Water Quality in Calcasieu Lake[1]

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INTRODUCTION

The Calcasieu River Basin is located in southwestern Louisiana. Originating in headwaters in the hills west of Alexandria, Louisiana, the Calcasieu River flows generally south for about 160 miles to the Gulf of Mexico. The River mouth is at Cameron, Louisiana, approximately 30 miles east of Sabine Pass and the Texas-Louisiana state line. This paper reviews past studies of water quality in the Calcasieu River/Lake/Estuary system. Water quality in the Lake and estuarine complex are assessed using monitoring data provided by the Louisiana Department of Environmental Quality (LDEQ). Additionally, water quality within other Louisiana coastal water bodies is compared to that observed in the Calcasieu system.

There are dramatic differences in land use between the Lower Calcasieu Lake/Estuary system (the lower 40 miles below the Saltwater Barrier) and the upper riverine system. Overall land use in the Calcasieu Basin (LDEQ, 1990) is 50.8% forest, 26.4% agriculture, 11.8% wetland, 2.6% urban, and 5.7% water. LDEQ divides the basin into subsegments. For example, LDEQ subsegment 04, located in the Lower Calcasieu Basin, includes Calcasieu Lake. Land use in subsegment 04 is 46.3% water, and 43.2% wetland. Thus, land use in the most southern region of the basin is markedly different from that in the upper basin.

A number of water quality studies have been performed within the Lower Calcasieu Basin. These studies are not exhaustively cited or reviewed here, however, a selected number are included to provide an indication of their diversity, and to suggest the need for additional studies. Lafleur (1956) reports chemical data from the upper section of the River collected during 1950 and 1955, and biological data from 1951 and 1955. Denoux (1976) analyzed plankton communities and incorporated selected water quality analyses in his study of the Lower Calcasieu from June 1974 to December 1975. The U.S. Army Corps of Engineers, New Orleans District (USACOE, 1977) conducted water quality studies in 1975-76 in the Lower Calcasieu which investigating of maintenance dredgingimpacts, and include regular monitoring data taken from a site near the Saltwater Barrier. DeLaune, et al. (1984) studied nutrient levels and eutrophic state of the Lower Calcasieu. Sampling for this study was performed from March through December 1984. The Louisiana District of the U.S. Geological Survey has also performed a number of studies on circulation, environmental toxicology, and water quality of the Calcasieu River.

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[1]" **Sabine Lake Conference: Where Texas and Louisiana Come Together**," Sept. 13-14, Beaumont, Tx

The Louisiana Department of Environmental Quality performed six intensive water quality surveys on the Lower Calcasieu in July 1978, October 1978, July 1979, August 1979, July 1980, and June 1984 (Duke, 1985). These studies provided water quality and hydrological data for the entire Lower Calcasieu over short time periods. A major purpose of these studies was to provide support for water quality modeling to determine appropriate water discharge permit limitations.

An extensive study of both biological and chemical water quality was conducted by McNeese State University from October 1983 through August 1986. Sampling stations were located from the Saltwater Barrier to the mouth of the system at Cameron, Louisiana. Tributaries to the Lower Calcasieu were also sampled.

HYDROLOGY

Area and discharge

Owing to the interchange of flow between basins, boundaries of drainage areas in the lower Calcasieu Basin are uncertain. Sloss (1971) estimates the drainage area of the Calcasieu River Basin at the Gulf of Mexico to be 3,772 square miles. This compares with 20,944 square miles for the Sabine River Basin at the Gulf. Drainage areas of the lower portions of the Sabine and Calcasieu Basins are based on judgement because of the connection formed by the Intracoastal Waterway. Drainage area of the Calcasieu River above the City of Lake Charles at the Saltwater Barrier is estimated to be 3,100 square miles (Duke, 1985). Forbes (1988) classifies the “Lower Calcasieu River” as that part of the system extending from about 10 miles north of the city of Lake Charles (near the saltwater barrier) to the Gulf of Mexico. In addition to the Ship Channel from the City of Lake Charles to the Gulf of Mexico, and the Intracoastal Waterway, the dominant features of the Lower Calcasieu include a series of shallow lakes. Physical data for these lakes are presented in Table 1. For comparison, Sabine Lake and Toledo Bend Reservoir are also listed in this table.

Freshwater discharge enters the Lower Calcasieu primarily from the Calcasieu River. The U.S.G.S. discharge monitoring station at Kinder on the Calcasieu River (station No. 08015500, 1700 square miles drainage area) is most commonly used to characterize freshwater contribution to the Lower Calcasieu. Based on a drainage area ratio, the freshwater discharge entering the Lower Calcasieu from the Calcasieu River at Lake Charles would be 82% larger than the discharge monitored at Kinder. Annual and monthly average discharge at the Kinder station are graphed in Figure 3. Maximum and minimum discharges over the period of record are 182,000 and 136 cfs respectively. Statistics including the 7Q10 flow (minimum annual 7-day average flow recurring once in 10 years) , the 10, 30, 50, 70, and 90 percentile flows, minimum and maximum daily flows over the period of record are listed in Table 2 (Forbes, 1988). For comparison, statistics for the Sabine river near Ruliff, Texas (station number 08030500, 9329 square miles drainage area, water years 1967-95, USGS, 1995), are also presented in this table. Retention time of the Lower Calcasieu is roughly 33 days at mean discharge, and 420 days at 7Q10.

The Lower Calcasieu is subject to tides from the Gulf (Forbes, 1988). The diurnal tide range at the mouth is approximately 2 feet, and are slightly attenuated at the Saltwater Barrier. Above the Saltwater Barrier, tides stages are small but detectable. Wind, rather than tide, causes the extreme stage events in the Lower Calcasieu, with stages at the City of Lake Charles falling several feet below sea level during sustained winds out of the north.

History of hydrological modification

The hydrology of the Lower Calcasieu has been modified to improve navigational access (Forbes, 1988). In the late 1800's the channel through Calcasieu Lake had a maximum depth of 13 feet, and a 3-foot depth existed across a bar at the northern end of Calcasieu Pass between Calcasieu Lake and the Gulf of Mexico. In 1871, the U.S. Army Corps of Engineers made its first report on navigation in the Calcasieu which resulted in construction of a 5-foot deep by 80-foot wide navigation channel through the bar. By the late 1930's, this 5-foot deep channel had been deepened to 13 feet.

A 30-foot deep by 125-foot wide deep-draft channel along the route of the present Intracoastal Waterway between the Sabine and Calcasieu Rivers was completed between 1937 and 1940. The present-day Gulf Intracoastal Waterway (GIWW) crosses the Calcasieu River Ship Channel just north of Calcasieu Lake. The GIWW is maintained at a depth of 12 feet and a width of 125 feet. A lock 2.5 miles east of the Ship Channel was completed in 1952, and reduces saltwater movement east toward Grand Lake.

Begun in 1941, the Calcasieu Ship Channel replaced the Lake Charles Deep Water Channel. The Ship Channel originally provided 30-foot deep by 250-foot wide access from the Gulf to the City of Lake Charles. In 1968, the channel was extended to a depth of 40 feet and a width of 400 feet. The route of the channel follows the western edge of Lake Charles. A 40 foot deep mooring basin south of Lake Charles is 350 feet wide and 2000 feet long. The thalweg elevation of the Ship Channel is generally near or below -40 feet. This depth results in dense highly saline water filling the channel trench. An upstream flow within this saltwater wedge is frequently observed replacing saltwater lost to erosion of the wedge into the overlying fresher flow.

A saltwater barrier just north of the City of Lake Charles was completed in 1968. The structure includes a navigation lock and a flood control barrier. The flood control barrier consists of 5 adjustable gates. The barrier is operated to maintain a stage of 2.5 feet on the upstream side of the structure. The purpose of the structure is to minimize movement of saltwater and particularly a saltwater wedge into the deep upstream channels.

In addition to other hydrological impacts, channel dredging has also resulted in spoil bank levees isolating channels from adjoining lakes and wetland (DeRouen and Stevenson, 1987). Although breaches have been cut in these levees, the levees still cause a directed circulation tending to channel freshwater through the Ship Channel to the Gulf without mixing. The levees also reduce enrichment of wetlands by sediments and freshwater, and potentially reduce ingress and egress of estuarine species..

WATER QUALITY

Water quality standards

The Calcasieu Basin is designated as basin number three, and is classified into twelve segments which are further classified into subsegments (LDEQ, 1996). Most of the basin has designated uses of primary and secondary contact recreation and propagation of fish and wildlife. Dissolved oxygen criteria for most of the Calcasieu River above the saltwater barrier is 5.0 mg/L. However, the upper Calcasieu River from the confluence with Marsh Bayou to the Saltwater Barrier is designated as naturally dystrophic waters, and have seasonal DO criteria of 3.5 mg/L from May through October. Under the Louisiana Natural and Scenic Rivers System, some of the upstream reaches of the Calcasieu River and tributaries above the Saltwater Barrier are classified as scenic. For segments downstream of the Saltwater Barrier, DO criteria are designated as 4 or 5 mg/L.

Toxic water quality assessment

LDEQ (1992) assesses the estimated size of waterbodies affected by toxic pollutants. It is estimated that 10.9 miles of the Calcasieu River (from buoy 112 to buoy 106, including Coon Island Loop), 1114 acres of Lake Charles, and 1083.5 acres of Prien Lake are affected by organic halogenated aliphatic and aromatic priority pollutants. Subsegments of the Calcasieu River, Calcasieu Lake, and Prien Lake are under informational fishing advisories by the Louisiana Department of Health and Hospitals (LDHH) and the LDEQ, notifying the public that priority organic contamination has been found. This joint advisory advises against fishing and consumption of seafood from the area, and against swimming, wading, and water sports in Bayou D'Inde. The source of this pollution is listed as industrial point source.

Section 304(l) of the Clean Water Act requires states to prepare lists of waterbodies which are not expected to achieve applicable water quality standards for toxic pollutants after technology based requirements have been met. Several segments of the Calcasieu Basin have been listed (LDEQ, 1992). Listed segments include Bayou Verdine (030306), Bayou D'Inde (030901), Calcasieu River and Ship Channel (030301), and Prien Lake (030303). Causes for listing include halogenated aliphatic and aromatic priority pollutant organic chemicals, and, in Bayou Verdine, phenol and nickel. Point source dischargers listed under section 304(l) include PPG, Conoco, and Vista.

Salinity

Salinity below the Saltwater Barrier is dependent on the intensity of freshwater inflow. Surface salinity is typically lowest near the Saltwater Barrier, and increase as the Gulf is approached (Duke, 1985). Typically, a "saltwater wedge" is observed in the Ship Channel. The existence of this wedge affects circulation patterns, water quality, and biological indicators of water quality.

Nutrients and eutrophication

Chlorophyll-a concentration is a common measure of algal biomass. Long-term monitoring of chlorophyll-a concentrations have not been maintained within this basin. Denoux (1976) reported average chlorophyll-a concentrations in the Lower Calcasieu to be 13.7 and 15.7 ug/L in oligohaline (<10 ppt) and medium salinity (>10 ppt) samples, respectively. Denoux found highest chlorophyll-a values in the summer of 1974 for oligohaline sites, and the fall of 1974 for the medium salinity sites, however, values observed in the summer and fall of 1975 were lower and did not follow the seasonal pattern observed in 1974. DeLaune, *et al*. (1984) report the site average values of chlorophyll-a in the Lower Calcasieu ranged from 17-21 ug/L during their sampling in 1984. Chlorophyll-a levels peaked in July 1984, with a mean of 44 ug/L, and four of 12 stations exceeding 50 ug/L. Although DeLaune, *et al*. state that determination of eutrophic state is complex, they conclude that based on phosphorus, nitrogen, and chlorophyll-a levels the Lower Calcasieu can be classified as somewhat eutrophic.

Maples (1987) reported a mean value of 26 ug/L for samples in Lake Calcasieu. In this study chlorophyll-a values were highest in winter, high in summer, and lowest in the fall. Maples found chlorophyll-a values were negatively correlated with temperature (r=-0.45), and positively correlated with conductivity (r=0.34). Maples also discusses an observed bloom of a red tide organism, *Gonyaulax monilata*.

The LDEQ measured chlorophyll-a concentrations during three of their six intensive water quality surveys of the Lower Calcasieu (Duke, 1985). Chlorophyll-a was found to range from 3 to 40 ug/L in July 1979, 10 to 30 in July 1980, and 2 to 14 in June 1984. Lowest values were observed at the saltwater barrier. In 1979 and 1980 maxima were observed midway between the Saltwater Barrier and the Gulf; in 1980, the maximum concentration was observed nearest the gulf.

In summary, chlorophyll-a concentrations in the Lower Calcasieu are highly variable. Concentrations have often been observed at levels which would be considered elevated. Regular long-term monitoring of chlorophyll-a concentration by a single agency would assist in the assessment of trophic status as well as contribute to an improved understanding of factors controlling algal abundance.

The LDEQ performs monthly monitoring of water quality parameters including nutrient levels at Burton's Landing (Figure 1). Over the past decade, annual median total phosphorus (Figure 4) and total nitrogen (Figure 5) are apparently declining at this station. For comparison, median values for the Sabine River at Orange, Texas, are also plotted in Figures 4 and 5.

Dissolved oxygen

Depth averaged concentrations of dissolved oxygen in the Lower Calcasieu are generally below saturation and display a minimum near the saltwater barrier (Duke, 1985). A second minimum, or DO sag occurs below the City of Lake Charles, and is associated with pollutant loading from point source dischargers. LDEQ monitoring data for surface (1 meter depth) DO concentration at Burton's Landing indicate that annual median concentrations have been rising over the period-of-record (Figure 6) from approximately 4 mg/L in the mid 70's to approximately 6 mg/L in the 90's. Again, median annual values from the Sabine River at Orange are plotted for comparison. Annual first and third quartile concentration values show patterns similar to the trend of the annual median concentration. This rising trend in DO may result from improved wastewater treatment from point sources in the Lower Calcasieu. Wetland water quality is often associated with organic enrichment and low DO. Rising DO in the Lower Calcasieu may, in part, also be related to reduction of water exchange with coastal wetlands due to wetland impoundment and coastal wetland loss.

Comparison of Louisiana Coastal waterbodies

Selected LDEQ coastal monitoring sites are listed in Table 2. Basins in Table 2 are listed from east to west; the LDEQ basin numbers listed here correspond to Pontchartrain (4), Barataria (2), Terrebonne (12), Vermilion (6), Mermentau (5), Calcasieu (3), and Sabine (11). Published median water quality parameters for these sites over 1992-93 are listed in Tables 3 and 4. Table 3 lists water temperature (Temp), pH (pH), dissolved oxygen concentration (DO), temperature compensated conductivity (Cond), chloride concentration (Cl), turbidity (Turb), secchi disk depth (Secchi), and total dissolved solids (TDS). Table 4 lists total organic carbon (TOC), total phosphorus (TP), nitrite plus nitrate nitrogen (NOx), total Kjeldahl nitrogen (TKN), total nitrogen (TN), and the mass ratio of TN to TP (TN:TP). Total nitrogen is the sum of NOx and TKN. In comparison to other coastal sites, the Lower Calcasieu sites, (CRLC and CRBL) exhibit low dissolved oxygen and intermediate nutrient levels.

Pollution sources

The Lower Calcasieu Basin receives discharges from numerous municipal and industrial point sources (Duke, 1985). Most of the dischargers are located in the area between the Saltwater Barrier and the Intracoastal Waterway. Municipal dischargers include the City of Lake Charles, the City of Sulphur, and the Town of Westlake. Industrial dischargers include Olin Corp., PPG Industries, CITGO, W.R. Grace, Certain-Teed, Himont, and Firestone. A few dischargers are located south of the Intracoastal Waterway, particularly in the area of Cameron.

Produced water, or oil field brine, a byproduct of the oil production process (LDEQ, 1992), is also discharged into the Lower Calcasieu. St. Pé (1990) reports that approximately 68 million gallons per day are discharged into Louisiana waters from 510 discharge points. Oil field brines are often highly saline, usually more than two to three times more saline than seawater. Because of high salinity, these discharges are dense, and flow along the bottom or into sediments without significant mixing. Produced waters may be high in radioactive radium 226, and hydrocarbons. Although coastal produced water discharges are being phased out, historic discharge sites are a focus for environmental concern.

Hydrological and water quality modeling

Duke (1985) reviewed water quality modeling and associated hydrological modeling in the Lower Calcasieu. Duke applied the RECEIV-II model in the calculation of a total maximum daily load (TMDL) for conventional oxygen-demanding pollutants. The TMDL assumes a 7Q10 freshwater discharge. Waldon (1988) updated this model to reflect changes in discharger locations and design flows. NUS Corporation, under contract to PPG, performed modeling studies of toxic organic pollutants in the Lower Calcasieu using the EPA WASP model (NUS Corp., 1990; reviewed by Waldon, 1990).

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NAME	SURFACE AREA (Sq. Miles)	VOLUME (Acre-Ft)	AVG DEPTH (Ft)
Mud Lake	3.85	3,700	1.5
Black Lake	3.4	8,770	4.0
Calcasieu Lake	67	210,000	4.9
Moss Lake	1.0	.	.
Prien Lake	1.53	5,320	5.4
Lake Charles	1.74	9,650	8.7
Sabine Lake*	87	301,000	5.4
Toledo Bend Res.*	284	4,450,000	24.5

****Not in Calcasieu Basin, listed for comparison.***

Table **1**. Dominant Lakes of the Lower Calcasieu River (Shampine, 1970).

Discharge Statistic	Calcasieu River at Kinder	Calcasieu River at Lake Charles (estimated)	Sabine River near Ruliff
Mean annual	2600	4732	8378
7Q10	203	369	432
10 percentile	6120	11,138	18,900
30 percentile	2270	4131	.
50 percentile	1030	1875	5240
70 percentile	538	979	.
90 percentile	319	581	1230
Minimum	136	248	278
Maximum	182,000	331,240	108,000

Table **2**. Discharge statistics (cfs).

Basin	Site #	Description	SYMBOL
4	58010109	Chef Menteur Pass at Chef Menteur	LPCM
4	58010035	Pass Rigolets	LPPR
4	58010138	Lake Pontchartrain (Causeway Crossover #4)	LPCW
2	58010295	B. Lafourche near Golden Meadow	BLGM
2	58010008	Little Lake at Temple	LLT
12	58010348	Bayou Grand Caillou south of Houma	BGC
12	58010351	Caillou Lake south of Houma	CL
6	58010316	Vermilion Bay South of New Iberia	VB
5	58010310	White Lake Southwest of Abbeville	WL
5	58010029	Mermentau River near Grand Cheniere	MRGC
3	58010093	Calcasieu River at Moss Bluff	CRMB
3	58010027	Calcasieu River near Lake Charles	CRLC
3	58010026	Calcasieu River near Burton Landing	CRBL
11	58010091	Sabine River Northeast of Orange	SROR

Table **3**. Selected LDEQ coastal monitoring sites.

SYMBOL	Temp (Deg C)	pH	DO (mg/L)	Cond (umhos/cm)	Cl (mg/L)	Turb (NTU)	Secchi (In)	TDS (mg/L)
LPCM	20.8	7.2	8.0	8775	2649.5	10	24	5039
LPPR	21.6	7.2	9.0	6900	2180.0	11	22	3537
LPCW	20.0	7.1	8.9	5980	1787.5	4	41	3282
BLGM	21.3	7.5	6.6	6880	2293.0	12		3852
LLT	22.0	7.5	8.2	1203	326.0	17	18	723
BGC	23.5	7.1	6.2	1930	521.5	20		1081
CL	21.6	7.8	7.9	12805	4133.0	18	15	7534
VB	21.0	7.6	8.1	4910	1445.5	26	7	2157
WL	21.5	7.0	8.6	436	98.4	155		471
MRGC	21.1	7.5	7.8	23850	7856.5	39	6	14720
CRMB	21.2	6.7	6.5	66	8.6	27	10	112
CRLC	22.1	7.1	5.8	2525	656.0	19	15	1347
CRBL	21.7	7.2	6.0	12045	3825.0	15	18	6880
SROR	20.7	7.0	5.9	149	17.4	11	17	128

Table **4**. Median parameter values for 1992-93 at selected coastal monitoring sites.

SYMBOL	TOC (mg/L)	TP (mg/L)	NOx (mg/L)	TKN (mg/L)	TN (mg/L)	TN:TP
LPCM	7.2	0.06	0.03	0.55	0.58	9.67
LPPR	7.3	0.07	0.03	0.59	0.62	8.86
LPCW	5.7	0.04	0.02	0.40	0.42	10.50
BLGM	9.1	0.10	0.13	0.85	0.98	9.80
LLT	9.4	0.10	0.36	0.81	1.17	11.70
BGC	9.1	0.17	0.22	0.99	1.21	7.12
CL	8.4	0.09	0.03	0.71	0.74	8.22
VB	8.9	0.15	0.20	0.72	0.92	6.13
WL	10.3	0.20	0.30	1.08	1.38	6.90
MRGC	7.3	0.17	0.13	0.73	0.86	5.06
CRMB	8.3	0.11	0.07	0.65	0.72	6.55
CRLC	10.6	0.11	0.10	0.96	1.06	9.64
CRBL	8.9	0.11	0.13	0.99	1.12	10.18
SROR	8.7	0.06	0.05	0.81	0.86	14.33

Table **5**. Median nutrient concentrations for 1992-93 at selected coastal monitoring sites.

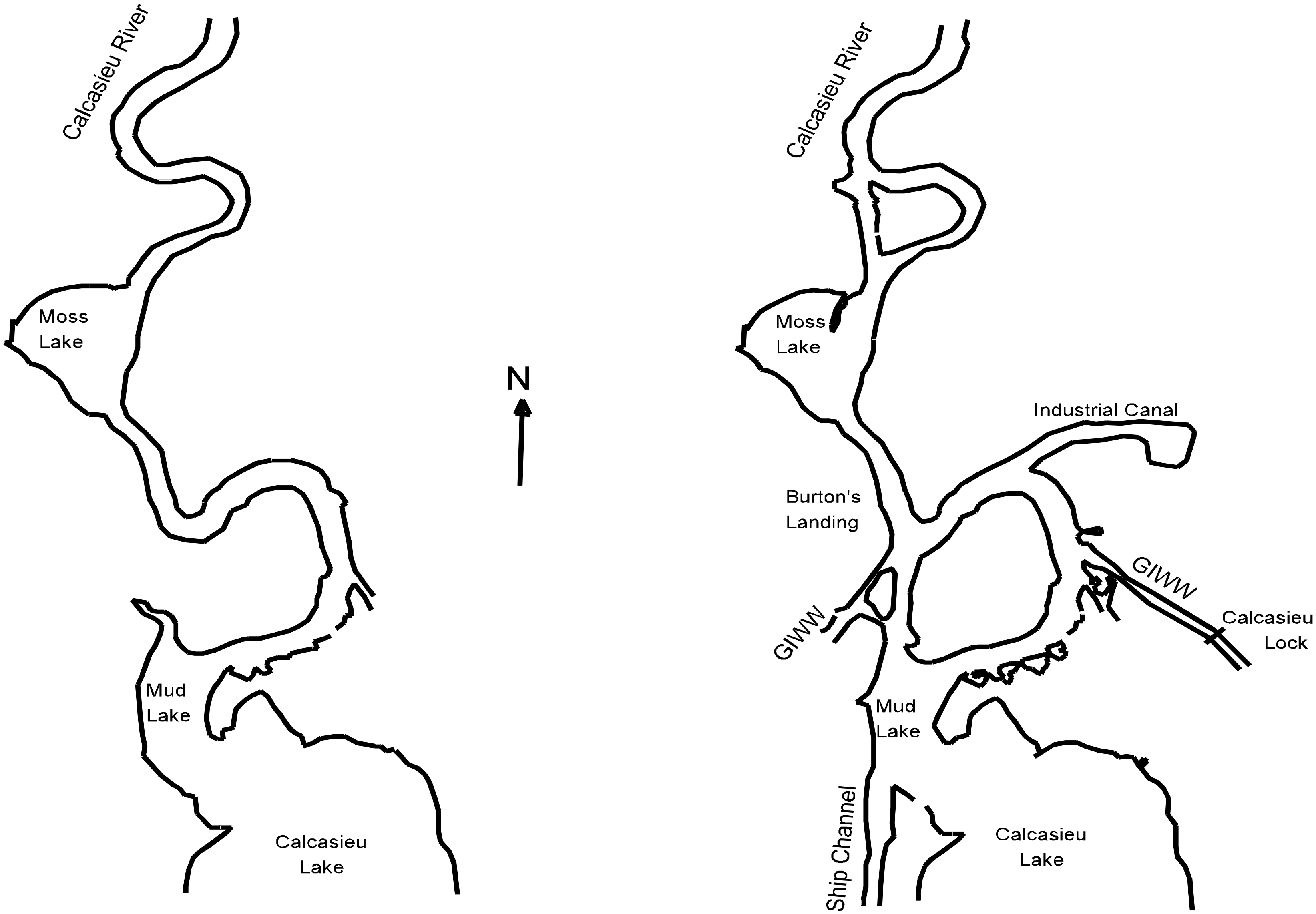

Figure 1. Lower River showing natural river pattern (left), and modified River (right), as adapted from Thompson (1986).

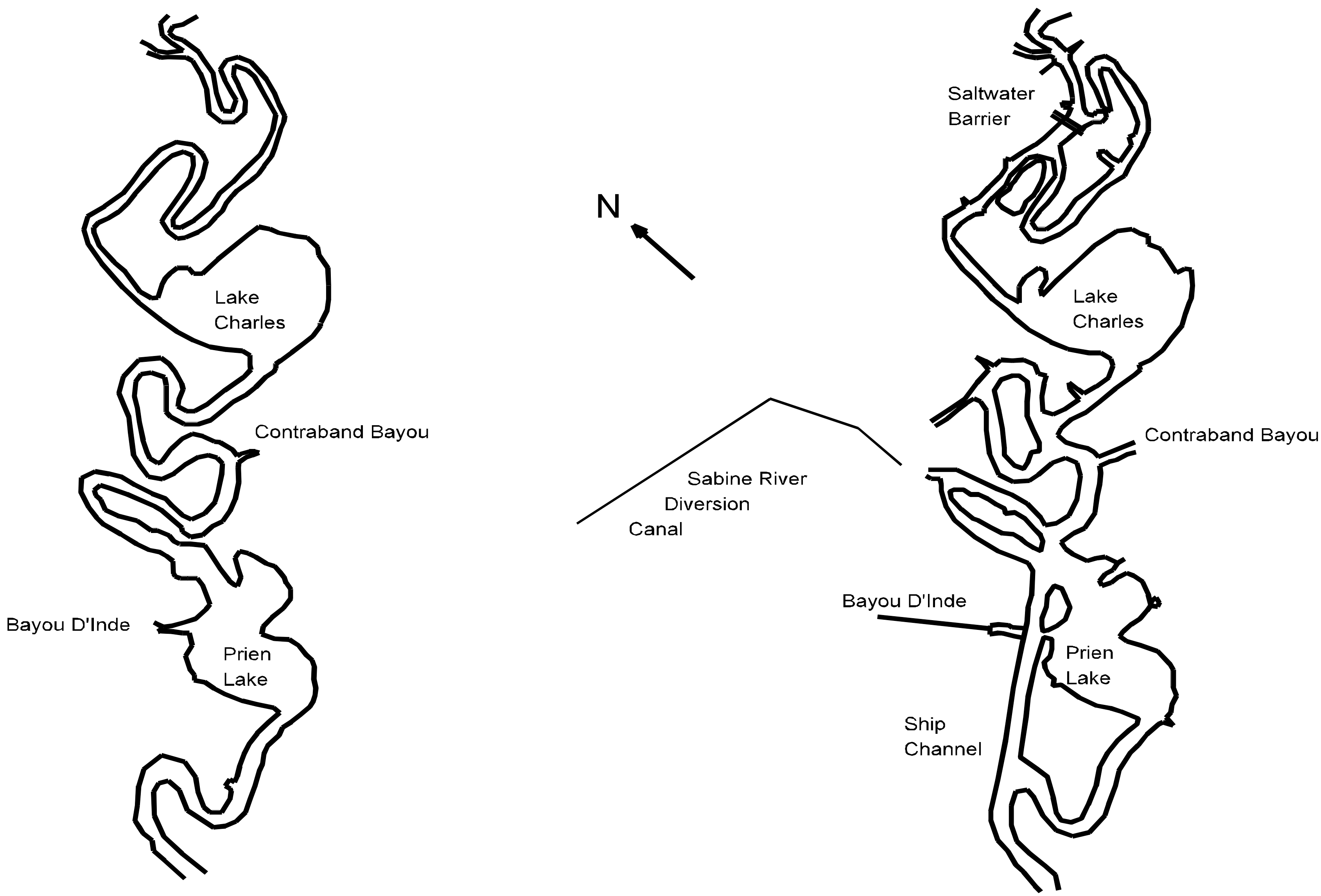

Figure 2. Upper River showing natural river pattern (left), and modified River (right), as adapted from Thompson (1986).

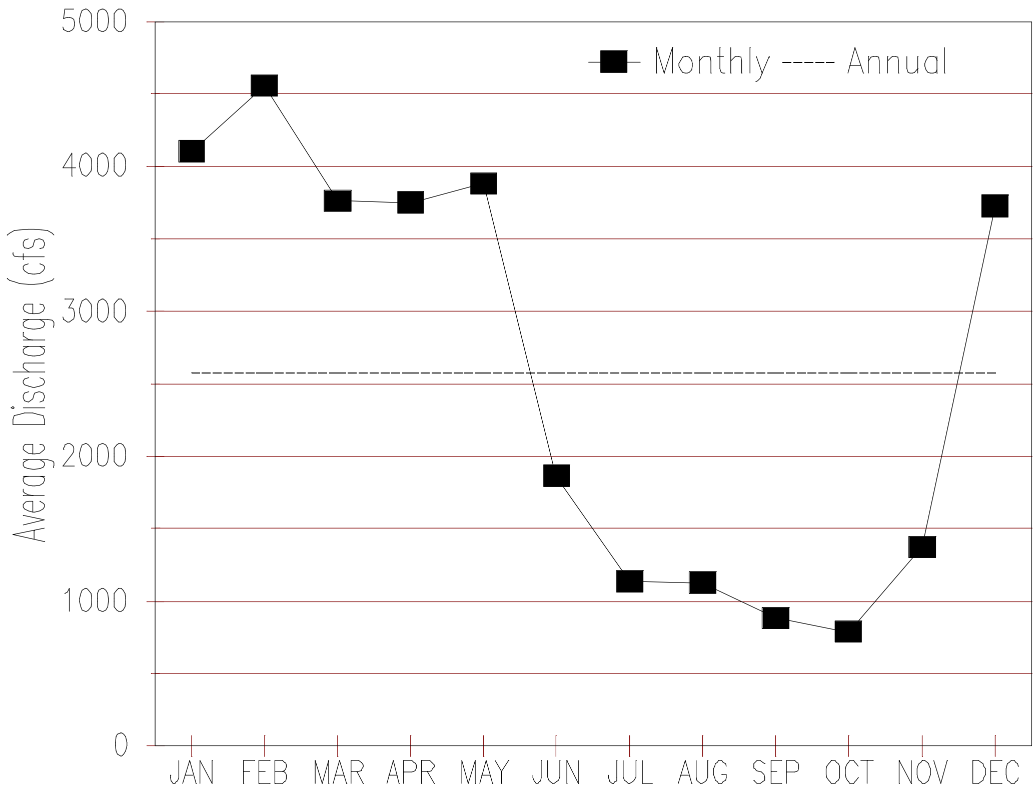

Figure 3. Average monthly and annual discharge in the Calcasieu River at Kinder, Louisiana.

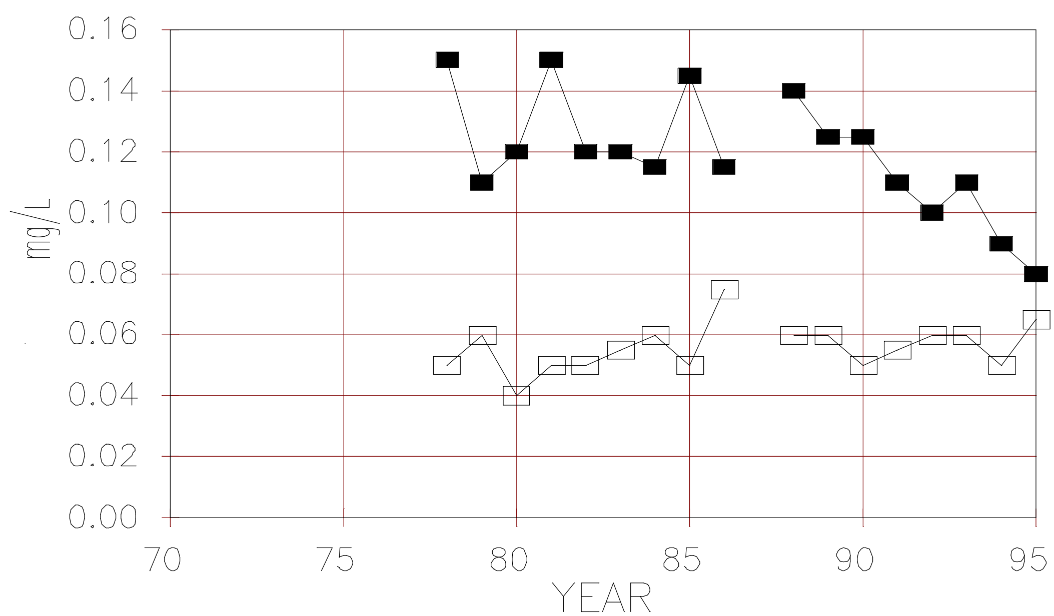

Figure 4. Annual median total phosphorus (mg/L) in the Calcasieu (solid marker) and Sabine (open marker).

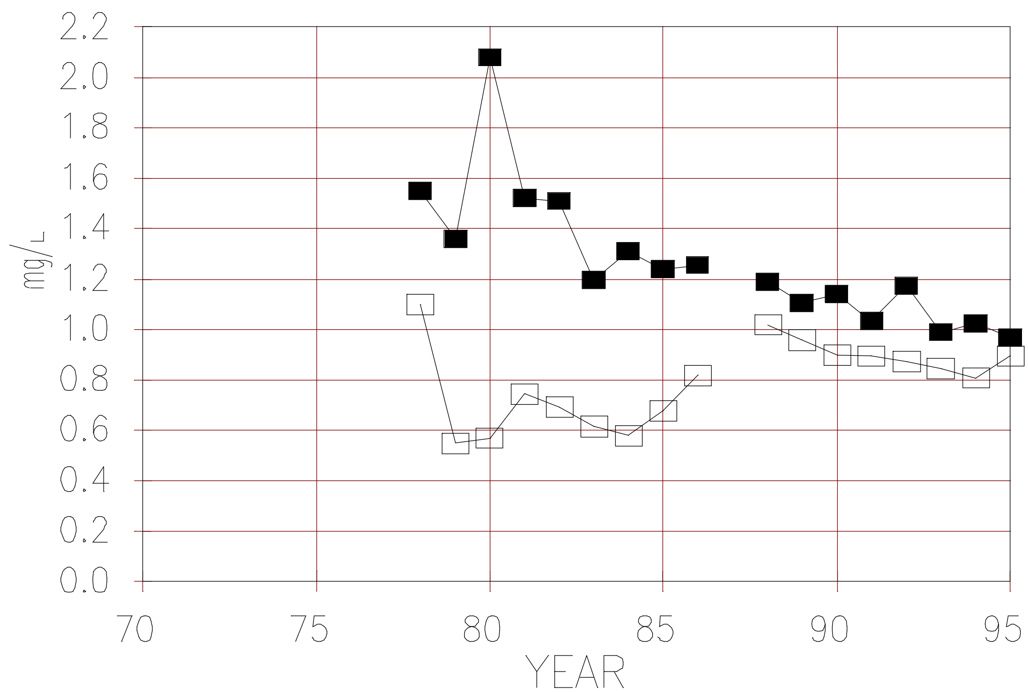

Figure 5. Annual median total nitrogen (mg/L) in the Calcasieu (solid marker) and Sabine (open marker).

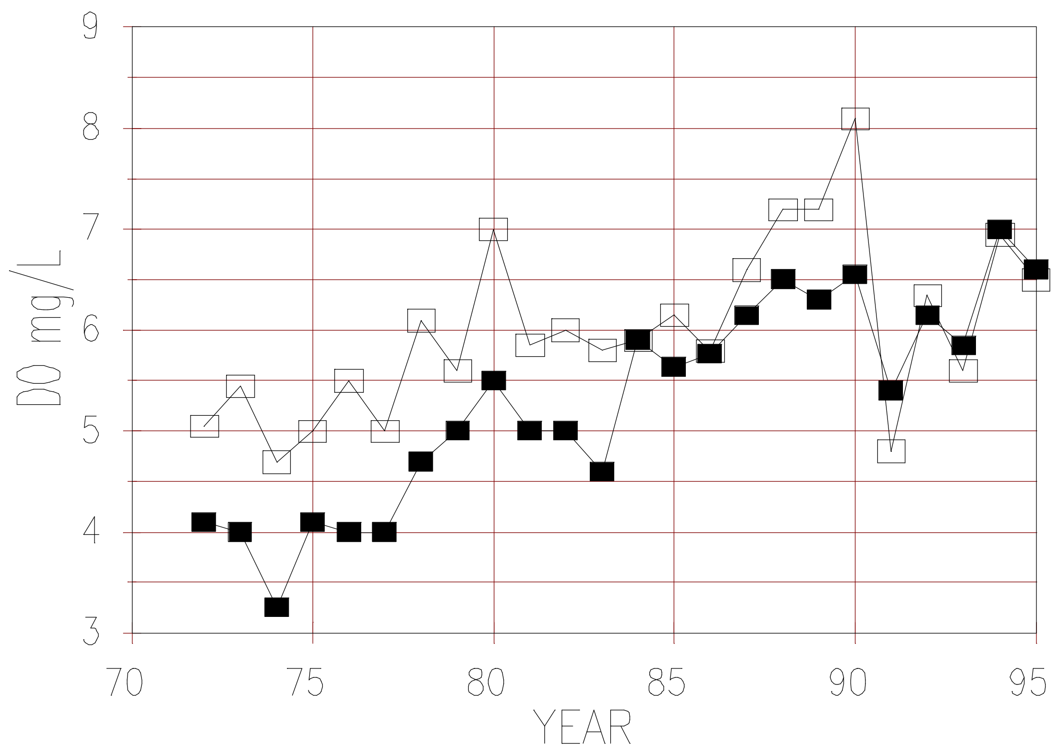

Figure 6. Annual median dissolved oxygen (mg/L) in the Calcasieu (solid marker) and Sabine (open marker).