DRAFT

TMDLs for Dissolved Oxygen and Nutrients (Nitrate/Nitrite, and Total Phosphorus) in Bayou Blue (Subsegment 120606) within the Terrebonne Basin, Louisiana

Prepared for:

United States Environmental Protection Agency, Region 6
Water Quality Protection Division
Permits, Oversight, and TMDL Team
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EXECUTIVE SUMMARY

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (at Title 40 of the *Code of Federal Regulations* [CFR] Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for impaired waterbodies. A TMDL establishes the amount of a pollutant that a waterbody can assimilate while still meeting the water quality standard for that pollutant. TMDLs provide the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of the state's water resources (USEPA 1991).

A TMDL for a given pollutant and waterbody is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include an implicit or explicit margin of safety (MOS) to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. The TMDL components are illustrated using the following equation:

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

The study area for this TMDL includes Bayou Blue in southeast Louisiana, and its watershed includes the following tributaries: Bayou Manuel, Hospital Bayou, Raccoon Bayou, Forty Arpent Canal, Canal Blue, Bully Camp Canal, and numerous numbers of unnamed canals and tributaries. The subsegment contains 12,007 acres of land. Subsegments 120604 and 120706 also contain portions of Bayou Blue. These subsegments lie to the east and south of subsegment 120606, respectively. The area is sparsely populated, and the majority of the land coverage is wetland forest, and agriculture and crop, or grassland. Heavy rainfall events typically occur in March and April as frontal weather systems pass through.

The Louisiana Department of Environmental Quality (LDEQ) has included Bayou Blue on the state's 2004 section 303(d) list of impaired waterbodies. The subsegments are listed for dissolved oxygen, nitrate/nitrite, and total phosphorus impairments. The impaired designated uses for the subsegment (Table ES-1) are primary and secondary contact recreation (PCR and SCR) and fish and wildlife propagation (FWP). Bayou Blue is primarily used for stormwater drainage and fishing.

Table ES-1. Section 303(d) listing for the subsegment included in this report

Subsegment	Subsegment name	Subsegment description	Designated use		
			PCR	SCR	FWP
120606	Bayou Blue	Bayou Chene to Lake Penchant	N	F	N

LDEQ recommends a Use Attainability Analysis (UAA) for the waterbody. Natural conditions prohibit Bayou Blue from sustaining the established water quality criteria. Bayou Blue is dominated by tidal flow, and there are no permitted dischargers along the waterbody. The surrounding land area consists primarily of saltwater marsh that has been impacted by oilfield and drainage canals. There is no urban development, and LDEQ feels that it is unlikely that any new dischargers will develop facilities along the waterbody. Therefore, LDEQ does not feel that a TMDL should be completed for Bayou Blue and that the current dissolved oxygen criterion should be reevaluated.

TMDLs were developed for Bayou Blue using T-QUAL until an UAA is completed. T-QUAL is a steady-state, one-dimensional spreadsheet water quality model that was developed by LDEQ's Water Quality Assessment Division, Water Quality Modeling Section. T-QUAL was developed using Microsoft Excel 2000 on a Windows 2000 platform. It was tested against LDEQ's more rigorous steady-state, one-dimensional water quality model, LA-QUAL. T-QUAL was able to adequately mimic the results of LA-QUAL (Carville and Baker 2003).

In TMDL development, allowable loads from all pollutant sources that cumulatively amount to no more than the TMDL must be established, thereby providing the basis for establishing water quality-based controls. Since there are no permitted point source dischargers, no WLAs were assigned in this subsegment. The LAs include background (natural) loadings and human-induced nonpoint sources. An MOS was not included for natural sources. Since there are no manmade sources, an MOS was not assigned.

Tables ES-2 and ES-3 present summaries of the TMDLs for the subsegments addressed in this report. The numeric water quality criterion that applies to the impaired subsegments and was used to calculate the total allowable dissolved oxygen pollutant loads is 4 mg/L. The state's nutrient criteria are narrative and include the following language (LDEQ 2007b):

> The naturally occurring range of nitrogen-phosphorous ratios shall be maintained. This range shall not apply to designated intermittent streams. To establish the appropriate range of ratios and compensate for natural seasonal fluctuations, the administrative authority will use site-specific studies to establish limits for nutrients. Nutrient concentrations that produce aquatic growth to the extent that it creates a public nuisance or interferes with designated water uses shall not be added to any surface waters.

Table ES-2. Summary of dissolved oxygen TMDLs for Bayou Blue

Subsegment	Oxygen demand (lb/d)			
120606	SOD	CBOD	NBOD	Total
PS WLA	0	0	0	0
Natural LA	2,450	7,949	4,313	14,711
Manmade LA	0	0	0	0
Manmade MOS for LA	0	0	0	0
TMDL	2,450	7,949	4,313	14,711

Note: SOD = sediment oxygen demand; CBOD = carbonaceous biochemical oxygen demand; NBOD = nitrogenous biochemical oxygen demand

Table ES-3. Summary of nutrient TMDLs for Bayou Blue

Nutrient	WLA (lb/d)	Natural LA (lb/d)	Manmade LA (lb/d)	Manmade MOS (lb/d)	TMDL (lb/d)
Total phosphorus	0.00	44.8	0.00	0.00	44.8
Total nitrogen	0.00	186.6	0.00	0.00	186.6

Hurricane Katrina made landfall on Monday, August 29, 2005, as a Category 4 hurricane. The storm brought heavy winds and rain to southeast Louisiana, breaching several levees and flooding up to 80 percent of New Orleans and large areas of coastal Louisiana. Both Hurricanes Katrina and Rita have caused a significant amount of change in sedimentation and water quality in southern Louisiana. Many wastewater treatment facilities were temporarily or permanently damaged. Some wastewater treatment facilities will be rebuilt; others will be relocated.

The proposed TMDLs in this report were developed on the basis of pre-hurricane water quality data. Post-hurricane water quality conditions and other factors could delay the implementation of these proposed TMDLs, render some proposed TMDLs obsolete, or require modifications of the TMDLs. Although hurricane effects might be valid for some TMDLs, any deviation from the TMDLs should be justified using site-specific data or information.

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1 INTRODUCTION

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (at Title 40 of the *Code of Federal Regulations* [CFR] Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not supporting their designated uses, even if pollutant sources have implemented technology-based controls. A TMDL establishes the maximum allowable load (in mass per unit time) of a pollutant that a waterbody is able to assimilate while still supporting its designated uses. The maximum allowable load is determined on the basis of the relationship between pollutant sources and in-stream water quality. A TMDL provides the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of the state's water resources (USEPA 1991).

The Louisiana Department of Environmental Quality (LDEQ) has included Bayou Blue on the state's 2004 section 303(d) list of impaired waterbodies. The subsegments are listed for dissolved oxygen, nitrate/nitrite, and total phosphorus impairments. The impaired designated uses for the subsegment are primary and secondary contact recreation (PCR and SCR) and fish and wildlife propagation (FWP). The subsegments are either fully supporting (F) or not supporting (N) the designated uses. Table 1-1 presents information from Louisiana's 2004 section 303(d) list for the subsegment. Bayou Blue is primarily used for stormwater drainage and fishing.

Table 1-1. Subsegment and impairments addressed in this report

Subsegment	Subsegment name	Subsegment description	Designated use		
			PCR	SCR	FWP
120606	Bayou Blue	Bayou Blue-Grand Bayou Canal to boundary between segments 1206 and 1207 (Estaurine)	N	F	N

Oxygen concentrations in the water column fluctuate under natural conditions, but severe depletion usually results from human activities that introduce large quantities of biodegradable organic materials into surface waters. In polluted waters, bacterial degradation of organic materials can result in a net decline in oxygen concentrations in the water. Oxygen depletion can also result from chemical reactions that place a chemical oxygen demand (COD) on receiving waters. Other factors, such as temperature and salinity, influence the amount of oxygen dissolved in water. Prolonged hot weather decreases oxygen concentrations and can cause fish kills even in clean waters because warm water cannot hold as much oxygen as cold water (Scorecard 2005).

Other factors that affect dissolved oxygen concentrations include the following (Murphy 2005):

- Volume and velocity of water flowing in the waterbody
- Climate and season
- The type and number of organisms in the waterbody
- Altitude
- Dissolved or suspended solids
- Amount of nutrients in the water
- Organic waste
- Riparian vegetation

- Ground water inflow

Low dissolved oxygen concentrations in streams can be linked to both natural conditions and human activities. In Louisiana, natural stream conditions like low flow, high temperature, and high organic content often result in dissolved oxygen levels already below current water quality criteria, making it difficult to develop standards for best management practices, or BMPs (Mason et al. 2007). Additional data for these 303(d)-listed areas are needed to determine whether the low dissolved oxygen occurs naturally or is related to human activity (i.e., is anthropogenic).

2 BACKGROUND INFORMATION

2.1 General Description

The study region consisted of Bayou Blue (subsegment 120606). In Louisiana, the subsegment 120606 includes 12,007 acres (48.6 km^2) in portions of La Fourche Parish. Figure 2-1 shows the location of the subsegment. The watershed's U.S. Geological Survey (USGS) hydrologic unit code is 08090302.

Bayou Blue is in southeast Louisiana, and its watershed includes the following tributaries: Bayou Manuel, Hospital Bayou, Raccoon Bayou, Forty Arpent Canal, Canal Blue, Bully Camp Canal, and numerous numbers of unnamed canals and tributaries. Subsegments 120604 and 120706 also contain portions of Bayou Blue. These subsegments lie to the east and south of subsegment 120606, respectively.

2.2 Land Use

The Terrebonne Basin covers an area extending approximately 120 miles from the Mississippi River on the north to the Gulf of Mexico on the south. It varies in width from 18 miles to 70 miles. This basin is bounded on the west by the Atchafalaya River Basin and on the east by the Mississippi River and Bayou LaFourche. The topography of the entire basin is lowland, and all the land is subject to flooding except the natural levees along major waterways. The coastal portion of the basin is prone to tidal flooding and consists of marshes ranging from fresh to saline.

The northwest end of Bayou Blue is at the confluence with Grand Bayou Canal. The bayou proceeds to the southeast into the saltwater marsh near Belle Amie, Louisiana. It is in the Bully Camp Oil and Gas Field and the Bayou Pointe au Chien State Wildlife Management Area.

Land use data were obtained from the 2001 USGS National Land Cover Dataset (NLCD; Table 2-1 and Figure 2-2). The subsegment land use is primarily wetlands and pasture. Urban land areas in the subsegment lie along and drain to Bayou LaFourche. The contributing area of Bayou Blue, which is only a portion of subsegment 120606, consists of entirely wetlands, swamps, and marshes.

Table 2-1. Land uses in subsegment 120606

Land use	Area (acres)	Percentage
Barren	14.3	0.12
Forest	98.2	0.82
Grassland	3.6	0.03
Pasture	3,239.3	26.98
Row crops	221.5	1.84
Urban	969.9	8.08
Water	605.9	5.05
Wetlands	6,854.4	57.09
Total	**12,007.0**	**100.00**

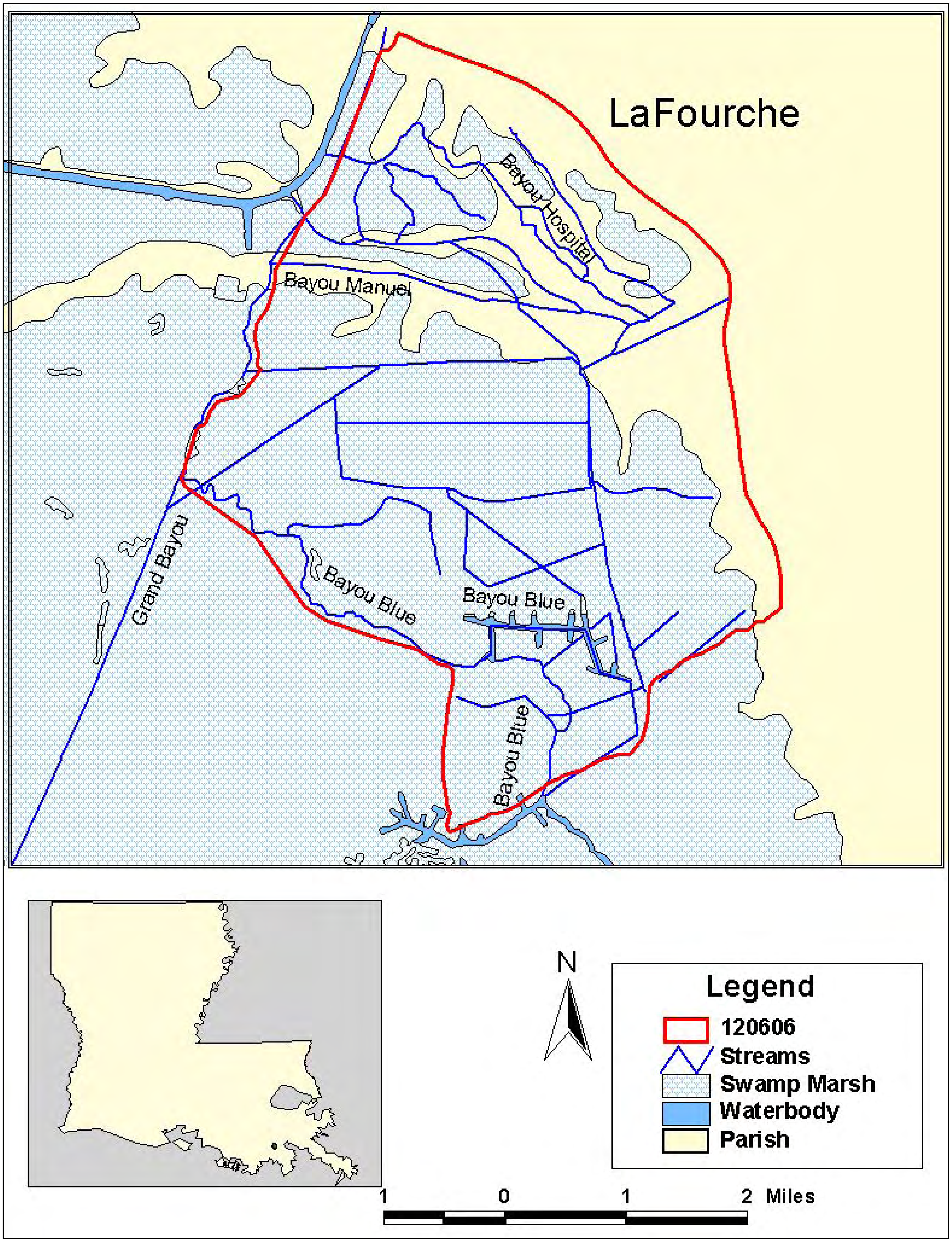

Figure 2-1. Map of subsegment 120206.

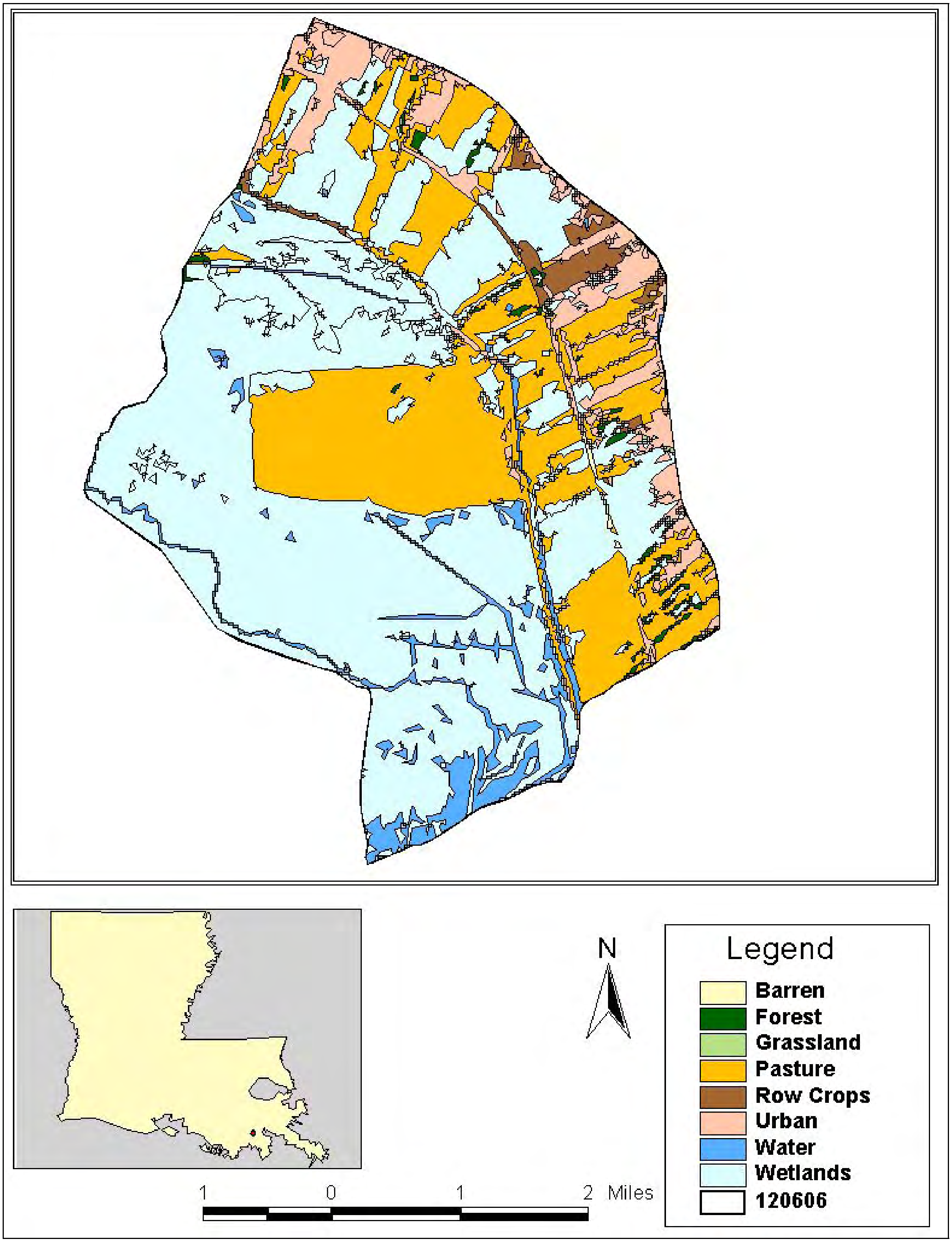

Figure 2-2. Land use in the subsegment 120206.

2.3 Hydrologic Setting

Because reversing flows occur at times throughout the Terrebonne Basin, there are very few USGS flow gages in the Terrebonne Basin. The USGS online hydrology database (NWISWeb) does not contain any USGS stations for this subsegment.

2.4 Designated Uses and Water Quality Criteria

Louisiana's 2004 section 303(d) list indicates that Bayou Blue—assigned a use of primary or secondary contact recreation, and fish and wildlife propagation—does not meet applicable water quality standards. Primary contact recreation includes any recreational or other water contact involving full-body exposure to water and a considerable probability of ingesting water. Examples of the use are swimming and water skiing. Secondary contact recreation involves activities like fishing, wading, or boating, where water contact is accidental or incidental, and there is a minimal chance of ingesting appreciable amounts of water. Fish and wildlife propagation includes the use of water for aquatic habitat, food, resting, reproduction, cover, or travel corridors for any indigenous wildlife and aquatic life species associated with the aquatic environment.

The suspected sources were listed as on-site treatment systems (septic systems and similar decentralized systems) and a package plant or other permitted small flow discharges. This listing assumes that small camps exist along the bayou. However aerial photography, LDEQ databases, and reconnaissance surveys indicate that the bayou is void of camps and other small dischargers.

The assessment methodology presented in LDEQ's 305(b) report (LDEQ 2004) specifies that primary contact recreation, secondary contact recreation, and fish and wildlife propagation uses are to be fully supported. The state minimum dissolved oxygen criterion for the subsegments in this TMDL is 4 milligrams per liter (mg/L) year-round.

Louisiana does not have numeric water quality criteria for nutrients, but its narrative criteria for nutrients states the following:

- The naturally occurring range of nitrogen-phosphorus ratios shall be maintained (except for intermittent streams), and
- Nutrient concentrations that produce aquatic growth to the extent that it creates a public nuisance or interferes with designated water uses shall not be added to any surface waters.

The Louisiana water quality standards also include an antidegradation policy (*Louisiana Administrative Code* [LAC] Title 33, Part IX, Section 1109.A), which states that state waters exhibiting high water quality should be maintained at that high level of water quality. If that is not possible, water quality of a level that supports the designated uses of the waterbody should be maintained. The designated uses of a waterbody may be changed to allow a lower level of water quality only through a use attainability study.

2.5 Identification of Sources

2.5.1 Point Sources

LDEQ stores permit information using internal databases. LDEQ generated a list of point source discharges in the study area by using the TEMPO and PTS databases. Information on point source discharges to the listed subsegment was obtained from the Electronic Document Management System (EDMS) database at LDEQ. Data were pulled from EDMS and analyzed for the TMDLs. Each facility was evaluated on the basis of its discharges and permit limits to determine whether the facility would be used in developing the TMDLs. There were no municipal separate sewer systems (MS4s) identified in the subsegment.

The evaluation yielded approximately 15 permitted facilities that exist in the geographical constraints of subsegment 120606 (Table 2-2). Fourteen of these facilities discharge to Bayou LaFourche or the Intracoastal Waterway. The Bully Camp Oilfield No. 2 Production Facility is on an oilfield canal approximately 0.5 km north of Bayou Blue. The facility discharge is small (less than 5,000 gallons per day [gpd]) and intermittent. On the basis of the proximity of Bayou Blue and the volume of wastewater, the impact of the Bully Camp Oilfield No. 2 Production Facility on Bayou Blue is considered insignificant.

Table 2-2. Point sources in the subsegment 120206

NPDES permit number	Facility name	Permitted flow (gpd)	BOD limit (mg/L)	Frequency	Receiving waterbody	Comments	Modeling comments
LAG530324	LaFourche Telephone Company, Inc.	< 5,000	45	weekly average	Unnamed ditch to unnamed canal		Does not impact Bayou Blue
LAG540624	Bon Service Shopping Center	< 25,000	30/45	monthly avg/ weekly avg	Bayou LaFourche		Does not impact Bayou Blue
LA0103039	Larose Gas Processing Plant		45	weekly average	Bayou Manuel, Grand Bayou	Treated sanitary wastewater, hydrostatic test water, and stormwater	Does not impact Bayou Blue
LAG33A117	Bully Camp Field No. 2 Production Facility	< 5,000			Oilfield canal to Bayou Blue	Intermittent discharge; Discharge from dewatering effluents; from reserve pits that have not received drilling fluids or drill cuttings	Typically a no discharge facility; no impact to Bayou Blue
LAG750411	Hot Water Works, Inc				Bayou LaFourche	Car wash	Does not impact Bayou Blue

Table 2-2. (continued)

NPDES permit number	Facility name	Permitted flow (gpd)	BOD limit (mg/L)	Frequency	Receiving waterbody	Comments	Modeling comments
LAG540455	Cutoff Elementary School	< 25,000	30/45	monthly avg/ weekly avg	Bayou LaFourche	Sanitary wastewater	Does not impact Bayou Blue
LAG540459	Larose-Cutoff Middle School	< 25,000	30/45	monthly avg/ weekly avg	Bayou LaFourche	Sanitary wastewater	Does not impact Bayou Blue
NA	Columbia Gulf Transmission Company # 661 Cutoff					Inactive and abandoned site	Does not impact Bayou Blue
NA	Columbia Gulf Transmission Company # 667 Cutoff					Inactive and abandoned site	Does not impact Bayou Blue
NA	Columbia Gulf Transmission Company # 663 and 681 (Cutoff)					Inactive and abandoned site	Does not impact Bayou Blue
	Poppee's Quick Stop				Bayou LaFourche	No surface water permit	Does not impact Bayou Blue
LAG541001	Happy Gardens	< 25,000	30/45	monthly avg/ weekly avg	Bayou LaFourche	Treated sanitary wastewater	Does not impact Bayou Blue
LAR10D577	LA Highway 307 in Raceland					Construction stormwater permit voided 7/23/2007	Permit temporary voided
LA0047686, LAF540452	LA-80-3 Larose	< 25,000	30/45	monthly avg/ weekly avg	Intracoastal Waterway near Larose	Sanitary wastewater	Does not impact Bayou Blue
	Larose Landfill Temporary C/D Site				Bayou LaFourche via ditch	Construction and debris landfill; stormwater	Does not impact Bayou Blue

Note: BOD = biochemical oxygen demand

2.5.2 Nonpoint Sources

Louisiana’s section 303(d) lists on-site treatment systems (septic systems and similar decentralized systems) and a package plant or other permitted small flow discharges as suspected sources in Bayou Blue. This listing assumes that small camps exist along the bayou. However, aerial photography, LDEQ databases, and reconnaissance surveys indicate that the bayou does not contain camps and other small dischargers. Runoff from urban and pasture land in the subsegment does not enter Bayou Blue.

3 CHARACTERIZATION OF EXISTING WATER QUALITY

3.1 Water Quality Data

Water quality data were obtained from LDEQ's water quality monitoring program and a targeted continuous monitoring program by LDEQ in 2004 (Figure 3-1)[1]. Data collected during the LDEQ survey from May 25 through June 3, 2004 represents a drought period for South Louisiana. Dissolved oxygen data available for the subsegment are listed in Table 3-1.

Table 3-1. Summary of LDEQ dissolved oxygen data for subsegment 120206

Station	Station name	Period of record	No. of obs.	Min (mg/L)	Max (mg/L)	Ave. (mg/L)
2844	Bayou Blue south of Larose, Louisiana	1/12/2004–12/11/2006	22	1.98	9.62	5.31
947	Forty Arpent Canal in Cutoff, Louisiana	1/04/2000–11/28/2000	12	1.66	9.46	4.29
BB2	Bayou Blue below pipeline	6/1/2004–6/3/2004	202	1.20	7.30	3.90
BB3	Bayou Blue below oxbow	6/1/2004–6/3/2004	199	0.80	5.10	2.16
BB6	Bayou Blue at lower subsegment boundary	6/1/2004–6/3/2004	201	3.10	8.10	5.74

Tables 3-2, 3-3, and 3-4 provide summaries of total phosphorus, nitrate+nitrite, and ammonia. Appendix A includes continuous water quality monitoring data for dissolved oxygen collected at 15-minute intervals from June 1 to 3, 2004. Appendix A also contains other water quality data and graphs for the subsegment. Appendix B contains the field notes and data collected during the June 2004 monitoring event.

Table 3-2. Summary of LDEQ phosphorus data for subsegment 120206

Station	Station name	Period of record	No. of obs.	Min (mg/L)	Max (mg/L)	Ave. (mg/L)
2844	Bayou Blue south of Larose, Louisiana	1/12/2004–12/11/2006	21	0.09	0.31	0.17
947	Forty Arpent Canal in Cutoff, Louisiana	1/04/2000–11/28/2000	12	0.14	1.28	0.59

Table 3-3. Summary of LDEQ nitrite+nitrate data for subsegment 120206

Station	Station name	Period of record	No. of obs.	Min (mg/L)	Max (mg/L)	Ave. (mg/L)
2844	Bayou Blue south of Larose, Louisiana	1/12/2004–12/11/2006	19	0.06	0.71	0.26
947	Forty Arpent Canal in Cutoff, Louisiana	1/04/2000–11/28/2000	12	0.02	0.50	0.16

Table 3-4. Summary of LDEQ ammonia data for subsegment 120206

Station	Station name	Period of record	No. of obs.	Min (mg/L)	Max (mg/L)	Ave. (mg/L)
2844	Bayou Blue south of Larose, Louisiana	1/12/2004–12/11/2006	11	0.10	0.44	0.20
947	Forty Arpent Canal in Cutoff, Louisiana	1/04/2000–11/28/2000	12	0.10	0.28	0.14

[1] Data collected after Hurricanes Katrina and Rita in August and September 2005, are not considered indicative of long-term water quality in Bayou Blue. The objective of the 2006 data collection was to gauge the recovery of the water bodies from Katrina effects, but is included on the tables in this section.

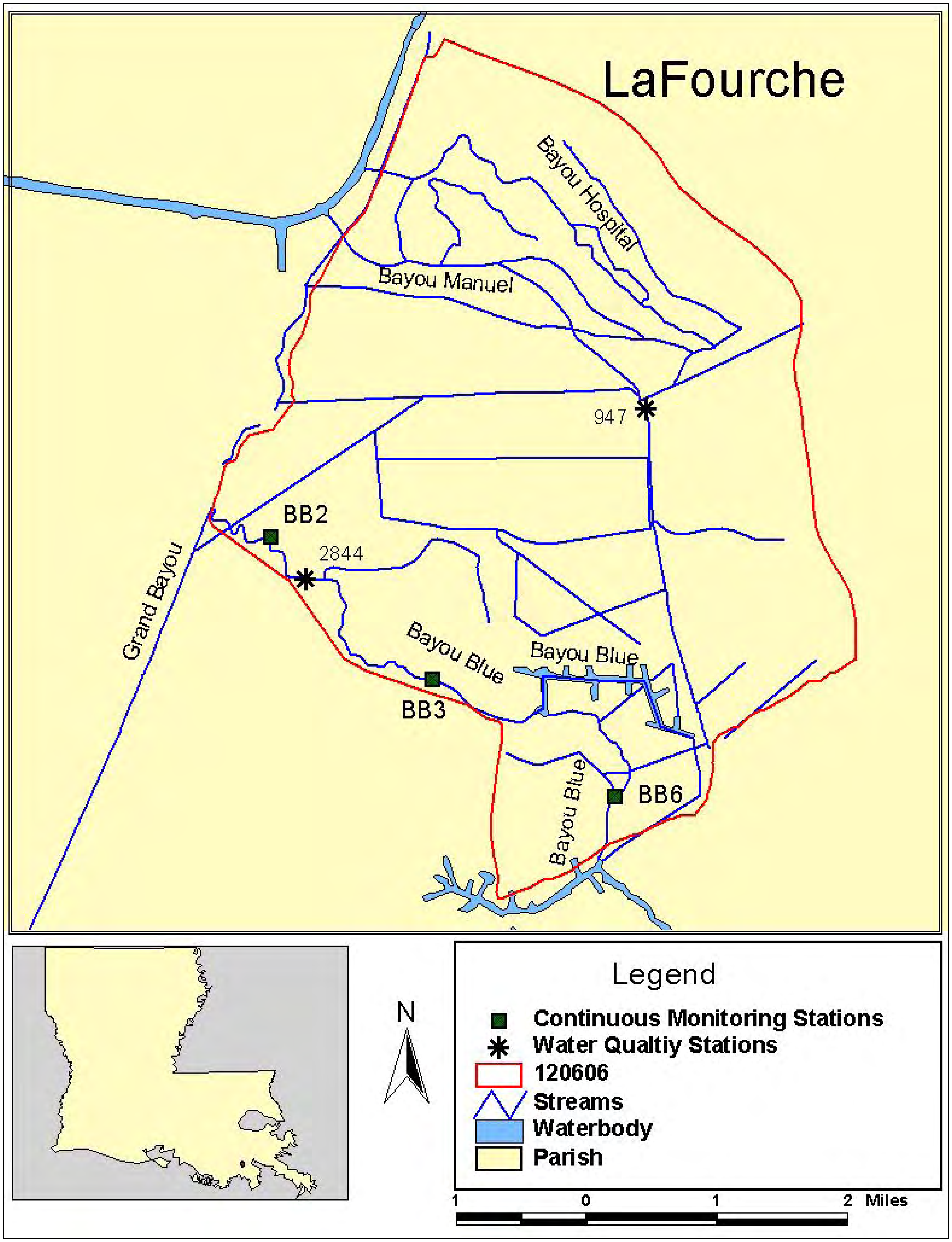

Figure 3-1. Locations of monitoring stations in subsegment 120206.

3.2 Comparison of Observed Data to Criteria

Water quality monitoring data were obtained from LDEQ and during the June 2004 continuous sampling event. Table 3-5 provides a summary of the LDEQ dissolved oxygen data available. The station had dissolved oxygen observations below the water quality criterion of 4 mg/L. All of the dissolved oxygen samples that did not meet criteria occurred during the summer months and fall months (Figures A-1 and A-2 in Appendix A).

Continuous monitoring data from June 2004 (Figures A-9 and A-10 in Appendix A) shows dissolved oxygen fluctuating within a 48-hour period. Dissolved oxygen did not meet criteria in the early morning (midnight) till late morning (noon). Of the continuous monitoring stations, BB6 had highest dissolved oxygen concentrations and BB3 had the lowest. Dissolved oxygen at BB3 was rarely met criteria.

Table 3-5. Comparison of dissolved oxygen data with water quality criterion

Station	Period of record	No. of obs.	Min (mg/L)	Max (mg/L)	Ave. (mg/L)	Percent < 4 mg/L
2844	1/12/2004–12/11/2006	22	1.98	9.62	5.31	36%
947	1/04/2000–11/28/2000	12	1.66	9.46	4.29	50%
BB2	6/1/2004–6/3/2004	202	1.20	7.30	3.90	58%
BB3	6/1/2004–6/3/2004	199	0.80	5.10	2.16	96%
BB6	6/1/2004–6/3/2004	201	3.10	8.10	5.74	10%

4 DISSOLVED OXYGEN MODEL SETUP AND CALIBRATION

4.1 Model Setup

T-QUAL was used to simulate DO concentrations in Bayou Blue. T-QUAL is a steady-state one-dimensional spreadsheet water quality model that was developed by the Water Quality Assessment Division, Water Quality Modeling Section of the LDEQ. T-QUAL was developed using Microsoft Excel 2000 on a Windows 2000 platform. It was tested against LDEQ's more rigorous steady-state one-dimensional water quality model; LA-QUAL. T-QUAL was able to adequately mimic the results of LA-QUAL (Carville and Baker 2003) T-QUAL uses finite difference equations from QUAL2E in an un-branched 5-segment system.

The model extends from the confluence with Grand Bayou Canal about 4 miles southwest of Larose, Louisiana, to the confluence with the Bully Camp Canal northwest of the town of Galliano, Louisiana. The vector diagram shows the locations of survey stations and the reach/element design (Figure 4-1).

Initial model set up was performed by LDEQ and described in *Bayou Blue Modeling Analysis for Biochemical Oxygen-Demanding Substances, Subsegment 120606* (LDEQ 2007a). The initial modeling conditions and coefficients, as well as portions of this report are taken from that report. Input data for this model was developed from data collected during the May 25 through June 3, 2004 survey. Only pre-Katrina water quality data was used in this model, with the exception of temperature data. Water quality data taken after Hurricanes Katrina and Rita were collected to gauge the recovery of waterbodies affected by the hurricanes. Temperature is considered not to be affected. Modeling input values are presented in Appendix C.

4.2 Headwater Data

Flow was not obtained during the 2004 survey in subsegment 120606. The headwater flow values were estimated on the basis of the length of the survey area, the typical range of tidal elevations and tidal periods for the area, and the cross sections measured during the survey. A detailed explanation of the calculations is presented in Appendix C.

The headwater water quality input was obtained from various sources. The headwater dissolved oxygen values were based on the average pre-Katrina summer concentrations for station 2844. Headwater BOD data was obtained average reference stream data in Louisiana. Ultimate nitrogenous biochemical oxygen demand (UNBOD) was derived from the average ammonia concentration obtained from LDEQ ambient monitoring. The average ammonia concentration was multiplied by 4.3 to obtain the UNBOD, as suggested in the *Standard Operating Procedure for Louisiana Total Maximum Daily Loads Technical Procedures* (LTP) (LDEQ 2006).

4.3 Wastewater Data

Wastewater data typically refers to any water quality data collected at a facility that is being included in a water quality model. However, any load entering into the main channel that is being addressed by T-QUAL may be included as wastewater data. Such sources may include tributaries.

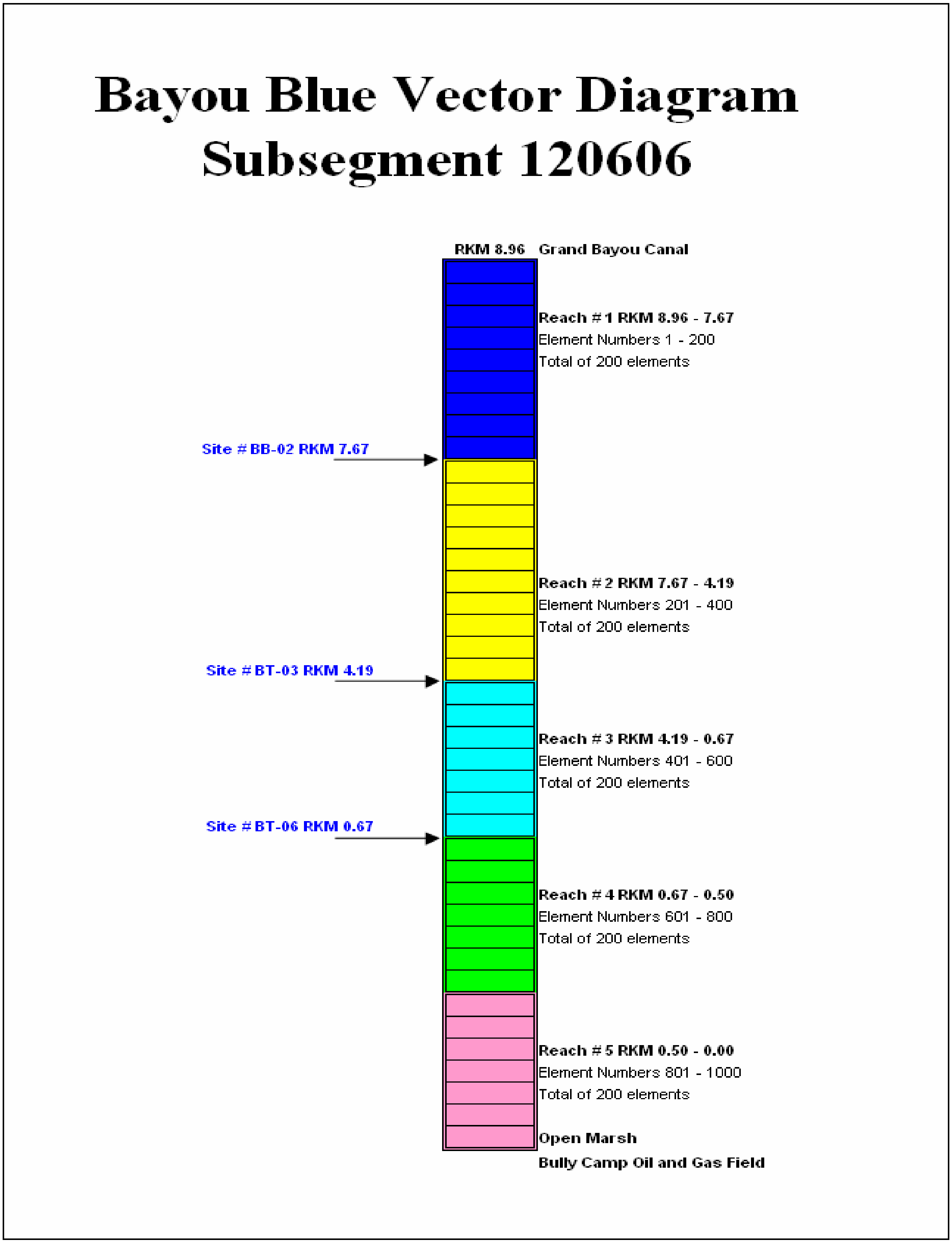

Figure 4-1. Bayou Blue vector diagram for subsegment 120606.

To simulate the dynamic flows of this tidal regime with this steady-state model, wastewater flow was used to simulate the increase in tidal flow between site BB02 and B06. Wastewater flow was introduced in reaches two and three so that the model produced the estimated tidal flow values from observed conditions.

Tidal flows were estimated using typical tidal amplitudes for the area and cross sections measured during the survey. Tidal flows were estimated on the basis of the length of the survey area, the typical ranges of tidal elevations and tidal periods for the area, and the cross sections measured during the survey (Forbes 2007) (see Appendix C).

The wastewater water quality input was obtained from various sources. The dissolved oxygen values were based on values from the 2004 survey. $CBOD_5$ was obtained from the last element of the previous model reach. The $CBOD_U$ were divided by 2.3 to convert to $CBOD_5$, as described in the LTP .Ammonia was determined from the average ammonia concentration obtained from LDEQ ambient monitoring.

4.4 BOD Deoxygenation and Settling Rates

The CBOD and NBOD deoxygenation and settling rates were based on values recommended in the LTP (LDEQ 2006), and presented in Appendix C. The CBOD deoxygenation rate that was used was slightly higher than the value in the LTP.

4.5 Reach Geometry

The survey area included an 8.96-kilometer section of Bayou Blue. The survey area was divided into five reaches. T-QUAL automatically subdivided each reach into 200 elements for a combined total of 1,000 elements. Cross sectional data were measured at three sites along the bayou. These data were used to estimate the widths and depths of each reach.

4.6 Reach Data and Nonpoint Loadings

Sediment oxygen demand (SOD) loading rates were initially based on values recommended in the LTP; however, they were adjusted to better simulate observed conditions. CBOD and NBOD resuspended loads were based on best professional judgment. Temperature was obtained from the average temperature during the 2004 monitoring at each station. Chlorinity values were calculated from salinity data measured by continuous monitors at the three survey sites.

4.7 Built-in Properties

The Louisiana Reaeration Equation was determined to be the most appropriate equation on the basis of the depth of the bayou and the dissolved oxygen concentrations. The equation is:

$$K_2 = 0.664 \times (1 + (21.52 \times V)) / D$$

where:

V = stream velocity (meters per second)
D = stream depth (meters)

Inhibition was based on a linear formula from a given threshold. The threshold was 2.0 mg/L for dissolved oxygen. In other words, once the dissolved oxygen fell below 2.0 mg/L, the decay rates decreased linearly as the dissolved oxygen concentrations decreased.

4.8 Calibration and Model Results

Model calibration was a multistep process using CBOD deoxygenation rate, CBOD resuspended load, NBOD resuspended load, and SOD concentrations for each reach, starting with the most upstream reach and working down to the outflow reach. These parameters were adjusted until the predicted dissolved oxygen concentrations were similar to the observed concentrations. Calibration values and results are presented in Appendix D.

Overall, the model did well in predicting the observed values of dissolved oxygen, and the model was considered adequately calibrated on the basis of the data available. Figure 4-2 is the calibration plot for dissolved oxygen with the observed average dissolved oxygen concentrations during the continuous monitoring in June 2004.

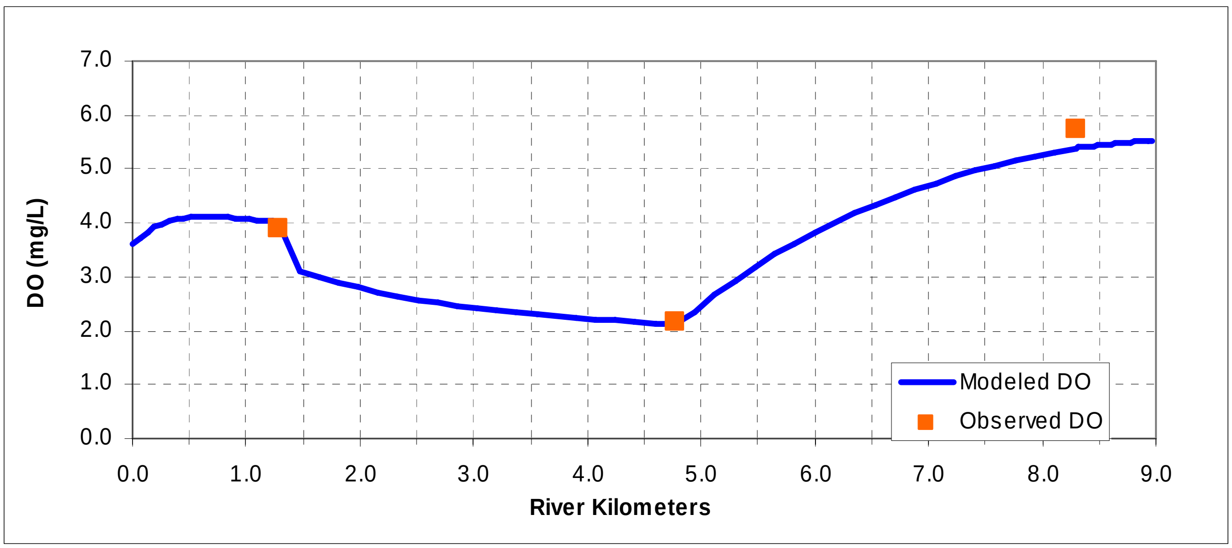

Figure 4-2. Calibration plot for dissolved oxygen in Bayou Blue.

There is no urban development within Bayou Blue. LDEQ considers subsegment 120606 to be in a *least impacted* or *natural* state. Table 4-1 lists the oxygen demand loadings for existing conditions.

Table 4-1. Existing oxygen demand

Subsegment	Oxygen demand (lb/d)			
120606	SOD	CBOD	NBOD	Total
WLA	0	0	0	0
LA	4,526	8,815	5,179	18,520
Total	4,526	8,815	5,179	18,520

5 DISSOLVED OXYGEN MODEL PROJECTION

5.1 Identification of Critical Conditions

The Clean Water Act requires the consideration of seasonal variation of conditions affecting the constituent of concern. For Bayou Blue, an analysis of LDEQ ambient data has been employed to determine critical seasonal conditions.

LDEQ historically has used graphical and regression analysis techniques to evaluate the temperature and dissolved oxygen data from the Ambient Monitoring Network and runoff determinations from the Louisiana Office of Climatology water budget. Because nonpoint loading is conveyed by runoff, this was a reasonable correlation to use. Temperature is strongly inversely proportional to dissolved oxygen and moderately inversely proportional to runoff. Dissolved oxygen and runoff are also moderately directly proportional. The analysis concluded that the critical conditions for stream dissolved oxygen concentrations were those of negligible nonpoint runoff and low stream flow combined with high stream temperature.

When the rainfall runoff (and nonpoint loading) and stream flow are high, turbulence is higher because of the higher flow, and the temperature is lowered by the runoff. In addition, runoff coefficients are higher in cooler weather because of reduced evaporation and evapotranspiration, so that the high flow periods of the year tend to be the cooler periods. Reaeration rates and dissolved oxygen saturation are, of course, much higher when water temperatures are cooler, but BOD decay rates are much lower. For these reasons, periods of high loading are periods of higher reaeration and dissolved oxygen but not necessarily periods of high BOD decay.

This phenomenon is interpreted in water quality modeling by assuming that nonpoint loading associated with flows into the stream are responsible for the benthic blanket, which accumulates on the stream bottom and that the accumulated benthic blanket of the stream, expressed as SOD or resuspended BOD or both in the calibration model, has reached steady state or normal conditions over the long term and that short term additions to the blanket are off set by short-term losses. This accumulated loading has its greatest impact on the stream during periods of higher temperature and lower flow. The only mechanism for changing this normal benthic blanket condition is to implement BMPs and reduce the amount of nonpoint source loading entering the stream and feeding the benthic blanket.

In reality, the highest temperatures occur from July to September. The lowest stream flows occur during high or low tides and the maximum headwater and lower boundary loads occur during an incoming or outgoing tide. The projection model is established as if the high water temperatures, high flow conditions, and high loading conditions occur simultaneously. Other conservative assumptions regarding rates and loads are also made during the projection model development. Ambient water quality data from LDEQ show that low dissolved oxygen concentrations occur during the summer months. (See Appendix A for data plots.)

5.2 Headwater Inputs

The inputs for the headwater and tributaries for the projection simulation were based on guidance in the LTP. Dissolved oxygen from headwaters was set to water quality criteria for the reach entering into subsegment 120606. Critical tidal flow values were estimated for the Bayou Blue projection models (Forbes 2007) and were set to one-third the average to typical flow averaged over one tidal cycle irrespective of flow direction.

Critical temperature values were determined for Bayou Blue using short-term water quality data from the LDEQ Ambient Network Site 2844 (Bayou Blue south of Larose, Louisiana). The 90th percentile temperature for summer was determined. Note that temperature data before and after Hurricane Katrina was used. Temperature data post-Katrina is not considered to be affected by the hurricane. Input values are in Appendix E.

5.3 Wastewater Inputs

The inputs into this section of the model were not changed from the calibration, except for dissolved oxygen concentrations, which were set to the water quality criterion. Wastewater flow was used to simulate the increase in tidal flow between sites BB02 and BB06.

5.4 Model Results for Projection

Model results for the TMDL projection are presented in Appendix E. The nonpoint source loads in this report were not divided between natural and anthropogenic because it is viewed that all loadings to Bayou Blue are from natural sources. The model projection indicated that the current dissolved oxygen criterion is inappropriate because it can not be met without reductions of the natural background load, which is practically difficult to achieve. There is no known manmade loading contributions to Bayou Blue, therefore, LDEQ recommends a Use Attainability Analysis (UAA) for the waterbody to evaluate the current dissolved oxygen criterion.

6 TMDL DEVELOPMENT

A TMDL is the total amount of a pollutant that a receiving waterbody can assimilate while still achieving water quality standards. In TMDL development, allowable loadings from all pollutant sources that cumulatively amount to no more than the TMDL must be established, thereby providing the basis for establishing water quality-based controls.

A TMDL for a given pollutant and waterbody is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include an implicit or explicit margin of safety (MOS) to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. The TMDL components are illustrated using the following equation:

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

The LA is the portion of the TMDL assigned to nonpoint sources such as from agricultural and forest land. The LAs include background (natural) loadings and human-induced nonpoint sources. Because there are no human-induced nonpoint sources of impairment, the entire LA is allocated to natural sources.

The WLA portion of the TMDL equation is the total loading of a pollutant that is assigned to point sources. No point sources were identified as impacting Bayou Blue.

Section 303(d) of the Clean Water Act and the regulations at 40 CFR 130.7 require that TMDLs include an MOS to account for uncertainty in available data or in the actual effect that controls will have on the loading reductions and receiving water quality. An MOS was not included for natural sources. Since there are no manmade sources, no MOS was assigned.

At times, natural disasters can affect water quality conditions. Hurricane Katrina made landfall on Monday, August 29, 2005, as a Category 4 hurricane. The storm brought heavy winds and rain to southeast Louisiana, breaching several levees and flooding up to 80 percent of New Orleans and large areas of coastal Louisiana. Both Hurricanes Katrina and Rita have caused a significant amount of change in sedimentation and water quality in southern Louisiana. Many wastewater treatment facilities were temporarily or permanently damaged. Some wastewater treatment facilities will be rebuilt; others will be relocated. Several federal and state agencies, including EPA and LDEQ, are engaged in collecting environmental data and assessing the recovery of the Gulf of Mexico waters.

The proposed TMDLs in this report were developed on the basis of pre-hurricane water quality data. Post-hurricane water quality conditions and other factors could delay the implementation of these proposed TMDLs, render some proposed TMDLs obsolete, or require modifications of the TMDLs. Although hurricane effects may be valid for some TMDLs, any deviation from the TMDLs should be justified using site-specific data or information.

6.1 Dissolved Oxygen TMDLs

The dissolved oxygen TMDLs are presented as oxygen demand from CBOD, ammonia nitrogen, and SOD, and they were derived using the T-QUAL model. A summary of the TMDLs is presented in Table 6-1. The TMDLs were calculated from SOD, CBOD, and from model inputs. There were no WLAs. The model projection indicated that the current dissolved oxygen criterion is inappropriate because it can not be met without reductions of the natural background load, which is practically difficult to achieve. There is no known manmade loading contributions to Bayou Blue, therefore, LDEQ recommends a Use Attainability Analysis (UAA) for the waterbody to evaluate the current dissolved oxygen criterion.

Table 6-1. Summary of dissolved oxygen TMDL for Bayou Blue, Subsegment 120606

Subsegment	Oxygen demand (lb/d)			
120606	**SOD**	**CBOD**	**NBOD**	**Total**
PS WLA	0	0	0	0
Natural LA	2,450	7,949	4,313	14,711
Manmade LA	0	0	0	0
Manmade MOS for LA	0	0	0	0
TMDL	2,450	7,949	4,313	14,711

Note: SOD = sediment oxygen demand; CBOD = carbonaceous biochemical oxygen demand; NBOD = nitrogenous biochemical oxygen demand

Seasonal Variation

Critical conditions for dissolved oxygen in Louisiana waterbodies have been determined to be the following: negligible nonpoint runoff and low stream flow combined with high water temperatures. Oxygen-demanding substances can enter a water system during high flows and settle to the bottom, where they exert a large oxygen demand during the high-temperature/low-flow seasons. Water temperature is one of the leading factors that affect dissolved oxygen in the three segments. High water temperatures lower the dissolved oxygen saturation concentration, decreasing the amount of dissolved oxygen that the stream can contain. In addition, high temperature increases CBOD decay and SOD. Therefore, it is most important to develop a TMDL to address the high water temperature conditions.

6.2 Nutrient TMDLs

Nutrients can enter a water system through surface runoff. Once they are in the environment, the most recognizable effect is algae blooms. The buildup of nutrients that leads to the blooms can occur over time even if the effects are not noticed in the short term. When algae die, the result is increased oxygen demand, which is detrimental to aquatic life.

Louisiana does not have numeric water quality criteria for nutrients. Water quality data were collected from non-nutrient-impaired subsegments in the Terrebonne Basin. The data included total phosphorus, nitrate+nitrite (NO_2+$NO_{3)}$, and total Kjeldahl nitrogen (TKN). The nitrate+nitrite and TKN were combined to obtain the total nitrogen concentration.

The observed data for station 2844 in subsegment 120606 is presented in Table 6-2. The data in the table represents pre-Katrina data only. The nitrogen-phosphorus ratio for subsegment 120606 is 3.2.

Table 6-2. Nutrient concentrations for Bayou Blue, Subsegment 120606

Statistic	Total P (mg/L)	NO_2+NO_3 (mg/L)	TKN (mg/L)	Total N (mg/L)
Minimum	0.09	0.02	0.51	0.82
Mean	0.34	0.22	1.22	1.42
Maximum	1.28	0.71	2.68	2.73

The nutrient TMDLs are presented in Table 6-3. The critical flow at station BB6 (see Appendix C) was used with the mean observed concentration to determine the LA portion of the TMDL.

Table 6-3. Summary of nutrient TMDLs for Bayou Blue, Subsegment 120606

Nutrient	WLA (lb/d)	Natural LA (lb/d)	Manmade LA (lb/d)	Manmade MOS (lb/d)	TMDL (lb/d)
Total phosphorus	0.00	44.8	0.00	0.00	44.8
Total nitrogen	0.00	186.6	0.00	0.00	186.6

7 CONCLUSIONS

LDEQ recommends a Use Attainability Analysis (UAA) for the waterbody. Natural conditions prohibit Bayou Blue from sustaining the established water quality criteria. Bayou Blue is dominated by tidal flow, and there are no permitted dischargers along the waterbody. The surrounding land area consists primarily of saltwater marsh that has been impacted by oilfield and drainage canals. There is no urban development, and LDEQ feels that it is unlikely that any new dischargers will develop facilities along the waterbody. Therefore, LDEQ does not feel that a TMDL should be completed for Bayou Blue and that the current dissolved oxygen criterion should be reevaluated.

LDEQ uses funds provided under section 106 of the Clean Water Act and under the authority of the Louisiana Environmental Quality Act to run a program for monitoring the quality of Louisiana's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations using appropriate sampling methods and procedures to ensure the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term database for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program are used to develop the state's biennial section 305(b) report (*Water Quality Inventory*) and section 303(d) list of impaired waters.

LDEQ has implemented a watershed approach to surface water quality monitoring. Through the approach, the entire state is sampled on a 4-year cycle. Long-term trend monitoring sites at various locations on the large rivers and Lake Pontchartrain are sampled throughout the 4-year cycle. Sampling is conducted monthly to yield approximately 12 samples per site during each year the site is monitored. Sampling sites are where they are considered representative of the waterbody. Under the current monitoring schedule, approximately one-half of the state's waters are newly assessed for section 305(b) and section 303(d) listing purposes during each biennial cycle; sampling occurs statewide each year. The 4-year cycle follows an initial 5-year rotation that covers all basins in the state according to the TMDL priorities. Monitoring allows LDEQ to determine whether there has been any improvement in water quality following TMDL implementation. As the monitoring results are evaluated at the end of each year, waterbodies might be added to or removed from the section 303(d) list of impaired waterbodies.

8 PUBLIC PARTICIPATION

Federal regulations require EPA to notify the public and seek comments concerning TMDLs that the Agency prepares. These TMDLs were developed under contract to EPA, and EPA held a public review period seeking comments, information, and data from the public and any other interested parties. The notice for the public review period was published in the *Federal Register* on XXX XX, XXXX, and the review period closed on XXX XX, XXXX.

Comments were received from XXX and were used to inform or revise this TMDL document.

EPA will submit the final TMDLs to LDEQ for implementation and incorporation into LDEQ's current water quality management plan.

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Appendix A:
Monitoring Data Tables and Plots

Tables

Figures

Table A-1. Routine LDEQ water quality monitoring data

Site ID	Site location	Date	Water temp. (°C)	DO (mg/L)	Specific conductivity (µmhos/cm)	pH (s.u.)
2844	Bayou Blue south of Larose, Louisiana	1/12/2004	11.63	8.98	722	7.63
2844	Bayou Blue south of Larose, Louisiana	2/9/2004	12.72	9.42	875	7.46
2844	Bayou Blue south of Larose, Louisiana	3/16/2004	20.50	5.94	468	7.27
2844	Bayou Blue south of Larose, Louisiana	4/13/2004	15.63	7.99	891	7.55
2844	Bayou Blue south of Larose, Louisiana	5/10/2004	26.50	3.14	350	7.04
2844	Bayou Blue south of Larose, Louisiana	6/7/2004	28.00	1.98	1,650	6.94
2844	Bayou Blue south of Larose, Louisiana	7/6/2004	31.01	3.82	312	7.28
2844	Bayou Blue south of Larose, Louisiana	8/2/2004	30.50	2.10	406	7.37
2844	Bayou Blue south of Larose, Louisiana	10/5/2004	27.30	4.59	990	7.35
2844	Bayou Blue south of Larose, Louisiana	11/29/2004	17.97	7.16	531	7.36
2844	Bayou Blue south of Larose, Louisiana	1/18/2006	10.08	7.85	11,730	7.67
2844	Bayou Blue south of Larose, Louisiana	2/6/2006	15.42	6.65	8,003	7.34
2844	Bayou Blue south of Larose, Louisiana	3/6/2006	18.40	4.34	1,245	7.37
2844	Bayou Blue south of Larose, Louisiana	4/3/2006	23.79	4.41	6,730	7.23
2844	Bayou Blue south of Larose, Louisiana	4/18/2006	26.31	3.35	25,000	7.23
2844	Bayou Blue south of Larose, Louisiana	6/6/2006	29.83	5.15	2,940	7.68
2844	Bayou Blue south of Larose, Louisiana	6/26/2006	29.10	4.68	5,120	7.75
2844	Bayou Blue south of Larose, Louisiana	7/17/2006	30.19	3.39	3,220	7.60
2844	Bayou Blue south of Larose, Louisiana	8/7/2006	29.84	3.54	536	7.41
2844	Bayou Blue south of Larose, Louisiana	9/25/2006	26.19	2.05	10,320	7.03
2844	Bayou Blue south of Larose, Louisiana	11/13/2006	18.34	6.62	5,680	7.35
2844	Bayou Blue south of Larose, Louisiana	12/11/2006	11.80	9.62	3,770	7.84
947	Forty Arpent Canal in Cutoff, Louisiana	1/4/2000	17.70	4.30	1,265	7.60
947	Forty Arpent Canal in Cutoff, Louisiana	2/1/2000	10.60	6.50	1,176	8.00
947	Forty Arpent Canal in Cutoff, Louisiana	2/29/2000	19.54	9.46	1,990	7.78
947	Forty Arpent Canal in Cutoff, Louisiana	4/4/2000	20.30	5.11	1,157	7.49
947	Forty Arpent Canal in Cutoff, Louisiana	5/2/2000	23.60	4.85	1,336	7.47

Table A-1. (continued)

Site ID	Site location	Date	Water temp. (°C)	DO (mg/L)	Specific conductivity (µmhos/cm)	pH (s.u.)
947	Forty Arpent Canal in Cutoff, Louisiana	5/30/2000	29.02	1.72	1,350	7.59
947	Forty Arpent Canal in Cutoff, Louisiana	6/27/2000	28.04	4.78	1,115	7.58
947	Forty Arpent Canal in Cutoff, Louisiana	8/1/2000	28.05	1.66	1,234	7.27
947	Forty Arpent Canal in Cutoff, Louisiana	8/29/2000	28.90	2.81	1,365	7.41
947	Forty Arpent Canal in Cutoff, Louisiana	9/26/2000	23.94	3.44	793	7.27
947	Forty Arpent Canal in Cutoff, Louisiana	10/24/2000	23.29	3.39	899	7.42
947	Forty Arpent Canal in Cutoff, Louisiana	11/28/2000	15.41	3.40	834	7.17

Table A-2. Routine LDEQ water quality monitoring data

Site ID	Site location	Date	DO (mg/L)	Phos-phorus (mg/L)	Nitrite+Nitrate (mg/L)	Ammonia (mg/L)
2844	Bayou Blue south of Larose, Louisiana	1/12/2004	8.98	0.17	0.42	0.15
2844	Bayou Blue south of Larose, Louisiana	2/9/2004	9.42	0.28	0.24	0.17
2844	Bayou Blue south of Larose, Louisiana	3/16/2004	5.94		0.06	
2844	Bayou Blue south of Larose, Louisiana	4/13/2004	7.99		0.22	0.14
2844	Bayou Blue south of Larose, Louisiana	5/10/2004	3.14	0.22	0.14	
2844	Bayou Blue south of Larose, Louisiana	6/7/2004	1.98	0.14	0.12	0.11
2844	Bayou Blue south of Larose, Louisiana	7/6/2004	3.82	0.19	0.12	0.17
2844	Bayou Blue south of Larose, Louisiana	8/2/2004	2.1	0.15	0.06	
2844	Bayou Blue south of Larose, Louisiana	10/5/2004	4.59	0.09	0.28	
2844	Bayou Blue south of Larose, Louisiana	10/26/2004		0.31		
2844	Bayou Blue south of Larose, Louisiana	11/29/2004	7.16	0.15	0.47	
2844	Bayou Blue south of Larose, Louisiana	1/18/2006	7.85			
2844	Bayou Blue south of Larose, Louisiana	2/6/2006		0.12	0.26	0.34
2844	Bayou Blue south of Larose, Louisiana	3/6/2006	4.34	0.15	0.56	0.23
2844	Bayou Blue south of Larose, Louisiana	4/3/2006	4.41	0.09	0.27	0.12
2844	Bayou Blue south of Larose, Louisiana	4/18/2006	3.35	0.15		
2844	Bayou Blue south of Larose, Louisiana	6/6/2006	5.15			
2844	Bayou Blue south of Larose, Louisiana	6/7/2006		0.15	0.71	

Table A-2. (continued)

Site ID	Site location	Date	DO (mg/L)	Phos-phorus (mg/L)	Nitrite+Nitrate (mg/L)	Ammonia (mg/L)
2844	Bayou Blue south of Larose, Louisiana	6/26/2006	4.68	0.22	0.23	
2844	Bayou Blue south of Larose, Louisiana	7/17/2006	3.39	0.19		
2844	Bayou Blue south of Larose, Louisiana	8/7/2006	3.54	0.19	0.1	
2844	Bayou Blue south of Larose, Louisiana	9/25/2006	2.05	0.21		
2844	Bayou Blue south of Larose, Louisiana	11/13/2006	6.62	0.14	0.18	0.1
2844	Bayou Blue south of Larose, Louisiana	12/11/2006	9.62	0.16	0.33	0.21
947	Forty Arpent Canal in Cutoff, Louisiana	1/4/2000	4.3	0.24	0.16	0.14
947	Forty Arpent Canal in Cutoff, Louisiana	2/1/2000	6.5	0.19	0.38	0.28
947	Forty Arpent Canal in Cutoff, Louisiana	2/29/2000	9.46	0.57	0.02	0.1
947	Forty Arpent Canal in Cutoff, Louisiana	4/4/2000	5.11	0.14	0.5	0.12
947	Forty Arpent Canal in Cutoff, Louisiana	5/2/2000	4.85	0.93	0.06	0.1
947	Forty Arpent Canal in Cutoff, Louisiana	5/30/2000	1.72	1.28	0.05	0.1
947	Forty Arpent Canal in Cutoff, Louisiana	6/27/2000	4.78	0.77	0.11	0.1
947	Forty Arpent Canal in Cutoff, Louisiana	8/1/2000	1.66	0.8	0.05	0.18
947	Forty Arpent Canal in Cutoff, Louisiana	8/29/2000	2.81	0.83	0.09	0.1
947	Forty Arpent Canal in Cutoff, Louisiana	9/26/2000	3.44	0.58	0.19	0.16
947	Forty Arpent Canal in Cutoff, Louisiana	10/24/2000	3.39	0.42	0.02	0.1
947	Forty Arpent Canal in Cutoff, Louisiana	11/28/2000	3.4	0.37	0.34	0.19

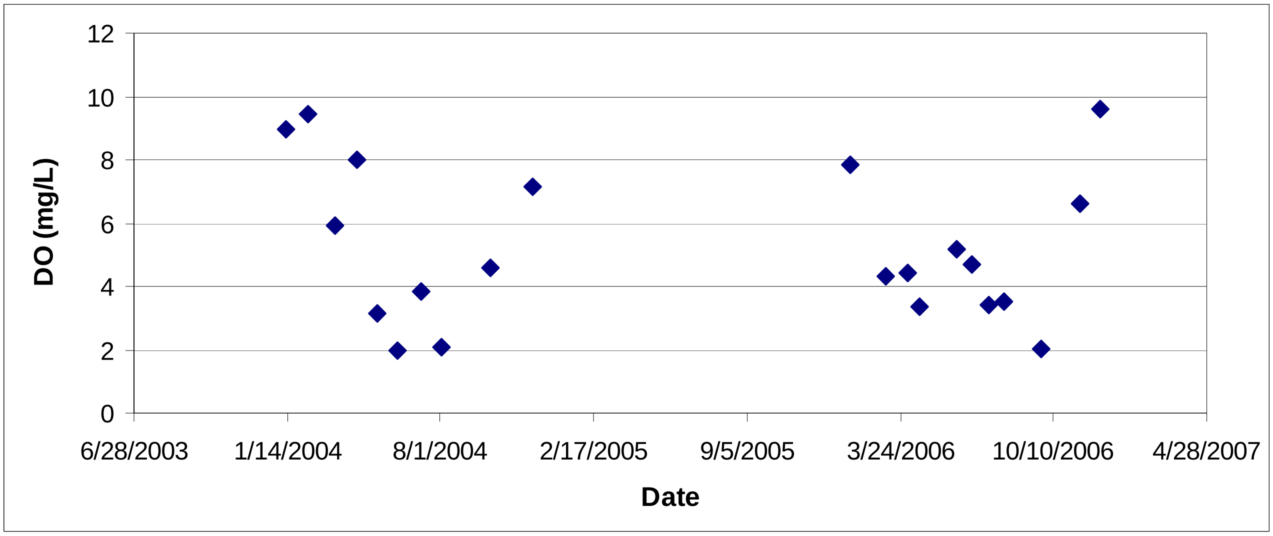

Figure A-1. Dissolved oxygen monitoring data observed at Bayou Blue south of Larose, LA (2844).

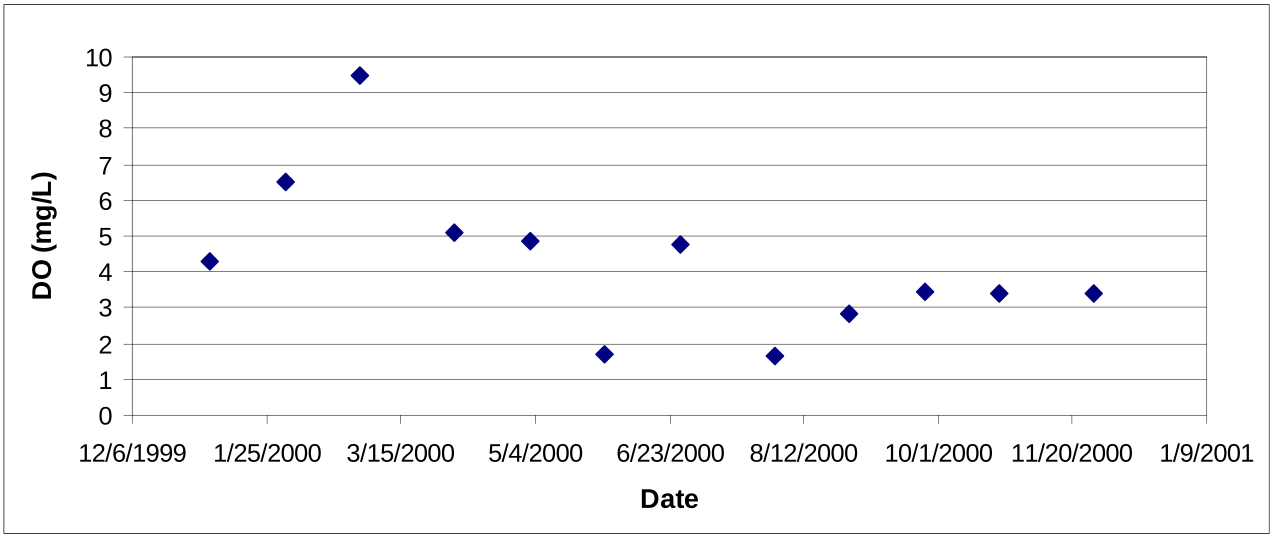

Figure A-2. Dissolved oxygen monitoring data observed at Forty Arpent Canal in Cutoff, LA (947).

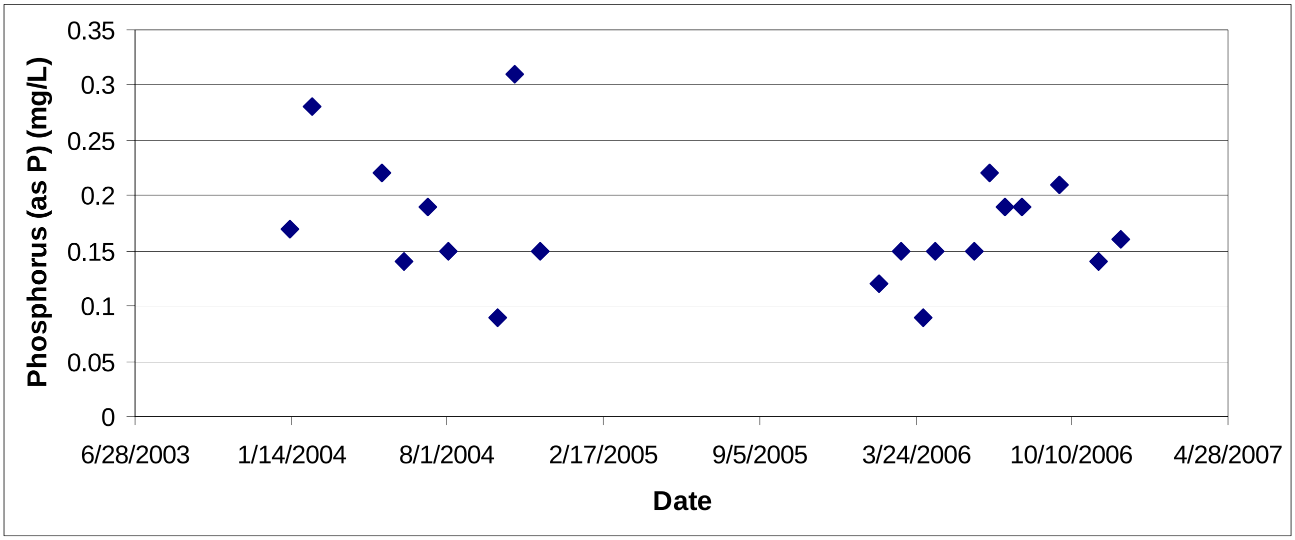

Figure A-3. Phosphorus monitoring data observed at Bayou Blue south of Larose, LA (2844).

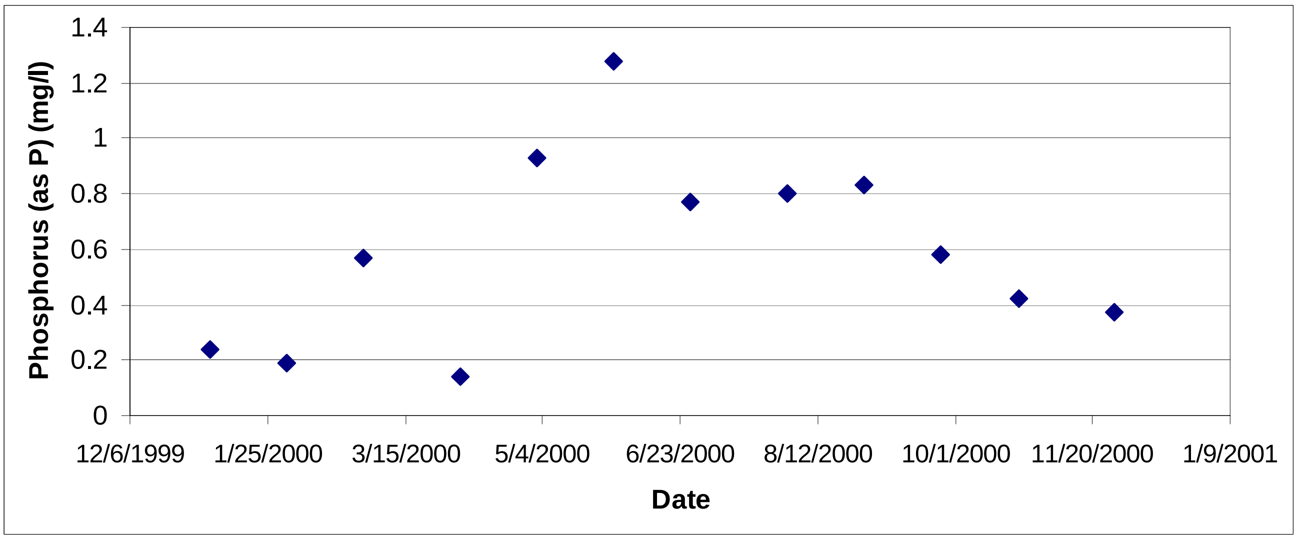

Figure A-4. Phosphorus monitoring data observed at Forty Arpent Canal in Cutoff, LA (947).

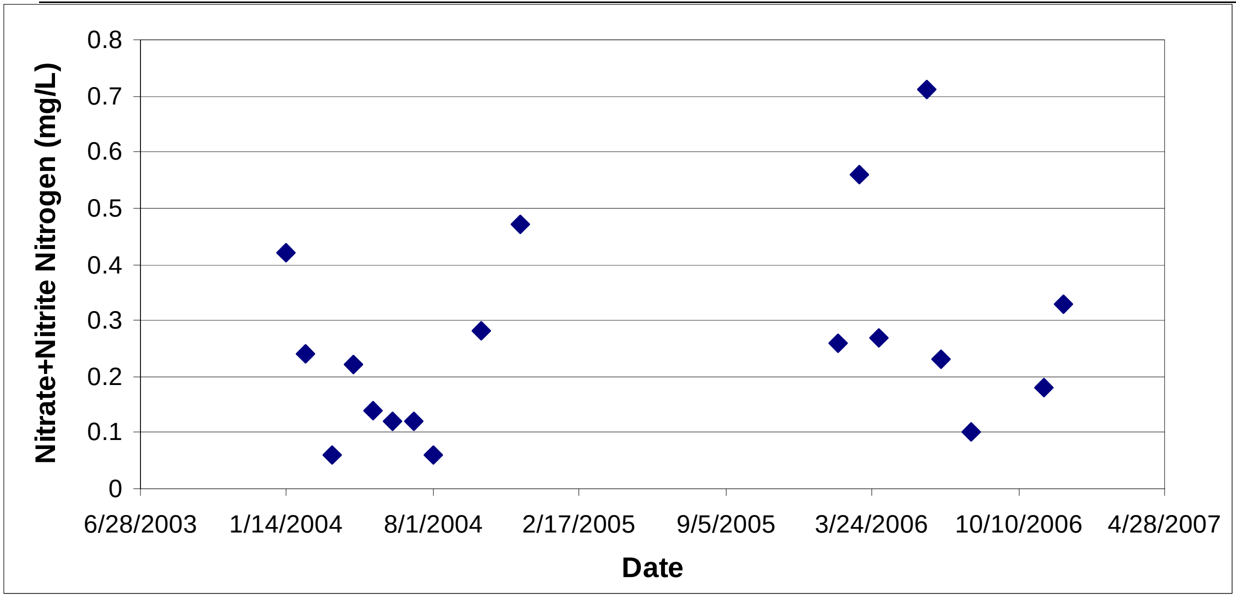

Figure A-5. Nitrate+nitrite monitoring data observed at Bayou Blue south of Larose, LA (2844).

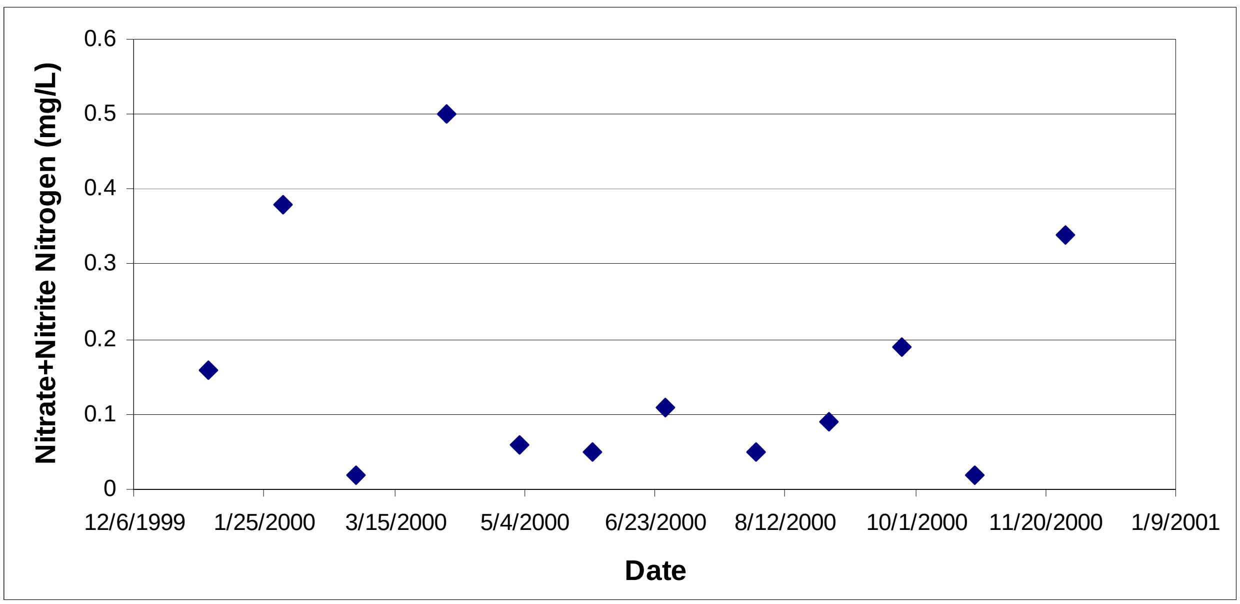

Figure A-6. Nitrate+nitrite monitoring data observed at Forty Arpent Canal in Cutoff, LA (947).

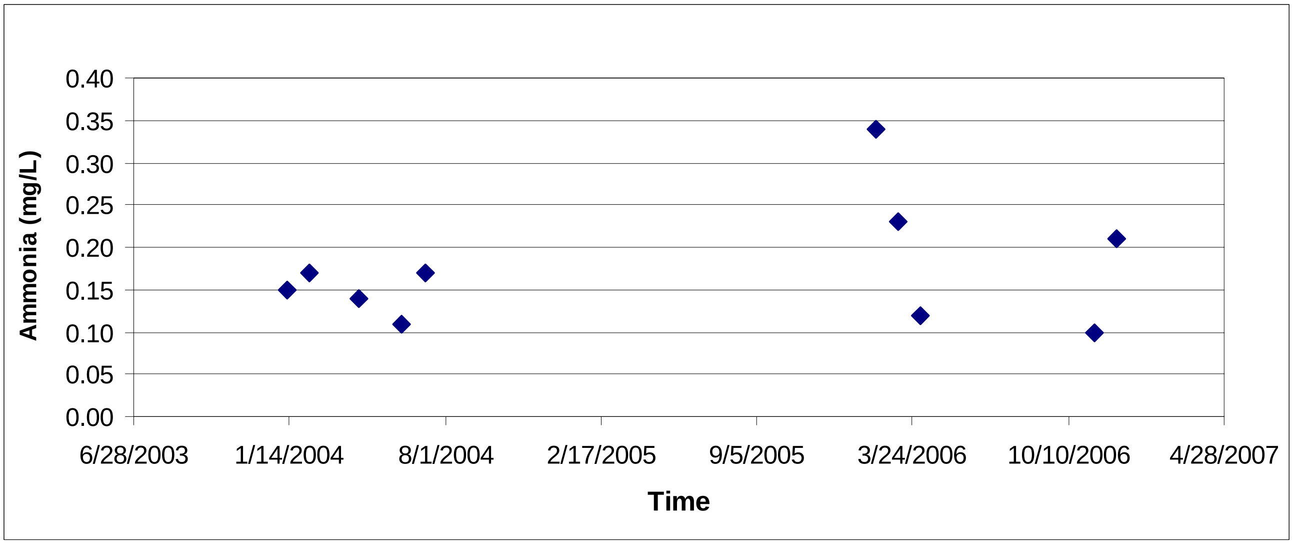

Figure A-7. Ammonia monitoring data observed at Bayou Blue south of Larose, LA (2844).

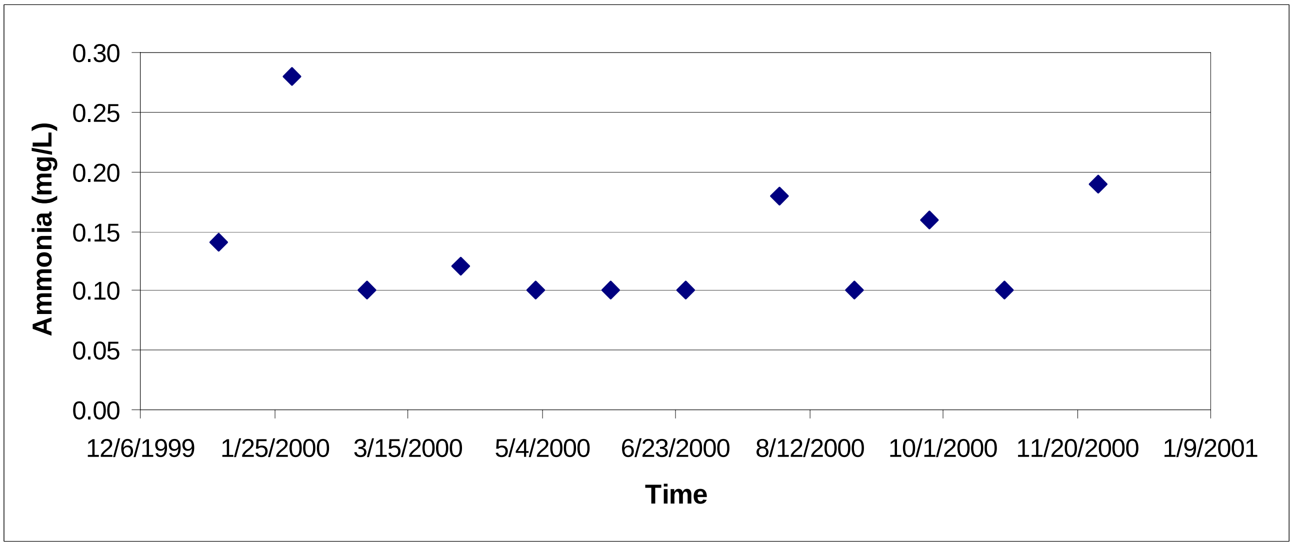

Figure A-8. Ammonia monitoring data observed at Forty Arpent Canal in Cutoff, LA (947).

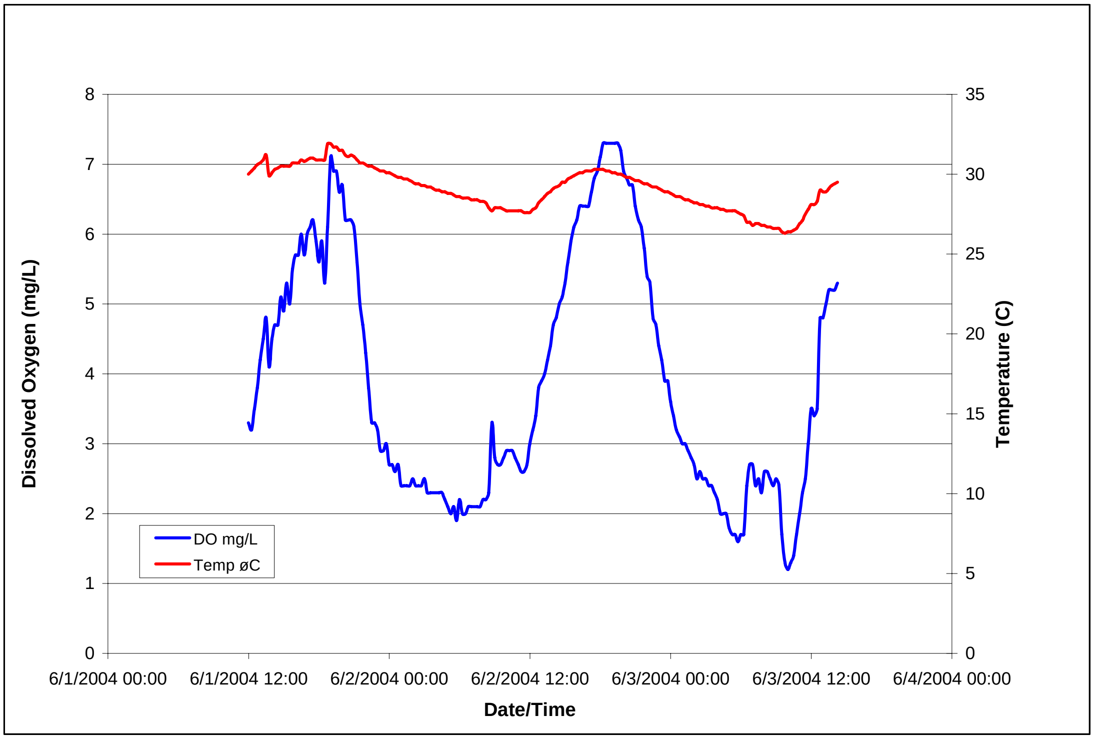

Figure A-9. Continuous monitoring results for DO and temperature at BB2.

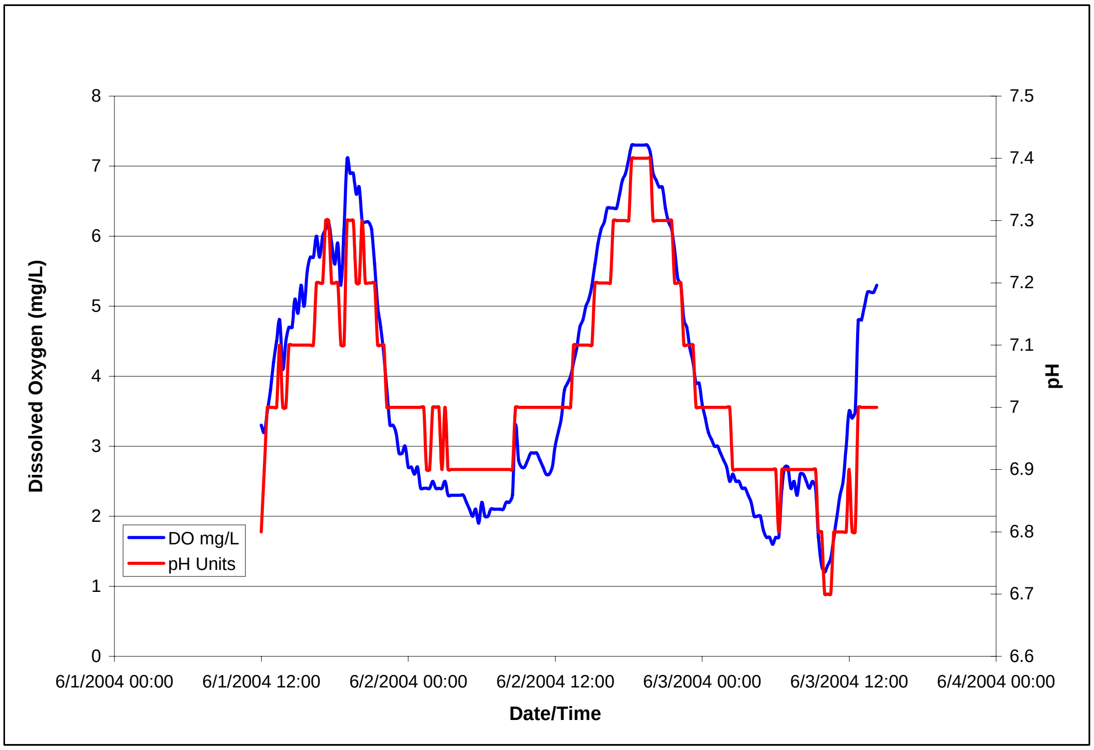

Figure A-10. Continuous monitoring results for DO and pH at BB2.

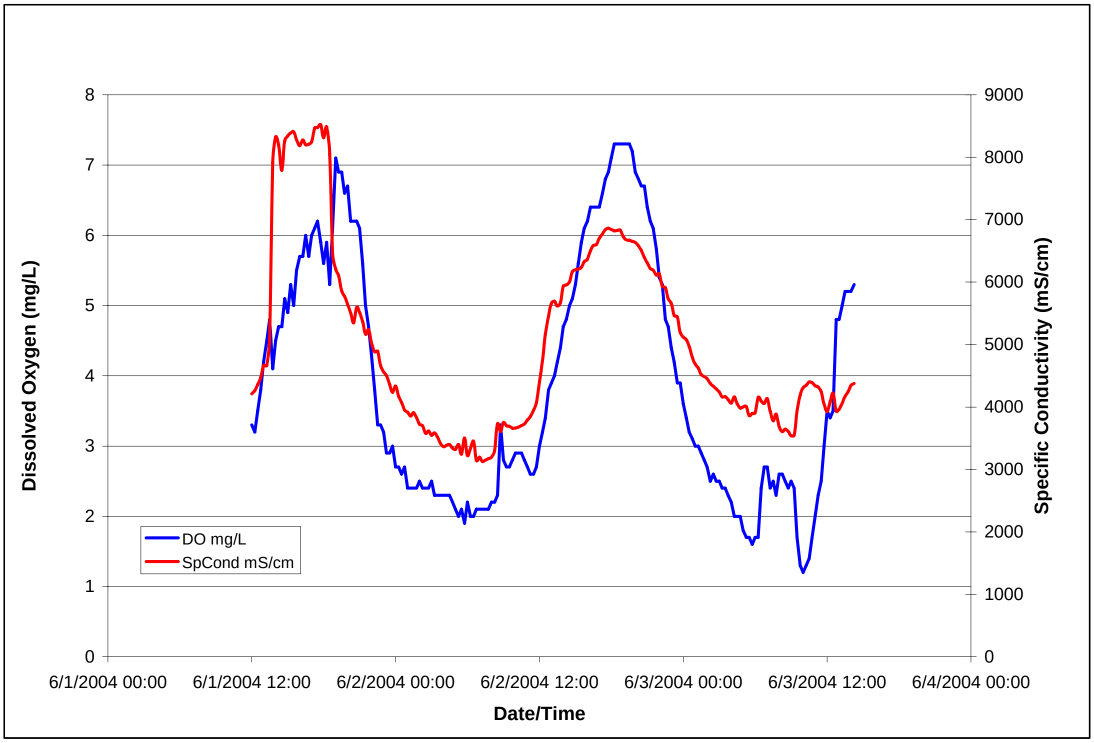

Figure A-11. Continuous monitoring results for DO and conductivity at BB2.

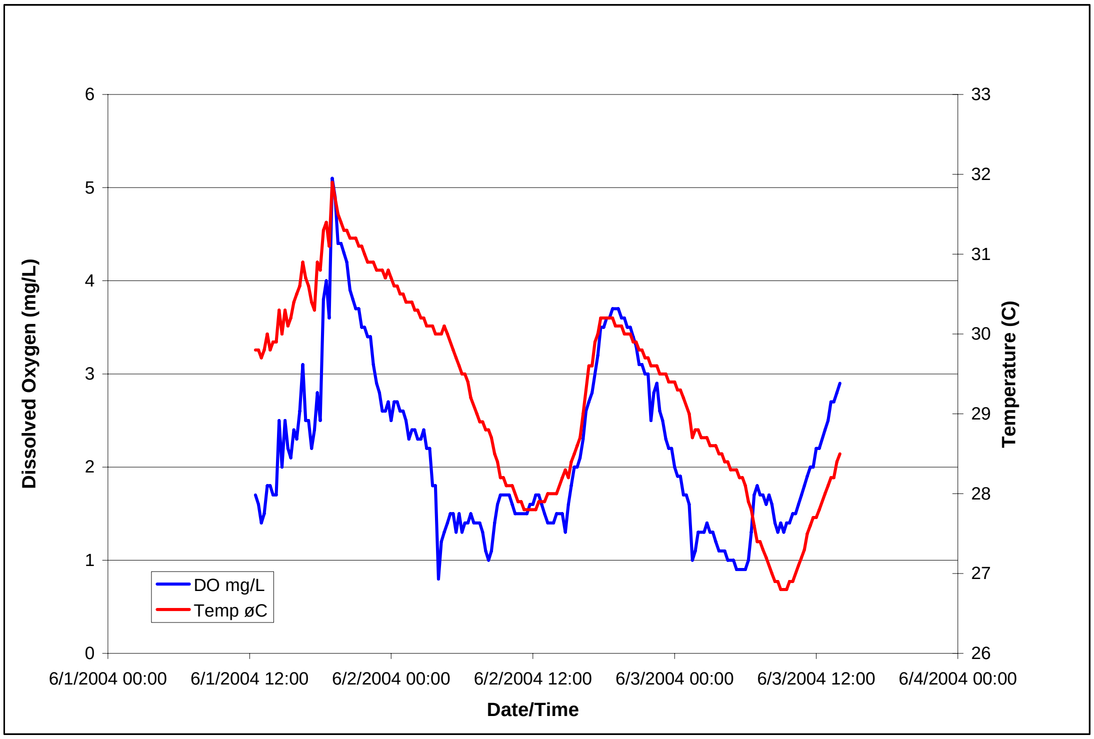

Figure A-12. Continuous monitoring results for DO and temperature at BB3.

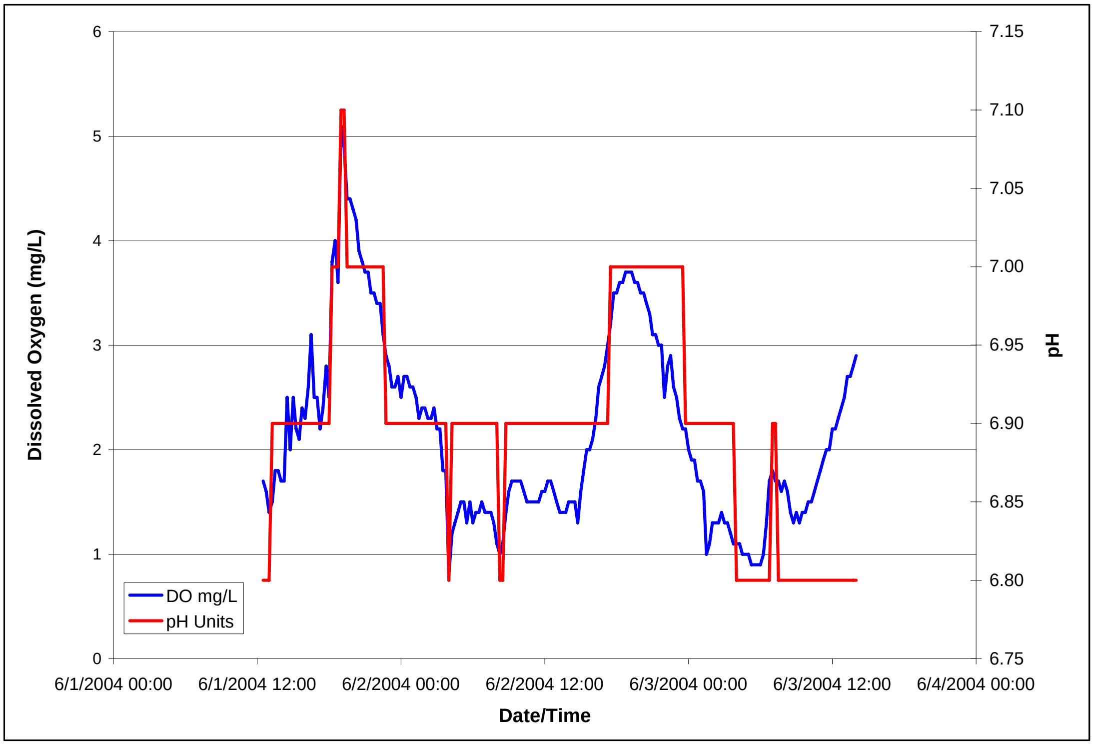

Figure A-13. Continuous monitoring results for DO and pH at BB3.

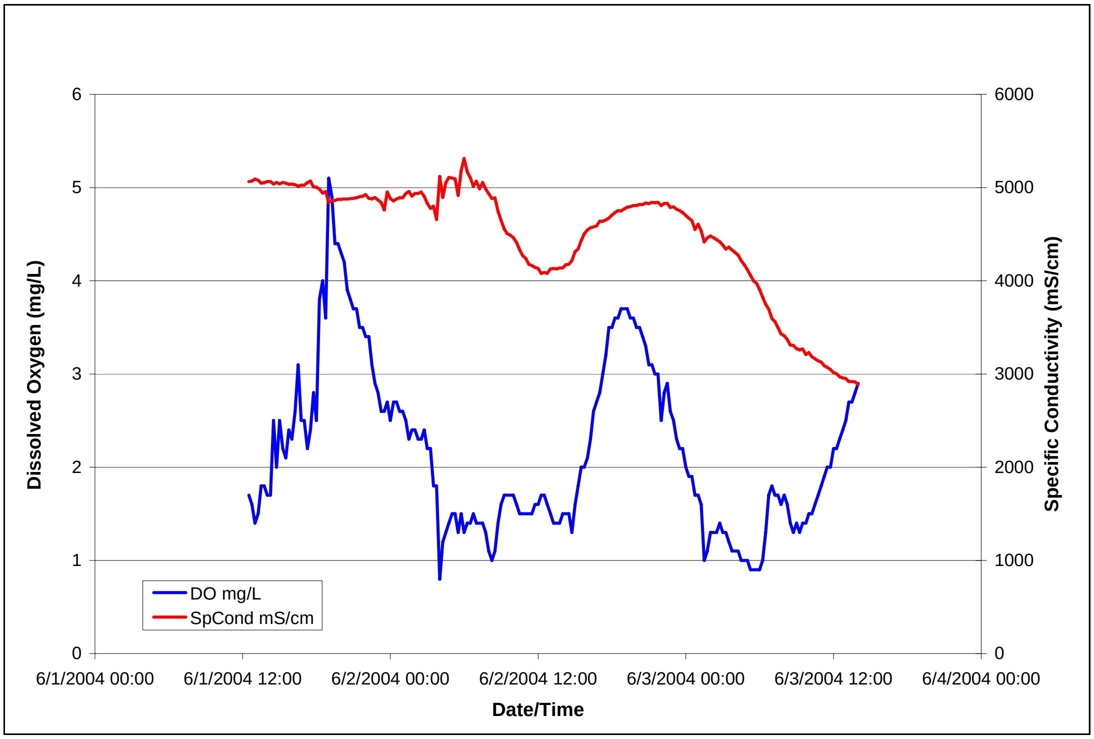

Figure A-14. Continuous monitoring results for DO and conductivity at BB3.

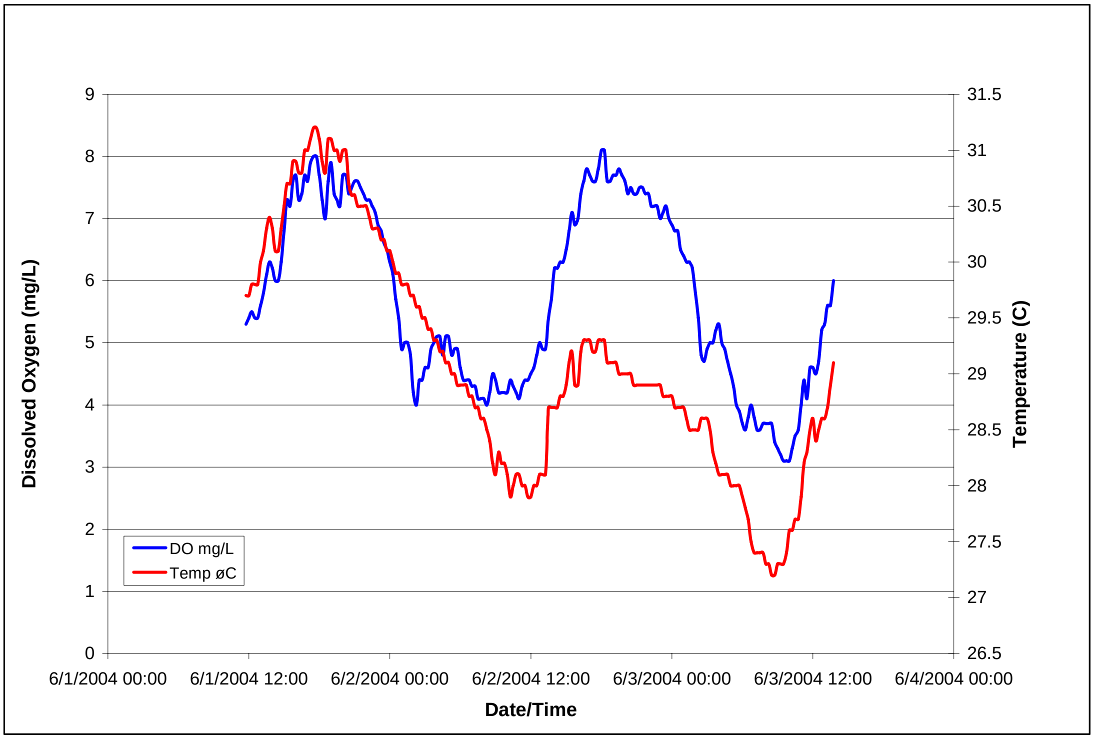

Figure A-15. Continuous monitoring results for DO and temperature at BB6.

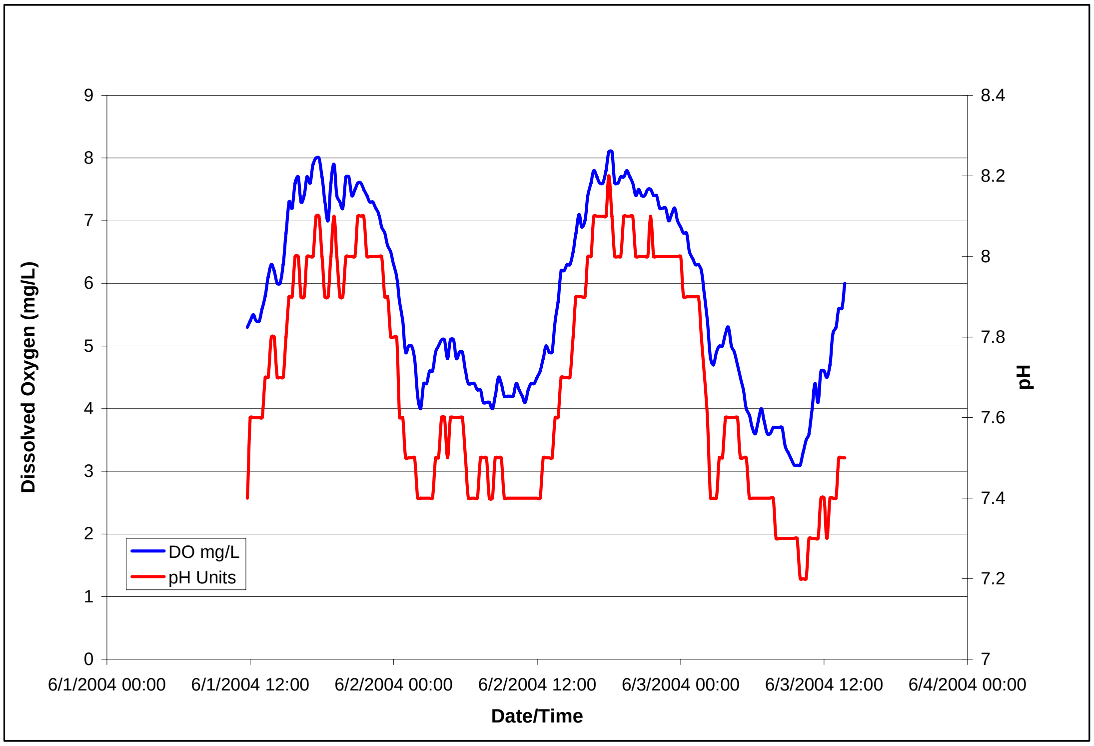

Figure A-16. Continuous monitoring results for DO and pH at BB6.

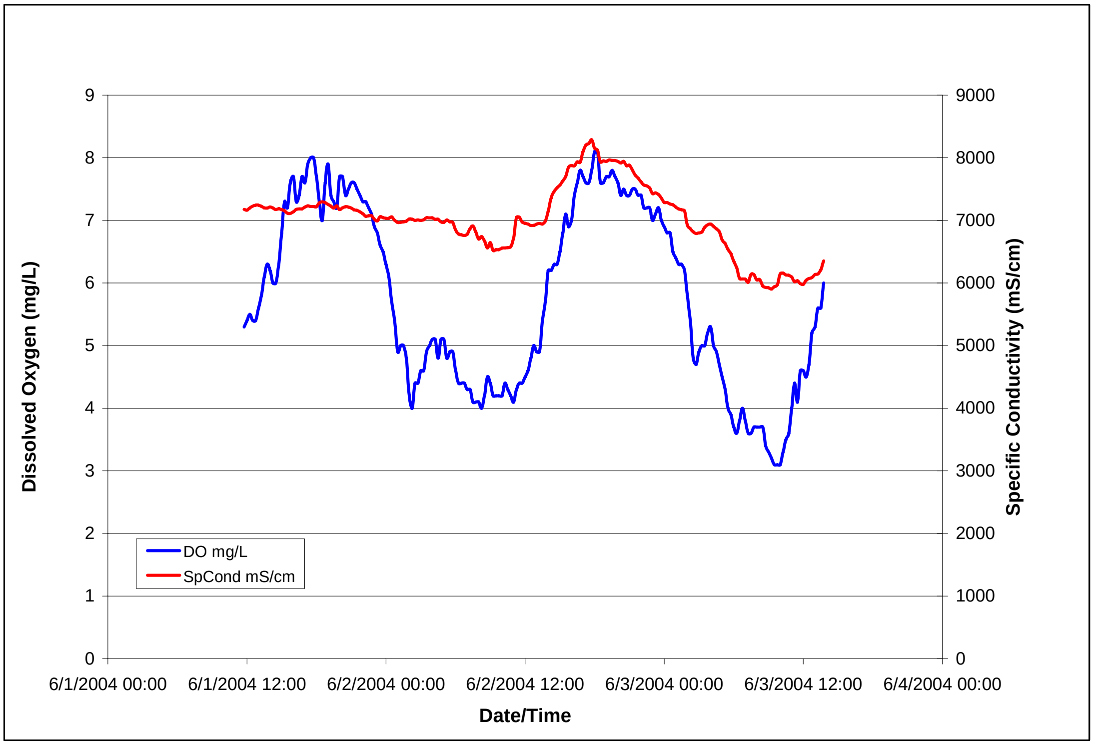

Figure A-17. Continuous monitoring results for DO and conductivity at BB6.

Appendix B:
Modeling Information

Exhibit B-1. Flow Rationale

August 22, 2007

To: Chuck Berger
From: Max Forbes
Subject: Tidal stream flows for Bayou Blue between Grand Bayou Canal and Site BB6.

Bayou Blue is a part of a complex tidally affected stream system. The Bayou intersects Grand Bayou Canal at the Bayou's western terminus and meanders southeasterly for about five miles to end in a complex of oil field canals. It is likely that the tide coming up Grand Bayou Canal reaches the juncture with Bayou Blue in advance of the tide coming up Bayou Blue. This is caused by the circuitous route that tidal flows have to follow before reaching the BB6 site. This supposed situation could result in tidal flows into Bayou Blue from Grand Bayou Canal until the incoming tide in lower Bayou Blue "catches up" with the water from Grand Bayou Canal. It is also likely that the tidal range in lower Bayou Blue is less than that in Grand Bayou Canal. It is also likely that any flows out of Bayou Lafourche that might reach Grand Bayou Canal are insignificant as compared to the tidal flows.

The supposed situation described above is beyond my ability to quantify. So, I decided to figuratively "block off" Bayou Blue at Grand Bayou Canal and compute tidal flows in the Bayou as an independent water body. The Bayou from the juncture to BB6 is about 4.89 miles; from the juncture to BB2 is about 0.61 miles; from BB2 to BB3 is about 2.14 miles; and from BB3 to BB6 is about 2.14 miles. I estimated a tidal range of 0.50 feet for Bayou Blue and a tidal period of 12 hours. I used widths of 174 feet for the juncture to BB2 segment, 147 feet for the BB2 to BB3 segment, and 200 feet for the BB3 to BB6 segment. NOTE: That latter segment includes a oil field complex to the north of the Bayou.

The results of the computations using the "Tidal Algorithm" are:

Juncture to BB2: Surface area = 556,800 square feet; volume = 278,400 cubic feet; average tidal flow = 6.44 CFS; critical tidal flow = 2.15 CFS. Flows are at BB2 for segment only.

BB2 to BB3: Surface area = 1,664,087 square feet; volume = 832,044 cubic feet; average tidal flow = 19.26 CFS; and critical tidal flow = 6.42. Flows are at BB3 segment only.

BB3 to BB6: Surface area = 4,084,840 square feet; volume = 2,042,420 cubic feet; average tidal flow = 47.28 CFS; and critical tidal flow = 15.76 CFS. Flows are at BB6 for segment only.

Totaling the flows results in:

BB2: Average tidal flow = 6.44 CFS; critical tidal flow = 2.15 CFS (as shown above)

BB3: Average tidal flow = 25.70 CFS; critical tidal flow = 8.57 CFS

BB6: Average tidal flow = 72.98 CFS; critical tidal flow = 24.33 CFS

I would expect this to be a conservative estimate of the tidal flow in the Bayou. I would suggest that the numbers presented be used in modeling to obtain a "first cut". If problems are revealed by the modeling, we can probably "tweak" the computations a bit. Let me know how this comes out.

Table B-1. Model data initial input parameters and sources

Category	Parameter	Units	Values by reach					Data source / comments
			1	2	3	4	5	
Headwater data	Dissolved oxygen	mg/L	4.00					Model output from upstream segment
	Ultimate CBOD	mg/L	4.03					Observed data in upstream subsegment
	Ultimate NBOD	mg/L	0.866					4.3 × 0.2 (conversion factor × observed ammonia)
	Flow	ft^3/sec	6.44					Flow based on tidal prism calculations provided by Max Forbes.
Wastewater data	Dissolved oxygen	mg/L	--	3	2	--	--	No facilities were included in this model. Wastewater was used to simulate the impact of increased tidal flow between sites BB02 and BB06. DO, $CBOD_5$, and ammonia taken from upstream observed data
	$CBOD_5$	mg/L	--	2.45	2.45	--	--	
	TKN/NH_3-N	mg/L	--	0.2	0.2	--	--	
	Flow	mgd	--	9.960	24.445	--	--	
Decay and settling rates @ 20°C	CBOD deoxygenation rate	1/day	0.35	0.35	0.35	0.35	0.35	Value recommended in the *Louisiana Total Maximum Daily Load Technical Procedures* (LTP) & calibration
	CBOD settling rate	1/day	0.05	0.05	0.05	0.05	0.05	Value recommended in the LTP.
	NBOD deoxygenation rate	1/day	0.1	0.1	0.1	0.1	0.1	Value recommended in the LTP.
	NBOD settling rate	1/day	0.025	0.025	0.025	0.025	0.025	Value selected based on standard LDEQ practice and best professional judgment (BPJ); one-half of the CBOD decay rate
Stream geometry	Reach length	kilo-meter	1.29	3.48	3.52	0.17	0.5	Reach length based on GIS and BPJ
	Reach average depth	meter	0.63	0.72	0.95	1.09	1.09	Reach depths based on values measured during the survey at sites BB2, BB3, and BB6
	Reach average width	meter	53.03	48.92	57.45	70.1	70.1	Reach widths based on values measured during the survey at sites BB2, BB3, and BB6

Table B-1. (continued)

Cate-gory	Parameter	Units	Values by reach					Data source / comments
			1	2	3	4	5	
Reaeration, inhibition, and nonpoint loading	Sediment oxygen demand @ 20 ℃	g-O_2/ m^2/day	0.8	1.75	0.5	0.2	0.2	Value based on LTP recommendations and calibration
	Stream temperature	^oC	28.9	29.0	29.1	28.9	28.9	Reaches 1, 3, & 4: Average of June 2004 continuous monitoring for associated station. Reach 2: Average of reach 1 & 3 Reach 5: Set equal to Reach 4
	CBOD resuspended load	g-O_2/ m^2/day	1	1	1	1	1	Calibration
	NBOD resuspended load	g-O_2/ m^2/day	0.5	0.5	0.5	0.5	0.5	Calibration
	Chlorinity	ppt	1.54	1.45	1.76	2.16	2.16	Values calculated from the average continuous monitor salinity data obtained at sites BB2, BB3, and BB6 during the Bayou Blue survey on 6/1–3/2004
	Reaeration equation		LA Eq.	LA Eq.	LA Eq.	LA Eq.	LA Eq.	Most applicable reaeration equation; BPJ
	CBOD inhibition type		Linear	Linear	Linear	Linear	Linear	Standard practice; BPJ
	CBOD inhibition threshold	mg/L	2.0	2.0	2.0	2.0	2.0	Standard practice; BPJ
	NBOD inhibition type		Linear	Linear	Linear	Linear	Linear	Standard practice; BPJ
	NBOD inhibition threshold	mg/L	2.0	2.0	2.0	2.0	2.0	Standard practice; BPJ

Table B-2. Summer (May–Oct) Temperature 90th Percentiles for Station 2844

Date	Water Temp. (°C)
05/10/2004	26.5
06/07/2004	28
07/06/2004	31.01
08/02/2004	30.5
10/05/2004	27.3
06/06/2006 10:30	29.83
06/26/2006 9:30	29.1
07/17/2006 9:10	30.19
08/07/2006 10:02	29.84
09/25/2006 9:15	26.19
90th Percentile	30.55

Appendix C:
Modeling Information

Table C-1. Model data initial input parameters and sources

Category	Parameter	Units	Values by reach					Data source / comments
			1	2	3	4	5	
Headwater data	Dissolved oxygen	mg/L	3.60					Average summer pre-Katrina concentration for Station 2844
	Ultimate CBOD	mg/L	2.57					Reference stream data
	Ultimate NBOD	mg/L	0.866					4.3 × 0.14 (conversion factor × observed ammonia)
	Flow	ft^3/sec	6.44					Flow based on tidal prism calculations provided by Max Forbes.
Wastewater data	Dissolved oxygen	mg/L	--	3	2	--	--	No facilities were included in this model. Wastewater was used to simulate the impact of increased tidal flow between sites BB02 and BB06. $CBOD_5$ was obtained from the last element of the previous model reach. The $CBOD_U$ were divided by 2.3 to convert to $CBOD_5$. DO taken from 2004 continuous monitoring observed data. Ammonia was taken from station 2844 observed data.
	$CBOD_5$	mg/L	--	1.12	1.12	--	--	
	TKN/NH_3-N	mg/L	--	0.14	0.14	--	--	
	Flow	mgd	--	9.960	24.445	--	--	
Decay and settling rates @ 20°C	CBOD deoxygenation rate	1/day	0.35	0.35	0.35	0.35	0.35	Value recommended in the *Louisiana Total Maximum Daily Load Technical Procedures* (LTP) & calibration
	CBOD settling rate	1/day	0.05	0.05	0.05	0.05	0.05	Value recommended in the LTP.
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Stream geometry	Reach length	kilo-meter	1.29	3.48	3.52	0.17	0.5	Reach length based on GIS and BPJ
	Reach average depth	meter	0.63	0.72	0.95	1.09	1.09	Reach depths based on values measured during the survey at sites BB2, BB3, and BB6
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Table C-1. (continued)

Category	Parameter	Units	Values by reach					Data source / comments
			1	2	3	4	5	
Reaeration, inhibition, and nonpoint loading	Sediment oxygen demand @ 20 °C	g-O_2/ m^2/day	1.1	2.75	0.2	0.2	0.2	Value based on LTP recommendations and calibration
	Stream temperature	^oC	28.9	29.0	29.1	28.9	28.9	Reaches 1, 3, & 4: Average of June 2004 continuous monitoring for associated station. Reach 2: Average of reach 1 & 3 Reach 5: Set equal to Reach 4
	CBOD resuspended load	g-O_2/ m^2/day	1.0	1.25	1.0	1.0	1.0	Calibration
	NBOD resuspended load	g-O_2/ m^2/day	1.0	1.25	0.5	0.5	0.5	Calibration
	Chlorinity	ppt	1.54	1.45	1.76	2.16	2.16	Values calculated from the average continuous monitor salinity data obtained at sites BB2, BB3, and BB6 during the Bayou Blue survey on 6/1–3/2004
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90th Percentile	30.55

Exhibit C-1. Flow Rationale

August 22, 2007

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From: Max Forbes
Subject: Tidal stream flows for Bayou Blue between Grand Bayou Canal and Site BB6.

Bayou Blue is a part of a complex tidally affected stream system. The Bayou intersects Grand Bayou Canal at the Bayou's western terminus and meanders southeasterly for about five miles to end in a complex of oil field canals. It is likely that the tide coming up Grand Bayou Canal reaches the juncture with Bayou Blue in advance of the tide coming up Bayou Blue. This is caused by the circuitous route that tidal flows have to follow before reaching the BB6 site. This supposed situation could result in tidal flows into Bayou Blue from Grand Bayou Canal until the incoming tide in lower Bayou Blue "catches up" with the water from Grand Bayou Canal. It is also likely that the tidal range in lower Bayou Blue is less than that in Grand Bayou Canal. It is also likely that any flows out of Bayou Lafourche that might reach Grand Bayou Canal are insignificant as compared to the tidal flows.

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I would expect this to be a conservative estimate of the tidal flow in the Bayou. I would suggest that the numbers presented be used in modeling to obtain a "first cut". If problems are revealed by the modeling, we can probably "tweak" the computations a bit. Let me know how this comes out.

Exhibit C-2. Reference Stream BOD

From Report by DeEtte "BOD STATISTICS for the REFERENCE STREAMS" dated July 18, 1997

Stream	Date	Time/ Sample	Site	BOD Dilution* NS, S (mg/l)	CBODu (mg/l)	kd (1/day)	NBODu (mg/l)	kn (1/day)	BODu (mg/l)	BOD60 (mg/l)
Beaucoup	10/10/1995	1315	1	100, 100	4.65	0.06	4.12	0.17	9.95	7.8
Creek		1330	1	100, 100	1.8	0.096	4.78	0.17	7.68	5.5
		1335	1	100, 100	1.7	0.172	8.5	0.18	9.49	6.9
Big Roaring	10/10/1995	1000	1	100, 100	3.57	0.194	4.51	0.017	6.23	6.5
Bayou		1010	1	100, 100	4.06	0.211	6.07	0.017	8.33	8
		1020	1	100, 100	2.82	0.141	5.66	0.015	6.43	6.3
Chemin-	10/10/1995	1845	1	100, 100	2.81	0.182	6.52	0.017	7.25	7.1
a-Haut		1900	1	100, 100	1.4	0.226	3.77	0.017	4.27	4.1
		1915	1	100, 100	2.48	0.126	3.58	0.018	4.7	4.9
Mid Fork B.	8/14/1995	1830	1	100, 100	1.35	0.081	13.09	0.021	11.44	9
D'Arbonne		1840	1	100, 100	0.65	0.226	13.46	0.023	15.75	9.5
		1850	1	100, 100	0.58	0.226	10.36	0.033	13.08	8.6
Indian	10/9/1995	1200	1	100, 100	3.27	0.106	7.66	0.018	8.61	8.1
Bayou		1215	1	100, 100	3.31	0.119	6.83	0.018	8.61	7.8
		1230	1	100, 100	2.25	0.111	7.3	0.017	8.5	6.8
Kisatchie	10/25/1995	805	1	200, 300	1.7	0.187	3.55	0.018	3.84	4.1
Bayou		0840-2	2	200, 300	1.2	0.187	3.85	0.021	3.83	4
		0840-3	3	200, 300	1.69	0.141	2.6	0.017	3.26	3.4
Leading	10/10/1995	1100	1	100, 100	1.04	0.182	7.7	0.018	7.24	6.1
Bayou		1105	1	100, 100	0.94	0.191	8.15	0.017	7.88	6.3
		1110	1	100, 100	1.02	0.221	7.62	0.021	6.93	6.4
Meridian	8/15/1995	740	1	200, 300	0.61	0.226	9.87	0.023	9.17	7.1
Creek		805	2	200, 300	0.81	0.226	9.03	0.038	9.43	7.8
		850	3	200, 300	0.81	0.226	9.85	0.023	9.45	7.2
Pearl	10/17/1995	730	1	200, 300	2.71	0.119	2.24	0.035	4.6	4.7
Creek		830	2	200, 300	2.06	0.035	2.23	0.02	4.06	3.3
		1135	3	200, 300	2.25	0.035	0.92	0.02	3.68	2.8
		1115-trib	Trib	200, 300	2.25	0.035	0.28	0.226	2.7	2.4
Saline	10/24/1995	800	1	200, 300	1.69	0.111	2.98	0.018	3.7	3.7
Bayou		830	2	200, 300	1.5	0.172	3.46	0.017	3.68	3.6
		2000	3	200, 300	1.7	0.187	3.94	0.018	4.22	4.4
Kisatchie	8/20/1996	800	1	300, 300	1.54	0.141	4.2	0.018	4.52	4.09
Bayou		1303	3	300, 300	1.51	0.096	4.23	0.018	5.65	4.11
		1935	4	300, 300	1.68	0.081	4.49	0.018	5.15	4.66
	8/22/1996	215	5	300, 300	2.59	0.05	2.73	0.02	5.44	4.23
Sixmile	9/17/1996	805	1	300, 300	0.9	0.202	4.01	0.018	4.21	3.61
Creek		958	2	300, 300	2.26	0.187	2.46	0.016	4	4.17
		1730	3	300, 300	1.78	0.187	4.58	0.018	4.7	4.6
Meridian	8/7/1996	755	1	300, 300	14.47	0.03	0.22	0.02	15.12	12.3
Creek		1000	2	300, 300	6.86	0.033	4.92	0.018	14.11	9.54
		1250	3	300, 300	4.06	0.048	7.73	0.018	12.89	9.1
Calcasieu	9/4/1996	830	1	300, 300	2.36	0.035	3.08	0.018	5.79	4.15
River		952	2	300, 300	2.24	0.035	3.56	0.018	6.06	4.34
		1533	2A	300, 300	9.58	0.035	10.92	0.017	23.25	15.5
		1612	3	300, 300	3.15	0.035	3.13	0.017	7.38	4.85
Average					2.57		5.44			

Appendix D:
Calibration Model

Table D-1. T-QUAL input values for calibration conditions

T-QUAL, version B.1

Stream Name / Description: Subsegment 120606 Bayou Blue - Calibration Conditions

Model Input Description		*Input Units*	*Input Values*				
			Reach 1	*Reach 2*	*Reach 3*	*Reach 4*	*Reach 5*
Head water DO	DO_H	mg/l	3.600	4.015	2.118	5.389	5.430
Head water ultimate CBOD	L_H	mg/l	2.570	2.714	2.905	2.394	2.361
Head water ultimate NBOD	N_H	mg/l	0.602	3.650	3.687	1.854	1.859
Head water flow	Q_H	$feet^3$/second	6.44	6.44	25.70	72.98	72.98
Wastewater DO	DOw	mg/l		3.000	2.000		
Wastewater CBOD5	Lw	mg/l		1.179	1.261		
Wastewater TKN / NH3-N	Nw	mg/l		0.140	0.140		
Wastewater flow	Qw	million gal./day		9.960	24.445		
CBOD deoxygenation rate constant @ 20°C	k_d	1/day	0.350	0.350	0.350	0.350	0.350
CBOD settling rate constant	k_s	1/day	0.050	0.050	0.050	0.050	0.050
NBOD deoxygenation rate constant @ 20°C	k_n	1/day	0.100	0.100	0.100	0.100	0.100
NBOD settling rate constant	k_{ns}	1/day	0.025	0.025	0.025	0.025	0.025
Reach Length	R_T	kilometers	1.290	3.480	3.520	0.170	0.500
Reach element length	R_E	kilometers	0.006	0.01740	0.018	0.001	0.003
Reach average depth	H	meters	0.630	0.720	0.950	1.090	1.090
Reach average width	u	meters	53.030	48.920	57.450	70.100	70.100
Reaeration rate constant @ 20°C	k_a	1/day	1.179	1.333	1.269	0.964	0.964
Sediment oxygen demand @ 20 °C	S	$g\text{-}O_2/m^2$/day	1.100	2.750	0.200	0.200	0.200
Stream Temperature	T	°C	28.900	29.000	29.100	28.900	28.900
CBOD resuspended load	$CBOD_R$	$g\text{-}O_2/m^2$/day	1.000	1.250	1.000	1.000	1.000
NBOD resuspended load	$NBOD_R$	$g\text{-}O_2/m^2$/day	1.000	1.250	0.500	0.500	0.500
Chlorinity(ppt)		ppt	1.540	1.450	1.760	2.160	2.160
DO saturation @ strm temperature	DO_S	mg/l	7.5870	7.5807	7.5441	7.5402	7.5402
Calculated Minimum Dissolved Oxygen (mg/l):			**3.615**	**2.118**	**2.075**	**5.389**	**5.430**
Gold cells = Input for model			Blue cells = Calculated value from input				

Table D-2. Rearation coefficients

Calculation of the Reaeration coefficients from recognized formulas.

Parameters	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
	English U(fps), H(ft)	English U(fps), H(ft)	English U(fps), H(ft)	English U(fps), H(ft)	English U(fps), H(ft)
Choose the appropriate Reaeration Eq. For your reach	Louisiana (1996)	Louisiana (1996)	Louisiana (1996)	Louisiana (1996)	Louisiana (1996)
Velocity(U) (note 1)	**0.018**	**0.068**	**0.124**	**0.089**	**0.089**
Depth(H) (note 2)	**2.067**	**2.362**	**3.117**	**3.576**	**3.576**

Output K2 values shown in the shaded areas are calculated from the example velocity & depth data above:

Author(s)	Calculated Values, (K2) (note 4)	Calculated Values, (K2) (note 4)	Calculated Values, (K2) (note 4)	Calculated Values, (K2) (note 4)	Calculated Values, (K2) (note 4)	Equation K2 =	Units
Bennett & Rathbun (1972) **	**0.5157**	**0.9233**	**0.8350**	**0.5397**	**0.5397**	[20.2(U^0.607)]/[H^1.689]	English
Churchill et. al. (1962) **	**0.0698**	**0.2029**	**0.2295**	**0.1316**	**0.1316**	[11.6(U^0.969)]/[H^1.673]	English
Isaacs & Gaudy (1968) **	**0.0520**	**0.1610**	**0.1946**	**0.1131**	**0.1131**	[8.62*U]/[H^1.5]	English
Langbein & Durum (1967) **	**0.0518**	**0.1643**	**0.2082**	**0.1239**	**0.1238**	[7.60*U]/[H^1.33]	English
Long (1984) **	**0.7008**	**0.8945**	**0.8237**	**0.6645**	**0.6645**	[1.923(U^0.273]/[H^0.894]	Metric
Negulescu & Rojanski (1969) **	**0.1925**	**0.5329**	**0.7045**	**0.4709**	**0.4709**	10.9*(U/H)^.85	English
O'Connor & Dobbins (1958) **	**0.5809**	**0.9252**	**0.8263**	**0.5682**	**0.5682**	[12.9*U^0.5]/[H^1.5]	English
Padden & Gloyna (1971) **	**0.1899**	**0.4205**	**0.4806**	**0.3282**	**0.3282**	[6.9(U^0.703]/[H^1.054]	English
Owens et. al. (1964) **	**0.3470**	**0.7258**	**0.6953**	**0.4276**	**0.4276**	[23.3(U^0.73)]/[H^1.75]	English
Louisiana (1996) ***	**1.1786**	**1.3333**	**1.2695**	**0.9644**	**0.9644**	2.18[(1+6.56U)/H]	English
Maximum K2	**25.0000**	**25.0000**	**25.0000**	**25.0000**	**25.0000**	25	English
Minimum K2	**1.1127**	**0.9736**	**0.7379**	**0.6431**	**0.6431**	2.3/H	English

Note 1 - Velocity (U) = The average velocity for the sampled reach.
Note 2 - Depth (H) = The average depth for the sampled reach.
Note 3 - Metric Conversion = FPS or Feet multiplied by .3048 to convert to MPS and Meters.
Note 4 - K2 units = (1/day, at 20 degrees Celsius, base e)
** - Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition) June, 1985, EPA/600/3-85/040. Table 3-6 on pages 103-106.
*** - Reaeration in Shallow, Low-Flow Louisiana Stream Reaches - Verification of the Louisiana Equation, Michael G. Waldon, March 27, 1996. Equation 2, Page 1.

Table D-3. Model results

		Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	
Reach Mean velocity	u	471.7	1785.5	3271.9	2337.0	2336.9	meters/day
Initial ultimate CBOD	L_o	2.570	2.712	2.901	2.394	2.361	mg/l
Initial ultimate NBOD	N_o	0.602	1.366	1.688	1.854	1.859	mg/l
Initial DO	DO_o	3.600	3.254	2.042	5.389	5.430	mg/l
Element Incremental travel time	d_t	0.014	0.010	0.005	0.000	0.001	days
CBOD deoxygenation rate constant @stream temp.	k_d	0.527	0.529	0.532	0.527	0.527	1/day
CBOD settling rate constant	k_s	0.050	0.050	0.050	0.050	0.050	1/day
Total CBOD loss rate constant	k_r	0.577	0.579	0.582	0.577	0.577	1/day
Initial deficit factor (k_a*d_t*DO_S)		0.146543	0.118137	0.062089	0.003189	0.009381	mg/l
CBOD deficit factor (k_n*d_t)		0.007	0.005	0.003	0.000	0.001	unitless
CBOD decay factor (1+k_r*d_t)		1.008	1.006	1.003	1.000	1.001	
NBOD deoxygenation rate constant @stream temp.	k_n	0.183	0.184	0.185	0.183	0.183	1/day
NBOD settling rate constant	ks_n	0.025	0.025	0.025	0.025	0.025	1/day
Total NBOD loss rate constant	kr_n	0.208	0.209	0.210	0.208	0.208	1/day
NBOD deficit factor (k_n*d_t)		0.002	0.002	0.001	0.000	0.000	unitless
NBOD decay factor (1+kr_n*d_t)		1.003	1.002	1.001	1.000	1.000	
CBOD resuspended load ($CBOD_R$*dt/H)		0.022	0.017	0.006	0.000	0.001	mg/l
NBOD resuspended load ($NBOD_R$*dt/H)		0.022	0.017	0.003	0.000	0.000	mg/l
DO Factor [1+k_a*d_t]		1.019	1.016	1.008	1.000	1.001	
Stream Length at end of reach	R_T	1290	4770	8290	8460	8960	meters
Reach element length	R_E	6.450	17.400	17.600	0.850	2.500	meters
Reach average depth	H	0.630	0.720	0.950	1.090	1.090	meters
Reach average width	W	53.030	48.920	57.450	70.100	70.100	meters
Reaeration rate constant @stream temp.	k_a	1.412	1.599	1.530	1.163	1.163	1/day
Sediment oxygen demand @stream temp. (S*d_t / H)		0.042	0.066	0.002	0.000	0.000	mg/l
Stream Temperature	T	28.900	29.000	29.100	28.900	28.900	^oC
DO saturation @ strm temperature	DO_S	7.5870	7.5807	7.5441	7.5402	7.5402	mg/l

Table D-4. Detailed model results

River kilometer	Travel time (days)	DO conc. (mg/L)	CBOD (mg/L)	NBOD (mg/L)	Initial deficit (mg/L)	CBOD deficit (mg/L)	NBOD deficit (mg/L)	SOD deficit (mg/L)
0.01	0.01	3.6148	2.5714	0.6219	3.7465	-0.0185	-0.0016	-0.0418
0.06	0.14	3.7338	2.5838	0.7989	3.8683	-0.0186	-0.0020	-0.0418
0.13	0.27	3.8390	2.5965	0.9903	3.9761	-0.0187	-0.0025	-0.0418
0.19	0.41	3.9209	2.6083	1.1763	4.0602	-0.0188	-0.0029	-0.0418
0.26	0.55	3.9837	2.6191	1.3571	4.1247	-0.0189	-0.0034	-0.0418
0.32	0.68	4.0308	2.6292	1.5329	4.1733	-0.0189	-0.0038	-0.0418
0.39	0.82	4.0653	2.6385	1.7038	4.2089	-0.0190	-0.0043	-0.0418
0.45	0.96	4.0894	2.6471	1.8699	4.2339	-0.0191	-0.0047	-0.0418
0.52	1.09	4.1050	2.6550	2.0313	4.2503	-0.0191	-0.0051	-0.0418
0.58	1.23	4.1139	2.6624	2.1882	4.2598	-0.0192	-0.0055	-0.0418
0.65	1.37	4.1173	2.6692	2.3408	4.2637	-0.0192	-0.0058	-0.0418
0.71	1.50	4.1163	2.6754	2.4891	4.2631	-0.0193	-0.0062	-0.0418
0.77	1.64	4.1118	2.6812	2.6332	4.2589	-0.0193	-0.0066	-0.0418
0.84	1.78	4.1045	2.6866	2.7733	4.2519	-0.0194	-0.0069	-0.0418
0.90	1.91	4.0951	2.6915	2.9095	4.2427	-0.0194	-0.0073	-0.0418

Table D-4. (continued)

River kilometer	Travel time (days)	DO conc. (mg/L)	CBOD (mg/L)	NBOD (mg/L)	Initial deficit (mg/L)	CBOD deficit (mg/L)	NBOD deficit (mg/L)	SOD deficit (mg/L)
0.97	2.05	4.0840	2.6961	3.0419	4.2317	-0.0194	-0.0076	-0.0418
1.03	2.19	4.0716	2.7004	3.1706	4.2194	-0.0195	-0.0079	-0.0418
1.10	2.32	4.0582	2.7043	3.2957	4.2061	-0.0195	-0.0082	-0.0418
1.16	2.46	4.0442	2.7079	3.4173	4.1921	-0.0195	-0.0085	-0.0418
1.23	2.60	4.0296	2.7113	3.5355	4.1776	-0.0195	-0.0088	-0.0418
1.29	2.74	4.0148	2.7143	3.6504	4.1628	-0.0196	-0.0091	-0.0418
1.46	2.83	3.1182	2.7277	1.5056	3.2492	-0.0141	-0.0027	-0.0656
1.64	2.93	2.9986	2.7424	1.6426	3.1281	-0.0141	-0.0029	-0.0656
1.81	3.03	2.8933	2.7564	1.7768	3.0214	-0.0142	-0.0032	-0.0656
1.99	3.12	2.8002	2.7696	1.9084	2.9272	-0.0143	-0.0034	-0.0656
2.16	3.22	2.7177	2.7821	2.0373	2.8437	-0.0143	-0.0036	-0.0656
2.33	3.32	2.6444	2.7939	2.1636	2.7695	-0.0144	-0.0039	-0.0656
2.51	3.42	2.5789	2.8050	2.2873	2.7033	-0.0145	-0.0041	-0.0656
2.68	3.51	2.5204	2.8156	2.4086	2.6441	-0.0145	-0.0043	-0.0656
2.86	3.61	2.4677	2.8255	2.5274	2.5909	-0.0146	-0.0045	-0.0656
3.03	3.71	2.4202	2.8349	2.6439	2.5429	-0.0146	-0.0047	-0.0656
3.20	3.81	2.3772	2.8439	2.7580	2.4994	-0.0147	-0.0049	-0.0656
3.38	3.90	2.3380	2.8523	2.8698	2.4599	-0.0147	-0.0051	-0.0656
3.55	4.00	2.3023	2.8602	2.9793	2.4239	-0.0147	-0.0053	-0.0656
3.73	4.10	2.2696	2.8677	3.0867	2.3909	-0.0148	-0.0055	-0.0656
3.90	4.20	2.2394	2.8749	3.1918	2.3604	-0.0148	-0.0057	-0.0656
4.07	4.29	2.2115	2.8816	3.2949	2.3324	-0.0149	-0.0059	-0.0656
4.25	4.39	2.1857	2.8879	3.3959	2.3063	-0.0149	-0.0061	-0.0656
4.42	4.49	2.1616	2.8939	3.4949	2.2820	-0.0149	-0.0063	-0.0656
4.60	4.59	2.1390	2.8996	3.5918	2.2593	-0.0150	-0.0064	-0.0656
4.77	4.68	2.1179	2.9050	3.6868	2.2381	-0.0150	-0.0066	-0.0656
4.95	4.74	2.3604	2.8679	1.6976	2.3917	-0.0082	-0.0017	-0.0020
5.12	4.79	2.6550	2.8354	1.7067	2.6887	-0.0081	-0.0017	-0.0020
5.30	4.85	2.9272	2.8038	1.7156	2.9630	-0.0080	-0.0017	-0.0020
5.47	4.90	3.1787	2.7733	1.7245	3.2166	-0.0079	-0.0017	-0.0020
5.65	4.95	3.4112	2.7436	1.7333	3.4509	-0.0078	-0.0017	-0.0020
5.83	5.01	3.6261	2.7149	1.7419	3.6675	-0.0078	-0.0017	-0.0020
6.00	5.06	3.8248	2.6871	1.7505	3.8677	-0.0077	-0.0017	-0.0020
6.18	5.11	4.0085	2.6601	1.7590	4.0529	-0.0076	-0.0018	-0.0020
6.35	5.17	4.1784	2.6340	1.7674	4.2241	-0.0075	-0.0018	-0.0020
6.53	5.22	4.3356	2.6086	1.7757	4.3825	-0.0075	-0.0018	-0.0020
6.71	5.28	4.4810	2.5841	1.7839	4.5290	-0.0074	-0.0018	-0.0020
6.88	5.33	4.6155	2.5603	1.7920	4.6646	-0.0073	-0.0018	-0.0020
7.06	5.38	4.7400	2.5372	1.8000	4.7901	-0.0073	-0.0018	-0.0020
7.23	5.44	4.8553	2.5148	1.8079	4.9062	-0.0072	-0.0018	-0.0020
7.41	5.49	4.9620	2.4931	1.8157	5.0138	-0.0071	-0.0018	-0.0020
7.59	5.54	5.0608	2.4721	1.8235	5.1134	-0.0071	-0.0018	-0.0020
7.76	5.60	5.1523	2.4518	1.8311	5.2056	-0.0070	-0.0018	-0.0020

Table D-4. (continued)

River kilometer	Travel time (days)	DO conc. (mg/L)	CBOD (mg/L)	NBOD (mg/L)	Initial deficit (mg/L)	CBOD deficit (mg/L)	NBOD deficit (mg/L)	SOD deficit (mg/L)
7.94	5.65	5.2372	2.4320	1.8387	5.2910	-0.0070	-0.0018	-0.0020
8.11	5.71	5.3157	2.4129	1.8462	5.3702	-0.0069	-0.0018	-0.0020
8.29	5.76	5.3886	2.3943	1.8536	5.4436	-0.0068	-0.0018	-0.0020
8.30	5.76	5.3907	2.3927	1.8538	5.3937	-0.0005	-0.0001	-0.0001
8.31	5.77	5.3928	2.3910	1.8541	5.3958	-0.0005	-0.0001	-0.0001
8.32	5.77	5.3949	2.3893	1.8544	5.3979	-0.0005	-0.0001	-0.0001
8.32	5.77	5.3970	2.3876	1.8546	5.4000	-0.0005	-0.0001	-0.0001
8.33	5.78	5.3991	2.3860	1.8549	5.4021	-0.0005	-0.0001	-0.0001
8.34	5.78	5.4012	2.3843	1.8552	5.4042	-0.0005	-0.0001	-0.0001
8.35	5.79	5.4032	2.3826	1.8554	5.4062	-0.0005	-0.0001	-0.0001
8.36	5.79	5.4053	2.3810	1.8557	5.4083	-0.0005	-0.0001	-0.0001
8.37	5.79	5.4074	2.3793	1.8560	5.4104	-0.0005	-0.0001	-0.0001
8.38	5.80	5.4094	2.3777	1.8562	5.4124	-0.0005	-0.0001	-0.0001
8.38	5.80	5.4115	2.3760	1.8565	5.4145	-0.0005	-0.0001	-0.0001
8.39	5.80	5.4135	2.3744	1.8568	5.4165	-0.0005	-0.0001	-0.0001
8.40	5.81	5.4156	2.3727	1.8570	5.4186	-0.0005	-0.0001	-0.0001
8.41	5.81	5.4176	2.3711	1.8573	5.4206	-0.0005	-0.0001	-0.0001
8.42	5.81	5.4196	2.3695	1.8576	5.4226	-0.0005	-0.0001	-0.0001
8.43	5.82	5.4217	2.3678	1.8578	5.4247	-0.0005	-0.0001	-0.0001
8.43	5.82	5.4237	2.3662	1.8581	5.4267	-0.0005	-0.0001	-0.0001
8.44	5.83	5.4257	2.3646	1.8584	5.4287	-0.0005	-0.0001	-0.0001
8.45	5.83	5.4277	2.3629	1.8586	5.4307	-0.0005	-0.0001	-0.0001
8.46	5.83	5.4297	2.3613	1.8589	5.4327	-0.0005	-0.0001	-0.0001
8.49	5.84	5.4356	2.3566	1.8597	5.4444	-0.0013	-0.0004	-0.0003
8.51	5.85	5.4414	2.3519	1.8605	5.4502	-0.0013	-0.0004	-0.0003
8.54	5.86	5.4471	2.3472	1.8612	5.4559	-0.0013	-0.0004	-0.0003
8.56	5.88	5.4529	2.3426	1.8620	5.4617	-0.0013	-0.0004	-0.0003
8.59	5.89	5.4585	2.3379	1.8628	5.4673	-0.0013	-0.0004	-0.0003
8.61	5.90	5.4641	2.3333	1.8635	5.4730	-0.0013	-0.0004	-0.0003
8.64	5.91	5.4697	2.3288	1.8643	5.4785	-0.0013	-0.0004	-0.0003
8.66	5.92	5.4753	2.3242	1.8651	5.4841	-0.0013	-0.0004	-0.0003
8.69	5.93	5.4807	2.3197	1.8658	5.4896	-0.0013	-0.0004	-0.0003
8.71	5.94	5.4862	2.3152	1.8666	5.4950	-0.0013	-0.0004	-0.0003
8.74	5.95	5.4916	2.3108	1.8674	5.5004	-0.0013	-0.0004	-0.0003
8.76	5.96	5.4969	2.3064	1.8681	5.5058	-0.0013	-0.0004	-0.0003
8.79	5.97	5.5023	2.3020	1.8689	5.5111	-0.0013	-0.0004	-0.0003
8.81	5.98	5.5075	2.2976	1.8696	5.5164	-0.0013	-0.0004	-0.0003
8.84	5.99	5.5128	2.2932	1.8704	5.5216	-0.0013	-0.0004	-0.0003
8.86	6.00	5.5179	2.2889	1.8711	5.5268	-0.0013	-0.0004	-0.0003
8.89	6.01	5.5231	2.2846	1.8719	5.5320	-0.0013	-0.0004	-0.0003
8.91	6.03	5.5282	2.2804	1.8726	5.5371	-0.0013	-0.0004	-0.0003
8.94	6.04	5.5333	2.2761	1.8734	5.5421	-0.0013	-0.0004	-0.0003
8.96	6.05	5.5383	2.2719	1.8741	5.5472	-0.0013	-0.0004	-0.0003

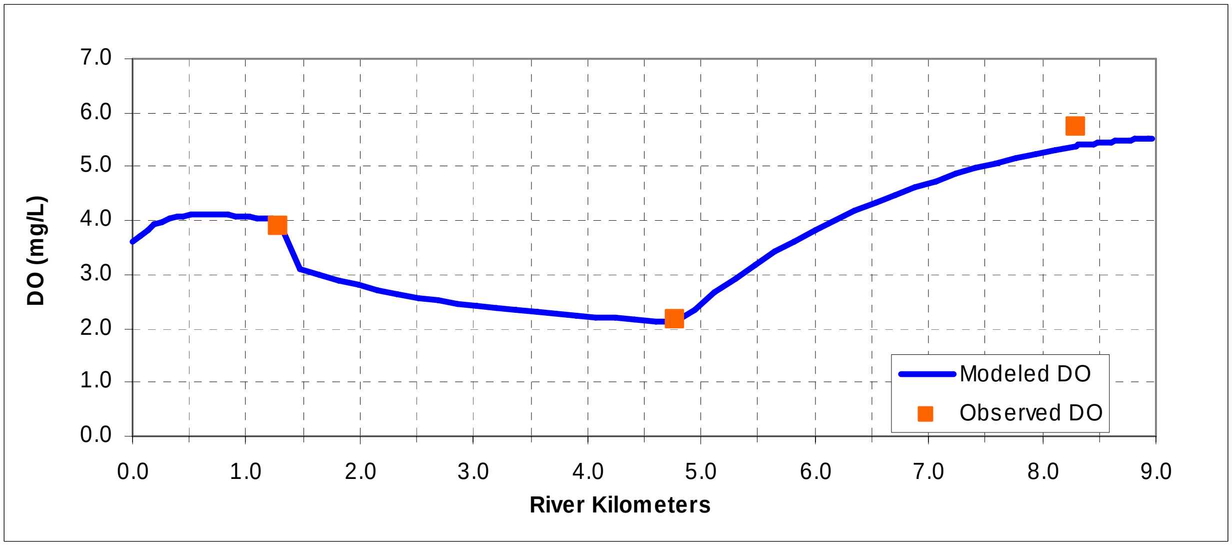

Figure D-1. Modeled and observed dissolved oxygen.

Appendix E:
TMDL Model

Table E-1. T-QUAL input values for TMDL conditions

T-QUAL, version B.1

Stream Name / Description: Subsegment 120606 Bayou Blue - TMDL projection

Model Input Description		*Input Units*	*Input Values*				
			Reach 1	*Reach 2*	*Reach 3*	*Reach 4*	*Reach 5*
Head water DO	DO_H	mg/l	5.000	4.002	4.474	5.675	5.629
Head water ultimate CBOD	L_H	mg/l	2.570	1.971	1.059	1.778	1.741
Head water ultimate NBOD	N_H	mg/l	0.602	4.580	2.442	1.796	1.806
Head water flow	Q_H	$feet^3/second$	2.15	2.15	8.57	24.33	24.33
Wastewater DO	DOw	mg/l		4.000	4.000		
Wastewater CBOD5	Lw	mg/l		1.179	1.261		
Wastewater TKN / NH3-N	Nw	mg/l		0.140	0.140		
Wastewater flow	Qw	million gal./day		3.320	8.150		
CBOD deoxygenation rate constant @ 20°C	k_d	1/day	0.350	0.350	0.350	0.350	0.350
CBOD settling rate constant	k_s	1/day	0.050	0.050	0.050	0.050	0.050
NBOD deoxygenation rate constant @ 20°C	k_n	1/day	0.100	0.100	0.100	0.100	0.100
NBOD settling rate constant	k_{ns}	1/day	0.025	0.025	0.025	0.025	0.025
Reach Length	R_T	kilometers	1.290	3.480	3.520	0.170	0.500
Reach element length	R_E	kilometers	0.006	0.01740	0.018	0.001	0.003
Reach average depth	H	meters	0.630	0.720	0.950	1.090	1.090
Reach average width	u	meters	53.030	48.920	57.450	70.100	70.100
Reaeration rate constant @ 20°C	k_a	1/day	1.113	1.060	0.889	0.728	0.728
Sediment oxygen demand @ 20 °C	S	$g\text{-}O_2/m^2/day$	0.843	0.996	0.200	0.200	0.200
Stream Temperature	T	°C	30.550	30.550	30.550	30.550	30.550
CBOD resuspended load	$CBOD_R$	$g\text{-}O_2/m^2/day$	0.766	0.453	1.000	1.000	1.000
NBOD resuspended load	$NBOD_R$	$g\text{-}O_2/m^2/day$	0.766	0.453	0.500	0.500	0.500
Chlorinity(ppt)		ppt	1.540	1.450	1.760	2.160	2.160
DO saturation @ strm temperature	DO_S	mg/l	7.3744	7.3810	7.3584	7.3293	7.3293
Calculated Minimum Dissolved Oxygen (mg/l):			**4.002**	**4.000**	**4.192**	**5.629**	**5.554**
Gold cells = Input for model			Blue cells = Calculated value from input				

Table E-2. Rearation coefficients

<u>Calculation of the Reaeration coefficients from recognized formulas.</u>

	Reach 1		Reach 2		Reach 3		Reach 4		Reach 5	
Parameters	English	U(fps), H(ft)	English	U(fps), H(ft)	English	U(fps), H(ft)	English	U(fps), H(ft)	English	U(fps), H(ft)
Choose the appropriate Reaeration Eq. For your reach	Louisiana (1996)		Louisiana (1996)		Louisiana (1996)		Louisiana (1996)		Louisiana (1996)	
Velocity(U) (note 1)		0.006		0.023		0.041		0.030		0.030
Depth(H) (note 2)		2.067		2.362		3.117		3.576		3.576

Output K2 values shown in the shaded areas are calculated from the example velocity & depth data above:

Author(s)	Calculated Values, (K2) (note 4)	Calculated Values, (K2) (note 4)	Calculated Values, (K2) (note 4)	Calculated Values, (K2) (note 4)	Calculated Values, (K2) (note 4)	Equation K2 =	Units
Bennett & Rathbun (1972) **	**0.2650**	**0.4741**	**0.4287**	**0.2771**	**0.2771**	[20.2(U^0.607)]/[H^1.689]	English
Churchill et. al. (1962) **	**0.0241**	**0.0700**	**0.0792**	**0.0454**	**0.0454**	[11.6(U^0.969)]/[H^1.673]	English
Isaacs & Gaudy (1968) **	**0.0173**	**0.0537**	**0.0649**	**0.0377**	**0.0377**	[8.62*U]/[H^1.5]	English
Langbein & Durum (1967) **	**0.0173**	**0.0548**	**0.0694**	**0.0413**	**0.0413**	[7.60*U]/[H^1.33]	English
Long (1984) **	**0.5194**	**0.6628**	**0.6103**	**0.4923**	**0.4923**	[1.923(U^0.273]/[H^0.894]	Metric
Negulescu & Rojanski (1969) **	**0.0758**	**0.2095**	**0.2770**	**0.1851**	**0.1851**	10.9*(U/H)^.85	English
O'Connor & Dobbins (1958) **	**0.3357**	**0.5342**	**0.4771**	**0.3281**	**0.3281**	[12.9*U^0.5]/[H^1.5]	English
Padden & Gloyna (1971) **	**0.0878**	**0.1943**	**0.2220**	**0.1516**	**0.1516**	[6.9(U^0.703]/[H^1.054]	English
Owens et. al. (1964) **	**0.1558**	**0.3256**	**0.3118**	**0.1918**	**0.1918**	[23.3(U^0.73)]/[H^1.75]	English
Louisiana (1996) ***	**1.0960**	**1.0597**	**0.8895**	**0.7279**	**0.7279**	2.18[(1+6.56U)/H]	English
Maximum K2	**25.0000**	**25.0000**	**25.0000**	**25.0000**	**25.0000**	25	English
Minimum K2	**1.1127**	**0.9736**	**0.7379**	**0.6431**	**0.6431**	2.3/H	English

Note 1 - Velocity (U) = The average velocity for the sampled reach.
Note 2 - Depth (H) = The average depth for the sampled reach.
Note 3 - Metric Conversion = FPS or Feet multiplied by .3048 to convert to MPS and Meters.
Note 4 - K2 units = (1/day, at 20 degrees Celsius, base e)
** - <u>Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition)</u>
June, 1985, EPA/600/3-85/040. Table 3-6 on pages 103-106.
*** - <u>Reaeration in Shallow, Low-Flow Louisiana Stream Reaches - Verification of the Louisiana Equation</u>,
Michael G. Waldon, March 27, 1996. Equation 2, Page 1.

Table E-3. Model results

		Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	
Reach Mean velocity	u	157.5	595.4	1090.9	779.2	779.2	meters/day
Initial ultimate CBOD	L_o	2.570	2.526	2.251	1.778	1.741	mg/l
Initial ultimate NBOD	N_o	0.602	1.600	1.250	1.796	1.806	mg/l
Initial DO	DO_o	5.000	4.001	4.167	5.675	5.629	mg/l
Element Incremental travel time	d_t	0.041	0.029	0.016	0.001	0.003	days
CBOD deoxygenation rate constant @stream temp.	k_d	0.568	0.568	0.568	0.568	0.568	1/day
CBOD settling rate constant	k_s	0.050	0.050	0.050	0.050	0.050	1/day
Total CBOD loss rate constant	k_r	0.618	0.618	0.618	0.618	0.618	1/day
Initial deficit factor (k_a*d_t*DO_s)		0.414417	0.281577	0.130477	0.00722	0.021235	mg/l
CBOD deficit factor (k_n*d_t)		0.023	0.017	0.009	0.001	0.002	unitless
CBOD decay factor (1+k_r*d_t)		1.025	1.018	1.010	1.001	1.002	
NBOD deoxygenation rate constant @stream temp.	k_n	0.204	0.204	0.204	0.204	0.204	1/day
NBOD settling rate constant	ks_n	0.025	0.025	0.025	0.025	0.025	1/day
Total NBOD loss rate constant	kr_n	0.229	0.229	0.229	0.229	0.229	1/day
NBOD deficit factor (k_n*d_t)		0.008	0.006	0.003	0.000	0.001	unitless
NBOD decay factor (1+kr_n*d_t)		1.009	1.007	1.004	1.000	1.001	
CBOD resuspended load ($CBOD_R$*dt/H)		0.050	0.018	0.017	0.001	0.003	mg/l
NBOD resuspended load ($NBOD_R$*dt/H)		0.050	0.018	0.008	0.001	0.001	mg/l
DO Factor [1+k_a*d_t]		1.056	1.038	1.018	1.001	1.003	
Stream Length at end of reach	R_T	1290	4770	8290	8460	8960	meters
Reach element length	R_E	6.450	17.400	17.600	0.850	2.500	meters
Reach average depth	H	0.630	0.720	0.950	1.090	1.090	meters
Reach average width	W	53.030	48.920	57.450	70.100	70.100	meters
Reaeration rate constant @stream temp.	k_a	1.372	1.305	1.099	0.903	0.903	1/day
Sediment oxygen demand @stream temp. (S*d_t / H)		0.106	0.079	0.007	0.000	0.001	mg/l
Stream Temperature	T	30.550	30.550	30.550	30.550	30.550	^oC
DO saturation @ strm temperature	DO_S	7.3744	7.3810	7.3584	7.3293	7.3293	mg/l

Table E-4. Detailed model results

River kilometer	Travel time (days)	DO conc. (mg/L)	CBOD (mg/L)	NBOD (mg/L)	Initial deficit (mg/L)	CBOD deficit (mg/L)	NBOD deficit (mg/L)	SOD deficit (mg/L)
0.01	0.04	4.9641	2.5551	0.6457	5.4144	-0.0595	-0.0054	-0.1065
0.06	0.41	4.7146	2.4365	1.0216	5.1512	-0.0567	-0.0085	-0.1065
0.13	0.82	4.5446	2.3326	1.4037	4.9725	-0.0543	-0.0117	-0.1065
0.19	1.23	4.4392	2.2517	1.7517	4.8622	-0.0524	-0.0147	-0.1065
0.26	1.64	4.3698	2.1886	2.0688	4.7900	-0.0509	-0.0173	-0.1065
0.32	2.05	4.3203	2.1395	2.3575	4.7390	-0.0498	-0.0197	-0.1065
0.39	2.46	4.2819	2.1013	2.6204	4.6998	-0.0489	-0.0219	-0.1065
0.45	2.87	4.2498	2.0715	2.8600	4.6673	-0.0482	-0.0239	-0.1065
0.52	3.28	4.2216	2.0484	3.0781	4.6387	-0.0477	-0.0257	-0.1065
0.58	3.69	4.1958	2.0303	3.2768	4.6127	-0.0473	-0.0274	-0.1065
0.65	4.10	4.1718	2.0163	3.4578	4.5885	-0.0469	-0.0289	-0.1065
0.71	4.51	4.1492	2.0053	3.6226	4.5659	-0.0467	-0.0303	-0.1065
0.77	4.92	4.1281	1.9968	3.7727	4.5446	-0.0465	-0.0316	-0.1065
0.84	5.33	4.1082	1.9901	3.9094	4.5246	-0.0463	-0.0327	-0.1065
0.90	5.73	4.0896	1.9850	4.0340	4.5058	-0.0462	-0.0337	-0.1065

Table E-4. (continued)

River kilometer	Travel time (days)	DO conc. (mg/L)	CBOD (mg/L)	NBOD (mg/L)	Initial deficit (mg/L)	CBOD deficit (mg/L)	NBOD deficit (mg/L)	SOD deficit (mg/L)
0.97	6.14	4.0722	1.9809	4.1474	4.4883	-0.0461	-0.0347	-0.1065
1.03	6.55	4.0561	1.9778	4.2507	4.4720	-0.0460	-0.0355	-0.1065
1.10	6.96	4.0410	1.9754	4.3448	4.4569	-0.0460	-0.0363	-0.1065
1.16	7.37	4.0271	1.9735	4.4305	4.4429	-0.0459	-0.0371	-0.1065
1.23	7.78	4.0143	1.9720	4.5085	4.4299	-0.0459	-0.0377	-0.1065
1.29	8.19	4.0025	1.9708	4.5796	4.4180	-0.0459	-0.0383	-0.1065
1.46	8.48	4.0100	2.2782	1.6735	4.2893	-0.0378	-0.0100	-0.0785
1.64	8.78	4.0433	2.0713	1.7425	4.3208	-0.0344	-0.0104	-0.0785
1.81	9.07	4.0883	1.8984	1.8071	4.3651	-0.0315	-0.0108	-0.0785
1.99	9.36	4.1374	1.7539	1.8675	4.4141	-0.0291	-0.0111	-0.0785
2.16	9.65	4.1861	1.6330	1.9240	4.4630	-0.0271	-0.0115	-0.0785
2.33	9.95	4.2318	1.5320	1.9768	4.5090	-0.0254	-0.0118	-0.0785
2.51	10.24	4.2731	1.4475	2.0263	4.5508	-0.0240	-0.0121	-0.0785
2.68	10.53	4.3096	1.3768	2.0725	4.5877	-0.0229	-0.0124	-0.0785
2.86	10.82	4.3411	1.3178	2.1157	4.6198	-0.0219	-0.0126	-0.0785
3.03	11.11	4.3680	1.2684	2.1562	4.6471	-0.0211	-0.0129	-0.0785
3.20	11.41	4.3907	1.2271	2.1941	4.6702	-0.0204	-0.0131	-0.0785
3.38	11.70	4.4096	1.1926	2.2295	4.6894	-0.0198	-0.0133	-0.0785
3.55	11.99	4.4251	1.1638	2.2626	4.7053	-0.0193	-0.0135	-0.0785
3.73	12.28	4.4378	1.1396	2.2936	4.7182	-0.0189	-0.0137	-0.0785
3.90	12.58	4.4480	1.1195	2.3225	4.7287	-0.0186	-0.0139	-0.0785
4.07	12.87	4.4561	1.1026	2.3496	4.7370	-0.0183	-0.0140	-0.0785
4.25	13.16	4.4625	1.0885	2.3750	4.7436	-0.0181	-0.0142	-0.0785
4.42	13.45	4.4675	1.0767	2.3987	4.7486	-0.0179	-0.0143	-0.0785
4.60	13.74	4.4712	1.0669	2.4209	4.7525	-0.0177	-0.0144	-0.0785
4.77	14.04	4.4739	1.0586	2.4417	4.7553	-0.0176	-0.0146	-0.0785
4.95	14.20	4.3982	2.1993	1.2879	4.5071	-0.0202	-0.0042	-0.0066
5.12	14.36	4.5951	2.1524	1.3244	4.7073	-0.0197	-0.0044	-0.0066
5.30	14.52	4.7629	2.1099	1.3597	4.8778	-0.0193	-0.0045	-0.0066
5.47	14.68	4.9060	2.0715	1.3936	5.0231	-0.0190	-0.0046	-0.0066
5.65	14.84	5.0280	2.0366	1.4263	5.1472	-0.0187	-0.0047	-0.0066
5.83	15.01	5.1322	2.0051	1.4579	5.2530	-0.0184	-0.0048	-0.0066
6.00	15.17	5.2211	1.9765	1.4883	5.3433	-0.0181	-0.0049	-0.0066
6.18	15.33	5.2971	1.9506	1.5175	5.4205	-0.0179	-0.0050	-0.0066
6.35	15.49	5.3620	1.9272	1.5458	5.4864	-0.0177	-0.0051	-0.0066
6.53	15.65	5.4175	1.9060	1.5730	5.5428	-0.0175	-0.0052	-0.0066
6.71	15.81	5.4649	1.8868	1.5992	5.5909	-0.0173	-0.0053	-0.0066
6.88	15.97	5.5053	1.8694	1.6245	5.6321	-0.0171	-0.0054	-0.0066
7.06	16.13	5.5400	1.8537	1.6488	5.6672	-0.0170	-0.0054	-0.0066
7.23	16.30	5.5695	1.8394	1.6723	5.6972	-0.0169	-0.0055	-0.0066
7.41	16.46	5.5947	1.8265	1.6949	5.7229	-0.0167	-0.0056	-0.0066
7.59	16.62	5.6162	1.8148	1.7167	5.7447	-0.0166	-0.0057	-0.0066
7.76	16.78	5.6346	1.8042	1.7377	5.7633	-0.0165	-0.0057	-0.0066

Table E-4. (continued)

River kilometer	Travel time (days)	DO conc. (mg/L)	CBOD (mg/L)	NBOD (mg/L)	Initial deficit (mg/L)	CBOD deficit (mg/L)	NBOD deficit (mg/L)	SOD deficit (mg/L)
7.94	16.94	5.6502	1.7946	1.7580	5.7792	-0.0165	-0.0058	-0.0066
8.11	17.10	5.6634	1.7859	1.7775	5.7926	-0.0164	-0.0059	-0.0066
8.29	17.26	5.6746	1.7781	1.7963	5.8041	-0.0163	-0.0059	-0.0066
8.30	17.27	5.6720	1.7761	1.7968	5.6795	-0.0011	-0.0004	-0.0004
8.31	17.29	5.6695	1.7741	1.7973	5.6769	-0.0011	-0.0004	-0.0004
8.32	17.30	5.6669	1.7722	1.7978	5.6744	-0.0011	-0.0004	-0.0004
8.32	17.31	5.6645	1.7703	1.7983	5.6719	-0.0011	-0.0004	-0.0004
8.33	17.32	5.6620	1.7683	1.7988	5.6695	-0.0011	-0.0004	-0.0004
8.34	17.33	5.6596	1.7664	1.7993	5.6671	-0.0011	-0.0004	-0.0004
8.35	17.34	5.6572	1.7645	1.7998	5.6647	-0.0011	-0.0004	-0.0004
8.36	17.35	5.6549	1.7626	1.8003	5.6623	-0.0011	-0.0004	-0.0004
8.37	17.36	5.6526	1.7608	1.8009	5.6600	-0.0011	-0.0004	-0.0004
8.38	17.37	5.6503	1.7589	1.8014	5.6577	-0.0011	-0.0004	-0.0004
8.38	17.38	5.6480	1.7571	1.8019	5.6555	-0.0011	-0.0004	-0.0004
8.39	17.39	5.6458	1.7552	1.8024	5.6533	-0.0011	-0.0004	-0.0004
8.40	17.41	5.6436	1.7534	1.8028	5.6511	-0.0011	-0.0004	-0.0004
8.41	17.42	5.6415	1.7516	1.8033	5.6489	-0.0011	-0.0004	-0.0004
8.42	17.43	5.6394	1.7498	1.8038	5.6468	-0.0011	-0.0004	-0.0004
8.43	17.44	5.6373	1.7480	1.8043	5.6447	-0.0011	-0.0004	-0.0004
8.43	17.45	5.6352	1.7462	1.8048	5.6426	-0.0011	-0.0004	-0.0004
8.44	17.46	5.6332	1.7445	1.8053	5.6406	-0.0011	-0.0004	-0.0004
8.45	17.47	5.6312	1.7427	1.8058	5.6386	-0.0011	-0.0004	-0.0004
8.46	17.48	5.6292	1.7410	1.8063	5.6366	-0.0011	-0.0004	-0.0004
8.49	17.51	5.6236	1.7359	1.8077	5.6454	-0.0032	-0.0012	-0.0011
8.51	17.55	5.6182	1.7310	1.8091	5.6400	-0.0032	-0.0012	-0.0011
8.54	17.58	5.6131	1.7262	1.8106	5.6348	-0.0031	-0.0012	-0.0011
8.56	17.61	5.6081	1.7214	1.8120	5.6299	-0.0031	-0.0012	-0.0011
8.59	17.64	5.6034	1.7167	1.8133	5.6251	-0.0031	-0.0012	-0.0011
8.61	17.67	5.5989	1.7122	1.8147	5.6206	-0.0031	-0.0012	-0.0011
8.64	17.71	5.5946	1.7077	1.8161	5.6163	-0.0031	-0.0012	-0.0011
8.66	17.74	5.5905	1.7033	1.8174	5.6122	-0.0031	-0.0012	-0.0011
8.69	17.77	5.5866	1.6990	1.8188	5.6082	-0.0031	-0.0012	-0.0011
8.71	17.80	5.5829	1.6948	1.8201	5.6045	-0.0031	-0.0012	-0.0011
8.74	17.83	5.5793	1.6907	1.8215	5.6009	-0.0031	-0.0012	-0.0011
8.76	17.87	5.5759	1.6866	1.8228	5.5975	-0.0031	-0.0012	-0.0011
8.79	17.90	5.5727	1.6826	1.8241	5.5942	-0.0031	-0.0012	-0.0011
8.81	17.93	5.5696	1.6787	1.8254	5.5911	-0.0031	-0.0012	-0.0011
8.84	17.96	5.5666	1.6749	1.8267	5.5882	-0.0031	-0.0012	-0.0011
8.86	18.00	5.5638	1.6712	1.8280	5.5853	-0.0030	-0.0012	-0.0011
8.89	18.03	5.5612	1.6675	1.8292	5.5827	-0.0030	-0.0012	-0.0011
8.91	18.06	5.5587	1.6639	1.8305	5.5801	-0.0030	-0.0012	-0.0011
8.94	18.09	5.5563	1.6604	1.8318	5.5777	-0.0030	-0.0012	-0.0011
8.96	18.12	5.5540	1.6569	1.8330	5.5754	-0.0030	-0.0012	-0.0011

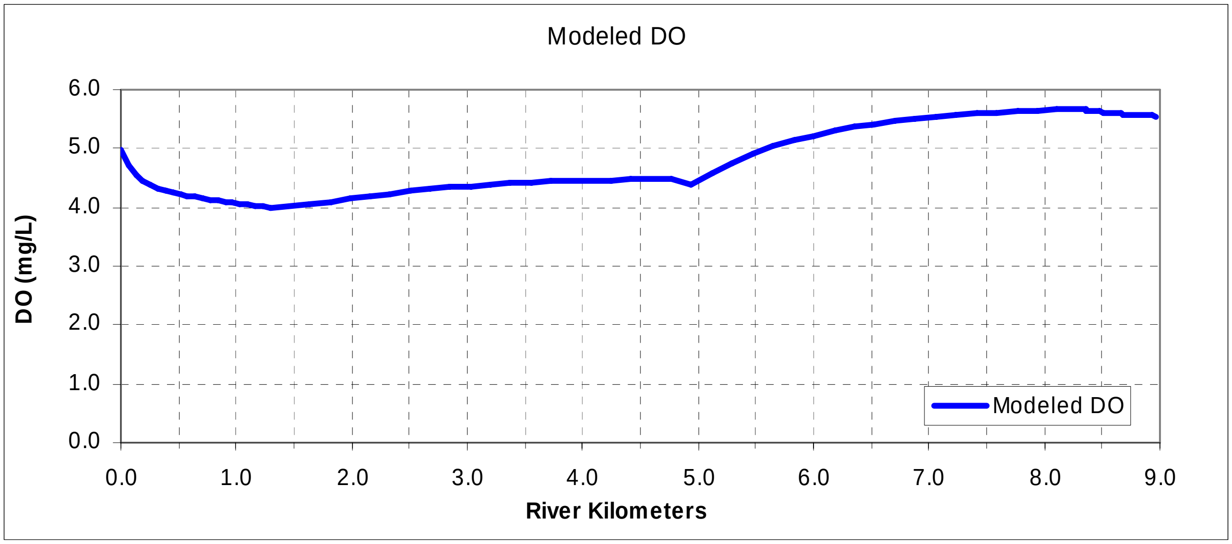

Figure E-1. Modeled and observed dissolved oxygen.