the Trinity River at Romayor site at about 6- to 7-week intervals during August 1983–May 1987. During May 1987–September 1990, sampling frequency was increased in the spring and summer so that slightly more than 60 percent of the samples were collected in the spring and summer.

A total of 3,727 water-quality samples were collected. Of this total, 3,182 samples were collected in Lake Houston, 480 samples were collected in the six selected tributaries, and 65 samples were collected in the Trinity River at Romayor.

Sample Collection, Measurement, and Analysis

Samples in Lake Houston typically were collected at depths of 1 ft beneath the surface, 1 ft above the bottom, and at one or more intermediate depths, depending on whether the reservoir was thermally stratified (summer) or well mixed (winter). Stratification was identified by obtaining water-temperature profiles. During stratification, measurements were made or water samples were collected immediately above and below the thermocline. During well-mixed periods, measurements were made or samples were collected at about mid-depth. Water temperature, specific conductance, DO, and pH were measured at various depths, and depth profiles were constructed. These properties were measured using a commercially available multiparameter meter mounted on a boat. Water was pumped from the desired depth using a peristaltic pump. The water flowed over multiparameter sensors inside a sensor/flow chamber, measurements were recorded, and the water then was discharged back into the lake. Secchi-disk transparency in Lake Houston was measured using a standard Secchi disk. Water-quality samples for laboratory analysis were collected using the same peristaltic pump.

Discharge measurements were made and water-quality samples were collected at tributary sampling sites and at the Trinity River site (stream sites). Discharge measurements were made at stream sites using techniques described in Buchanan and Somers (1969). All stream sites had continuous streamflow-monitoring equipment. Depth-integrated samples were collected at each stream site using either the equal-discharge increment method or the equal-width increment method (Buchanan and Somers, 1969). Storm-event samples (point samples) were collected using automatic-sampling equipment. Plastic bottles were filled by stage-activated peristaltic pumps.

Samples were collected, preserved, and analyzed according to USGS guidelines and quality-control procedures (Wells and others, 1990). Chemical analyses were done by the USGS National Water Quality Laboratory in Arvada, Colo.

WATER QUALITY

Data presented in this section characterize the water quality in the study area. Properties and constituents in water-quality samples collected in the six tributaries are included in the analysis because water from these sources affects the water quality of Lake Houston. Properties and constituents in water-quality samples collected in the Trinity River are included because the river is a potential source for interbasin transfer of water into Lake Houston.

Longitudinal Profiles of Selected Properties and Constituents in Lake Houston

Two longitudinal profiles showing vertical distributions of six selected physical properties and chemical constituents represent the water quality in Lake Houston for a typical winter day (February 14, 1985) (figs. 2a, b, c) and a typical summer day (August 31, 1985) (figs. 3a, b, c). The properties and constituents for which profiles are shown are water temperature, DO, specific conductance, pH, and nutrients (total nitrite plus nitrate nitrogen and total phosphorus). The profiles show variation with depth along the length of Lake Houston. The two profiles extend through the center sites for each transect from the lake nearest the dam (transect A) to the East Fork of Lake Houston (transect E) and to the West Fork of Lake Houston (transect F) (fig. 1).

Water temperature, DO, specific conductance, pH, and nutrients are important indicators of water quality. Water temperature affects biological, physical, and chemical processes in water. For example, biological activity, saturation levels of gases, and solubility of minerals in water are affected by temperature. Specific conductance is a measure of the ability of water to conduct an electrical current and is a function of the type and concentration of dissolved ions in the water—and thus can be an indicator of the concentration of selected ions in the water. pH describes hydrogen ion activity and is defined as the negative logarithm of the hydrogen ion concentration expressed in moles per liter. In most waters, pH generally ranges from 0 to 14. A pH greater than 7.0 indicates the water is alkaline, and a pH less than 7.0 indicates the water is acidic. The nutrients nitrogen and phosphorus are essential to plant and animal nutrition and are necessary for productive aquatic ecosystems; but in large concentrations, they can adversely affect aquatic life and human health (Mueller and Helsel, 1996).

Water temperatures for February 14, 1985, were slightly warmer in the central part of the lake than near the dam or in the East and West Forks (fig. 2a). Profiles of DO show that, in winter, vertical mixing occurs throughout the lake, except near the dam (fig. 2a). Specific conductance increased gradually from the East and West Forks to the dam (fig. 2b). Larger specific conductance was measured in the West Fork than in the East Fork. pH (fig. 2b) and nutrients (fig. 2c), in general, show patterns similar to those of specific conductance—increases toward the dam and larger values in the West Fork than the East Fork. Larger specific conductance, pH, and nutrients in the West Fork could be related to greater urban development in the western part of the study area, which includes wastewater-treatment plants along the West Fork and the western tributaries.

Profiles of water temperature, DO, and pH, for August 31, 1985 (figs. 3a, b), indicate that Lake Houston is stratified during the summer, with larger values near the surface and smaller values near the bottom. Stratification is typical in a reservoir or lake during the summer. DO has a greater range from near-surface to bottom in the West Fork than the East Fork. As in the winter profiles, specific conductance, pH (fig. 3b), and total phosphorus concentrations (fig. 3c) were larger in the West Fork than the East Fork.

Summary Statistics and Graphical Descriptions of Selected Properties and Constituents

Summary statistics (mean, standard deviation, minimum, 25th percentile, median, 75th percentile, maximum) are one way to define the variability in the properties and constituents. Summary statistics of all 59 physical properties and chemical constituents, grouped by the five categories previously stated, are listed for seven locations (table 3 at end of report). The seven locations are the main body (transects A–D combined), the lake nearest the dam (transect A), East Fork of the lake (transect E), West Fork of the lake (transect F),

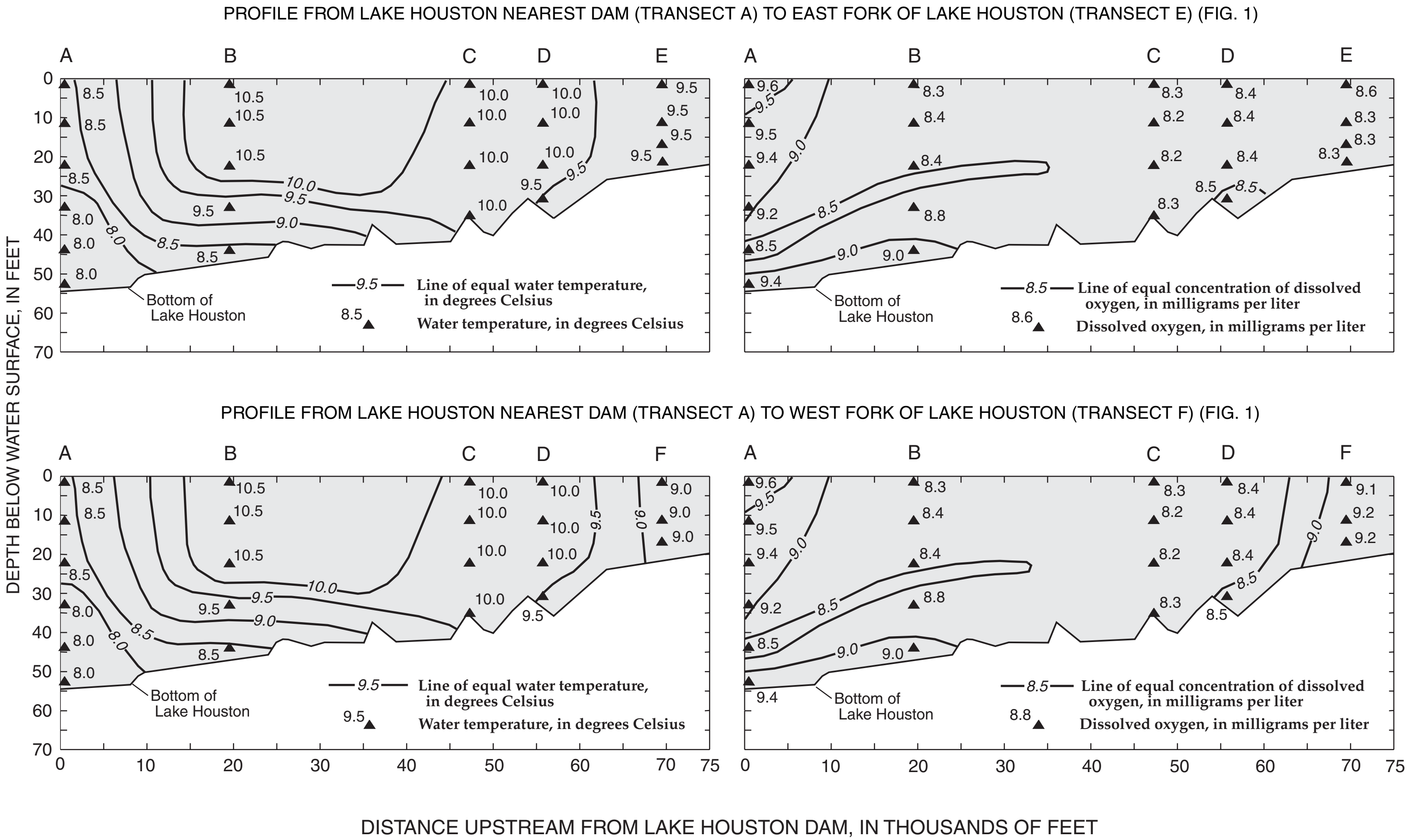

Figure 2a. Longitudinal profiles and vertical distribution of water temperature and dissolved oxygen in Lake Houston, February 14, 1985.

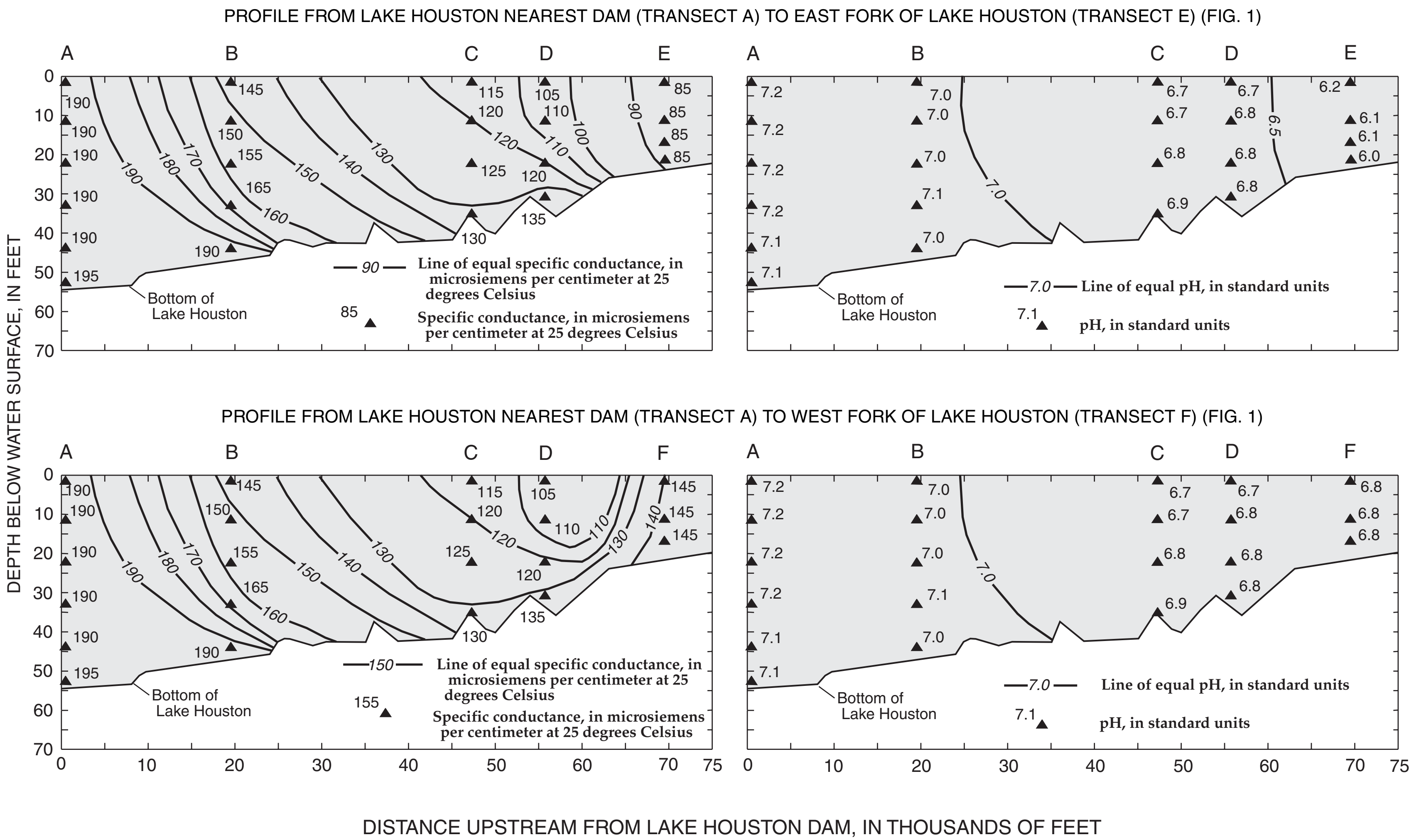

Figure 2b. Longitudinal profiles and vertical distribution of specific conductance and pH in Lake Houston, February 14, 1985.

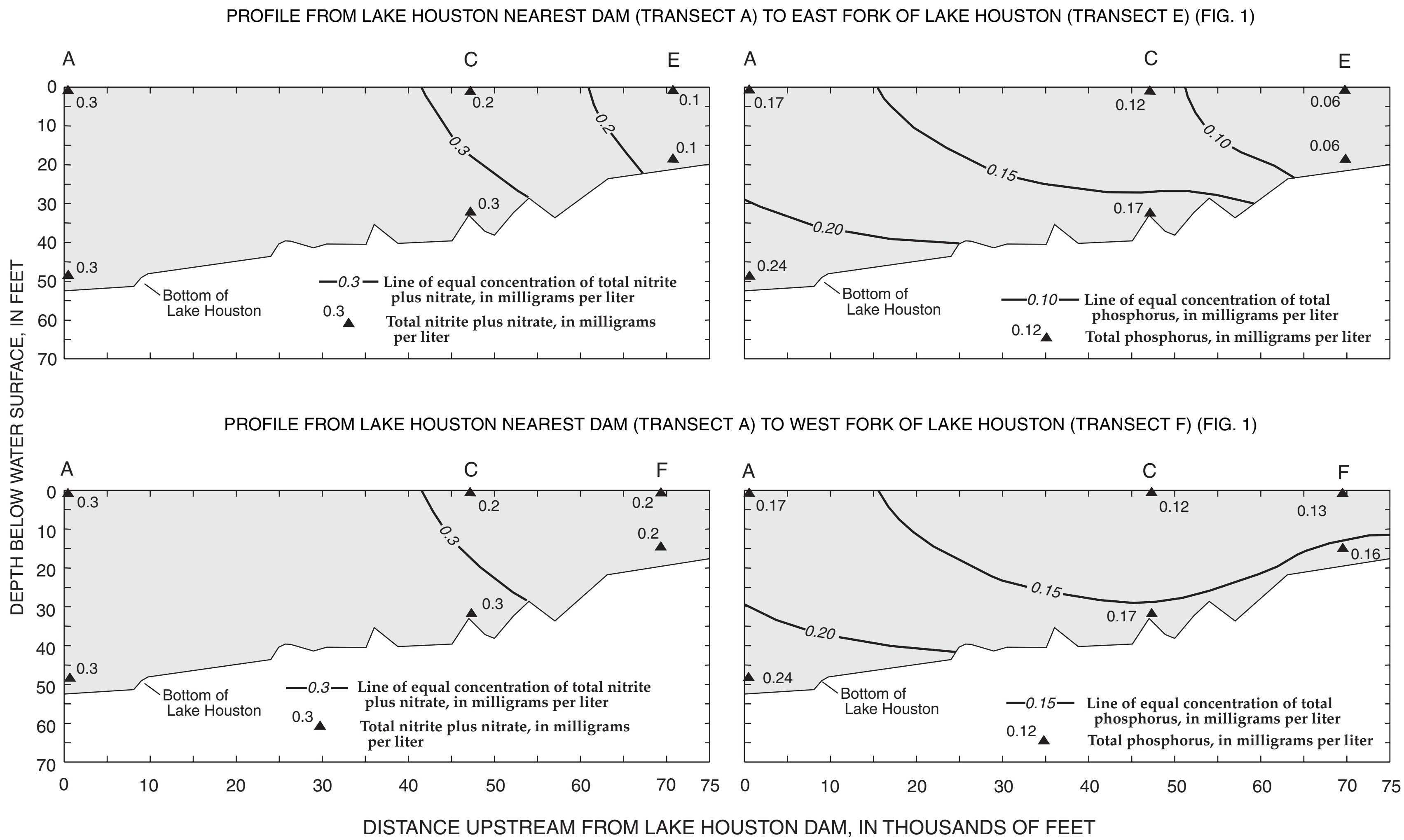

Figure 2c. Longitudinal profiles and vertical distribution of total nitrite plus nitrate nitrogen and total phosphorus in Lake Houston, February 14, 1985.

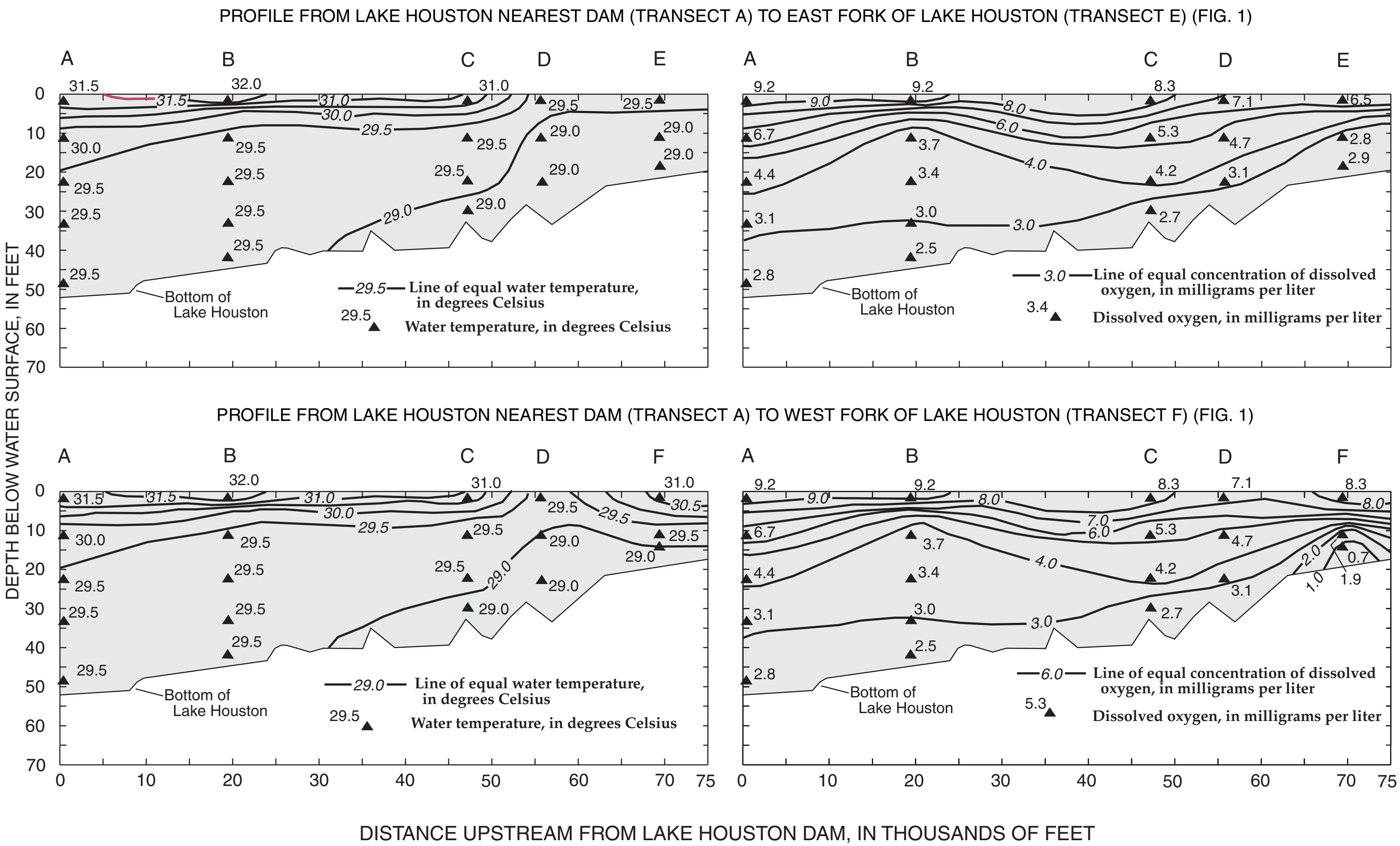

Figure 3a. Longitudinal profiles and vertical distribution of water temperature and dissolved oxygen in Lake Houston, August 31, 1985.

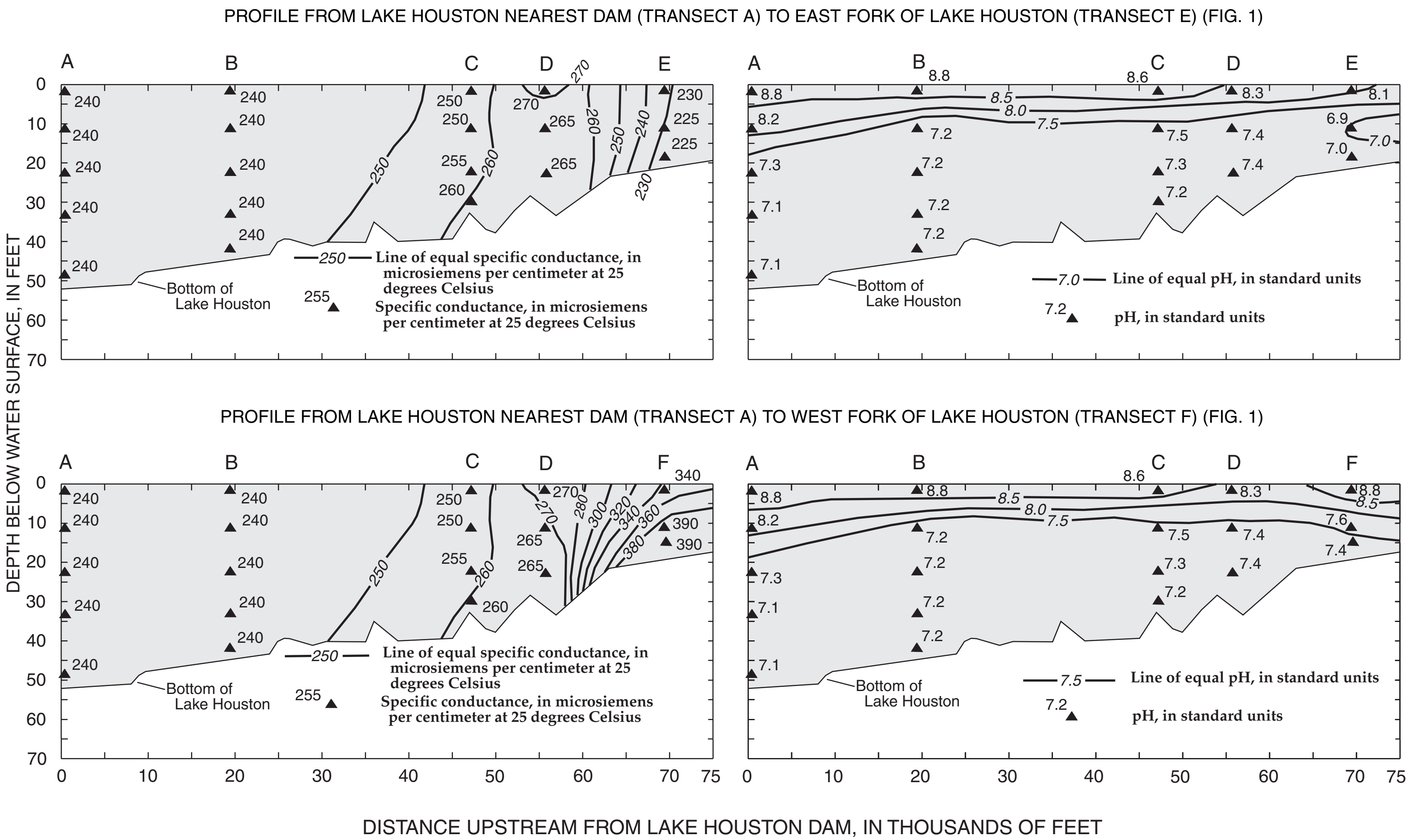

Figure 3b. Longitudinal profiles and vertical distribution of specific conductance and pH in Lake Houston, August 31, 1985.

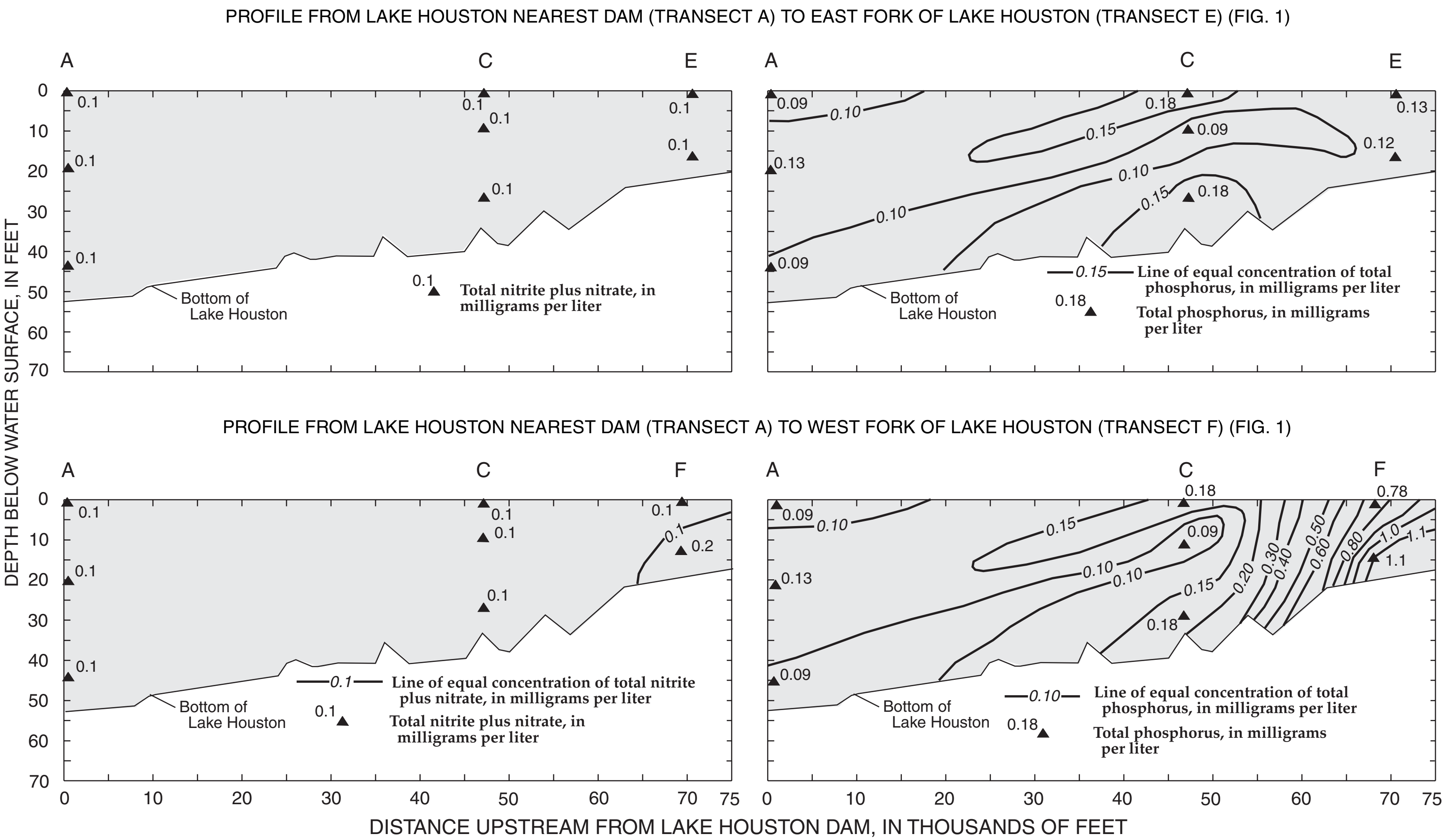

Figure 3c. Longitudinal profiles and vertical distribution of total nitrite plus nitrate nitrogen and total phosphorus in Lake Houston, August 31, 1985.

eastern tributaries, western tributaries, and the Trinity River at Romayor.

Although table 3 summarizes essentially all of the data collected in the study, boxplots of selected properties and constituents show how the water quality varies on the basis of season (summer or non-summer[1]), relative depth (near-surface or bottom), location, and relative streamflow (low-medium or high[2]). Boxplots of 17 properties and constituents selected as important factors affecting biological, physical, and chemical processes in water are shown in figures 4–33. A boxplot shows the distribution of concentrations determined for a physical property or chemical constituent. The ends of the box define the range of values between the 25th and 75th percentiles (interquartile range). For example, 25 percent of observed values are equal to or less than the 25th percentile value. The median is the 50th percentile. The "whiskers" extending from the ends of each box represent the range of data within 1.5 times the interquartile range outside the box. Data values beyond the whiskers are extreme values—1.5 to 3.0 times the interquartile range outside the box and more than 3.0 times the interquartile range outside the box. If a property or constituent represented in a boxplot has a maximum contaminant level (MCL), secondary maximum contaminant level (SMCL), or other criterion established by the EPA, those levels are indicated on the boxplots. MCLs, SMCLs, and other limiting criteria for selected properties and constituents are listed in table 4 (at end of report).

Water temperatures at six locations (lake nearest the dam [transect A], East Fork of the lake [transect E], West Fork of the lake [transect F], eastern tributaries, western tributaries, and Trinity River at Romayor) ranged from 5.0 °C (western tributaries) to 34.5 °C (lake nearest the dam) (table 3). Medians of temperatures grouped on the basis of season and depth for the three lake locations ranged from 13.0 °C for the lake nearest the dam for the non-summer period (for near-surface and bottom) to 30.0 °C for the West Fork for the summer (near-surface) (fig. 4). Medians for the tributaries to Lake Houston grouped on the basis of season and streamflow ranged from 13.0 °C for non-summer low-medium flows for the eastern tributaries to 27.0 °C for summer low-medium flows for the western tributaries (fig. 5). Medians for the Trinity River at Romayor ranged from 14.8 °C for non-summer low-medium flows to 28.8 °C for summer low-medium flows.

Specific conductance at the six locations (table 3) ranged from 22.0 µS/cm (western tributaries) to 867 µS/cm (western tributaries). Medians for the lake locations ranged from 127 µS/cm for the East Fork for the non-summer period (bottom) to 300 µS/cm for the West Fork for the summer (bottom) (fig. 6). Medians for the lake tributaries ranged from 80.0 µS/cm for summer high flows for the eastern tributaries to 474 µS/cm for summer low-medium flows for the western tributaries (fig. 7). Medians for the Trinity River did not range as widely as those for the tributaries—from 304 µS/cm for summer high flows to 372 µS/cm for summer low-medium flows—but generally were larger than those for the tributaries.

DO concentrations at the six locations (table 3) ranged from 0 (lake nearest the dam, East and West Forks) to 13.9 mg/L (Trinity River). Medians for the lake locations ranged from 1.7 mg/L for the lake nearest the dam for the summer (bottom) to 9.2 mg/L for the lake nearest the dam for the non-summer period (near-surface) (fig. 8). Differences in DO concentrations in the summer between locations in Lake Houston are another indication that stratification occurs during the summer (fig. 3a). Anoxic conditions (no DO) can exist near the bottom of Lake Houston during the summer. Medians for the lake tributaries ranged from 6.1 mg/L for summer high flows for the western tributaries to 9.4 mg/L for non-summer low-medium flows for the western tributaries (fig. 9). Medians for the Trinity River ranged from 8.0 mg/L for summer high flows to 11.0 mg/L for non-summer high flows.

Five-day BOD concentrations at the six locations (table 3) ranged from 0.4 mg/L (eastern tributaries) to 8.3 mg/L (western tributaries). Medians for the lake locations ranged from 1.7 mg/L for the lake nearest the dam for the non-summer period (near-surface) to 5.5 mg/L for the West Fork for the summer (near-surface) (fig. 10). Medians for the lake tributaries ranged from 1.1 mg/L for summer low-medium flows for the eastern tributaries to 3.8 mg/L for summer high flows for the western tributaries (fig. 11). Medians for the Trinity River ranged from 1.7 mg/L for non-summer high flows to 3.1 mg/L for summer low-medium flows.

pH at the six locations (table 3) ranged from 5.4 standard units (eastern tributaries) to 9.4 standard units

[1] For boxplots (and statistical tests), summer is defined as May 15–September 30; non-summer is the remainder of the year.

[2] For boxplots (and statistical tests), high streamflow is defined as the streamflow that is exceeded 10 percent or less of the time on the basis of station records; low-medium is all other streamflow.

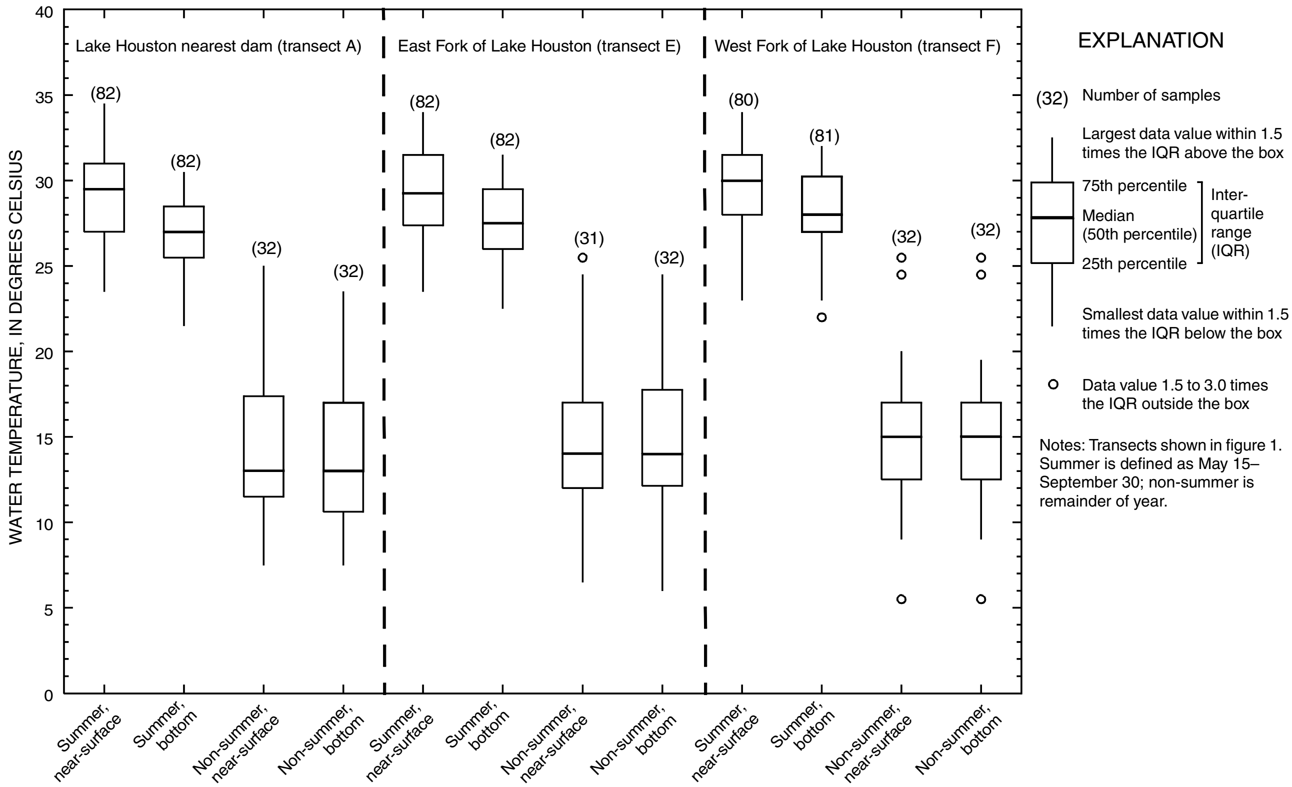

Figure 4. Range and distribution of water temperature in relation to season, depth, and location in Lake Houston.

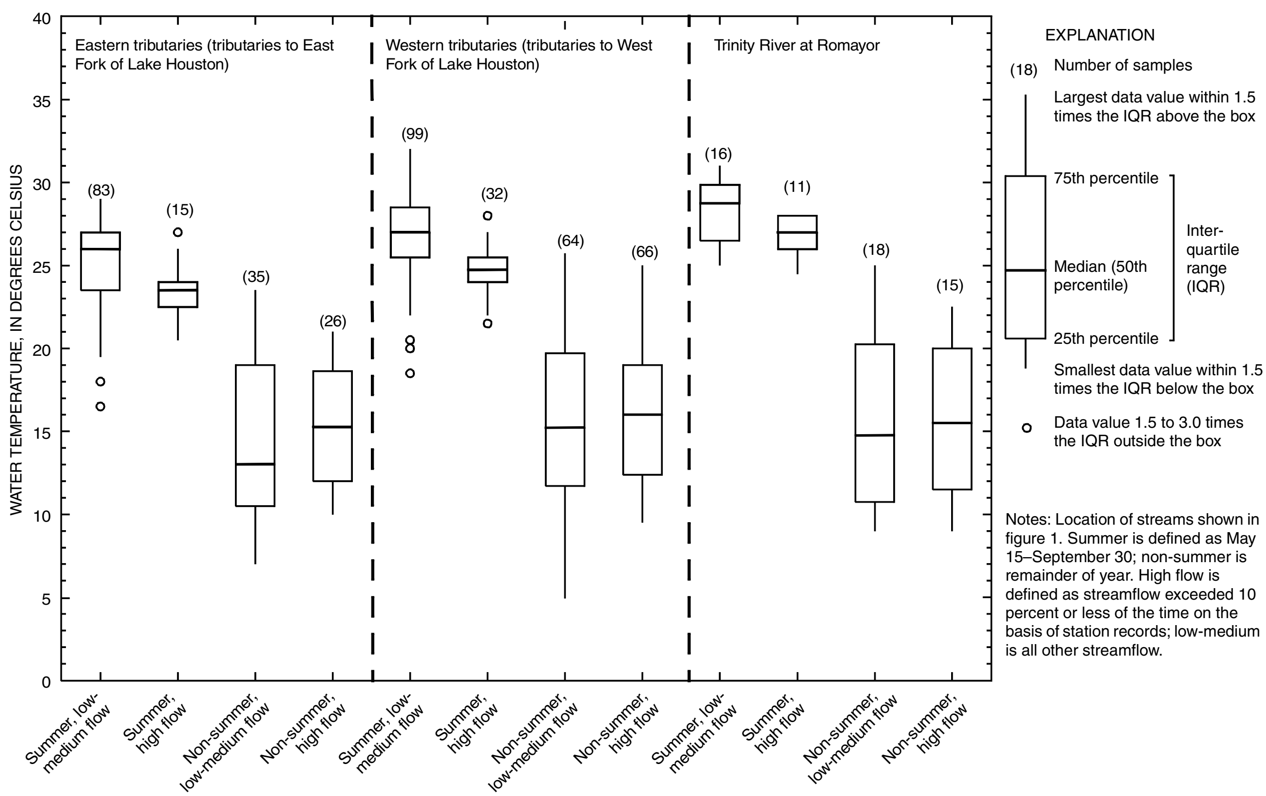

Figure 5. Range and distribution of water temperature in relation to season and flow in eastern and western tributaries and Trinity River.

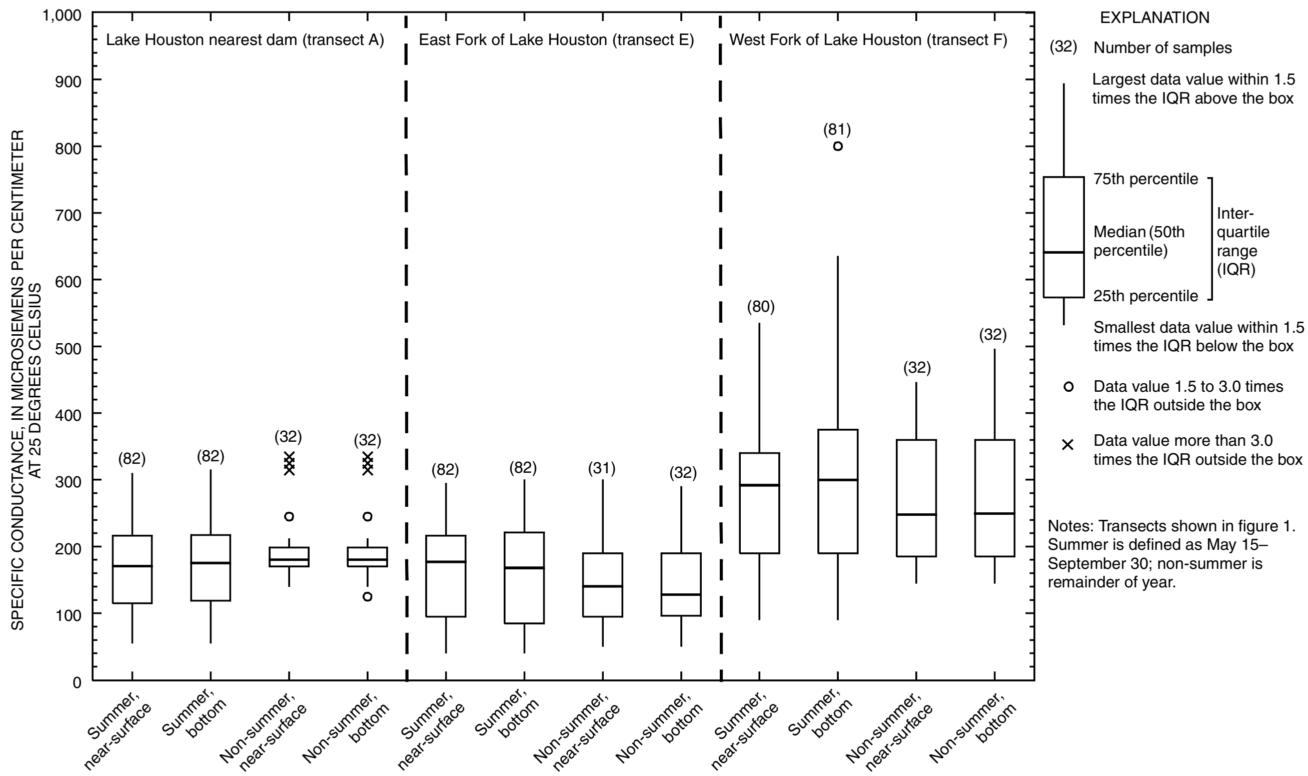

Figure 6. Range and distribution of specific conductance in relation to season, depth, and location in Lake Houston.

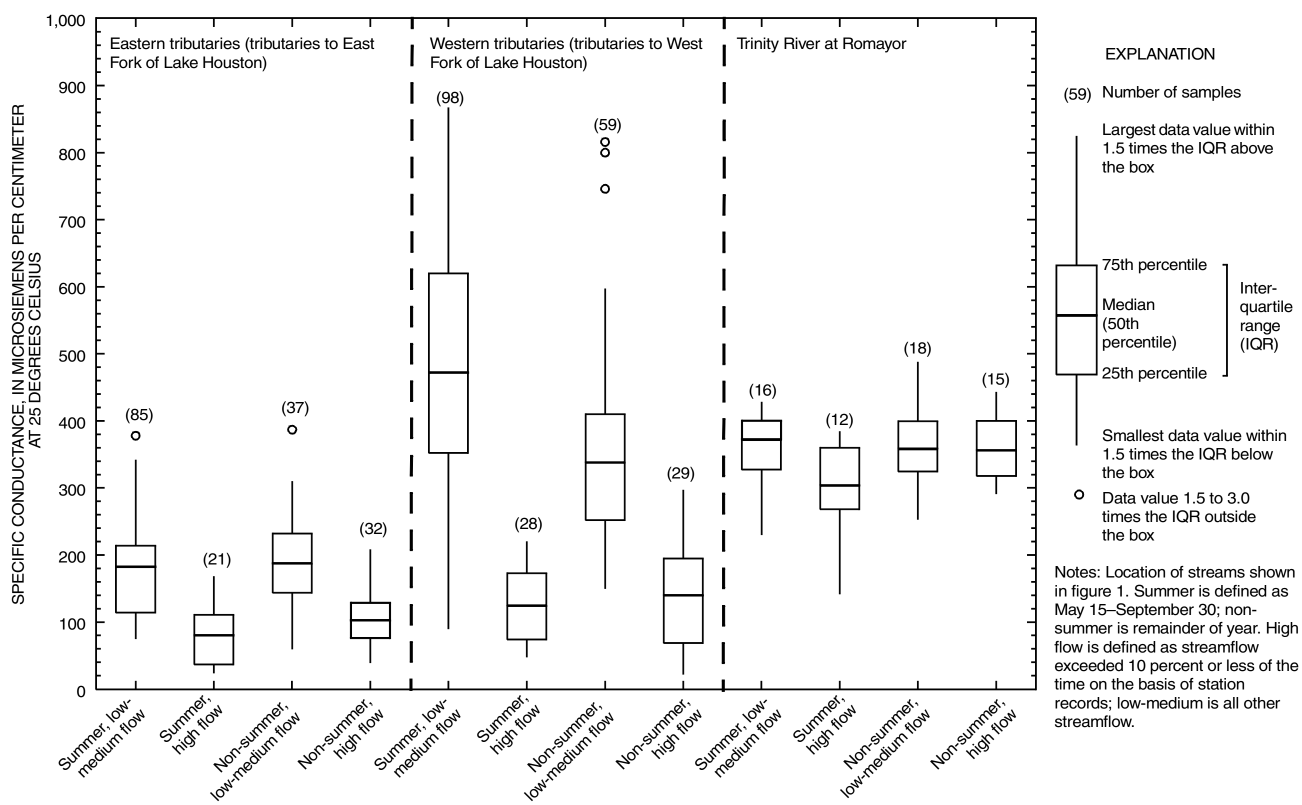

Figure 7. Range and distribution of specific conductance in relation to season and flow in eastern and western tributaries and Trinity River.

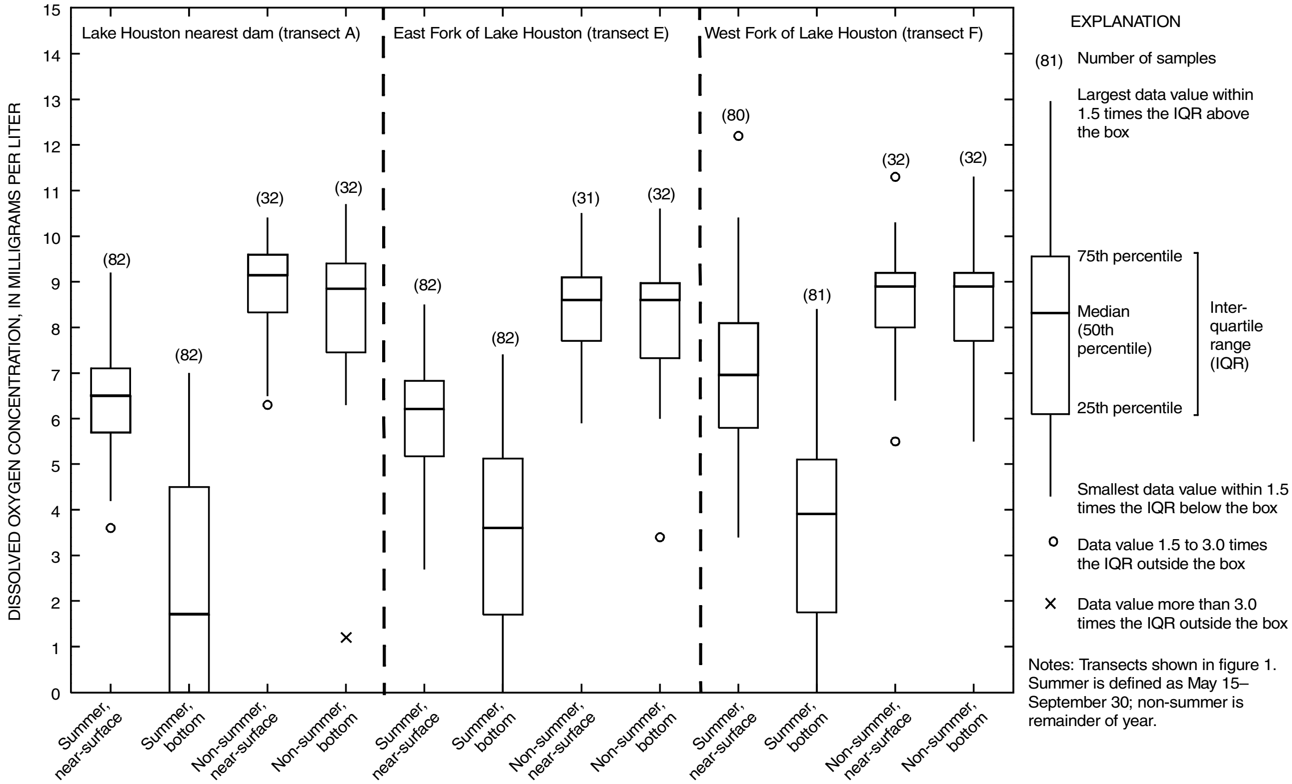

Figure 8. Range and distribution of dissolved oxygen concentrations in relation to season, depth, and location in Lake Houston.

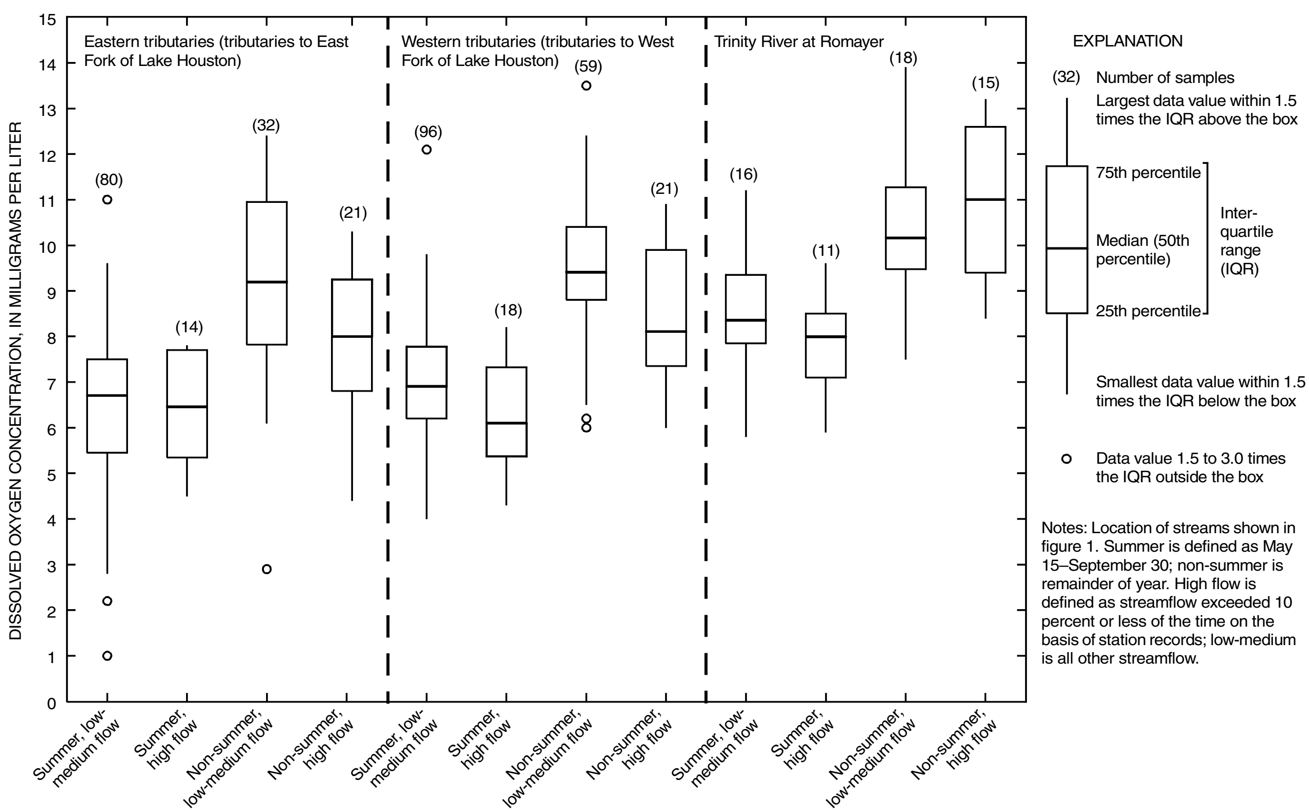

Figure 9. Range and distribution of dissolved oxygen concentrations in relation to season and flow in eastern and western tributaries and Trinity River.

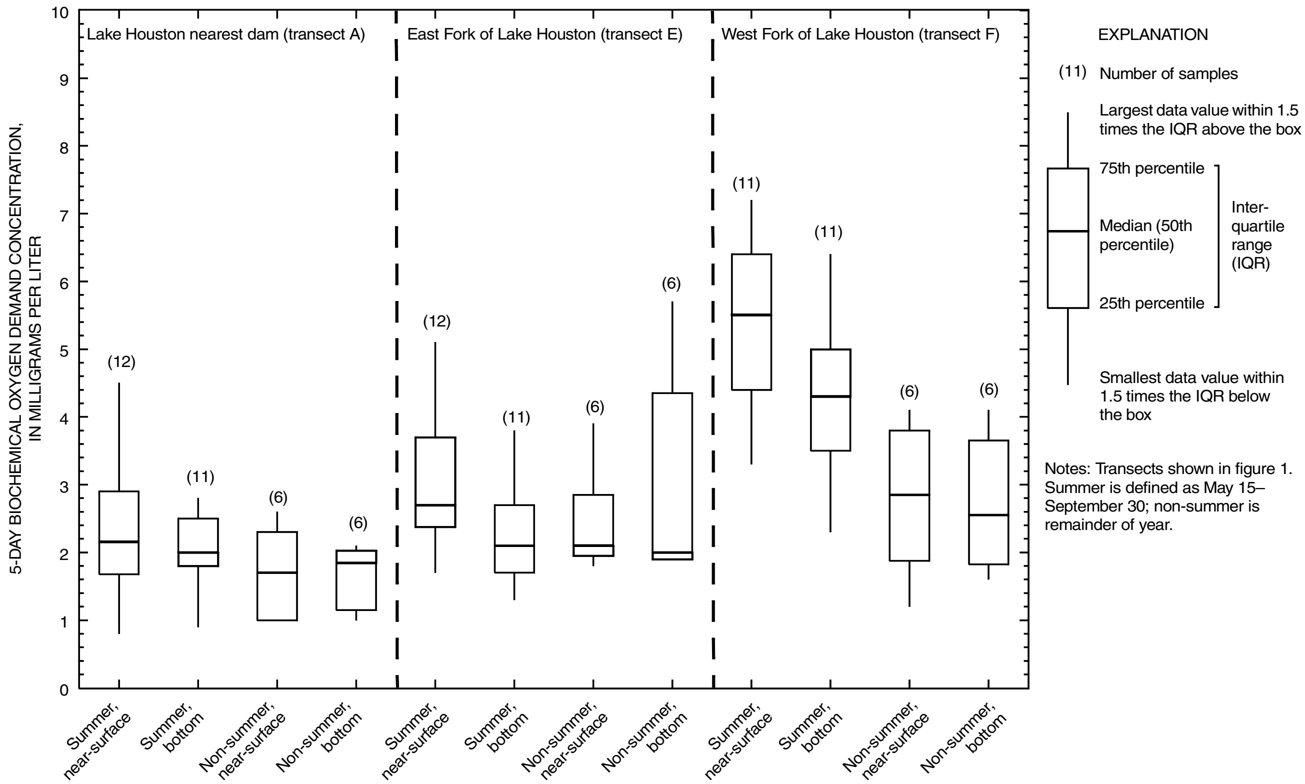

Figure 10. Range and distribution of 5-day biochemical oxygen demand concentrations in relation to season, depth, and location in Lake Houston.

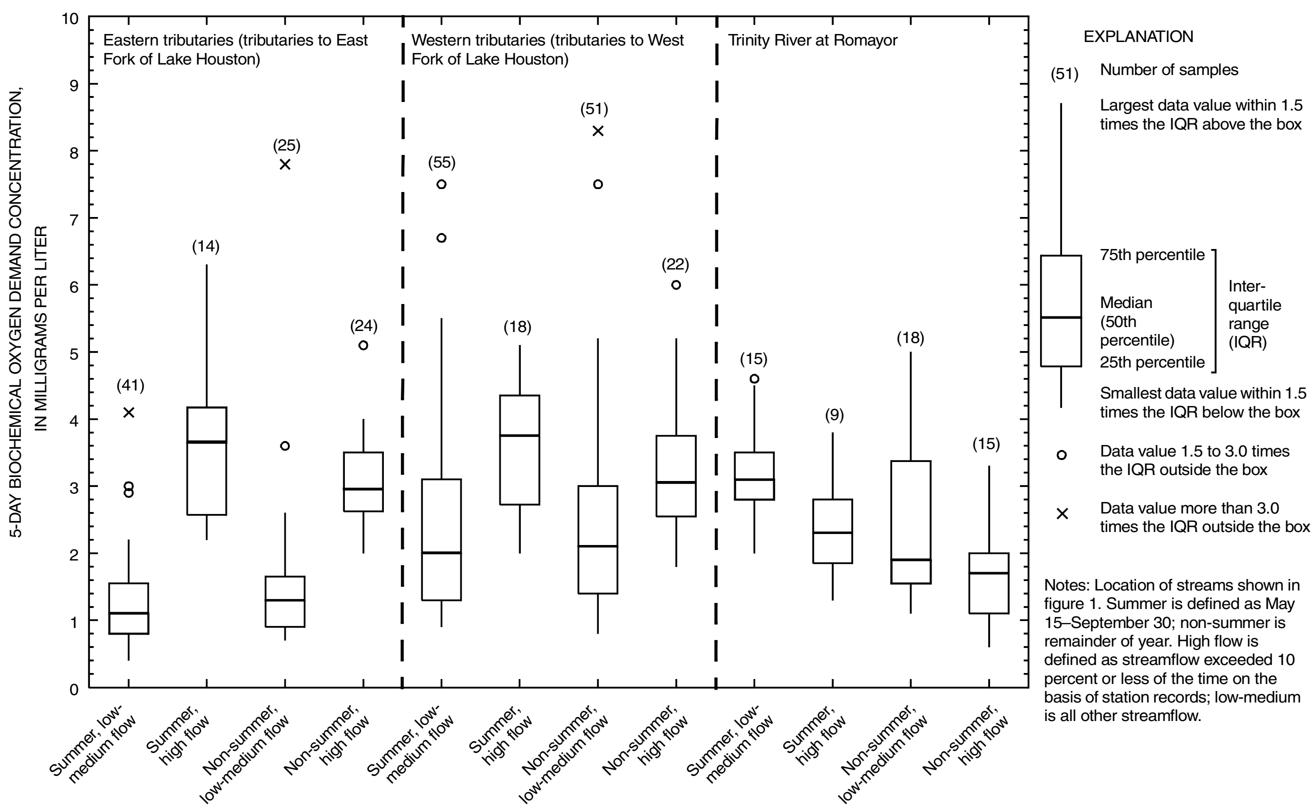

Figure 11. Range and distribution of 5-day biochemical oxygen demand concentrations in relation to season and flow in eastern and western tributaries and Trinity River.

(West Fork). Medians for the lake locations ranged from 7.0 standard units for the lake nearest the dam and East Fork for the summer (bottom) to 8.1 standard units for the West Fork for the summer (near-surface) (fig. 12). Medians for the lake tributaries ranged from 6.6 standard units for both summer and non-summer high flows for the eastern tributaries to 7.5 standard units for summer low-medium flows for the western tributaries (fig. 13). Medians for the Trinity River ranged from 7.7 standard units for non-summer high flows to 8.3 standard units for summer low-medium flows. Medians at all locations were within the range of the SMCL for drinking water (6.5 to 8.5 standard units, table 4). Individual pH values exceeded the SMCL in about 14 percent of all samples collected during the study. Larger pH during the summer near the surface is consistent with stratification (fig. 3b) and greater photosynthetic activity.

Fecal coliform and fecal streptococcus bacteria samples were collected at all locations during the study; however, an insufficient number of samples was collected from locations in Lake Houston to determine medians for data grouped on the basis of season and depth. Therefore, boxplots are presented only for samples collected from the eastern and western tributaries and the Trinity River. Fecal coliform bacteria densities at the six locations (table 3) ranged from 20 cols./100 mL (East and West Forks, western tributaries, Trinity River) to 18,000 cols./100 mL (western tributaries). Medians for the lake tributaries ranged from 120 cols./100 mL for summer low-medium flows for the eastern tributaries to 2,600 cols./100 mL for non-summer high flows for the western tributaries (fig. 14). Medians for the Trinity River ranged from 48 cols./100 mL for non-summer low-medium flows to 110 cols./100 mL for summer high flows. Densities in the eastern and western tributaries generally are larger than in the Trinity River.

Fecal streptococcus bacteria densities at the six locations (table 3) ranged from 5 cols./100 mL (lake nearest dam) to 14,000 cols./100 mL (western tributaries). Medians for the lake tributaries ranged from 150 cols./100 mL for non-summer low-medium flows for the eastern tributaries to 6,200 cols./100 mL for summer high flows for the western tributaries (fig. 15). Medians for the Trinity River ranged from 74 cols./100 mL for non-summer high flows to 135 cols./100 mL for summer high flows.

Turbidity (cloudiness of water) at the six locations (table 3) ranged from 0.60 TU (Trinity River) to 1,600 TU (western tributaries). Medians for the lake locations ranged from 16 TU for the East Fork for the summer (near-surface) to 54 TU for the West Fork for the non-summer period (bottom) (fig. 16). Medians for the lake tributaries ranged from 15 TU for summer low-medium flows for the western tributaries to 84 TU for non-summer high flows for the western tributaries (fig. 17). Medians for the Trinity River ranged from 3.1 TU for summer low-medium flows to 12 TU for summer high flows. The EPA standard for turbidity in drinking water (table 4) requires that turbidity not exceed 5 TU; and that turbidity not exceed 1 TU in at least 95 percent of daily samples for any 2 consecutive months. All or most of the turbidity measurements for all locations and conditions, except for Trinity River summer low-medium flows, exceeded the 5-TU standard. The high natural turbidity relative to the standard indicates reduced light penetration, which in turn could reduce biological activity.

Secchi-disk transparency was measured only in the main body of the lake, which included the lake nearest the dam, and the East and West Forks. Secchi-disk transparency is a measure of the depth of light penetration and thus was measured only near the lake surface. Transparency for the lake nearest the dam and the East and West Forks ranged from 0.05 m (West Fork) to 1.44 m (East Fork) (table 3). Medians ranged from 0.17 m for the West Fork for the summer to 0.43 m for the lake nearest the dam for the summer (fig. 18). The increase in transparency as water flows toward the lake nearest the dam likely is a result of suspended material settling in the slow-moving water.

Suspended solids concentrations in the six locations (table 3) ranged from 1 mg/L (West Fork) to 3,340 mg/L (western tributaries). Medians for the lake locations ranged from 14 mg/L for the lake nearest the dam for the summer (near-surface) to 69 mg/L for the West Fork for the summer (bottom) (fig. 19). Medians for the lake tributaries ranged from 13 mg/L for non-summer low-medium flows for the eastern tributaries to 161 mg/L for non-summer high flows for the western tributaries (fig. 20). Medians for the Trinity River ranged from 12 mg/L for summer low-medium flows to 35 mg/L for non-summer high flows.

Total nitrogen concentrations in the six locations (table 3) ranged from 0.20 mg/L (western tributaries) to 12 mg/L (western tributaries). Medians for the lake locations ranged from 0.90 mg/L for the lake nearest the

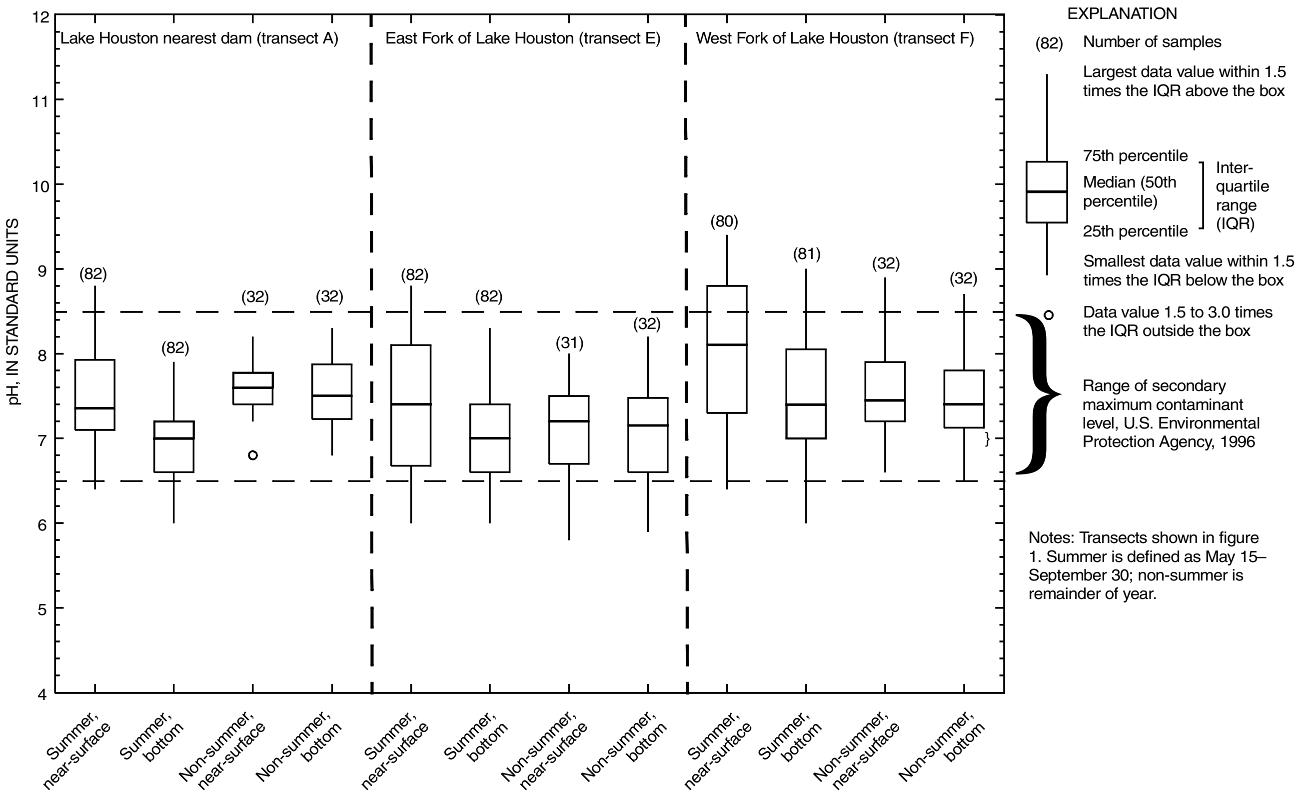

Figure 12. Range and distribution of pH in relation to season, depth, and location in Lake Houston.

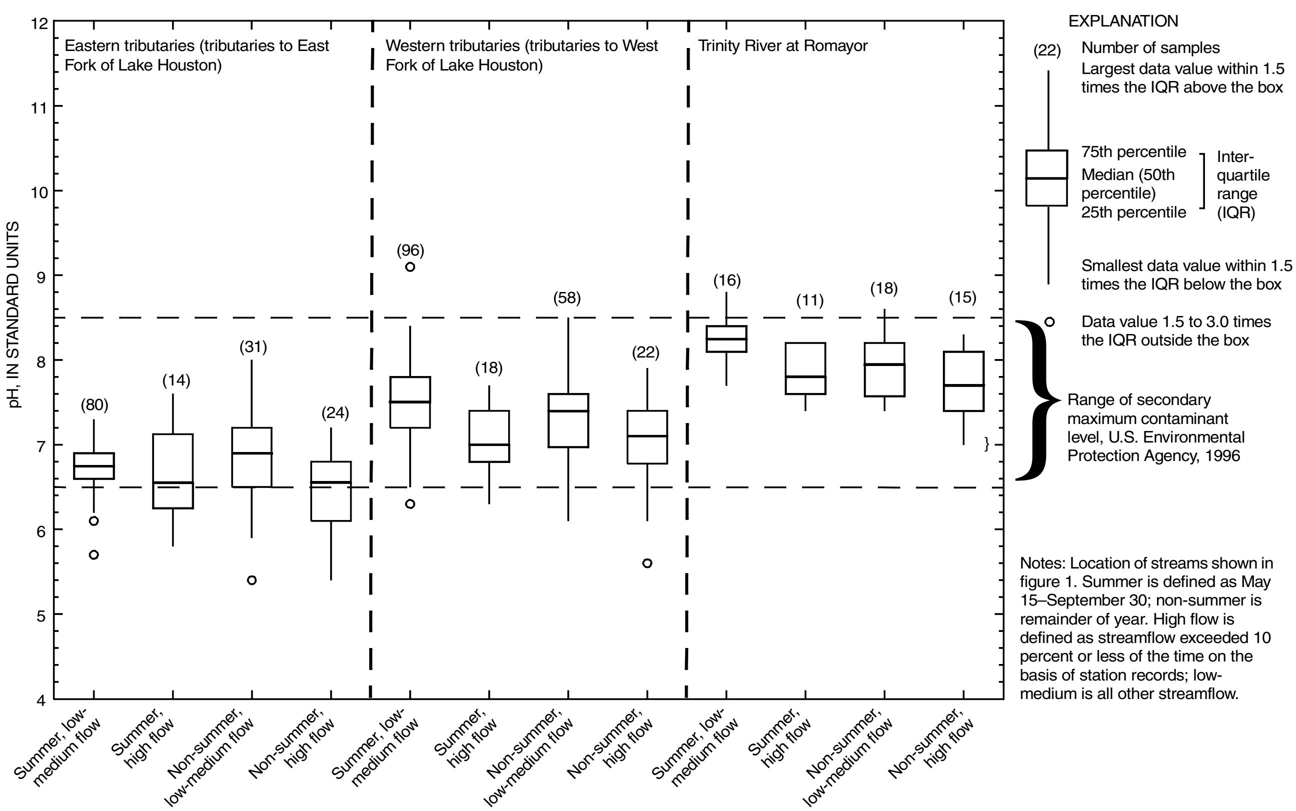

Figure 13. Range and distribution of pH in relation to season and flow in eastern and western tributaries and Trinity River.

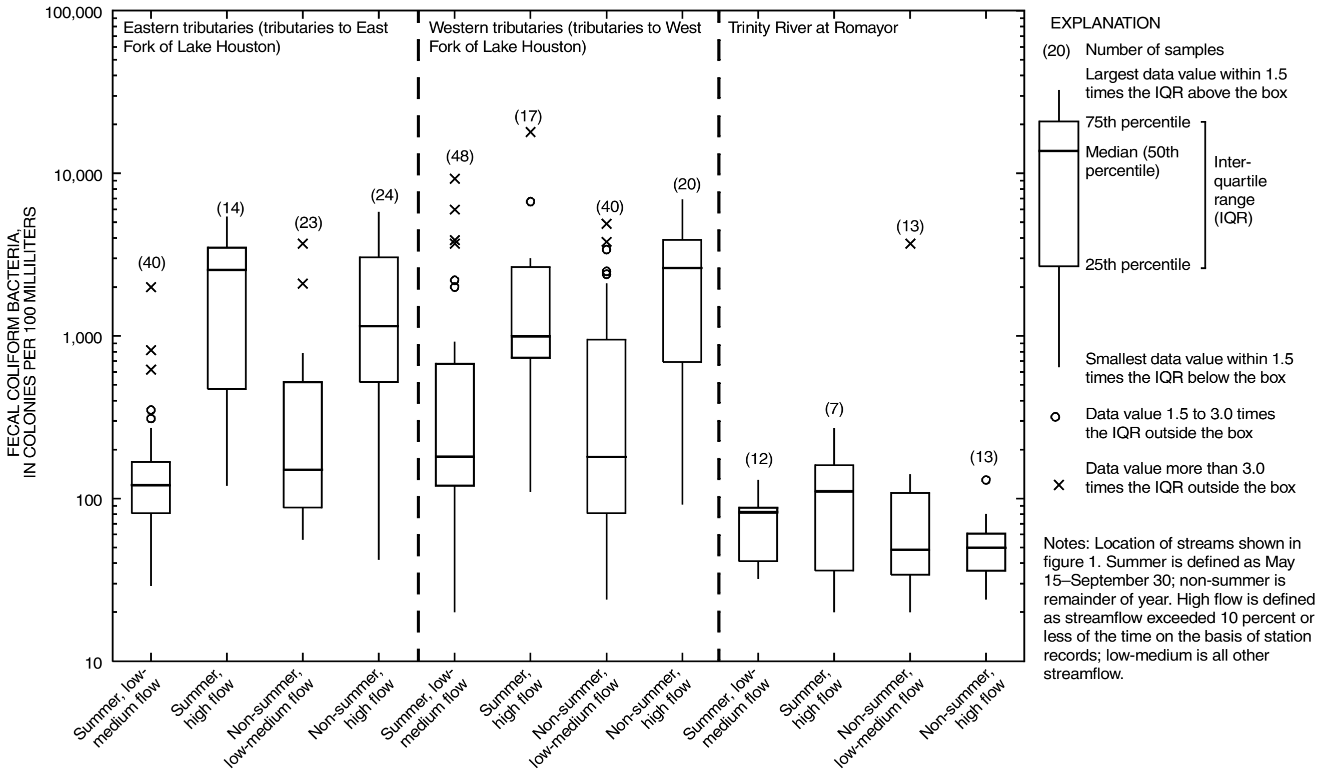

Figure 14. Range and distribution of fecal coliform bacteria densities in relation to season and flow in eastern and western tributaries and Trinity River.

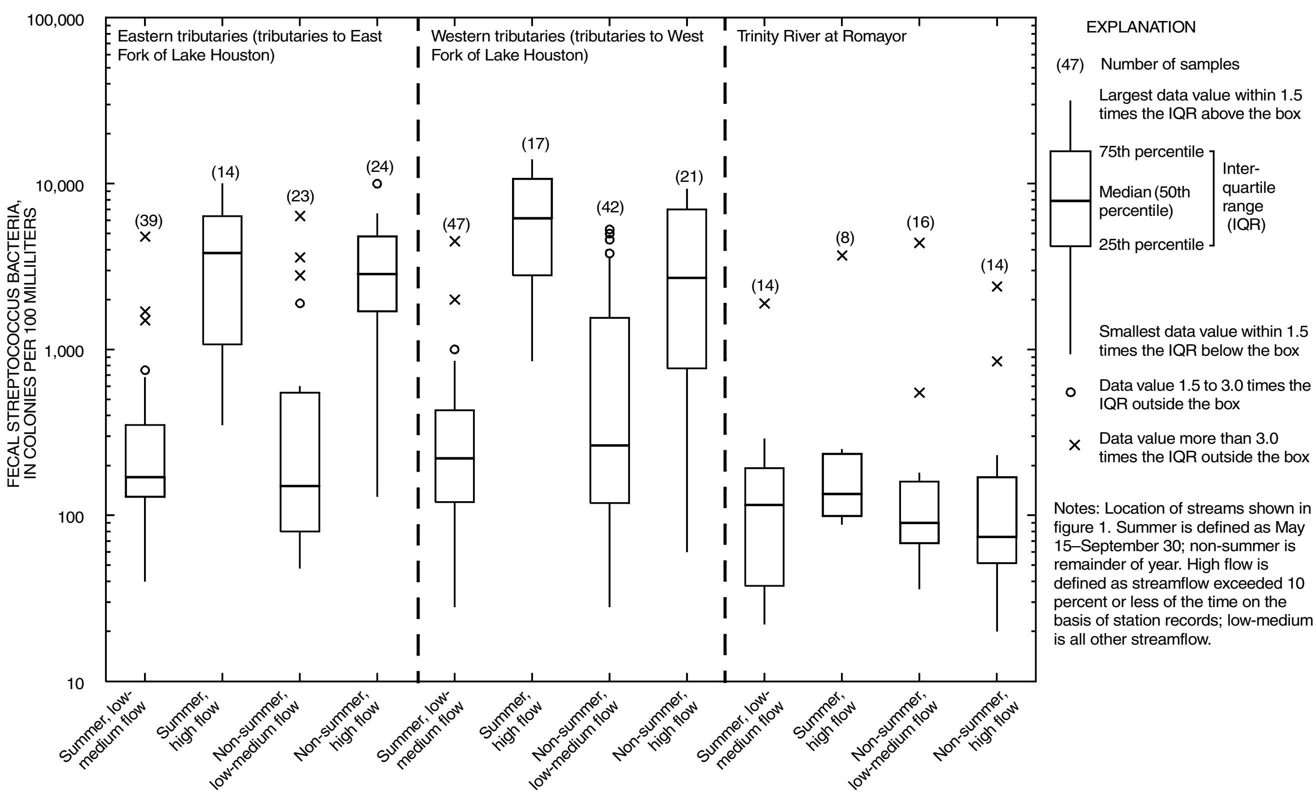

Figure 15. Range and distribution of fecal streptococcus bacteria densities in relation to season and flow in eastern and western tributaries and Trinity River.

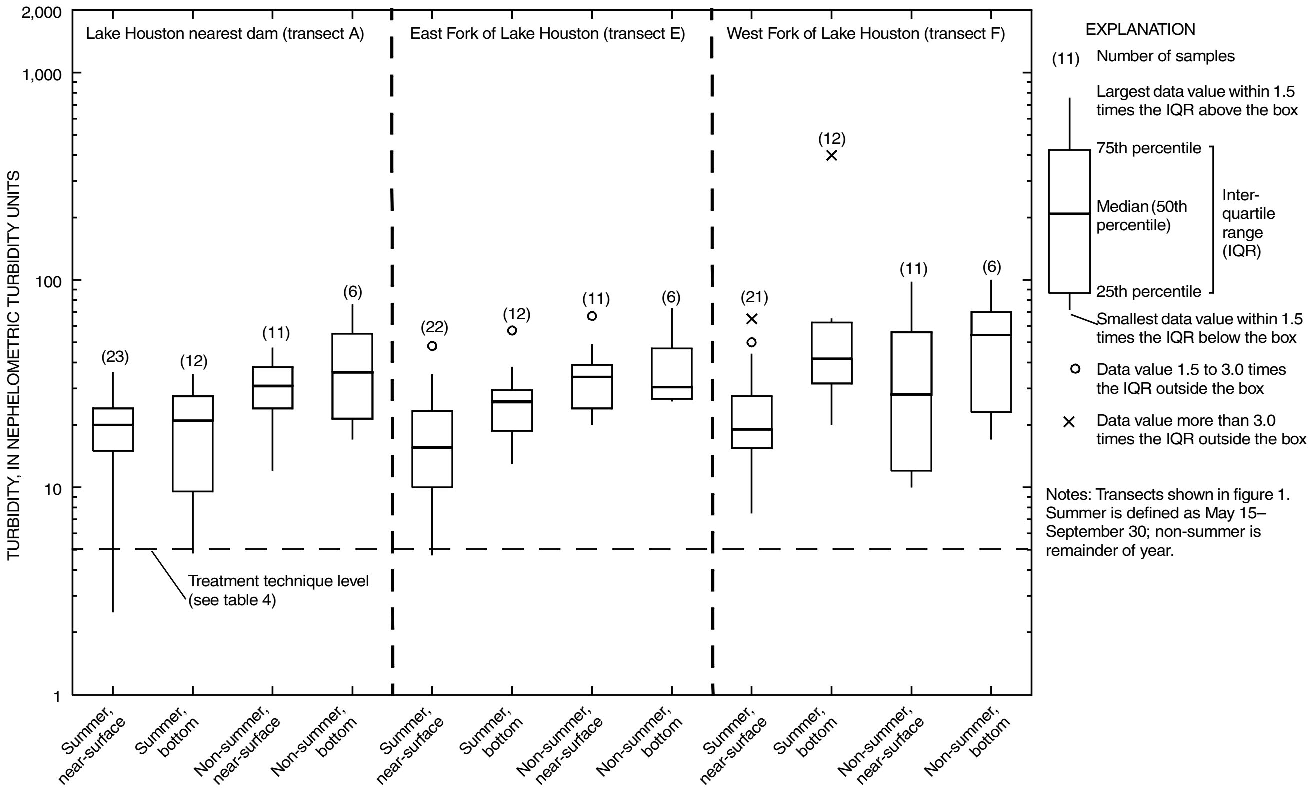

Figure 16. Range and distribution of turbidity measurements in relation to season, depth, and location in Lake Houston.

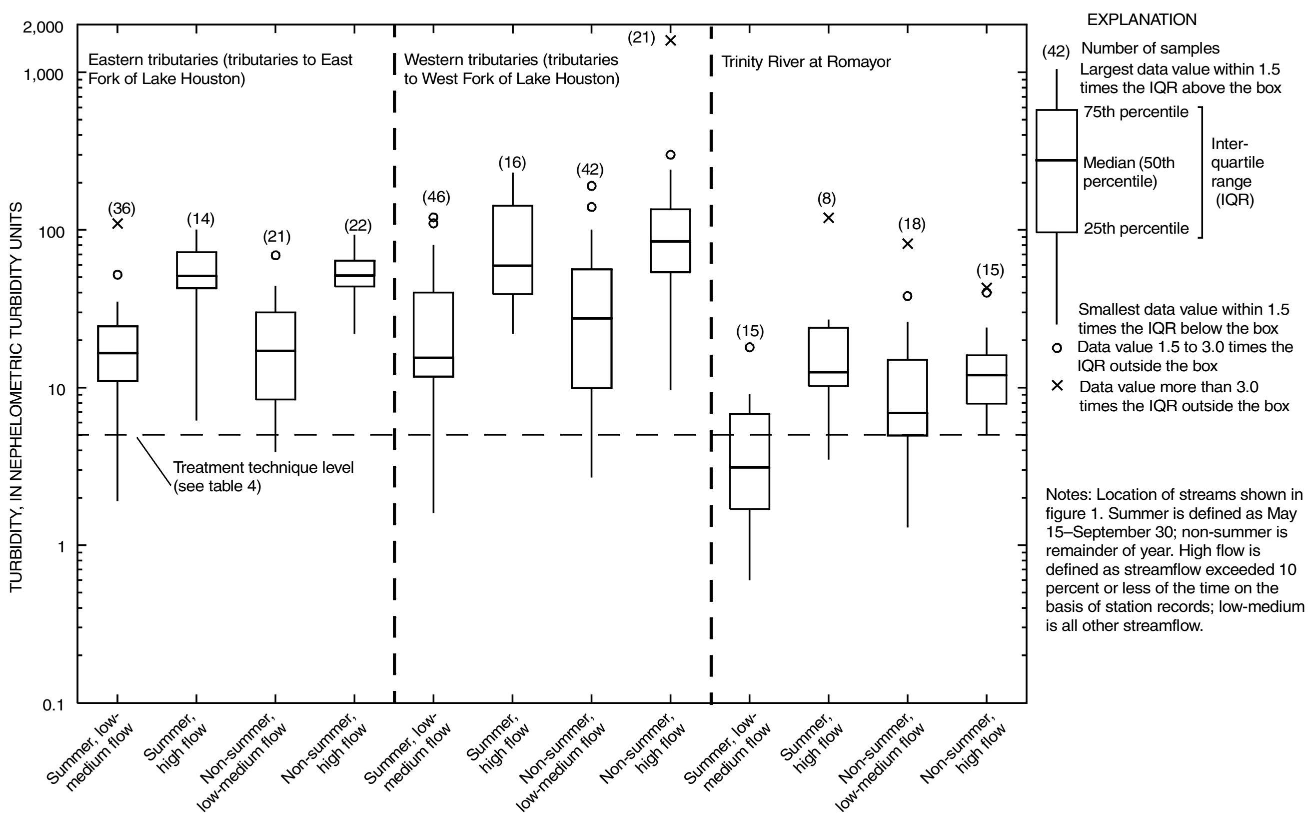

Figure 17. Range and distribution of turbidity measurements in relation to season and flow in eastern and western tributaries and Trinity River.

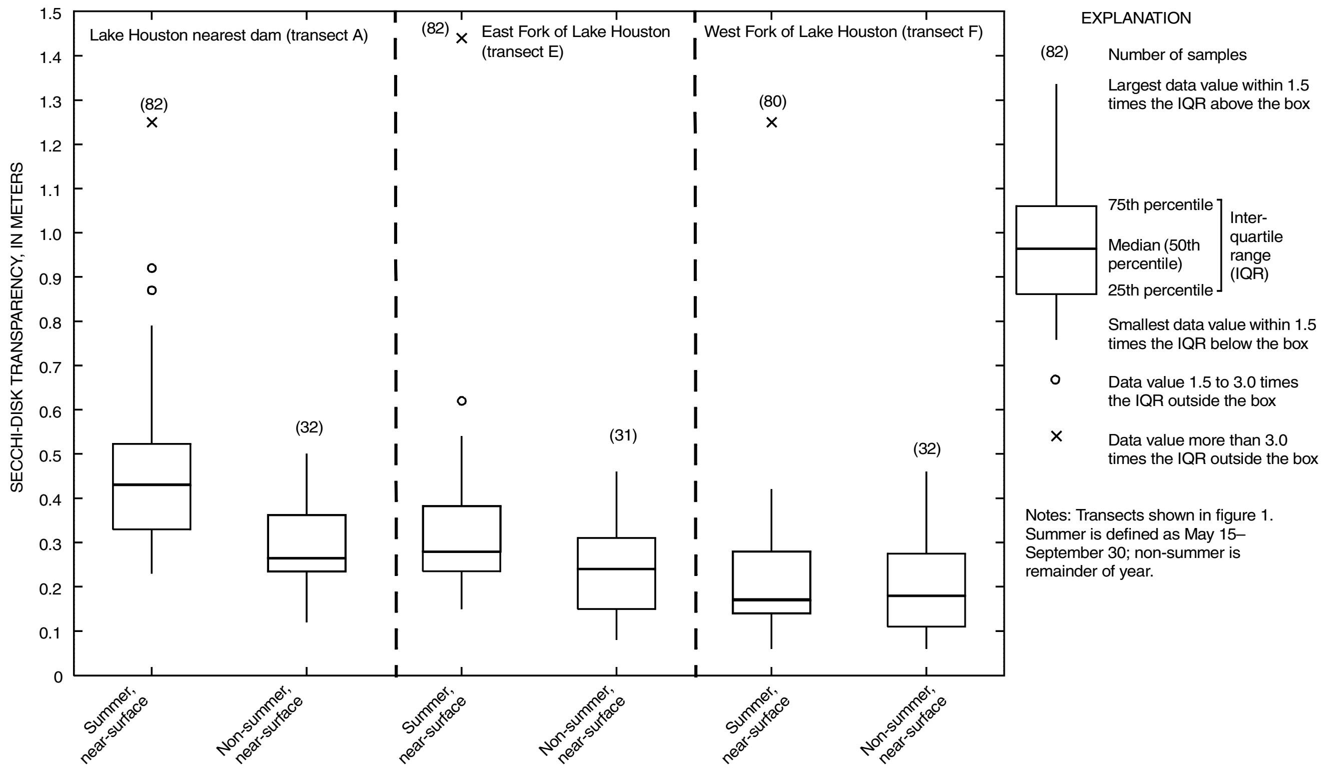

Figure 18. Range and distribution of Secchi-disk transparency in relation to season and location in Lake Houston.

dam for the summer (near-surface) and for the East Fork for the non-summer period (near-surface and bottom) to 1.60 mg/L for the West Fork for the non-summer period (near-surface) (fig. 21). Medians for the lake tributaries ranged from 0.70 mg/L for summer low-medium flows for the eastern tributaries to 3.2 mg/L for summer low-medium flows for the western tributaries (fig. 22). Medians for the Trinity River ranged from 0.80 mg/L (on the basis of one summer low-medium flow sample) to 1.2 mg/L for summer high flows and non-summer low-medium and high flows.

Total nitrite plus nitrate nitrogen concentrations in the six locations (table 3) ranged from less than 0.10 mg/L (all locations) to 10 mg/L (western tributaries). Medians for lake locations ranged from 0.10 mg/L for the lake nearest the dam for the summer (near-surface) and for the East Fork for the summer and non-summer periods (near-surface and bottom) to 0.50 mg/L for the West Fork for the non-summer period (near-surface and bottom) (fig. 23). Medians for the lake tributaries ranged from 0.10 mg/L for summer and non-summer high flows for the eastern tributaries to 2.1 mg/L for summer low-medium flows for the western tributaries (fig. 24). Medians for the Trinity River ranged from 0.10 mg/L (on the basis of one summer low-medium flow sample) to 0.60 mg/L for non-summer high flows. No medians exceeded the 10-mg/L MCL (table 4), although concentrations in two samples from the western tributaries equaled the MCL.

Total phosphorus concentrations in the six locations (table 3) ranged from 0.01 mg/L (East Fork, eastern tributaries) to 7.0 mg/L (western tributaries). Medians for the lake locations ranged from 0.075 mg/L for the East Fork for the non-summer period (near-surface) to 0.56 mg/L for the West Fork for the summer (bottom) (fig. 25). Medians for the lake tributaries ranged from 0.055 mg/L for non-summer low-medium flows for the eastern tributaries to 1.2 mg/L for summer low-medium flows for the western tributaries (fig. 26). Medians for the Trinity River ranged from 0.12 mg/L for non-summer low-medium flows to 0.20 mg/L for summer low-medium flows.

Total organic carbon (TOC) concentrations in the six locations (table 3) ranged from 2.2 mg/L (eastern tributaries) to 45 mg/L (eastern tributaries). Medians for the lake locations ranged from 9.2 mg/L for the lake

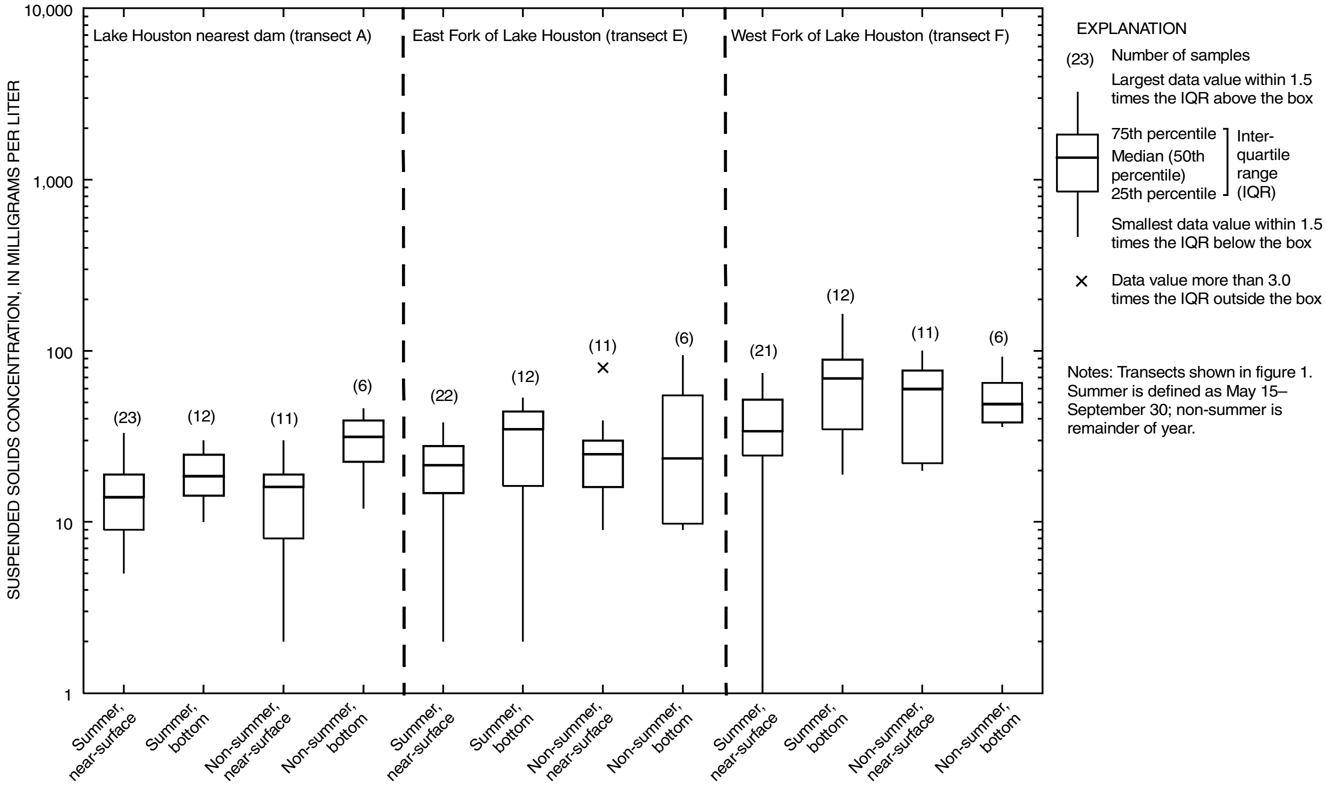

Figure 19. Range and distribution of suspended solids concentrations in relation to season, depth, and location in Lake Houston.

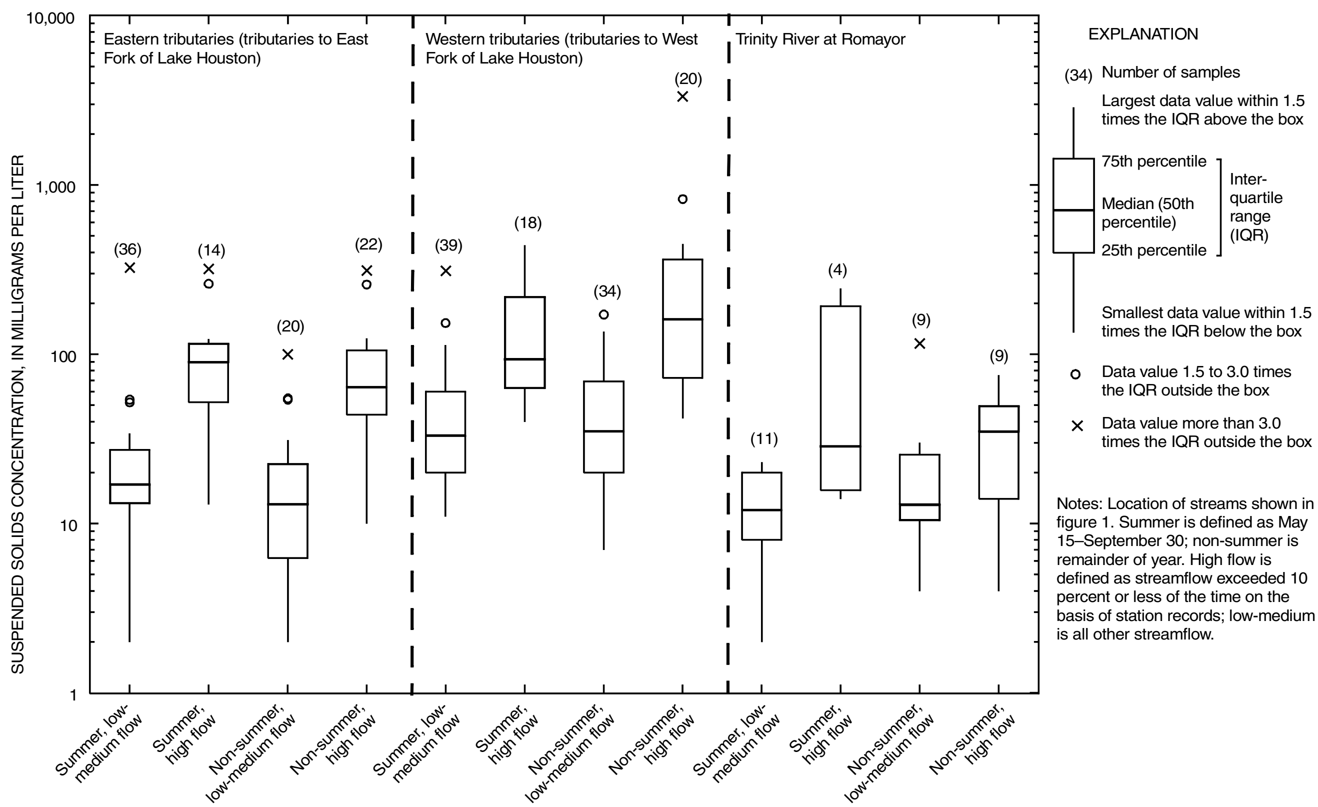

Figure 20. Range and distribution of suspended solids concentrations in relation to season and flow in eastern and western tributaries and Trinity River.

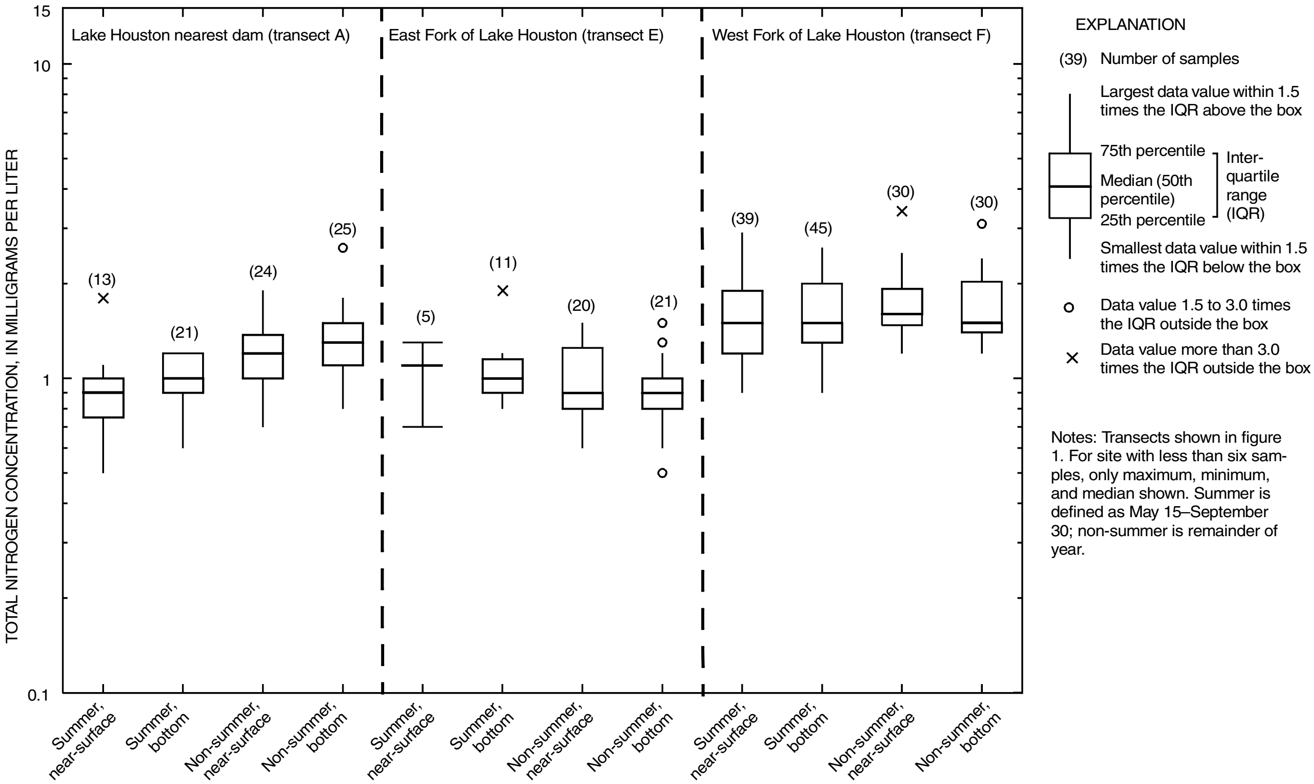

Figure 21. Range and distribution of total nitrogen concentrations in relation to season, depth, and location in Lake Houston.

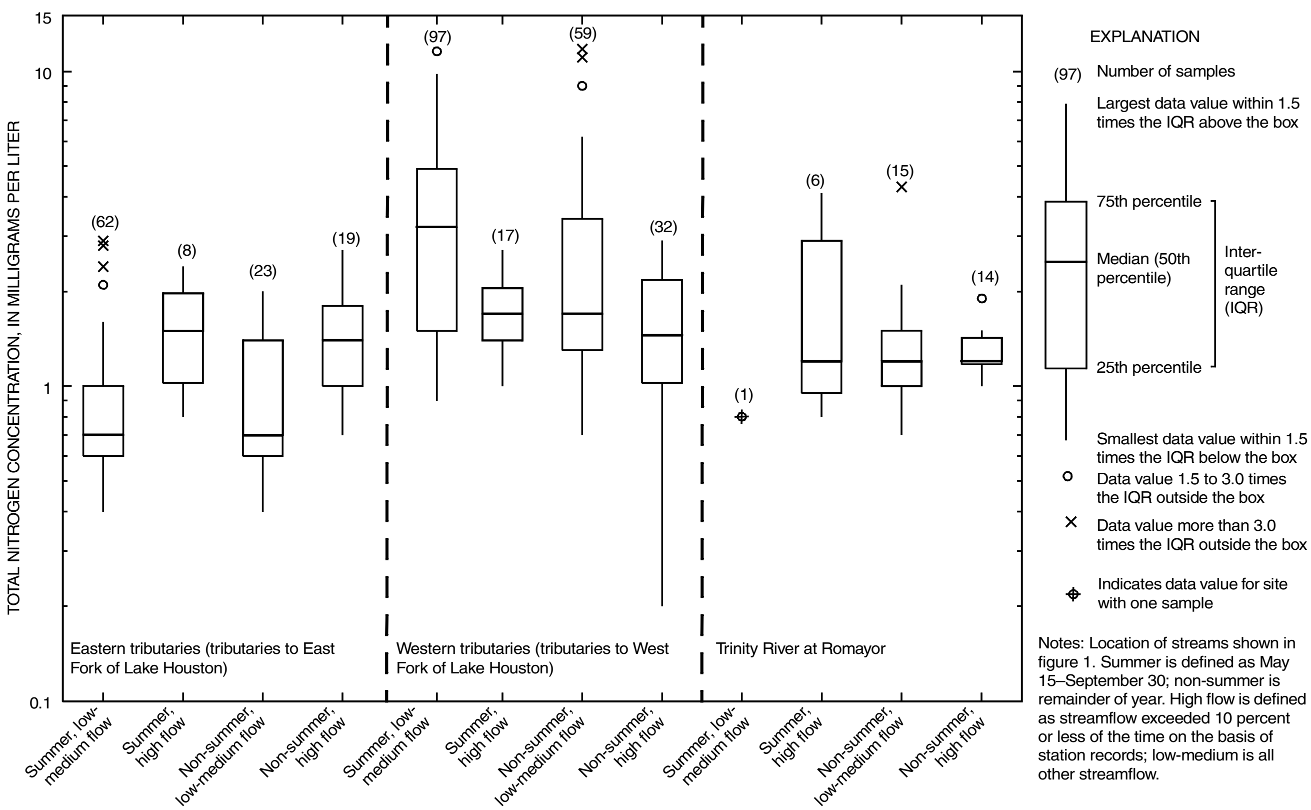

Figure 22. Range and distribution of total nitrogen concentrations in relation to season and flow in eastern and western tributaries and Trinity River.

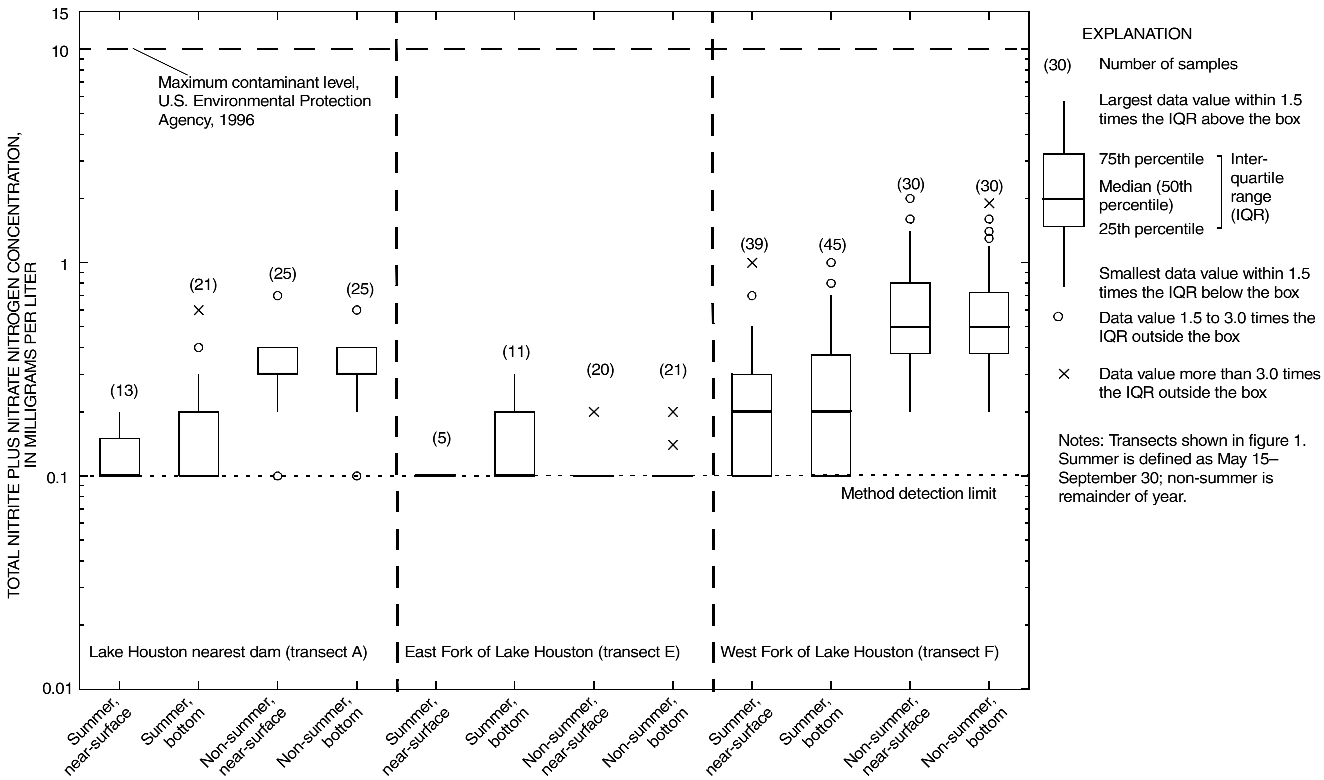

Figure 23. Range and distribution of total nitrite plus nitrate nitrogen concentrations in relation to season, depth, and location in Lake Houston.

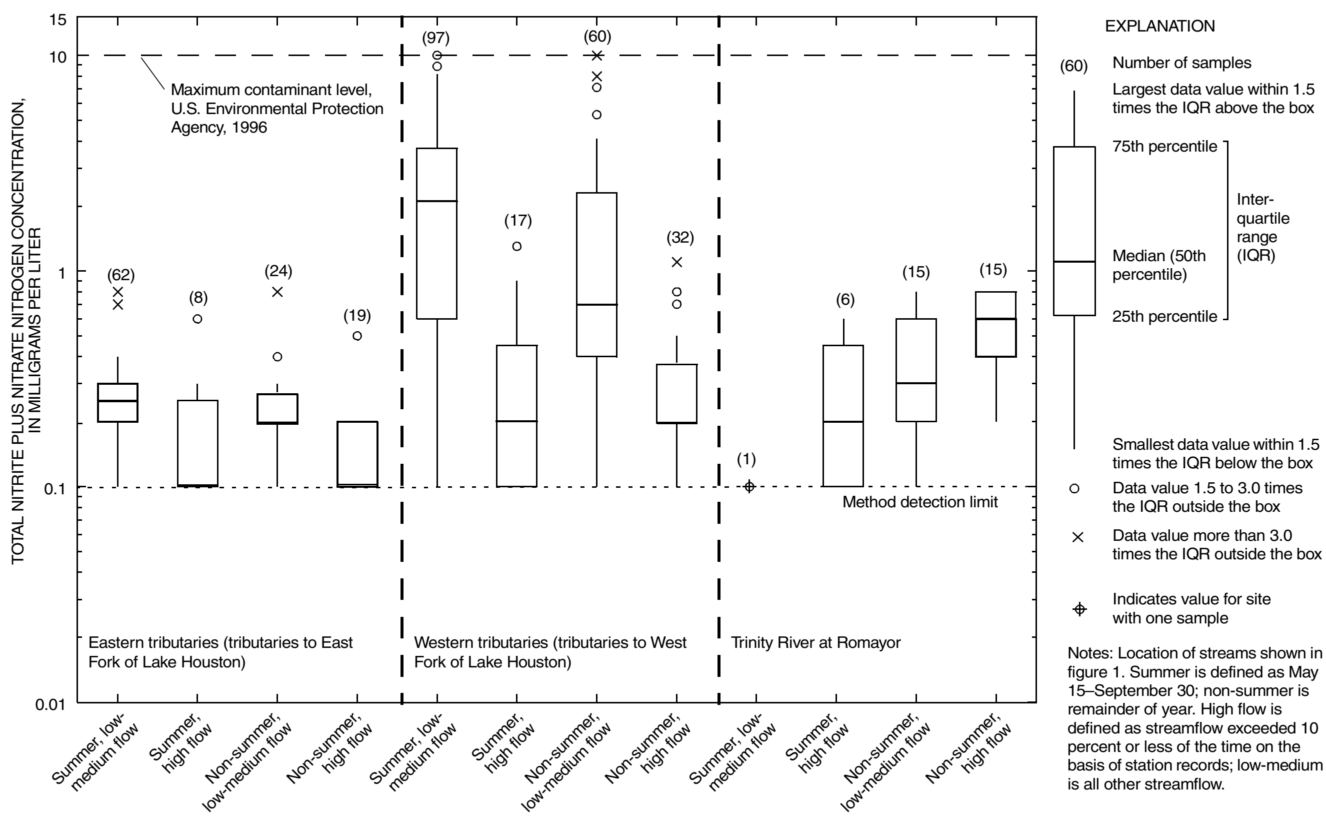

Figure 24. Range and distribution of total nitrite plus nitrate nitrogen concentrations in relation to season and flow in eastern and western tributaries and Trinity River.

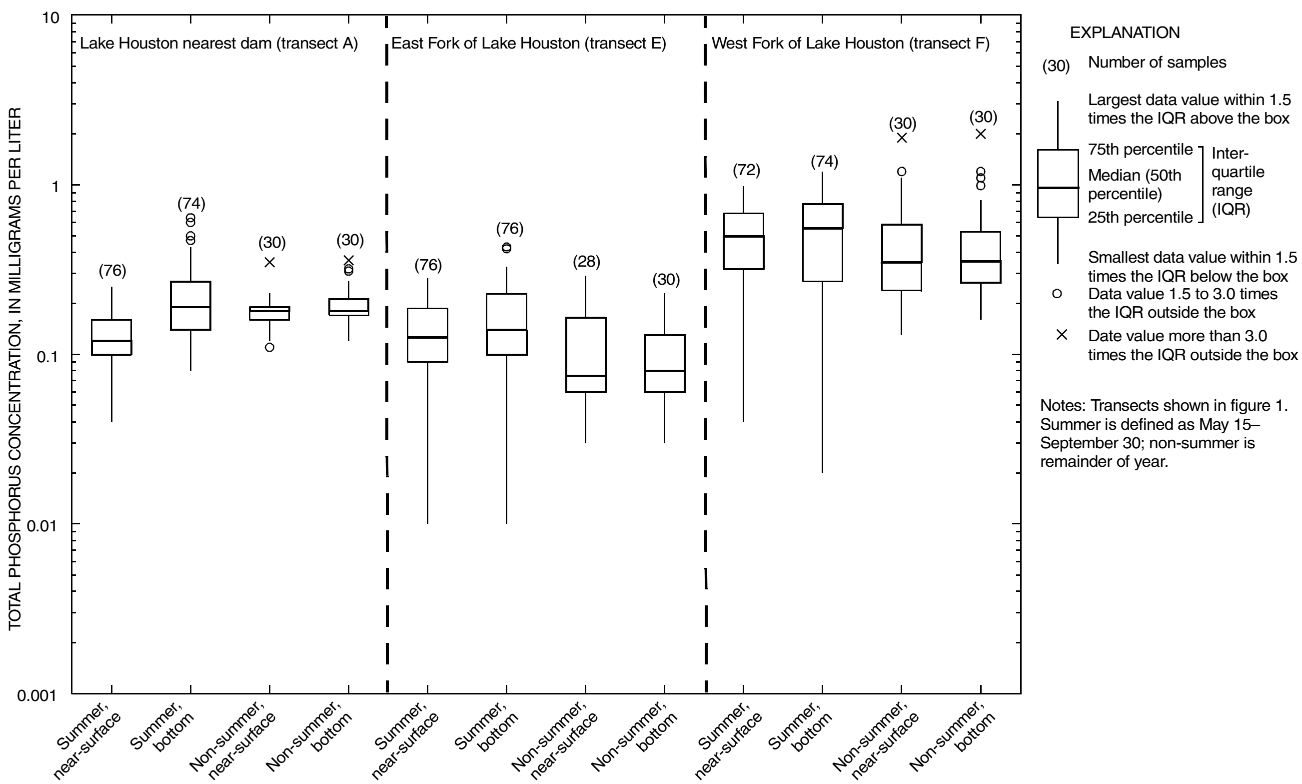

Figure 25. Range and distribution of total phosphorus concentrations in relation to season, depth, and location in Lake Houston.

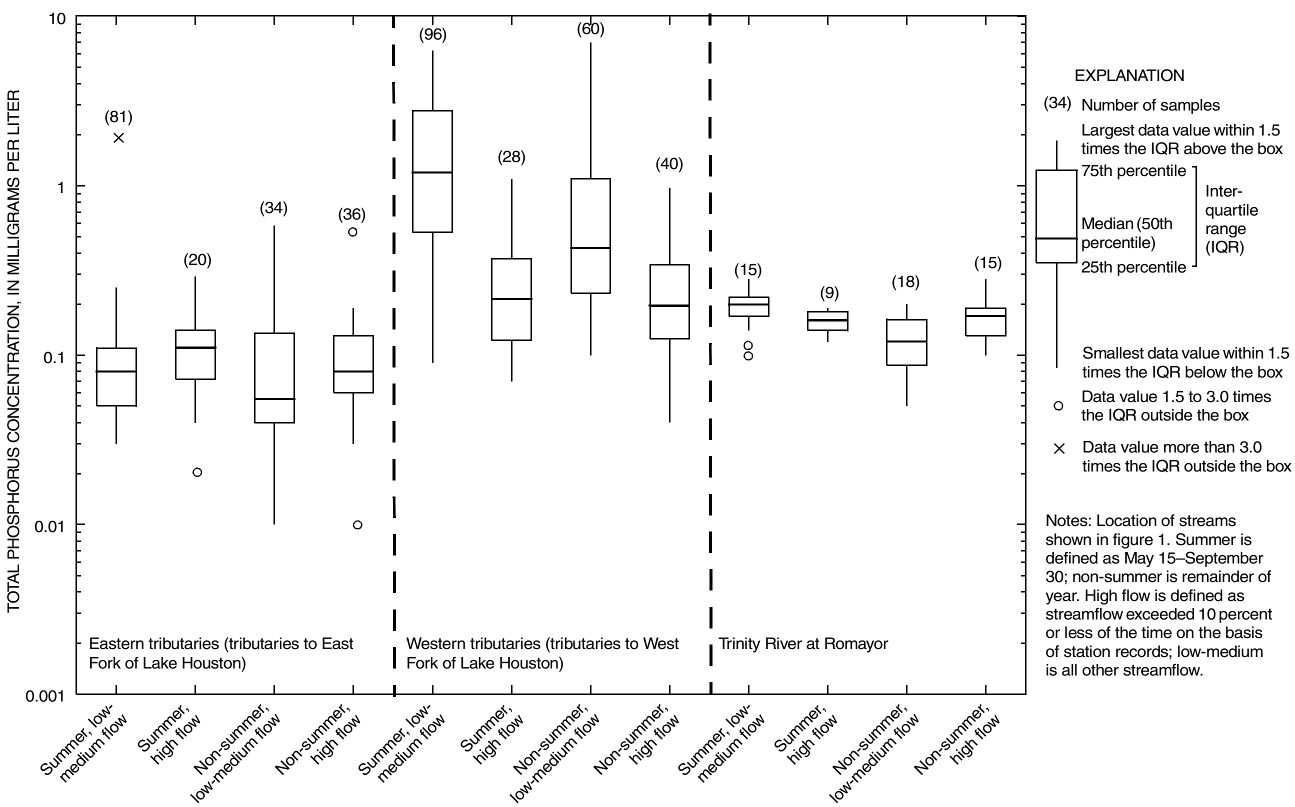

Figure 26. Range and distribution of total phosphorus concentrations in relation to season and flow in eastern and western tributaries and Trinity River.

nearest the dam for the non-summer period (near-surface) to 15 mg/L for the East Fork for the non-summer period (near-surface) (fig. 27). Medians for the lake tributaries ranged from 5.4 mg/L for summer low-medium flows for the eastern tributaries to 18 mg/L for non-summer high flows, also for the eastern tributaries (fig. 28). Medians for the Trinity River ranged from 6.6 mg/L for summer high flows to 7.9 mg/L for non-summer low-medium flows.

Samples for chlorophyll *a* were collected only near the surface in the main body of the lake, which included the lake nearest the dam, and the East and West Forks. Concentrations of chlorophyll *a* ranged from 0.30 µg/L (East Fork) to 68 µg/L (West Fork) (table 3). Medians ranged from 1.5 µg/L for the lake nearest the dam for the non-summer period to 24 µg/L for the West Fork for the summer (fig. 29). The summer median for each location is larger than the corresponding non-summer median, which is caused by increased biological activity (algae) during the summer. Larger seasonal concentrations of chlorophyll *a* in the West Fork are consistent with larger nutrient concentrations that were present in the West Fork and western tributaries.

Dissolved iron concentrations in the six locations (table 3) ranged from 3 µg/L (Trinity River) to 2,400 µg/L (lake nearest the dam). Medians for the lake locations ranged from 20 µg/L for the West Fork for the summer (near-surface and bottom) to 190 µg/L for the East Fork for the non-summer period (bottom) (fig. 30). Medians for the lake tributaries ranged from 31 µg/L for summer low-medium flows for the western tributaries to 350 µg/L for non-summer high flows for the eastern tributaries (fig. 31). Medians for the Trinity River ranged from 8 µg/L for summer low-medium flows to 23 µg/L for non-summer high flows. The median of non-summer samples from the eastern tributaries exceeded the SMCL for iron in drinking water (300 µg/L, table 4). About 16 percent of all individual-sample dissolved iron concentrations exceeded the SMCL.

Dissolved manganese concentrations in the six locations (table 3) ranged from 1 µg/L (lake nearest the dam, western tributaries, Trinity River) to 1,800 µg/L (lake nearest the dam). Medians for lake locations ranged from 10 µg/L for the West Fork for the summer (near-surface) to 320 µg/L for the lake nearest the dam for the summer (bottom) (fig. 32). Medians for the lake tributaries ranged from 9 µg/L for non-summer high flows for the western tributaries to 65 µg/L for summer low-medium flows for the eastern tributaries (fig. 33). Medians for the Trinity River ranged from 2 µg/L for both summer low-medium and high flows to 5.5 µg/L for non-summer low-medium flows. One seasonal median each of samples from the lake nearest the dam, the East Fork, and the eastern tributaries exceeded the SMCL for manganese in drinking water (50 µg/L, table 4). About 35 percent of all individual-sample dissolved manganese concentrations exceeded the SMCL.

Significant Differences in Selected Properties and Constituents on the Basis of Season, Depth, Location, and Streamflow

To support the results portrayed graphically in the boxplots, results of Mann-Whitney rank-sum tests summarized in tables 5–8 indicate properties and constituent concentrations that were significantly different when compared on the basis of season, depth, location, and streamflow. Although of no practical significance in and of themselves, the statistical test results provide an objective, consistent means to compare the magnitudes of differences (either not significant or significant) between concentrations portrayed in the boxplots.

Differences With Season and Depth in Lake Houston

Natural lakes commonly show distinct differences during the winter and summer. Complete mixing of water in a lake occurs during the winter as the water, cooled at the surface, increases in density and moves toward the bottom of the lake. During the summer, the warmer water at the surface does not mix with the deeper, denser, cooler water and the lake becomes stratified. Three distinct layers develop as a result of the stratification—a warm, freely circulating surface layer, a middle layer characterized by a rapid decrease in temperature with increasing depth, and a cold, stagnant bottom layer. Lake Houston is a fairly shallow reservoir (mean depth 12 ft; maximum depth about 50 ft) that does not stratify to the degree seen in larger, deeper natural lakes. The shallow depths of Lake Houston and the almost constant wind combine to keep the reservoir mixed for longer periods during a year than a larger, deeper reservoir with little wind.

Mann-Whitney rank-sum tests comparing 15 selected physical properties and chemical constituents in water samples collected at three locations in Lake Houston (nearest the dam [transect A], East Fork [transect E], and West Fork [transect F]) were done to indicate (1) whether there were significant differences

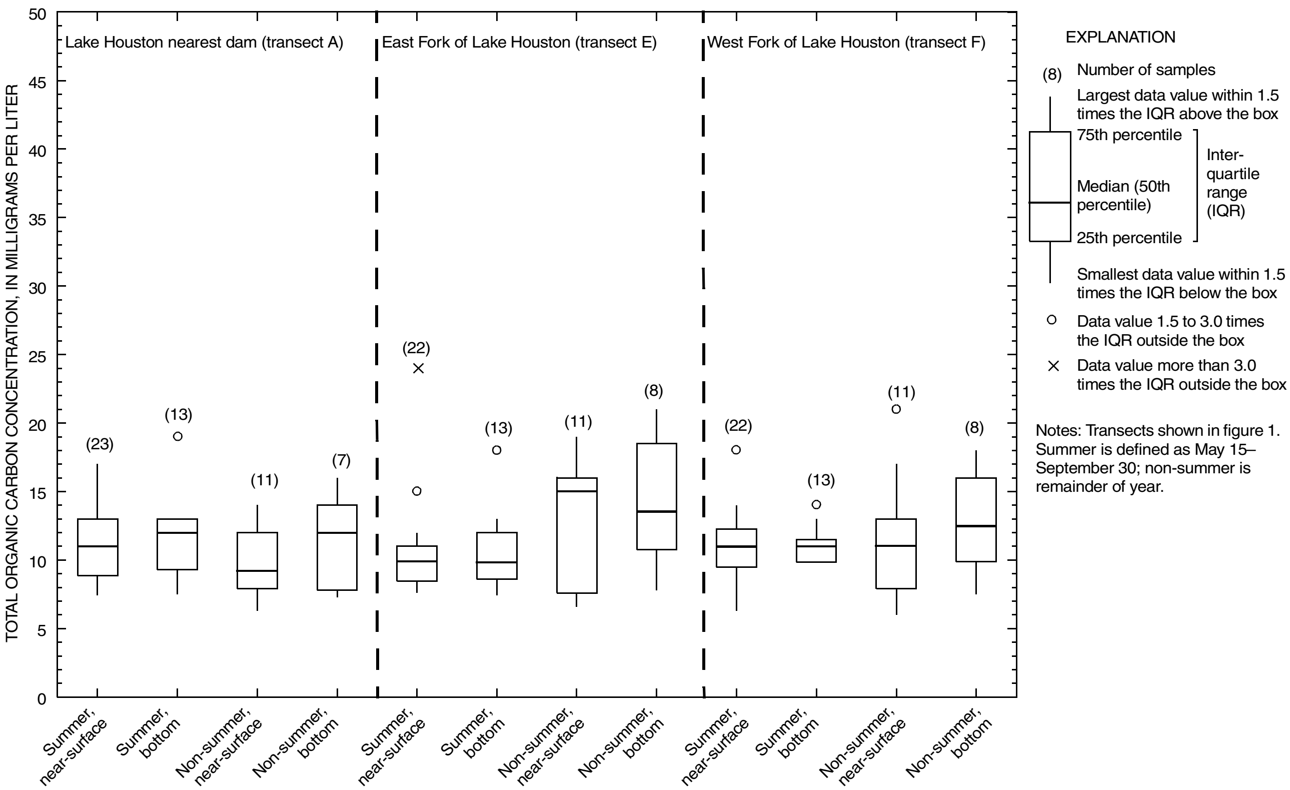

Figure 27. Range and distribution of total organic carbon concentrations in relation to season, depth, and location in Lake Houston.

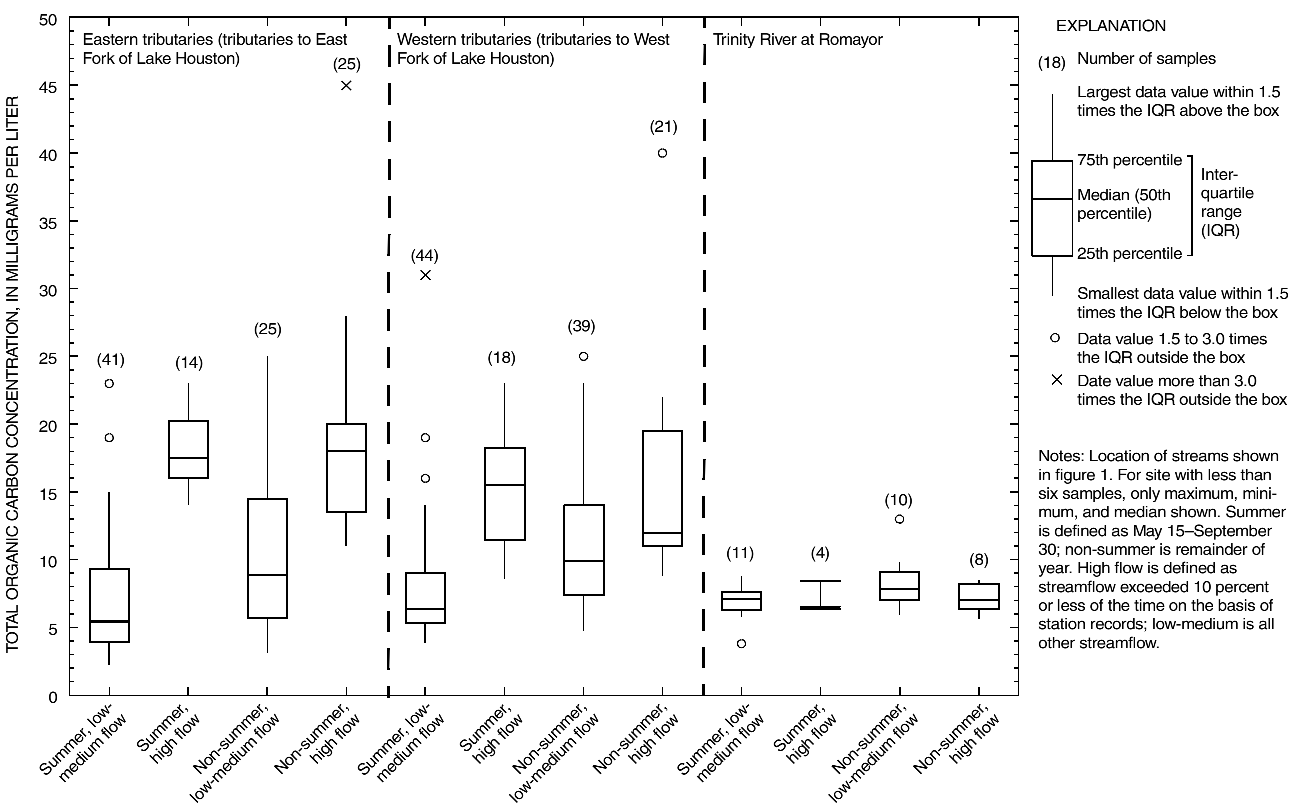

Figure 28. Range and distribution of total organic carbon concentrations in relation to season and flow in eastern and western tributaries and Trinity River.

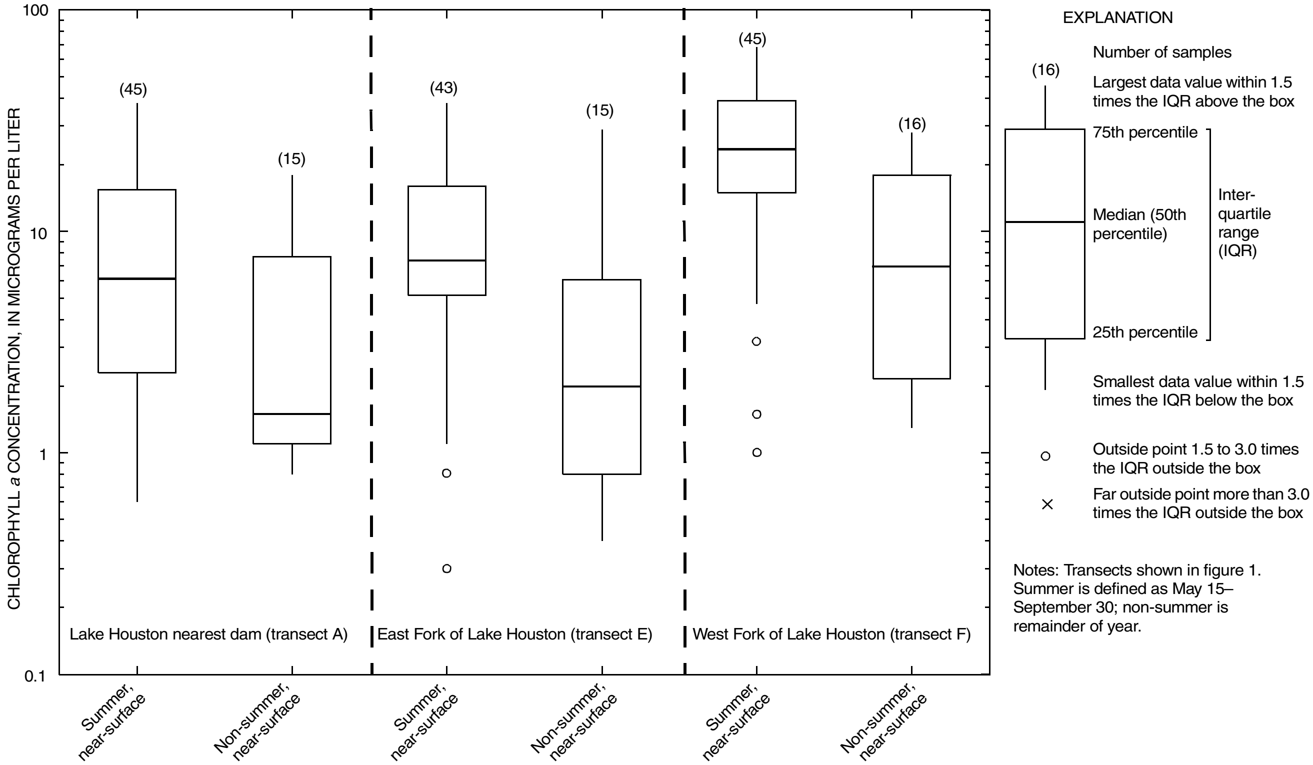

Figure 29. Range and distribution of chlorophyll *a* concentrations in relation to season and location in Lake Houston.

between seasons (summer and non-summer) for samples collected at the same relative depth (near-surface and bottom), and (2) whether there were significant differences within seasons between samples collected near the surface and at the bottom of the lake.

The results of tests to determine whether there were significant differences between summer and non-summer samples collected at the same relative depth were mixed. Results of the statistical tests showed significant differences between summer and non-summer samples for at least one of the three locations for samples collected at the same relative depth for all properties and constituents except specific conductance (table 5 at end of report). Among the tests that yielded significant differences, only those for water temperature, Secchi-disk transparency, and chlorophyll *a* had larger medians for the summer than for the non-summer period at all three locations; only DO had a larger median for the non-summer period than for the summer at all three locations.

The differences between samples collected at all three locations near the surface and at the bottom in the non-summer period for all properties and constituents were not significant, with the exception of suspended solids in the lake nearest the dam (table 5); suspended solids in the lake nearest the dam had a larger median for bottom samples.

Several properties and constituents showed significant differences between near-surface and bottom samples collected during the summer. Temperature, DO, pH, and dissolved manganese were significantly different between near-surface and bottom samples at all three locations. The medians were larger for the near-surface samples for temperature, DO, and pH at all three locations; and the medians were larger for the bottom samples for dissolved manganese at all three locations. Turbidity was significantly different between near-surface and bottom samples at two of the three locations, with larger medians for the bottom samples at both locations.

Suspended solids at two locations and total nitrite plus nitrate nitrogen and total phosphorus at one location were each significantly different between near-surface and bottom samples; the medians were larger for the bottom samples for each constituent.

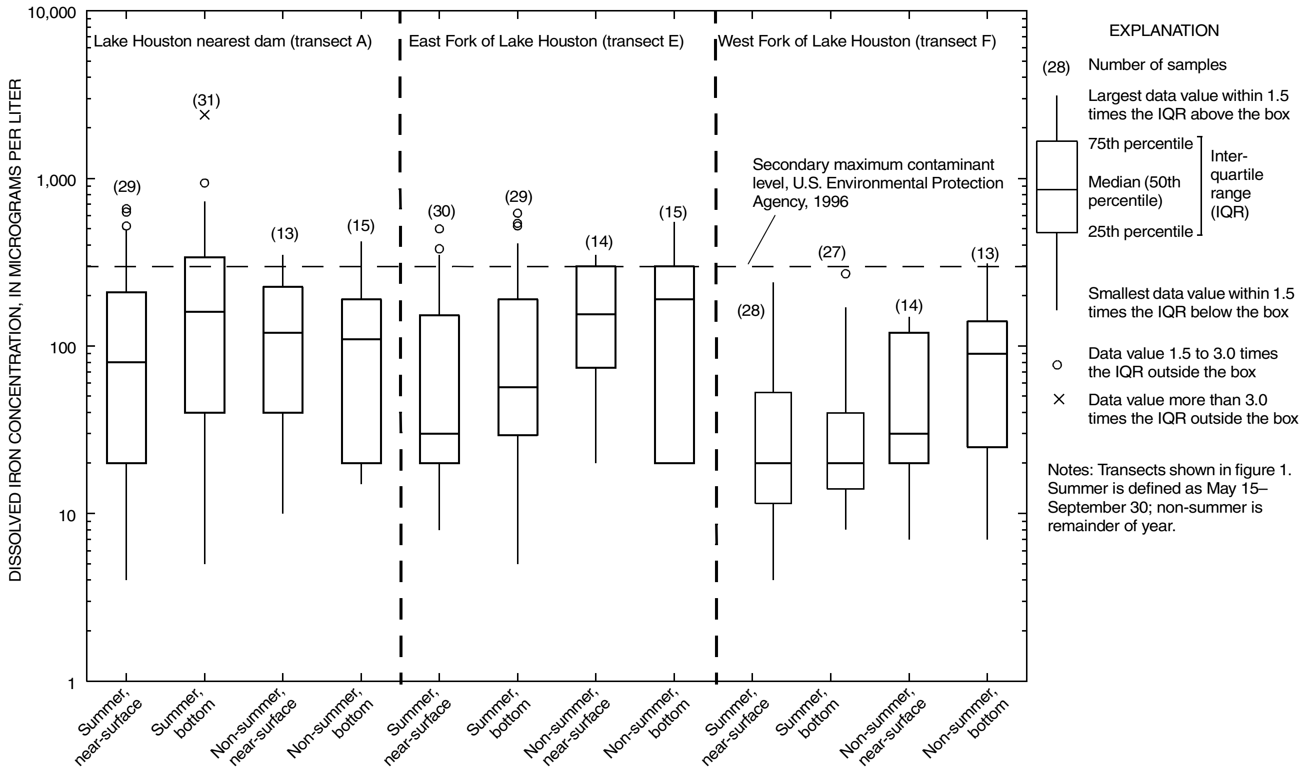

Figure 30. Range and distribution of dissolved iron concentrations in relation to season, depth, and location in Lake Houston.

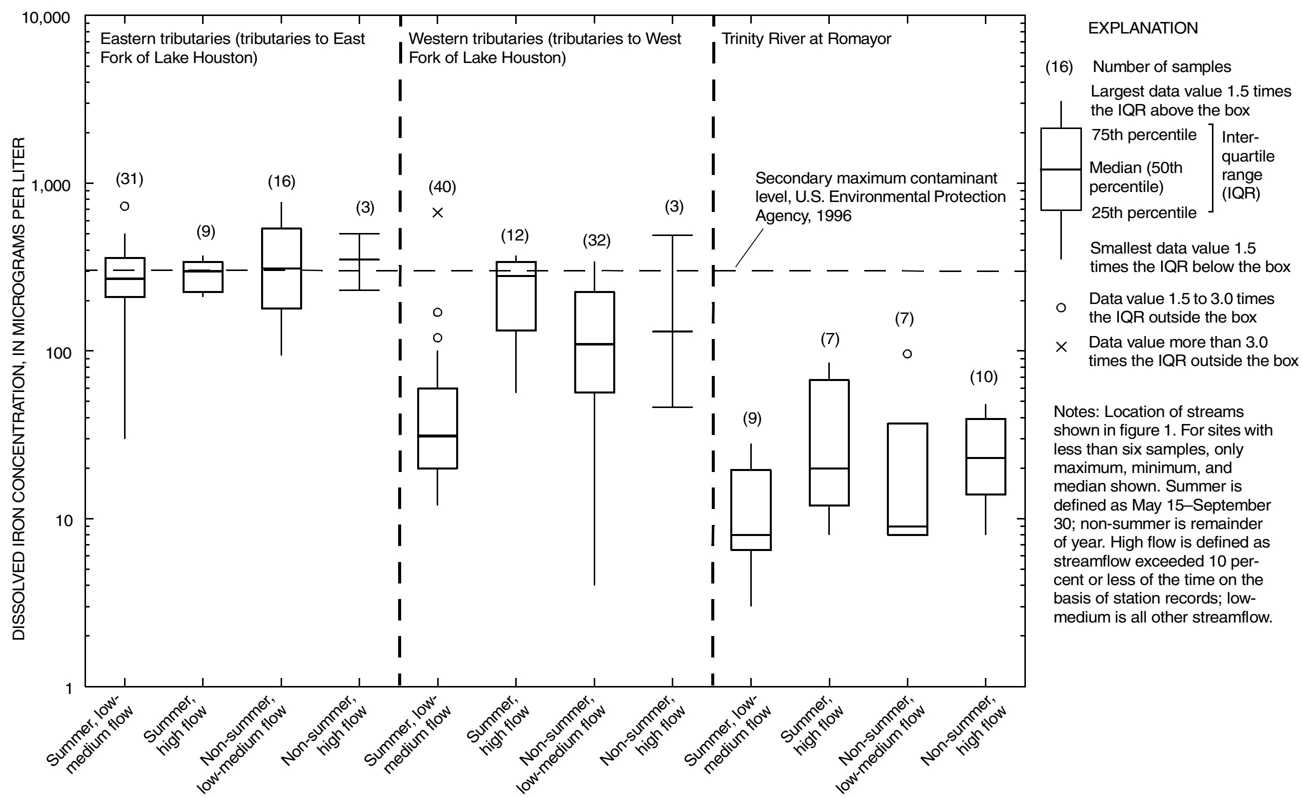

Figure 31. Range and distribution of dissolved iron concentrations in relation to season and flow in eastern and western tributaries and Trinity River.

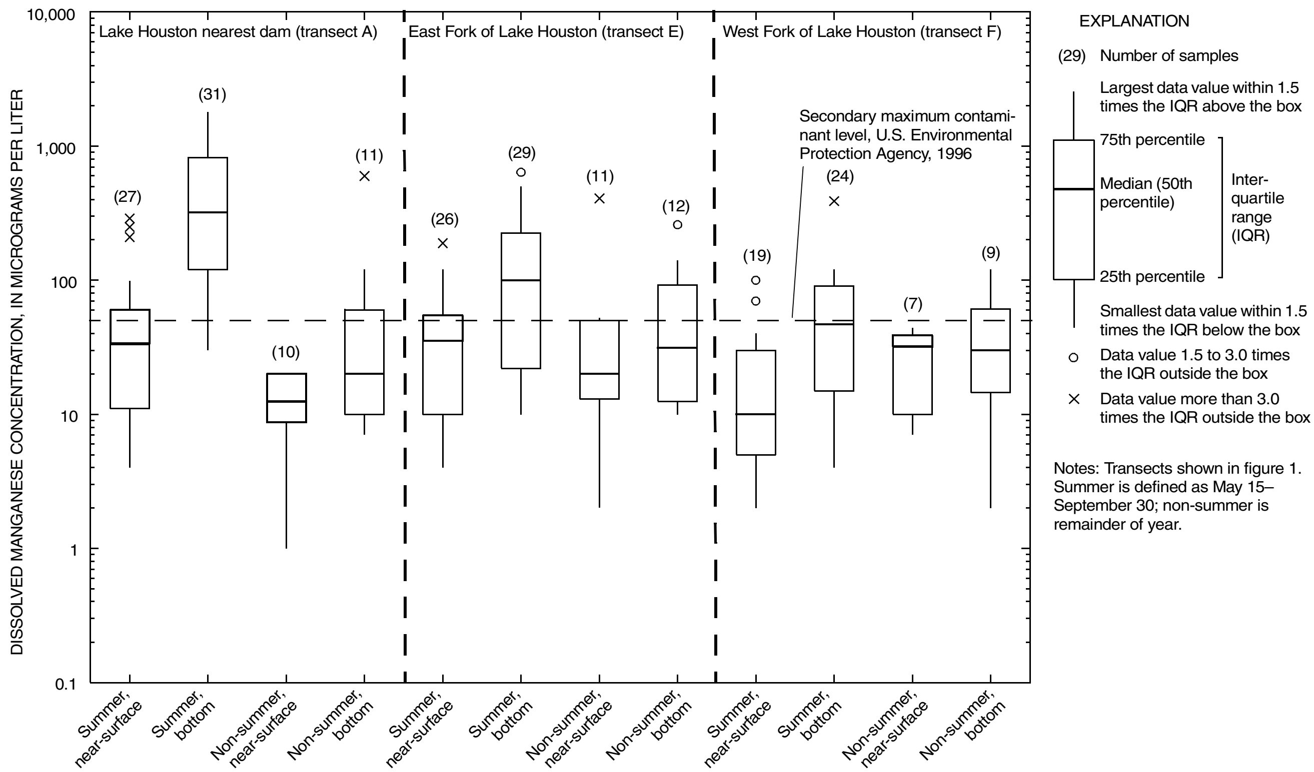

Figure 32. Range and distribution of dissolved manganese concentrations in relation to season, depth, and location in Lake Houston.

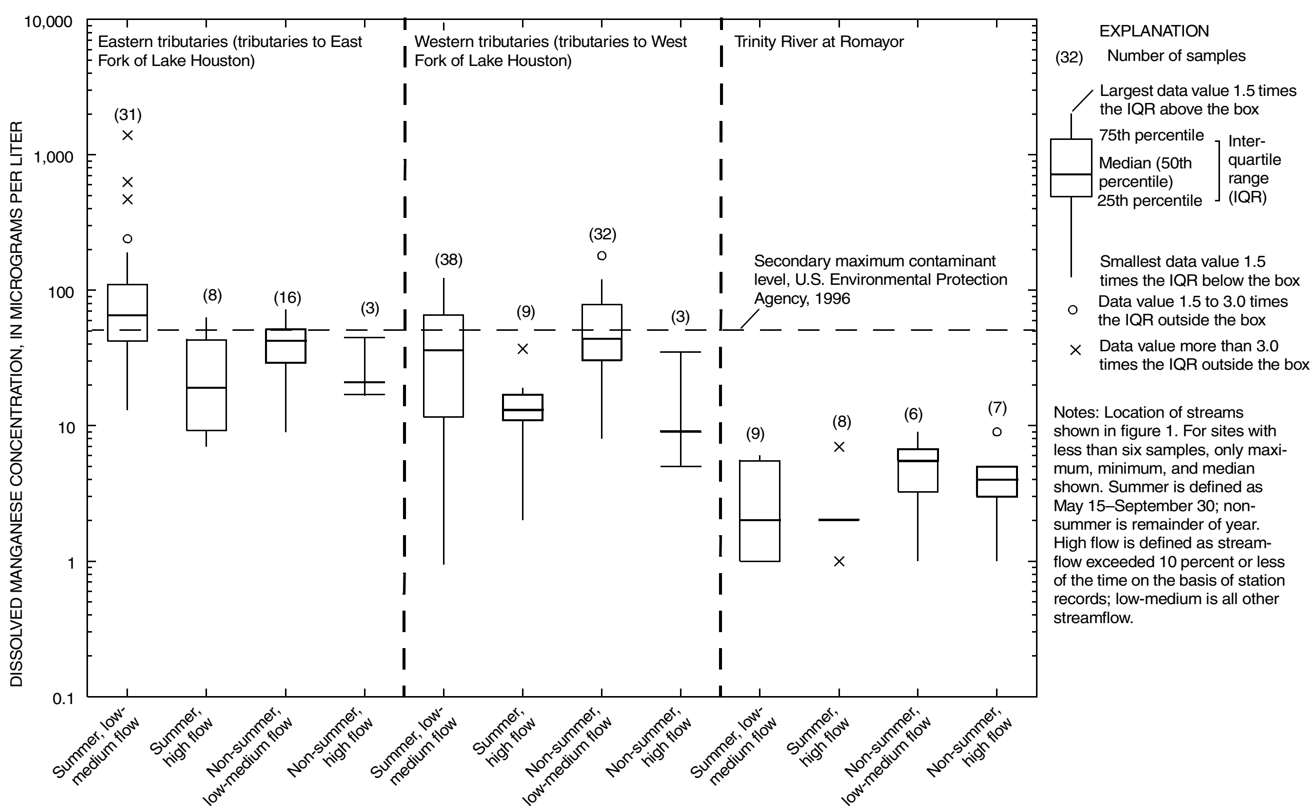

Figure 33. Range and distribution of dissolved manganese concentrations in relation to season and flow in eastern and western tributaries and Trinity River.

The results of tests to determine whether there were significant differences within seasons between samples collected near the surface and at the bottom of the lake in general indicate that Lake Houston is well mixed in the non-summer period and stratified with respect to selected properties (for example temperature, DO, pH, turbidity) and constituents (for example manganese) in summer.

Differences Between Locations in Lake Houston

Mann-Whitney rank-sum tests were done to compare the same 15 properties and constituents in water samples at the same three locations in Lake Houston (same as in the tests for seasonal and depth differences) to determine whether there were significant differences between the three locations for samples collected during the same season at the same relative depth.

Rank-sum tests of field measurements, 5-day BOD (which can be an indicator of organic contamination in a waterbody [Hem, 1989]), and physical and aesthetic properties between the lake nearest the dam and the East Fork showed significant differences in 12 of the 30 tests (table 6 at end of report); medians were larger for the lake nearest the dam than for the East Fork in 8 of the 12 tests that yielded significant differences. No notable seasonal or depth patterns were evident among the properties that showed significant differences between locations. Rank-sum tests of the same properties between the lake nearest the dam and the West Fork showed significant differences for 18 of the 30 tests; 13 of the 18 significant differences were between summer samples. West Fork medians were larger than medians for the lake nearest the dam in all but 2 of the 18 tests that yielded significant differences; the 2 tests in which medians were larger for the lake nearest the dam than for the West Fork were for Secchi-disk transparency (summer and non-summer). Rank-sum tests of the same properties between the East Fork and the West Fork showed significant differences in 15 of the 30 tests. Eleven of the 15 significant differences were between summer samples. West Fork medians were larger than East Fork medians in all but 1 of the 15 tests that yielded significant differences. The test in which the East Fork median was larger than the West Fork median was for Secchi-disk transparency (summer).

Rank-sum tests comparing nutrient concentrations between the lake nearest the dam and the East Fork showed significant differences in all six tests of non-summer samples (table 6) but only in one of six tests of summer samples. In all tests, median nutrient concentrations were larger for the lake nearest the dam than for the East Fork. In the tests comparing nutrient concentrations between the lake nearest the dam and the West Fork, and between the East Fork and the West Fork, all tests of samples for both seasons and both depths showed significant differences; in all tests, median nutrient concentrations were larger for the West Fork. In contrast, tests comparing TOC between the three locations showed no significant differences for either season or either depth. Tests comparing near-surface chlorophyll *a* between the lake nearest the dam and the East Fork showed no significant difference for either season; but tests for near-surface chlorophyll *a* between the lake nearest the dam and the West Fork, and between the East Fork and the West Fork, showed significant differences for both seasons, with larger median concentrations for the West Fork than for the two other locations.

The results of tests to determine whether there were significant differences between selected properties and between nutrient concentrations, organic carbon, and chlorophyll *a* at the three lake locations for samples collected during the same season at the same relative depth showed that significant differences were common; generally, the West Fork had the largest median concentrations among the three locations.

The tests comparing trace element concentrations between the lake nearest the dam and the East Fork showed mixed results. Dissolved manganese had larger median concentrations for Lake Houston in bottom samples in the summer and larger median concentrations in the East Fork in near-surface samples in the non-summer period. The tests comparing trace element concentrations between the lake nearest the dam and the West Fork and the tests comparing trace element concentrations between the East Fork and the West Fork showed significant differences in concentrations in the summer at both depths but not in the non-summer period (with one exception—non-summer near-surface samples between the East Fork and the West Fork were significantly different); the West Fork had the smaller median concentration in each test.

Differences Between Eastern and Western Tributaries to Lake Houston and Between Tributaries and Trinity River

Mann-Whitney rank-sum tests were done to compare 15 properties and constituents in water samples between the eastern and western tributaries to Lake Houston and between the tributaries and the Trinity River to determine whether there were significant differences in the properties and constituents between these locations for samples collected during the same season (summer or non-summer) at the same relative streamflow (low-medium or high).

Rank-sum tests of field measurements, 5-day BOD, bacteria, and physical and aesthetic properties between the eastern and western tributaries showed significant differences in 16 of the 36 tests (table 7 at end of report). No notable patterns associated with season or relative flow were evident among the properties that showed significant differences with location. Medians were larger for the western tributaries in all 16 of the tests that yielded significant differences. Only pH was significantly different between the tributaries for both the summer and non-summer periods for both low-medium and high flows. Specific conductance and suspended solids were significantly different between the tributaries in three of the four season/streamflow tests.

Rank-sum tests of the same properties between the eastern tributaries and the Trinity River showed significant differences for 29 of the 36 tests; medians for the Trinity River were larger than those for the eastern tributaries in 15 of the 29 tests. Specific conductance, 5-day BOD, pH, fecal coliform bacteria, and turbidity were significantly different between the eastern tributaries and the Trinity River for both the summer and non-summer periods for both low-medium and high flows; medians of specific conductance and pH for the Trinity River were larger in all four season/streamflow tests, and medians of fecal coliform bacteria and turbidity for the eastern tributaries were larger in all four season/streamflow tests.

Rank-sum tests of the same properties between the western tributaries and the Trinity River showed significant differences in 31 of the 36 tests; medians for the western tributaries were larger than those for the Trinity River in 18 of the 31 tests. Dissolved oxygen and pH were significantly different between the western tributaries and the Trinity River for both the summer and non-summer periods for both low-medium and high flows, with larger medians for the Trinity River. Fecal coliform and streptococcus bacteria and turbidity also were significantly different between the western tributaries and the Trinity River in all four season/streamflow tests, with larger medians for the western tributaries.

Nutrient concentrations in the eastern tributaries were significantly different from those in the western tributaries in 9 of the 12 rank-sum tests (table 7); medians for the western tributaries were larger than those for the eastern tributaries in all 9 tests. In the tests comparing nutrients in the eastern tributaries to those in the Trinity River, 7 of 12 showed significant differences; total phosphorus differences were significant for both seasons and both streamflows; medians for the Trinity River were larger in all 7 tests that showed significant differences. In the tests comparing nutrients in the western tributaries to those in the Trinity River, 5 of 12 showed significant differences; medians were larger for the western tributaries in 4 of the 5 tests. Tests results comparing TOC concentrations on the basis of season and streamflow between the three sites were mixed—7 of 12 tests showed significant differences. In the tests that showed significant differences, medians of TOC for the eastern tributaries generally were larger than those for the western tributaries and for the Trinity River, and medians for the western tributaries were larger than those for the Trinity River.

The results of tests comparing selected properties, 5-day BOD, bacteria, nutrients, and TOC between the eastern tributaries and the western tributaries, between the eastern tributaries and the Trinity River, and between the western tributaries and the Trinity River during the same season (summer or non-summer) at the same relative streamflow (low-medium or high) showed that significant differences were more common than not. In the comparisons of the eastern tributaries with the western tributaries that resulted in significant differences, medians for the western tributaries were larger for all properties and constituents except TOC; in the comparisons of the eastern tributaries with the Trinity River that resulted in significant differences, medians were larger for the Trinity River in about 60 percent of the tests; and in the comparisons of the western tributaries with the Trinity River that resulted in significant differences, medians were larger for the western tributaries in about 60 percent of the tests.

In the tests comparing trace elements between the eastern and western tributaries during the same season at the same relative streamflow, five of the eight tests showed no significant differences (table 7); between the eastern tributaries and the Trinity River, all eight trace element tests showed significant differences, with medians larger for the eastern tributaries in all tests; and between the western tributaries and the Trinity River, seven of eight trace element tests showed significant differences, with medians larger for the western tributaries in all seven tests.

Differences Between Eastern Tributaries and East Fork, Western Tributaries and West Fork, and Trinity River and Lake Houston

A final series of Mann-Whitney rank-sum tests was done to compare the same 15 properties and constituents between the eastern tributaries and the East Fork of Lake Houston, between the western tributaries and the West Fork of Lake Houston, and between the Trinity River and the lake nearest the dam, the East Fork, and the West Fork. The tests were to indicate whether there were significant differences in the properties and constituents between those locations for samples collected during the same season (summer or non-summer). Because the tributary and Trinity River samples were depth-integrated or point samples rather than multiple-point (in the water column) samples as in Lake Houston, the Lake Houston multiple-point samples were averaged to make single-point values for these tests.

Rank-sum tests for significant differences in field measurements, 5-day BOD, and physical and aesthetic properties between the tributaries and the respective forks of the lake to which the tributaries drain (table 8 at end of report) yielded mixed results. Temperature, DO, 5-day BOD, and pH were significantly different in the summer; pH (for eastern tributaries-East Fork comparisons) and DO and pH (for western tributaries-West Fork comparisons) were significantly different in the non-summer period. Among the measurements and properties that yielded more than one seasonal significant difference, tributary medians were larger for DO, and lake medians were larger for temperature and pH. In the tests comparing those measurements and properties between the Trinity River and the three locations in the lake, season tended to have less association with significant difference than in the tributary-lake tests. Specific conductance, DO, and turbidity were significantly different for both seasons for all three comparisons (all six tests for each property); in those tests, Trinity River medians were larger than those for the three lake locations for specific conductance and DO, and Trinity River medians were smaller than those for the three lake locations for turbidity.

Rank-sum tests for significant differences in nutrients between the tributaries and the respective forks of the lake to which the tributaries drain also yielded mixed results. Nutrient concentrations were significantly different in the summer but not in the non-summer period, with the exception of total nitrite plus nitrate nitrogen in the eastern tributaries-East Fork comparison. The western tributaries had larger median concentrations than the West Fork. The eastern tributaries had larger median concentrations of total nitrite plus nitrate than the East Fork; the East Fork had larger total nitrogen and phosphorus medians. In the tests comparing nutrients between the Trinity River and the three locations in the lake, more significant differences occurred in non-summer than summer. Among the Trinity River-lake tests that showed significant differences, Trinity River medians were larger than East Fork medians, smaller than West Fork medians, and one smaller and one larger than the lake nearest the dam. In the tests comparing TOC between the tributaries and the respective forks of the lake to which the tributaries drain, three of four tests yielded no significant differences. In contrast, all the tests comparing TOC between the Trinity River and the three locations in the lake yielded significant differences; lake medians were larger than Trinity River medians in all those tests.

The tests comparing selected properties, 5-day BOD, nutrients, and TOC between the eastern tributaries and the East Fork of Lake Houston, between the western tributaries and the West Fork of Lake Houston, and between the Trinity River and the lake nearest the dam, the East Fork, and the West Fork during the same season (summer or non-summer) yielded significant differences in about 60 percent of the tests. No discernible pattern emerged to associate significant differences with season; among the tests that showed significant differences, medians were not consistently larger for the tributaries compared to those for the lake or for the Trinity River compared to those for the lake.

In the tests comparing trace elements between the tributaries and the respective forks of the lake to which the tributaries drain, iron concentrations were significantly different in three of the four tests; medians were larger for the tributaries than for the lake in these tests. The tests of manganese showed no significant differences. All the tests comparing manganese between the Trinity River and the three locations in the lake yielded significant differences; lake medians were larger than Trinity River medians in all these tests.

SUMMARY

Lake Houston, a reservoir completed in 1954 about 25 mi east-northeast of Houston, Tex., is a principal surface-water source for the city of Houston. The increase in water supply to meet future demands is expected to be accommodated by supplementing surface-water inflows to Lake Houston. The Trinity River is considered a potential source for interbasin transfer of water to Lake Houston. Before beginning to supplement inflows, the City needs to better understand the potential effects on Lake Houston water quality from streams that flow into or might contribute water to Lake Houston. In 1983, the USGS, in cooperation with the City of Houston, began an investigation of the potential effects. Phase I of the investigation, the results of which are the subject of this report, involved the collection of water-quality data in Lake Houston, the eastern and western tributaries to Lake Houston, and the Trinity River near Lake Houston to characterize the water quality of those waterbodies. A total of 3,727 water-quality samples were collected from 27 sites in Lake Houston, 6 of the 7 main tributaries to the lake, and the Trinity River at Romayor during August 1983–September 1990.

Longitudinal profiles of water temperature, DO, specific conductance, pH, and nutrients from the dam to the East and West Forks of Lake Houston constructed for a winter day and a summer day indicate that in general the lake water is mixed in the winter and stratified in the summer. The winter profiles show gradual increases in specific conductance, pH, and nutrients from the East and West Forks to the dam. Both the winter and summer profiles show larger specific conductance, pH, and total phosphorus concentrations in the West Fork than in the East Fork.

Fifty-nine physical properties and chemical constituents were measured or analyzed, and summary statistics computed for each. Seventeen of the 59 properties and constituents (which include field measurements, 5-day BOD, and bacteria; physical and aesthetic properties; nutrients, organic carbon, and chlorophyll *a*; and trace elements) were selected as important factors affecting biological, physical, and chemical processes in water. The 17 properties and constituents were grouped by location (the lake nearest the dam, East Fork of the lake, West Fork of the lake, the eastern and western tributaries, and the Trinity River) to allow graphical comparisons (boxplots) and statistical tests for differences (Mann-Whitney rank-sum tests on subsets of 13 to 15 of the 17 properties and constituent concentrations) on the basis of combinations of season, depth, location, and streamflow.

Although of no practical significance in and of themselves, the statistical test results provide an objective, consistent means to compare the magnitudes of differences (either not significant or significant) between properties and constituent concentrations at the six locations for the summer and non-summer periods, the lake near-surface and bottom, and low-medium and high streamflows. The results of rank-sum tests to determine whether there were significant differences between summer and non-summer Lake Houston samples collected in the lake nearest the dam, the East Fork of the lake, and the West Fork of the lake at the same relative depth were mixed. Results of the tests showed significant differences between summer and non-summer samples for at least one of the three locations for samples collected at the same relative depth for all 15 properties and constituents tested except specific conductance. Among the tests that yielded significant differences, only those for water temperature, Secchi-disk transparency, and chlorophyll *a* indicated larger medians for the summer than for the non-summer period at all three locations; only DO had a larger median for the non-summer period than for the summer at all three locations. The test results generally indicate that Lake Houston is well mixed in the non-summer period and stratified with respect to selected properties (for example temperature, DO, pH, turbidity) and constituents (for example manganese) in summer.

The results of rank-sum tests to determine whether there were significant differences between field measurements (water temperature, specific conductance, DO, pH), 5-day BOD, physical and aesthetic properties (turbidity, Secchi-disk transparency, suspended solids), nutrients (total nitrogen, total nitrite plus nitrate, total phosphorus), organic carbon, and chlorophyll *a* at the three lake locations for samples collected during the same season at the same relative depth showed that significant differences were common; generally, the West Fork had the largest median concentrations among the three locations. The tests comparing trace element (iron and manganese) concentrations between the lake nearest the dam and the East Fork showed mixed results—larger median dissolved manganese concentrations in lake bottom samples in the summer and in East Fork near-surface samples in the

non-summer period. The tests comparing trace element concentrations between the lake nearest the dam and the West Fork and the tests comparing trace element concentrations between the East Fork and the West Fork, for the most part, showed significant differences in concentrations in the summer but not in the non-summer period.

The results of rank-sum tests comparing selected properties, 5-day BOD, bacteria, nutrients, and TOC in the eastern tributaries with those in the western tributaries, in the eastern tributaries with those in the Trinity River, and in the western tributaries with those in the Trinity River during the same season (summer or non-summer) at the same relative streamflow (low-medium or high) showed that significant differences were more common than not. In the comparisons of the eastern tributaries with the western tributaries that resulted in significant differences, medians for the western tributaries were larger for all properties and constituents except TOC; in the comparisons of the eastern tributaries with the Trinity River that resulted in significant differences, medians were larger for the Trinity River in about 60 percent of the tests; and in the comparisons of the western tributaries with the Trinity River that resulted in significant differences, medians were larger for the western tributaries in about 60 percent of the tests.

In the tests comparing trace elements between the eastern and western tributaries during the same season at the same relative streamflow, five of the eight tests showed no significant differences; between the eastern tributaries and the Trinity River, all eight tests showed significant differences, with eastern tributary medians larger in all tests; and between the western tributaries and the Trinity River, seven of the eight tests showed significant differences, with western tributary medians larger in all seven tests.

The tests comparing selected properties, 5-day BOD, nutrients, and TOC between the eastern tributaries and the East Fork of Lake Houston, between the western tributaries and the West Fork of Lake Houston, and between the Trinity River and the lake nearest the dam, the East Fork, and the West Fork during the same season (summer or non-summer) yielded significant differences in about 60 percent of the tests. No discernible pattern emerged to associate significant differences with season; among the tests that showed significant differences, medians were not consistently larger for the tributaries compared to those for the lake or for the Trinity River compared to those for the lake.

In the tests comparing trace elements between the tributaries and the respective forks of the lake to which the tributaries drain, iron concentrations were significantly different in three of the four tests with medians larger for the tributaries; manganese concentrations showed no significant differences. All the tests comparing manganese between the Trinity River and the three locations in the lake yielded significant differences; lake medians were larger than Trinity River medians in all these tests.

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Table 3. Summary statistics of properties and constituents in Lake Houston, tributaries to Lake Houston, and Trinity River at Romayer

[°C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; cols./100 mL, colonies per 100 milliliters; TU, nephelometric turbidity units; m, meters; --, no value available; Pt-Co, platinum-cobalt; µg/L, micrograms per liter]

Location (fig. 1)	No. of observations	Mean[1]	Standard deviation[2]	Low[3]	P.25[4]	Median[5]	P.75[6]	High[7]
Group 1—Field measurements, biochemical oxygen demand, bacteria								
Water temperature, °C								
Main body of Lake Houston	2,186	25.0	6.2	6.5	24.0	27.0	29.0	34.5
Lake Houston nearest dam	625	24.7	6.2	7.5	23.5	27.0	29.0	34.5
East Fork of Lake Houston	403	25.1	6.6	6.0	24.0	27.5	30.0	34.0
West Fork of Lake Houston	320	25.2	7.0	5.5	23.0	28.0	30.5	34.0
Eastern tributaries	159	21.0	5.9	7.0	17.5	23.0	26.0	29.0
Western tributaries	261	21.2	6.3	5.0	15.8	23.0	26.5	32.0
Trinity River	60	21.2	7.1	9.0	14.1	22.2	27.9	31.0
Specific conductance, µS/cm								
Main body of Lake Houston	2,182	185	70	35.0	130	185	230	610
Lake Houston nearest dam	624	180	65	55.0	130	180	215	335
East Fork of Lake Houston	401	168	71	40.0	102	175	220	300
West Fork of Lake Houston	319	284	107	90.0	190	300	360	800
Eastern tributaries	175	153	71	24.0	94.0	148	205	387
Western tributaries	214	354	205	22.0	184	332	493	867
Trinity River	61	350	62	142	317	358	391	488
Dissolved oxygen, mg/L								
Main body of Lake Houston	2,181	5.1	2.7	0	3.2	5.4	7.0	11.1
Lake Houston nearest dam	624	5.0	2.8	0	2.9	5.3	6.9	10.7
East Fork of Lake Houston	401	5.5	2.4	0	3.9	5.5	7.2	10.6
West Fork of Lake Houston	319	6.1	2.5	0	4.5	6.3	8.1	12.2
Eastern tributaries	147	7.2	2.2	1.0	6.1	7.2	8.6	12.4
Western tributaries	194	7.8	1.7	4.0	6.5	7.5	9.1	13.5
Trinity River	60	9.6	1.9	5.8	8.2	9.4	11.0	13.9
Dissolved oxygen, percent of saturation								
Main body of Lake Houston	2,180	59	28	0	41	69	81	134
Lake Houston nearest dam	624	58	29	0	37	67	80	124
East Fork of Lake Houston	401	63	24	0	50	69	81	112
West Fork of Lake Houston	319	72	27	0	58	76	88	163
Eastern tributaries	147	79	20	13	75	85	91	133
Western tributaries	194	88	14	50	80	88	95	148
Trinity River	56	107	13	78	100	104	112	146
5-day biochemical oxygen demand, mg/L								
Main body of Lake Houston	69	2.2	.8	.8	1.8	2.2	2.8	4.5
Lake Houston nearest dam	35	2.0	.8	.8	1.6	2.0	2.5	4.5
East Fork of Lake Houston	35	2.7	1.0	1.3	2.0	2.3	3.4	5.7
West Fork of Lake Houston	35	4.1	1.5	1.2	2.9	4.1	5.1	7.2
Eastern tributaries	104	2.1	1.4	.4	1.1	1.7	3.0	7.8
Western tributaries	146	2.8	1.5	.8	1.5	2.6	3.6	8.3
Trinity River	57	2.4	1.0	.6	1.6	2.2	3.2	5.0

Footnotes at end of table.

Table 3. Summary statistics of properties and constituents in Lake Houston, tributaries to Lake Houston, and Trinity River at Romayer—Continued

Location (fig. 1)	No. of observations	Mean[1]	Standard deviation[2]	Low[3]	P.25[4]	Median[5]	P.75[6]	High[7]
Group 1—Field measurements, biochemical oxygen demand, bacteria—Continued								
pH, standard units								
Main body of Lake Houston	2,182	7.2	0.5	5.8	6.9	7.2	7.5	9.0
Lake Houston nearest dam	624	7.2	.5	5.8	6.9	7.2	7.5	8.8
East Fork of Lake Houston	401	7.2	.6	5.8	6.7	7.2	7.6	8.8
West Fork of Lake Houston	319	7.8	.8	6.0	7.2	7.6	8.4	9.4
Eastern tributaries	149	6.7	.4	5.4	6.5	6.7	7.0	8.0
Western tributaries	194	7.3	.5	5.6	7.0	7.4	7.7	9.1
Trinity River	60	8.0	.4	7.0	7.6	8.0	8.2	8.8
Fecal coliform bacteria, cols./100 mL								
Main body of Lake Houston	13	240	261	4	80	130	400	820
Lake Houston nearest dam	10	300	274	27	84	200	580	820
East Fork of Lake Houston	9	390	905	20	43	120	140	2,800
West Fork of Lake Houston	14	230	284	20	52	160	220	1,000
Eastern tributaries	101	980	1,463	29	94	190	1,000	5,800
Western tributaries	125	1,400	2,305	20	120	520	2,000	18,000
Trinity River	45	150	543	20	38	54	92	3,700
Fecal streptococcus bacteria, cols./100 mL								
Main body of Lake Houston	16	180	204	5	41	130	200	680
Lake Houston nearest dam	14	190	215	5	38	130	250	680
East Fork of Lake Houston	12	480	1,180	26	50	120	230	4,200
West Fork of Lake Houston	16	210	294	22	57	92	180	1,000
Eastern tributaries	100	1,700	2,333	40	140	490	2,800	10,000
Western tributaries	127	2,000	3,083	28	150	480	2,900	14,000
Trinity River	52	360	857	20	60	98	180	4,400
Group 2—Physical and aesthetic properties								
Turbidity, TU								
Main body of Lake Houston	132	27	14	2.5	17	24	33	80
Lake Houston nearest dam	52	24	13	2.5	16	22	30	76
East Fork of Lake Houston	51	26	14	4.7	15	25	34	73
West Fork of Lake Houston	51	43	56	7.5	17	28	54	400
Eastern tributaries	93	34	25	1.9	14	26	50	110
Western tributaries	125	64	149	1.6	14	34	70	1,600
Trinity River	56	14	20	.60	4.1	8.0	15	120
Secchi-disk transparency, m								
Main body of Lake Houston	450	.35	.17	.05	.24	.32	.43	1.35
Lake Houston nearest dam	114	.41	.17	.12	.28	.40	.50	1.25
East Fork of Lake Houston	114	.29	.15	.08	.21	.26	.34	1.44
West Fork of Lake Houston	113	.21	.14	.06	.12	.17	.28	1.25
Eastern tributaries	0	--	--	--	--	--	--	--
Western tributaries	0	--	--	--	--	--	--	--
Trinity River	0	--	--	--	--	--	--	--

Footnotes at end of table.

Table 3. Summary statistics of properties and constituents in Lake Houston, tributaries to Lake Houston, and Trinity River at Romayer—Continued

Location (fig. 1)	No. of observations	Mean[1]	Standard deviation[2]	Low[3]	P.25[4]	Median[5]	P.75[6]	High[7]
Group 2—Physical and aesthetic properties—Continued								
Color, Pt-Co units								
Main body of Lake Houston	133	89	47	16	55	80	110	220
Lake Houston nearest dam	52	85	45	17	51	90	108	190
East Fork of Lake Houston	51	81	42	22	45	70	120	220
West Fork of Lake Houston	51	79	54	16	48	60	100	300
Eastern tributaries	93	92	64	18	48	70	125	350
Western tributaries	111	79	66	3	27	70	100	350
Trinity River	33	30	21	5	15	29	38	95
Suspended solids, mg/L								
Main body of Lake Houston	133	23	19	1	14	20	28	186
Lake Houston nearest dam	52	18	9	2	11	17	24	46
East Fork of Lake Houston	51	27	17	2	15	24	35	94
West Fork of Lake Houston	51	50	31	1	28	44	67	164
Eastern tributaries	92	52	68	2	13	24	65	326
Western tributaries	111	122	330	7	25	52	103	3,340
Trinity River	33	30	45	2	10	17	32	244
Volatile nonfiltrable residue, mg/L								
Main body of Lake Houston	115	8	6	1	4	7	12	32
Lake Houston nearest dam	41	7	5	1	3	6	12	24
East Fork of Lake Houston	43	8	6	1	2	7	12	25
West Fork of Lake Houston	45	12	10	1	5	9	14	49
Eastern tributaries	78	16	16	1	4	10	23	80
Western tributaries	99	20	27	1	7	13	25	236
Trinity River	25	12	16	1	2	6	14	61
Group 3—Major inorganic constituents, related physical properties								
Total alkalinity, mg/L as $CaCO_3$								
Main body of Lake Houston	76	44	14	14	34	46	51	79
Lake Houston nearest dam	38	44	14	14	34	44	50	78
East Fork of Lake Houston	38	36	16	7	21	40	49	61
West Fork of Lake Houston	38	68	20	28	50	69	80	106
Eastern tributaries	122	27	16	5	17	26	34	115
Western tributaries	156	67	41	4	38	64	87	200
Trinity River	56	97	12	62	90	98	110	116
Total hardness, mg/L as $CaCO_3$								
Main body of Lake Houston	76	50	12	19	45	50	57	75
Lake Houston nearest dam	38	50	12	19	44	49	58	73
East Fork of Lake Houston	38	43	12	14	35	47	53	62
West Fork of Lake Houston	38	67	15	30	58	67	76	97
Eastern tributaries	122	38	16	8	26	36	47	110
Western tributaries	156	64	26	8	42	70	83	120
Trinity River	56	120	13	74	110	120	130	140

Footnotes at end of table.

Table 3. Summary statistics of properties and constituents in Lake Houston, tributaries to Lake Houston, and Trinity River at Romayer—Continued

Location (fig. 1)	No. of observations	Mean[1]	Standard deviation[2]	Low[3]	P.25[4]	Median[5]	P.75[6]	High[7]
Group 3—Major inorganic constituents, related physical properties—Continued								
Dissolved calcium, mg/L								
Main body of Lake Houston	76	16	4.0	5.8	15	16	19	25
Lake Houston nearest dam	38	16	3.9	5.8	14	16	19	24
East Fork of Lake Houston	38	14	4	4.1	11	15	17	20
West Fork of Lake Houston	38	22	5	9.6	19	22	25	33
Eastern tributaries	122	12	5	2.4	8.0	12	15	38
Western tributaries	156	21	9	2.1	13	23	28	38
Trinity River	56	40	5	26	38	41	44	47
Dissolved magnesium, mg/L								
Main body of Lake Houston	76	2.2	.5	1.0	1.9	2.3	2.5	3.2
Lake Houston nearest dam	38	2.2	.5	1.0	1.9	2.2	2.5	3.2
East Fork of Lake Houston	38	2.1	.5	.80	1.8	2.2	2.4	2.9
West Fork of Lake Houston	38	2.9	.6	1.4	2.6	3.0	3.4	4.3
Eastern tributaries	122	1.8	.6	.50	1.4	1.8	2.2	4.4
Western tributaries	156	2.9	1.2	.60	1.9	3.0	3.7	5.9
Trinity River	56	4.0	.5	2.2	3.6	4.0	4.4	5.0
Dissolved sodium, mg/L								
Main body of Lake Houston	76	19	7.9	3.7	13	18	23	38
Lake Houston nearest dam	38	18	8.0	4.2	13	16	21	38
East Fork of Lake Houston	38	18	7.7	2.5	12	17	24	32
West Fork of Lake Houston	38	36	21	7.1	19	35	42	130
Eastern tributaries	122	13	8.1	1.7	7.4	11	20	44
Western tributaries	155	35	31	1.5	12	23	49	130
Trinity River	56	26	7.2	14	21	25	31	43
Sodium adsorption ratio								
Main body of Lake Houston	76	1	.4	.4	.9	1	1	2
Lake Houston nearest dam	38	1	.4	.4	.8	1	1	2
East Fork of Lake Houston	38	1	.4	.3	.8	1	1	2
West Fork of Lake Houston	38	2	1.0	.6	1	2	2	6
Eastern tributaries	122	1	.5	.2	.6	1	1	3
Western tributaries	155	2	1.4	.2	.8	1	3	6
Trinity River	56	1	.3	.5	.9	1	1	2
Dissolved potassium, mg/L								
Main body of Lake Houston	76	2.7	.5	1.6	2.5	2.7	3.0	3.9
Lake Houston nearest dam	38	2.7	.4	1.6	2.4	2.6	2.9	3.9
East Fork of Lake Houston	38	2.4	.5	1.4	2.1	2.5	2.7	3.2
West Fork of Lake Houston	38	3.9	.7	2.7	3.4	3.9	4.4	5.2
Eastern tributaries	122	1.9	.6	.90	1.5	1.8	2.2	4.8
Western tributaries	156	4.0	1.7	1.8	2.9	3.5	4.6	9.9
Trinity River	56	4.9	.5	3.4	4.6	4.9	5.1	6.0

Footnotes at end of table.

Table 3. Summary statistics of properties and constituents in Lake Houston, tributaries to Lake Houston, and Trinity River at Romayer—Continued

Location (fig. 1)	No. of observations	Mean[1]	Standard deviation[2]	Low[3]	P.25[4]	Median[5]	P.75[6]	High[7]
Group 3—Major inorganic constituents, related physical properties—Continued								
Dissolved chloride, mg/L								
Main body of Lake Houston	76	26	10.0	6.1	19	27	32	45
Lake Houston nearest dam	38	25	9.8	6.6	18	24	30	45
East Fork of Lake Houston	38	26	9.8	4.5	20	25	34	42
West Fork of Lake Houston	38	46	26.7	11	29	45	51	170
Eastern tributaries	122	23	13.8	2.9	12	18	35	65
Western tributaries	156	40	27.1	2.2	19	36	60	110
Trinity River	56	28	8.1	13	22	27	34	47
Dissolved sulfate, mg/L								
Main body of Lake Houston	76	12	3.8	5.0	9.6	12	15	20
Lake Houston nearest dam	38	12	4.0	5.0	9.5	12	15	20
East Fork of Lake Houston	38	11	3.9	3.7	8.0	10	13	19
West Fork of Lake Houston	38	14	3.2	7.0	11	14	16	19
Eastern tributaries	118	10	3.9	2.0	7.0	10	13	20
Western tributaries	151	16	8.6	4.0	11	14	18	71
Trinity River	56	36	8.5	19	30	36	44	51
Dissolved fluoride, mg/L								
Main body of Lake Houston	57	.10	.06	.10	.10	.10	.20	.30
Lake Houston nearest dam	28	.10	.06	.10	.10	.10	.20	.30
East Fork of Lake Houston	28	.10	.05	.10	.10	.10	.10	.30
West Fork of Lake Houston	36	.20	.06	.10	.20	.20	.20	.30
Eastern tributaries	47	.10	.06	.10	.10	.10	.20	.30
Western tributaries	143	.20	.13	.10	.10	.20	.30	.70
Trinity River	55	.30	.08	.20	.30	.30	.40	.50
Dissolved silica, mg/L								
Main body of Lake Houston	76	7.7	2.8	.90	5.7	8.0	9.4	19
Lake Houston nearest dam	38	7.7	2.7	.90	6.0	8.2	9.4	13
East Fork of Lake Houston	38	8.2	2.6	2.8	7.1	8.0	9.3	14
West Fork of Lake Houston	38	10	3.2	1.8	8.1	10	12	17
Eastern tributaries	122	9.7	3.8	1.7	6.5	9.8	13	20
Western tributaries	155	13	6.1	2.6	8.1	13	18	25
Trinity River	56	6.8	1.3	3.9	5.9	6.8	7.8	10
Total dissolved solids, mg/L								
Main body of Lake Houston	76	113	30	45	93	113	130	181
Lake Houston nearest dam	38	111	30	46	90	111	126	181
East Fork of Lake Houston	38	103	31	38	81	106	126	152
West Fork of Lake Houston	38	177	62	73	136	178	200	424
Eastern tributaries	118	90	33	21	63	87	117	178
Western tributaries	150	181	102	23	101	167	236	466
Trinity River	56	206	29	128	185	203	225	269

Footnotes at end of table.

Table 3. Summary statistics of properties and constituents in Lake Houston, tributaries to Lake Houston, and Trinity River at Romayer—Continued

Location (fig. 1)	No. of observations	Mean[1]	Standard deviation[2]	Low[3]	P.25[4]	Median[5]	P.75[6]	High[7]
Group 4—Nutrients, organic carbon, chlorophyll								
Total nitrogen, mg/L as N								
Main body of Lake Houston	194	1.2	0.35	0.40	0.90	1.1	1.3	2.6
Lake Houston nearest dam	108	1.1	.33	.40	.90	1.1	1.3	2.6
East Fork of Lake Houston	62	.99	.25	.50	.80	1.0	1.1	1.9
West Fork of Lake Houston	149	1.6	.47	.90	1.3	1.5	1.9	3.4
Eastern tributaries	112	1.1	.56	.40	.60	.90	1.4	2.9
Western tributaries	205	2.9	2.32	.20	1.3	2.0	3.8	12
Trinity River	36	1.4	.78	.70	1.0	1.2	1.5	4.3
Total organic nitrogen, mg/L as N								
Main body of Lake Houston	208	.78	.31	.12	.58	.73	.91	2.9
Lake Houston nearest dam	116	.79	.35	.12	.56	.72	.93	2.9
East Fork of Lake Houston	80	.85	.30	.35	.64	.80	1.1	1.6
West Fork of Lake Houston	74	1.2	.54	.36	.77	1.1	1.6	2.9
Eastern tributaries	156	.84	.52	.15	.47	.73	1.1	3.0
Western tributaries	222	.98	.42	.04	.68	.93	1.2	2.5
Trinity River	48	.90	.68	.39	.57	.69	.95	4.1
Dissolved ammonia nitrogen, mg/L as N								
Main body of Lake Houston	124	.10	.20	.01	.02	.04	.07	1.80
Lake Houston nearest dam	90	.12	.23	.01	.03	.05	.09	1.80
East Fork of Lake Houston	70	.05	.04	.01	.02	.04	.06	.19
West Fork of Lake Houston	74	.10	.10	.01	.03	.07	.13	.50
Eastern tributaries	65	.04	.03	.01	.02	.03	.05	.14
Western tributaries	108	.16	.20	.01	.06	.12	.17	1.4
Trinity River	36	.03	.02	.01	.02	.02	.04	.10
Total ammonia nitrogen, mg/L as N								
Main body of Lake Houston	209	.08	.09	.01	.03	.05	.08	.57
Lake Houston nearest dam	117	.08	.10	.01	.03	.04	.08	.52
East Fork of Lake Houston	80	.05	.05	.01	.02	.04	.07	.25
West Fork of Lake Houston	74	.11	.09	.01	.04	.09	.16	.42
Eastern tributaries	157	.06	.05	.01	.03	.05	.08	.39
Western tributaries	223	.18	.21	.01	.07	.13	.20	2.1
Trinity River	49	.04	.04	.01	.02	.03	.05	.18
Total nitrite nitrogen, mg/L as N								
Main body of Lake Houston	174	.02	.02	.01	.01	.02	.02	.13
Lake Houston nearest dam	96	.02	.01	.01	.01	.02	.02	.09
East Fork of Lake Houston	59	.02	.01	.01	.01	.02	.02	.05
West Fork of Lake Houston	72	.04	.02	.01	.02	.03	.05	.08
Eastern tributaries	125	.03	.02	.01	.01	.02	.03	.14
Western tributaries	221	.07	.06	.01	.03	.05	.08	.43
Trinity River	29	.03	.02	.01	.01	.02	.02	.12

Footnotes at end of table.

Table 3. Summary statistics of properties and constituents in Lake Houston, tributaries to Lake Houston, and Trinity River at Romayer—Continued

Location (fig. 1)	No. of observations	Mean[1]	Standard deviation[2]	Low[3]	P.25[4]	Median[5]	P.75[6]	High[7]
Group 4—Nutrients, organic carbon, chlorophyll—Continued								
Total nitrate nitrogen, mg/L as N								
Main body of Lake Houston	80	0.23	0.18	0.01	0.08	0.18	0.35	0.78
Lake Houston nearest dam	45	.19	.16	.01	.08	.09	.25	.65
East Fork of Lake Houston	22	.09	.04	.04	.07	.08	.09	.18
West Fork of Lake Houston	56	.60	.47	.06	.27	.44	.84	1.90
Eastern tributaries	83	.19	.15	0	.08	.18	.28	.78
Western tributaries	203	1.7	2.14	0	.26	.68	2.6	9.9
Trinity River	26	.41	.25	0	.18	.43	.61	.78
Dissolved ammonia plus organic nitrogen, mg/L as N								
Main body of Lake Houston	164	.75	.45	.20	.50	.60	.90	5.0
Lake Houston nearest dam	123	.78	.49	.20	.50	.70	.90	5.0
East Fork of Lake Houston	112	.71	.35	.20	.50	.60	.80	3.0
West Fork of Lake Houston	110	.84	.50	.20	.60	.70	1.0	4.3
Eastern tributaries	71	.59	.40	.20	.30	.50	.70	2.5
Western tributaries	81	1.0	.42	.30	.80	1.0	1.3	2.3
Trinity River	0	--	--	--	--	--	--	--
Total ammonia plus organic nitrogen, mg/L as N								
Main body of Lake Houston	523	.94	.35	.20	.70	.90	1.1	3.2
Lake Houston nearest dam	279	.92	.36	.20	.70	.80	1.1	3.2
East Fork of Lake Houston	224	1.0	.37	.40	.80	.90	1.2	3.3
West Fork of Lake Houston	220	1.3	.47	.40	.92	1.2	1.6	2.9
Eastern tributaries	171	.89	.55	.20	.50	.80	1.2	3.1
Western tributaries	225	1.2	.50	.10	.80	1.1	1.4	3.8
Trinity River	56	.96	.67	.40	.60	.75	1.1	4.1
Total nitrite plus nitrate nitrogen, mg/L as N								
Main body of Lake Houston	195	.26	.14	<.10	.20	.20	.40	.80
Lake Houston nearest dam	109	.25	.13	<.10	<.10	.30	.40	.70
East Fork of Lake Houston	62	.11	.04	<.10	<.10	<.10	<.10	.30
West Fork of Lake Houston	149	.42	.36	<.10	.20	.30	.50	2.0
Eastern tributaries	113	.22	.13	<.10	<.10	.20	.30	.80
Western tributaries	206	1.8	2.16	<.10	.30	.70	2.7	10
Trinity River	37	.44	.24	<.10	.20	.50	.65	.80
Dissolved nitrite plus nitrate nitrogen, mg/L as N								
Main body of Lake Houston	73	.30	.27	.07	.13	.23	.40	2.0
Lake Houston nearest dam	54	.30	.30	.07	.13	.20	.38	2.0
East Fork of Lake Houston	29	.15	.10	.10	.10	.12	.15	.53
West Fork of Lake Houston	72	.58	.46	.10	.26	.41	.73	2.0
Eastern tributaries	64	.24	.11	.10	.18	.21	.30	.81
Western tributaries	108	2.2	2.22	.11	.48	1.2	3.5	9.9
Trinity River	29	.46	.24	.10	.20	.53	.65	.80

Footnotes at end of table.

Table 3. Summary statistics of properties and constituents in Lake Houston, tributaries to Lake Houston, and Trinity River at Romayer—Continued

Location (fig. 1)	No. of observations	Mean[1]	Standard deviation[2]	Low[3]	P.25[4]	Median[5]	P.75[6]	High[7]
Group 4—Nutrients, organic carbon, chlorophyll—Continued								
Total phosphorus, mg/L as P								
Main body of Lake Houston	523	0.20	0.10	0.030	0.13	0.18	0.23	1.2
Lake Houston nearest dam	279	.18	.09	.040	.12	.16	.21	.64
East Fork of Lake Houston	223	.13	.07	.010	.080	.12	.19	.43
West Fork of Lake Houston	217	.51	.31	.020	.27	.43	.68	2.0
Eastern tributaries	171	.11	.16	.010	.050	.080	.12	1.9
Western tributaries	224	1.2	1.47	.040	.22	.50	1.6	7.0
Trinity River	57	.16	.05	.050	.12	.16	.19	.28
Dissolved phosphorus, mg/L as P								
Main body of Lake Houston	165	.16	.09	.01	.11	.14	.19	.59
Lake Houston nearest dam	123	.15	.09	.01	.10	.14	.18	.59
East Fork of Lake Houston	112	.11	.07	.02	.05	.10	.15	.39
West Fork of Lake Houston	111	.51	.32	.02	.25	.47	.73	1.6
Eastern tributaries	76	.07	.08	.02	.03	.05	.09	.51
Western tributaries	108	1.5	1.58	.03	.29	.77	2.2	7.0
Trinity River	43	.11	.05	.03	.07	.12	.15	.28
Dissolved orthophosphate phosphorus, mg/L as P								
Main body of Lake Houston	4	.16	.05	.12	.12	.15	.22	.23
Lake Houston nearest dam	1	.12	0	.12	.12	.12	.12	.12
East Fork of Lake Houston	1	.12	0	.12	.12	.12	.12	.12
West Fork of Lake Houston	1	.67	0	.67	.67	.67	.67	.67
Eastern tributaries	0	--	--	--	--	--	--	--
Western tributaries	28	.48	.46	.03	.14	.29	.77	1.8
Trinity River	43	.10	.04	.03	.07	.09	.13	.19
Total organic carbon, mg/L as C								
Main body of Lake Houston	138	11	2.7	6.3	8.8	11	13	19
Lake Houston nearest dam	54	11	2.8	6.3	8.5	11	13	19
East Fork of Lake Houston	55	12	4.2	6.6	8.7	11	15	24
West Fork of Lake Houston	54	11	2.9	6.0	9.7	11	13	21
Eastern tributaries	105	12	7.4	2.2	5.4	12	18	45
Western tributaries	122	11	5.8	3.9	6.9	9.6	14	40
Trinity River	33	7.4	1.6	3.8	6.4	7.3	8.2	13
Dissolved organic carbon, mg/L as C								
Main body of Lake Houston	8	8.2	1.7	6.1	6.5	8.4	9.9	10
Lake Houston nearest dam	4	8.1	2.2	6.1	6.2	8.2	10	10
East Fork of Lake Houston	4	10	2.2	7.7	8.0	10	12	12
West Fork of Lake Houston	4	8.9	1.6	7.6	7.6	8.6	11	11
Eastern tributaries	0	--	--	--	--	--	--	--
Western tributaries	0	--	--	--	--	--	--	--
Trinity River	0	--	--	--	--	--	--	--

Footnotes at end of table.

Table 3. Summary statistics of properties and constituents in Lake Houston, tributaries to Lake Houston, and Trinity River at Romayer—Continued

Location (fig. 1)	No. of observations	Mean[1]	Standard deviation[2]	Low[3]	P.25[4]	Median[5]	P.75[6]	High[7]
Group 4—Nutrients, organic carbon, chlorophyll—Continued								
Chlorophyll *a*, µg/L								
Main body of Lake Houston	167	9.3	9.0	0.60	2.5	5.8	15	43
Lake Houston nearest dam	70	8.5	7.6	.60	1.8	5.8	14	38
East Fork of Lake Houston	60	9.7	9.5	.30	3.6	6.4	14	38
West Fork of Lake Houston	62	23	17.6	1.0	10	20	32	68
Eastern tributaries	0	--	--	--	--	--	--	--
Western tributaries	0	--	--	--	--	--	--	--
Trinity River	0	--	--	--	--	--	--	--
Chlorophyll *b*, µg/L								
Main body of Lake Houston	134	.76	.87	.10	.20	.45	.90	5.9
Lake Houston nearest dam	55	.76	.80	.10	.30	.50	1.1	4.0
East Fork of Lake Houston	55	.76	.75	.10	.20	.50	1.0	3.6
West Fork of Lake Houston	58	1.8	1.30	.10	.70	1.7	2.6	4.7
Eastern tributaries	0	--	--	--	--	--	--	--
Western tributaries	0	--	--	--	--	--	--	--
Trinity River	0	--	--	--	--	--	--	--
Group 5—Trace elements								
Dissolved arsenic, µg/L								
Main body of Lake Houston	17	3	1.3	1	2	3	4	6
Lake Houston nearest dam	17	3	1.3	1	2	3	4	6
East Fork of Lake Houston	16	2	1.6	1	1	2	3	7
West Fork of Lake Houston	22	3	2.0	1	1	4	5	6
Eastern tributaries	14	1	.3	1	1	1	1	2
Western tributaries	54	2	1.3	1	1	2	3	5
Trinity River	33	3	1.5	1	2	3	4	7
Dissolved barium, µg/L								
Main body of Lake Houston	26	67	14.5	35	58	68	77	91
Lake Houston nearest dam	26	67	14.5	35	58	68	77	91
East Fork of Lake Houston	24	61	24.1	4.0	52	62	74	130
West Fork of Lake Houston	25	73	19.0	38	60	69	86	120
Eastern tributaries	36	65	27.6	21	42	68	82	130
Western tributaries	63	89	24.2	34	74	94	110	140
Trinity River	35	55	6.9	46	51	53	58	78
Dissolved beryllium, µg/L								
Main body of Lake Houston	0	--	--	--	--	--	--	--
Lake Houston nearest dam	0	--	--	--	--	--	--	--
East Fork of Lake Houston	0	--	--	--	--	--	--	--
West Fork of Lake Houston	0	--	--	--	--	--	--	--
Eastern tributaries	0	--	--	--	--	--	--	--
Western tributaries	2	.8	.21	.6	.6	.8	.9	.9
Trinity River	2	.8	.21	.7	.7	.8	1	1

Footnotes at end of table.

Table 3. Summary statistics of properties and constituents in Lake Houston, tributaries to Lake Houston, and Trinity River at Romayer—Continued

Location (fig. 1)	No. of observations	Mean[1]	Standard deviation[2]	Low[3]	P.25[4]	Median[5]	P.75[6]	High[7]
Group 5—Trace elements—Continued								
Dissolved cadmium, µg/L								
Main body of Lake Houston	5	1	0.4	1	1	1	2	2
Lake Houston nearest dam	5	1	.4	1	1	1	2	2
East Fork of Lake Houston	4	1	0	1	1	1	1	1
West Fork of Lake Houston	2	3	2.8	1	1	3	5	5
Eastern tributaries	5	4	4.0	1	1	1	8	10
Western tributaries	20	2	1.2	1	1	1	2	6
Trinity River	8	2	1.3	1	1	2	4	4
Dissolved chromium, µg/L								
Main body of Lake Houston	5	20	20.4	1	1	10	40	50
Lake Houston nearest dam	5	20	20.4	1	1	10	40	50
East Fork of Lake Houston	4	20	12.5	1	3	20	30	30
West Fork of Lake Houston	3	10	9.5	1	1	10	20	20
Eastern tributaries	6	20	13.1	1	2	20	30	30
Western tributaries	12	6	4.3	1	1	7	10	10
Trinity River	1	1	0	1	1	1	1	1
Dissolved copper, µg/nL								
Main body of Lake Houston	26	5	5.8	1	2	3	5	29
Lake Houston nearest dam	26	5	5.8	1	2	3	5	29
East Fork of Lake Houston	23	5	4.8	1	2	3	6	20
West Fork of Lake Houston	25	6	5.8	1	3	4	9	23
Eastern tributaries	29	3	3.2	1	1	2	3	16
Western tributaries	56	3	2.2	1	2	2	3	13
Trinity River	32	3	2.4	1	2	2	4	11
Dissolved iron, µg/L								
Main body of Lake Houston	215	180	268	4	25	90	220	2,400
Lake Houston nearest dam	129	200	290	4	31	100	240	2,400
East Fork of Lake Houston	91	150	159	5	20	70	230	620
West Fork of Lake Houston	86	55	64	4	20	28	82	310
Eastern tributaries	59	310	149	30	220	300	360	770
Western tributaries	87	120	127	4	25	66	180	670
Trinity River	33	24	22	3	8	18	32	96
Dissolved lead, µg/L								
Main body of Lake Houston	9	4	5	1	1	2	7	15
Lake Houston nearest dam	9	4	5	1	1	2	7	15
East Fork of Lake Houston	10	6	6	1	2	3	11	17
West Fork of Lake Houston	9	4	4	1	2	3	3	13
Eastern tributaries	14	2	1	1	1	2	3	6
Western tributaries	21	4	3	1	2	3	4	11
Trinity River	10	7	13	1	1	2	7	42

Footnotes at end of table.

Table 3. Summary statistics of properties and constituents in Lake Houston, tributaries to Lake Houston, and Trinity River at Romayer—Continued

Location (fig. 1)	No. of observations	Mean[1]	Standard deviation[2]	Low[3]	P.25[4]	Median[5]	P.75[6]	High[7]
Group 5—Trace elements—Continued								
Dissolved lithium, µg/L								
Main body of Lake Houston	0	--	--	--	--	--	--	--
Lake Houston nearest dam	0	--	--	--	--	--	--	--
East Fork of Lake Houston	0	--	--	--	--	--	--	--
West Fork of Lake Houston	0	--	--	--	--	--	--	--
Eastern tributaries	0	--	--	--	--	--	--	--
Western tributaries	23	9	4.2	4	6	8	12	20
Trinity River	28	12	9.5	4	7	10	13	54
Dissolved manganese, µg/L								
Main body of Lake Houston	202	180	283	1	20	60	210	1,800
Lake Houston nearest dam	121	220	327	1	20	80	270	1,800
East Fork of Lake Houston	80	88	126	2	20	40	100	640
West Fork of Lake Houston	62	41	55	2	10	30	50	390
Eastern tributaries	58	93	202	7	25	46	70	1,400
Western tributaries	82	44	37	1	13	36	65	180
Trinity River	30	4	2.4	1	2	3	5	9
Dissolved mercury, µg/L								
Main body of Lake Houston	4	.2	.1	.1	.1	.2	.3	.3
Lake Houston nearest dam	4	.2	.1	.1	.1	.2	.3	.3
East Fork of Lake Houston	4	.2	.2	.1	.1	.2	.4	.4
West Fork of Lake Houston	2	.2	.2	.1	.1	.2	.4	.4
Eastern tributaries	2	.1	0	.1	.1	.1	.1	.1
Western tributaries	6	.3	.2	.1	.1	.3	.4	.5
Trinity River	4	.2	.06	.1	.1	.2	.2	.2
Dissolved molybdenum, µg/L								
Main body of Lake Houston	0	--	--	--	--	--	--	--
Lake Houston nearest dam	0	--	--	--	--	--	--	--
East Fork of Lake Houston	0	--	--	--	--	--	--	--
West Fork of Lake Houston	0	--	--	--	--	--	--	--
Eastern tributaries	0	--	--	--	--	--	--	--
Western tributaries	0	--	--	--	--	--	--	--
Trinity River	2	10	0	10	10	10	10	10
Dissolved nickel, µg/L								
Main body of Lake Houston	0	--	--	--	--	--	--	--
Lake Houston nearest dam	0	--	--	--	--	--	--	--
East Fork of Lake Houston	0	--	--	--	--	--	--	--
West Fork of Lake Houston	0	--	--	--	--	--	--	--
Eastern tributaries	0	--	--	--	--	--	--	--
Western tributaries	16	2	1	1	1	2	3	4
Trinity River	24	4	3	1	2	3	4	17

Footnotes at end of table.

Table 3. Summary statistics of properties and constituents in Lake Houston, tributaries to Lake Houston, and Trinity River at Romayer—Continued

Location (fig. 1)	No. of observations	Mean[1]	Standard deviation[2]	Low[3]	P.25[4]	Median[5]	P.75[6]	High[7]
Group 5—Trace elements—Continued								
Dissolved selenium, µg/L								
Main body of Lake Houston	0	--	--	--	--	--	--	--
Lake Houston nearest dam	0	--	--	--	--	--	--	--
East Fork of Lake Houston	0	--	--	--	--	--	--	--
West Fork of Lake Houston	0	--	--	--	--	--	--	--
Eastern tributaries	0	--	--	--	--	--	--	--
Western tributaries	1	1	0	1	1	1	1	1
Trinity River	0	--	--	--	--	--	--	--
Dissolved silver, µg/L								
Main body of Lake Houston	2	4	2.1	2	2	4	5	5
Lake Houston nearest dam	2	4	2.1	2	2	4	5	5
East Fork of Lake Houston	3	2	.6	2	2	2	3	3
West Fork of Lake Houston	3	2	1.0	1	1	2	3	3
Eastern tributaries	4	1	.5	1	1	1	2	2
Western tributaries	7	2	.8	1	1	2	3	3
Trinity River	2	1	0	1	1	1	1	1
Dissolved strontium, µg/L								
Main body of Lake Houston	0	--	--	--	--	--	--	--
Lake Houston nearest dam	0	--	--	--	--	--	--	--
East Fork of Lake Houston	0	--	--	--	--	--	--	--
West Fork of Lake Houston	0	--	--	--	--	--	--	--
Eastern tributaries	0	--	--	--	--	--	--	--
Western tributaries	26	170	69	80	120	160	200	380
Trinity River	29	300	36	220	280	310	320	370
Dissolved zinc, µg/L								
Main body of Lake Houston	20	9	5.9	3	6	7	11	31
Lake Houston nearest dam	20	9	5.9	3	6	7	11	31
East Fork of Lake Houston	19	12	8.0	3	7	9	15	35
West Fork of Lake Houston	16	7	4.0	3	5	6	10	17
Eastern tributaries	31	15	13.7	3	6	10	16	62
Western tributaries	63	15	11.1	3	10	12	20	73
Trinity River	29	11	9.2	4	5	8	14	43

[1] Computed mean from measurements or analyses.
[2] Computed standard deviation from measurements or analyses.
[3] Smallest measured value.
[4] Computed value, the 25th percentile, that 25 percent of observed values are equal to or less than.
[5] Computed value, the 50th percentile, that 50 percent of observed values are equal to or less than.
[6] Computed value, the 75th percentile, that 75 percent of observed values are equal to or less than.
[7] Largest measured value.

Table 4. Maximum and secondary maximum contaminant levels of selected properties and constituents

[From U.S. Environmental Protection Agency, 1996. --, no established level; TU, nephelometric turbidity units; Pt-Co, platinum-cobalt; mg/L, milligrams per liter; µg/L, micrograms per liter]

Parameter	Unit	Maximum contaminant level goal[1]	Maximum contaminant level[2]	Secondary maximum contaminant level[3]
Group 1—Field measurements				
pH	standard units	--	--	6.5–8.5
Group 2—Physical and aesthetic properties				
Turbidity	TU	--	TT[4]	0.5–1.0
Color	Pt-Co units	--	--	15
Group 3—Major inorganic constituents				
Chloride	mg/L	--	--	250
Sulfate	mg/L	--	--	250
Fluoride	mg/L	4.0	4.0	2.0
Total dissolved solids	mg/L	--	--	500
Group 4—Nutrients				
Nitrate (as N)	mg/L	10	10	--
Nitrite plus nitrate	mg/L	10	10	--
Nitrite	mg/L	1.0	1.0	--
Group 5—Trace elements				
Arsenic	µg/L	--	50	--
Barium	µg/L	2,000	2,000	--
Cadmium	µg/L	5.0	5.0	--
Chromium	µg/L	100	100	--
Copper	mg/L	1.3	1.3	--
Iron	µg/L	--	--	300
Lead	µg/L	0	15	--
Manganese	µg/L	--	--	50
Mercury	µg/L	2.0	2.0	--
Silver	µg/L	--	--	100
Zinc	mg/L	--	--	5.0

[1] MCLG—nonenforceable concentration of a drinking water contaminant that is protective of adverse human effects and allows an adequate margin of safety. Formerly known as recommended maximum contaminant level.

[2] MCL—maximum permissible level of a contaminant in water delivered to any user of a public water system. An enforceable standard.

[3] SMCL—nonenforceable guidelines regarding taste, odor, and color, and certain nonaesthetic effects of drinking water; intended as guidelines for States.

[4] TT, treatment technique—an enforceable procedure or level of technical performance which public water systems must follow to ensure control of a contaminant. At no time can turbidity (cloudiness of water) go above 5 TU; systems that filter must ensure that the turbidity is no higher than 1 TU (0.5 TU for conventional or direct filtration) in at least 95 percent of the daily samples for any 2 consecutive months (U.S. Environmental Protection Agency, 1999).

Table 5. Summary of Mann-Whitney rank-sum tests to indicate property and constituent differences with season and depth in Lake Houston

[Transects shown on figure 1. Season or sampling location listed [summer (S), non-summer (N), near-surface (SUR), bottom (BOT)] indicates samples compared are significantly different at the 0.05 level; samples of the season or location listed have the higher median; ==, samples compared are not significantly different at the 0.05 level; **, comparison not made because only near-surface samples available]

Property or constituent	Summer samples compared with non-summer samples						Near-surface samples compared with bottom samples					
	Location:						Location:					
	Lake nearest dam (transect A)		East Fork (transect E)		West Fork (transect F)		Lake nearest dam (transect A)		East Fork (transect E)		West Fork (transect F)	
	Relative depth:						Season:					
	Near-surface	Bottom	Near-surface	Bottom	Near-surface	Bottom	Summer	Non-summer	Summer	Non-summer	Summer	Non-summer
Field measurements, biochemical oxygen demand, bacteria[1]												
Water temperature	S	S	S	S	S	S	SUR	==	SUR	==	SUR	==
Specific conductance	==	==	==	==	==	==	==	==	==	==	==	==
Dissolved oxygen	N	N	N	N	N	N	SUR	==	SUR	==	SUR	==
5-day biochemical oxygen demand	==	==	==	==	S	S	==	==	SUR	==	==	==
pH	==	N	==	==	S	==	SUR	==	SUR	==	SUR	==
Physical and aesthetic properties												
Turbidity	N	N	N	==	==	==	==	==	BOT	==	BOT	==
Secchi-disk transparency	S	**	S	**	S	**	**	**	**	**	**	**
Suspended solids	==	N	==	==	==	==	==	BOT	==	==	BOT	==
Nutrients, organic carbon, chlorophyll												
Total nitrogen	N	N	==	==	==	==	==	==	==	==	==	==
Total nitrite plus nitrate nitrogen	N	N	==	==	N	N	BOT	==	==	==	==	==
Total phosphorus	N	==	S	S	==	==	BOT	==	==	==	==	==
Total organic carbon	==	==	==	N	==	==	==	==	==	==	==	==
Chlorophyll *a*	S	**	S	**	S	**	**	**	**	**	**	**
Trace elements												
Dissolved iron	==	==	N	==	==	N	==	==	==	==	==	==
Dissolved manganese	S	S	==	==	==	==	BOT	==	BOT	==	BOT	==

[1] Insufficient number of samples for bacteria analysis collected at transects A, E, F.

Table 6. Summary of Mann-Whitney rank-sum tests to indicate property and constituent differences between locations in Lake Houston

[Transects shown on figure 1. Sampling location listed [Lake Houston nearest dam (LH), East Fork (EF), West Fork (WF)] indicates samples compared are significantly different at the 0.05 level; samples of the location listed have the higher median; ==, samples compared are not significantly different at the 0.05 level; **, comparison not made because only near-surface samples available]

Property or constituent	Lake nearest dam (transect A) compared with East Fork (transect E)				Lake nearest dam (transect A) compared with West Fork (transect F)				East Fork (transect E) compared with West Fork (transect F)			
	Season: Summer		Season: Non-summer		Season: Summer		Season: Non-summer		Season: Summer		Season: Non-summer	
	Relative depth: Near-surface	Bottom	Near-surface	Bottom	Near-surface	Bottom	Near-surface	Bottom	Near-surface	Bottom	Near-surface	Bottom
Field measurements, biochemical oxygen demand, bacteria[1]												
Water temperature	==	EF	==	==	==	WF	==	==	==	==	==	==
Specific conductance	==	==	LH	LH	WF	WF	WF	WF	WF	WF	WF	WF
Dissolved oxygen	LH	EF	LH	==	WF	WF	==	==	WF	==	==	==
5-day biochemical oxygen demand	==	==	==	==	WF	WF	==	==	WF	WF	==	==
pH	==	==	LH	LH	WF	WF	==	==	WF	WF	WF	WF
Physical and aesthetic properties												
Turbidity	==	==	==	==	==	WF	==	==	==	WF	==	==
Secchi-disk transparency	LH	**	LH	**	LH	**	LH	**	EF	**	==	**
Suspended solids	EF	EF	==	==	WF	WF	WF	WF	WF	WF	==	==
Nutrients, organic carbon, chlorophyll												
Total nitrogen	==	==	LH	LH	WF	WF	WF	WF	WF	WF	WF	WF
Total nitrite plus nitrate nitrogen	==	==	LH	LH	WF	WF	WF	WF	WF	WF	WF	WF
Total phosphorus	==	LH	LH	LH	WF	WF	WF	WF	WF	WF	WF	WF
Total organic carbon	==	==	==	==	==	==	==	==	==	==	==	==
Chlorophyll *a*	==	**	==	**	WF	**	WF	**	WF	**	WF	**
Trace elements												
Dissolved iron	==	==	==	==	LH	LH	==	==	EF	EF	EF	==
Dissolved manganese	==	LH	EF	==	LH	LH	==	==	EF	EF	==	==

[1] Insufficient number of samples for bacteria analysis collected at transects A, E, F.

Table 7. Summary of Mann-Whitney rank-sum tests to indicate property and constituent differences between eastern and western tributaries to Lake Houston and between tributaries and Trinity River

[Tributaries and Trinity River shown on figure 1. Sampling location listed [eastern tributaries (Et), western tributaries (Wt), Trinity River (T)] indicates samples compared are significantly different at the 0.05 level; samples of the location listed have the higher median; ==, samples compared are not significantly different at the 0.05 level]

Property or constituent	Eastern tributaries compared with western tributaries				Eastern tributaries compared with Trinity River				Western tributaries compared with Trinity River			
	Season:				Season:				Season:			
	Summer		Non-summer		Summer		Non-summer		Summer		Non-summer	
	Relative streamflow:				Relative streamflow:				Relative streamflow:			
	Low-medium	High	Low-medium	High	Low-medium	High	Low-medium	High	Low-medium	High	Low-medium	High
Field measurements, biochemical oxygen demand, bacteria												
Water temperature	Wt	Wt	==	==	T	T	==	==	T	T	==	==
Specific conductance	Wt	Wt	Wt	==	T	T	T	T	Wt	T	==	T
Dissolved oxygen	==	==	==	==	T	T	==	T	T	T	T	T
5-day biochemical oxygen demand	Wt	==	Wt	==	T	Et	T	Et	T	Wt	==	Wt
pH	Wt	Wt	Wt	Wt	T	T	T	T	T	T	T	T
Fecal coliform bacteria	Wt	==	==	==	Et	Et	Et	Et	Wt	Wt	Wt	Wt
Fecal streptococcus bacteria	==	==	==	==	Et	Et	==	Et	Wt	Wt	Wt	Wt
Physical and aesthetic properties												
Turbidity	==	==	==	Wt	Et	Et	Et	Et	Wt	Wt	Wt	Wt
Suspended solids	Wt	==	Wt	Wt	==	==	==	Et	Wt	==	Wt	Wt
Nutrients, organic carbon, chlorophyll[1]												
Total nitrogen	Wt	==	Wt	==	==	==	T	==	==	==	Wt	==
Total nitrite plus nitrate nitrogen	Wt	==	Wt	Wt	==	==	T	T	==	==	Wt	T
Total phosphorus	Wt	Wt	Wt	Wt	T	T	T	T	Wt	==	Wt	==
Total organic carbon	Wt	Et	==	Et	==	Et	==	Et	==	Wt	==	Wt
Trace elements												
Dissolved iron	Et	==	Et	==	Et	Et	Et	Et	Wt	Wt	Wt	Wt
Dissolved manganese	Et	==	==	==	Et	Et	Et	Et	Wt	Wt	Wt	==

[1] Chlorophyll not measured in tributaries and Trinity River.

Table 8. Summary of Mann-Whitney rank-sum tests to indicate property and constituent differences between eastern tributaries and East Fork, western tributaries and West Fork, and Trinity River and Lake Houston

[Transects, tributaries, and Trinity River shown on figure 1. Sampling location listed [Lake Houston (LH), East Fork (EF), West Fork (WF), eastern tributaries (Et), western tributaries (Wt), and Trinity River (T)] indicates samples compared are significantly different at the 0.05 level; samples of the location listed have the higher median; ==, samples compared are not significantly different at the 0.05 level]

Property or constituent	Eastern tributaries compared with East Fork (transect E)		Western tributaries compared with West Fork (transect F)		Trinity River compared with Lake nearest dam (transect A)		Trinity River compared with East Fork (transect E)		Trinity River compared with West Fork (transect F)	
	Season:		Season:		Season:		Season:		Season:	
	Summer	Non-summer	Summer	Non-summer	Summer	Non-summer	Summer	Non-summer	Summer	Non-summer
Field measurements, biochemical oxygen demand, bacteria[1]										
Water temperature	EF	==	WF	==	==	==	==	==	WF	==
Specific conductance	==	==	Wt	==	T	T	T	T	T	T
Dissolved oxygen	Et	==	Wt	Wt	T	T	T	T	T	T
5-day biochemical oxygen demand	EF	==	Wt	==	T	==	==	==	WF	==
pH	EF	EF	WF	WF	T	T	T	T	==	T
Physical and aesthetic properties										
Turbidity	==	==	==	==	LH	LH	EF	EF	WF	WF
Suspended solids	==	==	==	==	==	==	EF	==	WF	WF
Nutrients, organic carbon, chlorophyll[2]										
Total nitrogen	EF	==	Wt	==	==	==	==	T	==	WF
Total nitrite plus nitrate nitrogen	Et	Et	Wt	==	==	T	==	T	==	==
Total phosphorus	EF	==	Wt	==	==	LH	T	T	WF	WF
Total organic carbon	==	==	Wt	==	LH	LH	EF	EF	WF	WF
Trace elements										
Dissolved iron	Et	Et	Wt	==	LH	LH	EF	EF	WF	WF
Dissolved manganese	==	==	==	==	LH	LH	EF	EF	WF	WF

[1] Insufficient number of samples for bacteria analysis collected at transects A, E, F.
[2] Chlorophyll not measured at one or more locations compared.