BAYOU PIERRE WATERSHED TMDL FOR BIOCHEMICAL OXYGEN-DEMANDING SUBSTANCES AND NUTRIENTS

SUBSEGMENT 100606

SURVEYED 7/19 - 21/2005

TMDL REPORT

By:
Water Quality Modeling
Water Quality Assessment Division
Office of Environmental Assessment
Louisiana Department of Environmental Quality

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EXECUTIVE SUMMARY

This report presents the results of a watershed based, calibrated modeling analysis of Bayou Pierre. The modeling was conducted to establish a TMDL for biochemical oxygen-demanding pollutants and nutrients for the Bayou Pierre watershed. The model extends from just below Bayou Pierre Lake to Red River. Bayou Pierre is located in north Louisiana and this subsegment includes Shell Bayou, Johnson Chute, Rolling Lake Bayou, Three League Bayou, Grand Bayou, Bailey Bayou, Butler Slough, Swift Bayou, Chicot Island Tributary, Garsia Bayou, Flat River, Bull Bayou, Pig Pen Bayou, Boggy Bayou, Bayou Lumbra, St. Mary Bayou, Bayou Winsey, Coon Slough, Jims River, Wright Bayou, Horseshoe Bayou, Squirrel Bayou, Bayou Pierre Lake, Red Bayou, Maguire Branch, Hickman Bayou, Mundy Bayou, and 65 unnamed tributaries. Bayou Pierre is in the Red River Basin and this study includes Water Quality Subsegment 100606. The area is sparsely populated and land use is dominated by agriculture and forestry. There are seven permitted dischargers located within this subsegment. Additionally, there are 6 known pumps located along Bayou Pierre.

Input data for the calibration model was developed from data collected during the July 2005 intensive survey; data collected by LDEQ monitoring stations in the watershed; USGS drainage area and low flow publications; and data garnered from several previous LDEQ studies on nonpoint source loadings. The nonpoint source loads included nonpoint loading not associated with flow. A satisfactory calibration was achieved for the main stem. For the projection models, data was taken from ambient temperature records. The Louisiana Total Maximum Daily Load Technical Procedures, Revision 8, have been followed in this study.

The various spreadsheets that were used in conjunction with the modeling program may be found in the appendices. Water quality calibration was also based on measurements taken during the survey. Projections were adjusted to meet the dissolved oxygen criteria by reducing total nonpoint source loads.

Modeling was limited to low flow scenarios for both the calibration and the projections since the constituent of concern was dissolved oxygen and the available data was limited to low flow conditions. The model used was LAQUAL, a modified version of QUAL-TX, which has been adapted to address specific needs of Louisiana waters.

Bayou Pierre, Subsegment 100606, was on the 303(d) list starting with the 1999 list. Subsegment 100606 is found to be "not supporting" its designated use of Fish and Wildlife Propagation. It is "fully supporting" Primary and Secondary Contact Recreation, and Agriculture. Bayou Pierre was subsequently scheduled for TMDL development with other listed waters in the Red River Basin. The suspected causes of impairment are dissolved oxygen and nutrients. The suspected sources are natural conditions and non-irrigated crop production. As stated on the 2004 303(d) list, a use attainability analysis is needed for this subsegment.

This TMDL establishes load limitations for oxygen-demanding substances and goals for reduction of those pollutants. LDEQ's position, as supported by the declaratory ruling issued by Secretary Givens in response to the lawsuit regarding water quality criteria for nutrients (Sierra Club v. Givens, 710 So.2d 249 (La. App. 1st Cir. 1997), writ denied, 705 So.2d 1106 (La. 1998), is that when oxygen-demanding substances are controlled and limited in order to ensure that the

dissolved oxygen criterion is supported, nutrients are also controlled and limited. The implementation of this TMDL through future wastewater discharge permits (if required) and implementation of best management practices to control and reduce runoff of soil and oxygen-demanding pollutants from nonpoint sources in the watershed will also control and reduce the nutrient loading from those sources.

A calibrated water quality model for the watershed was developed and projections were modeled to quantify the non-point source load reductions which would be necessary in order for Bayou Pierre, subsegment 100606 to comply with its established water quality standards and criteria. This report presents the results of that analysis.

There are seven permitted dischargers located in this subsegment. All of the dischargers located on this waterbody are small and need not be included in a model of this scale because it is unlikely that they are having an impact on the targeted waterbody due to the small load and/or the distance from the waterbody named in the 303(d) lists. These dischargers are accounted for as nonpoint loading through the process of calibration. They fall within one of several state or regional policies that govern permit limitations. Therefore, the limits for these facilities will remain the same and will continue to be permitted using state policy. Current permit information and discharge monitoring reports were reviewed for all of these facilities. A discharger inventory list is presented at the end of this summary in Table 2.

Additionally, there are six known pumps located on the mainstem of Bayou Pierre. These pumps are used for farming practices in the area. When in use, the pumps can have a significant impact on the flow of Bayou Pierre. Because these pumps are operated intermittently, it is very difficult to quantify their impact. Only two were running during the survey and were included in the calibration. However, in order to project to critical conditions, no pumps were included in the projections.

Although there are over 80 tributaries located along Bayou Pierre, only two were flowing at the time of the survey. Those tributaries, Shell Bayou and Johnson Chute Bayou, were included in the model. The survey was conducted during a period of low flow, therefore, all other tributaries located along Bayou Pierre were assumed to be intermittent for the calibration and the projection runs.

The results of the projection modeling for subsegment 100606 show that the water quality standard for dissolved oxygen can be maintained during the summer critical season with a 100% reduction of man-made nonpoint source pollution and 30% reduction of background loading. The minimum DO is 5.01 mg/l. Kisatchie Bayou was the reference stream used to calculate background conditions. The calculations are found in Appendix F5.

Table 1. Total Maximum Daily Load (Sum of UCBOD, UNBOD, and SOD)

ALLOCATION	SUMMER		WINTER	
	% Reduction Required	(MAR-NOV) (lbs/day)	% Reduction Required	(DEC-FEB) (lbs/day)
Natural Nonpoint Source LA	30	8,198	30	7,312
Natural Nonpoint Source Reserve MOS (not used)		0		0
Manmade Nonpoint Source LA	100	0	100	0
Manmade Nonpoint Source Reserve MOS (20%)		0		0
TMDL		8,198		7,312

***Note1: UCBOD as stated in this allocation is Ultimate CBOD.
UCBOD to $CBOD_5$ ratio = 2.3 for all treatment levels
Permit allocations are generally based on $CBOD_5$***

The results of the projection modeling for subsegment 100606 show that the water quality standard for dissolved oxygen can be maintained during the winter critical season with the same 100% reduction of man-made nonpoint source pollution and a 30% reduction of background loading. The minimum DO is 7.71 mg/l. Subsegment 100606 has a year round water quality standard for dissolved oxygen of 5.0 mg/l.

The high reduction in the man-made nonpoint source and background loading, indicates that the current criterion for subsegment 100606 is inappropriate. A reassessment of the dissolved oxygen criteria for this subsegment is recommended. All summer and winter runs assumed a 5.0 dissolved oxygen standard.

LDEQ will work with other agencies such as local Soil Conservation Districts to implement agricultural best management practices in the watershed through the 319 programs. LDEQ will also continue to monitor the waters to determine whether standards are being attained.

In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state’s surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring 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 data base for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state’s biennial 305(b) report (*Water Quality Inventory*) and the 303 (d) list of impaired waters. This information is also utilized in establishing priorities for the LDEQ nonpoint source program.

The LDEQ is continuing to implement a watershed approach to the surface water quality monitoring. In 2004 a four year sampling cycle replaced the previous five year cycle. Approximately one quarter of the states watersheds will be sampled in each year so that all of the states watersheds will be sampled within the four year cycle. This will allow the LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list.

Table 2. Bayou Pierre Dischargers Subsegment 100606

			Current Expected Flow	Current Monthly Average Concentration Limits		TMDL Monthly Average Concentration Limits		TMDL Monthly Average Mass Limits		
Facility	File/AI No.	Out-fall No.	GPD	BOD_5/ $CBOD_5$, mg/L	NH_3-N, mg/L	BOD_5/ $CBOD_5$, mg/L	NH_3-N, mg/L	$CBOD_5$, lbs./day	NH_3-N, lbs./day	Modeling Comments
International Paper: Bayou Pierre Woodyard	84371	1	479000	N/A	N/A	N/A	N/A	N/A	N/A	Modeling not needed - ample chance to recover (UNT to Sampson's Channel to Bayou Pierre)
ConAgra Poultry: Robeline Truck Shop	10883	1	500	30	15	30	15	0.12521	0.0626	Modeling not needed - 500 GPD and ample chance to recover
Robeline Sanitary Sewerage System	43068	1	36000	20	10	20	10	6.00984	3.00492	Modeling not needed - ample chance to recover
Bayou Pierre Alligator Farm Inc.	40736	1	4000	30	15	30	15	1.00164	0.50082	Modeling not needed - ample chance to recover (Ditch to Red Bayou…)
Oak Grove Apartments	19049	1	8800	30	15	30	15	2.20361	1.1018	Modeling not needed - Intermitent stream
DeSoto Parish Police Jury Mundy Sanitary Landfill	19803	1	17.4	N/A	N/A	N/A	N/A	N/A	N/A	Modeling not needed - ample chance to recover
Dolet Hills Lignite Company, LLC	11541	S1CC\S1V\ S1M05	Intermittent	30	15	30	15	N/A	N/A	Modeling not needed - Intermitent stream

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Introduction

Bayou Pierre, subsegment 100606, of the Red River Basin is listed on the 2004 303(d) list. The subsegment is listed as not supporting fish and wildlife propagation. It is, however, meeting its designated use of Primary and Secondary Contact Recreation and Agriculture. The suspected causes of impairment are low DO and nutrients. The suspected sources are natural conditions and non-irrigated crop production. The 303(d) report recommends that a use attainability analysis be conducted. Because of the impairment, this subsegment requires the development of a total maximum daily load (TMDL) for oxygen demanding substances and nutrients. A calibrated water quality model for the Bayou Pierre, subsegment 100606 watershed was developed and projections for current dissolved oxygen standards were run to quantify the wasteload required to meet established dissolved oxygen criteria. This report presents the model development and results.

2. Study Area Description

2.1 General Information

Red River Basin

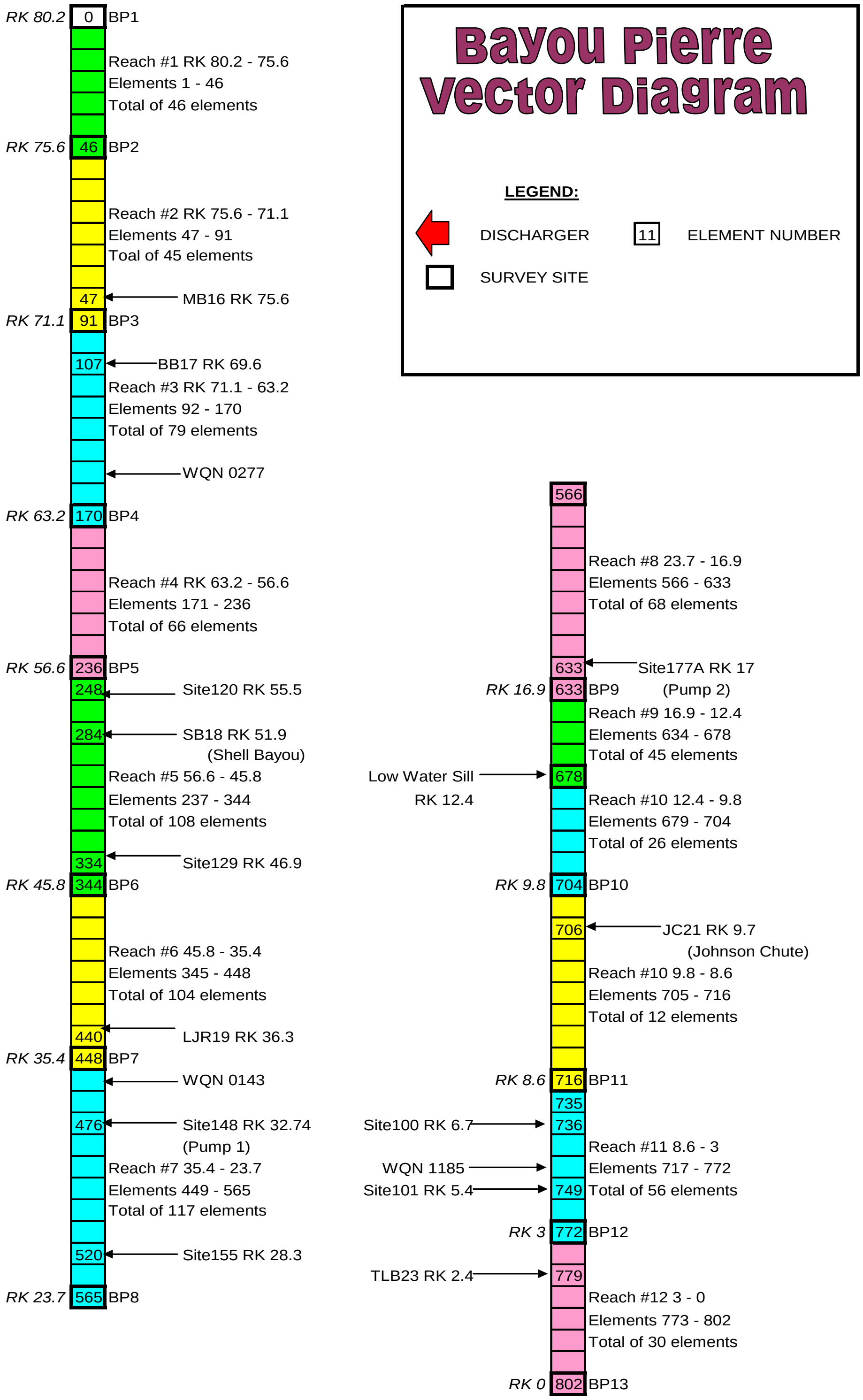
The Red River has its origin in eastern New Mexico and flows across portions of Texas, Oklahoma and Arkansas before entering northwestern Louisiana. The river flows south to Shreveport, where it turns southeast and flows for approximately 160 miles to its junction with the Atchafalaya River. From the Arkansas state line to Alexandria, the Red River is contained within high banks which range from 20 to 35 feet above low water level. Below Alexandria, the river flows through a flat alluvial plain which is subject to backwater flooding during periods of high water. The Sabine River Basin lies to the southwest of the Red River Basin, and the Ouachita River Basin lies to the east. The Calcasieu, Vermilion – Teche, and Atchafalaya River Basins lie south of the Red River Basin. The Red River drains approximately 7,760 squares miles within Louisiana.

Subsegment 100606 includes Bayou Pierre from just below Bayou Pierre Lake to the Red River. This area is typical of the basin and is primarily comprised of forestry and agriculture as documented in Table 3 (LADEQ, 1999). A detailed land cover map of Subsegment 100606 is also included in Appendix H2. Average annual precipitation in the segment, based on the nearest Louisiana Climatic Station, is 52 inches based on a 30-year period of record (LSU, 1999). There is a Louisiana average annual precipitation map located in Appendix H3.

Table 3. Land Uses in Segment 100606

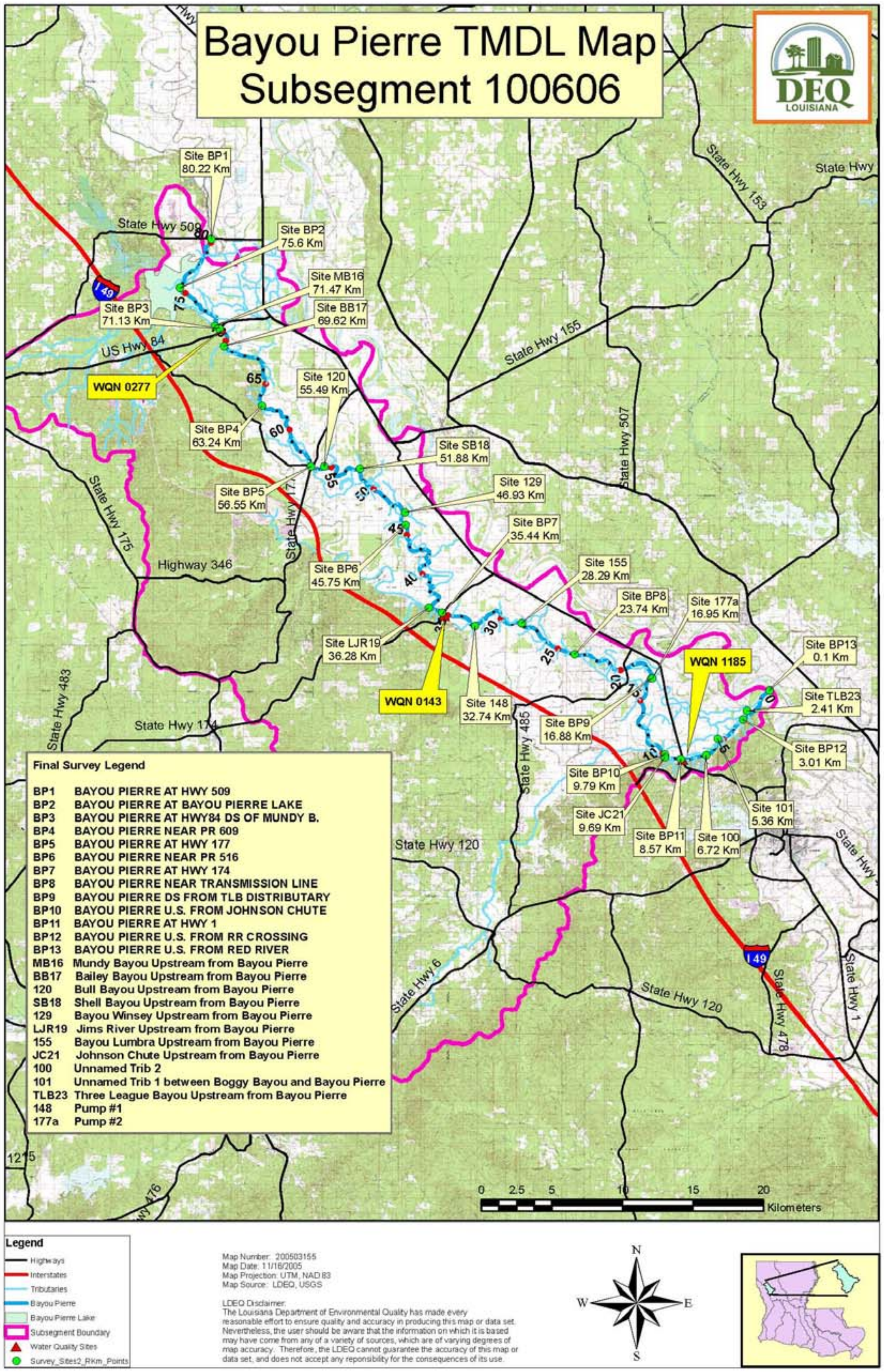
Land Type	Acres 100606	Percent Land use 100606
Agriculture/Cropland/Grassland	114941.93	34.47%
Upland Forest Evergreen	69357.28	20.80%
Wetland Forest Deciduous	35145.00	10.54%
Upland Forest Mixed	28827.22	8.65%
Upland S/S Mixed	28826.78	8.65%
Dense Pine Thicket	15734.63	4.72%
Upland Forest Deciduous	13148.63	3.94%
Water	9896.56	2.97%
Upland S/S Evergreen	7537.62	2.26%
Upland S/S Deciduous	3797.39	1.14%
Wetland Forest Mixed	3157.78	0.95%
Wetland S/S Deciduous	2459.24	0.74%
Non-Vegetated Urban	296.90	0.09%
Fresh Marsh	131.88	0.04%
Upland Barren	88.96	0.03%
Vegetated Urban	55.38	0.02%
Wetland Barren	38.70	0.01%

Figure1. Model Layout



***Tributaries not flowing during survey are not shown.**

Figure 2. Map of Study Area



2.2 Water Quality Standards

The Water Quality criteria and designated uses for Bayou Pierre Watershed are shown in Table 4. As noted in the table, Bayou Pierre, Subsegment 100606 has a year round dissolved oxygen standard of 5.0 mg/L.

Table 4. Water Quality Numerical Criteria and Designated Uses

Parameter	Value
Designated Uses	A B C F
DO, mg/L	5.0
Cl, mg/L	150
SO_4, mg/L	75
pH	6.0 – 8.5
BAC	1
Temperature, deg Celsius	32
TDS, mg/L	500

USES: A – primary contact recreation; B - secondary contact recreation; C – propagation of fish and wildlife; D – drinking water supply; E – oyster propagation; F – agriculture; G – outstanding natural resource water; L – limited aquatic life and wildlife use.

Note 1 – 200 colonies/100mL maximum log mean and no more than 25% of samples exceeding 400 colonies/100mL for the period May through October; 1,000 colonies/100mL maximum log mean and no more than 25% of samples exceeding 2,000 colonies/100mL for the period November through April.

2.3 Wastewater Discharges

There are seven permitted dischargers located in this subsegment. All of the dischargers located on this waterbody are small and need not be included in a model of this scale because it is unlikely that they are having an impact on the targeted waterbody due to the small load and/or the distance from the waterbody named in the 303(d) lists. These dischargers are accounted for as nonpoint loading through the process of calibration. They fall within one of several state or regional policies that govern permit limitations. Therefore, the limits for these facilities will remain the same and will continue to be permitted using state policy. Current permit information and discharge monitoring reports were reviewed for all of these facilities.

Table 5. Bayou Pierre Discharger Inventory Subsegment 100606

FACILITY	FILE No.	Out-fall No.	OUTFALL DESCRIP-TION	FACILITY TYPE	RECEIVING WATER	EXPECTED FLOW GPD	MONTHLY AVERAGE CONCENTRATION LIMITS		MONTHLY AVERAGE MASS LIMITS		MODELING COMMENTS
							BOD5/ CBOD5, mg/L	NH_3-N, mg/L	BOD, lbs./day	NH_3-N, lbs./day	
International Paper Co Bayou Pierre Woodyard	LA0083101	1	External	LOG STORAGE	BAYOU PIERRE	479000	N/A	N/A	N/A	N/A	Modeling not needed- ample chance to recover (UNT to Sampson's Channel to Bayou Pierre)
ROBELINE TRUCK SHOP / CONAGRA BROILER CO	LAG531226	1	External	TRUCK MAINTENANCE	DITCH-CRIB CREEK	500	30	15	0.12521	0.0626	Modeling not needed- 500 GPD and ample chance to recover
Robeline Village of - STP	LAG560209	1	External	3-CELL OXIDATION POND	WINN CR-B DUPONT-LITTLE RV-RED RV	36000	20	10	6.00984	3.00492	Modeling not needed- ample chance to recover
MUNDY SANITARY LANDFILL / DESOTO PH. POLICE JURY	LA0066702	1	External	SANITARY LANDFILL	BAYOU PIERRE LAKE	17400	N/A	N/A	N/A	N/A	Modeling not needed- ample chance to recover
/ BAYOU PIERRE ALLIGATOR FARM	LA0107239	1	External	ALLIGATOR PARK/GIFTS/SNACKS	RED BAYOU	4000	30	15	1.00164	0.50082	Modeling not needed- ample chance to recover (Ditch to Red Bayou…)
OAK GROVE APT / FAIR PROP MGT DBA ROY FAIR	LAG540034	1	External	APT. STP	BAYOU PIERRE	8800	30	15	2.20361	1.1018	Modeling not needed- Intermittent Stream
DOLET HILLS LIGNITE CO LLC	LA0064076	1	External	LIGNITE SURFACE MINE	FIVE MILE BAYOU	Intermittent	30	15	N/A	N/A	Modeling not needed- Intermittent Stream

2.4 Water Quality Conditions/Assessment

Bayou Pierre, subsegment 100606, of the Red River Basin is listed on the 2004 303(d) list. This subsegment is listed as not supporting fish and wildlife propagation. It is, however, meeting its designated use of Primary and Secondary Contact Recreation, and Agriculture. The suspected causes of impairment in subsegment 100606 are DO and nutrients. The suspected sources for 100606 are natural conditions and non-irrigated crop production. It is recommended in this report that a use attainability analysis be conducted. Because of the impairment, this subsegment requires the development of a total maximum daily load (TMDL) for oxygen demanding substances and nutrients.

2.5 Prior Studies

LDEQ had three monthly water quality sampling stations on Bayou Pierre. LDEQ Water Quality Site 0277, Bayou Pierre west of Grand Bayou, has a period of record from January 1990 to May 1998. LDEQ Water Quality Site 0143, Bayou Pierre near Lake End, has a period of record from January 1987 to December 1989. LDEQ Water Quality Site 1185, Bayou Pierre at Hwy 1, northwest of Natchitoches, has two periods, January 2002 to November 2002 and January 2004 to November 2004. Data collected during the Eularian survey conducted in July 2005, included discharge data, cross-section data, field in-situ data, continuous monitor data, and lab water quality data. This data was used to establish the input for the model calibration and is presented in Appendix F.

3. Documentation Calibration Model

3.1 Program Description

"Simulation models are used extensively in water quality planning and pollution control. Models are applied to answer a variety of questions, support watershed planning and analysis and develop total maximum daily loads (TMDLs). . . . Receiving water models simulate the movement and transformation of pollutants through lakes, streams, rivers, estuaries, or near shore ocean areas. . . . Receiving water models are used to examine the interactions between loadings and response, evaluate loading capacities (LCs), and test various loading scenarios. . . . A fundamental concept for the analysis of receiving waterbody response to point and nonpoint source inputs is the principle of mass balance (or continuity). Receiving water models typically develop a mass balance for one or more constituents, taking into account three factors: transport through the system, reactions within the system, and inputs into the system." (EPA841-b-97-006, pp. 1-30)

The model used for this TMDL was LA-QUAL, a steady-state one-dimensional water quality model. LA-QUAL history dates back to the QUAL-I model developed by the Texas Water Development Board with Frank D. Masch & Associates in 1970 and 1971. William A. White wrote a original code.

In June, 1972, the United States Environmental Protection Agency awarded Water Resources Engineers, Inc. (now Camp Dresser & McKee) a contract to modify QUAL-I for application to the Chattahoochee-Flint River, the Upper Mississippi River, the Iowa-Cedar River, and the Santee River. The modified version of QUAL-I was known as QUAL-II.

Over the next three years, several versions of the model evolved in response to specific client needs. In March, 1976, the Southeast Michigan Council of Governments (SEMCOG) contracted with Water

Resources Engineers, Inc. to make further modifications and to combine the best features of the existing versions of QUAL-II into a single model. That became known as the QUAL-II/ SEMCOG version.

Between 1978 and 1984, Bruce L. Wiland with the Texas Department of Water Resources modified QUAL-II for application to the Houston Ship Channel estuarine system. Numerous modifications were made to enable modeling this very large and complex system including the addition of tidal dispersion, lower boundary conditions, nitrification inhibition, sensitivity analysis capability, branching tributaries, and various input/output changes. This model became known as QUAL-TX and was subsequently applied to streams throughout the State of Texas.

In 1999, the Louisiana Department of Environmental Quality and Wiland Consulting, Inc. developed LA-QUAL based on QUAL-TX Version 3.4. The program was converted from a DOS-based program to a Windows-based program with a graphical interface and enhanced graphic output. Other program modifications specific to the needs of Louisiana and the Louisiana DEQ were also made. LA-QUAL is a user-oriented model and is intended to provide the basis for evaluating total maximum daily loads in the State of Louisiana.

The development of a TMDL for dissolved oxygen generally occurs in 3 stages. Stage 1 encompasses the data collection activities. These activities may include gathering such information as stream cross-sections, stream flow, stream water chemistry, stream temperature and dissolved oxygen and various locations on the stream, location of the stream centerline and the boundaries of the watershed which drains into the stream, and other physical and chemical factors which are associated with the stream. Additional data gathering activities include gathering all available information on each facility which discharges pollutants in to the stream, gathering all available stream water quality chemistry and flow data from other agencies and groups, gathering population statistics for the watershed to assist in developing projections of future loadings to the water body, land use and crop rotation data where available, and any other information which may have some bearing on the quality of the waters within the watershed. During Stage 1, any data available from reference or least impacted streams which can be used to gauge the relative health of the watershed is also collected.

Stage 2 involves organizing all of this data into one or more useable forms from which the input data required by the model can be obtained or derived. Water quality samples, field measurements, and historical data must be analyzed and statistically evaluated in order to determine a set of conditions which have actually been measured in the watershed. The findings are then input to the model. Best professional judgment is used to determine initial estimates for parameters which were not or could not be measured in the field. These estimated variables are adjusted in sequential runs of the model until the model reproduces the field conditions which were measured. In other words, the model produces a value of dissolved oxygen, temperature, or other parameter which matches the measured value within an acceptable margin of error at the locations along the stream where the measurements were actually made. When this happens, the model is said to be calibrated to the actual stream conditions. At this point, the model should confirm that there is an impairment and give some indications of the causes of the impairment. If a second set of measurements is available for slightly different conditions, the calibrated model is run with these conditions to see of the calibration holds for both sets of data. When this happens, the model is said to be verified.

Stage 3 covers the projection modeling which results in the TMDL. The critical conditions of flow and temperature are determined for the waterbody and the maximum pollutant discharge conditions from the point sources are determined. These conditions are then substituted into the model along with any related condition changes which are required to perform worst case scenario predictions. At this point, the loadings from the point and nonpoint sources (increased by an acceptable margin of safety) are run at various levels and distributions until the model output shows that dissolved oxygen criteria are achieved. It is critical that a balanced distribution of the point and nonpoint source loads be made in order to predict any success in future achievement of water quality standards. At the end of Stage 3, a TMDL is produced which shows the point source permit limits and the amount of reduction in man-made nonpoint source pollution which must be achieved to attain water quality standards. The man-made portion of the NPS pollution is estimated from the difference between the calibration loads and the loads observed on reference or least impacted streams.

3.2 Input Data Documentation

Data collected during an intensive survey conducted from July 19-21, 2005, was used to establish the input for the model calibration. It is presented in Appendix F. The widths and depths in each reach and headwater were based on the survey measurements.

Field and laboratory water quality data were entered in a spreadsheet for ease of analysis. Upon review of the measured CBOD daily values it became apparent that there were two distinct CBOD components, which had varying ultimate values as well as decay rates and lag times. The first component started its decay almost immediately while the second component had substantial lag times. The total CBOD curve presented in Appendix F5 is the sum of the two first order equations, which were derived using the Microsoft Excel Solver and were based on the measured daily CBOD values. These two CBOD components were modeled separately as CBOD1 and CBOD2 in the LAQUAL model. NBOD simulated organic nitrogen, ammonia nitrogen, and nitrate/nitrite nitrogen. The Louisiana BOD program was applied to the BOD data in a separate spreadsheet and values were computed for each sample taken of ultimate CBOD1, CBOD1 decay rate, CBOD1 lag time, ultimate CBOD2, CBOD2 decay rate, and CBOD2 lag time as well as the NBOD, NBOD decay rate, and NBOD lag time. The survey data was the primary source of the model input data for initial conditions, decay rates, mainstem water temperature, dissolved oxygen loading, headwater temperature, and DO data.

3.2.1 Model Schematics and Maps

A vector diagram of the modeled area is presented in Figure 1 and Appendix C1. The vector diagram shows the locations of survey stations, the reach/element design, and the locations of the tributaries included in the model. An ARCVIEW map of the stream and subsegment showing river kilometers, survey stations, subsegment boundary and other points of interest are also included in Figure 2 and Appendix H1.

3.2.2 Model Options, Data Type 2

Six constituents were modeled during the calibration process. These were dissolved oxygen, carbonaceous biochemical oxygen demand1, carbonaceous biochemical oxygen demand2, nitrogenous biochemical oxygen demand, chlorides, and conductivity. The continuous monitors did show small diurnal swings indicative of algal activity beginning around Pump 1 down to the Red River. The algae cycle was not modeled; however, the measured chlorophyll A values were included in the initial conditions. This allowed the model to simulate the oxygen production associated with algae without modeling the entire algal cycle. A review of the data showed that chlorides were more reliable as a conservative constituent for this watershed.

3.2.3 Temperature Correction of Kinetics, Data Type 4

The temperature values computed are used to correct the rate coefficients in the source/sink terms for the other water quality variables. These coefficients are input at 20 °C and are then corrected to temperature using the following equation:

$$X_T = X_{20} * \text{Theta}^{(T-20)}$$

Where:

X_T = the value of the coefficient at the local temperature T in degrees Celsius
X_{20} = the value of the coefficient at the standard temperature at 20 degrees Celsius
Theta = an empirical constant for each reaction coefficient

In the absence of specified values for data type 4, the model uses default values. A complete listing of these values can be found in the LA-QUAL for Windows User's Manual (LDEQ, 2004). For this model all values used were LAQUAL default values.

3.2.4 Reach Identification Data, Data Type 8

A diagram of the modeled area is presented in Appendix C1. The vector diagram shows the reach/element design and the location of Pump 1, Pump 2, Shell Bayou and Johnson Chute. The modeled area is characterized by 26 sample sites. The model starts just below Bayou Pierre Lake and extends to the Red River. This calibrated model includes 13 reaches, 802 elements, one headwater, two pumps, and two tributaries. A digitized map of the stream showing river kilometers, and the July 2005 survey sampling sites are included in Figure 2 and Appendix H1.

3.2.5 Advective Hydraulic Coefficients, Data Type 9

Louisiana streams typically do not go dry when the flow in the stream goes to zero. Therefore, hydraulic calculation method two was used for this stream to more accurately depict the geometry. The modified Leopold equations were utilized in this model for calibration. The measured widths and depths were averaged across reaches. These averages were used as the constants in data type 9.

3.2.6 Dispersive Hydraulic Coefficients, Data Type 10

Since Bayou Pierre is characterized by frequent flow reverses and is deep and wide, the dispersive hydraulic coefficients were used for all reaches. Most of the dispersion was assumed to be near the bottom of the stream where the flow from Bayou Pierre is combining with the Red River. There is a large amount of barge traffic along the Red River, which contributes to the frequent flow reverses. Also, during the time of the survey there were pilings being driven downstream of Johnson Chute on

Bayou Pierre. Additionally, there are six known pumps located along Bayou Pierre. The pumps are used as needed and are not run at regular intervals of time. These pumps can greatly influence the flow on Bayou Pierre depending on whether or not any or all are in use. Finally, there are many intermittent tributaries connecting to Bayou Pierre which affect the flow patterns of the mainstem. The flow from the large number of tributaries are greatly influenced by the irrigation practices of the farmland located in this subsegment as well as the amount of rainfall. Additonally, the low water sill located along Bayou Pierre holds water for irrigation and livestock during extreme low flow conditions.

3.2.7 Initial Conditions, Data Type 11

The initial conditions are used to reduce the number of iterations required by the model. The values required for this model were temperature and DO by reach. The input values came from continuous monitoring averages of the survey stations located closest to the reach. Chlorophyll a values were also used since the mild effects of algae on the dissolved oxygen concentrations were also simulated with this model. Since the initial conditions are only a starting point for the model, all values were set to the calibration values. The input data and sources are shown in Appendix D.

3.2.8 Reaeration Rates, Data Type 12

The applicability of the various equations was examined. The review showed that the Texas Equation was most applicable to Bayou Pierre for Reaches 1-7. In reaches 8-12, the average river depths and low velocities for Bayou Pierre do not meet the depth and velocity limitations for the reaeration equations available. Therefore, these reaeration rates were determined through calibration. The input data and sources are shown in Appendix D.

3.2.9 Sediment Oxygen Demand, Data Type 12

The SOD values were achieved through calibration. The values were determined to be zero towards the bottom of the stream. This was probably a result of the deeper waters of Bayou Pierre. The SOD value for each reach is shown in Appendix B. The values were considered to be reasonable for this type of stream. The conversion ratio of settled CBOD and settled NBOD to SOD was considered to be zero for all reaches.

3.2.10 Carbonaceous BOD Decay and Settling Rates, Data Type 12

The decay rates used were based on the bottle rates from the survey. Review of the measured CBOD daily values revealed two distinct CBOD components, which had varying decay rates and lag times. The first component started its decay almost immediately with decay rates ranging from 0.11 to 0.252 per day. The second component had substantial lag times ranging from 12.25 to 24.84 days and decay rates from 0.025 to 0.043 per day. The total CBOD curves presented in Appendix F5 are the sum of the two first order equations, which were derived using the Microsoft Excel Solver and were based on the measured daily CBOD values. These two components were modeled separately as CBOD1 and CBOD2 in the LAQUAL model. The decay and settling rates used for each reach are shown in Appendix B2.

3.2.11 Nitrogenous BOD Decay and Settling Rates, Data Type 15

These rates are labeled NBOD Decay and Settling in the model. The decay rates used were based on the bottle rates from the survey. NBOD decay rates along the main stem ranged from 0.058 to 0.595. The decay and settling rates used for each reach are shown in Appendix B2.

3.2.12 Incremental Conditions, Data Types 16, 17, and 18

The incremental conditions were used in the calibration to represent nonpoint source loads associated with flows. It was determined from the flow measurements along the mainstem and an evaluation of the water chemistry that groundwater inflow and bank flow could be assumed. Characteristically, the BOD loads for groundwater were assumed to be zero. The data and its source for each reach are presented in Appendix F2.

3.2.13 Nonpoint Sources, Data Type 19

Nonpoint source loads which are not associated with a flow are input into this part of the model. These can be most easily understood as resuspended load from the bottom sediments and are modeled as SOD, CBOD1, CBOD2, and NBOD loads. The data and sources are presented in Appendix B2.

3.2.14 Headwaters, Data Types 20, 21, and 22

The headwater flow was determined from the measurements obtained during the July 2005 survey. The hydrology used for the headwater was from BP1. The data and sources are presented in Appendix B2.

3.2.15 Wasteloads, Data Types 23, 24, and 25

There are seven permitted dischargers located in this subsegment. All of the dischargers located on this waterbody are small and need not be included in a model of this scale because it is unlikely that they are having an impact on the targeted waterbody due to the small load and/or the distance from the waterbody named in the 303(d) lists. These dischargers are accounted for as nonpoint loading through the process of calibration. They fall within one of several state or regional policies that govern permit limitations. Therefore, the limits for these facilities will remain the same and will continue to be permitted using state policy. Current permit information and discharge monitoring reports were reviewed for all of these facilities.

There were however two significant pumps and two tributaries, Shell Bayou and Johnson Chute, that have been included.

3.2.16 Boundary Conditions, Data Type 27

The lower boundary conditions were assumed to be equivalent to the measurements taken at BP13 (Bayou Pierre upstream from Red River). This station is located at the model boundary.

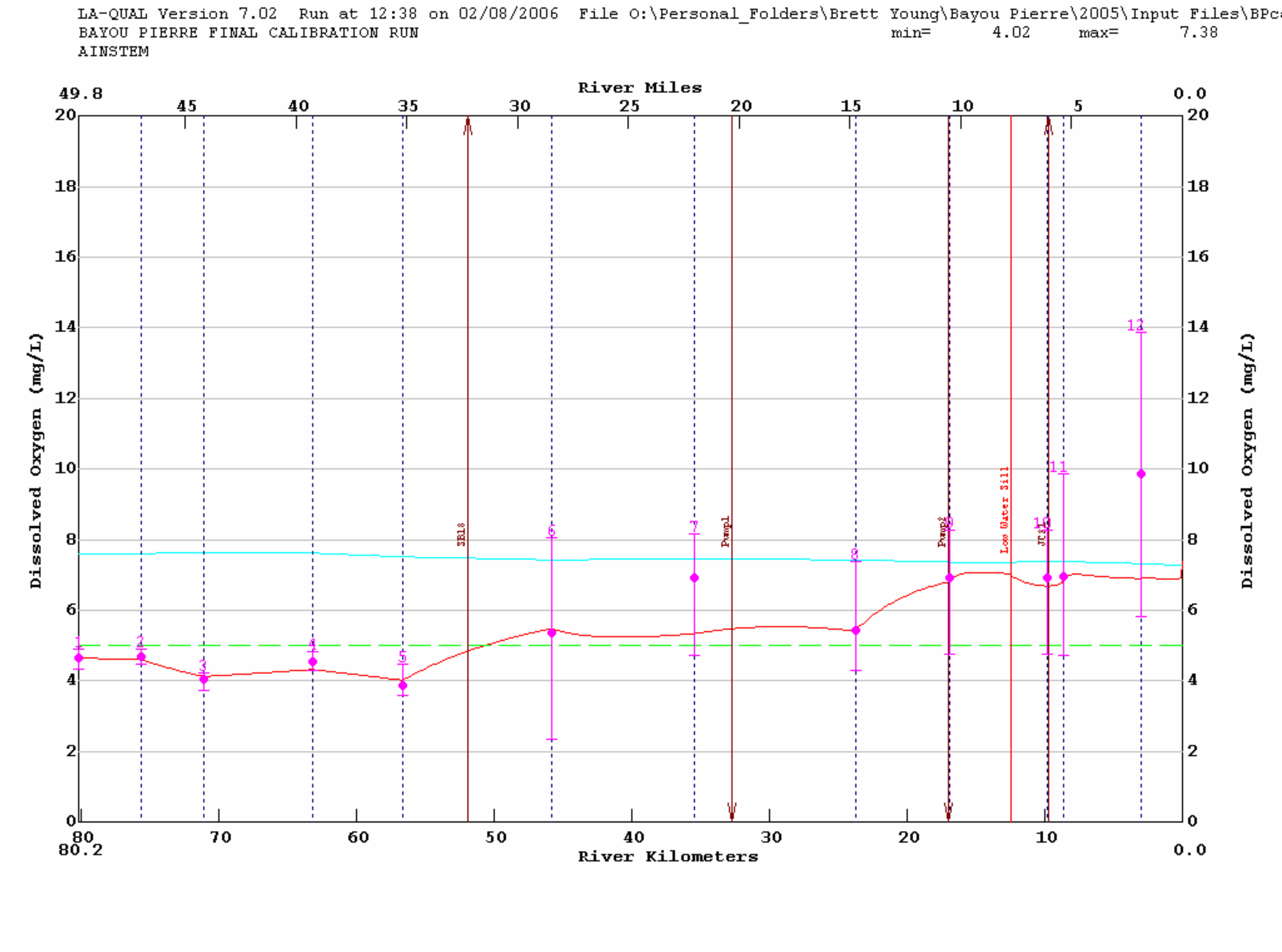
3.3 Model Discussion and Results

The calibration model input and output is presented in Appendix B. The overlay plotting option was used to determine if calibration had been achieved. A plot of the dissolved oxygen concentration versus river kilometer is presented in Figure 3. The sites chosen for each reach were a representative cross section of that reach. The coefficients and exponents were determined through calibration for this model.

The calibration points for dissolved oxygen and temperature were based on survey site measurements. The calibration points for CBOD1, CBOD2, and NBOD were the measured values from the water quality samples.

An adequate calibration was achieved for DO, CBOD1, CBOD2, NBOD, chlorides, and conductivity on the main stem. The calibration model shows that during July 2005 survey period, the DO standard of 5.0 mg/l was not being met in subsegment 100606 in five of the upper modeled reaches. The calibration model minimum DO on the main stem was 4.02 mg/l. A better calibration was achieved in the upper reaches. At the lower reaches calibration was more difficult because of the flow reversals due to the large amount of barge traffic and the low water sill.

Figure 3. Calibration Model Dissolved Oxygen versus River Kilometer



- numbered points indicate survey stations
- lines through numbered points represent the min and max values
- red vertical lines indicate significant points along the waterbody
- the green horizontal line indicates the DO Criterion
- upper plotted blue line indicates DO saturation
- lower plotted red line indicates calibration model output

4. Water Quality Projections

The traditional summer critical projection loading scenario was performed at the current annual DO standard. This scenario was based on reduced total nonpoint loads at summer season critical conditions (ie. 90th percentile seasonal temperatures and 7Q10 flows) in accordance with the LTP. A winter projection was run based on the percent reduction of total nonpoint loads used for summer critical projections. A no-load scenario was run to identify more appropriate critera.

4.1 Critical Conditions, Seasonality and Margin of Safety

The Clean Water Act requires the consideration of seasonal variation of conditions affecting the constituent of concern, and the inclusion of a margin of safety (MOS) in the development of a TMDL.

For the Bayou Pierre, subsegment 100606 TMDL, an analysis of LDEQ ambient data has been employed to determine critical seasonal conditions and an appropriate margin of safety.

Critical conditions for dissolved oxygen were determined for Bayou Pierre using short term water quality data from Bayou Pierre water quality sites on the LDEQ Ambient Monitoring Network. The WQ sites used were 0277, 0143, and 1185. The 90th percentile temperature for each season and the corresponding 90% of saturation DO was determined. Ambient temperature data, critical temperature and DO saturation determinations are shown in Appendix G1.

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

When the rainfall run-off (and non-point loading) and stream flow are high, turbulence is higher due to the higher flow and the temperature is lowered by the run-off. In addition, run-off coefficients are higher in cooler weather due to reduced evaporation and evapotranspiration, so that the high flow periods of the year tend to be the cooler periods. Reaeration rates and DO 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 TMDL 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 and/or resuspended BOD 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 manmade portion of the NPS loading is the difference between the calibration load and the reference stream load where the calibration load is higher. The only mechanism for changing this normal benthic blanket condition is to implement best management practices and reduce the amount of nonpoint source loading entering the stream and feeding the benthic blanket.

Critical season conditions were simulated in the Bayou Pierre, subsegment 100606 dissolved oxygen TMDL projection modeling by using the 7Q10 flow and the 90th percentile temperature. Groundwater inflow was present during this survey, but it is assumed to be zero during both summer and winter conditions. The USGS calculated 7Q10 for Bayou Pierre near Grand Bayou of 6.1 cfs = 0.1727 cms was used for the headwater during both summer and winter conditions. In accordance with the LTP, a summer flow of 0.1 cfs = 0.0028 cms and a winter flow of 1.0 cfs = 0.028 cms for Shell Bayou and Johnson Chute was assumed.

In reality, the highest temperatures occur in July-August, the lowest stream flows occur in October-November, and the maximum point source discharge occurs following a significant rainfall, i.e., high-flow conditions. The summer projection model is established as if all these conditions happened at the same time. The winter projection model accounts for the seasonal differences in flows and BMP efficiencies. Other conservative assumptions regarding rates and loadings are also made during the modeling process. In addition to the conservative measures, an explicit MOS of 20% was used for all loads to account for future growth, safety, model uncertainty and data inadequacies.

4.2 Input Data Documentation

The USGS calculated 7Q10 for Bayou Pierre near Grand Bayou of 6.1 cfs = 0.1727 cms was used for the headwater during both summer and winter conditions. The flows in Shell Bayou and Johnson Chute were set to 0.0028 cms in the summer and 0.028 cms for winter critical conditions in accordance with the LTP.

The calibration values were retained for the remaining parameters and used as input values in the summer and winter projections. The model adjusts the input values for SOD, CBODU decay, and NBODU decay based upon the input temperature.

4.2.1 Model Options, Data Type 2

Six constituents were modeled during the projection process. These were dissolved oxygen, carbonaceous biochemical oxygen demand 1, carbonaceous biochemical oxygen demand 2, nitrogenous biochemical oxygen demand, chlorides, and conductivity.

4.2.2 Temperature Correction of Kinetics, Data Type 4

The temperature correction factors specified in the LTP are entered in the model.

4.2.3 Reach Identification Data, Data Type 8

The reach-element design from the calibration was used in the projection modeling.

4.2.4 Advective Hydraulic Coefficients, Data Type 9

The hydraulic coefficients, exponents, and constants determined for the calibration were used in the projection model.

4.2.5 Initial Conditions, Data Type 11

The initial conditions were set to the 90^{th} percentile critical season temperature in accordance with the LTP. The dissolved oxygen values for the initial conditions were set at the stream criteria.

4.2.6 Reaeration Rates, Carbonaceous BOD Decay and Settling Rates, Nitrogenous BOD Decay and Settling Rates, Data Type 12 and 15

The reaeration rate equations, CBOD decay and settling rates, NBOD decay and settling rates, and the fractions converting settled CBOD and settled NBOD to SOD were not changed from the calibration.

4.2.7 Incremental Conditions, Data Types 16, 17, and 18

The incremental conditions were used in the calibration to represent nonpoint source loads associated with flows (groundwater). The incremental flow was assumed to be zero during projections.

4.2.8 Sediment Oxygen Demand, Nonpoint Sources, Headwaters, Wasteloads, Data Type 12, 19, 20, 21, 22, 24, 25, and 26

The NPS values were calculated for each projection scenario using a load equivalent spreadsheet. An analysis was made of the calibration NPS and SOD loads in terms of total loading in units of gm-O_2/m^2/day. The same spreadsheet also calculated load reductions for the headwaters and wasteloads. The values and sources of the input data and the load analyses are presented in Appendix D for each of the projection runs.

LDEQ has collected and measured the CBOD and NBOD oxygen demand loading components for a number of years. These loads have been found in all streams including the non-impacted reference streams. It is LDEQ’s opinion that much of this loading is attributable to run-off loads which are flushed into the stream during run-off events, and subsequently settle to the bottom in our slow moving streams. These benthic loads decay and breakdown during the year, becoming easily resuspended into the water column during the low flow/high temperature season. This season has historically been identified as the critical dissolved oxygen season.

LDEQ simulates part of the non-point source oxygen demand loading as resuspended benthic load and SOD. The calibrated non-point loads, UCBOD, UNBOD and SOD, are summed to produce the total calibrated benthic load. The total calibrated benthic load is then reduced by the total background benthic load (determined from LDEQ’s reference stream research) to determine the total manmade benthic loading. The manmade portion is then reduced incrementally on a percentage basis to determine the necessary percentage reduction of manmade loading required to meet the water body’s dissolved oxygen criteria. These reductions are applied uniformly to all reaches sharing similar hydrology and land uses.

Following the same protocol as the point source discharges, the total reduced manmade benthic load is adjusted for the margin of safety by dividing the value by one minus the margin of safety. This adjusted load is added back to the total background benthic value to obtain the total projection model benthic load. This total projection benthic load is then broken out into its components of SOD, resuspended CBOD and resuspended NBOD by multiplying the total projection benthic load by the ratio of each calibrated component to the total calibrated benthic load.

LDEQ has found variations in the breakdown of the individual CBOD and NBOD components. While the total BOD is reliable, the carbonaceous and nitrogenous component allocation is subject to the type of test method. In the past, LDEQ used a method which suppressed the nitrogenous component to obtain the carbonaceous component value, which was then subtracted from the total measured BOD to determine the nitrogenous value. The suppressant in this method was only reliable for twenty days thus leading to the assumption that the majority of the carbonaceous loading was depleted within that period of time. The test results supported this assumption. Recently the suppressant started failing around day seven and the manufacturer of the suppressant will only guarantee it's potency for a five day period. LDEQ felt a five day test would not adequately depict the water quality of streams and began a search for a new test method. The research found a new proposed method for testing long term BODs in Standard Methods.

This proposed method is a sixty day test which measures the incremental total BOD of the sample while at the same time measuring the increase in nitrite/nitrate in the sample. This increase in nitrite/nitrate allows LDEQ to calculate the incremental nitrogenous portion by multiplying the increase by 4.57 to determine the NBOD daily readings. These NBOD daily readings are then subtracted from the daily reading for total BOD to determine the CBOD daily values. A curve fit algorithm is then applied to the daily component readings to obtain the estimated ultimate values of each component as well as the decay rate and lag times of the first order equations.

LDEQ implemented the new test method beginning with the 2000 survey season. The results obtained using the new method showed that a portion of the CBOD first order equation does begin to level off prior to the twentieth day, however a secondary CBOD component begins to use dissolved oxygen sometime between day ten and day twenty-five. This secondary CBOD component was not being assessed as CBOD using the previous method but was being included in the NBOD load. Thus the CBOD and NBOD component loading used in the reference stream studies is not consistent with the results using the new proposed 60 day method and the individual values should not be used to determine background values for samples processed using the new test methods. However, the sum of CBOD and NBOD should be about the same for both new and old test methods. For this reason LDEQ decided to use the sum of reference stream benthic loads as background values.

The resuspended total nonpoint CBOD and NBOD loading was reduced by 100% of man-made and 30% of background loading for all reaches in the summer critical projection scenario to meet the summer water quality criterion for dissolved oxygen. Since LDEQ assumes these benthic loads are long-term loads brought to the stream by various sources throughout the year, the same percentage reductions were made in the winter projection model as were in the summer critical projection model. These reductions met the summer dissolved oxygen criteria and well surpassed requirements in the non-critical winter projection.

The reductions were determined using the calibrated values for nonpoint CBOD1, CBOD2, and NBOD. These values were summed by reach, as justified above and adjusted for the margin of safety. Each reach's total benthic nonpoint load was then reduced to meet the dissolved oxygen criteria in each reach. Using the ratios determined in calibration, this reduced total nonpoint load was then broken into its components of CBOD1, CBOD2, NBOD, and SOD. The percentage reduction within the mainstem was calculated based on the comparison of the reduced total nonpoint benthic load to the calibration total nonpoint benthic load. These calculations are shown in Appendix E. The value and sources of CBOD1, CBOD2, and NBOD for each projection run are presented in Appendix D.

4.2.12 Boundary Conditions, Data Type 27

The lower boundary conditions were set at the 90^{th} percentile critical season temperature, the dissolved oxygen criteria was set to the DO criteria for Bayou Pierre, and the measured stream UCBOD and UNBOD loads for all projections and scenarios.

4.3 Model Discussion and Results

The projection model input and output data sets are presented in Appendix D.

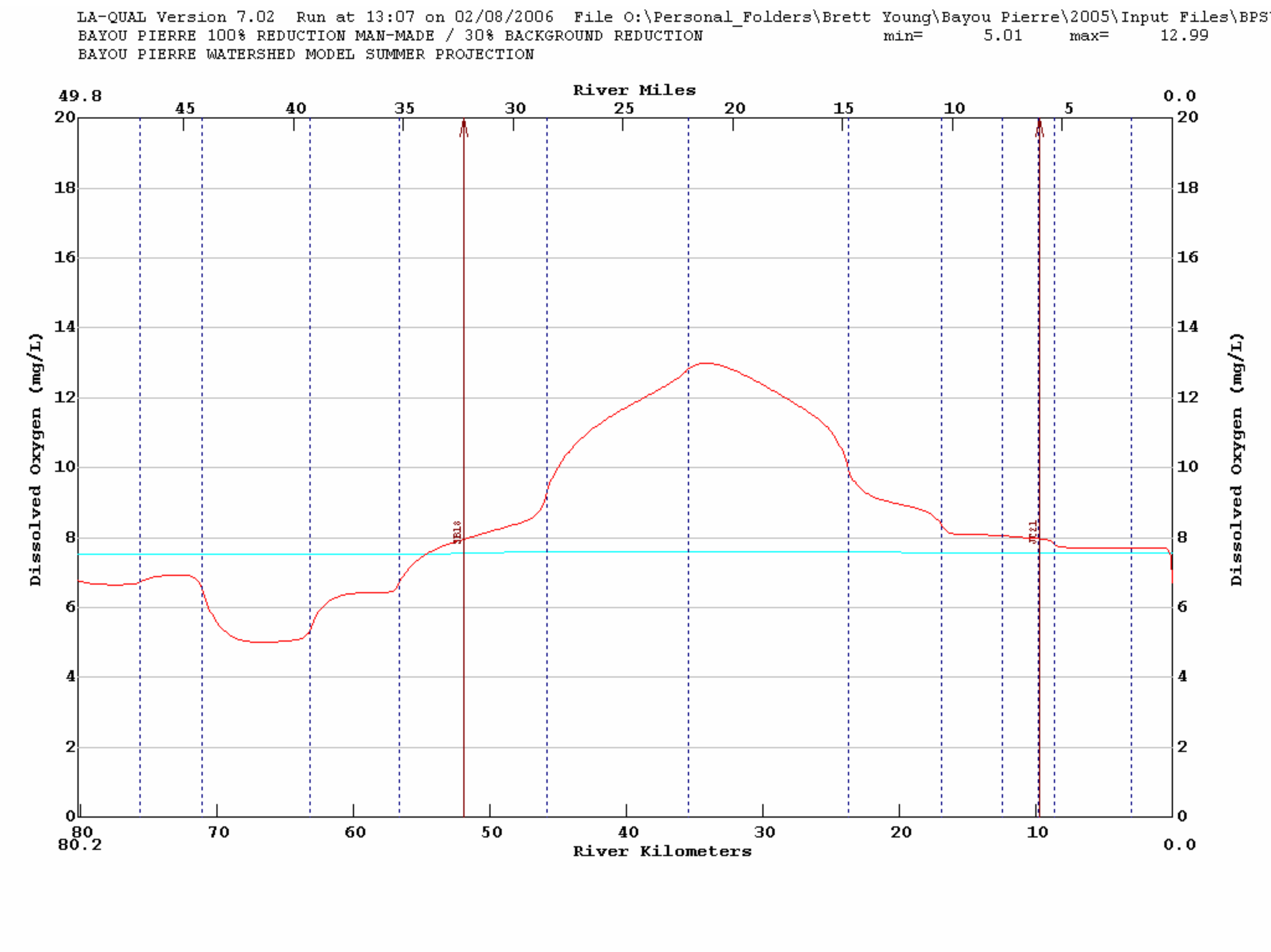
4.3.1 No Load Scenario

An individual no load scenario was run for this stream to identify more appropriate criteria. With 100% removal of manmade sources, the minimum DO was 3.66. Appropriate criteria should be set at 3.0 mg/l DO or less. It is recommended that a use attainability analysis be conducted on this waterbody.

4.3.2 Summer Projection

Summer critical season projections were run for the current standard of 5.0 mg/L May – November. In order to meet the standard, a 100% reduction of man-made and 30% reduction of background loading is necessary. With these percentage reductions in the benthic oxygen loads, Bayou Pierre meets the dissolved oxygen criterion. The minimum DO on the main stem is 5.01 mg/L. A graph of the dissolved oxygen concentration versus river kilometer for the summer projection is presented in Figure 4.

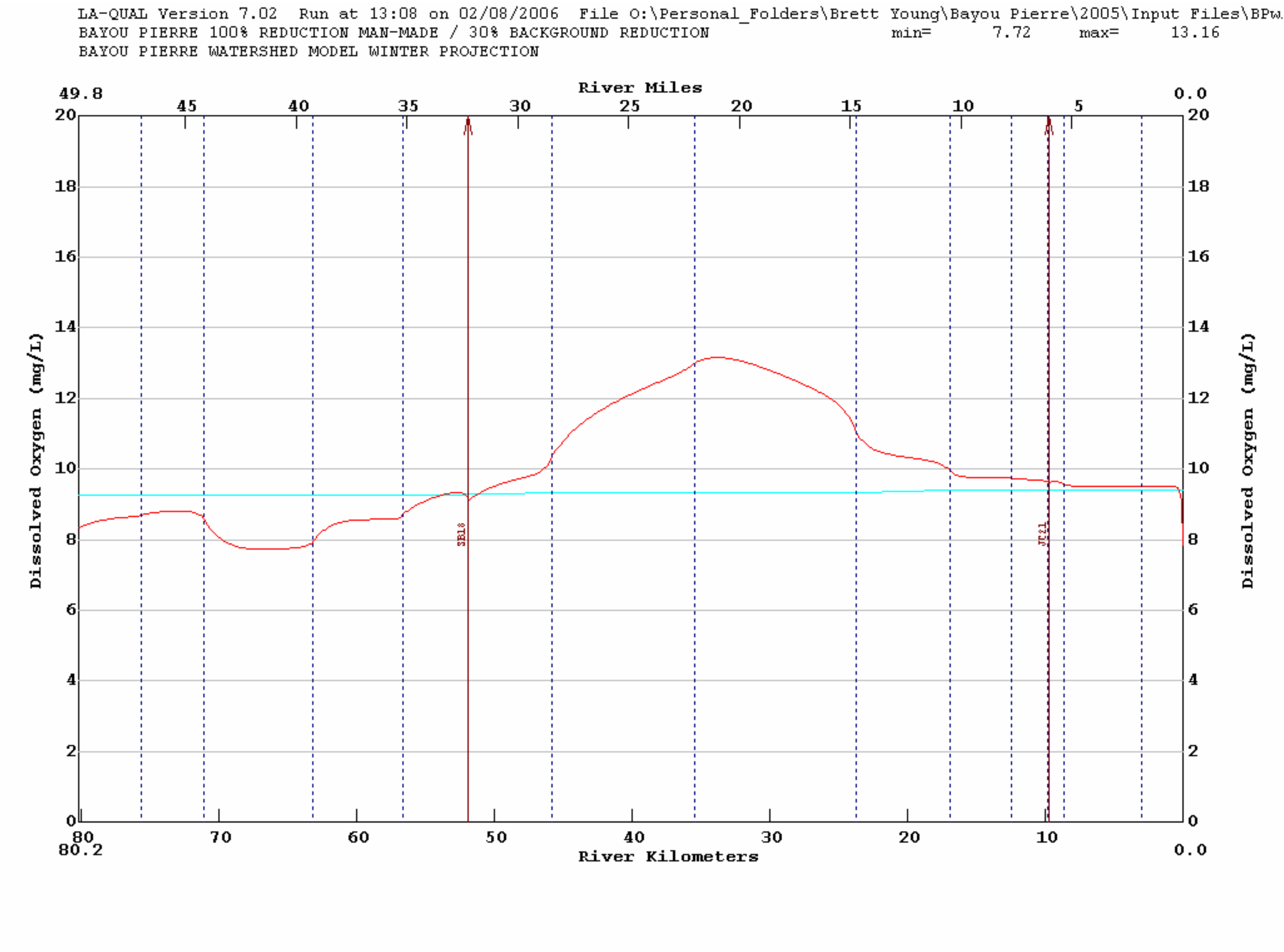
Figure 4. Summer Projection at 100% Removal of Man-Made NPS Loads



4.3.3 Winter Projection

The results of the model show that the water quality criterion for dissolved oxygen of Bayou Pierre of 5.0 mg/l can be maintained during the winter critical season. The minimum dissolved oxygen is 7.71 mg/l. To achieve the criterion, the model assumed a 100% reduction from all man-made nonpoint sources and a 30% reduction of background loading. A graph of the dissolved oxygen concentration versus river kilometer for the winter projection is presented in Figure 5.

Figure 5. Winter Projection at 100% Removal of Man-Made NPS Loads



4.4 Calculated TMDL, WLAs and Las

4.4.1 Outline of TMDL Calculations

An outline of the TMDL calculations is provided to assist in understanding the calculations in the Appendices. Slight variances may occur based on individual cases.

4.4.1.1 The natural backgrounds benthic loading was estimated from reference stream resuspension (nonpoint CBOD and NBOD), and SOD load data.

4.4.1.2 The calibration man-made benthic loading was determined as follows:

- Calibration resuspension and SOD loads were summed for each reach as gm O_2/m^2-day to get the calibration benthic loading.
- The natural background benthic loading was subtracted from the calibration benthic loading to obtain the man-made calibration benthic loading.

4.4.1.3 Projection benthic loads are determined by trail and error during the modeling process using a uniform percent reduction for resuspension and SOD. Point sources are reduced as necessary to subsequently more stringent levels of treatment consistent with the size of the treatment facility as much as possible. Point source design flows are increased to obtain an explicit MOS of 20%. Headwater and tributary concentrations of CBOD, NBOD and DO range from reference stream levels to calibration levels based on the character of the headwater. Where headwaters and tributaries exhibit man-made pollutant loads in excess of reference stream values, the loadings are reduced by the same uniform percent reduction as the benthic loads.

- The projection benthic loading at 20 °C is calculated as the sum of the projection resuspension and SOD components expressed as gm O_2/m^2-day.

- The natural background benthic load is subtracted from the projection benthic load to obtain the man-made projection benthic load for each reach.

- The percent reduction of man-made loads for each reach is determined from the difference between the projected man-made non-point load and the man-made non-point load found during calibration.

- The projection loads are also computed in units of lb/d and kg/d for each kind.

4.4.1.4 The total stream loading capacity at critical water temperature is calculated as the sum of:

- Headwater and tributary CBOD and NBOD loading in lb/d and kg/d.

- The natural and man-made projection benthic loading for all reaches of the stream is converted to the loading at critical temperature and summed in lb/d and kg/d.

- Point source CBOD and NBOD loading in lb/d and kg/d.

- The margin of safety in lb/d and kg/d.

4.4.2 Bayou Pierre, Subsegment 100606 TMDL

The TMDLs for the biochemical oxygen demanding constituents (CBOD, NBOD, and SOD), have been calculated for the summer and winter critical seasons. The TMDLs for the Bayou Pierre, Subsegment 100606 watershed were set equal to the total stream loading capacity. There is no MOS counted in this TMDL since there was a 100% reduction of man-made NPS. They are presented in Appendix A by reach. A summary of the loads is presented in Table 6.

Table 6. Total Maximum Daily Load (Sum of UCBOD, UNBOD, and SOD)

ALLOCATION	SUMMER		WINTER	
	% Reduction Required	(MAR-NOV) (lbs/day)	% Reduction Required	(DEC-FEB) (lbs/day)
Natural Nonpoint Source LA	30	8,198	30	7,312
Natural Nonpoint Source Reserve MOS (not used)		0		0
Manmade Nonpoint Source LA	100	0	100	0
Manmade Nonpoint Source Reserve MOS (20%)		0		0
TMDL		8,198		7,312

***Note1: UCBOD as stated in this allocation is Ultimate CBOD.
UCBOD to $CBOD_5$ ratio = 2.3 for all treatment levels
Permit allocations are generally based on $CBOD_5$***

5. Sensitivity Analysis

All modeling studies necessarily involve uncertainty and some degree of approximation. It is therefore of value to consider the sensitivity of the model output to changes in model coefficients, and in the hypothesized relationships among the parameters of the model. The LAQUAL model allows multiple parameters to be varied with a single run. The model adjusts each parameter up or down by the percentage given in the input set. The rest of the parameters listed in the sensitivity section are held at their original projection value. Thus the sensitivity of each parameter is reviewed separately. A sensitivity analysis was performed on the calibration. The sensitivity of the model's minimum DO projections to these parameters is presented in Appendix I. Parameters were varied by +/- 30%, except temperature, which was adjusted +/- 2 degrees Centigrade.

Values reported in Appendix I are percentage variations of minimum DO in the main stem Bayou Pierre. As shown in Table 6, stream reaeration, headwater DO, and benthal demand are the parameters to which DO is most sensitive. The model is moderately sensitive to velocity, headwater flow, baseflow, and initial temperature. The model is slightly sensitive to insensitive to the remaining parameters.

Table 7. Summary of Calibration Model Sensitivity Analysis

	Positive Changes in Parameter			Negative Changes in parameter		
Parameter	% change	Minimum DO (mg/l)	Percentage Difference	% change	Minimum DO (mg/l)	Percentage Difference
Stream Baseflow	30	4.27	6.1	-30	3.59	-10.8
Initial Chlorophyll a	30	4.10	1.8	-30	3.95	-1.8
Stream Velocity	30	4.22	5	-30	3.69	-8.2
Initial Temperature	2	3.51	-12.7	-2	4.44	10.3
BOD Decay Rate	30	3.97	-1.4	-30	4.09	1.5
BOD Settling Rate	30	4.03	0.2	-30	4.02	-0.2
NBOD Decay Rate	30	3.99	-0.7	-30	4.06	0.8
NBOD Settling Rate	30	4.03	0.1	-30	4.02	-0.1
Benthal Demand	30	3.17	-21.3	-30	4.65	15.6
Stream Dispersion	30	4.02	0	-30	4.02	0
Stream Reaeration	30	4.58	13.9	-30	2.95	-26.7
Headwater Flow	30	4.27	6.1	-30	3.65	-9.3
Headwater DO	30	4.16	3.3	-30	3.26	-18.9
Headwater BOD	30	3.99	-0.9	-30	4.06	0.9
Headwater NBOD	30	4.01	-0.4	-30	4.04	0.4
Stream Depth	30	3.88	-3.5	-30	4.22	4.8
Incremental Inflow	30	4.04	0.4	-30	4.00	-0.5
Incremental Outflow	30	4.01	-0.3	-30	4.03	0.3
Incremental Temperature	2	4.02	0	-30	4.02	0
Incremental DO	30	4.05	0.7	-30	4.00	-0.7
Incremental BOD	30	4.02	0	-30	4.02	0
Incremental NBOD	30	4.02	0	-30	4.02	0
Wasteload Flow	30	4.02	0	-30	4.02	0
Wasteload Temperature	30	4.02	0	-30	4.02	0
Wasteload DO	30	4.02	0	-30	4.02	0
Wasteload BOD	30	4.02	0	-30	4.02	0
Wasteload NBOD	30	4.02	0	-30	4.02	0
Lower Boundary Temperature	30	4.02	0	-30	4.02	0
Lower Boundary DO	30	4.02	0	-30	4.02	0
Lower Boundary BOD	30	4.02	0	-30	4.02	0
Lower Boundary NBOD	30	4.02	0	-30	4.02	0

6. Conclusions

This TMDL establishes load limitations for oxygen-demanding substances and nutrients and goals for reduction of those pollutants. LDEQ's position, as supported by the declaratory ruling issued by Secretary Givens in response to the lawsuit regarding water quality criteria for nutrients (Sierra Club v. Givens, 710 So.2d 249 (La. App. 1st Cir. 1997), writ denied, 705 So.2d 1106 (La. 1998), is that when oxygen-demanding substances are controlled and limited in order to ensure that the dissolved oxygen criterion is supported, nutrients are also controlled and limited. The implementation of this TMDL through wastewater discharge permits and implementation of best management practices to control and reduce runoff of soil and oxygen-demanding pollutants from nonpoint sources in the watershed will also control and reduce the nutrient loading from those sources.

A calibrated water quality model for the watershed was developed and projections were modeled to quantify the non-point source load reductions which would be necessary in order for Bayou Pierre, subsegment 100606 to comply with its established water quality standards and criteria. This report presents the results of that analysis.

The modeling, which has been conducted for this TMDL, is conservative and based on limited information. The TMDL requires a watershed-wide 100% decrease in man-made nonpoint sources and 30% reduction of background loads in order to meet the DO criterion of 5.0 mg/L in the summer critical season. A use-attainability analysis is needed for this stream.

LDEQ has developed this TMDL to be consistent with the state antidegradation policy (LAC 33:IX.1109.A).

LDEQ will work with other agencies such as local Soil Conservation Districts to implement agricultural best management practices in the watershed through the 319 programs. LDEQ will also continue to monitor the waters to determine whether standards are being attained.

In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring 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 is used to develop the state's biennial 305(b) report (*Water Quality Inventory*) and the 303(d) list of impaired waters. This information is also utilized in establishing priorities for the LDEQ nonpoint source program.

The LDEQ is continuing to implement a watershed approach to surface water quality monitoring. In 2004 a four year sampling cycle replaces the previous five year cycle. Approximately one quarter of the states watersheds will be sampled each year so that all of the state's watersheds will be sampled within the four year cycle. This will allow LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list.

7. References

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8. Appendices