GEOLOGICAL SURVEY OF ALABAMA

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WATER INVESTIGATIONS PROGRAM

A SYNOPTIC WATER-QUALITY SURVEY IN THE UPPER MOBILE-TENSAW RIVER DELTA, 2005-2007

OPEN-FILE REPORT 0704

by

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Daphne Ecological Services Office

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CONTENTS

TABLES

FIGURES

ABSTRACT

Water and sediment samples were collected at seven sites in the upper Mobile-Tensaw River Delta from 2005-07 with the objectives of (1) qualitatively comparing constituent concentrations at different river discharge stages, and (2) collecting one series of bottom sediment samples and examining them for the presence of toxic trace metals and related constituents. In addition to standard physical and inorganic characteristics, some samples were also analyzed for selected organic constituents. Water samples were collected during low, average, and flood discharge with sediment samples collected once during low river discharge. Several measured parameters (temperature, pH, and dissolved oxygen) were outside of established limits for the water-use classifications applicable to streams in the delta. Turbidity and total suspended solids were highest during flood flow periods at the main river channel sites (highest in the Mobile River), less turbid conditions in the Middle River, and lowest turbidity in the Tensaw River. Nitrogen was highest in the Mobile River and decreased to the east in the Tensaw River while phosphorus was not particularly elevated at any site. Main river channels and Tensaw Lake had sufficient phytoplankton density to be classified as mesotrophic to eutrophic at times, while samples from Cedar Creek indicated low algal densities and oligotrophic conditions. Concentrations of selected trace metals and toxic trace metals exceeded detection limits 28 times during the study with the highest number of detections occurring in the Mobile River. Metals most frequently detected were titanium, arsenic, nickel, antimony, and lead. The toxic trace metals cadmium, chromium, copper, mercury, molybdenum, selenium, silver, and vanadium were not detected in the water column samples, and all pesticide and herbicide analytes were below detection limits in the water column samples. Sediment samples were collected once from each site during November 2005. Cedar Creek and Tensaw Lake–sites off the main delta river channels–had the lowest pH values and highest concentrations of TKN-nitrogen, cadmium, mercury, and total organic carbon. It is postulated that excess flow during flood events in the Alabama River is passed through the Tensaw Lake area which provides treatment by removing sediments and pollutants as water passes through.

INTRODUCTION

The Mobile River Basin ranks as one of the largest and most biologically diverse river basins in the United States. It encompasses nearly 44,000 square miles (mi^2) draining portions of Georgia, Tennessee, Mississippi, and Alabama with approximately two-thirds of the basin in Alabama (fig. 1). In terms of average annual flow, the Mobile River Basin is fourth nationally at 62,100 cubic feet per second (ft^3/s) with about 47 percent contributed by the Tombigbee River and 52 percent contributed by the Alabama River. Land use is mixed, with around 70 percent of the basin forested, 26 percent in agriculture, and 3 percent in urban use. The environmental setting and water-quality issues in the Mobile River Basin were recently summarized by Johnson and others (2002) as part of the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) program. The Alabama and Tombigbee Rivers merge at the terminus of the Mobile River Basin to form the Mobile-Tensaw River Delta, a 960 mi^2 complex of braided river channels, off-channel bayous and lakes, interconnecting streams, and forested and emergent wetlands serving as the interface between fresh upland waters and the brackish waters of Mobile Bay (fig. 1).

A study undertaken during the NAWQA Mobile Basin program (McPherson and others, 2003) found that total nitrogen, nitrate, and total phosphorus loads were nearly twice as high in the Tombigbee River compared to the Alabama River due principally to the greater agricultural influences in the Tombigbee River drainage. McPherson and others (2003) also noted differences between the Alabama and Tombigbee Rivers relative to pesticide contamination. Pesticides in the Tombigbee River were dominated by atrazine, and to a lesser extent 2-hydroxyatrazine, 2,4-D, and metolachlor. Pesticides in the Alabama River were dominated by simazine, and to a lesser extent by by atrazine and 2,4-D.

The Geological Survey of Alabama (GSA) conducted a brief water-quality survey of the Tensaw River in 1997 which focused on water-quality parameters pertaining to Alabama's water-use classification system. This study was conducted to support the proposed upgrading of the water-use classification for the Tensaw River from Fish and Wildlife (F&W) to Outstanding Alabama Water (OAW) (Chandler, 1997). Findings of

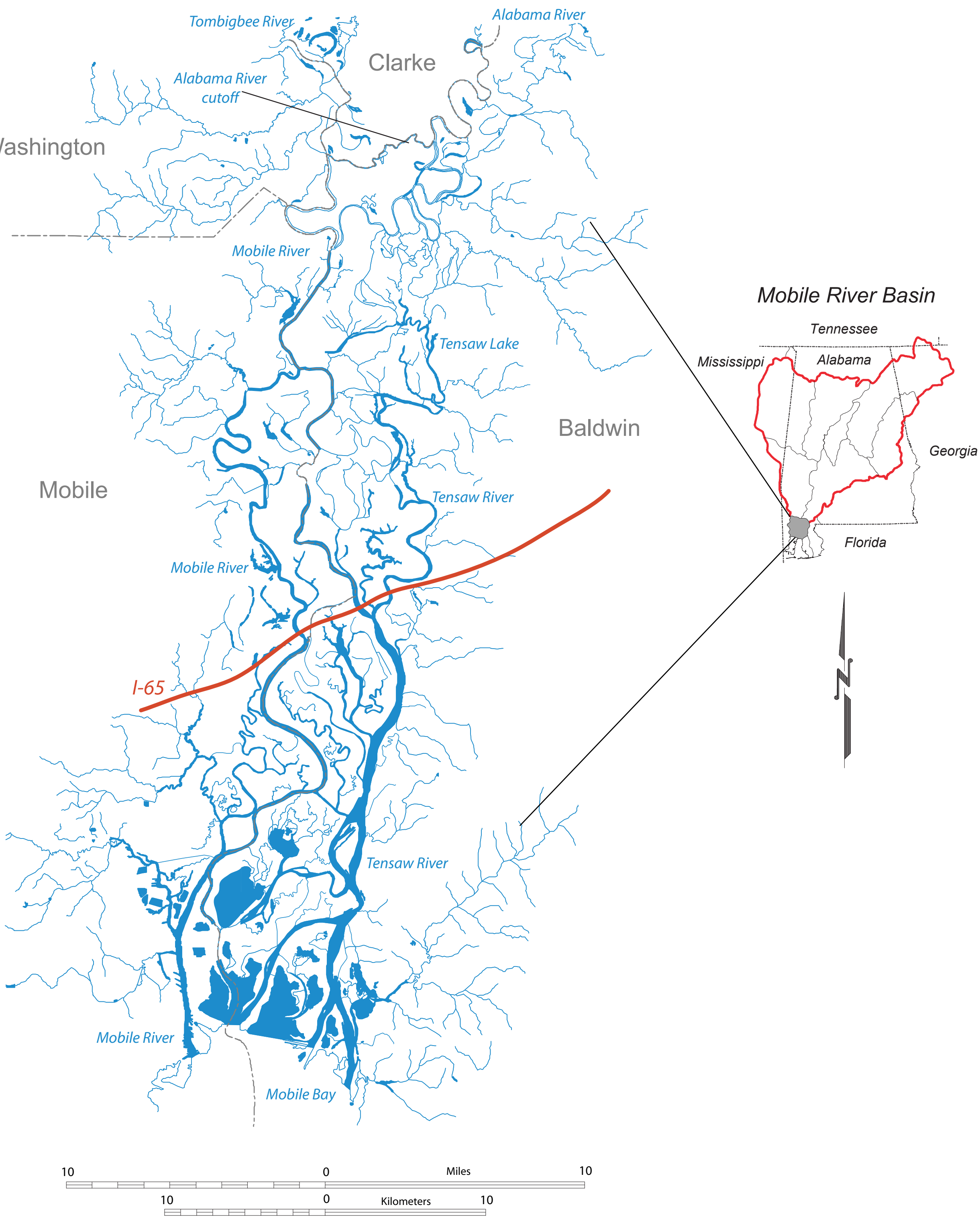


Figure 1. Location map of the the Mobile-Tensaw River Delta, Alabama.

this study demonstrated that pH, turbidity, and dissolved oxygen measurements all met OAW criteria during the period of study (September and October), summer maximum temperatures were near the upper temperature criterion, and that fecal coliform bacteria was low with only a few samples exceeding the limit of 200 colonies/100 mL. Waters were low in nitrogen and phosphorus with low biochemical oxygen demands. The Alabama Department of Environmental Management acted on this data and added the OAW water-use classification to the Tensaw River.

The Mobile basin supports a diverse endemic aquatic fauna of 40 fish species, 33 mussel species, and 110 aquatic snail species. The U.S. Fish and Wildlife Service has listed 39 species of aquatic animals and plants as either threatened or endangered including 2 plants, 2 turtles, 7 snails, 17 mussels and 11 fish species. An aquatic species inventory in the upper Mobile-Tensaw River Delta (O'Neil and others, 2005) found 271 species of crustaceans, aquatic insects, mollusks, and fishes, with the Tensaw Lake region the most productive and diverse area of the upper delta.

The seasonal interconnection of the delta's large river channels (Mobile, Middle, and Tensaw) with its many lakes, and the water contributions of small blackwater tributaries, results in a highly dynamic wetland system. This system functions as a productive fishery resource, biodiversity preserve, water-quality filter, and future conservation legacy for Alabama.

ACKNOWLEDGMENTS

Several individuals and institutions provided assistance with this study, and we sincerely appreciate their time and contributions. Pete Tuttle of the U.S. Fish and Wildlife Service, Daphne Ecological Services Office, provided critical support for the study and discussed many aspects of sampling, sampling sites, and water-quality data needs in the Mobile-Tensaw River Delta. Pesticide analyses were supported by Tony Cofer and Danny LeCompte of the Alabama Department of Agriculture and Industries, Pesticide Laboratory. Neil Moss, Maurice Mettee, Marlon Cook, and Cal Johnson of the Geological Survey of Alabama provided field assistance at various times during the course of this study.

OBJECTIVES

The objectives of this investigation were to (1) collect a series of water column samples at various river stages ranging from flood to summer low flows and qualitatively compare constituent concentrations in the upper Mobile-Tensaw River Delta, and (2) collect one series of bottom sediment samples and examine them for the presence of toxic trace metals and related constituents. Because of the limited number of samples collected during this study, the data should be used only as a general synoptic survey of water-quality conditions at varying river flow conditions in the delta and as a screening tool for toxic water column and bottom sediment constituents. The data are inadequate for constituent loading calculations and other analyses requiring time series water-quality data.

METHODS

Water samples were collected from seven sampling sites (table 1) located in the upper Mobile-Tensaw River Delta extending from the Interstate Highway 65 crossing upstream to the Alabama River cutoff in both the Tombigbee and Alabama Rivers (fig. 2). Sampling sites were selected to isolate flow entering the delta from both the Tombigbee and Alabama Rivers and evaluate water quality in the Mobile, Middle, and Tensaw Rivers individually at the downstream end of the study area. Two backwater sampling sites, removed from main river channel influence, were selected to represent water-quality conditions in a blackwater stream system (Cedar Creek, site 3) and in an off-channel lake (Tensaw Lake, site 4). Three water samples were taken at sites 1, 2, 3, 4, and 6, while six samples were taken at sites 5 and 7, Mobile and Tensaw Rivers (tables 1 and 2). Sediment samples were collected once during a low river flow period, November 1-2, 2005. Pesticide samples were taken during four sampling periods (table 2).

Water samples were collected using a modified equal-width increment method described by Shelton (1994). From 5 to 7 water samples were collected at a depth of approximately 5 feet using a Wildco Van Dorn “Beta” horizontal water sampler made of PVC. These samples were composited into a clean polyethylene bucket from which all water column samples for both inorganic and organic constituents were taken.

Table 1. Location information for seven water-quality sampling sites in the Mobile-Tensaw River Delta.

Sampling station	County	Latitude	Longitude	Section, Township, Range	Number of samples	
					water	sediment
1. Tombigbee River upstream of Alabama River cutoff	Washington	31.19839	87.95044	sec. 50, T. 3 N., R. 1 E.	3	1
2. Alabama River upstream of Alabama River cutoff	Clarke	31.20881	87.87592	sec. 21, T. 3 N., R. 2 E.	3	1
3. Cedar Creek upstream of Cedar Creek landing	Mobile	31.06781	88.00794	sec. 7, T. 1 N., R. 1 E.	3	1
4. Tensaw Lake near Dead Lake Island	Baldwin	31.05208	87.90281	sec. 18, T. 1 N., R. 2 E.	3	1
5. Mobile River just upstream of I-65 bridge	Mobile	30.91703	87.96539	sec. 42, T. 15 N., R. 1 E.	6	1
6. Middle River just upstream of I-65 bridge	Baldwin	30.93564	87.92394	sec. 25, T. 1 S., R. 1 E.	3	1
7. Tensaw River just upstream of I-65 bridge	Baldwin	30.93967	87.90281	sec. 29, T. 1 S., R. 2 E.	6	1

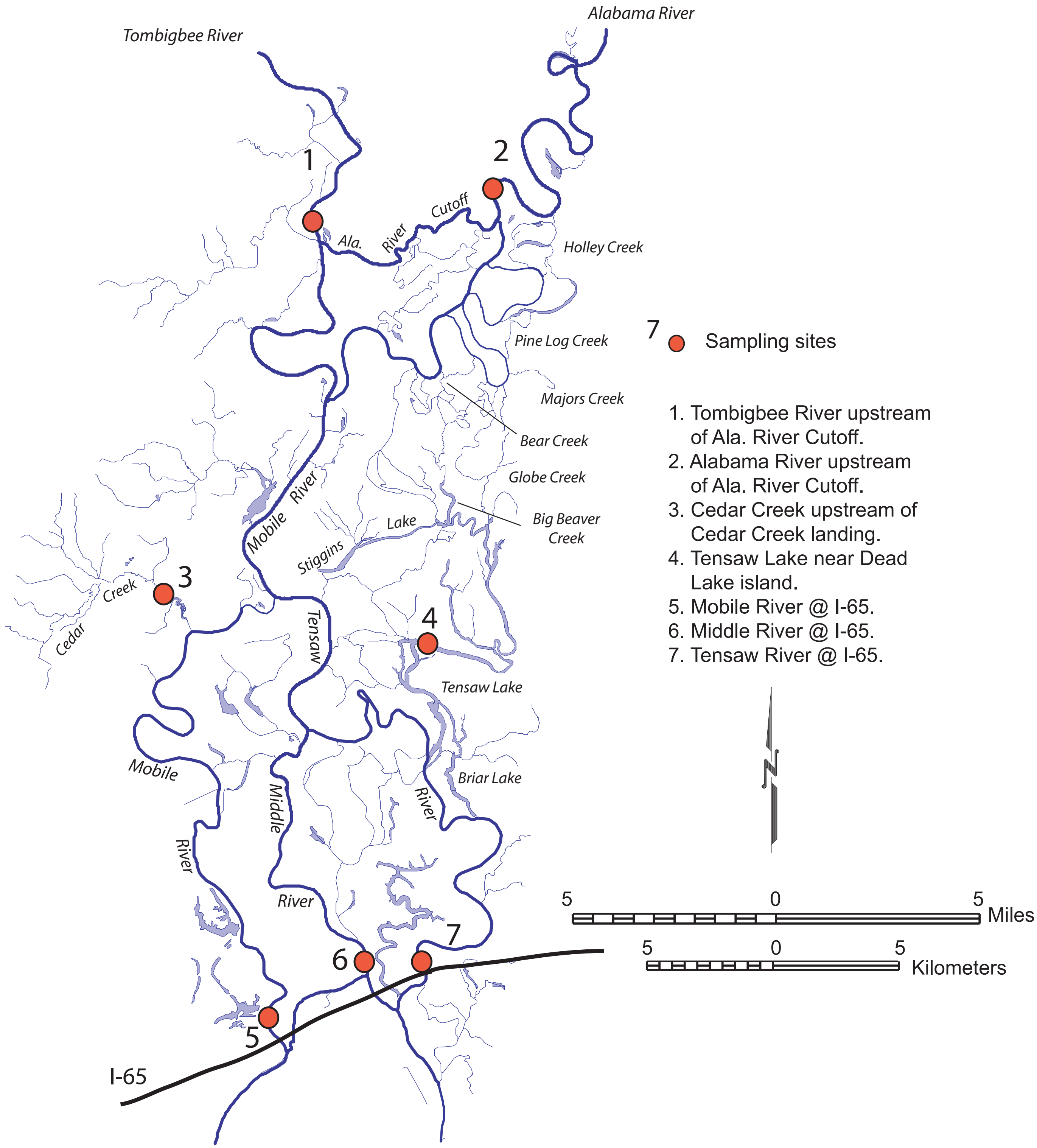


Figure 2. Sampling sites in the upper Mobile-Tensaw River Delta, 2005-07.

Table 2. Dates of water, sediment, and pesticide sample collections in the Mobile-Tensaw River Delta, 2005-07.

Sampling sites	Sampling dates[1]					
	Mar-2-05	Jul-26,27-05	Nov-1,2-05	Feb-21,22-06	Aug-15-06	Jan-8,9-07
1. Tombigbee River upstream of Alabama River cutoff	n/c	W, P	W, S, P	n/c	n/c	W, P
2. Alabama River upstream of Alabama River cutoff	n/c	W, P	W, S, P	n/c	n/c	W, P
3. Cedar Creek upstream of Cedar Creek landing	n/c	W, P	W, S, P	n/c	n/c	W, P
4. Tensaw Lake near Dead Lake Island	n/c	W, P	W, S, P	n/c	n/c	W, P
5. Mobile River just upstream of I65 bridge	W, P	W, P	W, S, P	W	W	W, P
6. Middle River just upstream of I65 bridge	n/c	W, P	W, S, P	n/c	n/c	W, P
7. Tensaw River just upstream of I65 bridge	W, P	W, P	W, S, P	W	W	W, P
Average daily flow (ft^3/s)[2]	96,700	53,400	8,000	72,800	13,100	126,800

[1] - n/c-not collected, W-water sample, S-sediment sample, P-pesticide/herbicide sample
[2] - Combined discharge for USGS stations 02470629 (Mobile River at Bucks) and 02471019 (Tensaw River near Mount Vernon).

Measurements of temperature, dissolved oxygen, pH, specific conductance, and turbidity were made in the field at the time of sample collection using a Horiba U-10 instrument. The following raw and filtered (0.45μm) individual samples were returned (in Nasco whirl-pak sterilized bags or polyethylene bottles) to the GSA Geochemical Laboratory for analysis: one 18-oz raw water bag, one 4-oz filtered-untreated bag, one 4-oz filtered-chilled bag (4°C), one 4-oz filtered-acidified (pH <2.0 with sulfuric acid) bag, one 4-oz raw-acidified (pH <2.0 with sulfuric acid) bag, one 4-oz raw bag preserved with NaOH, one filtered-acidified (pH <2.0 with nitric acid) sample in a white polyethylene bottle, one filtered-acidified (pH <2.0 with sulfuric acid) sample in a brown polyethylene bottle, two standard BOD bottles filled with raw sample, one brown 0.5 L polyethylene bottle for chlorophyll-a, a single 1-L clear polyethylene bottle with raw sample for surfactants, and a clear 2-L glass bottle filled halfway and preserved with 5 mL of 50 percent hydrochloric acid for oil and grease and total petroleum hydrocarbons. One gallon of raw sample in amber glass and two 40 mL amber glass vials with raw sample were returned to the laboratory for pesticides analyses.

Sediment samples were collected by taking subsamples along about 50 meters of shoreline and compositing these in a clean polyethylene bowl. One clear 250 mL glass bottle was filled with sediment for oil and grease analyses, one 125 mL polyethylene container was filled for standard analyses, and two 4-ounce and one 2-ounce glass jars were filled for sulfide and pesticide analyses.

Water and sediment samples were analyzed for a suite of inorganic and organic characteristics (table 3). Chemical analyses completed in the GSA laboratory were conducted in accordance with U.S. Environmental Protection Agency (USEPA, 1973, 1983, 1988, 1990, 1991), Fishman and Friedman (1989), Greenberg and others (1992), and Wershaw and others (1987). Trace metals were measured in all samples using inductively coupled atomic absorption spectrophotometry (ICP); however, certain toxic trace metals were measured with the more sensitive graphite furnace atomic absorption spectrophotometer (GF), thereby enhancing the ability to detect lower metal

Table 3. Water and sediment parameters, lower limit of detection, and analytical methods.

Parameter	Units	Lower limit of detection	Method
Temperature	°C	--	Electrometric, field
Dissolved oxygen	mg/L	0.1	Electrometric, field
BOD 5-day	mg/L	0.1	Incubation, electrometric, EPA 405.1
Total residual chlorine	mg/L	0.02	Colorimetric, APHA 4500-Cl G
pH	units	--	Electrometric, field
Carbon dioxide-free	mg/L	1	Calculated, APHA 4500-CO2 D
Alkalinity	mg/L as $CaCO_3$	3	Colorimetric, EPA 310.2
Hardness	mg/L as $CaCO_3$	1	Calculated, USGS I-1340-85
Specific conductance	$\mu S/cm^2$	1	Electrometric, field
Total dissolved solids	mg/L	10	Gravimetric, USGS I-1750-85
Silica	mg/L	0.05	ICP, EPA 200.7
Calcium	mg/L	0.01	ICP, EPA 200.7
Magnesium	mg/L	0.04	ICP, EPA 200.7
Sodium	mg/L	0.05	ICP, EPA 200.7
Potassium	mg/L	0.5	ICP, EPA 200.7
Sulfate	mg/L	0.06	Ion chromatography, EPA 300.0
Chloride	mg/L	0.05	Ion chromatography, EPA 300.0
Fluoride	mg/L	0.02	Ion chromatography, USGS I-2057-85
Bicarbonate	mg/L	1	Calculated, APHA 4500-CO2 D
Carbonate	mg/L	1	Calculated, APHA 4500-CO2 D
Ammonia as N	mg/L	0.02	Colorimetric, USGS I-2522-85
Total Kjeldahl nitrogen	mg/L	0.1	Colorimetric, EPA 351.2
Nitrite as N	mg/L	0.01	Ion chromatography, EPA 300.0
Nitrite as NO_2	mg/L	0.03	Ion chromatography, EPA 300.0
Nitrate as N	mg/L	0.020	Ion chromatography, EPA 300.0
Nitrate as NO_3	mg/L	0.09	Ion chromatography, EPA 300.0
Total nitrate-nitrite as N	mg/L	0.020	Ion chromatography, EPA 300.0
Total nitrate-nitrite as NO_3	mg/L	0.09	Ion chromatography, EPA 300.0
Total phosphorus as P	mg/L	0.020	Colorimetric, EPA 365.1
Orthophosphate as PO_4	mg/L	0.02	Ion chromatography, EPA 300.0
Chlorophyll *a*	mg/L	0.0002	Spectrophotometric, APHA 10200 H
Total suspended solids	mg/L	4	Gravimetric, USGS I-3765-85
Turbidity	NTU	1	Turbidometric, USGS I-380-85
Aluminum	$\mu g/L$	60	ICP, EPA 200.7
Antimony	$\mu g/L$	3.0	Graphite-furnace atomic absorption, EPA 200.9
Arsenic	$\mu g/L$	2	Graphite-furnace atomic absorption, EPA 200.9
Barium	$\mu g/L$	2.0	ICP, EPA 200.7
Beryllium	$\mu g/L$	1	ICP, EPA 200.7
Boron	$\mu g/L$	10	ICP, EPA 200.7
Bromide	mg/L	0.05	Ion chromatography, EPA 300.0
Cadmium	$\mu g/L$	4.0	ICP, EPA 200.7
Chromium	$\mu g/L$	8	ICP, EPA 200.7
Cobalt	$\mu g/L$	7	ICP, EPA 200.7
Copper	$\mu g/L$	8	ICP, EPA 200.7
Iron	$\mu g/L$	3	ICP, EPA 200.7
Lithium	$\mu g/L$	5	ICP, EPA 200.7
Manganese	$\mu g/L$	2	ICP, EPA 200.7
Mercury	$\mu g/L$	0.06	Cold vapor atomic absorption, USGS I-2462-85
Molybdenum	$\mu g/L$	20	ICP, EPA 200.7
Nickel	$\mu g/L$	10	ICP, EPA 200.7

Table 3. Water and sediment parameters, lower limit of detection, and analytical methods.

Parameter	Units	Lower limit of detection	Method
Lead	μg/L	2	Graphite-furnace atomic absorption, EPA 200.9
Selenium	μg/L	3.0	Graphite-furnace atomic absorption, EPA 200.9
Silver	μg/L	10	ICP, EPA 200.7 (GF, EPA 200.9)
Strontium	μg/L	1.0	ICP, EPA 200.7
Thallium	μg/L	2	Graphite-furnace atomic absorption, EPA 200.9
Tin	μg/L	1.0	Graphite-furnace atomic absorption, EPA 200.9
Titanium	μg/L	4.0	ICP, EPA 200.7
Vanadium	μg/L	4.0	ICP, EPA 200.7
Zinc	μg/L	4.0	ICP, EPA 200.7
Cyanide, total recoverable	μg/L	0.003	Colorimetric, USGS I-4302-85
Anionic surfactants as MBAS	mg/L	0.025	Colorimetric, APHA 5540 C
Oil and Grease	mg/L	0.1	Spectrophotometric, Infrared, EPA 413.2
Hydrocarbons	mg/L	0.1	Spectrophotometric, Infrared, EPA 418.1
Chemical oxygen demand	mg/L	30	Colorimetric, EPA 410.4
2,4-D	mg/L	0.7	Immunoassay, EPA 4015
Recoverable phenolics	μg/L	3.0	Colorimetric, EPA 420.2
Total organic carbon	mg/L	0.40	Combustion, EPA 415.1
Atrazine	μg/L	0.7	Gas chromotography with TSD, EPA 507, 508
Simazine	μg/L	3	Gas chromotography with TSD, EPA 507, 508
Metolachlor	μg/L	0.5	Gas chromotography with ECD, EPA 507, 508
Tebuthiron	μg/L	0.82	Gas chromotography with TSD, EPA 507, 508
Prometon	μg/L	0.8	Gas chromotography with TSD, EPA 507, 508
Chlorpyrifos	μg/L	0.05	Gas chromotography with ECD, EPA 507, 508
Cyanazine	μg/L	0.82	Gas chromotography with TSD, EPA 507, 508
Lindane	μg/L	0.020	Gas chromotography with ECD, EPA 507, 508
alpha-BHC	μg/L	0.010	Gas chromotography with ECD, EPA 507, 508
Dieldrin	μg/L	0.06	Gas chromotography with ECD, EPA 507, 508
Chlorothalonil	μg/L	0.020	Gas chromotography with ECD, EPA 507, 508
DDE	μg/L	0.040	Gas chromotography with ECD, EPA 507, 508
DDT	μg/L	4.0	Gas chromotography with ECD, EPA 507, 508
Endosulfan	μg/L	0.06	Gas chromotography with ECD, EPA 507, 508
PCB	μg/L	0.82	Gas chromotography with ECD, EPA 507, 508
Alachlor	μg/L	0.08	Gas chromotography with ECD, EPA 507, 508
Aldicarb	μg/L	25	HPLC Fluorescence, EPA 531.1
Fluometuron	μg/L	1.6	Gas chromotography with TSD, EPA 507, 508
Diazinon	μg/L	0.8	TSD, FPD, EPA 507, 508
Carbaryl	μg/L	0.25	HPLC Fluorescence, EPA 531.1
Metalaxyl	μg/L	0.8	Gas chromotography with TSD, EPA 507, 508
Malathion	μg/L	0.8	TSD, FPD, EPA 507, 508
Carbofuran	μg/L	0.25	HPLC Fluorescence, EPA 531.1
Methomyl	μg/L	25	HPLC Fluorescence, EPA 531.1

Table 3. Water and sediment parameters, lower limit of detection, and analytical methods.

Parameter	Units	Lower limit of detection	Method
Temperature	°C	--	Electrometric, field
Dissolved oxygen	mg/L	0.1	Electrometric, field
BOD 5-day	mg/L	0.1	Incubation, electrometric, EPA 405.1
Total residual chlorine	mg/L	0.02	Colorimetric, APHA 4500-Cl G
pH	units	--	Electrometric, field
Carbon dioxide-free	mg/L	1	Calculated, APHA 4500-CO2 D
Alkalinity	mg/L as $CaCO_3$	3	Colorimetric, EPA 310.2
Hardness	mg/L as $CaCO_3$	1	Calculated, USGS I-1340-85
Specific conductance	μS/cm²	1	Electrometric, field
Total dissolved solids	mg/L	10	Gravimetric, USGS I-1750-85
Silica	mg/L	0.05	ICP, EPA 200.7
Calcium	mg/L	0.01	ICP, EPA 200.7
Magnesium	mg/L	0.04	ICP, EPA 200.7
Sodium	mg/L	0.05	ICP, EPA 200.7
Potassium	mg/L	0.5	ICP, EPA 200.7
Sulfate	mg/L	0.06	Ion chromatography, EPA 300.0
Chloride	mg/L	0.05	Ion chromatography, EPA 300.0
Fluoride	mg/L	0.02	Ion chromatography, USGS I-2057-85
Bicarbonate	mg/L	1	Calculated, APHA 4500-CO2 D
Carbonate	mg/L	1	Calculated, APHA 4500-CO2 D
Ammonia as N	mg/L	0.02	Colorimetric, USGS I-2522-85
Total Kjeldahl nitrogen	mg/L	0.1	Colorimetric, EPA 351.2
Nitrite as N	mg/L	0.01	Ion chromatography, EPA 300.0
Nitrite as NO_2	mg/L	0.03	Ion chromatography, EPA 300.0
Nitrate as N	mg/L	0.020	Ion chromatography, EPA 300.0
Nitrate as NO_3	mg/L	0.09	Ion chromatography, EPA 300.0
Total nitrate-nitrite as N	mg/L	0.020	Ion chromatography, EPA 300.0
Total nitrate-nitrite as NO_3	mg/L	0.09	Ion chromatography, EPA 300.0
Total phosphorus as P	mg/L	0.020	Colorimetric, EPA 365.1
Orthophosphate as PO_4	mg/L	0.02	Ion chromatography, EPA 300.0
Chlorophyll *a*	mg/L	0.0002	Spectrophotometric, APHA 10200 H
Total suspended solids	mg/L	4	Gravimetric, USGS I-3765-85
Turbidity	NTU	1	Turbidometric, USGS I-380-85
Aluminum	μg/L	60	ICP, EPA 200.7
Antimony	μg/L	3.0	Graphite-furnace atomic absorption, EPA 200.9
Arsenic	μg/L	2	Graphite-furnace atomic absorption, EPA 200.9
Barium	μg/L	2.0	ICP, EPA 200.7
Beryllium	μg/L	1	ICP, EPA 200.7
Boron	μg/L	10	ICP, EPA 200.7
Bromide	mg/L	0.05	Ion chromatography, EPA 300.0
Cadmium	μg/L	4.0	ICP, EPA 200.7
Chromium	μg/L	8	ICP, EPA 200.7
Cobalt	μg/L	7	ICP, EPA 200.7
Copper	μg/L	8	ICP, EPA 200.7
Iron	μg/L	3	ICP, EPA 200.7
Lithium	μg/L	5	ICP, EPA 200.7
Manganese	μg/L	2	ICP, EPA 200.7
Mercury	μg/L	0.06	Cold vapor atomic absorption, USGS I-2462-85
Molybdenum	μg/L	20	ICP, EPA 200.7
Nickel	μg/L	10	ICP, EPA 200.7

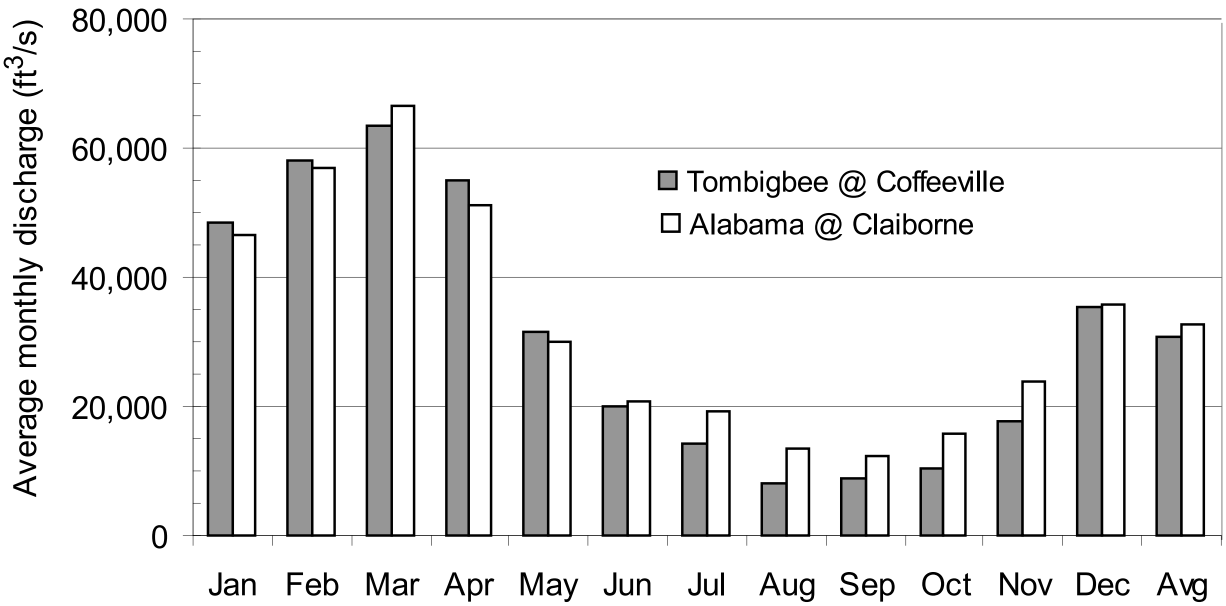
concentrations. Analyses for pesticide and herbicide analytes (table 3) were conducted by the Pesticide Laboratory of the Alabama Department of Agriculture and Industries in Auburn.

RESULTS AND DISCUSSION

Measuring river flows through the Mobile-Tensaw River Delta is complex because of the braided nature of channels in the region. The USGS, along with the U.S. Army Corps of Engineers (COE), maintains flow records for the Alabama River at Claiborne Lock and Dam (USGS station 02428400) and for the Tombigbee River at Coffeeville Lock and Dam (USGS station 02469761). Discharge for sites 1 and 2 was estimated with flow records taken at these USGS stations. The USGS also maintains 2 gaging stations in the delta proper: the Mobile River at River Mile 31 at Bucks (USGS station 02470630) and the Tensaw River near Mount Vernon (USGS station 02471019). Discharge for site 5 was taken from the Mobile River station. Discharge for site 3 (Cedar Creek) was estimated from continuous flow records taken from USGS station 02471001, Chickasaw Creek near Kushla. Flows could not be determined for site 4 (Tensaw Lake), site 6 (Middle River), or site 7 (Tensaw River). Although flow data are available for the Tensaw River, the station is located upstream of the Middle River-Tensaw River fork and flow could not be proportioned accurately for these two sites.

Flows from the Tombigbee and Alabama Rivers are usually highest during the month of March and lowest during August and September (fig. 3). Average annual discharge for water years 1976-2005 was 30,779 ft^3/s for the Tombigbee at Coffeeville and 32,536 ft^3/s for the Alabama at Claiborne (fig. 3). Flows from these two rivers were combined to estimate the total amount of stream flow entering the Mobile-Tensaw River Delta. Average annual discharge entering the delta for the period 1976-2005 was 63,315 ft^3/s ranging from an annual average low of 25,360 ft^3/s in 1988 to a high of 102,530 ft^3/s in 1983 (fig. 3).

Discharge data taken from the Mobile and Tensaw River USGS gaging sites were combined to create a hydrograph to represent river discharge during the time of sample collection (fig. 4). Water-quality samples collected from the main river channels were distributed over a variety of flow regimes with two sampling periods during low



Average annual discharge (ft^3/s)	Alabama R. 02428400	Tombigbee R. 02469761	Total
Average	32,536	30,779	63,315
Median	32,285	29,645	62,975
Minimum	13,590	10,740	25,360
Maximum	48,670	57,420	102,530

Figure 3. Average monthly and annual discharge of the Alabama and Tombigbee Rivers, water years 1976-2005.

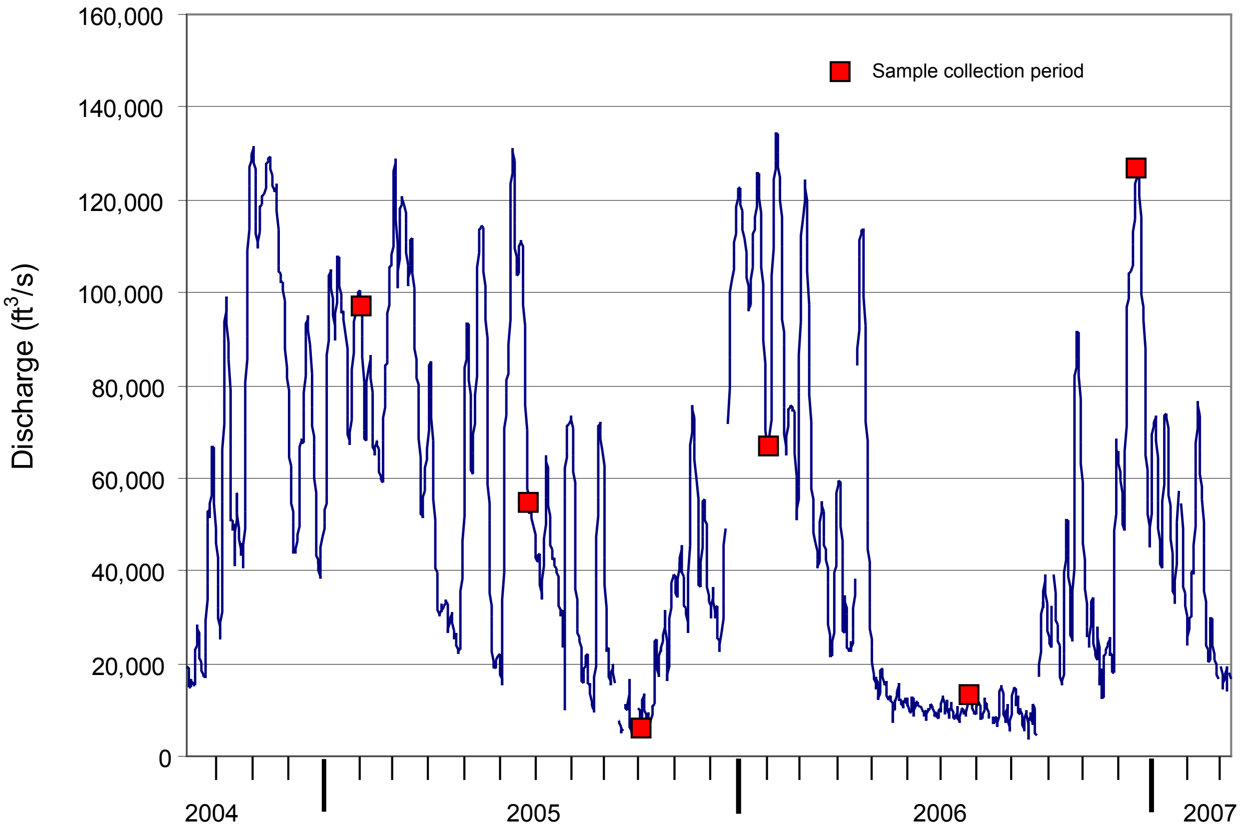


Figure 4. Average daily discharge of the Mobile and Tensaw Rivers, October 2004 through March 2007.

flows (8,000 to 13,100 ft^3/s), two sampling periods during intermediate flows (53,400 to 72,800 ft^3/s), and two sampling periods during high flows (96,700 to 126,800 ft^3/s) (fig. 4, table 2).

Water-quality data were compared to water-use classification criteria applicable to streams in the Mobile-Tensaw River Delta: Fish and Wildlife, Swimming and other Whole-Body Water Contact Sports, and Outstanding Alabama Water. Temperature either equaled or exceeded the 30°C criterion at five sites (fig. 5, table 4). Temperature for the August 2006 samples measured 35°C at site 5, Mobile River, and 32°C at site 7, Tensaw River. The pH for most samples was between 6.0 and 7.5. One sample from site 2, Alabama River, measured 5.6 and two samples from site 3, Cedar Creek, were less than 5.0 (4.6 and 4.9). Cedar Creek is one of many blackwater streams draining sandy pine lands in north Mobile and Baldwin Counties. Blackwater streams are known to be acidic (low pH), usually have high organic content, are poorly buffered, and have very low dissolved solids content. Dissolved oxygen was below the 5.0 mg/L criterion at five sites during the July 2005 sample period (fig. 5, table 4). Turbidity and total suspended solids were high during flood flow periods at the main channel sites, while the two off-channel sites, Cedar Creek (site 3) and Tensaw Lake (site 4), had lower turbidity through the study period (fig. 6, table 4). The Tombigbee and Alabama Rivers generally provided turbid water to the delta during flood periods. Turbidity remained high in the Mobile River (site 5) during these times and was lower in the Middle River (site 6) and still lower in the Tensaw River (site 7) (fig. 6).

Total dissolved solids (TDS) content was within expectation for large rivers (50 to 150 mg/L) at most sites through the study period (fig. 7, table 4). The exception was Cedar Creek (site 3), where TDS ranged from 19 to 59 mg/L. The effects of brackish water movement from Mobile Bay upstream to the delta were observed in elevated measurements of sodium and chloride in samples taken from the Alabama River (site 2), Tensaw Lake (site 4), Mobile River (site 5), Tensaw River (site 7), and to a lesser extent the Middle River (site 6).

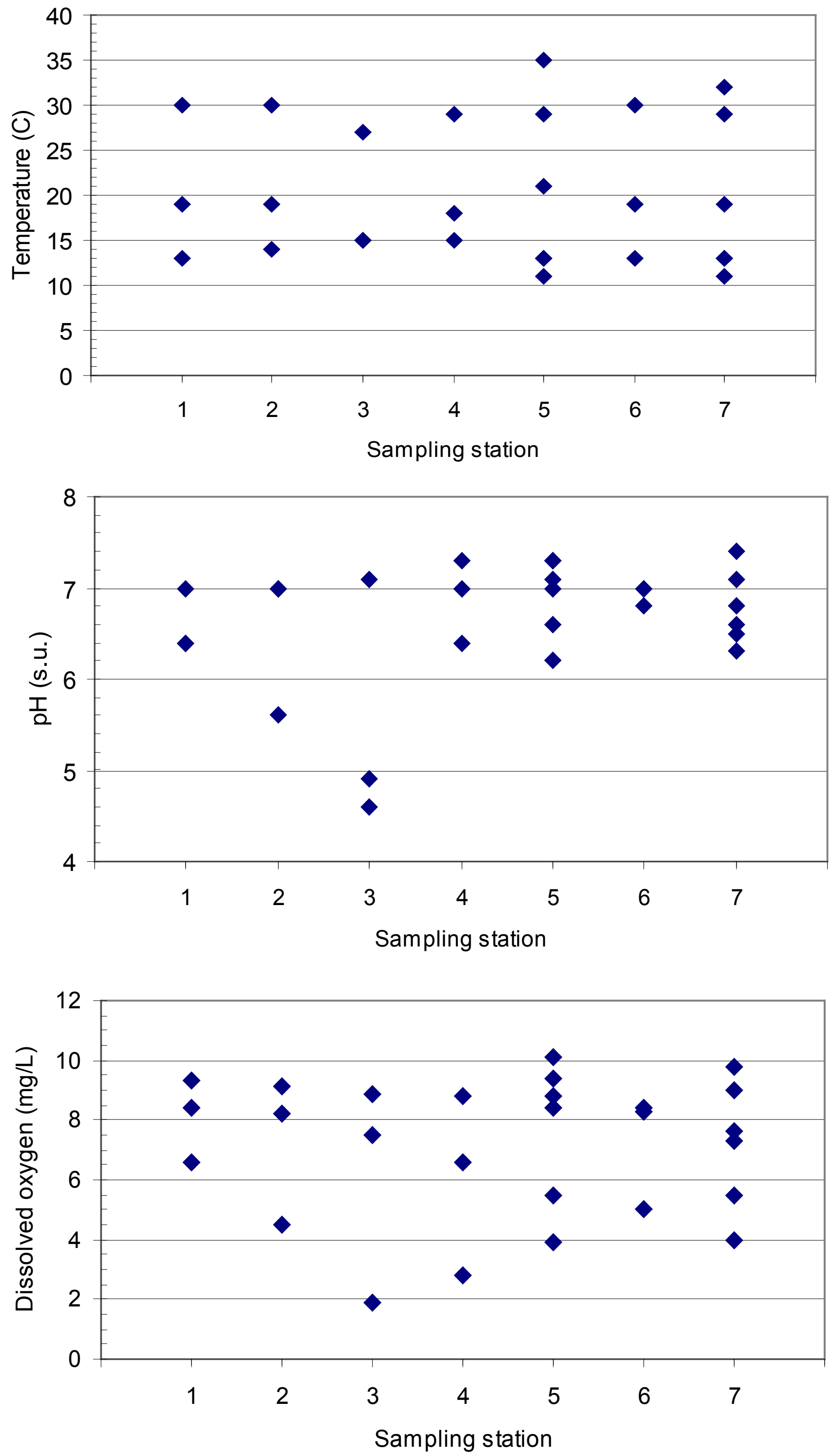


Figure 5. Temperature, pH, and dissolved oxygen content at sites in the Mobile-Tensaw River Delta.

Table 4. Range of water-quality measurements at seven sites in the Mobile-Tensaw River Delta, 2005-07.

Parameter	Units	Sampling site						
		1	2	3	4	5	6	7
Temperature	°C	13 - 30	14 - 30	15 - 27	15 - 29	11 - 35	13 - 30	11 - 32
Dissolved oxygen	mg/L	6.6 - 9.3	4.5 - 9.1	1.9 - 8.9	2.8 - 8.8	3.9 - 10.1	5.0 - 8.4	4.0 - 9.8
DO saturation percent	--	86.5 - 88.8	60.2 - 86.7	23.8 - 86.4	36.7 - 91.1	51.1 - 92.7	66.9 - 87.8	52.4 - 87.3
BOD (5-day)	mg/L	1.4 - 1.7	1.3 - 1.5	0.4 - 0.8	1.3 - 1.4	0.9 - 1.5	1.0 - 1.3	1.0 - 1.7
pH	s.u.	6.4 - 7.0	5.6 - 7.0	4.6 - 7.1	6.4 - 7.3	6.2 - 7.3	6.8 - 7.0	6.3 - 7.4
Carbon dioxide-free	mg/L	7 - 33	6 - 197	362 - 362	2 - 26	4 - 37	7 - 11	6 - 39
Alkalinity as $CaCO_3$	mg/L	32 - 43	33 - 47	7 - 7	25 - 37	30 - 63	35 - 43	35 - 61
Hardness as $CaCO_3$	mg/L	42 - 52	44 - 67	6 - 8	30 - 42	41 - 61	43 - 48	42 - 60
Specific conductance	μS/cm	121 - 165	140 - 287	23 - 37	111 - 160	126 - 307	120 - 196	112 - 276
Total dissolved solids	mg/L	74 - 100	69 - 179	19 - 59	70 - 102	75 - 161	76 - 143	72 - 145
Silica	mg/L	5.71 - 9.94	6.35 - 9.42	6.56 - 9.85	6.96 - 8.70	1.18 - 8.67	6.3 - 8.59	0.362 - 8.41
Calcium	mg/L	12.6 - 15	13.2 - 20.5	1.6 - 1.77	8.16 - 12.9	12.4 - 17.6	13.1 - 14.4	12.7 - 16.8
Magnesium	mg/L	2.58 - 4.37	2.62 - 3.75	0.521 - 0.869	2.25 - 2.62	2.49 - 4.06	2.47 - 3.05	2.4 - 4.24
Sodium	mg/L	6.04 - 16	7.83 - 29.1	2.40 - 4.02	5.04 - 18	7.28 - 28.4	6.15 - 19	5.20 - 23.8
Potassium	mg/L	1.18 - 2.1	1.50 - 2.92	0 - 0	1.36 - 1.57	1.11 - 2.48	1.34 - 2.20	1.15 - 2.21
Sulfate	mg/L	7.84 - 20.1	13.2 - 35.6	1.54 - 5.51	5.87 - 14.5	12.2 - 31.4	9.51 - 20	7.18 - 28.4
Chloride	mg/L	4.41 - 9.73	7.23 - 27.9	3.84 - 5.79	4.32 - 25.1	6.22 - 26.5	4.91 - 13.3	4.46 - 20.2
Bicarbonate	mg/L	39 - 52	40 - 57	9 - 9	30 - 45	37 - 77	43 - 52	43 - 74
Carbonate	mg/L	0 - 0	0 - 0	0 - 0	0 - 0	0 - 0	0 - 0	0 - 0
Ammonia as N	mg/L	.043 - .059	.028 - .053	.032 - .081	.022 - .039	.031 - .095	.033 - .072	.029 - .179
Total Kjeldahl nitrogen	mg/L	.23 - 1.23	.61 - 1.08	.20 - .55	.30 - .86	.25 - 1.14	.45 - .91	.23 - .89
Total nitrate-nitrite as N	mg/L	.083 - .317	.11 - .322	.041 - .118	.041 - .106	.057 - .44	.083 - .26	.075 - .262
Total phosphorus as P	mg/L	.023 - .087	.043 - .082	.024 - .061	.021 - .082	.031 - .084	.033 - .085	.026 - .075
Orthophosphate as PO_4	mg/L	0 - 0	0 - 0	0 - 0	0 - 0	0 - 0	0 - 0	0 - 0
Chlorophyll a	mg/L	.0008 - .0111	.006 - .0117	.0011 - .0011	.0028 - .0099	.002 - .0095	.0058 - .0069	.0032 - .0136
Carlson's TSI	mg/L	28 - 54	48 - 55	32 - 32	41 - 53	37 - 53	48 - 50	42 - 56
Total suspended solids	mg/L	14 - 104	28 - 54	5 - 12	8 - 20	14 - 102	13 - 70	13 - 46
Turbidity	NTU	21 - 130	54 - 113	5 - 33	13 - 29	22 - 110	35 - 100	11 - 55

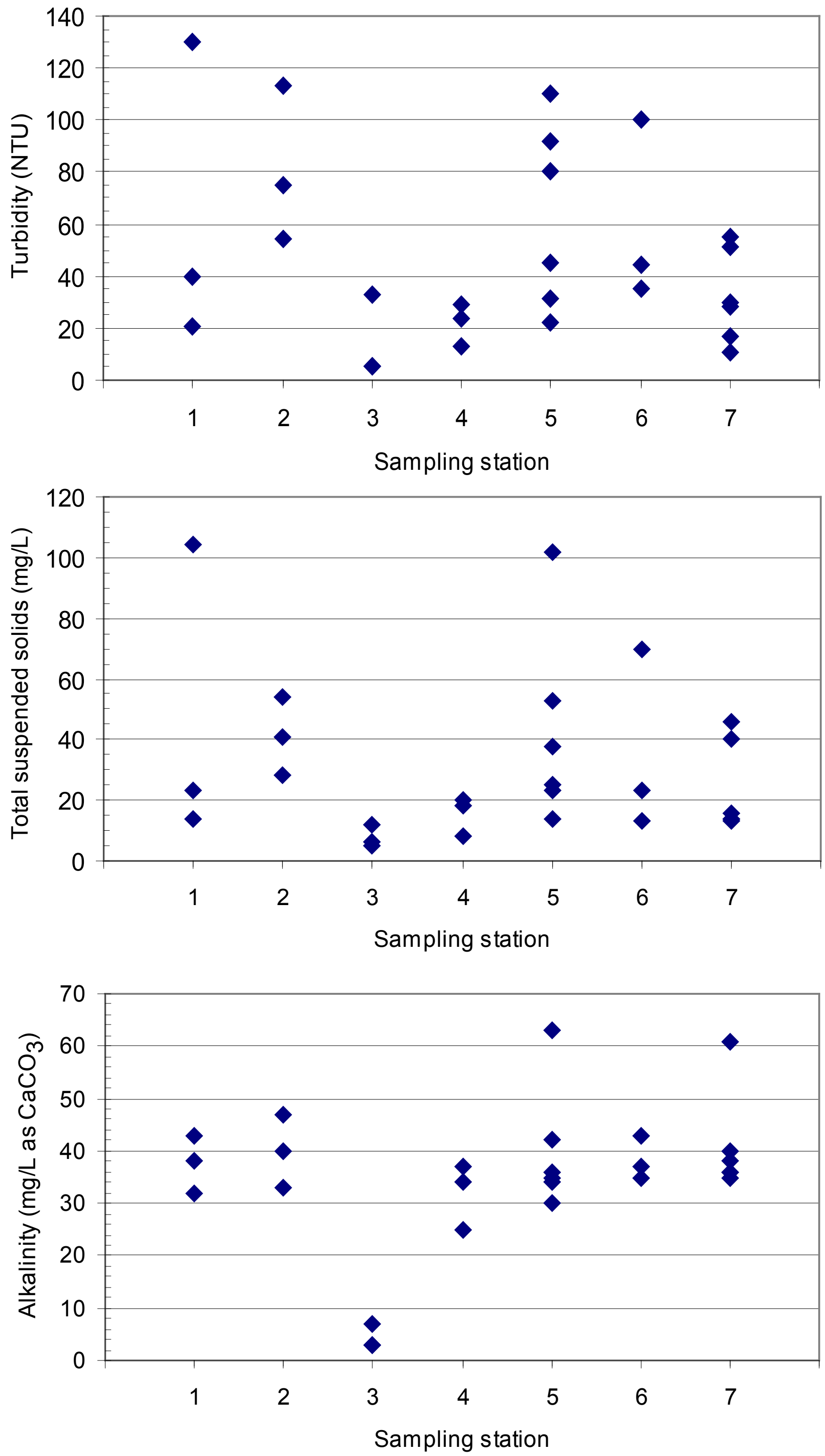


Figure 6. Turbidity, total suspended solids, and alkalinity at sites in the Mobile-Tensaw River Delta.

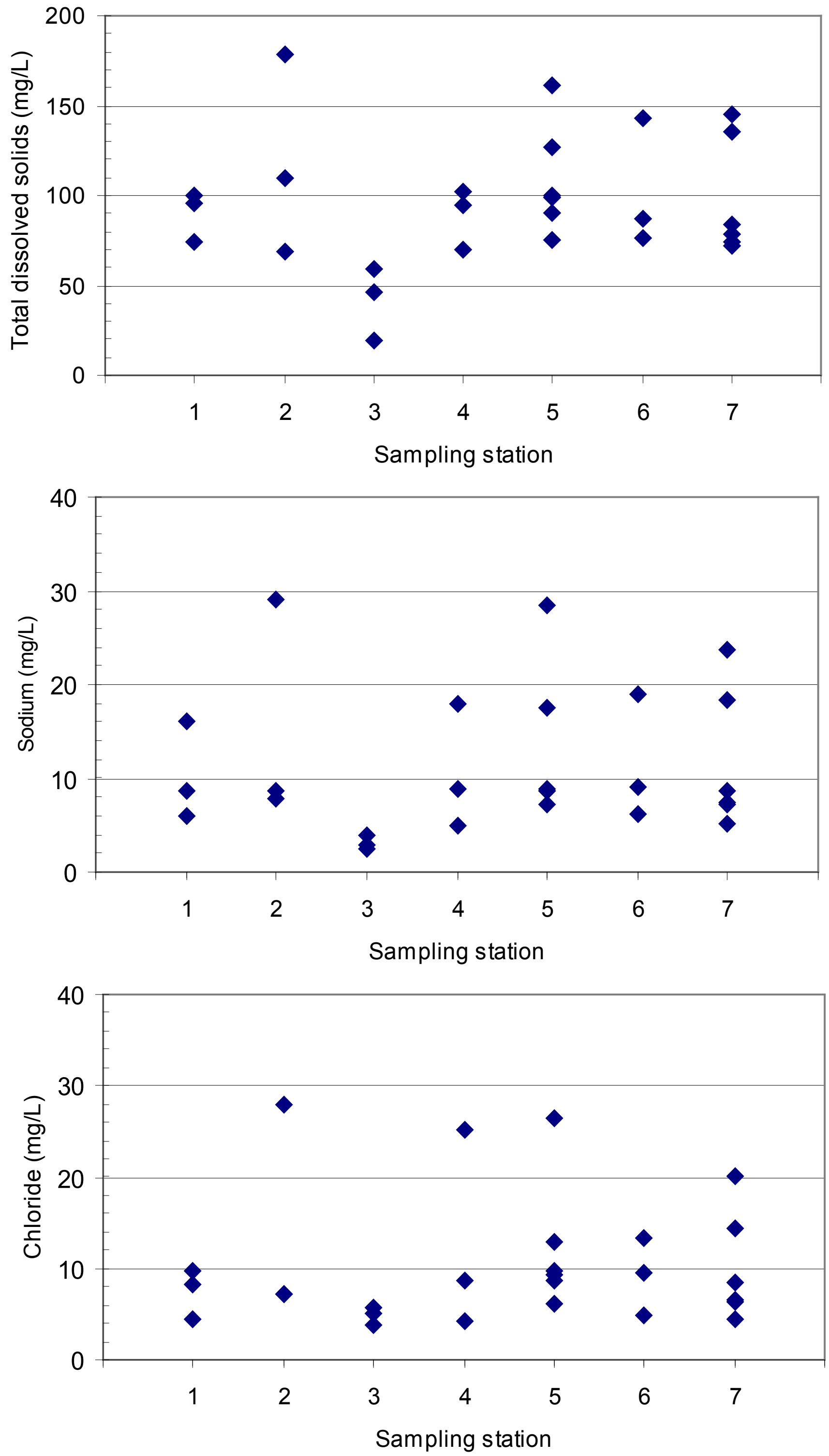


Figure 7. Total dissolved solids, sodium, and chloride content at sites in the Mobile-Tensaw River Delta.

Nitrogen was higher in the Tombigbee (site 1), Alabama (site 2), and Mobile Rivers (site 5) compared to the Tensaw (site 7) and Middle (site 6) Rivers (fig. 8, table 4) and decreased progressively to the east from the Mobile to the Tensaw River; a similar pattern was observed for turbidity. Phosphorus content was not particularly elevated at any one site (fig. 9), but there was sufficient quantity for phytoplankton to bloom in the summer months. Conversion of chlorophyll-*a* concentrations to the Carlson Trophic Status Index (TSI) (Carlson, 1977) revealed that the main river channels (sites 1, 2, 5, 6, and 7) and Tensaw Lake (site 4) had sufficient phytoplankton density to result in mesotrophic to eutrophic conditions at times (fig. 9, table 4). Samples from Cedar Creek (site 3) indicated low algae densities with resulting oligotrophic conditions.

Plots of selected metal concentrations among sites (figs. 10, 11) show that all sites were relatively similar with respect to concentrations of these metals with the exception of Cedar Creek, which had distinctly elevated zinc and low strontium compared to the other sites. Manganese was somewhat elevated in samples from the Alabama River and Tensaw Lake. Concentrations of other selected trace metals and toxic trace metals (table 5) exceeded detection limits 28 times during the study. Site 5, Mobile River, had the highest number of detections with 8 followed by sites 4 and 7, Tensaw Lake and Tensaw River, respectively, each with 5 detections, and by site 6, Middle River, with 4 detections. Titanium was the trace metal most frequently detected with 8, followed by arsenic with 6, nickel with 5, antimony with 4, and lead with 3. Titanium ranged from 4.7 to 10.9 μg/L, arsenic from 2.8 to 4.2 μg/L, nickel from 12 to 21 μg/L, antimony from 3.0 to 3.8 μg/L, and lead from 2.2 to 5.9 μg/L (appendix A). The toxic trace metals cadmium, chromium, copper, mercury, molybdenum, selenium, silver, and vanadium were not detected in the water column samples (table 5). The 25 pesticide and herbicide analytes examined by the Agriculture and Industries Laboratory were all below detection limits in the water column samples analyzed during this study (appendix A).

Sediment samples were collected once from each site during November 2005 and analyzed for physical, inorganic, and organic characteristics and selected pesticide and herbicide analytes (appendix B). Sites 3 and 4, Cedar Creek and Tensaw

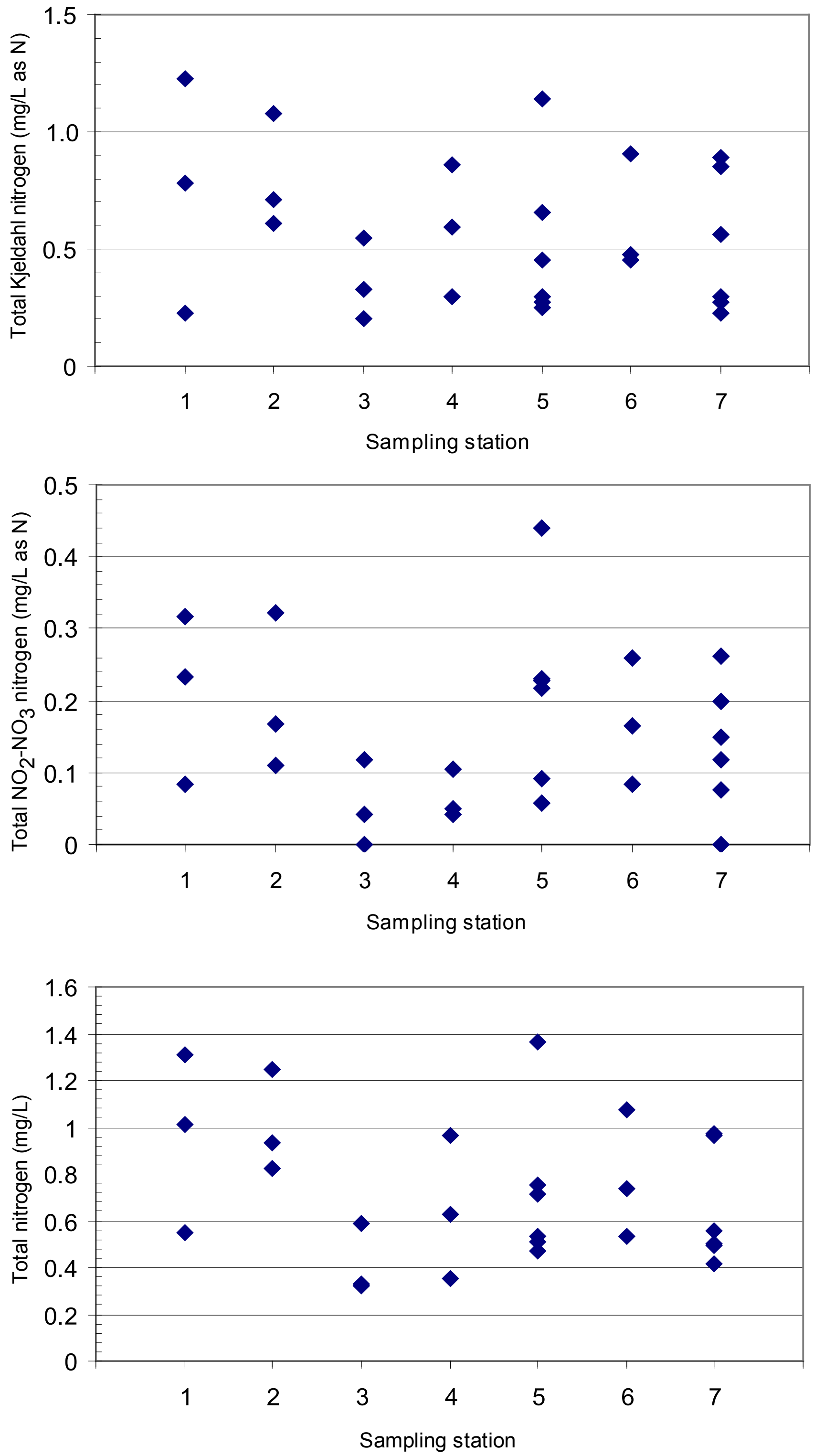


Figure 8. Total Kjeldahl nitrogen, total NOx nitrogen, and total nitrogen content at sites in the Mobile-Tensaw River Delta.

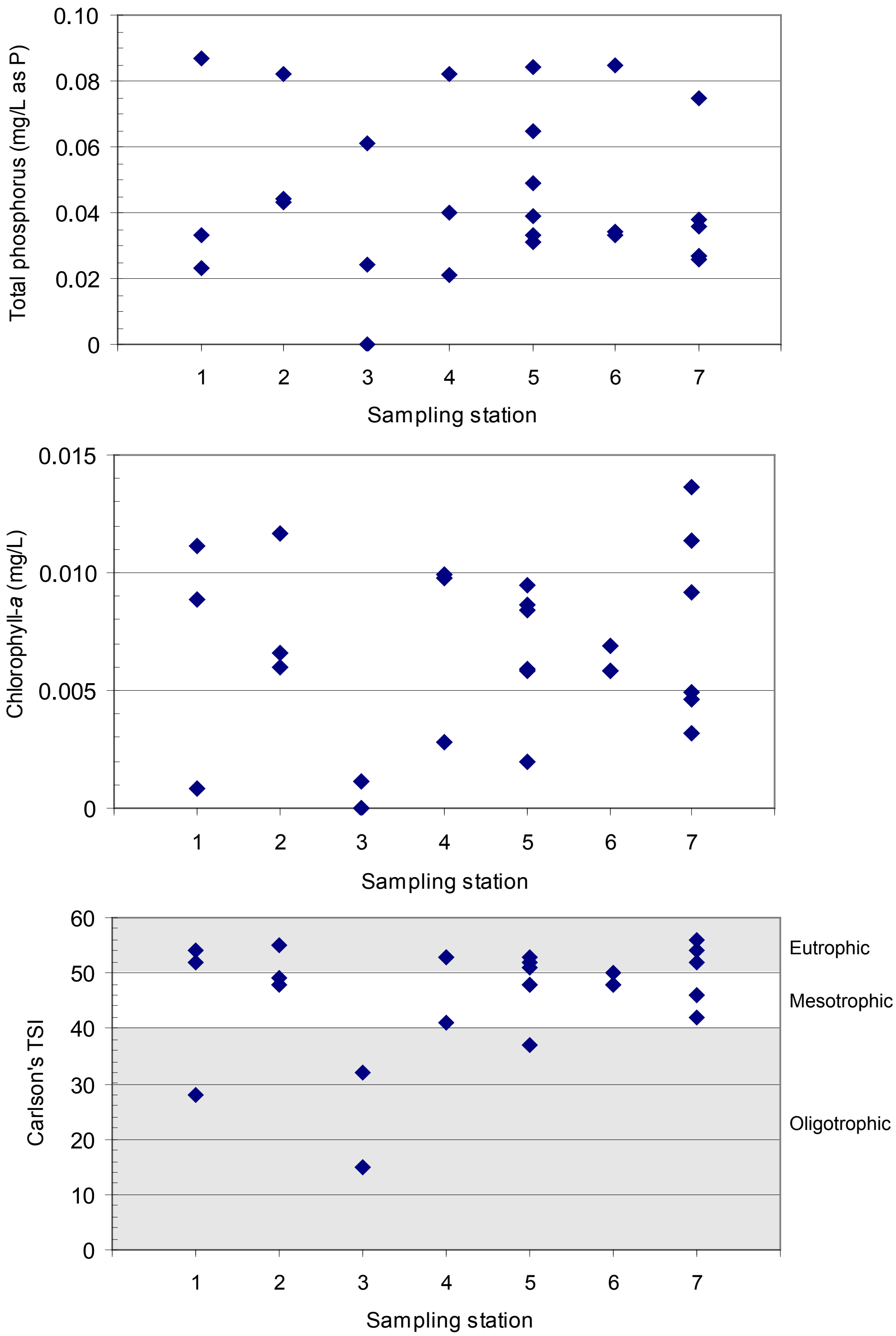


Figure 9. Total phosphorus, chlorophyll-*a* content, and Carlson's TSI at sites in the Mobile-Tensaw River Delta.

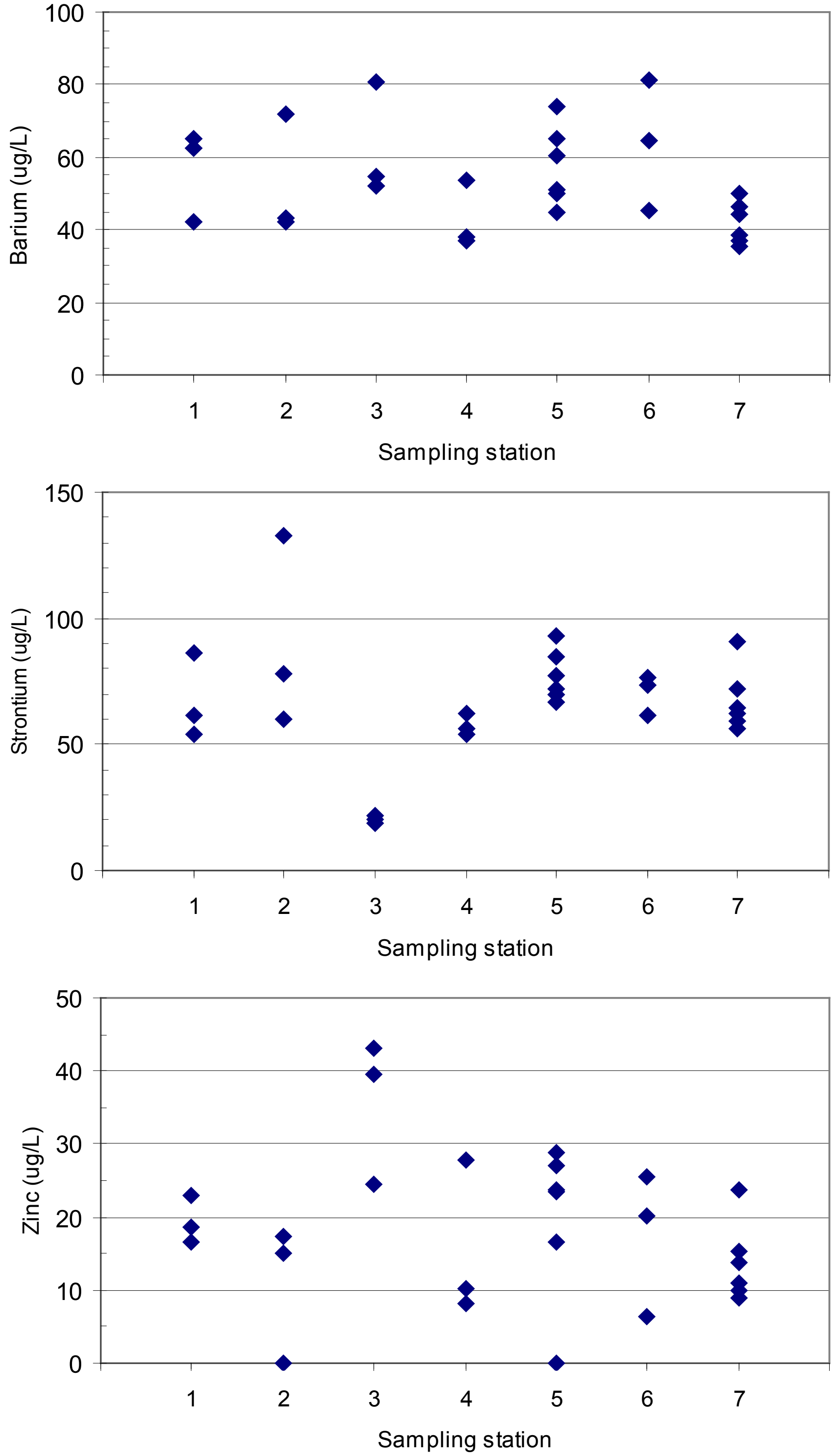


Figure 10. Barium, strontium, and zinc content at sites in the Mobile-Tensaw River Delta.

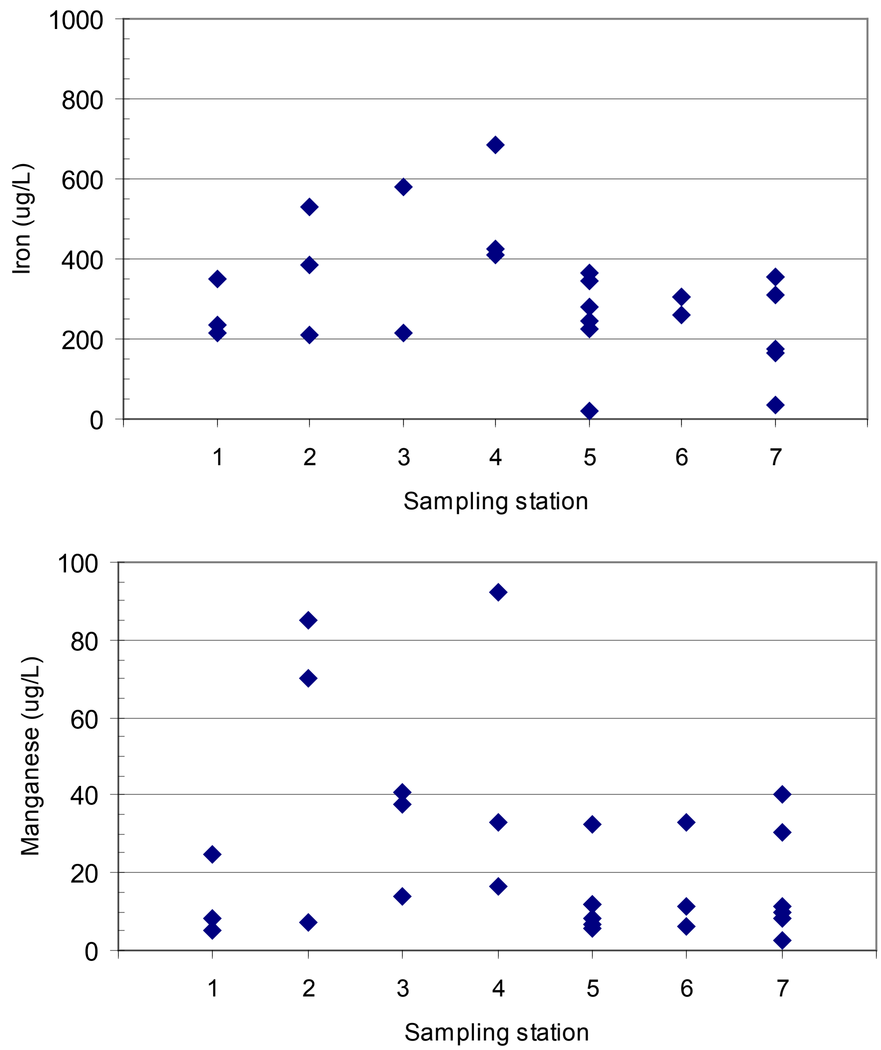


Figure 11. Iron and manganese content at sites
in the Mobile-Tensaw River Delta.

Table 5. Trace metal detections in water column samples from seven sites in the Mobile-Tensaw River Delta, 2005-07.

Trace metal	Sampling sites							
	1	2	3	4	5	6	7	Total
	Number of detections							
Antimony	0	0	1	2	0	1	0	4
Arsenic	0	0	1	1	2	1	1	6
Beryllium	0	0	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0
Chromium	0	0	0	0	0	0	0	0
Cobalt	0	0	0	0	0	0	0	0
Copper	0	0	0	0	0	0	0	0
Lithium	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0
Molybdenum	0	0	0	0	0	0	0	0
Nickel	1	0	0	0	2	1	1	5
Lead	0	0	0	0	2	0	1	3
Selenium	0	0	0	0	0	0	0	0
Silver	0	0	0	0	0	0	0	0
Thallium	0	0	0	1	0	0	0	1
Tin	0	0	0	0	0	0	1	1
Titanium	1	2	0	1	2	1	1	8
Vanadium	0	0	0	0	0	0	0	0
Total detections	2	2	2	5	8	4	5	28

Lake, respectively, had the lowest pH values (5.0 - 5.6), highest TKN-nitrogen (4,010 - 4,760 mg/kg), high cadmium (0.52 - 0.82 mg/kg), highest mercury (0.082 - 0.085 mg/kg), and highest total organic carbon content (33,900 - 37,200 mg/kg) of all sites examined. These results indicate that off-channel lakes and smaller tributary embayments with accumulations of fine sediments, reducing chemical conditions, lower pH, and higher percentages of organic material are likely depositional areas for metal pollutants in the delta system. The only pesticide/herbicide found above detection limit in sediments was 2,4-D at station 3.

Understanding flow patterns in the upper delta, particularly the area around Tensaw Lake and upper Tensaw River, is important because of its high ecological and conservation value for wildlife management and habitat preservation. Assigning specific flow values to ungaged rivers is difficult in the delta because of the braided river channel network, off-channel lakes and bayous, and interconnecting streams. Water typically overflows river channels during flood periods creating a large, flooded palustrine system for extended periods of time.

Until recently, there was only one gaging station in the delta located on the Mobile River at Bucks. The U.S. Geological Survey recently added a gage for the Tensaw River making flow data available near the divergence of the Mobile River into the Mobile and Tensaw Rivers. With this new gaging station, a very general water budget for the upper delta can now be created by examining the input and output of flow relative to river network geography and location of USGS gages. The Tensaw River gage has been in operation for nearly four years, so data for three water years—2003-04, 2004-05, and 2005-06—were used to create the budget. Another important consideration in creating the budget is the excess water that overflows river channels during floods. Flooding is a critical part of the delta hydrological process for it provides water and nutrients to the Tensaw Lake region thereby maintaining its wetland function and supporting biological productivity and diversity. The ability to estimate the amount of flood water entering the Tensaw Lake area would be of great value for managing water, wildlife, and fishery resources in the future.

The volume of flood water that overflows river channels is difficult to determine accurately with the existing gaging network but was estimated by comparing the total water volume entering the delta from the Alabama and Tombigbee Rivers (AT) with the volume of water passing the Mobile and Tensaw River (MT) gages. Approximately 12.3 percent of the total water volume entering the delta over water years 2003-04, 2004-05, and 2005-06 at the Alabama River cutoff was unaccounted for at the MT gages (fig. 12), and was assumed to be flood waters which were unaccounted for at the MT gages. Assuming that average to low river flows move within established main channel routes (fig. 13a), then most of the unaccounted for water must be spilled out of main river channels during flood events. Although water could bypass the MT gages in several places, we think the most likely area is the lower reach of the Alabama River before its junction with the Tombigbee River. The channel geography of the Alabama River from the cutoff to its mouth is highly sinuous with many smaller stream channels intersecting the main Alabama River including Holley Creek, Pine Log Creek, Majors Creek, and Bear Creek. Flood water from the Alabama enters the lower reaches of these creeks and flows south through creek channels and overland to Stiggins Lake, Globe Creek, Big Beaver Creek, Tensaw Lake, and several other smaller off-channel lakes. Water continues flowing south through Tensaw Lake and Briar Lake eventually joining the Tensaw River west of Stockton thereby effectively bypassing the USGS Tensaw River gage (figs. 2, 13b). The unaccounted flow was considered to have originated in the Alabama River and left the channel during flood events traveling through the Tensaw Lake region and bypassing the Mobile-Tensaw gages before reentering the Tensaw River downstream.

The difference in the amount of water in the AT versus the MT was 7.8 percent in year 2003-04, 18.2 percent in year 2004-05, and 6.5 percent in year 2005-06 (fig. 12). The amount of flow entering the Tensaw Lake region was graphically modeled by comparing AT and MT daily flows for each of the three water years (fig. 14). The AT flow exceeded MT flow several times during each water year with the timing and degree of difference between the hydrographs varying from year to year. It appears from figure 14 that there is an upper limit to the amount of discharge that can travel down the MT. This limit was estimated to be around 120,000 to 130,000 ft^3/s based on the height of the peak flow in figure 14. This upper MT flow limit was also evaluated by plotting all of

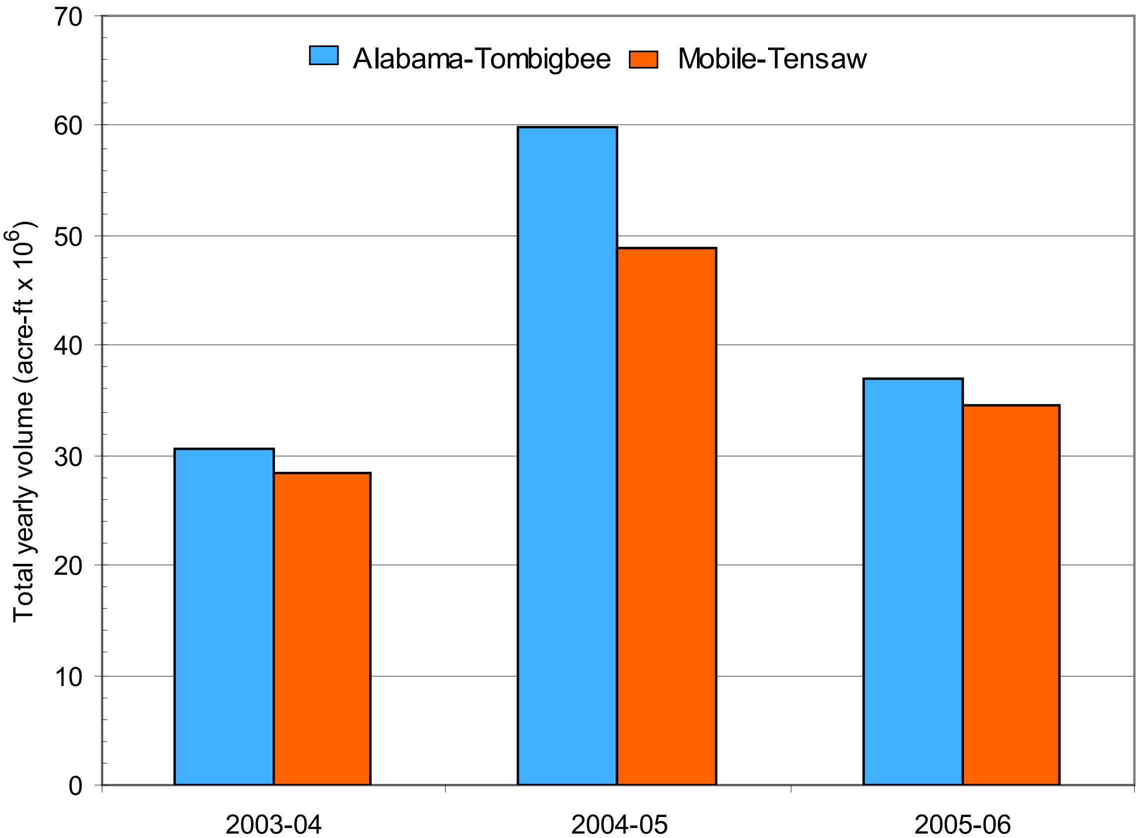


Figure12. Water budget for the upper Mobile-Tensaw River Delta, water years 2003-04, 2004-05, and 2005-06.

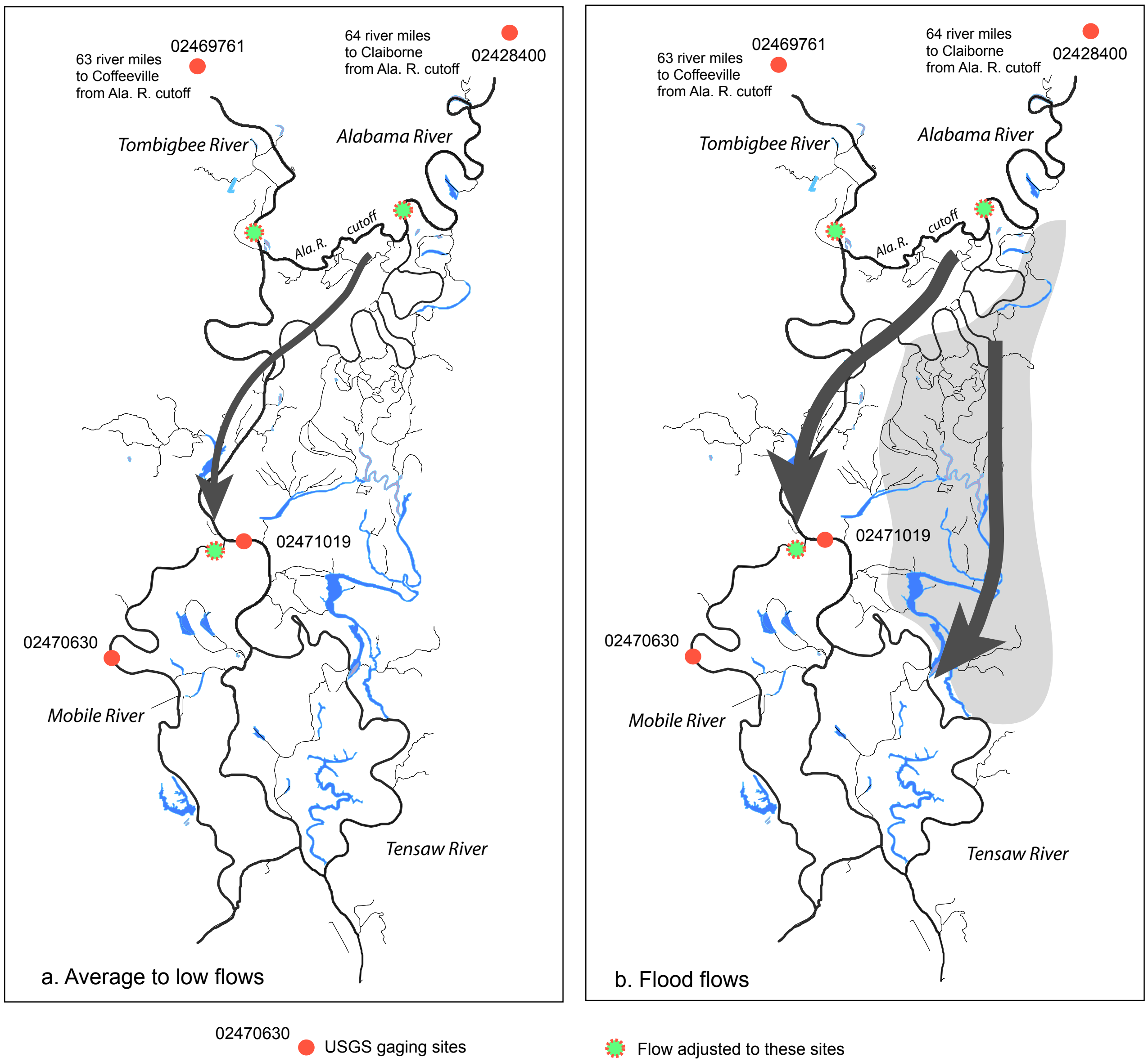


Figure 13. Hypothesized flow patterns in the upper Mobile-Tensaw River Delta.

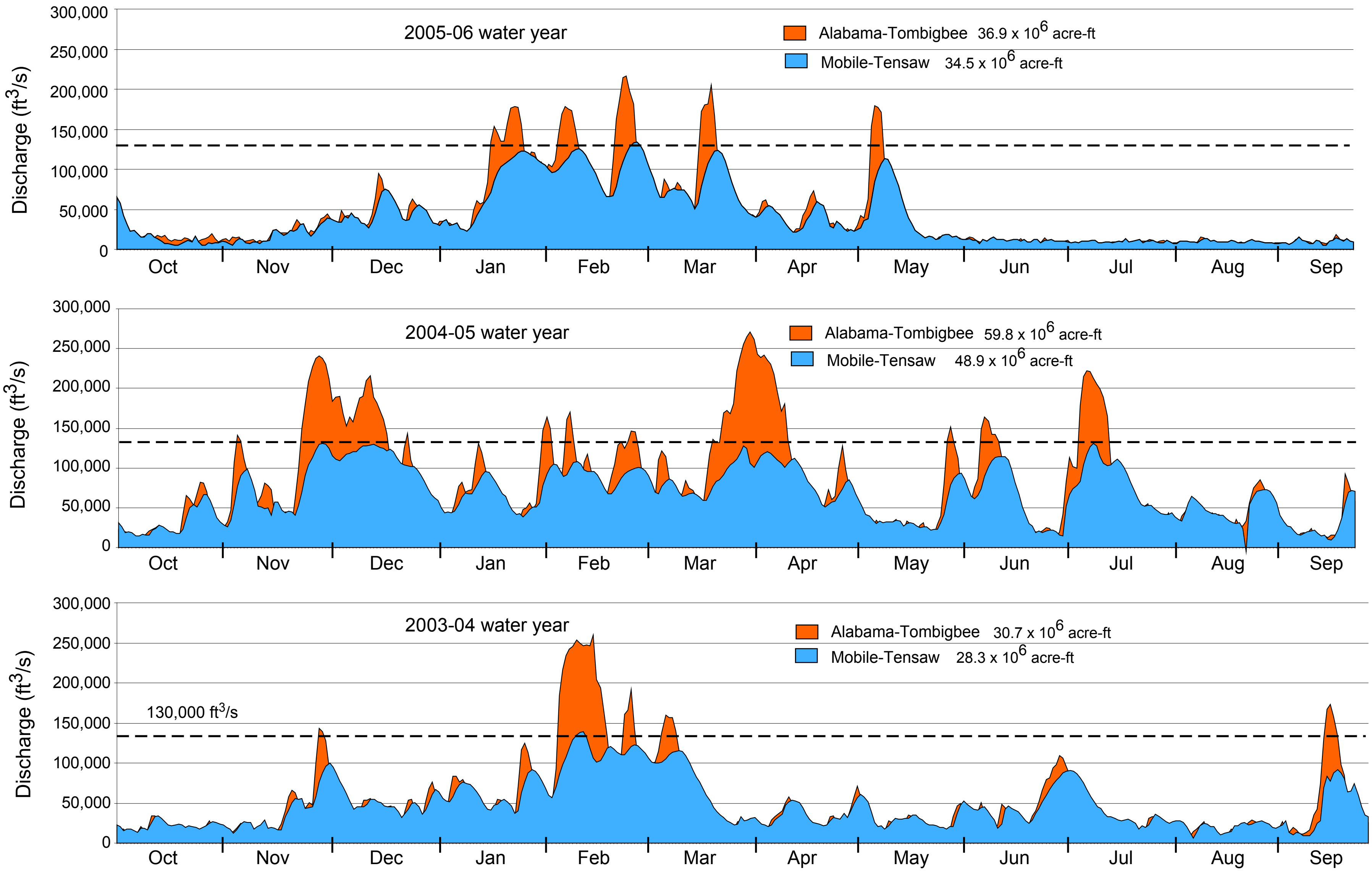


Figure 14. Daily discharge of the Alabama-Tombigbee and Mobile-Tensaw Rivers for water years 2003-04, 2004-05, and 2005-06.

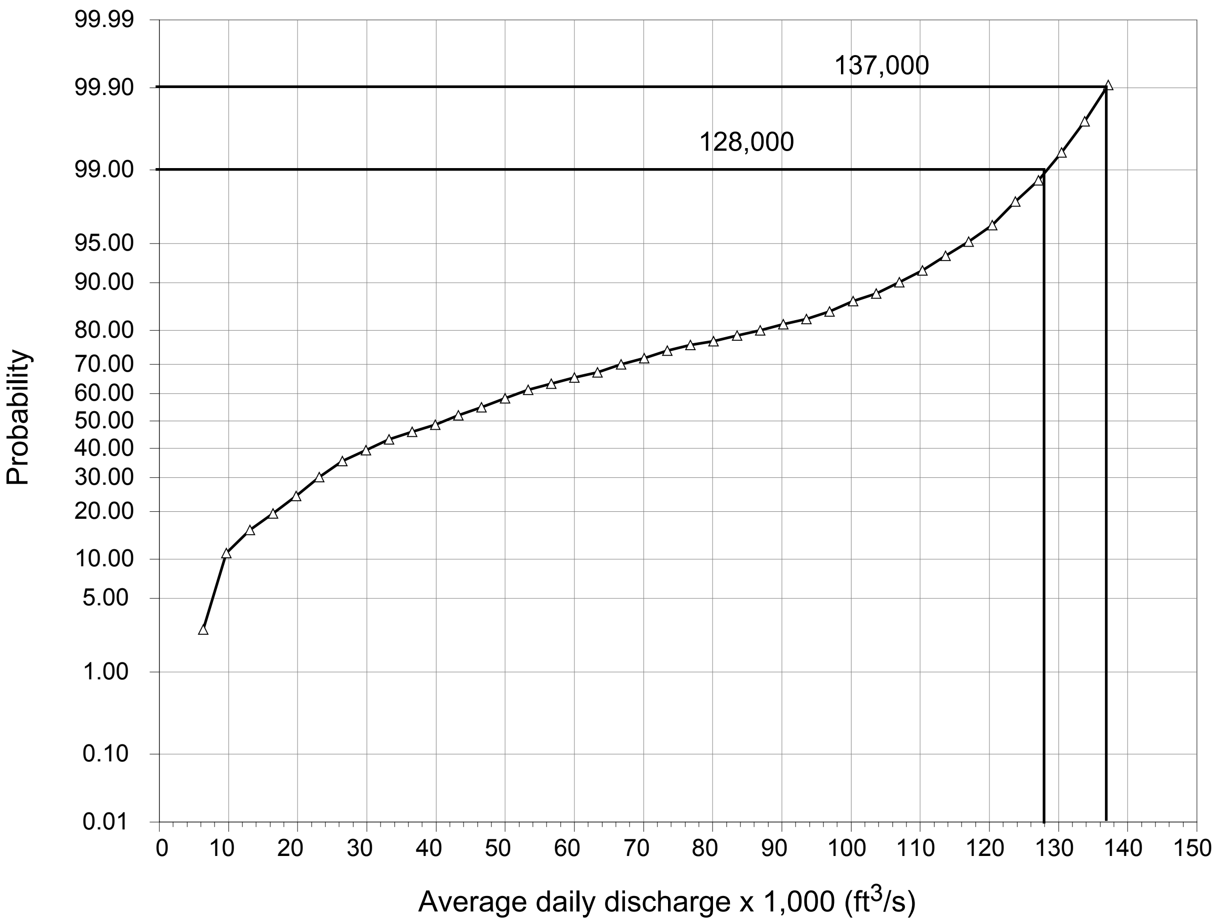


Figure 15. Normal probability plot of average daily discharge of the Mobile and Tensaw Rivers for water years 2003-04, 2004-05, and 2005-06.

the daily flow values for the MT on probability paper (fig. 15). Over the three years of study 99.0 percent of the flows were less than 128,000 ft^3/s, and 99.9 percent of the flows were less than 137,000 ft^3/s (fig. 15). The highest daily flow measured for MT was 138,832 ft^3/s. This unaccounted flood water in AT above 130,000 ft^3/s is what we believe eventually enters the Tensaw Lake region.

Flood waters from the Alabama River are a major source of nutrients to the wetlands of the Tensaw Lake region, and the highly braided and sinuous network of channels and off-channel lakes have a filtering effect on inflow water by reducing turbidity and capturing pollutants. This was confirmed by the water-quality data collected during this study. Turbidity and suspended solids were both lower in Tensaw Lake and the Tensaw River compared to the Mobile, Alabama, Tombigbee, and Middle Rivers (fig. 6). Total nitrogen was lower in Tensaw Lake and Tensaw River samples (fig. 8). In contrast, off-channel lakes and embayments appear to be sinks for metals because of their higher organic content and less opportunity for flushing flows. Likewise, blackwater streams entering the delta also appear to be sinks for metals because of their higher acidity, increased organic content, and less dynamic hydrology.

These data suggest that the Tensaw Lake region functions as a water-quality filter by decreasing turbidity and sediments, and by processing nutrients from Alabama River flood waters entering the system. Productivity was somewhat greater in the Tensaw Lake region probably because of the more lake-like character of the backwaters and bayous during low river flows resulting in greater water residence times. Greater residence times can enhance conditions that result in a higher trophic state. Recent unpublished fish survey work in the upper Mobile-Tensaw River Delta (O’Neil and others, 2005) found that fish populations were generally more abundant and diverse in the Tensaw Lake region compared to the Middle and Mobile River areas and in the lower Tensaw River downstream of the Tensaw Lake mouth. These observations, combined with the water-quality data collected for this study, indicate that the Tensaw Lake region is highly productive of fish and wildlife and is an area of natural water-quality treatment and management, but also may be vulnerable to the accumulation of toxic pollutants because of its backwater character.

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Appendix A

Water-quality data collected at seven sites in the Mobile-Tensaw River Delta, 2003-05.

Parameter	Units	Lower limit of detection	1 - Tombigbee River			2 - Alabama River		
			27-Jul-05	1-Nov-05	8-Jan-07	27-Jul-05	1-Nov-05	8-Jan-07
Discharge (est.) [1]	ft^3/s	--	14,400	4,820	72,200	29,500	7,130	72,300
Sample time	24 hr	--	14:50	11:00	13:10	16:30	13:00	12:00
Temperature	°C	--	30	19	13	30	19	14
Dissolved oxygen	mg/L	--	6.6	8.4	9.3	4.5	8.2	9.1
DO saturation percent	--	--	88.3	88.8	86.5	60.2	86.7	86.5
BOD (5-day)	mg/L	--	<.1	1.4	1.7	<.1	1.3	1.5
Total residual chlorine	mg/L	0.02	<.02	<.02	<.02	<.02	<.02	<.02
pH	s.u.	0.1	7.0	6.4	6.4	7.0	7.0	5.6
Carbon dioxide-free	mg/L	1	7	33	25	6	9	197
Alkalinity as $CaCO_3$	mg/L	3	38	43	32	33	47	40
Hardness as $CaCO_3$	mg/L	1	42	52	49	44	67	50
Specific conductance	$\mu S/cm^2$	1	121	163	165	140	287	153
Total dissolved solids	mg/L	10	96	100	74	110	179	69
Silica	mg/L	0.05	5.71	9.94	7.15	7.22	9.42	6.35
Calcium	mg/L	0.01	12.60	13.50	15.00	13.20	20.50	13.80
Magnesium	mg/L	0.04	2.58	4.37	2.76	2.62	3.68	3.75
Sodium	mg/L	0.05	6.04	16.00	8.63	7.83	29.10	8.60
Potassium	mg/L	0.50	1.18	2.10	1.83	1.53	2.92	1.50
Sulfate	mg/L	0.06	7.84	14.70	20.10	14.90	35.60	13.20
Chloride	mg/L	0.05	4.41	8.19	9.73	7.24	27.90	7.23
Bromide	mg/L	0.05	<.05	<.05	<.05	<.05	<.05	<.05
Fluoride	mg/L	0.02	0.05	0.04	0.07	0.06	0.06	0.05
Bicarbonate	mg/L	1	46	52	39	40	57	49
Carbonate	mg/L	1	<1	<1	<1	<1	<1	<1
Ammonia as N	mg/L	0.02	0.05	0.04	0.06	0.03	0.04	0.05
Total Kjeldahl nitrogen	mg/L	0.10	1.23	0.23	0.78	0.71	0.61	1.08
Nitrite as N	mg/L	0.01	<.01	<.01	<.01	<.01	<.01	<.01
Nitrite as NO_2	mg/L	0.03	<.03	<.03	<.03	<.03	<.03	<.03
Nitrate as N	mg/L	0.02	0.083	0.317	0.233	0.11	0.322	0.167
Nitrate as NO_3	mg/L	0.09	0.37	1.4	1.03	0.49	1.43	0.74
Total nitrate-nitrite as N	mg/L	0.02	0.083	0.317	0.233	0.11	0.322	0.167
Total nitrate-nitrite as NO_3	mg/L	0.09	0.37	1.4	1.03	0.49	1.43	0.74
Total phosphorus as P	mg/L	0.02	0.033	0.023	0.087	0.043	0.044	0.082
Orthophosphate as PO_4	mg/L	0.02	<.02	<.02	<.02	<.02	<.02	<.02
Chlorophyll *a*	mg/L	0.0002	0.0111	0.0089	0.0008	0.0117	0.006	0.0066
Carlson's TSI			54	52	28	55	48	49
Total suspended solids	mg/L	4	23	14	104	28	54	41
Turbidity	NTU	1	40	21	130	54	113	75
Aluminum	µg/L	60	<60	162	152	<60	223	88
Antimony	µg/L	3	<3	<3	<3	<3	<3	<3
Arsenic	µg/L	2	<2	<2	<2	<2	<2	<2
Barium	µg/L	2	65.2	42.2	62.3	42.3	72.0	43.3
Beryllium	µg/L	1	<1	<1	<1	<1	<1	<1
Boron	µg/L	10	13	<10	19	<10	28	15
Cadmium	µg/L	4	<4	<4	<4	<4	<4	<4
Chromium	µg/L	8	<8	<8	<8	<8	<8	<8
Cobalt	µg/L	7	<7	<7	<7	<7	<7	<7
Copper	µg/L	8	<8	<8	<8	<8	<8	<8
Iron	µg/L	3	216	233	348	386	530	212
Lithium	µg/L	5	<5	<5	<5	<5	<5	<5

1 - estimated discharge from USGS gages
2 - n/d-not determined; n/c-not collected

Parameter	Units	Lower limit of detection	1 - Tombigbee River			2 - Alabama River		
			27-Jul-05	1-Nov-05	8-Jan-07	27-Jul-05	1-Nov-05	8-Jan-07
Manganese	μg/L	2	5.1	8	25	70.2	84.8	7
Mercury	μg/L	0.06	<.06	<.06	<.06	<.06	<.06	<.06
Molybdenum	μg/L	20	<20	<20	<20	<20	<20	<20
Nickel	μg/L	10	<10	19	<10	<10	<10	<10
Lead	μg/L	2	<2	<2	<2	<2	<2	<2
Selenium	μg/L	3	<3	<3	<3	<3	<3	<3
Silver	μg/L	10	<10	<10	<10	<10	<10	<10
Strontium	μg/L	1	54.0	61.4	86.2	78.0	133.0	59.9
Thallium	μg/L	2	<2	<2	<2	<2	<2	<2
Tin	μg/L	1	<1	<1	<1	<1	<1	<1
Titanium	μg/L	4	<4	<4	10.7	<4	4.7	6.1
Vanadium	μg/L	4	<4	<4	<4	<4	<4	<4
Zinc	μg/L	4	16.5	18.6	23	<4	17.4	15
Cyanide	μg/L	0.003	<.003	<.003	<.003	<.003	<.003	<.003
Total organic carbon	mg/L	0.4	5.17	2.50	5.34	7.41	3.61	3.97
Recoverable phenolics	μg/L	3	<3	<3	<3	<3	<3	<3
Anionic surfactants	mg/L	0.025	0.03	<.025	<.025	0.058	<.025	<.025
Oil and Grease	mg/L	0.1	<.1	<.1	<.1	<.1	<.1	<.1
Total petroleum hydrocarbons	mg/L	0.1	<.1	<.1	<.1	<.1	<.1	<.1
Chemical oxygen demand	mg/L	30	284	340	175	88	319	88
2,4-D	mg/L	0.7	<.7	<.7	<.7	<.7	<.7	<.7
Atrazine	μg/L	0.7	<.7	<.7	<.7	<.7	<.7	<.7
Simazine	μg/L	3	<3	<3	<3	<3	<3	<3
Metolachlor	μg/L	0.5	<.5	<.5	<.5	<.5	<.5	<.5
Tebuthiron	μg/L	0.82	<.82	<.82	<.82	<.82	<.82	<.82
Prometon	μg/L	0.8	<.8	<.8	<.8	<.8	<.8	<.8
Chlorpyrifos	μg/L	0.05	<.05	<.05	<.05	<.05	<.05	<.05
Cyanazine	μg/L	0.82	<.82	<.82	<.82	<.82	<.82	<.82
Lindane	μg/L	0.02	<.02	<.02	<.02	<.02	<.02	<.02
alpha-BHC	μg/L	0.01	<.01	<.01	<.01	<.01	<.01	<.01
Dieldrin	μg/L	0.06	<.06	<.06	<.06	<.06	<.06	<.06
Chlorothalonil	μg/L	0.02	<.02	<.02	<.02	<.02	<.02	<.02
DDE	μg/L	0.04	<.04	<.04	<.04	<.04	<.04	<.04
DDT	μg/L	4	<4	<4	<4	<4	<4	<4
Endosulfan	μg/L	0.06	<.06	<.06	<.06	<.06	<.06	<.06
PCB	μg/L	0.82	<.82	<.82	<.82	<.82	<.82	<.82
Alachlor	μg/L	0.08	<.08	<.08	<.08	<.08	<.08	<.08
Aldicarb	μg/L	25	<25	<25	<25	<25	<25	<25
Fluometuron	μg/L	1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6
Diazinon	μg/L	0.8	<.8	<.8	<.8	<.8	<.8	<.8
Carbaryl	μg/L	0.25	<.25	<.25	<.25	<.25	<.25	<.25
Metalaxyl	μg/L	0.8	<.8	<.8	<.8	<.8	<.8	<.8
Malathion	μg/L	0.8	<.8	<.8	<.8	<.8	<.8	<.8
Carbofuran	μg/L	0.25	<.25	<.25	<.25	<.25	<.25	<.25
Methomyl	μg/L	25	<25	<25	<25	<25	<25	<25

1 - estimated discharge from USGS gages
2 - n/d-not determined; n/c-not collected

Parameter	Units	Lower limit of detection	3 - Cedar Creek			4 - Tensaw Lake		
			27-Jul-05	1-Nov-05	8-Jan-07	27-Jul-05	2-Nov-05	8-Jan-07
Discharge (est.) [1]	ft^3/s	--	183	93	292	nd [2]	nd	nd
Sample time	24 hr	--	12:50	14:30	14:20	10:35	10:30	16:00
Temperature	°C	--	27	15	15	29	18	15
Dissolved oxygen	mg/L	--	1.9	8.9	7.5	2.8	8.8	6.6
DO saturation percent	--	--	23.8	86.4	72.8	36.7	91.1	64.1
BOD (5-day)	mg/L	--	<.1	0.8	0.4	<.1	1.3	1.4
Total residual chlorine	mg/L	0.02	<.02	<.02	<.02	<.02	<.02	<.02
pH	s.u.	0.1	4.9	7.1	4.6	7.0	7.3	6.4
Carbon dioxide-free	mg/L	1	<1	<1	362	7	2	26
Alkalinity as $CaCO_3$	mg/L	3	<3	<3	7	37	25	34
Hardness as $CaCO_3$	mg/L	1	6.2	8.1	7.4	42	30	42
Specific conductance	$\mu S/cm^2$	1	23	30	37	111	160	147
Total dissolved solids	mg/L	10	59	46	19	95	102	70
Silica	mg/L	0.05	8.49	9.85	6.56	7.13	8.70	6.96
Calcium	mg/L	0.01	1.60	1.77	1.75	12.90	8.16	12.50
Magnesium	mg/L	0.04	0.52	0.87	0.72	2.37	2.25	2.62
Sodium	mg/L	0.05	2.40	4.02	2.90	5.04	18.00	8.88
Potassium	mg/L	0.50	0.00	0.00	0.00	1.53	1.36	1.57
Sulfate	mg/L	0.06	1.54	2.43	5.51	5.87	9.01	14.50
Chloride	mg/L	0.05	3.84	5.79	5.08	4.32	25.10	8.73
Bromide	mg/L	0.05	<.05	<.05	<.05	<.05	<.05	<.05
Fluoride	mg/L	0.02	0.03	0.00	0.00	0.05	0.04	0.05
Bicarbonate	mg/L	1	<1	<1	9	45	30	41
Carbonate	mg/L	1	<1	<1	<1	<1	<1	<1
Ammonia as N	mg/L	0.02	0.08	0.06	0.03	0.04	0.02	0.03
Total Kjeldahl nitrogen	mg/L	0.10	0.55	0.20	0.33	0.59	0.30	0.86
Nitrite as N	mg/L	0.01	<.01	<.01	<.01	<.01	<.01	<.01
Nitrite as NO_2	mg/L	0.03	<.03	<.03	<.03	<.03	<.03	<.03
Nitrate as N	mg/L	0.02	0.041	0.118	<.041	0.041	0.05	0.106
Nitrate as NO_3	mg/L	0.09	0.18	0.52	<.09	0.18	0.22	0.47
Total nitrate-nitrite as N	mg/L	0.02	0.041	0.118	<.041	0.041	0.05	0.106
Total nitrate-nitrite as NO_3	mg/L	0.09	0.18	0.52	<.09	0.18	0.22	0.47
Total phosphorus as P	mg/L	0.02	0.024	<.02	0.061	0.04	0.021	0.082
Orthophosphate as PO_4	mg/L	0.02	<.02	<.02	<.02	<.02	<.02	<.02
Chlorophyll *a*	mg/L	0.0002	<.0002	0.0011	<.0002	0.0099	0.0098	0.0028
Carlson's TSI			<15	32	<15	53	53	41
Total suspended solids	mg/L	4	12	6	5	8	18	20
Turbidity	NTU	1	33	5	5	13	29	24
Aluminum	$\mu g/L$	60	165	68	147	<60	72	78
Antimony	$\mu g/L$	3	<3	3.5	<3	3	3.6	<3
Arsenic	$\mu g/L$	2	2.8	<2	<2	3.7	<2	<2
Barium	$\mu g/L$	2	80.9	54.7	52.0	37.1	53.6	38.2
Beryllium	$\mu g/L$	1	<1	<1	<1	<1	<1	<1
Boron	$\mu g/L$	10	16	<10	18	11	20	18
Cadmium	$\mu g/L$	4	<4	<4	<4	<4	<4	<4
Chromium	$\mu g/L$	8	<8	<8	<8	<8	<8	<8
Cobalt	$\mu g/L$	7	<7	<7	<7	<7	<7	<7
Copper	$\mu g/L$	8	<8	<8	<8	<8	<8	<8
Iron	$\mu g/L$	3	1770	579	216	409	685	424
Lithium	$\mu g/L$	5	<5	<5	<5	<5	<5	<5

1 - estimated discharge from USGS gages
2 - n/d-not determined; n/c-not collected

Parameter	Units	Lower limit of detection	3 - Cedar Creek			4 - Tensaw Lake		
			27-Jul-05	1-Nov-05	8-Jan-07	27-Jul-05	2-Nov-05	8-Jan-07
Manganese	µg/L	2	37.5	13.9	40.5	92.5	16.7	32.8
Mercury	µg/L	0.06	<.06	<.06	<.06	<.06	<.06	<.06
Molybdenum	µg/L	20	<20	<20	<20	<20	<20	<20
Nickel	µg/L	10	<10	<10	<10	<10	<10	<10
Lead	µg/L	2	<2	<2	<2	<2	<2	<2
Selenium	µg/L	3	<3	<3	<3	<3	<3	<3
Silver	µg/L	10	<10	<10	<10	<10	<10	<10
Strontium	µg/L	1	18.8	19.9	22.1	54.3	62.2	56.1
Thallium	µg/L	2	<2	<2	<2	3.2	<2	<2
Tin	µg/L	1	<1	<1	<1	<1	<1	<1
Titanium	µg/L	4	<4	<4	<4	<4	<4	7.3
Vanadium	µg/L	4	<4	<4	<4	<4	<4	<4
Zinc	µg/L	4	43.2	24.6	39.6	8.1	27.9	10.3
Cyanide	µg/L	0.003	<.003	<.003	<.003	<.003	<.003	<.003
Total organic carbon	mg/L	0.4	13.50	4.37	6.10	6.55	3.35	4.79
Recoverable phenolics	µg/L	3	<3	<3	<3	<3	<3	<3
Anionic surfactants	mg/L	0.025	0.029	<.025	0.043	<.025	0.03	<.025
Oil and Grease	mg/L	0.1	<.1	<.1	<.1	<.1	0.159	<.1
Total petroleum hydrocarbons	mg/L	0.1	<.1	<.1	<.1	<.1	<.1	<.1
Chemical oxygen demand	mg/L	30	143	339	111	343	76	151
2,4-D	mg/L	0.7	<.7	<.7	<.7	<.7	<.7	<.7
Atrazine	µg/L	0.7	<.7	<.7	<.7	<.7	<.7	<.7
Simazine	µg/L	3	<3	<3	<3	<3	<3	<3
Metolachlor	µg/L	0.5	<.5	<.5	<.5	<.5	<.5	<.5
Tebuthiron	µg/L	0.82	<.82	<.82	<.82	<.82	<.82	<.82
Prometon	µg/L	0.8	<.8	<.8	<.8	<.8	<.8	<.8
Chlorpyrifos	µg/L	0.05	<.05	<.05	<.05	<.05	<.05	<.05
Cyanazine	µg/L	0.82	<.82	<.82	<.82	<.82	<.82	<.82
Lindane	µg/L	0.02	<.02	<.02	<.02	<.02	<.02	<.02
alpha-BHC	µg/L	0.01	<.01	<.01	<.01	<.01	<.01	<.01
Dieldrin	µg/L	0.06	<.06	<.06	<.06	<.06	<.06	<.06
Chlorothalonil	µg/L	0.02	<.02	<.02	<.02	<.02	<.02	<.02
DDE	µg/L	0.04	<.04	<.04	<.04	<.04	<.04	<.04
DDT	µg/L	4	<4	<4	<4	<4	<4	<4
Endosulfan	µg/L	0.06	<.06	<.06	<.06	<.06	<.06	<.06
PCB	µg/L	0.82	<.82	<.82	<.82	<.82	<.82	<.82
Alachlor	µg/L	0.08	<.08	<.08	<.08	<.08	<.08	<.08
Aldicarb	µg/L	25	<25	<25	<25	<25	<25	<25
Fluometuron	µg/L	1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6
Diazinon	µg/L	0.8	<.8	<.8	<.8	<.8	<.8	<.8
Carbaryl	µg/L	0.25	<.25	<.25	<.25	<.25	<.25	<.25
Metalaxyl	µg/L	0.8	<.8	<.8	<.8	<.8	<.8	<.8
Malathion	µg/L	0.8	<.8	<.8	<.8	<.8	<.8	<.8
Carbofuran	µg/L	0.25	<.25	<.25	<.25	<.25	<.25	<.25
Methomyl	µg/L	25	<25	<25	<25	<25	<25	<25

1 - estimated discharge from USGS gages
2 - n/d-not determined; n/c-not collected

Parameter	Units	Lower limit of detection	5 - Mobile River					
			2-Mar-05	27-Jul-05	2-Nov-05	21-Feb-06	15-Aug-06	9-Jan-07
Discharge (est.) [1]	ft^3/s	--	51,900	38,200	4,520	39,700	4,060	61,300
Sample time	24 hr	--	9:15	9:15	9:10	15:00	13:40	9:15
Temperature	°C	--	13	29	21	11	35	13
Dissolved oxygen	mg/L	--	9.4	3.9	8.4	10.1	5.5	8.8
DO saturation percent	--	--	87.4	51.1	92.7	90	81.9	81.8
BOD (5-day)	mg/L	--	1.5	<.1	0.9	1.1	1.2	1.3
Total residual chlorine	mg/L	0.02	<.02	<.02	<.02	<.02	<.02	<.02
pH	s.u.	0.1	7.3	6.6	7.3	6.2	7.1	7.0
Carbon dioxide-free	mg/L	1	4	16	4	37	<1	7
Alkalinity as $CaCO_3$	mg/L	3	36	34	42	30	63	35
Hardness as $CaCO_3$	mg/L	1	51	44	47	41	61	48
Specific conductance	$\mu S/cm^2$	1	147	130	187	126	307	162
Total dissolved solids	mg/L	10	99	100	127	90	161	75
Silica	mg/L	0.05	6.32	7.16	8.67	6.04	1.18	7.01
Calcium	mg/L	0.01	16.20	13.40	13.30	12.40	17.60	14.50
Magnesium	mg/L	0.04	2.62	2.49	3.42	2.49	4.06	2.80
Sodium	mg/L	0.05	8.58	7.28	17.60	8.73	28.40	8.91
Potassium	mg/L	0.50	1.11	1.38	1.79	1.51	2.48	1.71
Sulfate	mg/L	0.06	15.60	12.20	18.00	15.30	31.40	18.00
Chloride	mg/L	0.05	8.64	6.22	12.90	9.31	26.50	9.64
Bromide	mg/L	0.05	<.05	<.05	<.05	<.05	<.05	<.05
Fluoride	mg/L	0.02	0.04	0.04	0.05	0.03	0.00	0.06
Bicarbonate	mg/L	1	44	41	51	37	77	43
Carbonate	mg/L	1	<1	<1	<1	<1	<1	<1
Ammonia as N	mg/L	0.02	0.04	0.10	0.03	<.02	0.05	0.05
Total Kjeldahl nitrogen	mg/L	0.10	0.25	0.66	0.30	0.27	0.45	1.14
Nitrite as N	mg/L	0.01	<.01	<.01	<.01	<.01	<.01	<.01
Nitrite as NO_2	mg/L	0.03	<.03	<.03	<.03	<.03	<.03	<.03
Nitrate as N	mg/L	0.02	0.218	0.091	0.231	0.44	0.057	0.228
Nitrate as NO_3	mg/L	0.09	0.97	0.4	1.02	1.95	0.25	1.01
Total nitrate-nitrite as N	mg/L	0.02	0.218	0.091	0.231	0.44	0.057	0.228
Total nitrate-nitrite as NO_3	mg/L	0.09	0.97	0.4	1.02	1.95	0.25	1.01
Total phosphorus as P	mg/L	0.02	0.039	0.049	0.033	0.065	0.031	0.084
Orthophosphate as PO_4	mg/L	0.02	<.02	<.02	<.02	<.02	<.02	<.02
Chlorophyll *a*	mg/L	0.0002	0.002	0.0095	0.0058	0.0084	0.0086	0.0059
Carlson's TSI			37	53	48	51	52	48
Total suspended solids	mg/L	4	53	23	25	38	14	102
Turbidity	NTU	1	92	31	45	80	22	110
Aluminum	µg/L	60	<60	<60	102	<60	<60	192
Antimony	µg/L	3	<3	<3	<3	<3	<3	<3
Arsenic	µg/L	2	<2	2.2	<2	<2	2.7	<2
Barium	µg/L	2	50.0	74.1	44.9	60.3	50.9	65.2
Beryllium	µg/L	1	<1	<1	<1	<1	<1	<1
Boron	µg/L	10	11	14	<10	<10	38	15
Cadmium	µg/L	4	<4	<4	<4	<4	<4	<4
Chromium	µg/L	8	<8	<8	<8	<8	<8	<8
Cobalt	µg/L	7	<7	<7	<7	<7	<7	<7
Copper	µg/L	8	<8	<8	<8	<8	<8	<8
Iron	µg/L	3	246	345	279	223	21.6	364
Lithium	µg/L	5	<5	<5	<5	<5	<5	<5

1 - estimated discharge from USGS gages
2 - n/d-not determined; n/c-not collected

Parameter	Units	Lower limit of detection	5 - Mobile River 2-Mar-05	27-Jul-05	2-Nov-05	21-Feb-06	15-Aug-06	9-Jan-07
Manganese	µg/L	2	5.8	12.1	11.7	8	6.6	32.5
Mercury	µg/L	0.06	<.06	<.06	<.06	<.06	<.06	<.06
Molybdenum	µg/L	20	<20	<20	<20	<20	<20	<20
Nickel	µg/L	10	<10	<10	<10	15	13	<10
Lead	µg/L	2	<2	<2	<2	2.2	5.9	<2
Selenium	µg/L	3	<3	<3	<3	<3	<3	<3
Silver	µg/L	10	<10	<10	<10	<10	<10	<10
Strontium	µg/L	1	84.6	66.8	70.1	72.3	92.7	77.4
Thallium	µg/L	2	<2	<2	<2	<2	<2	<2
Tin	µg/L	1	<1	<1	<1	<1	<1	<1
Titanium	µg/L	4	<4	<4	<4	5.9	<4	10.9
Vanadium	µg/L	4	<4	<4	<4	<4	<4	<4
Zinc	µg/L	4	27	23.7	<4	23.4	16.7	28.9
Cyanide	µg/L	0.003	<.003	<.003	<.003	0.0058	<.003	<.003
Total organic carbon	mg/L	0.4	4.09	6.50	2.80			5.66
Recoverable phenolics	µg/L	3	<3	<3	<3	<3	<3	<3
Anionic surfactants	mg/L	0.025	<.025	<.025	<.025	<.025	<.025	0.03
Oil and Grease	mg/L	0.1	0.39	<.1	<.1	<.1	<.1	<.1
Total petroleum hydrocarbons	mg/L	0.1	<.1	<.1	<.1	<.1	<.1	<.1
Chemical oxygen demand	mg/L	30	57	573	224	131	79	194
2,4-D	mg/L	0.7	<.7	<.7	<.7	<.7	<.7	<.7
Atrazine	µg/L	0.7	<.7	<.7	<.7	n/c [2]	n/c	<.7
Simazine	µg/L	3	<3	<3	<3	n/c	n/c	<3
Metolachlor	µg/L	0.5	<.5	<.5	<.5	n/c	n/c	<.5
Tebuthiron	µg/L	0.82	<.82	<.82	<.82	n/c	n/c	<.82
Prometon	µg/L	0.8	<.8	<.8	<.8	n/c	n/c	<.8
Chlorpyrifos	µg/L	0.05	<.05	<.05	<.05	n/c	n/c	<.05
Cyanazine	µg/L	0.82	<.82	<.82	<.82	n/c	n/c	<.82
Lindane	µg/L	0.02	<.02	<.02	<.02	n/c	n/c	<.02
alpha-BHC	µg/L	0.01	<.01	<.01	<.01	n/c	n/c	<.01
Dieldrin	µg/L	0.06	<.06	<.06	<.06	n/c	n/c	<.06
Chlorothalonil	µg/L	0.02	<.02	<.02	<.02	n/c	n/c	<.02
DDE	µg/L	0.04	<.04	<.04	<.04	n/c	n/c	<.04
DDT	µg/L	4	<4	<4	<4	n/c	n/c	<4
Endosulfan	µg/L	0.06	<.06	<.06	<.06	n/c	n/c	<.06
PCB	µg/L	0.82	<.82	<.82	<.82	n/c	n/c	<.82
Alachlor	µg/L	0.08	<.08	<.08	<.08	n/c	n/c	<.08
Aldicarb	µg/L	25	<25	<25	<25	n/c	n/c	<25
Fluometuron	µg/L	1.6	<1.6	<1.6	<1.6	n/c	n/c	<1.6
Diazinon	µg/L	0.8	<.8	<.8	<.8	n/c	n/c	<.8
Carbaryl	µg/L	0.25	<.25	<.25	<.25	n/c	n/c	<.25
Metalaxyl	µg/L	0.8	<.8	<.8	<.8	n/c	n/c	<.8
Malathion	µg/L	0.8	<.8	<.8	<.8	n/c	n/c	<.8
Carbofuran	µg/L	0.25	<.25	<.25	<.25	n/c	n/c	<.25
Methomyl	µg/L	25	<25	<25	<25	n/c	n/c	<25

1 - estimated discharge from USGS gages
2 - n/d-not determined; n/c-not collected

Parameter	Units	Lower limit of detection	6 - Middle River		
			26-Jul-05	2-Nov-05	9-Jan-07
Discharge (est.) [1]	ft^3/s	--	nd	nd	nd
Sample time	24 hr	--	16:15	8:15	8:04
Temperature	°C	--	30	19	13
Dissolved oxygen	mg/L	--	5	8.3	8.4
DO saturation percent	--	--	66.9	87.8	78.1
BOD (5-day)	mg/L	--	<.1	1	1.3
Total residual chlorine	mg/L	0.02	<.02	<.02	<.02
pH	s.u.	0.1	7.0	7.0	6.8
Carbon dioxide-free	mg/L	1	7	8	11
Alkalinity as $CaCO_3$	mg/L	3	35	43	37
Hardness as $CaCO_3$	mg/L	1	43	47	48
Specific conductance	$\mu S/cm^2$	1	120	196	167
Total dissolved solids	mg/L	10	87	143	76
Silica	mg/L	0.05	6.30	8.59	6.49
Calcium	mg/L	0.01	13.10	13.60	14.40
Magnesium	mg/L	0.04	2.47	3.05	2.91
Sodium	mg/L	0.05	6.15	19.00	9.17
Potassium	mg/L	0.50	1.34	2.20	1.78
Sulfate	mg/L	0.06	9.51	20.00	17.00
Chloride	mg/L	0.05	4.91	13.30	9.60
Bromide	mg/L	0.05	<.05	<.05	<.05
Fluoride	mg/L	0.02	0.04	0.05	0.06
Bicarbonate	mg/L	1	43	52	45
Carbonate	mg/L	1	<1	<1	<1
Ammonia as N	mg/L	0.02	0.07	0.03	0.05
Total Kjeldahl nitrogen	mg/L	0.10	0.45	0.48	0.91
Nitrite as N	mg/L	0.01	<.01	<.01	<.01
Nitrite as NO_2	mg/L	0.03	<.03	<.03	<.03
Nitrate as N	mg/L	0.02	0.083	0.26	0.166
Nitrate as NO_3	mg/L	0.09	0.37	1.15	0.73
Total nitrate-nitrite as N	mg/L	0.02	0.083	0.26	0.166
Total nitrate-nitrite as NO_3	mg/L	0.09	0.37	1.15	0.73
Total phosphorus as P	mg/L	0.02	0.033	0.034	0.085
Orthophosphate as PO_4	mg/L	0.02	<.02	<.02	<.02
Chlorophyll *a*	mg/L	0.0002	0.0069	0.0058	0.0058
Carlson's TSI			50	48	48
Total suspended solids	mg/L	4	13	23	70
Turbidity	NTU	1	35	44	100
Aluminum	µg/L	60	<60	174	92
Antimony	µg/L	3	<3	3.8	<3
Arsenic	µg/L	2	<2	<2	4.2
Barium	µg/L	2	81.1	45.2	64.8
Beryllium	µg/L	1	<1	<1	<1
Boron	µg/L	10	13	<10	18
Cadmium	µg/L	4	<4	<4	<4
Chromium	µg/L	8	<8	<8	<8
Cobalt	µg/L	7	<7	<7	<7
Copper	µg/L	8	<8	<8	<8
Iron	µg/L	3	262	303	305
Lithium	µg/L	5	<5	<5	<5

1 - estimated discharge from USGS gages
2 - n/d-not determined; n/c-not collected

Parameter	Units	Lower limit of detection	6 - Middle River		
			26-Jul-05	2-Nov-05	9-Jan-07
Manganese	μg/L	2	11.3	6.4	33
Mercury	μg/L	0.06	<.06	<.06	<.06
Molybdenum	μg/L	20	<20	<20	<20
Nickel	μg/L	10	<10	<10	12
Lead	μg/L	2	<2	<2	<2
Selenium	μg/L	3	<3	<3	<3
Silver	μg/L	10	<10	<10	<10
Strontium	μg/L	1	61.5	76.4	73.5
Thallium	μg/L	2	<2	<2	<2
Tin	μg/L	1	<1	<1	<1
Titanium	μg/L	4	<4	<4	8.6
Vanadium	μg/L	4	<4	<4	<4
Zinc	μg/L	4	25.6	6.4	20.1
Cyanide	μg/L	0.003	<.003	<.003	<.003
Total organic carbon	mg/L	0.4	6.09	2.89	4.52
Recoverable phenolics	μg/L	3	<3	<3	<3
Anionic surfactants	mg/L	0.025	0.076	<.025	0.094
Oil and Grease	mg/L	0.1	<.1	<.1	<.1
Total petroleum hydrocarbons	mg/L	0.1	<.1	<.1	<.1
Chemical oxygen demand	mg/L	30	<30	281	252
2,4-D	mg/L	0.7	<.7	<.7	<.7
Atrazine	μg/L	0.7	<.7	<.7	<.7
Simazine	μg/L	3	<3	<3	<3
Metolachlor	μg/L	0.5	<.5	<.5	<.5
Tebuthiron	μg/L	0.82	<.82	<.82	<.82
Prometon	μg/L	0.8	<.8	<.8	<.8
Chlorpyrifos	μg/L	0.05	<.05	<.05	<.05
Cyanazine	μg/L	0.82	<.82	<.82	<.82
Lindane	μg/L	0.02	<.02	<.02	<.02
alpha-BHC	μg/L	0.01	<.01	<.01	<.01
Dieldrin	μg/L	0.06	<.06	<.06	<.06
Chlorothalonil	μg/L	0.02	<.02	<.02	<.02
DDE	μg/L	0.04	<.04	<.04	<.04
DDT	μg/L	4	<4	<4	<4
Endosulfan	μg/L	0.06	<.06	<.06	<.06
PCB	μg/L	0.82	<.82	<.82	<.82
Alachlor	μg/L	0.08	<.08	<.08	<.08
Aldicarb	μg/L	25	<25	<25	<25
Fluometuron	μg/L	1.6	<1.6	<1.6	<1.6
Diazinon	μg/L	0.8	<.8	<.8	<.8
Carbaryl	μg/L	0.25	<.25	<.25	<.25
Metalaxyl	μg/L	0.8	<.8	<.8	<.8
Malathion	μg/L	0.8	<.8	<.8	<.8
Carbofuran	μg/L	0.25	<.25	<.25	<.25
Methomyl	μg/L	25	<25	<25	<25

1 - estimated discharge from USGS gages
2 - n/d-not determined; n/c-not collected

Parameter	Units	Lower limit of detection	7 - Tensaw River					
			2-Mar-05	26-Jul-05	2-Nov-05	21-Feb-06	15-Aug-06	9-Jan-07
Discharge (est.) [1]	ft^3/s	--	nd	nd	nd	nd	nd	nd
Sample time	24 hr	--	8:20	14:30	7:30	15:45	12:50	8:10
Temperature	°C	--	13	29	19	11	32	13
Dissolved oxygen	mg/L	--	9	4	7.6	9.8	5.5	7.3
DO saturation percent	--	--	83.7	52.4	80.4	87.3	76.8	67.9
BOD (5-day)	mg/L	--	1.3	<.1	1	1.1	1.7	1.1
Total residual chlorine	mg/L	0.02	<.02	<.02	<.02	<.02	<.02	<.02
pH	s.u.	0.1	7.1	6.8	6.3	6.6	7.4	6.5
Carbon dioxide-free	mg/L	1	6	11	39	17	<1	22
Alkalinity as $CaCO_3$	mg/L	3	38	36	40	35	61	36
Hardness as $CaCO_3$	mg/L	1	48	42	46	42	60	44
Specific conductance	$\mu S/cm^2$	1	131	112	191	124	276	155
Total dissolved solids	mg/L	10	84	79	135	72	145	74
Silica	mg/L	0.05	5.66	6.90	8.41	5.67	0.36	6.78
Calcium	mg/L	0.01	14.50	12.70	13.20	12.70	16.80	13.10
Magnesium	mg/L	0.04	2.83	2.40	3.12	2.52	4.24	2.76
Sodium	mg/L	0.05	7.48	5.20	18.30	7.16	23.80	8.72
Potassium	mg/L	0.50	1.15	1.73	1.96	1.44	2.21	1.60
Sulfate	mg/L	0.06	10.80	7.18	18.90	12.60	28.40	15.60
Chloride	mg/L	0.05	6.29	4.46	14.40	6.51	20.20	8.53
Bromide	mg/L	0.05	<.05	<.05	<.05	<.05	<.05	<.05
Fluoride	mg/L	0.02	0.04	0.05	0.04	0.03	0.05	0.05
Bicarbonate	mg/L	1	46	44	49	43	74	44
Carbonate	mg/L	1	<1	<1	<1	<1	<1	<1
Ammonia as N	mg/L	0.02	0.18	0.04	0.03	<.02	0.05	0.04
Total Kjeldahl nitrogen	mg/L	0.10	0.23	0.89	0.30	0.27	0.56	0.85
Nitrite as N	mg/L	0.01	<.01	<.01	<.01	<.01	<.01	<.01
Nitrite as NO_2	mg/L	0.03	<.03	<.03	<.03	<.03	<.03	<.03
Nitrate as N	mg/L	0.02	0.262	0.075	0.2	0.148	<.041	0.119
Nitrate as NO_3	mg/L	0.09	1.16	0.33	0.89	0.66	<.09	0.53
Total nitrate-nitrite as N	mg/L	0.02	0.262	0.075	0.2	0.148	<.041	0.119
Total nitrate-nitrite as NO_3	mg/L	0.09	1.16	0.33	0.89	0.66	<.09	0.53
Total phosphorus as P	mg/L	0.02	0.027	0.038	0.036	0.026	0.027	0.075
Orthophosphate as PO_4	mg/L	0.02	<.02	<.02	<.02	<.02	<.02	<.02
Chlorophyll *a*	mg/L	0.0002	0.0046	0.0114	0.0049	0.0092	0.0136	0.0032
Carlson's TSI			46	54	46	52	56	42
Total suspended solids	mg/L	4	40	16	14	13	14	46
Turbidity	NTU	1	51	11	30	28	17	55
Aluminum	$\mu g/L$	60	<60	<60	100	<60	<60	99
Antimony	$\mu g/L$	3	<3	<3	<3	<3	<3	<3
Arsenic	$\mu g/L$	2	<2	2.9	<2	<2	<2	<2
Barium	$\mu g/L$	2	35.4	38.6	44.1	36.8	46.1	50.2
Beryllium	$\mu g/L$	1	<1	<1	<1	<1	<1	<1
Boron	$\mu g/L$	10	<10	11	<10	<10	30	14
Cadmium	$\mu g/L$	4	<4	<4	<4	<4	<4	<4
Chromium	$\mu g/L$	8	<8	<8	<8	<8	<8	<8
Cobalt	$\mu g/L$	7	<7	<7	<7	<7	<7	<7
Copper	$\mu g/L$	8	<8	<8	<8	<8	<8	<8
Iron	$\mu g/L$	3	174	355	355	163	33.8	311
Lithium	$\mu g/L$	5	<5	<5	<5	<5	<5	<5

1 - estimated discharge from USGS gages
2 - n/d-not determined; n/c-not collected

Parameter	Units	Lower limit of detection	7 - Tensaw River					
			2-Mar-05	26-Jul-05	2-Nov-05	21-Feb-06	15-Aug-06	9-Jan-07
Manganese	µg/L	2	9.6	30.5	2.6	11.2	8.1	40
Mercury	µg/L	0.06	<.06	<.06	<.06	<.06	<.06	<.06
Molybdenum	µg/L	20	<20	<20	<20	<20	<20	<20
Nickel	µg/L	10	<10	<10	<10	21	<10	<10
Lead	µg/L	2	<2	<2	<2	<2	4.3	<2
Selenium	µg/L	3	<3	<3	<3	<3	<3	<3
Silver	µg/L	10	<10	<10	<10	<10	<10	<10
Strontium	µg/L	1	62.2	56.5	72.2	59.1	90.5	64.5
Thallium	µg/L	2	<2	<2	<2	<2	<2	<2
Tin	µg/L	1	<1	<1	<1	<1	<1	53
Titanium	µg/L	4	<4	<4	<4	<4	<4	8.2
Vanadium	µg/L	4	<4	<4	<4	<4	<4	<4
Zinc	µg/L	4	13.7	11	9	10	23.7	15.3
Cyanide	µg/L	0.003	<.003	<.003	<.003	<.003	0.0034	<.003
Total organic carbon	mg/L	0.4	4.17	6.58	3.24			4.12
Recoverable phenolics	µg/L	3	<3	<3	4.1	4.3	<3	<3
Anionic surfactants	mg/L	0.025	0.057	0.124	0.147	<.025	<.025	<.025
Oil and Grease	mg/L	0.1	<.1	<.1	<.1	<.1	<.1	<.1
Total petroleum hydrocarbons	mg/L	0.1	<.1	<.1	<.1	<.1	<.1	<.1
Chemical oxygen demand	mg/L	30	52	273	153	80	69	171
2,4-D	mg/L	0.7	<.7	<.7	<.7	<.7	<.7	<.7
Atrazine	µg/L	0.7	<.7	<.7	<.7	n/c	n/c	<.7
Simazine	µg/L	3	<3	<3	<3	n/c	n/c	<3
Metolachlor	µg/L	0.5	<.5	<.5	<.5	n/c	n/c	<.5
Tebuthiron	µg/L	0.82	<.82	<.82	<.82	n/c	n/c	<.82
Prometon	µg/L	0.8	<.8	<.8	<.8	n/c	n/c	<.8
Chlorpyrifos	µg/L	0.05	<.05	<.05	<.05	n/c	n/c	<.05
Cyanazine	µg/L	0.82	<.82	<.82	<.82	n/c	n/c	<.82
Lindane	µg/L	0.02	<.02	<.02	<.02	n/c	n/c	<.02
alpha-BHC	µg/L	0.01	<.01	<.01	<.01	n/c	n/c	<.01
Dieldrin	µg/L	0.06	<.06	<.06	<.06	n/c	n/c	<.06
Chlorothalonil	µg/L	0.02	<.02	<.02	<.02	n/c	n/c	<.02
DDE	µg/L	0.04	<.04	<.04	<.04	n/c	n/c	<.04
DDT	µg/L	4	<4	<4	<4	n/c	n/c	<4
Endosulfan	µg/L	0.06	<.06	<.06	<.06	n/c	n/c	<.06
PCB	µg/L	0.82	<.82	<.82	<.82	n/c	n/c	<.82
Alachlor	µg/L	0.08	<.08	<.08	<.08	n/c	n/c	<.08
Aldicarb	µg/L	25	<25	<25	<25	n/c	n/c	<25
Fluometuron	µg/L	1.6	<1.6	<1.6	<1.6	n/c	n/c	<1.6
Diazinon	µg/L	0.8	<.8	<.8	<.8	n/c	n/c	<.8
Carbaryl	µg/L	0.25	<.25	<.25	<.25	n/c	n/c	<.25
Metalaxyl	µg/L	0.8	<.8	<.8	<.8	n/c	n/c	<.8
Malathion	µg/L	0.8	<.8	<.8	<.8	n/c	n/c	<.8
Carbofuran	µg/L	0.25	<.25	<.25	<.25	n/c	n/c	<.25
Methomyl	µg/L	25	<25	<25	<25	n/c	n/c	<25

1 - estimated discharge from USGS gages
2 - n/d-not determined; n/c-not collected

Appendix B

Sediment-quality data collected at seven sites in the Mobile-Tensaw River Delta, 2005.

Parameter	Units	Lower limit of detection	Sampling sites 1	2	3	4
Date sampled	dd-mm-yy	--	1-Nov-05	1-Nov-05	1-Nov-05	2-Nov-05
Time	24-hr	--	11:00	13:00	14:30	10:30
pH	s.u.	--	6.1	6.0	5.0	5.6
Calcium	mg/kg	2	1,880	2,320	648	2,800
Magnesium	mg/kg	4	1,310	1,030	281	1,070
Sodium	mg/kg	6	43	65	27	91
Potassium	mg/kg	40	782	586	148	591
Sulfate	mg/kg	0.9	32	38.5	38.9	108
Chloride	mg/kg	0.6	<.6	<.6	<.6	11.7
Bromide	mg/kg	0.6	<.6	<.6	<.6	<.6
Fluoride	mg/kg	0.25	<.25	<.25	<.25	<.25
Ammonia as N	mg/kg	0.4	42	50.4	45.6	43.9
Total Kjeldahl nitrogen	mg/kg	0.4	1,220	1,580	4,010	4,760
Total nitrate-nitrite as N	mg/kg	0.25	1.68	0.866	<.25	1.34
Total nitrate-nitrite as NO_3	mg/kg	1.1	7.44	3.83	<1.1	5.93
Total phosphorus as P	mg/kg	14	299	365	149	410
Orthophosphate as PO_4	mg/kg	0.25	<.25	<.25	<.25	<.25
Aluminum	mg/kg	7	7,630	5,890	3,620	8,920
Antimony	mg/kg	0.2	<.2	<.2	0.21	<.2
Arsenic	mg/kg	0.2	3.49	3.28	1.4	3.81
Barium	mg/kg	0.2	69.6	74.2	50.6	97.3
Beryllium	mg/kg	0.1	0.66	0.68	0.56	0.98
Cadmium	mg/kg	0.4	<.4	<.4	0.52	0.82
Chromium	mg/kg	0.8	15.2	9.9	4.8	14.8
Cobalt	mg/kg	0.7	6.4	7	2.6	9.5
Copper	mg/kg	0.6	4.1	4.4	3.4	8.6
Iron	mg/kg	0.3	16,500	14,300	7,460	19,700
Lithium	mg/kg	0.5	6.7	5.5	1.4	8.2
Manganese	mg/kg	0.1	554	775	648	432
Mercury	mg/kg	0.006	0.04	0.037	0.082	0.085
Molybdenum	mg/kg	2	<2	<2	<2	<2
Nickel	mg/kg	1	8.1	9.5	5.7	10.1
Lead	mg/kg	0.1	5.16	5.75	6.29	17.7
Selenium	mg/kg	0.3	<.3	<.3	<.3	<.3
Silver	mg/kg	1	<1	<1	<1	<1
Strontium	mg/kg	0.1	12.2	19.2	9.24	17.7
Thallium	mg/kg	0.2	<.2	<.2	<.2	<.2
Tin	mg/kg	5	<5	<5	<5	<5
Vanadium	mg/kg	0.4	19.5	16.2	11.1	27.3
Zinc	mg/kg	0.4	37.7	35.1	63.6	52.6
Cyanide	mg/kg	0.06	<.06	<.06	<.06	<.06
Petroleum hydrocarbons	mg/kg	0.6	36	<.6	23.1	<.6
Total organic carbon	mg/kg	40	7,910	7,360	33,900	37,200
Oil and Grease	mg/kg	0.6	39.7	5.5	40.1	10
2,4-D	mg/kg	0.1	<0.1	<0.1	0.2350	<0.1
Atrazine	mg/kg	0.82	<0.82	<0.82	<0.82	<0.82
Simazine	mg/kg	0.8	<0.8	<0.8	<0.8	<0.8
Metolachlor	mg/kg	0.16	<0.16	<0.16	<0.16	<0.16
Tebuthiron	mg/kg	0.8	<0.8	<0.8	<0.8	<0.8
Prometon	mg/kg	0.8	<0.8	<0.8	<0.8	<0.8

Parameter	Units	Lower limit of detection	Sampling sites			
			1	2	3	4
Chlorpyrifos	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05
Cyanazine	mg/kg	0.82	<0.82	<0.82	<0.82	<0.82
Lindane	mg/kg	0.02	<0.02	<0.02	<0.02	<0.02
alpha-BHC	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01
Dieldrin	mg/kg	0.06	<0.06	<0.06	<0.06	<0.06
Chlorothalonil	mg/kg	0.02	<0.02	<0.02	<0.02	<0.02
DDE	mg/kg	0.04	<0.04	<0.04	<0.04	<0.04
DDT	mg/kg	4	<4	<4	<4	<4
Endosulfan	mg/kg	0.06	<0.06	<0.06	<0.06	<0.06
PCB	mg/kg	0.82	<0.82	<0.82	<0.82	<0.82
Alachlor	mg/kg	0.08	<0.08	<0.08	<0.08	<0.08
Aldicarb	mg/kg	25	<25	<25	<25	<25
Fluometuron	mg/kg	1.6	<1.6	<1.6	<1.6	<1.6
Diazinon	mg/kg	0.8	<0.8	<0.8	<0.8	<0.8
Carbaryl	mg/kg	0.25	<0.25	<0.25	<0.25	<0.25
Metalaxyl	mg/kg	0.8	<0.8	<0.8	<0.8	<0.8
Malathion	mg/kg	0.8	<0.8	<0.8	<0.8	<0.8
Carbofuran	mg/kg	0.25	<0.25	<0.25	<0.25	<0.25
Methomyl	mg/kg	25	<25	<25	<25	<25
Total Sulfide	mg/kg	20	52	88	150	901

Parameter	Units	Lower limit of detection	Sampling sites 5	6	7
Date sampled	dd-mm-yy	--	2-Nov-05	2-Nov-05	2-Nov-05
Time	24-hr	--	9:10	8:15	7:30
pH	s.u.	--	6.1	6.0	5.7
Calcium	mg/kg	2	1,780	1,790	1,760
Magnesium	mg/kg	4	974	1,230	1,000
Sodium	mg/kg	6	53	56	70
Potassium	mg/kg	40	0	749	594
Sulfate	mg/kg	0.9	27	27.3	<.9
Chloride	mg/kg	0.6	<.6	<.6	2.48
Bromide	mg/kg	0.6	<.6	<.6	<.6
Fluoride	mg/kg	0.25	<.25	<.25	<.25
Ammonia as N	mg/kg	0.4	75.5	40.1	34
Total Kjeldahl nitrogen	mg/kg	0.4	1,250	1,040	1,550
Total nitrate-nitrite as N	mg/kg	0.25	0.623	2.59	0.509
Total nitrate-nitrite as NO_3	mg/kg	1.1	2.76	11.47	2.25
Total phosphorus as P	mg/kg	14	294	348	331
Orthophosphate as PO_4	mg/kg	0.25	<.25	<.25	<.25
Aluminum	mg/kg	7	6,000	6,490	5,960
Antimony	mg/kg	0.2	<.2	0.24	<.2
Arsenic	mg/kg	0.2	3.53	3.61	2.7
Barium	mg/kg	0.2	66.6	66.3	67.2
Beryllium	mg/kg	0.1	0.57	0.69	0.63
Cadmium	mg/kg	0.4	<.4	<.4	0.66
Chromium	mg/kg	0.8	10	11.5	10.2
Cobalt	mg/kg	0.7	5.4	6.1	6.1
Copper	mg/kg	0.6	4.6	3.8	4.8
Iron	mg/kg	0.3	13,100	15,800	14,200
Lithium	mg/kg	0.5	5.4	6.3	5.46
Manganese	mg/kg	0.1	478	448	382
Mercury	mg/kg	0.006	0.038	0.027	0.054
Molybdenum	mg/kg	2	<2	<2	<2
Nickel	mg/kg	1	7.7	8.4	7.2
Lead	mg/kg	0.1	3.23	5.52	8.63
Selenium	mg/kg	0.3	<.3	<.3	<.3
Silver	mg/kg	1	<1	<1	<1
Strontium	mg/kg	0.1	13.8	14.9	12.6
Thallium	mg/kg	0.2	<.2	<.2	<.2
Tin	mg/kg	5	<5	<5	<5
Vanadium	mg/kg	0.4	16.1	17	17.4
Zinc	mg/kg	0.4	32.9	34.8	34
Cyanide	mg/kg	0.06	<.06	<.06	0.15
Petroleum hydrocarbons	mg/kg	0.6	7.5	10.5	0.6
Total organic carbon	mg/kg	40	6,830	7,220	10,500
Oil and Grease	mg/kg	0.6	8.4	13.4	6.3
2,4-D	mg/kg	0.1	<0.1	<0.1	<0.1
Atrazine	mg/kg	0.82	<0.82	<0.82	<0.82
Simazine	mg/kg	0.8	<0.8	<0.8	<0.8
Metolachlor	mg/kg	0.16	<0.16	<0.16	<0.16
Tebuthiron	mg/kg	0.8	<0.8	<0.8	<0.8
Prometon	mg/kg	0.8	<0.8	<0.8	<0.8

Parameter	Units	Lower limit of detection	Sampling sites 5	6	7
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Metalaxyl	mg/kg	0.8	<0.8	<0.8	<0.8
Malathion	mg/kg	0.8	<0.8	<0.8	<0.8
Carbofuran	mg/kg	0.25	<0.25	<0.25	<0.25
Methomyl	mg/kg	25	<25	<25	<25
Total Sulfide	mg/kg	20	127	117	308

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