

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
OFFICE OF PUBLIC WORKS, HURRICANE FLOOD PROTECTION
AND INTERMODAL TRANSPORTATION
PUBLIC WORKS AND WATER RESOURCES SECTION



WATER RESOURCES

TECHNICAL REPORT

NO. 77



**FLUORIDE CONCENTRATIONS IN
FRESHWATER AQUIFERS IN
LOUISIANA, 1931-2006**



Prepared by the
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
In cooperation with the
LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

2007

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By
Jason M. Griffith
U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS, DATUMS, ABBREVIATED WATER-QUALITY UNIT, AND SYMBOLS

	Multiply	By	To obtain
	mile (mi)	1.609	cubic meter per day (m ³ /d)
	million gallons per day (Mgal/d)	3,785	kilometer (km)

Horizontal coordinate information in this report is referenced to the North American Datum of 1927.

Vertical coordinate information in this report is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Abbreviated water-quality unit:

milligrams per liter (mg/L)

Symbols:

- >, greater than
- ≥, greater than or equal to
- <, less than
- ≤, less than or equal to

FLUORIDE CONCENTRATIONS IN FRESHWATER AQUIFERS IN LOUISIANA, 1931-2006

By Jason M. Griffith

ABSTRACT

Data from 5,594 samples collected from 1931 through 2006 were used to describe naturally occurring fluoride concentrations in freshwater aquifers in Louisiana. Statistical analyses were used to summarize fluoride concentrations in the aquifers.

Louisiana aquifers in sediments of Pleistocene and Holocene ages include the Red River alluvial aquifer, Mississippi River alluvial aquifer, upland terrace aquifer, Chicot aquifer system, and Chicot equivalent aquifer system (southeast Louisiana). The range (minimum and maximum) and the median fluoride concentrations for the aquifers were as follows: the Red River alluvial aquifer--from 0 to 4 mg/L (milligrams per liter) with a median of 0.4 mg/L; the Mississippi River alluvial aquifer--from 0 to 3 mg/L with a median of 0.2 mg/L; the upland terrace aquifer--from 0 to 2 mg/L with a median of 0.1 mg/L; the Chicot aquifer system--from 0 to 2 mg/L with a median of 0.2 mg/L; and the Chicot equivalent aquifer system (southeast Louisiana)--from 0 to 2.2 mg/L with a median of 0.2 mg/L.

Louisiana aquifers in sediments of Miocene and Pliocene ages include the Evangeline aquifer and Evangeline equivalent aquifer system (southeast Louisiana). The range (minimum and maximum) and the median fluoride concentrations for the aquifers were as follows: the Evangeline aquifer--from 0 to 12 mg/L with a median of 0.7 mg/L; the Evangeline equivalent aquifer system (southeast Louisiana)--from 0 to 2.6 mg/L with a median of 0.2 mg/L.

Louisiana aquifers in sediments of Oligocene and Miocene ages include the Jasper aquifer system, Jasper equivalent aquifer system (southeast Louisiana), and Catahoula aquifer. The range (minimum and maximum) and the median fluoride concentrations for the aquifers were as follows: the Jasper aquifer system--from 0 to 3 mg/L with a median of 0.6 mg/L; the Jasper equivalent aquifer system (southeast Louisiana)--from 0 to 5 mg/L with a median of 0.3 mg/L; and the Catahoula aquifer--from 0 to 2.4 mg/L with a median of 0.3 mg/L.

Louisiana aquifers in sediments of Paleocene and Eocene ages include the Cockfield, Sparta, and Carrizo-Wilcox aquifers. The range (minimum and maximum) and the median fluoride concentrations for the aquifers were as follows: the Cockfield aquifer--from 0 to 6 mg/L with a median of 0.2 mg/L; the Sparta aquifer--from 0 to 6.5 mg/L with a median of 0.2 mg/L; and the Carrizo-Wilcox aquifer--from 0 to 11 mg/L with a median of 0.3 mg/L.

INTRODUCTION

Some naturally occurring fluoride minerals in rocks and soils are easily dissolved and retained by percolating ground water (Hem, 1985, p. 121-123). Knowledge of naturally occurring fluoride concentrations in freshwater aquifers in Louisiana (fig. 1) may be useful in determining whether the quality of the water is suitable for public supply. Naturally occurring fluoride in ground water used as a community water supply can provide a good source of dietary fluoride (Centers for Disease Control and Prevention, 2001, p. 9, 10). However, in areas where natural fluoride concentrations are deficient, many communities add supplemental fluoride to the water supply (Centers for Disease Control and Prevention, 2001, p. 10; Centers for Disease Control and Prevention, 2002, table 1; Centers for Disease Control and Prevention, 2006). The U.S. Public Health Service (PHS), Centers for Disease Control and Prevention (CDC), and U.S. Environmental Protection Agency (USEPA) have established guidelines and standards regarding fluoride use in community water supplies because of the importance of fluoride to the health of bones and teeth (U.S. Public Health Service, 1991; Centers for Disease Control and Prevention, 2001; U.S. Environmental Protection Agency, 2004).

The freshwater aquifers and aquifer systems in Louisiana include the Red River alluvial, Mississippi River alluvial, and upland terrace aquifers, and the Chicot aquifer system, Chicot equivalent aquifer system (southeast Louisiana), Evangeline aquifer, Evangeline equivalent aquifer system (southeast Louisiana), Jasper aquifer system, Jasper equivalent aquifer system (southeast Louisiana), and the Catahoula, Cockfield, Sparta, and Carrizo-Wilcox aquifers (table 1, fig. 1). Other freshwater aquifers are present in Louisiana, but the listed aquifers and aquifer systems are regional in extent and account for more than 99 percent of the ground water withdrawn in Louisiana for public supply (Sargent, 2007). In 2005, about 2.0 million people or 44 percent (calculations modified from Sargent, 2007, p. 7) of Louisiana's total population of 4.5 million (U.S. Census Bureau, 2005) used about 354 Mgal/d (Sargent, 2007, p. 7) of ground water provided by public suppliers (table 1).

Table 1. Ground-water withdrawals in Louisiana for public supply by aquifer or aquifer system, 2005.

[Source: Sargent (2007, p. 86-101)]

Aquifer or aquifer system	Withdrawal, in million gallons per day
All	353.65
Red River alluvial aquifer	0.19
Mississippi River alluvial aquifer	9.51
Upland terrace aquifer	6.34
Chicot aquifer system	93.49
Chicot equivalent aquifer system (southeast Louisiana)	13.18
Evangeline aquifer	13.94
Evangeline equivalent aquifer system (southeast Louisiana)	59.21
Jasper aquifer system	31.74
Jasper equivalent aquifer system (southeast Louisiana)	72.57
Catahoula aquifer	2.26
Cockfield aquifer	7.29
Sparta aquifer	35.70
Carrizo-Wilcox aquifer	7.49

System	Series	Stratigraphic unit	Hydrogeologic unit												
			Northern Louisiana	Central and southwestern Louisiana			Southeastern Louisiana								
			Aquifer or confining unit	Aquifer system or confining unit	Aquifer or confining unit		Aquifer system ¹ or confining unit	Aquifer ² or confining unit							
Lake Charles area	Rice growing area	Baton Rouge area			St. Tammany, Tangipahoa, and Washington Parishes	New Orleans area and lower Mississippi River Parishes ³									
Quaternary	Holocene ?	Red River alluvial deposits Mississippi River alluvial deposits	Red River alluvial aquifer or surficial confining unit Mississippi River alluvial aquifer or surficial confining unit	Units absent			Near surface aquifers or surficial confining unit	Mississippi River alluvial aquifer or surficial confining unit	Units absent						
	Pleistocene	Northern Louisiana terrace deposits Unnamed Pleistocene deposits	Upland terrace aquifer or surficial confining unit	Chicot aquifer system or surficial confining unit	"200-foot" sand "500-foot" sand "700-foot" sand	Upper sand unit Lower sand unit	Chicot equivalent aquifer system or surficial confining unit	Shallow sands Upland terrace aquifer "400-foot" sand "600-foot" sand	Upland terrace aquifer Upper Ponchatoula aquifer	Gramercy aquifer Norco aquifer Gonzales-New Orleans aquifer "1200-foot" sand					
Tertiary	Pliocene ?	Fleming Formation	Blounts Creek Member	Aquifers in Pliocene-Miocene sediments are absent in this area			Evangeline aquifer or surficial confining unit		Evangeline equivalent aquifer system or surficial confining unit	"800-foot" sand "1,000-foot" sand "1,200-foot" sand "1,500-foot" sand "1700-foot" sand	Lower Ponchatoula aquifer Kentwood aquifer Big Branch aquifer Abita aquifer Covington aquifer Slidell aquifer				
			Castor Creek Member				Castor Creek confining unit					Unnamed confining unit			
			Williamson Creek Member Dough Hills Member Carnahan Bayou Member				Jasper aquifer system or surficial confining unit	Williamson Creek aquifer Dough Hills confining unit Carnahan Bayou aquifer				Jasper equivalent aquifer system or surficial confining unit	"2,000-foot" sand "2,400-foot" sand "2,800-foot" sand	Tchefuncte aquifer Hammond aquifer Amite aquifer Ramsay aquifer	
			Lena Member				Lena confining unit					Unnamed confining unit			
	?	Catahoula Formation	Catahoula aquifer			Catahoula equivalent aquifer system or surficial confining unit		Catahoula aquifer	Franklinton aquifer						
						Vicksburg Group, undifferentiated	Vicksburg-Jackson confining unit	No freshwater occurs in deeper units							
	Eocene	Jackson Group, undifferentiated	Cockfield aquifer or surficial confining unit												
		Claiborne Group				Cockfield Formation									
						Cook Mountain Formation	Cook Mountain aquifer or surficial confining unit								
						Sparta Sand	Sparta aquifer or surficial confining unit								
Cane River Formation						Cane River aquifer or surficial confining unit									
Carrizo Sand	Carrizo-Wilcox aquifer or surficial confining unit														
Paleocene	Wilcox Group, undifferentiated	Midway confining unit													
	Midway Group, Undifferentiated														

¹The interval containing the four aquifer systems is called the Southern Hills regional aquifer system.
²Clay units separating aquifers in southeastern Louisiana are discontinuous, unnamed, and not listed herein.
³The interval containing the four aquifers is called the New Orleans aquifer system.

Figure 1. Correlation of hydrogeologic units in Louisiana (modified from Lovelace and Lovelace, 1995, fig. 1).

Previous studies by the U.S. Geological Survey (USGS) documented the presence and concentration of natural fluoride in Louisiana's freshwater aquifers. Maher (1939) documented elevated fluoride concentrations in ground water in Avoyelles and Rapides Parishes (fig. 2). Tomaszewski (1992) presented a statistical summary of fluoride concentrations in water from aquifers in Louisiana based on analyses of about 5,000 water samples collected from 1960 to 1988. Since 1988, the USGS has collected and analyzed 2,000 additional samples. Assessment of previous data along with the additional data can improve knowledge of naturally occurring fluoride concentrations in Louisiana's freshwater aquifers. In response to this need, the USGS, in cooperation with the Louisiana Department of Transportation and Development, began a study in 2004 to assess and document the fluoride concentrations in fresh ground water in Louisiana.

Purpose and Scope

This report documents the naturally occurring fluoride concentrations in freshwater aquifers in Louisiana. Water-quality data for 5,594 fresh ground-water samples collected from Louisiana aquifers and aquifer systems from 1931 through 2006 were used in this report. Fluoride concentrations were summarized statistically and, for purposes of this report, were compared to PHS, CDC, and USEPA drinking-water guidelines and standards regarding the use of fluoride in community water supplies. The concentrations are presented in a table, boxplots, and six maps. This report addresses the USGS Priority Water-Resources Issue, drinking water availability and quality, as well as a high-priority issue for Cooperative Program involvement, environmental effects on human health.

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METHODS OF STUDY

Information from previous reports and water-quality data from wells throughout Louisiana were used to show the fluoride concentrations in Louisiana's freshwater aquifers. No new data were collected for this report. Data used for this report are stored in the USGS National Water Information System (NWIS) data base (<http://waterdata.usgs.gov/nwis>) and are available at the USGS office in Baton Rouge, Louisiana, along with the previous reports.

In July 2006, the USGS NWIS data base contained fluoride concentrations from a total of 9,269 ground-water samples in Louisiana. Fluoride concentrations for some samples are recorded as less than specified minimum analytical reporting levels. Minimum reporting levels for fluoride concentrations have varied over time and have ranged from 0.1 to 0.2 mg/L. The highest (and current, 2006) minimum reporting level for fluoride concentrations for USGS laboratories is 0.2 mg/L. However, in Louisiana historical fluoride concentrations in NWIS range from 0 to 12 mg/L. For this report, concentrations that were reported as less than 0.2 mg/L were used for the statistical analyses, but any concentration less than 0.2 mg/L was dashed on the boxplots.



Base map modified from Official Map of Louisiana, Department of Transportation and Development, 1986

Figure 2. Parishes in Louisiana.

Fluoride concentrations were selected for this report using four criteria: (1) if fluoride concentrations were available from multiple samples of a well, only the most recent concentration was selected; (2) only samples with chloride concentrations less than the USEPA Secondary Drinking Water Regulation Secondary Maximum Contaminant Level (SMCL) of 250 mg/L¹ were selected; (3) fluoride concentrations with improbable reporting levels were excluded; and (4) fluoride concentrations in water from wells with missing or ambiguous aquifer designations were excluded. The resulting data set of 5,594 fluoride concentrations in water samples collected from 1931 to 2006 was used to show the areal distribution on the maps in this report. These data include 235 left-censored² and 13 estimated fluoride concentrations.

For quality-assurance and quality-control purposes, data included fluoride concentrations in 35 quality-control samples that were collected from 2003 to 2006: 2 blank samples; replicate samples from 29 wells; and duplicate samples from 4 wells. Fluoride concentrations for the blank samples were less than the minimum reporting level of 0.1 mg/L. Fluoride concentrations for any sample and its corresponding replicate or duplicate sample was 0.74 mg/L or less. The maximum difference between any sample and its corresponding replicate or duplicate sample was 0.2 mg/L.

Data were statistically analyzed using S-PLUS (version 7.0.6) (Insightful Corporation, 2005), predictive analysis software that provides mathematical tools to catalog and interpret numerical data. For this report, the data were analyzed using the automated USGS S-PLUS library function that generates a summary report showing the statistical analyses of non-parametric left-censored data as described in Helsel and Hirsch (1992, p. 357-375).

Boxplots (Helsel and Hirsch, 1992, p. 5-6, 8, 24) were used to graphically summarize and illustrate the characteristics of fluoride concentrations in the aquifers and aquifer systems in Louisiana. The boxplots in this report show the median, the central 50 percent of the data (range between the 25th and the 75th percentiles), the central 80 percent of the data (range between the 10th and the 90th percentiles), and the central 90 percent of the data (range between the 5th and the 95th percentiles). Outliers (greater than the 95th percentile or less than the 5th percentile) are not shown on the boxplots.

The PHS and CDC have recommended that optimally fluoridated water contain 0.7 to 1.2 mg/L fluoride (U.S. Public Health Service, 1991; Centers for Disease Control and Prevention, 2001, p. 10). The USEPA has established a Primary Drinking Water Regulations Maximum Contaminant Level (MCL)³ of 4 mg/L fluoride in community water supplies (U.S. Environmental Protection Agency, 2004, p. iv, 8). Also, the USEPA has established an SMCL of 2 mg/L fluoride in community water supplies (U.S. Environmental Protection Agency, 2004, p. v, 10). Based on these drinking-water guidelines and standards, fluoride concentrations are grouped into five categories listed in table 2.

¹For this report, freshwater is defined as water that contains less than 250 mg/L chloride, which is less than the SMCL (U.S. Environmental Protection Agency, 2004, p. 10). SMCL: Non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. The USEPA recommends SMCLs to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards (U.S. Environmental Protection Agency, 2004).

²Statistically, data recorded as being less than a specified level is called "left-censored" data (Helsel and Hirsch, 1992, p. 2).

³National Primary Drinking Water Regulations Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to Maximum Contaminant Level Goals as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards (U.S. Environmental Protection Agency, 2004).

Table 2. Fluoride category for drinking-water guidelines and standards and corresponding concentration.

[<, less than; ≥, greater than or equal to; ≤, less than or equal to; >, greater than]

Category	Concentration, in milligrams per liter
Low	< 0.7 ^{a,b}
Recommended	≥ 0.7 and ≤ 1.2 ^{a,b}
Acceptable	> 1.2 and ≤ 2 ^{a,b,c}
High	> 2 and ≤ 4 ^c
Excessive	> 4 ^c

^aU.S. Public Health Service (1991).

^bCenters for disease Control and Prevention (2001).

^cU.S. Environmental Protection Agency (2004).

FLUORIDE CONCENTRATIONS IN FRESHWATER AQUIFERS

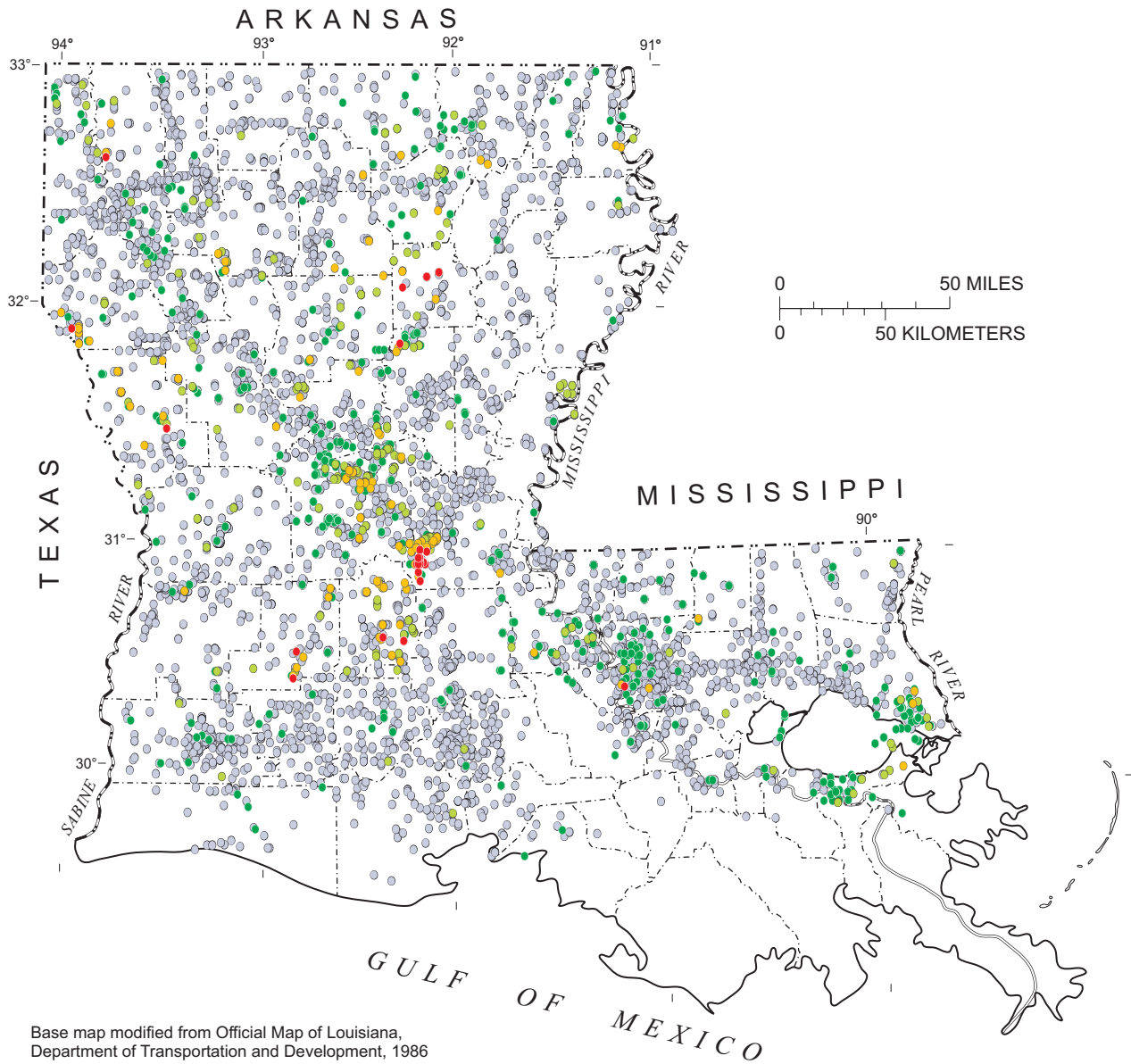
Fluoride concentrations varied in freshwater aquifers in Louisiana. The varied fluoride concentrations could be due to aquifer depth, changes in mineralogy of the aquifer, distance from the recharge area, or mixing of ground water from adjacent aquifers.

In this report, fluoride concentrations are not necessarily representative of the fluoride concentrations in community water supplies. This report only shows the distribution of fluoride concentrations in freshwater aquifers in Louisiana.

The statewide distribution of fluoride shown in figure 3 includes concentrations from samples collected from 1931 through 2006 from freshwater aquifers in Louisiana. Concentrations in fresh ground water in Louisiana ranged from 0 to 12 mg/L with a median of 0.2 mg/L (table 3). Fluoride concentrations in the low category (<0.7 mg/L) were detected in ground-water samples throughout the State. Concentrations in the recommended category (≥ 0.7 and ≤ 1.2 mg/L) were detected in 54 of 64 parishes. Generally, concentrations in the high (>2 and ≤ 4 mg/L) or excessive category (>4 mg/L) were detected in samples only from central and northern Louisiana; only 9 samples from southeastern Louisiana had concentrations >2 mg/L. Concentrations in the excessive category were detected in samples from the Evangeline aquifer (15 samples), Carrizo-Wilcox aquifer (3 samples), Sparta aquifer (3 samples), Cockfield aquifer (1 sample), Jasper equivalent aquifer system (southeast Louisiana) (1 sample), and other local aquifers (6 samples). Concentrations were the highest in Avoyelles (4.9 to 12 mg/L) and Sabine Parishes (11 mg/L).

Pleistocene and Holocene Ages

Louisiana aquifers and aquifer systems in sediments of Pleistocene and Holocene ages include the Red River alluvial aquifer, Mississippi River alluvial, and upland terrace aquifers, Chicot aquifer system, and Chicot equivalent aquifer system (southeast Louisiana) (fig. 1). Fluoride concentrations in freshwater from these aquifers ranged from 0 to 4 mg/L. Only four samples from these aquifers had concentrations greater than the acceptable category (>1.2 and ≤ 2 mg/L).



EXPLANATION

FLUORIDE SAMPLE SITE
concentration, in milligrams per liter,
and category

- Low, <0.7 ^{a, b}
- Recommended, ≥ 0.7 and ≤ 1.2 ^{a, b}
- Acceptable, >1.2 and ≤ 2.0 ^{a, b, c}
- High, >2.0 and ≤ 4.0 ^c
- Excessive, >4.0 ^c

^a U.S. Public Health Service (1991)

^b Centers for Disease Control and Prevention (2001)

^c U.S. Environmental Protection Agency (2004)

See fig. 2 for parish and other geographic names

Figure 3. Fluoride concentration at sample sites in freshwater aquifers in Louisiana.

Table 3. Statistical summary of fluoride concentrations in freshwater aquifers in Louisiana.

Aquifer or aquifer system	Number of samples	Concentration, in milligrams per liter			Period of record
		Minimum	Median	Maximum	
All	5,594	0	0.2	12	1931 - 2006
Red River alluvial aquifer	360	0	0.4	4	1931 - 2000
Mississippi River alluvial aquifer	380	0	0.2	3	1935 - 2005
Upland terrace aquifer	268	0	0.1	2	1938 - 2005
Chicot aquifer system	1,010	0	0.2	2	1931 - 2006
Chicot equivalent aquifer system (southeast Louisiana)	299	0	0.2	2.2	1937 - 2006
Evangeline aquifer	283	0	0.7	12	1931 - 1995
Evangeline equivalent aquifer system (southeast Louisiana)	436	0	0.2	2.6	1939 - 2006
Jasper aquifer system	385	0	0.6	3	1931 - 2003
Jasper equivalent aquifer system (southeast Louisiana)	447	0	0.3	5	1933 - 2006
Catahoula aquifer	168	0	0.3	2.4	1938 - 1984
Cockfield aquifer	262	0	0.2	6	1938 - 1998
Sparta aquifer	615	0	0.2	6.5	1938 - 2005
Carrizo-Wilcox aquifer	480	0	0.3	11	1931 - 2004

Data for 360 water samples were used to delineate the areal distribution of fluoride concentrations in the Red River alluvial aquifer. Fluoride concentrations were available for the extent of the Red River alluvial aquifer (fig. 4) except for an area in northeastern Caddo Parish. Concentrations in freshwater from the aquifer ranged from 0 to 4 mg/L with a median of 0.4 mg/L (table 3), and the 25th and 75th percentiles were 0.3 and 0.5 mg/L (fig. 5). Fluoride concentrations in freshwater from the Red River alluvial aquifer were generally in the low category (fig. 5). Only one water sample from the Red River alluvial aquifer had a fluoride concentration greater than the acceptable category (fig. 4).

Data for 380 water samples were used to delineate the areal distribution of fluoride concentrations in the Mississippi River alluvial aquifer. Concentrations were somewhat sparse for the Mississippi River alluvial aquifer (fig. 4) except in northern Avoyelles Parish and southeastern Iberville Parish. Concentrations in freshwater from the aquifer ranged from 0 to 3 mg/L with a median of 0.2 mg/L (table 3), and the 25th and 75th percentiles were 0.2 and 0.3 mg/L (fig. 5). Fluoride concentrations in freshwater from the aquifer were generally in the low category (fig. 5). A few scattered samples had concentrations in the recommended category (fig. 4).

Data for 268 water samples were used to delineate the areal distribution of fluoride concentrations in the upland terrace aquifer. Few concentrations were available for the upland terrace aquifer (fig. 4) in parts of Avoyelles, Bossier, Catahoula, Grant, Bienville, Ouachita, and Morehouse Parishes. Concentrations in freshwater from the aquifer ranged from 0 to 2 mg/L with a median of 0.1 mg/L

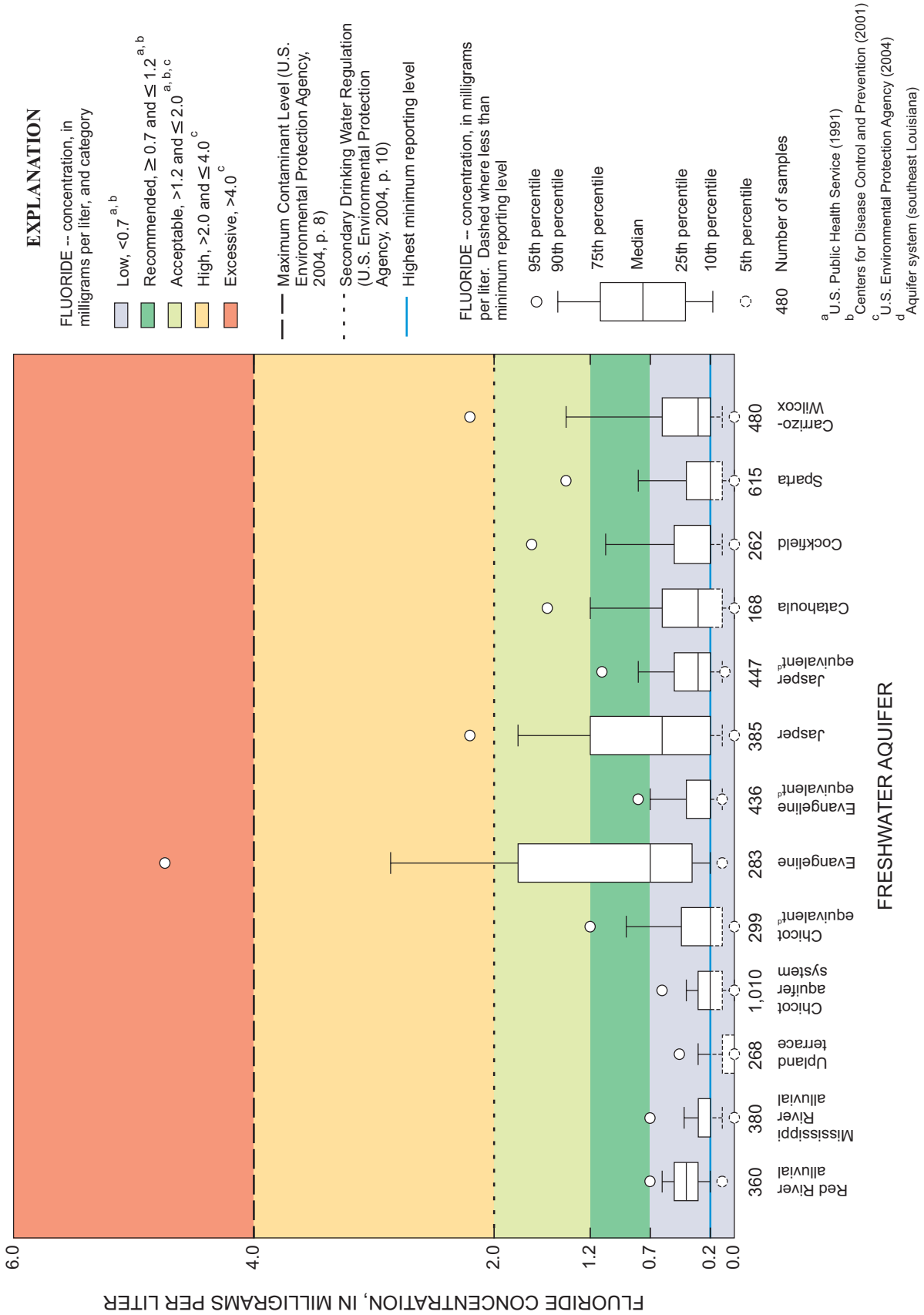


Figure 5. Fluoride concentration in samples from freshwater aquifers in Louisiana.

(table 3), and the 25th and 75th percentiles were 0 and 0.1 mg/L (fig. 5). Fluoride concentrations in freshwater from the aquifer were generally in the low category (fig. 5). Although the aquifer is somewhat discontinuous, the distribution of fluoride concentrations in water from the aquifer was very small (fig. 4).

Data for 1,010 water samples were used to delineate the areal distribution of fluoride concentrations in the Chicot aquifer system. Concentrations were available for the areal extent of the Chicot aquifer system (fig. 4) except for areas in eastern Cameron Parish, western Vermilion Parish, and parts of Beauregard Parish. Concentrations in freshwater from the aquifer system ranged from 0 to 2 mg/L with a median of 0.2 mg/L (table 3), and the 25th and 75th percentiles were 0.1 and 0.3 mg/L (fig. 5). Fluoride concentrations in freshwater from the aquifer system were generally in the low category (fig. 5). Generally, concentrations greater than the low category were detected in samples only from the southern part of the Chicot aquifer system.

Data for 299 water samples were used to delineate the areal distribution of fluoride concentrations in the Chicot equivalent aquifer system (southeast Louisiana). Concentrations were unavailable in West Feliciana and St. Helena Parishes. Concentrations were sparse for the Chicot equivalent aquifer system (southeast Louisiana) (fig. 4) in parts of East Feliciana, Livingston, Tangipahoa, Washington, and St. Tammany Parishes. Concentrations in freshwater from the aquifer system ranged from 0 to 2.2 mg/L with a median of 0.2 mg/L (table 3), and the 25th and 75th percentiles were 0.1 and 0.44 mg/L (fig. 5). Fluoride concentrations in freshwater from the aquifer system were generally in the low category (fig. 5). Concentrations greater than the recommended category were detected in samples from Jefferson, Orleans, St. John the Baptist, and St. Tammany Parishes.

Miocene and Pliocene Ages

Louisiana aquifers and aquifer systems in sediments of Miocene and Pliocene ages include the Evangeline aquifer and Evangeline equivalent aquifer system (southeast Louisiana) (fig. 2). Fluoride concentrations in freshwater from these aquifers ranged from 0 to 12 mg/L.

Data for 283 water samples were used to delineate the areal distribution of fluoride concentrations in the Evangeline aquifer. Concentrations were unavailable or sparse for the Evangeline aquifer (fig. 6) in parts of Calcasieu, Jefferson Davis, St. Landry, Vernon, Beauregard, Rapides, and Allen Parishes. Concentrations in freshwater from the aquifer ranged from 0 to 12 mg/L with a median of 0.7 mg/L (table 3), and the 25th and 75th percentiles were 0.35 and 1.8 mg/L (fig. 5). Fluoride concentrations in freshwater from the aquifer were generally in the low to acceptable category (fig. 5). Generally, concentrations were in the low category in the western and northwestern part of the Evangeline aquifer. Concentrations greater than the acceptable category were detected in samples from the Evangeline aquifer in Allen, Evangeline, Rapides, and Avoyelles Parishes. Concentrations in freshwater from the Evangeline aquifer were the highest of aquifers and aquifer systems in Louisiana.

Data for 436 water samples were used to delineate the areal distribution of fluoride concentrations in the Evangeline equivalent aquifer system (southeast Louisiana). Fluoride concentrations for the aquifer system (fig. 6) were sparse in parts of Livingston, Tangipahoa, and Washington Parishes. Concentrations were unavailable for the Evangeline equivalent aquifer system (southeast Louisiana) in St. Helena Parish. Concentrations in freshwater from the aquifer system ranged from 0 to 2.6 mg/L with a median of 0.2 mg/L (table 3), and the 25th and 75th percentiles were 0.2 and 0.4 mg/L (fig. 5). Fluoride concentrations in freshwater from the aquifer system were generally in the low category (fig. 5). Generally, concentrations were in the low category in the northeastern part of the Evangeline

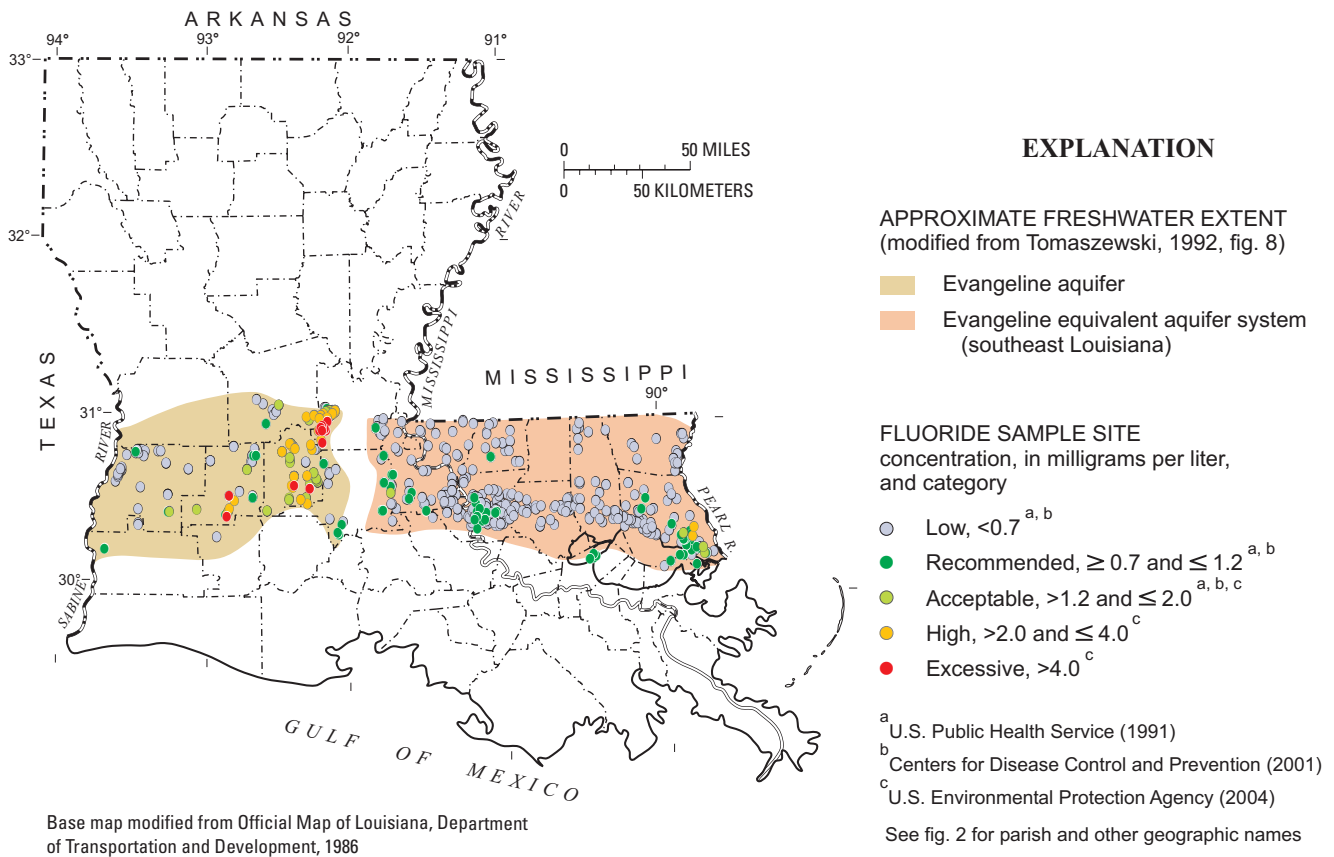


Figure 6. Fluoride concentration at sample sites in freshwater aquifers in sediments of Miocene and Pliocene ages in Louisiana.

equivalent aquifer system (southeast Louisiana). Concentrations greater than the acceptable category were detected in samples from the Evangeline equivalent aquifer system (southeast Louisiana) in southern St. Tammany Parish.

Oligocene and Miocene Ages

Louisiana aquifers and aquifer systems in sediments of Oligocene and Miocene ages include the Jasper aquifer system, Jasper equivalent aquifer system (southeast Louisiana), and Catahoula aquifer (fig. 2). Fluoride concentrations in freshwater from these aquifers ranged from 0 to 5 mg/L.

Data for 385 water samples were used to delineate the areal distribution of fluoride concentrations in the Jasper aquifer system. Few concentrations were available for the southeastern part of the Jasper aquifer system (fig. 7) including areas in Beauregard, Allen, Vernon, and southern Rapides Parishes. Concentrations in freshwater from the aquifer system ranged from 0 to 3 mg/L with a median of 0.6 mg/L (table 3), and the 25th and 75th percentiles were 0.2 and 1.2 mg/L (fig. 5). Fluoride concentrations in freshwater from the aquifer system were generally in the low to recommended category (fig. 5). Concentrations in the high category were detected in several samples from the Jasper aquifer system in central Rapides Parish.

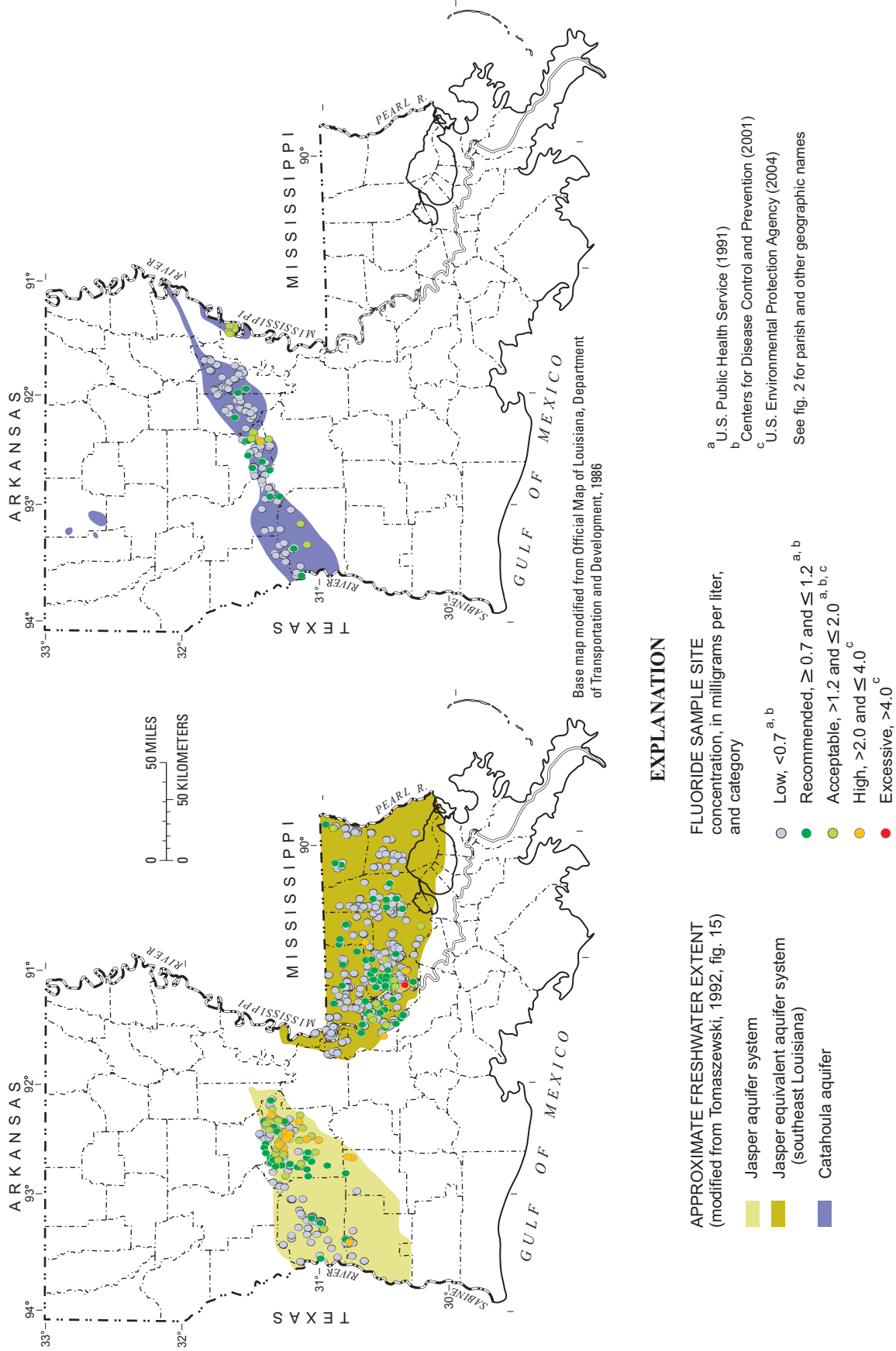


Figure 7. Fluorine concentration at sample sites in freshwater aquifers in sediments of Oligocene and Miocene ages in Louisiana.

Data for 447 water samples were used to delineate the areal distribution of fluoride concentrations in the Jasper equivalent aquifer system (southeast Louisiana). Few concentrations were available for the Jasper equivalent aquifer system (southeast Louisiana) (fig. 7) in parts of Livingston, Tangipahoa, Washington, and St. Tammany Parishes. Concentrations in freshwater from the aquifer system ranged from 0 to 5 mg/L with a median of 0.3 mg/L (table 3), and the 25th and 75th percentiles were 0.2 and 0.5 mg/L (fig. 5). Fluoride concentrations in freshwater from the aquifer system were generally in the low category (fig. 5). Generally, concentrations greater than the recommended category were detected only in samples from Pointe Coupee, West Baton Rouge, East Baton Rouge, St. Helena, and Livingston Parishes.

Data for 168 water samples were used to delineate the areal distribution of fluoride concentrations in the Catahoula aquifer. Concentrations were sparse for the Catahoula aquifer (fig. 7) in parts of Vernon and Natchitoches Parishes. Concentrations in freshwater from the aquifer ranged from 0 to 2.4 mg/L with a median of 0.3 mg/L (table 3), and the 25th and 75th percentiles were 0.1 and 0.6 mg/L (fig. 5). Fluoride concentrations in freshwater from the aquifer were generally in the low category (fig. 5). Generally, concentrations greater than the recommended category were detected in southern Grant Parish, northeastern Concordia Parish, and parts of Vernon Parish.

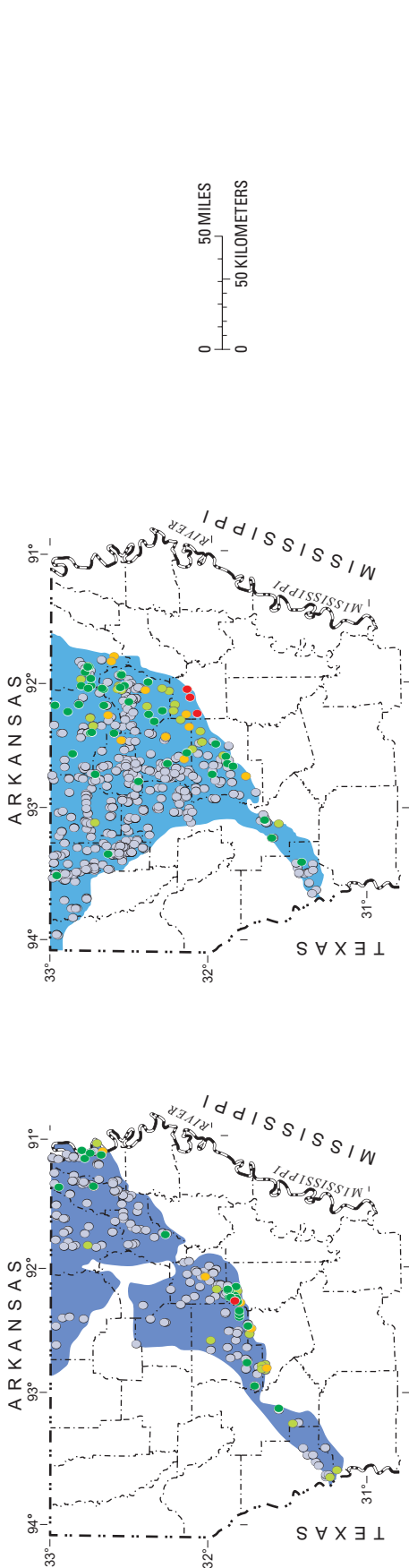
Paleocene and Eocene Ages

Aquifers in Louisiana in sediments of Paleocene and Eocene ages include the Cockfield, Sparta, and Carrizo-Wilcox aquifers (fig. 2). Fluoride concentrations in freshwater from these aquifers ranged from 0 to 11 mg/L.

Data for 262 water samples were used to delineate the areal distribution of fluoride concentrations in the Cockfield aquifer. Concentrations were unavailable or sparse for the Cockfield aquifer (fig. 8) in most of Union Parish and in parts of Morehouse, Ouachita, Jackson, Winn, Natchitoches, and Sabine Parishes. Concentrations in freshwater from the aquifer ranged from 0 to 6 mg/L with a median of 0.2 mg/L (table 3), and the 25th and 75th percentiles were 0.2 and 0.5 mg/L (fig. 5). Fluoride concentrations in freshwater from the aquifer were generally in the low category (fig. 5). Fluoride concentrations greater than acceptable levels were detected in water from the Cockfield aquifer in LaSalle Parish, Grant Parish, central Caldwell Parish, and eastern East Carroll Parish.

Data for 615 water samples were used to delineate the areal distribution of fluoride concentrations in the Sparta aquifer. Concentrations were unavailable for the Sparta aquifer (fig. 8) in parts of Natchitoches and Sabine Parishes. Concentrations in freshwater from the aquifer ranged from 0 to 6.5 mg/L with a median of 0.2 mg/L (table 3), and the 25th and 75th percentiles were 0.1 and 0.4 mg/L (fig. 5). Fluoride concentrations in freshwater from the aquifer were generally in the low category (fig. 5). Concentrations greater than the acceptable category were detected in samples from the Sparta aquifer near the eastern boundary of the aquifer.

Data for 480 water samples were used to delineate the areal distribution of fluoride concentrations in the Carrizo-Wilcox aquifer. Few concentrations were available for the Carrizo-Wilcox aquifer (fig. 8) in parts of Bossier and Webster Parishes. Concentrations in freshwater from the aquifer ranged from 0 to 11 mg/L with a median of 0.3 mg/L (table 3), and the 25th and 75th percentiles were 0.2 and 0.6 mg/L. Fluoride concentrations in freshwater from the aquifer were generally in the low category (fig. 5). Concentrations in the low to acceptable categories were detected in samples throughout the Carrizo-Wilcox aquifer. Fluoride concentrations greater than the acceptable category were detected in samples throughout the areal extent of the Carrizo-Wilcox aquifer; most concentrations were detected in the western half of the aquifer extent.



EXPLANATION

APPROXIMATE FRESHWATER EXTENT
(modified from Tomaszewski, 1992, fig. 22)

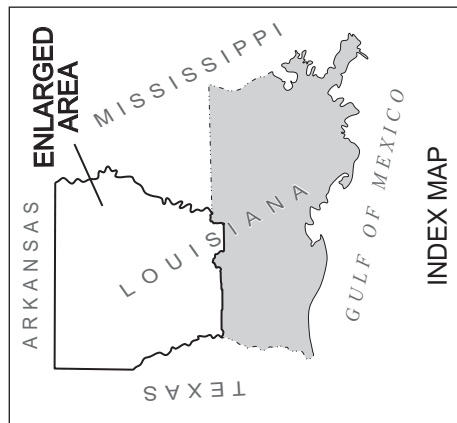
- Cockfield aquifer
- Sparta aquifer
- Carrizo-Wilcox aquifer

FLUORIDE SAMPLE SITE
concentration, in milligrams per liter,
and category

- Low, <math>< 0.7</math>^{a, b}
- Recommended, >math>\ge 0.7</math> and ≤ 1.2^{a, b}
- Acceptable, >math>1.2</math> and ≤ 2.0^{a, b, c}
- High, >math>2.0</math> and ≤ 4.0^c
- Excessive, >math>4.0</math>^c

^a U.S. Public Health Service (1991)
^b Centers for Disease Control and Prevention (2001)
^c U.S. Environmental Protection Agency (2004)

See fig. 2 for parish and other geographic names



Base map modified from Official Map of Louisiana, Department of Transportation and Development, 1986

Figure 8. Fluoride concentration at sample sites in freshwater aquifers in sediments of Paleocene and Eocene ages in Louisiana.

SUMMARY

Statistical analyses of 5,594 ground-water samples collected from 1931 through 2006 were used to summarize naturally occurring fluoride concentrations in freshwater aquifers in Louisiana. The U.S. Public Health Service, Centers for Disease Control and Prevention, and U.S. Environmental Protection Agency have established guidelines and standards regarding fluoride use in community water supplies because of the importance of fluoride to the health of bones and teeth. The guidelines and standards were the basis for five categories used to group fluoride concentrations: low (less than 0.7 mg/L [milligrams per liter]), recommended (greater than or equal to 0.7 and less than or equal to 1.2 mg/L), acceptable (greater than 1.2 and less than or equal to 2 mg/L), high (greater than 2 and less than or equal to 4 mg/L), and excessive (greater than 4 mg/L).

Aquifers in sediments of Pleistocene and Holocene ages include the Red River alluvial aquifer, Mississippi River alluvial aquifer, upland terrace aquifer, Chicot aquifer system, and Chicot equivalent aquifer system (southeast Louisiana). Fluoride concentrations in freshwater from these aquifers ranged from 0 to 4 mg/L, but concentrations were generally in the low category. Concentrations in the Red River alluvial aquifer ranged from 0 to 4 mg/L with a median of 0.4 mg/L, and the 25th and 75th percentiles were 0.3 and 0.5 mg/L. Concentrations in the Mississippi River alluvial aquifer ranged from 0 to 3 mg/L with a median of 0.2 mg/L, and the 25th and 75th percentiles were 0.2 and 0.3 mg/L. Concentrations in the upland terrace aquifer ranged from 0 to 2 mg/L with a median of 0.1 mg/L, and the 25th and 75th percentiles were 0 and 0.1 mg/L. Concentrations in the Chicot aquifer system ranged from 0 to 2 mg/L with a median of 0.2 mg/L, and the 25th and 75th percentiles were 0.1 and 0.3 mg/L. Concentrations in the Chicot equivalent aquifer system (southeast Louisiana) ranged from 0 to 2.2 mg/L with a median of 0.2 mg/L, and the 25th and 75th percentiles were 0.1 and 0.44 mg/L.

Louisiana aquifers in sediments of Miocene and Pliocene ages include the Evangeline aquifer and Evangeline equivalent aquifer system (southeast Louisiana). Fluoride concentrations in freshwater from these aquifers ranged from 0 to 12 mg/L. Concentrations in the Evangeline aquifer were generally in the low to acceptable categories, and ranged from 0 to 12 mg/L with a median of 0.7 mg/L; the 25th and 75th percentiles were 0.35 and 1.8 mg/L. Concentrations in the Evangeline equivalent aquifer system (southeast Louisiana) were generally in the low category, and ranged from 0 to 2.6 mg/L with a median of 0.2 mg/L; the 25th and 75th percentiles were 0.2 and 0.4 mg/L.

Louisiana aquifers in sediments of Oligocene and Miocene ages include the Jasper aquifer system, Jasper equivalent aquifer system (southeast Louisiana), and Catahoula aquifer. Fluoride concentrations in freshwater from these aquifers ranged from 0 to 5 mg/L. Concentrations in the Jasper aquifer system were generally in the low to recommended categories, and ranged from 0 to 3 mg/L with a median of 0.6 mg/L, and the 25th and 75th percentiles were 0.2 and 1.2 mg/L. Concentrations in the Jasper equivalent aquifer system (southeast Louisiana) were in the low category, and ranged from 0 to 5 mg/L with a median of 0.3 mg/L, and the 25th and 75th percentiles were 0.2 and 0.5 mg/L. Concentrations in the Catahoula aquifer were in the low category, and ranged from 0 to 2.4 mg/L with a median of 0.3 mg/L, and the 25th and 75th percentiles were 0.1 and 0.6 mg/L.

Louisiana aquifers in sediments of Paleocene and Eocene ages include the Cockfield, Sparta, and Carrizo-Wilcox aquifers. Fluoride concentrations in freshwater from these aquifers ranged from 0 to 11 mg/L; concentrations were generally in the low category. Concentrations in the Cockfield aquifer ranged from 0 to 6 mg/L with a median of 0.2 mg/L, and the 25th and 75th percentiles were 0.2 and 0.5 mg/L. Concentrations in the Sparta aquifer ranged from 0 to 6.5 mg/L with a median of 0.2 mg/L, and the 25th and 75th percentiles were 0.1 and 0.4 mg/L. Concentrations in the Carrizo-Wilcox aquifer ranged from 0 to 11 mg/L with a median of 0.3 mg/L, and the 25th and 75th percentiles were 0.2 and 0.6 mg/L.

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