INTENSIVE SURFACE WATER MONITORING SURVEY FOR SEGMENT NO. 0401 (CADDO LAKE)

REPORT NO. IMS-50

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INTRODUCTION

DIRECTIVE

This intensive survey was accomplished in accordance with the Texas Water Quality Act, Section 21.257, as amended in 1973. The report is to be used in developing and maintaining the State Water Quality Strategy required by regulations published in 40 CFR 130.40 pursuant to Section 303(e) of the Federal Water Pollution Control Act as amended on October 18, 1972.

PURPOSE

The purpose of this intensive survey was to provide the Texas Water Quality Board with a valid information source:

1) to determine quantitative cause and effect relationships of water quality;

2) to obtain data for updating water quality management plans, setting effluent limits, and, where appropriate, verifying the classifications of segments;

3) to set priorities for establishing or improving pollution controls; and

4) to determine any additional water quality management actions required.

SUMMARY

Caddo Dam and Caddo Lake are located in the Cypress Creek Basin in Caddo Parish, Louisiana and Harrison and Marion Counties, Texas. The lake is 29 miles northeast of Marshall, Texas. A natural dam was formed many years ago by log jams, resulting in the formation of the lake. Construction of the dam and the navigation channel from Mooringsport, Louisiana to Jefferson, Texas was completed in 1914. The project is owned by the U. S. Government and operated by the U. S. Army Corps of Engineers. The lake has a capacity of 175,000 acre-feet, a surface area of 32,700 acres, and a drainage area (in Texas) of 2,639 square miles.

There are no Texas Water Quality Board permitted wastewater discharges into Caddo Lake (Segment 0401). Several facilities located in Segment 0402 (Cypress Creek above Caddo Lake to Lake O' the Pines Dam) discharge wastewaters which ultimately reach Caddo Lake. Most of these are sewage treatment plants. The City of Jefferson's treated wastewater discharge is probably the most significant due to its proximity to the lake and its relatively high loading of BOD_5 and nutrients. The most probable origin of non-point source loads to the lake are septic tank effluent, forest and agricultural runoff, and runoff from oil and gas producing areas.

Most of the inflow to the lake (76%) was from Little Cypress Creek (720 cfs), Big Cypress Creek (363 cfs), and Black Cypress Bayou (600 cfs). Tributary inflow was higher than normal during the survey due to appreciable rainfall during the previous week. Water was released from Caddo Dam at a rate of 11,900 cfs.

All dissolved oxygen levels were above the minimum segment standard of 5.0 mg/l and none exceeded 100% saturation. Diurnal fluctuations were minimal, indicating little photosynthetically induced water quality changes. Depth-integrated pH levels ranged from 5.5 (Station 4) to 7.2 (Station 6), averaging 6.1. Observed individual values at Stations 2, 3, and 4 (located in Louisiana) were below the minimum segment standard of 6.0. Whether or not these levels are natural is not known. Conductivity and alkalinity levels were typically low and water temperatures were normal for the season. Tributary field data did not indicate any problem areas.

Chemical analyses of all lake water samples and most tributary samples indicated good water quality, as indicated by low concentrations of conservative substances,

organic material, nutrients and suspended solids. The organic and inorganic constituents of Tiger Branch in Louisiana (Station 17) were relatively high. The cause for these values is not known, but the impact upon water quality of Caddo Lake is probably minimal.

Sediment samples of the lake, except those at Stations 7 and 9, had high contents of organic material (as indicated by COD and volatile solids), total phosphates, and Kjeldahl nitrogen. Decomposing plant material is probably the major contributor of these elevated concentrations. Sediment pesticides (except PCB's) were not detected at any lake station. The average level for PCB's (48.3 ug/kg) is the second highest found in the 31 reservoirs studies to date in the intensive monitoring program. The cause and significance of these levels has not been determined. Lead and zinc concentrations in the sediments exceeded the levels reported for natural soils and were apparently high in Caddo Lake. Station 4 had the highest level of lead (47 mg/kg), and Stations 4 and 8 both had the highest zinc levels (170 mg/kg). The causes and effects of these apparently elevated levels are unknown.

Chlorophyll a levels in the lake and its tributaries were low and are considered indicative of mesotrophic waters. Phytoplankton assemblages were very diverse and were composed of green algae and diatoms in roughly equal proportions. Several genera recognized as clean water types were present, while none associated with polluted water were found. Phytoplankton densities were relatively low and the diversity indices were high, which indicates the community in Caddo Lake was well-balanced and stable during the study period. Fecal coliform densities were relatively low, which suggests that contamination from warm-blooded animals is minimal. Algal assay results revealed that the filtered lake water is incapable of stimulating significant algal growth. The lake is apparently both nitrogen and phosphorus limited for phytoplankton production, since these additions together resulted in significant algal biomass increases directly proportional to the amount added.

WATER QUALITY PROBLEMS

Data collected during this survey indicate no water quality problems of significance in Caddo Lake. Station 11 (Gray's Creek) had the highest amount of total phosphates and Station 17 (Tiger Branch) in Louisiana had the highest amount of conservative substances, organic constituents and total suspended solids. However, the impact of these tributaries on water quality of Caddo Lake is evidently minimal. It is not known if the apparently elevated contents of lead, zinc, and PCB's in the sediments are indicative of water quality problems since the causes and signficance of the observed levels have not been determined.

In concurrence with the waste load evaluation, it is recommended that Segment 0401 be reclassified from water quality limiting to effluent limiting since the data collected in the Texas portion of the lake is indicative of good, and probably stable, water quality.

METHODS

Field and laboratory procedures used during this survey are described in Appendix A. The data were collected February 20 and 21, 1975 by Special Studies Section personnel assisted by Texas Water Quality Board District 5 (Kilgore) personnel. Laboratory analyses of water and sediment samples were conducted by the Texas Department of Health Resources, Chemistry Laboratory, in Austin. Bacteriological analyses were conducted by the survey personnel using the portable membrane filter technique. Parametric coverage, sampling frequencies, and spatial relationships of sampling stations are consistent with the objectives of the survey and with known or suspected forms and variability of pollutants entering the reservoir.

DESCRIPTION OF SURVEY AREA

Caddo Dam and Caddo Lake are located in the Cypress Creek Basin in Caddo Parish, Louisiana and Harrison and Marion Counties, Texas. The lake is 29 miles northeast of Marshall, Texas. (1)

A natural dam was formed many years ago by log jams, resulting in the formation of a natural lake. Although a dam now exists, Caddo Lake is considered the only natural lake of significant size in Texas. In 1913, federal authorization provided for a four-foot navigation depth in the lake from Mooringsport, Louisiana to Jefferson, Texas. Construction of the dam and navigation channel was completed in 1914. The project is owned by the U. S. Government and operated by the U. S. Army Corps of Engineers. (1)

The lake has a capacity of 175,000 acre-feet and a surface area of 32,700 acres at elevation 168.5 feet above mean sea level. Of this total, 58,000 acre-feet of the capacity (33%) and 11,000 acres of the surface area (34%) are in Texas. The drainage area in Texas to Caddo Lake is 2,639 square miles (1), most of which consists of forest land. The remaining area is used primarily for recreational and agricultural activities.

Sampling stations were included in the main body of the lake, in the bays created by major tributaries, and on each significantly flowing tributary. Figure 1 is a map of the area showing the station locations, and Table 1 provides descriptions of their locations.

Table 1
Station Descriptions

Station No.	Location
1	Lower lake in Channel G near dam
2	Lower lake in Channel G at power line crossing above Louisiana Hwy 538 bridge
3	Lower lake at Channel C and Channel D intersection
4	James' Bayou arm of lake in Channel E off Plum Pt.
5	Mid-lake at intersection of Channel G and Channel F near Hawley's Arm
6	Mid-lake at intersection of Channel G and Channel I-G near Tow Head
7	Upper lake in Government Ditch near Cockle Burr
8	Upper lake at Judd Hole
9	Big Cypress Bayou at bend below Texas Hwy 43
10	Little Cypress Creek at FM 3001
11	Little Cypress Creek at FM 154
12	Gray's Creek at FM 1997
13	Big Cypress Creek at FM 134
14	Black Cypress Bayou at U.S. Hwy 59
15	Karnack Creek at county road crossing
16	Picnitt Creek at county road crossing
17	Kitchen Creek at county road crossing below SH 43
18	James' Bayou at SH 43
19	Tiger Branch at Louisiana Hwy 538
20	Twelve Mile Bayou below dam at USGS Gaging Station at Louisiana Hwy 169
21	Harrison Bayou at FM 134

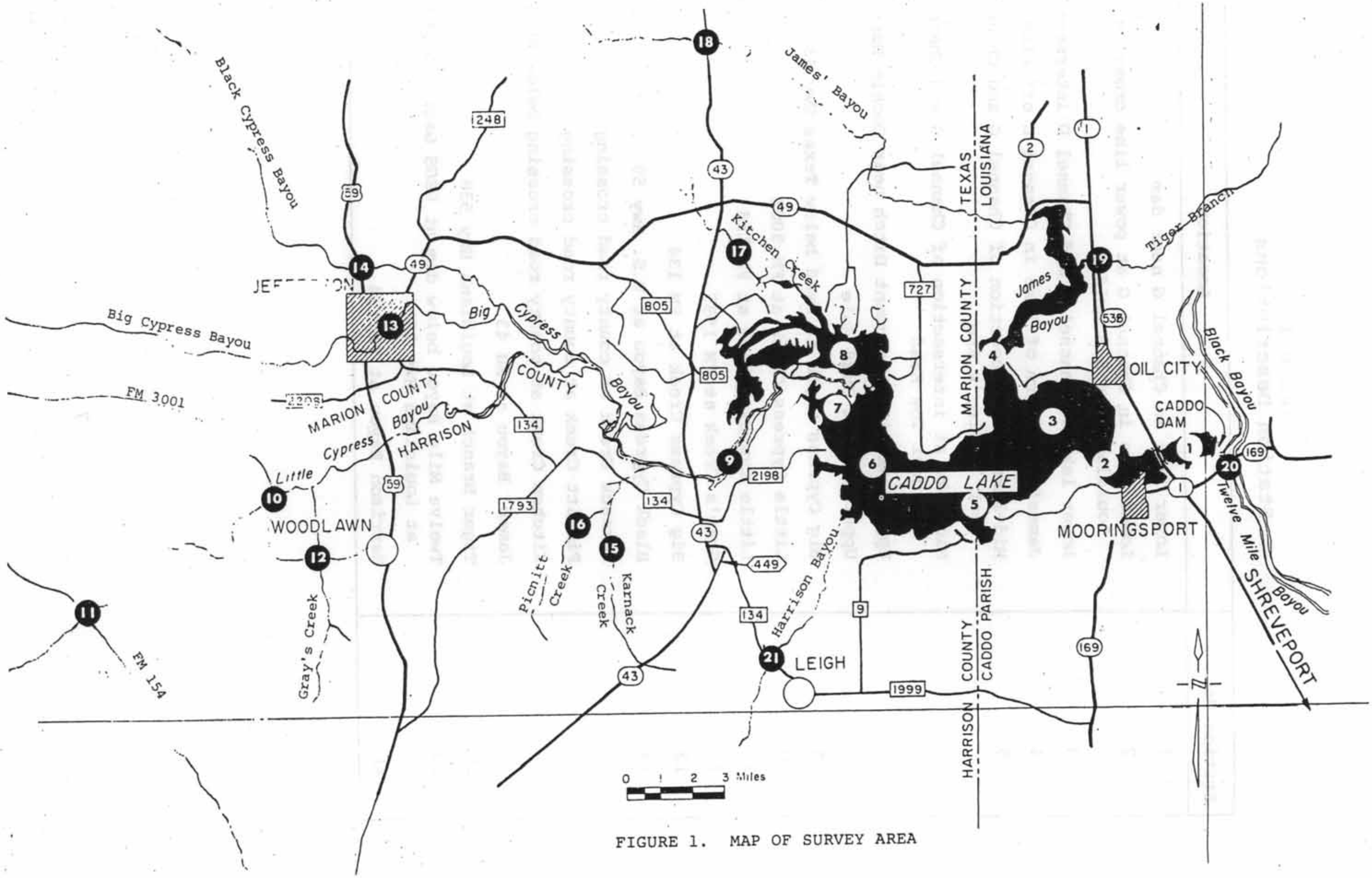

FIGURE 1. MAP OF SURVEY AREA

WASTE SOURCES IN SURVEY AREA

POINT SOURCES

Longhorn Ordinance Works is the only facility located in Segment 0401 which discharges wastewater to Caddo Lake. Since it is a federal installation, no water quality information is available to the Texas Water Quality Board. Several other entities located in the Segment 0402 (Cypress Creek above Caddo Lake to Lake O' the Pines Dam) drainage basin discharge wastewaters which ultimately reach Caddo Lake. Most of these are sewage treatment plants. The City of Jefferson's treated wastewater discharge is probably the most significant due to its proximity to the lake and its relatively high loading of BOD_5 and nutrients. The average BOD_5 load from this facility between February 1974 and January 1975 was 158.8 lbs/day (2). The average inorganic nitrogen and orhto-phosphate loads were 11.3 and 64.5 lbs/day respectively (3). The Cities of Hugh Springs and Gilmer discharge relatively high loads of BOD_5 and nutrients, but since they are located far from the lake near the periphery of its drainage basin, their effects are probably minimal. Locmere Angus Ranch and T. J. Blackburn Syrup Works reportedly made no discharge from February 1974 through January 1975 (2). BOD_5 and nutrient loadings from the remaining facilities were low.

Table 2
Permitted Wastewater Dischargers
February 1974 - January 1975

Permit No.	Name	Organic Loading lbs/day BOD_5	Nutrient Loading lbs/day NH_3-N+NO_2-N+NO_3-N	O-PO_4
01052-01	Robroy Industries	22.2	**	**
01317-01	Locmere Angus Ranch	*	*	*
01361-01	Gilmer Potteries, Inc.	<1.0	**	**
01428-01	T. J. Blackburn Syrup Works	*	*	*
10230-01	City of Naples (Sewage Treatment Plant)	20.0	2.4	6.6
10415-01	City of Hugh Springs (Sewage Treatment Plant)	18.4	75.0	105.0
10415-02	City of Hugh Springs (Sewage Treatment Plant)	<1.0	**	**
10457-01	City of Gilmer (Sewage Treatment Plant)	182.3	64.7	80.1
10646-01	City of Avinger (Sewage Treatment Plant)	4.4	8.0	9.5
10801-01	City of Jefferson (Sewage Treatment Plant)	158.8	11.3	64.5
10801-02	City of Jefferson (Sewage Treatment Plant)	**	**	**
11199-01	Diana Water Supply Corp. (Sewage Treatment Plant)	3.0	1.2	4.1
11361-01	Oak Haven Guest Home (Sewage Treatment Plant)	<1.0	<1.0	1.3

* - No discharge
** - No data available

NON-POINT SOURCES

The most probable origin of non-point source loads to the lake are septic tank effluent, forest and agricultural runoff, and runoff from oil and gas producing areas. There are numerous homes and cottages located along the periphery of the lake, many of which were observed to have malfunctioning drain fields because of poor soil percolation. Forest runoff may contribute to reduced pH levels, and small-scale agricultural activities may contribute fertilizers, pesticides and silt to the lake. Past and present production of oil and gas in the area and probable subsequent leakages could contribute to elevated concentrations of organic material and oil and grease in the sediments. Occasional elevated chloride levels could occur from oil and gas production fields located in the immediate drainage area of the lake's headwaters.

PRESENTATION OF DATA

The raw hydrological, physico-chemical, and biological data are availabe in the Texas Water Quality Board Central Office files.

HYDROLOGICAL

Most of the inflow to the lake (76%) was from Little Cypress Creek (720 cfs), Big Cypress Creek (363 cfs), and Black Cypress Bayou (600 cfs) during the time of survey (Table 3). Ninety-three percent of the remaining inflow was contributed by other tributaries such as James' Bayou, Kitchen's Creek, Picnitt Creek, and Gray's Creek. Appreciable rainfall during the previous week caused tributary discharges to be higher than normal. Water was released from Caddo Dam at a rate of 11,900 cfs.

Table 3
Hydrological Data

Station No.	Name	Method	Date	Time	Discharge, cfs
10	Little Cypress Creek	Estimated	2/19/75	1600	3.0
11	Little Cypress Creek	USGS Station*	2/20/75	0830	720.0
12	Gray's Creek	Price Meter	2/19/75	1530	66.9
13	Big Cypress Creek	USGS Station	2/18/75	1730	363.0
14	Black Cypress Bayou	USGS Station	2/19/75	1700	600.0
15	Karnack Creek	Pygmy Meter	2/19/75	1300	24.6
16	Picnitt Creek	Pygmy Meter	2/18/75	1330	65.6
17	Kitchen's Creek	Estimated	2/19/75	1830	160.0
18	James' Bayou	Estimated	2/19/75	1745	200.0
19	Tiger Branch	**	--	--	--
21	Harrison Bayou	Pygmy Meter	2/20/75	0940	13.0
					2216.1 (Total measured inflow)
20	Twelve Mile Bayou	USGS Station	2/19/75	0930	11,900 (dam release)

* - United States Geological Survey Gauging Station
** - flow measurement not possible due to inundation of creek by lake

FIELD MEASUREMENTS

Field measurements of temperature, dissolved oxygen, pH, conductivity, and alkalinity were made at each lake station (Table 4). Diurnal measurements were made at Stations 1, 6, and 9.

Depth-integrated dissolved oxygen (D.O.) concentrations ranged from 8.5 mg/l (71% of saturation) at Station 4 to 10.4 mg/l (95% of saturation) at Station 7. The average depth-integrated D.O. for all stations was 9.6 mg/l. All D.O. levels were above the minimum segment standard of 5.0 mg/l and none exceeded 100% saturation. Diurnal fluctuations at Stations 1, 6, and 9 were minimal, indicating little photosynthetically induced water quality changes.

Temperature at the nine lake stations averaged 49.9°F, which is considered normal for the season. Spatial fluctuations (45.5°F at Stations 5 and 6 to 52.7°F at Stations 1, 2, and 7) are probably due to diurnal variation in air temperature and exposure to direct sunlight.

Depth-integrated pH values ranged from 5.5 (Station 4) to 7.2 (Station 6), averaging 6.1 for all stations. Observed individual values at Stations 2, 3, and 4 (in Louisiana) were below the minimum segment standard of 6.0. Soil characteristics, forest runoff, and softness of water in most East Texas water bodies result in naturally acidic pH levels. Whether or not the low pH levels in James' Bayou are natural is not known at this time.

Conductivities were typically low, ranging from 105 umhos/cm at Stations 7 and 9 to 40 umhos/cm at Station 3. The average conductivity for all stations was 76 umhos/cm, which is typical of East Texas waters.

Alkalinities were low throughout the impoundment. Phenolphthalein alkalinity was not detected since the pH at all stations was below 8.3. Total alkalinity for the nine lake stations averaged 11 mg/l as $CaCO_3$, ranging from 3 mg/l at Station 3 to 15 mg/l at Station 9. Carbon dioxide from inorganic sources is thus very limited in Caddo Lake. However, due to their low pH and dissolved solids, most natural East Texas water bodies exhibit very low alkalinities.

Tributary field data (Table 5) did not indicate any problem areas during the survey period. Water temperatures were normal for the season, pH, and alkalinities were low as expected and dissolved oxygen concentrations were consistently high.

Table 4
Field Measurements

Station 1 — Time 0900

Depth ft.	D.O. mg/1	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	10.0	89	50.9	6.3	50	0	11
.05	10.0	89	50.9	6.3	50	--	--
10	10.0	89	50.9	6.2	50	--	--
Avg.	10.0	89	50.9	6.3	50	0	11

Station 1 — Time 1300

Depth ft.	D.O. mg/1	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	9.9	89	51.8	6.3	60	0	11
05	9.9	89	51.8	6.3	60	--	--
10	9.9	89	51.8	6.3	60	--	--
Avg.	9.9	89	51.8	6.3	60	0	11

Station 1 — Time 1800

Depth ft.	D.O. mg/1	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	9.9	90	52.7	6.4	55	0	11
05	10.0	91	52.7	6.4	55	--	--
10	10.0	91	52.7	6.4	55	--	--
Avg.	10.0	91	52.7	6.4	55	0	11

Table 4 (cont.)

Field Measurements

Station 2 — Time 1445

Depth ft.	D.O. mg/l	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	10.0	93	53.6	6.1	55	0	9
05	9.5	87	52.7	5.9	55	--	--
10	9.3	84	51.8	5.9	50	--	--
Avg.	9.6	88	52.7	6.0	53.3	0	9

Station 3 — Time 1030

Depth ft.	D.O. mg/l	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	9.4	84	50.9	5.6	40	0	3
05	9.3	83	50.9	5.6	40		
10	9.3	83	50.9	5.7	40		
Avg.	9.3	83	50.9	5.6	40	0	3

Station ____ — Time ____

Depth ft.	D.O. mg/l	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.

Table 4 (cont.)

Field Measurements

Station 4 — Time 1040

Depth ft.	D.O. mg/l	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	8.6	72	46.4	5.5	60	0	6
05	8.5	71	46.4	5.4	60		
10	8.45	71	46.4	5.4	60		
15	8.4	71	46.4	5.6	60		
Avg.	8.5	71	46.4	5.5	60	0	6

Station 5 — Time ____

Depth ft.	D.O. mg/l	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	10.0	83	45.5	6.3	80	0	13
05	10.0	83	45.5	6.3	80		
10	10.0	83	45.5	6.3	80		
Avg.	10.0	83	45.5	6.3	80	0	13

Station ____ — Time ____

Depth ft.	D.O. mg/l	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.

Table 4 (cont.)

Field Measurements

Station 6 Time 0800

Depth ft.	D.O. mg/l	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	9.2	76	45.5	6.2	90	0	16
05	9.15	76	45.5	6.2	90		
10	9.25	77	45.5	6.2	90		
Avg.	9.2	76	45.5	6.2	90	0	16

Station 6 Time 1255

Depth ft.	D.O. mg/l	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	9.4	80	47.3	6.1	105	0	13
05	9.3	79	47.3	6.1	105		
10	9.2	78	47.3	6.1	105		
15	9.2	78	47.3	6.1	105		
Avg.	9.3	79	47.3	6.1	105	0	16

Station 6 Time 1735

Depth ft.	D.O. mg/l	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	9.5	81	47.3	7.25	100	0	13
05	9.3	79	47.3	7.25	100		
10	9.3	79	47.3	7.15	100		
Avg.	9.4	80	47.3	7.2	100	0	13

Table 4 (cont.)

Field Measurements

Station 7							Time 1230
Depth ft.	D.O. mg/1	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	10.4	95	52.7	6.4	105	0	14
05	10.3	94	52.7	6.4	105		
10	10.4	95	52.7	6.4	105		
Avg.	10.4	95	52.7	6.4	105	0	14

Station 8							Time 1100
Depth ft.	D.O. mg/1	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	9.5	85	50.9	6.2	90	0	13
05	9.5	85	51.0	6.2	90		
Avg.	9.5	85	51.0	6.2	90	0	13

Station							Time
Depth ft.	D.O. mg/1	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.

Table 4 (cont.)

Field Measurements

Station 9 Time 0725

Depth ft.	D.O. mg/1	D.O. %Sat.	Temp. F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	10.1	90	51.0	6.4	100	0	14
10	10.1	91	51.8	6.5	100		
20	10.2	92	52.0	6.4	100		
30	9.9	89	52.0	6.4	100		
Avg.	10.1	90.5	51.7	6.4	100	0	14

Station 9 Time 1320

Depth ft.	D.O. mg/1	D.O. %Sat.	Temp. F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	10.0	89	51.0	6.4	110	0	15
10	10.0	89	51.0	6.4	110		
20	10.0	89	51.0	6.4	110		
30	9.6	86	51.0	6.5	110		
Avg.	9.9	88	51.0	6.4	110	0	15

Station 9 Time 1730

Depth ft.	D.O. mg/1	D.O. %Sat.	Temp. °F	pH	Cond. umhos /cm	Alk. Phen.	Alk. Tot.
01	10.3	93	51.8	6.5	105	0	15
10	10.3	93	51.8	6.5	105		
20	10.3	93	51.8	6.45	105		
30	10.4	94	51.8	6.45	105		
Avg.	10.3	93	51.8	6.5	105	0	15

Table 5
Tributary Field Measurements

Station No.	Name	Alkalinity, mg/l as $CaCO_3$ Phen.	Alkalinity, mg/l as $CaCO_3$ Total	Temp, °F	pH units	Dissolved oxygen mg/l	Dissolved oxygen %sat.
10	Little Cypress Creek	0	12	52	5.7	11.1	100
11	Little Cypress Creek	0	14	48	6.2	9.6	83
12	Gray's Creek	0	14	51	6.5	10.5	94
13	Big Cypress Creek	0	18	51	6.7	12.1	108
14	Black Cypress Bayou	0	14	52	6.1	10.4	94
15	Karnack Creek	0	14	49	--	11.3	99
16	Picnitt Creek	0	1	52	6.4	10.8	97
17	Kitchen Creek	0	8	50	5.3	10.2	90
18	James' Bayou	0	16	52	6.2	10.1	91
19	Tiger Branch	2	74	58	8.0	10.5	102
20	Twelve Mile Bayou	0	7	49	6.3	10.5	92
21	Harrison Bayou	0	34	48	6.9	10.9	94

LABORATORY WATER ANALYSES

Chemical analyses of lake water samples (Table 6) indicated good water quality at all stations. Acidic pH and very low conductivity, total dissolved solids, sulfate, and chloride values at all stations are characteristic of natural East Texas waters. No areas of excessive accumulations of organic material, as indicated by BOD_5, VSS, and TOC, were apparent. Ammonia, nitrite, and nitrate nitrogen concentrations were low throughout the lake, as were ortho-phosphate and total phosphate levels. Both nitrogen and phosphorus concentrations were below the levels considered conducive for nuisance growths of aquatic vegetation in Texas waters (4). Total suspended solids (TSS) were detectable at only one station (Station 3). The concentration was low (11 mg/l).

Tributary chemical analyses revealed acceptable water quality at most stations, as indicated by low concentrations of conservative substances, organic material, nutrients and suspended solids. Total phosphates were highest (0.39 mg/l) in Gray's Creek (Station 12), while Tiger Branch in Louisiana (Station 19) supported the highest conductivity (1127 umhos/cm), total dissolved solids (564 mg/l), BOD_5 (4.0 mg/l), total suspended solids (22 mg/l), chlorides (266 mg/l), and total organic carbon (14 mg/l). The cause for these somewhat elevated values is not known; however, their impact upon the water quality of Caddo Lake is evidently minimal.

Table 6
Laboratory Analytical Results - Water

Parameter	Station Number																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
pH, units	6.8	6.7	6.4	6.1	6.4	6.6	6.5	6.4	6.6												
Cond., µmhos/cm	80	83	69	63	83	103	107	95	106	59	150	88	119	44	196	66	120	100	1127	96	150
TDS, mg/l	40	42	35	32	42	52	54	48	53	30	75	44	55	22	98	33	60	50	564	48	75
BOD_5, mg/l	3.0	1.5	3.0	2.0	2.5	1.0	2.0	2.5	2.5	1.5	2.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	3.0	2.0
NH_3-N, mg/l	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
NO_2-N, mg/l	0.01	.01	.01	<.01	<.01	0.01	0.01	0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
NO_3-N, mg/l	<.02	<.02	<.02	<.02	<.02	<.02	<.02	.02	<.02	0.18	<.02	0.02	<.02	<.02	<.02	0.03	0.04	<.02	<.02	<.02	0.04
Kjel-N, mg/l	0.4	0.4	0.6	0.3	0.4	0.3	0.3	0.2	0.3	0.2	0.4	0.2	0.3	0.3	0.2	0.2	0.2	0.3	0.6	0.4	0.3
O-PO_4, mg/l	0.03	<.03	<.03	<.03	<.03	0.03	0.03	<.03	<.03	<0.03	0.05	0.12	<.03	0.05	0.03	<.03	0.03	<.03	<.03	0.03	0.06
T-PO_4, mg/l	0.14	0.11	0.11	0.07	0.11	0.09	0.11	0.11	0.11	<0.03	0.14	0.39	0.07	0.13	0.12	0.07	0.05	0.09	0.20	0.14	0.15
TSS, mg/l	<10	<10	11	<10	<10	<10	<10	<10	<10	<10	10	13	<10	10	15	<10	<10	<10	22	14	14
FSS, mg/l	<10	<10	7	<10	<10	<10	<10	<10	<10	<10	6	9	<10	6	12	<10	<10	<10	16	8	10
VSS, mg/l	<10	<10	4	<10	<10	<10	<10	<10	<10	<10	4	4	<10	4	3	<10	<10	<10	6	6	4
$SO_4^{=}$, mg/l	11	13	5	5	13	15	15	14	16	14	17	14	19	7	40	9	6	6	9	10	17
Cl^-, mg/l	10	9	14	12	10	13	13	13	13	6	28	10	13	4	21	7	28	22	266	15	28
TOC, mg/l	11	8	13	11	9	8	8	7	7	2	8	5	8	7	7	8	7	7	14	11	6

SEDIMENT ANALYSES

Sediment samples were obtained from each lake station. Visual examination revealed a dark gray to black color with a thin layer of lighter colored (red-brown) silt on top. Organic detritus (decomposing plant material) was abundant in most samples due to a large amount of vegetation in the lake (Cypress trees with spanish moss and aquatic macrophytes). Most samples also had a slight hydrogen sulfide odor due to anaerobic decomposition of the organic material.

Chemical

All sediments except those at Stations 7 and 9 had high contents of organic material (Table 7). COD and volatile solids (parameters which indicate the amount of organic material) at these stations were above the mean values reported for all Texas reservoirs studied in the intensive monitoring program, as were total phosphates and Kjeldahl nitrogen (5). Highest values of COD (265,000 mg/kg) and volatile solids (22%) were found at Station 8. Heavy concentrations of rooted macrophytes (Cabomba sp. and Ceratophyllum sp.) were found growing at this station. The plant material itself, as well as various stages of its decomposition, was evidently the reason for such high values. Station 4 exhibited the next highest values of COD (238,300 mg/kg) and volatile solids (18.3%) and by far the highest level of oil and grease (21,500 mg/kg). Since heavy concentrations of rooted macrophytes were not found at this station, the cause for the observed levels is not known. However, oil production in the past and subsequent leakages could contribute to these highest observed levels. The remaining stations exhibited levels of chemical parameters typical of sediments with a large amount of decomposing plant material.

Table 7
Sediment Chemical Analytical Results

Parameter	1	2	3	4	5	6	7	8	9
COD, mg/kg	79,020	88,300	115,980	238,300	117,300	90,300	68,100	265,000	28,600
$T\text{-}PO_4$, mg/kg	2,000	1,800	2,400	3,200	2,900	2,800	1,300	5,300	1,300
Kjel-N, mg/kg	3,250	2,540	3,020	6,080	3,990	2,210	1,490	8,650	500
Volatile Solids, %	8.7	9.6	11.0	18.3	11.8	9.3	6.6	22.0	3.5
Oil & Grease mg/kg	2,500	3,500	2,500	21,500	4,200	2,400	2,000	6,800	530

Pesticides

No pesticides were detected at any lake station (Table 8). PCB's, however, were found at all stations. PCB's are industrial chemicals formerly used as sealers, plasticizers, dielectrics, and lubricants, and in heat transfer media, asphaltic materials, and hydraulic and grinding fluids. They exhibit toxic properties similar to DDT and are reportedly widespread in the environment. (6)

Station 4 (in Louisiana) had the highest level of PCB's (115 ug/kg). The levels observed at the remaining stations were similar to those found in Lake O' the Pines (located on Big Cypress Creek upstream of Caddo Lake) (7). Since the biological significance of PCB's in sediment has not been determined, it is not known if the levels found in Caddo Lake are acceptable. The average level for PCB's throughout the lake (48.3 ug/kg) is the second highest of 31 reservoirs studies to date in the intensive monitoring survey program.

Table 8
Sediment Pesticides Concentrations
ug/kg

Parameter	Station Number 1	2	3	4	5	6	7	8	9
Silvex	*	*	*	*	*	*	*	*	*
Aldrin	*	*	*	*	*	*	*	*	*
Chlordane	*	*	*	*	*	*	*	*	*
DDD	*	*	*	*	*	*	*	*	*
DDE	*	*	*	*	*	*	*	*	*
DDT	*	*	*	*	*	*	*	*	*
Diazinon	*	*	*	*	*	*	*	*	*
Dieldrin	*	*	*	*	*	*	*	*	*
Endrin	*	*	*	*	*	*	*	*	*
Heptachlor	*	*	*	*	*	*	*	*	*
Heptachlor Epoxide	*	*	*	*	*	*	*	*	*
Lindane	*	*	*	*	*	*	*	*	*
Methoxychlor	*	*	*	*	*	*	*	*	*
Methyl Parathion	*	*	*	*	*	*	*	*	*
Parathion	*	*	*	*	*	*	*	*	*
Toxaphene	*	*	*	*	*	*	*	*	*
PCB's	18.0	46.0	57.0	115.0	38.0	45.0	41.0	54.0	21.0

* - indicates pesticide was not detected

Heavy Metals

As shown in Table 9, values for chromium, mercury, and nickel at all stations were below those levels reported for natural soils (8). Values for arsenic, cadmium, copper, manganese, and silver only slightly exceeded the average levels reported for natural soils and are comparable to levels observed in other Texas reservoirs (5). Lead and zinc exceeded the reported natural soil levels (10 and 50 mg/kg, respectively) at all stations. Station 4 had the highest level of lead (47 mg/kg), and Stations 4 and 8 both had the highest zinc levels (170 mg/kg). The causes and effects of these apparently elevated levels of lead and zinc in Caddo Lake are unknown.

Table 9
Sediment Heavy Metals Concentrations
mg/kg

Parameter	Station Number									
	1	2	3	4	5	6	7	8	9	Bowen (8)
Arsenic (As)	4.1	6.3	<1	7.1	5.3	1.4	2.6	8.2	1.2	6
Cadmium (Ca)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.7	<0.5	0.06
Copper (Cu)	23	19	14	19	12	9.0	4.7	16	6.0	20
Chromium (Cr)	18	21	23	23	25	17	11	26	12	100
Lead (Pb)	23	29	36	47	32	41	20	26	12	10
Manganese (Mn)	990	1100	1100	820	1500	720	330	700	590	850
Mercury (Hg)	0.09	0.11	0.16	0.21	0.12	0.14	0.10	0.22	0.05	0.03-0.8
Nickel (Ni)	25	29	26	28	28	16	12	33	15	40
Silver (Ag)	0.6	1.0	1.4	1.6	1.1	0.5	0.5	0.9	<0.5	0.1
Zinc (Zn)	110	110	120	170	130	96	88	170	71	50

BIOLOGICAL

Collections of biological field data were made during this survey realizing that optimal biological growing conditions did not prevail. Biological parameters are more useful when data are collected throughout at least one seasonal cycle. Their inclusion in this report, however, is to assess immediate or potential problem areas which may require further investigation and to provide data for evaluation of long-term cause and effect relationships of water quality.

Chlorophyll a

Chlorophyll a analyses are used as indicators of phytoplankton standing crop. Detectable levels (≥0.004 mg/l) were found at all lake stations except Station 3 (Table 10). The maximum level was 0.011 mg/l at Station 5, and the average was 0.007 mg/l for the lake. These levels are relatively low and are considered indicative of mesotrophic waters (9).

Tributary chlorophyll a levels were lower than those of the lake. Undetectable levels (<0.004 mg/l) were found at eight of the twelve stations, and the remaining four were relatively low. These data indicate sparse phytoplankton standing crops in the Caddo Lake tributaries.

Table 10
Chlorophyll a Concentrations

Station Number	Chlorophyll a mg/l
1	0.007
2	0.007
3	<0.004
4	0.006
5	0.011
6	0.007
7	0.009
8	0.006
9	0.007
10	<0.004
11	0.007
12	<0.004
13	0.007
14	<0.004
15	<0.004
16	<0.004
17	<0.004
18	<0.004
19	0.006
20	0.007
21	<0.004

Phytoplankton

Phytoplankton assemblages in Caddo Lake were very diverse and were composed of green algae and diatoms in roughly equal proportions (Table 11). The green algae *Micrasterias* and *Scenedesmus* and the diatoms *Melosira*, *Diploneis*, and *Pleurosigma* were found at all lake stations. *Micrasterias* (as well as *Euastrum*, *Closterium*, and *Cosmarium*, which were present at most stations) is included in the green algae family Desmidiaceae (desmids), which are commonly found in soft, acidic East Texas waters (10). *Scenedesmus* is a green alga commonly found in Texas reservoirs. *Melosira*, the most abundant algal genus encountered during this survey, and *Synedra*, which was present at most stations, are diatoms associated with murky waters such as Caddo Lake (10). Most Texas reservoirs are favorable for the growth and proliferation of diatoms because their trubidity is due to colloidal clay containing an aluminum silicate compound which furnishes the necessary silica, along with the inorganic phosphorus necessary for their growth (10).

Several algal genera (*Pinnularia*, *Ankistrodesmus*, and *Micrasterias*) recognized as clean water types were present, while none associated with polluted water were found (11). Generic composition suggests that organic pollution of the lake is not high (12). Phytoplankton densities, expressed as the total number of individuals per milliliter, were not unusually high at any station. Numbers of individuals for each genus were relatively low and the number of genera encountered at each station was relatively high. Thus, the species diversities ($\bar{d}$) were high (>3.0) at all stations, which indicates the phytoplanktonic community in Caddo Lake was well-balanced and stable during the study period (13).

Table 11
Phytoplankton Analyses

Station Number	1	2	3	4	5	7	8	9
No. Individuals/ml	525	435	465	435	705	450	540	525
Diversity Index ($\bar{d}$)	3.48	3.27	3.45	3.09	3.61	3.33	3.04	3.35
Organisms								
CHLOROPHYTA (Green Algae)								
Actinastrum	30	45	15	15	60		15	
Micrasterias	15	15	15	30	30	30	30	15
Euastrum	15	15	15	15	15	15		15
Selenastrum	75	30	45			60		
Closterium	15		15		60		30	15
Cosmarium	30	15	30	30	15	15		
Crucigenia	60	30	15		45	30	30	45
Coelastrum		15		15	60			15
Oocystis	15		15				15	45
Scenedesmus	60	45	75	60	75	75	90	75
Ankistrodesmus				30			15	
Gonium					15	30		30
Eudornia								30
CHRYSOPHYTA BACILLARIOPHYCEAE (Diatoms)								
Melosira	120	135	105	150	195	105	210	150
Synedra	15	30	45	15	30	15		
Diploneis	15	15	15	30	15	15	30	15
Pinnularia	15			15	15	15	15	
Caloneis	30	15	30		30		15	30
Pleurosigma	15	30	30	30	15	30	15	15
Epithemia					15		15	
Stephanodiscus					15			
Gyrosigma						15	15	30

Bacteria

Bacteriological analyses for fecal coliforms revealed relatively low concentrations in both the lake and its tributaries (Table 12). None of the lake densities approached the segment standard of 200/100 ml although the standard is based on the geometric mean of at least five individual samples collected within a 30 day period. These results indicate that contamination of the lake by warm-blooded animals is not excessive.

Table 12
Fecal Coliform Concentrations

Station Number	Fecal Coliform No./100 ml
1	8
2	6
3	<1
4	4
5	14
6	22
7	42
8	4
9	72
10	158
11	8
12	86
13	22
14	136
15	292
16	116
17	78
18	142
19	56
20	42
21	192

Algal Assay

An algal growth study was accomplished to provide an estimation of the growth potential of the lake and the effects of added nitrogen and phosphorus on algal production. A test culture of the green alga *Selenastrum capricornutum* was added to filtered lake water (controls) from Stations 1, 6, and 9. Additionally, nitrogen, phosphorus, and a combination of both were added in varying quantities to the filtered lake water.

The results of this bioassay are presented in Table 13. Algal production in the filtered lake water with no added nutrients was low at all three stations. Nitrogen additions alone resulted in no increase in algal biomass at Stations 1 and 6. At Station 9, however, the heaviest nitrogen spike, 0.75 mg/l, resulted in almost four times the biomass produced in the control. Phosphorus additions had no effect on algal production at Station 6. The heaviest phosphorus spike (0.05 mg/l) produced about twice the algal biomass of the controls at Stations 1 and 9. The intermediate phosphorus spike (0.015 mg/l) produced about the same results at Station 9. Combined nitrogen and phosphorus additions resulted in significant biomass increases over the control at all three stations. The lowest spike of both (0.75 mg/l nitrogen and 0.005 mg/l phosphorus) resulted in no biomass increase over the controls at any station. Intermediate spikes roughly doubled the biomass at all stations and the heaviest spikes almost doubled the biomass at Station 1, but roughly quadrupled the biomass at Stations 6 and 9.

The results of this algal assay indicate that algal growth at Station 1 is primarily phosphorus limited, and at Stations 6 and 9 it is limited by both nitrogen and phosphorus. Neither nitrogen nor phosphorus additions alone resulted in significant biomass increases at Station 6, although both separate additions produced significant increases at Station 9. Thus, during the time of survey, it appears that both nitrogen and phosphorus were limiting in Caddo Lake for algal production.

Table 13
Algal Assay Results
(14 Day Growth)

Treatment	Selenastrum capricornutum		
	Dry Weight Biomass, mg/l		
	Station 1	Station 6	Station 9
Control	4.5 ± 0.4	3.8 ± 0.5	3.0 ± 0.3
0.005 mg/l P added	4.0	3.6	3.6
0.015 mg/l P added	5.2	4.3	6.8
0.05 mg/l P added	8.3	4.2	7.0
0.075 mg/l N added	4.3	3.4	3.3
0.225 mg/l N added	4.8	3.6	3.3
0.75 mg/l N added	4.6	3.7	11.0
0.005 mg/l P + 0.075 mg/l N	4.7	3.8	3.5
0.015 mg/l P + 0.225 mg/l N	6.2	7.4	5.8
0.05 mg/l P + 0.75 mg/l N	7.8	15.1	11.4

RELATED TEXAS WATER QUALITY BOARD ACTIVITIES

Several activities presently underway by the Texas Water Quality Board have direct influence on the protection of water quality of Caddo Lake.

WASTE LOAD EVALUATIONS

A waste load evaluation of Caddo Lake has been performed by the Modeling and Engineering Technology Section of the Texas Water Quality Board (14). Since there are no actual wastewater discharges in the segment, a water quality model and waste load allocation were not necessary. The segment had been classified water quality limiting based on a single dissolved oxygen violation of 4.2 mg/l. The waste load evaluation recommended that Segment 0401 be reclassified as effluent limiting since no recent dissolved oxygen violations have occurred.

TWQB PERMITS AND REGISTRATIONS; NPDES PERMITS

All wastewater dischargers and confined feeding operations are required to have a permit or registration from the Texas Water Quality Board and an NPDES (National Pollutant Discharge Elimination System) permit from the Environmental Protection Agency. These documents place restrictions on the quantity and quality of wastewater that can be released to the receiving stream.

COMPLIANCE INSPECTIONS

Personnel from the Texas Water Quality Board District 5 Office in Kilgore will make periodic inspections of all waste sources in the segment to confirm that the quality of effluent and retention facilities are in compliance with the Texas Water Quality Board and NPDES permits.

STREAM MONITORING

Personnel from the Texas Water Quality Board District 5 Office will continue to monitor water quality of Caddo Lake near Station 6 (TWQB Stream Monitoring Station 0401.0100) on a quarterly basis. The major tributaries on the Texas side will also continue to be monitored on a quarterly basis. These are: Little Cypress Creek at US 59 south of Jefferson (Stream Monitoring Station 0400.0300), Black Cypress Creek at US 59 north of Jefferson (Stream Monitoring Station 0400.0400, Station 14 for this survey), and Cypress Creek at State Highway 43 above Caddo Lake (Stream Monitoring Station 0402.0100, near Station 9 for this survey).

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APPENDIX A

FIELD AND LABORATORY PROCEDURES

The following methods are utilized for field and laboratory determinations of specified physical and chemical parameters. Unless otherwise indicated composite water samples are collected at each sampling station and stored in polyethylene containers on ice until delivery to the laboratory. Sediment samples are collected with a dredge or coring device, decanted, mixed, placed in appropriate containers (glass for pesticides analyses and plastic for metals analyses), and stored on ice until delivery to the laboratory. Laboratory chemical analyses are conducted by the Water Chemistry Laboratory of the Texas Department of Health Resources unless otherwise noted.

WATER ANALYSES

Field Measurements

Parameter	Method
Temperature	Hand mercury thermometer or temperature probe of Hydrolab Model 60 Surveyor.
Dissolved Oxygen	Azide modification of Winkler titration method or oxygen probe attachment of Hydrolab Model 60 Surveyor.
pH	Hydrolab Model 60 Surveyor or Sargent-Welch portable pH meter.
Conductivity	Hydrolab Model 60 Surveyor or Hydrolab TC-2 conductivity meter.
Alkalinity	Titration as described in "Standard Methods for the Examination of Water and Wastewater" 13th Ed., using phenolphthalein and methyl red/bromcresol green indicators.

Laboratory Analyses

Parameter	Method
BOD_5	Membrane electrode method(1).
TSS	Gooch crucibles and glass fiber discs(1).
VSS	Gooch crucibles and glass fiber discs(1).
Kjel-N	Micro-Kjeldahl digestion and automated colorimetric phenate method(2).
NH_3-N	Distillation and automated colorimetric phenate method(2).
NO_2-N	Colorimetric method(1).
NO_3-N	Automated cadmium reduction method(2).
T-PO_4	Persulfate digestion followed by ascorbic acid method(1).
O-PO_4	Ascorbic acid method(1).
Sulfates	Turbidimetric method(1).
Chlorides	Automated thiocyanate method(2).
TDS	Evaporation at 180"C(2).
TOC	Beckman TOC analyzer.
Conductivity	Wheatstone bridge utilizing 0.01 cell constant(1).
BOD_{1-7}*	Membrane electrode method(1).
Chlorophyll <u>a</u>	Trichromatic method(1).
Pheophytin <u>a</u>	Pheophytin correction method(1).

* For significant wastewater discharges only.

SEDIMENT ANALYSES

Field Measurements

Immediate Dissolved Oxygen Demand (IDOD)

$$mg/l\ IDOD = \frac{D_oP - D_1}{P}$$

where D_o = D.O. of original dilution water

$$p = \frac{\text{dilution water used (ml)}}{\text{volume of BOD bottle (ml)}}$$

$$p = \frac{\text{amount of sample used (ml)}}{\text{volume of BOD bottle (ml)}}$$

D_1 = D.O. of diluted sample 15 min. after preparation using membrane electrode method

Laboratory Analyses

Parameter	Method
Arsenic	Colorimetric
Mercury	Potassium permanganate digestion followed by atomic absorption(3).
All other metals	Atomic absorption(3).
Volatile Solids	Ignition in a muffle furnace.
COD	Dichromate reflux method.
Kjel-N	Micro-Kjeldahl digestion and automated colorimetric method(2).
$T\text{-}PO_4$	Ammonium molybdate(3).
Pesticides	Gas chromatographic method(4).

BACTERIOLOGICAL

Bacteriological samples are collected in sterilized glass bottles provided by the Texas Department of Health Resources and stored on ice until delivery to the laboratory or until cultures are set up by survey personnel (within 6 hours of collection). Bacteriological analyses are conducted by survey personnel or a suitable laboratory in the survey area.

Parameter	Method
Total Coliform	Membrane filter method(1)
Fecal Coliform	Membrane filter method(1)
Fecal Streptococci	Membrane filter method(1)

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates are collected with a Surber sampler (1.0 ft.^{2}) in riffle areas and with an Ekman dredge (0.25 ft.^{2}) in pool areas. Samples are preserved in 10% formalin in the field and stained with Rose Bengal. They are later sorted according to taxa and counted in the laboratory.

Analysis of diversity is accomplished with a computer program adopted from Wilhm(5) for use on the Univac 1106 computer operated by the Texas Water Development Board. The program computes the diversity index, d, for each sample using the following equation:

$$\bar{d} = -\sum_{1}^{s} (ni/n) \log_2 (ni/n)$$

where n = total number of organisms, ni = number of individuals per taxon, s = number of taxa and $\bar{d}$ = diversity.

The number of individuals per square foot is determined by dividing the total number of individuals by the area sampled.

PLANKTON

Phytoplankton

Phytoplankton samples in streams (which are usually vertically mixed) are collected beneath the water surface in quart polyethylene containers. Sampling stations are generally located both upstream and downstream from pollution sources and care is taken to preclude confusing interferences such as contributions of plankton from reservoirs, from backwater areas, scouring of periphyton from the streambed, etc.

Phytoplankton samples from reservoirs are collected with a tube device in which sample collection is integrated from the surface to depth of the euphotic zone (3 times Secchi disc measurement). In cases where the euphotic zone depth is greater than the tube length, samples are collected with an appropriate water sampler at depths evenly spaced from the surface to the bottom of the euphotic zone. These samples are composited and stored in quart containers.

Phytoplankton samples collected during both stream and reservoir surveys are preserved in the field in a final concentration of 3 to 5 percent buffered formalin. The samples are returned to the laboratory and stored in the dark until microscopic examination is completed. Prior to examination, the samples are concentrated utilizing sedimentation chambers. Identification and enumeration of phytoplankton is conducted with an inverted microscope utilizing standard techniques. The diversity index ($\bar{d}$) is calculated as described previously.

Zooplankton

Zooplankton are concentrated at the site by either filtering a known volume of water through a No. 20 mesh standard Wisconsin plankton net or vertically towing the net a known distance. Concentrated samples are preserved in a final concentration of 5% formalin. The organisms are identified to the lowest taxonomic level possible and counts are made utilizing a Sedgwick-Rafter cell. Diversity is calculated as described previously.

NEKTON

Nekton samples are collected by the following methods(1):

Common-sense minnow seine	- 20' x 6' with 1/4" mesh
Otter trawl	- 12' with 1 3/16" outer mesh and 1/2" mesh liner
Chemical fishing	- rotenone

Experimental gill nets	- 125' x 8' (five 25' sections ranging in mesh size of 3/4" to 2 1/2")
Electrofishing	- backpack and boat units (both equipped with AC or DC selection). Boat unit is equipped with variable voltage pulsator.

These organisms are collected to determine: (1) species present, (2) relative and absolute abundance of each species, (3) size distribution, (4) condition, (5) success of reproduction, (6) incidence of disease and/or parasitism, (7) palatability, and/or (8) presence or accumulations of toxins.

Nekton collected for palatability are iced or frozen immediately. Samples collected for heavy metals analyses are placed in leak-proof plastic bags and placed on ice. Samples collected for pesticides analyses are wrapped in aluminum foil, placed in a water proof plastic bag and placed on ice.

As special instances dictate, specimens necessary for positive identification, parasite examination, etc., are preserved in 10% formalin containing 3 grams borax and 50 ml glycerin per liter. Specimens over 7.5 cm in length are slit at least one-third of the length of the body to enhance preservation of the internal organs. Other specimens are weighed and measured before being returned to the reservoir or stream.

ALGAL ASSAYS

The algal assay procedure was adapted from the "Algal Assay Procedure Bottle Test".(6) The water samples used for the algal assay are composite samples collected from the euphotic zone. They are stored in polyethylene containers on ice for transport to the laboratory.

Upon delivery the samples are autoclaved (15 psi; 250°F, 10 min./l). After autoclaving and cooling, they are allowed to equilibrate by bubbling air to restore the carbon dioxide lost during autoclaving.

The water is then distributed in 60 ml aliquots in 125 ml Erlenmeyer flasks. Appropriate amounts of sodium nitrate and potassium phosphate dibasic solutions are added separately or in combination to the test flasks to arrive at final concentrations of 0.005, 0.015, 0.050 mg P/l for the phosphorus spikes, 0.075, 0.225, 0.750 mg N/l for the nitrogen spikes and 0.005 mg P/l + 0.075 mg N/l, 0.015 mg P/l + 0.225 mg N/l, 0.050 mg P/l + 0.750 mg N/l for the combined spikes. No nutrients are added to the control flasks.

Finally, all the flasks are seeded with a 7 day old culture of <u>Selenastrum capricornutum</u> to give a final concentration of 5×10^3 cells/ml. The stock culture of <u>Selenastrum capricornutum</u> obtained from the National Eutrophication Research Program, Corvallis, Oregon is maintained in the laboratory.

The cultures are incubated for 14 days in a reach-in incubator (Hotpack Corporation). The temperature is maintained at 24 ± 2°C, and continuous, 400 ft.-c illumination is provided by 40 watt cool-white fluorescent lights.

After 14 days, the biomass dry weight is obtained by filtering the algal suspension through a prewashed tared Reeve Angel glass filter (AH-934). The filters are dried for 16 to 21 hours at 110°C then cooled in a dessicator and weighed.

PRODUCTIVITY/RESPIRATION

Two methods are utilized to estimate productivity and respiration in the study area. In areas where restricted flow produces natural or artificial ponding of sufficient depth, standard light bottle-dark bottle techniques are used. In flowing water the diurnal curve analysis described by Odum(7) is utilized.

Light Bottle-Dark Bottle Analyses

The light and dark bottle technique is used to measure net production and respiration in the euphotic zone of a lentic environment. The depth of the euphotic zone is considered to be three times the Secchi disc transparency ($3 \times Z_{SD}$). This region is subdivided into three sections. Duplicate light bottles (300 ml BOD bottles) and dark bottles (300 ml BOD bottles covered with electrical tape, wrapped in aluminum foil and enclosed in a plastic bag) are filled with water collected from the mid-point of each of the three vertical sections, placed on a horizontal metal rack and suspended from a flotation platform to the mid-point of each vertical section. The platform is oriented in a north-south direction to minimize shading of the bottles. An additional BOD bottle is filled at each depth for determining initial dissolved oxygen concentrations (modified Winkler method). The bottles are allowed to incubate for a varying time interval, depending on the expected productivity of the waters. A minimum of four hours incubation is considered necessary.

The following equations are used to calculate respiration and photosynthesis:

(1) For plankton community respiration (R), expressed as mg/l 0_2/hour

$$R = \frac{DO_I - DO_{DB}}{\text{Hours incubated}}$$

where DO_I = initial dissolved oxygen concentration.

and DO_{DB} = average dissolved oxygen concentration of the duplicate dark bottles.

(2) For plankton net photosynthesis (P_N), expressed as mg/l 0_2/hour

$$P_N = \frac{DO_{LB} - DO_I}{\text{Hours incubated}}$$

where DO_{LB} = average dissolved oxygen concentration of the duplicate light bottles.

(3) For plankton gross photosynthesis (P_G), expressed as mg/l 0_2/hour

$$P_G = P_N + R$$

Conversions of respiration and photosynthesis may be accomplished by multiplying the depth of each of the three vertical zones (expressed in meters) by the measured dissolved oxygen levels expressed in grams/m^3. These products are added and the result is expressed as grams $0_2/m^2$/day by multiplying by the photoperiod. Conversions from oxygen to carbon may be accomplished by multiplying grams 0_2 by 12/32.

Diurnal Curve Analyses

In situations where the stream is flowing, relatively shallow, and/or contains extensive rooted macrophytes, the diurnal curve analysis adopted from Odum(7) is utilized to determine productivity and respiration. Values for productivity and respiration in grams of oxygen per square meter per day are calculated with the aid of a Univac 1106 computer operated by the Texas Water Development Board. The program includes options which provide several methods for determination of diffusion rate constants as indicated in the program listing which follows. These options are: (a) calculations from raw data as described by Odum(7), Odum and Hoskin(8), Odum and Wilson(9), and Blain and McDonnel(10), (b) substitution into various published formulas for determination of K_2, and (c) arbitrary selection of a value from tables of measured diffusion rates for similar streams.(11)

HYDROLOGICAL

Parameter	
Flow Measurement	(1) Pygmy current meter (Weather Measure Corp. Model F583) (2) gage height readings at USGS gaging stations.
Time of Travel	Tracing of Rhodamine WT dye using a Turner Model 110 fluorometer.
Stream Cross-sections	Measure average width and average depth at each mainstream station. At least 4 cross-section measurements are made in the vicinity of each mainstream station.

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APPENDIX B

Detection Levels of Heavy Metal and Pesticide Analyses (Sediment Analyses)

Parameter	Code	Detection Level
Arsenic, mg/kg	01003	<1.0
Cadmium, mg/kg	01028	<0.5
Chromium, mg/kg	01029	<1.0
Copper, mg/kg	01043	<1.0
Lead, mg/kg	01052	<1.0
Manganese, mg/kg	01053	<1.0
Mercury, mg/kg	71921	<0.01
Nickel, mg/kg	01068	<1.0
Silver, mg/kg	01078	<0.5
Zinc, mg/kg	01093	<1.0
Silver, µg/kg	39761	<20.0
Aldrin, µg/kg	39333	<1.0
Chlordane, µg/kg	39351	<20.0
DDD, µg/kg	39363	<3.0
DDE, µg/kg	39368	<2.0
DDT, µg/kg	39373	<5.0
Diazinon, µg/kg	39571	<5.0
Dieldrin, µg/kg	39383	<3.0
Endrin, µg/kg	39393	<3.0
Heptachlor, µg/kg	39413	<1.0
Heptachlor Epoxide, µg/kg	39423	<1.0
Lindane, µg/kg	39783	<1.0
Methoxychlor, µg/kg	39481	<20.0
Methyl Parathion, µg/kg	39601	<5.0
Parathion, µg/kg	39541	<5.0
Toxaphene, µg/kg	39403	<50.0
PCB, µg/kg	39519	<20.0