BAYOU QUEUE DE TORTUE WATERSHED TMDL FOR DISSOLVED OXYGEN AND NUTRIENTS INCLUDING A POINT SOURCE WASTELOAD ALLOCATION FOR THE CITY OF DUSON STP AND A WATERSHED NONPOINT SOURCE LOAD ALLOCATION

SUBSEGMENT 0505

VOLUME I

TMDL Report

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Bayou Queue de Tortue Watershed TMDL
Subsegment 0505
W.C. Berger, Jr.
Originated: January 10, 2000

EXECUTIVE SUMMARY

A TMDL for dissolved oxygen has been developed for the Bayou Queue de Tortue Watershed based on hydrologic and water quality data available as of November, 1999. Bayou Queue de Tortue was listed on both the 1996 and 1998 Section 303(d) Lists as not meeting the water quality standard for dissolved oxygen. Bayou Queue de Tortue was ranked as high priority (priority 1) on both lists for development of a total maximum daily load (TMDL) determination.

This waterbody was also listed as impaired due to nutrients. This TMDL establishes load limitations for oxygen-demanding substances and goals for reduction of those pollutants. LDEQ's position, as supported by the ruling in 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.

The Bayou Queue de Tortue watershed is segment 0505 of the Mermentau River Basin (Basin 5). Subsegment 0505 is comprised of Bayou Queue de Tortue and all tributaries, including Indian Bayou, Prime Gully, Coulee des Iles/Grand Marais Bayou, Lyon's Point Gully, Lazy Point Canal and numerous unnamed tributaries.

Bayou Queue de Tortue has been heavily hydromodified in all reaches except the upper (above LA Hwy. 35) and lower (below LA Hwy. 91) reaches. The bayou and its tributaries are dominated by rice and soybean propagation. Both of these conditions have inhibited the bayous natural process, including reaeration and fish propagation (Smythe and Malone, 1989a-a, 1990).

A use attainability analysis (UAA) was implemented for the Mermentau Basin in 1998. The UAA set the dissolved oxygen standards to 3 mg/L for the summer season (March – November) and 5.0 mg/L for the winter season (December – February) (LA DEQ, 1998). It is projected that compliance with dissolved oxygen criteria will require a 60 percent reduction of man-made nonpoint loading in the watershed and limitations for the City of Duson STP discharge as follows:

		Permit limitations	Projected limits (BOD_5/NH_3-N/DO)	
Facility	Flow (MGD)	(mg/L) BOD_5/TSS	Summer	Winter
City of Duson STP	0.190	10/15	10/5/6	30/15/5

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There are 30 known dischargers in subsegment 0505, the majority of which are too small to have a significant impact on the watershed model. Limits for these small facilities are generally set by state policy. Only two known dischargers had a design capacity that would impact their receiving waterbody. The City of Duson STP was included in the model. The Village of Morse STP was not included in the model because it has an intermittent discharge and it was not discharging at the time of the survey. The facility itself consists of an overland flow system with sprayers and chlorinators. Apparently, they do not need to be turned on for long periods during the summer. Whenever the sprayers are turned on, the ground soaks up most of the water or it is collected and recirculated.

Bayou Queue de Tortue was modeled from its headwaters (River Kilometer 74.00) to its confluence with the Mermentau River (River Kilometer 0.00). The survey was conducted during a period of very dry weather. The Bayou Queue de Tortue watershed was in a condition of low flow. There were no tributaries that had a velocity that could be measured with typical survey equipment. Consequently, none of the tributaries were included in the model. Any gain or loss in flow between survey sites was treated as nonpoint flow. Both point and nonpoint source loads were represented in the model. The nonpoint source loads included headwater loading, nonpoint loading associated with flow, benthic sediment oxygen demand and resuspension, and other nonpoint loading not associated with flow, such as resuspension.

The various spreadsheets that were used in conjunction with the modeling program may be found in the appendices in the order in which they were used. The flow calibration was based on measurements taken during the intensive survey of Bayou Queue de Tortue near Duson (October 7-14, 1991), the low flow watershed survey (May 24-26, 1999), and on flows at USGS stations 08012285 and 08012300 corresponding to the low flow watershed survey. Water quality calibration was also based on measurements taken during these surveys. Projections were adjusted to meet the dissolved oxygen criteria by reducing both point source and nonpoint source loads to obtain wasteload (WLA) and load allocations (LA). Additional summer and winter projections were simulated. A summer projection was run with increased nonpoint source loads. This run violated the summer D.O. criteria. Summer and winter runs that contained no nonpoint loading were run. These runs did not violate summer or winter criteria.

Land use in the Bayou Queue de Tortue watershed is fairly homogeneous. It is 86.5 percent agriculture, principally rice and soybean farming. TMDLs have therefore been calculated for the entire watershed and are presented in the following table. Due to the many assumptions made while developing the model, the inherent error within the model algorithms, and the scale of a watershed-based model, the results of the model should be used only as an aid in making water quality based decisions.

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	Summer season (Mar – Nov)		Winter season (Dec – Feb)	
Point source allocations (WLA)	Load (lbs./day)	% of TMDL	Load (lbs./day)	% of TMDL
Total point source allocations (WLA)	79.8	0.16	239.5	0.63
Point source margin of safety (MOS)	20.0	0.04	59.9	0.16
Headwater/Tributary Loads	4.5	0.009	45.0	0.12
Benthic Loads	48,339.9	99.8	37,857.3	99.10
Reduction of man-made nonpoint	60 %		60 %	
Nonpoint source margin of safety (MOS)	0 %		0 %	
Total maximum daily load (TMDL)	48,444	100.0	38,202	100.0

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1. Introduction

Bayou Queue de Tortue, Segment 0505 of the Mermentau Basin, is listed on the 1998 303(d) list as being impaired due to organic enrichment/low DO and requiring the development of a total maximum daily load (TMDL) for dissolved oxygen. A calibrated water quality model for the Bayou Queue de Tortue Brule watershed was developed and projections were run to quantify the point source wasteload allocations (WLAs) and nonpoint source load allocations (LAs) required to meet established dissolved oxygen criteria. This report presents the model development and results.

This waterbody was also listed as impaired due to nutrients. This TMDL establishes load limitations for oxygen-demanding substances and goals for reduction of those pollutants. LDEQ's position, as supported by the ruling in 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.

Examination of multiple sets of survey data and the historical water quality data from the LA DEQ Ambient Water Quality Site on Bayou Queue de Tortue north of Geuydan, LA indicated that the bayou is not showing the negative impacts of nutrients. The pH values[1] were within the typical standard range of 6 to 9. The continuous monitor data[1] showed no diurnal swings[2] for dissolved oxygen or pH, which would have indicated algal production due to excessive nutrient loading (Smythe, 2000).

However, in order for the excessive nutrient loading to cause algal production, the nutrients, nitrogen and phosphorus, must be present in the proper relative amounts. This relative amount is referred to as the ratio of total nitrogen to total phosphorus.

A high nitrogen to phosphorus ratio may indicate that phosphorus is the limiting nutrient. This situation occurs in natural freshwater lakes and streams that do not receive municipal and industrial wastewater discharges, which typically contain phosphorus. As the amount of municipal and industrial wastewater discharges increase, the phosphorus concentration in the receiving waterbody generally increases, lowering the ratio. This

[1] Generally, when algae production is significant, CO_2 is stripped from the water column, driving the pH up. This causes a distinct diurnal (sine) curve in which the pH is up in the late afternoon hours and down in the late morning hours (Smythe, 2000).

[2] In the presence of algal production, graph profiles for both dissolved oxygen and pH will show distinct diurnal (sine) curves (Smythe, 2000).

process may cause an algal bloom. However, the amount of phosphorus in a waterbody tends to accumulate because organic phosphorus is sorbed onto clay particles, making it unavailable to algae. The phosphorus recycles very slowly back into the water column. In these types of waterbodies, algae is controlled by controlling the amount of phosphorus in the waterbody (Jarrell, 1999), (Smythe, 2000), (Tchobanoglous, 1985).

A low nitrogen to phosphorus ratio may indicate that nitrogen is the limiting nutrient. This situation is known to occur in streams that receive agricultural runoff and estuaries. (Jarrell, 1999), (Smythe, 2000).

1.1 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 Queue de Tortue TMDL, LDEQ has employed an analysis of its long-term ambient data to determine critical seasonal conditions and used a combination of implied and explicit margins of safety.

Critical conditions for dissolved oxygen were determined for the Mermentau Basin using long-term water quality data from six stations on the LDEQ Ambient Monitoring Network and the Louisiana Office of State Climatology water budget. Graphical and regression techniques were used to evaluate the temperature and dissolved oxygen data from the Ambient Network and the run-off determined from the water budget. Since nonpoint loading is conveyed by run-off, this seemed 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. (Grymes, 1999)

When the rainfall run-off (and nonpoint 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 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.

LDEQ interprets this phenomenon in its TMDL modeling by assuming that the annual nonpoint loading, rather than loading for any particular day, is responsible for the accumulated benthic blanket of the stream, which is, in turn, expressed as SOD and/or resuspended BOD in the model. This accumulated loading has its greatest impact on the stream during periods of higher temperature and lower flow.

LDEQ simulated critical summer conditions in the Bayou Queue de Tortue dissolved oxygen TMDL projection modeling by using the annual 7Q10 flow or 0.1 cfs, whichever is higher, for all headwaters, and 90th percentile temperature for the summer season. Incremental flow was assumed to be zero; model loading was from point sources, perennial tributaries, sediment oxygen demand, and resuspension of sediments. LDEQ simulated critical winter conditions by using the lowest of the monthly 7Q10 flow published for the winter months or 1 cfs, whichever was higher, for all headwaters, and 90th percentile temperature for the season. Again, incremental flow was assumed to be zero; model loading was from point sources, perennial tributaries, sediment oxygen demand, and resuspension of sediments. In addition, LDEQ assumes that all point sources are discharging at maximum capacity.

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 combination of these conditions plus the impact of other conservative assumptions regarding rates and loadings yields an implied margin of safety, which is estimated to be in excess of 10%. Over and above this implied margin of safety, LDEQ typically uses an explicit MOS of 20% for point source loads. Based upon available landuse data, 86.5 percent of the land is used for agriculture and the Bayou Queue de Tortue watershed has minimal land available for further agricultural development. Also, nonpoint source loads had to be reduced in order to project to the seasonal criteria. Therefore, no explicit margin of safety for nonpoint source loading was included in the summer and winter projections.

2. Study Area Description

2.1 Mermentau River Basin

The Mermentau River Basin is located in southwestern Louisiana, and it encompasses the prairie region of the state and a section of the coastal zone. The Mermentau River Basin is bounded on the north and east by the Vermilion-Teche River Basin, on the west by the Calcasieu River Basin, and on the south by the Gulf of Mexico. The Mermentau River Basin is approximately 3,710 square miles in area, excluding the gulf waters segment (LA DEQ, 1996).

The slope of the land toward the Gulf is very gradual, and as a result, the streams in the Mermentau Basin are characteristically sluggish. Fish kills have been commonly reported throughout the basin. Because waterbodies in the basin have little gradient and sluggish flows, their reaeration potential is low (LA DEQ, 1990).

Prior studies have shown that the water quality problems in the basin are largely due to agricultural runoff and hydrologic modification (Smythe and Malone, 1989-f, 1990). During April and May, large volumes of very turbid water have been observed flowing downstream in these waterbodies, and this has been associated with planting activities in adjacent rice fields (LA DEQ, 1990).

2.2 Bayou Queue de Tortue Watershed, Segment 0505

This area is typical of the basin with its low relief, which is an ideal condition for agricultural use as documented in Table 1 (LADEQ, 1999). Segment 0505 is comprised of Bayou Queue de Tortue as the main stem with several tributaries. These tributaries include Indian Bayou, Prime Gully, Coulee des Iles/Bayou Grand Marais, Lyon's Point Gully, Lazy Point Canal, and many unnamed tributaries.

Average annual precipitation in the segment, based on the nearest Louisiana Climatic Station in Crowley is 56.91 inches based on a 30-year record (LSU, 1999). Land use in the Mermentau River Basin is largely agricultural, the primary crops being rice and soybeans. Originally, this area was covered by tall prairie grasses, among which there were scattered clumps of trees. (Soil Survey, 1962). In the segment under study, agricultural uses account for 86.5 percent of the total segment area. Land uses in Segment 0505 are shown in Table 1 below (LA DEQ, 1999).

Table 1. Land uses in Segment 0505 of the Mermentau River Basin

Land use	Acres	%
Urban	7,051	3.6
Rangeland	490	0.3
Agricultural	168,853	86.5
Forest Land	2,820	1.4
Water	4,110.0	2.1
Wetland	11,849	6.1
Barren Land	47	0.0

In order to irrigate the ricefields, Bayou Queue de Tortue has been periodically dredged. This procedure has been occurring for many years. It has altered the route and flow of the bayou. The procedure has reduced the bayou's abilities to perform natural processes, such as reaeration (Smythe and Malone, 1989a-f, 1990).

2.3 Water Quality Standards

Water quality standards for the State of Louisiana have been defined (LA DEQ, 1999). The standards are defined according to designated uses of the waterbodies. Both general narrative standards and numerical criteria have been defined. General standards include prevention of objectionable color, taste and odor, solids, toxics, oil and grease, foam, and nutrient conditions as well as aesthetic degradation. The numerical criteria are shown in Table 2.

Designated uses for Bayou Queue de Tortue from its headwaters to the Mermentau River (waterbody subsegment 050501) include primary contact recreation, secondary contact recreation, propagation of fish and wildlife, and agriculture.

Bayou Queue de Tortue is listed on the 1998 303(d) list as a waterbody requiring a dissolved oxygen TMDL. Section 303(d) of the Clean Water Act requires the identification, listing, ranking and development of TMDLs for waters that do not meet applicable water quality standards after implementation of technology-based controls. Current dissolved oxygen criteria are shown in Table 3. Waterbodies are placed on the 303(d) list based on the comparison of data from ambient monthly samples and the criteria. Due to diurnal variations in dissolved oxygen, the time in which the assessment samples were taken was an important factor. Algae and macrophytes that produce dissolved oxygen in the water column in the presence of sunlight (photosynthesis) and utilize dissolved oxygen in the absence of sunlight (respiration) cause diurnal variations in dissolved oxygen. This process can cause the dissolved oxygen levels of the water to be depressed during the early morning hours and elevated during the evening hours. Either extreme is not representative of the stream. It is uncertain if the samples that were used to assess Bayou Queue de Tortue and place it on the 303(d) waterbody list were representative of the stream or the diurnal effects of algae and macrophytes. Instead of individual samples, time-weighted averages based on a 24-hour time period may be a better representation of the stream.

Table 2. Current Numerical Criteria for Bayou Queue de Tortue (LA DEQ, 1999)

Parameter	Criteria
Cl, mg/L	90
SO_4, mg/L	30
pH	6.0-8.5
BAC, # col./100 mL	200 (5/1-10/31) and 1,000 (11/1-4/30)
Temperature, deg Celsius	32
TDS, m8g/L	260

Table 3. Current Dissolved Oxygen Criteria, (mg/L) (LA DEQ, 1999)

March-November (Summer)	3.0
December-February (February)	5.0

2.4 Discharger Inventory

The Bayou Queue de Tortue watershed includes approximately 30 known dischargers, according to LA DEQ's permit tracking system. Most of the facilities have effluent flows less than 50,000 gallons per day. LA DEQ has several state policies that govern permit limits for these and other facilities with discharges less than 50,000 gallons per day. Many of the facilities in the watershed are package plants used to treat wastewater from trailer parks and subdivisions that are located in the headwater regions of the tributaries. Due to the small loads and their distances from the main waterbody, it is unlikely that they are having an impact on the waterbody named in the 303(d) list. Most of these facilities need not be included in a model of this scale.

If the receiving tributary was included in the model by modeling the stream, these dischargers are accounted for as nonpoint loading, through the process of calibration. The impact of the facility could also be represented in the model by including the tributary as a point source discharge to the main waterbody. However, no tributaries were flowing at the time of the watershed survey. Therefore the tributaries and any facilities discharging into them were not included in the watershed model.

Current permit information and discharge monitoring reports were reviewed for all of these facilities. Based upon available effluent discharge information, two facilities were considered to have the potential to impact Bayou Queue de Tortue. However, only one of these facilities was included in the watershed model. The permit numbers for both of these facilities are shown in Table 4.

Table 4. List of Facilities

Facility Name	Permit Number
City of Duson STP	LA0055085
Village of Morse STP	LA0064572

2.4.1 City of Duson STP

This facility treats municipal wastewater with an aerated lagoon with final clarifier, chlorine contact chamber, and sludge return. It has a design flow of 0.190 MGD (1.24 cfs, 0.035 cms). The average monthly permit limits are as follows are shown in Table 5. Discharge Monitoring Reports (DMRs) for the City of Duson STP show that the facility rarely exceeds its permit limits in quality or quantity.

Table 5. Permit Limits for the City of Duson STP

Parameter	Permit Limit
FLOW	0.190 MGD
$CBOD_5$	10.0 mg/L
TSS	15.0 mg/L

2.4.2 Village of Morse STP

This facility utilizes an overland flow system. The system includes an aerated sludge pond, a storage pond, sprayers, 5.1 acres of sewer-irrigated fields, and a chlorine contact chamber with gas chlorinators.

According to facility personnel the drought discharge is approximately 30,000 gal/day. The normal discharge is approximately 88,000 gal/day. The discharge associated with a heavy rainfall is approximately 110,000 gal/day. The facility may not discharge into state waters for several days at a time.

During much of the summer season, the wastewater is sprayed on the fields, collected in a storage pond, and stored until the water reaches a predetermined elevation. At that point, the pumps automatically discharge the water into the bayou. Therefore, the facility has an intermittent discharge, which is received by an unnamed canal, Lazy Point Canal, and then Bayou Queue de Tortue (Richard, 1999).

Monthly Discharge Monitoring Reports for 1998 indicated discharges as high as 120,000 gallons per day and the permit application showed the average discharge to be approximately 100,000 gallons per day. Monthly permit limits for both BOD_5 and TSS are 20.0 mg/L. The monthly permit limit for total residual chlorine is 0.8 mg/L. At the time of the survey, the sprayers were not turned on and the facility was not discharging. The wastewater was being held in the storage pond. Therefore, the facility was not included in the calibrated model.

As previously stated, the receiving stream was not flowing at the time of the survey. Since both the facility and the receiving stream could not be included in the calibration model, justifiable summer and winter WLAs can not be obtained by including them in the projection runs. Therefore a wasteload allocation was not determined for the Village of Morse STP. However, this does not mean that the WLA for the Village of Morse has been determined to be 0.0 lbs./day.

2.5 Previous Studies and Other Data

The majority of the data used for this project was obtained during a watershed survey conducted on May 24-26, 1999. Additional cross-sections were obtained during a following survey conducted on June 22, 1999. Additional data was obtained from an intensive survey of Bayou Queue de Tortue near Duson conducted October 7-14, 1991 (Pilione, 1993), and an intensive Survey of Bayou Queue de Tortue South of Crowley conducted March 30 – April 3, 1992 (Pilione, 1992). Calibrated models followed both of these surveys. Headwater loads, facility loads, and kinetic rates from these models were used in the appropriate reaches of the watershed model (Smythe, 1992).

Data from a survey of Bayou Blanc near Rayne, LA, was also incorporated into the model (Pilione, 1994). This was justifiable since both the Bayou Blanc and Bayou Queue de Tortue watersheds are dominated by rice production. The data consisted of headwater concentrations, which were considered to be representative of the incremental concentrations that would be present in ricefield areas.

Discharge data, cross-section data, field data, and lab water quality data from the watershed survey are presented in Appendix A. The BOD_U plots are in Appendix C. Additional survey data from previous surveys are also presented in Appendix A.

3. Model Documentation

3.1 Program Description

The model used for this TMDL was LA-QUAL, a steady-state one-dimensional water quality model. Its 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 the 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 though out 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.

3.2 Model Schematic and Description

The Bayou Queue de Tortue watershed was modeled according to the vector diagram on the following page. The modeled portion of Bayou Queue de Tortue extended from river kilometer (RKM 74.00 to RKM 0.0. Everything above RKM 74.00 was input as headwaters. River kilometer 0.0 is located at the confluence of Bayou Queue de Tortue and the Mermentau River. One permitted discharger was specifically included in the system.

All tributaries to Bayou Queue de Tortue, which were believed to be perennial, are indicated on the vector diagram. At the time of the watershed survey, all of these tributaries contained water but were not flowing. Therefore, they were not simulated as point source inputs.

3.3 Calibration and Projection

The various spreadsheets that were used in conjunction with the modeling program may be found in the appendices in the order in which they were used and are described below.

The flow calibration was based on headwater and facility measurements obtained from the "Total Maximum Daily Load and Calibrated Wasteload Allocation Model and Report: City of Duson" and stream flow measurements taken during the watershed survey conducted on May 24-26, 1999 (Smythe, 1992). Water quality calibration data was also obtained from the previous models and the watershed survey.

Although none of the tributaries had a flow that could be detected by LA DEQ equipment, Bayou Queue de Tortue did gain flow throughout 15 of the 17 reaches during the watershed survey. Two reaches showed a loss of flow.

Water quality values for $CBOD_U$, $NBOD_U$ and dissolved oxygen had to be associated with these inflows and outflows. Bayou Blanc was the only waterbody within the watershed that had similar geography and land uses as the Bayou Queue de Tortue watershed while containing data for all three parameters. Therefore, water quality data from the survey of Bayou Blanc near Rayne was used to represent the incremental water quality data in the watershed model.

"No Load" models were developed to simulate summer and winter scenarios void of all man-made loads. This was developed in order to demonstrate that the bayou meets or violates the dissolved oxygen criteria under natural conditions.

Projections were adjusted to meet the dissolved oxygen criteria by reducing both point source and nonpoint source loading to obtain wasteload and load allocations. Spreadsheets were developed in order to aid in the calculation of nonpoint and incremental load reductions.

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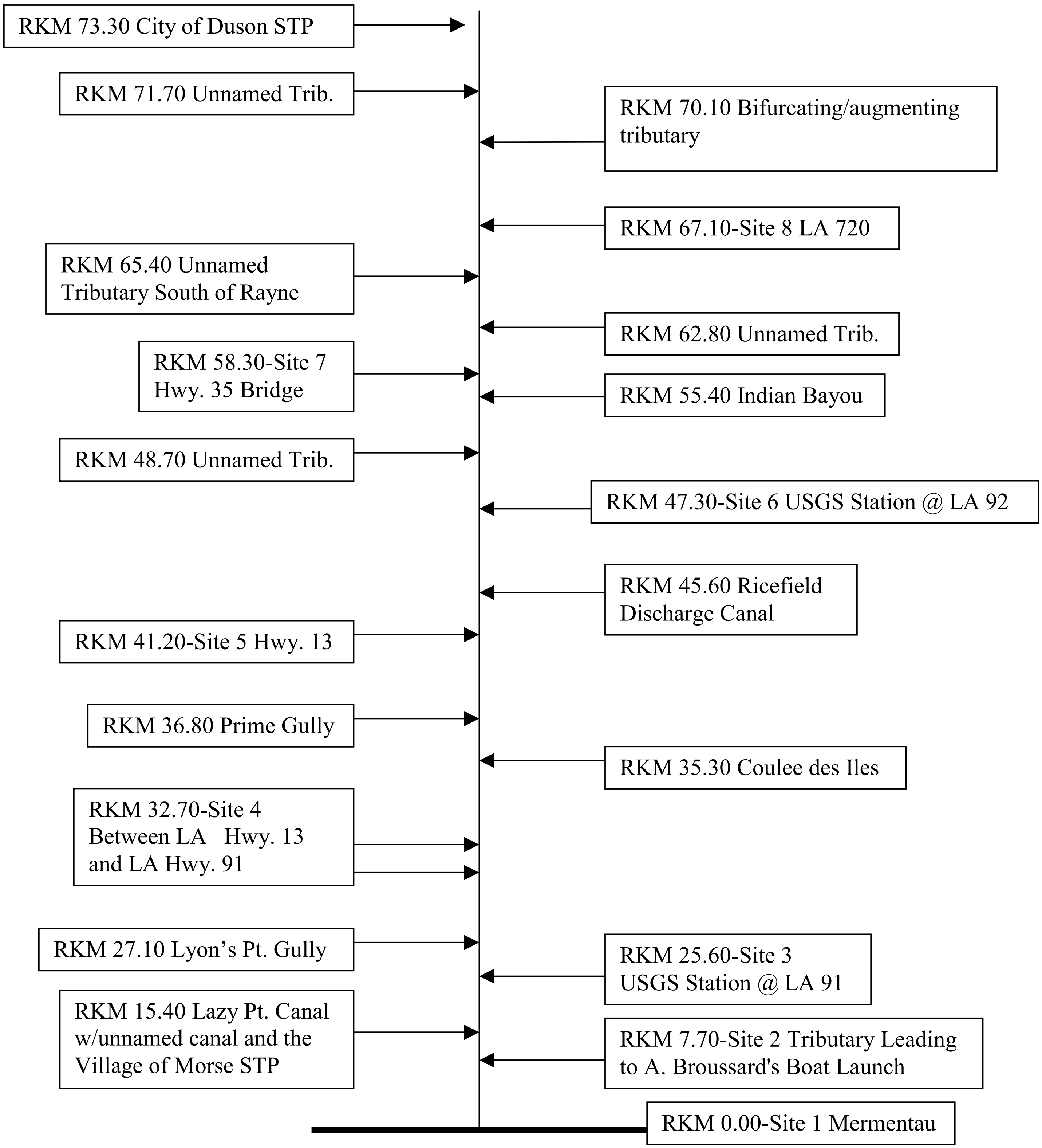

Figure 1. Vector Diagram of the Bayou Queue de Tortue Watershed

3.3.1 Flow Calibration

The vector diagram is presented in Figure 1 and Appendix A. The spreadsheets in items 2 through 5 are presented in Appendix C in the order in which they are explained.

1. Vector Diagram

   The vector diagram shows the main stem of Bayou Queue de Tortue, the major tributaries, and significant dischargers.

   The length of the bayou had to be measured in order to set up the model reaches and elements. The lower reaches of Bayou Queue de Tortue have many meanders and cutoffs, which form oxbows. The route of the majority of the flow had to be determined. Calculations were made to determine if the dominant route of the stream flow passed through the meander channel or the cutoff channel. These calculations involved determining the ratio of the flow in the cutoff to the flow in the oxbow. The flows were estimated using Manning's Equation, the length of the section of cutoff or oxbow, and a cross-sectional area from the location or a representative location.

2. Reach and Element Layout for Bayou Queue de Tortue LA-QUAL Model

   This spreadsheet lists the descriptions and details of every reach. The details include river kilometers, reach length, element sizes, and the number of elements in every reach.

3. Bayou Queue de Tortue Flow Calibration

   The spreadsheet was used to perform a preliminary flow calibration for the model using upstream, tributary, and point source flows. Distributed flow was varied to obtain calibration. A characteristic flow was calculated for each reach. These characteristic flows were used to calculate widths and depth parameters in the spreadsheet explained in item 5. The incremental flow (cms) is simply the distributed flow (cms/kilometer) times the reach length (kilometer).

4. Bayou Queue de Tortue Stream Geometry

   The various cross-sectional data used for the hydrologic calibration of the model is listed in the spreadsheet. Cross-sections were grouped based upon location within individual reaches. In cases where there were multiple values, the spreadsheet calculates the average for the reach. Otherwise, the single value was used.

5. Reaches and Elements

   The spreadsheet lists the model reaches that were selected, and details the layout of elements.

   The spreadsheet referenced some values from other spreadsheets. The columns containing widths and depths were filled in based upon the average values from item 4. The characteristic flow was obtained from item 3. The Leopold equation exponents suggested by Leopold for "ephemeral" and "158 streams" were used without change. These values were the basis for the constants used in the modified Leopold equations in item 5.

An assumption was made that the cross-sectional geometry for reaches 1 through 6 of Bayou Queue de Tortue varied slightly with flow while reaches 7 through 17 did not change much. This assumption was based on the fact that the upper reaches had small, defined channels with measurable velocities at low flow conditions, while the lower reaches had larger channels with flows that were not measurable with LA DEQ survey equipment due to low velocities. The lower reaches also stretched out into forests and swamps.

Therefore, the width and depth constants were set at 75 percent of the average value for reaches 1 through 6 and the coefficients were determined by calibration.

In reaches 7 through 17, the width and depth constants were assumed to be 95 percent of the average value for each individual reach. Modified versions of the Leopold equations for width and depth were used to calculate the coefficients for reaches 7 through 17 based upon the characteristic flow.

At this point, the input file was created and the model was run. The model output confirmed the preliminary flow calibration and plots of flow, velocity, width, and depth versus river kilometer were printed. Plots of conservative water quality constituents, Cl and SO_4, were also created. The measured flows, velocities, chloride concentrations, and sulfate concentrations were overlaid on their respective simulated plots to demonstrate calibration. The plots are presented in Appendix C along with the complete calibration output file and additional water quality plots.

3.3.2 Water quality calibration

The basic premise governing water quality calibration and projection is that the dominant oxygen demanding load in the watershed at low flow is from an accumulation of benthic material washed into the streams during periods of higher flow. This load is exerted as sediment oxygen demand and as resuspension of material from the bottom. This phenomenon was detailed in two other steady-state models on Bayou Queue de Tortue. One model was at high flow conditions (Smythe, 1991) and the other model was at low flow conditions (Smythe, 1991b). The LA-QUAL model can accommodate both a baseline SOD and a steady state SOD from the settling of CBOD and NBOD. It is suspected that in most of the Mermentau Basin, the accumulation of benthic material is considerable and that the settling of BOD at low flow as simulated by the model does not significantly alter the sediment oxygen demand. SOD was therefore not tied to settling in the execution of this model.

Bayou Queue de Tortue Watershed TMDL
Subsegment 0505
W.C. Berger, Jr.
Originated: January 10, 2000

Except where indicated, the following spreadsheets, reports, and plots are presented in Appendix D in the order in which they are explained.

1. $CBOD_U$, $NBOD_U$, and Dissolved Oxygen Loads, Bayou Queue de Tortue Watershed Calibration Model
   The point source loads, incremental flows and concentrations, and nonpoint loads are listed by reach.

2. BOD_U plots
   All BODU plots from the watershed survey are presented in Appendix A, along with the survey data. It appears that the nitrification suppressant failed in the running of suppressed BOD for samples taken at site 5.

3. Model Output File
   The model output file is presented. It includes all input values.

4. Model Output Plots
   The model output plots are presented. They include plots for flow, width, depth, velocity, chloride concentrations, sulfate concentrations, dissolved oxygen concentrations, CBODU concentrations, NBODU concentrations, sediment oxygen demand (SOD), reaeration, and dispersion. In addition, the dissolved oxygen plot can be seen in Figure 2.

5. Bayou Queue de Tortue Water Quality Calibration Model Input Description
   These spreadsheets present all the data that were used in the calibration model. They also provide the source of the data or justifications for their usage. Some of the data included are:

   a. Advective dispersion
      LA-QUAL uses the equation $D_L = 18.53nuh^{5/6}$ for advective dispersion, where n is Manning's "n", u is the velocity in m/s, and h is the depth in meters.

   b. Tidal Dispersion
      The dispersion values for reaches 1 through 5 were obtained from the model of Bayou Queue de Tortue near Duson, LA (Smythe, 1992). The dispersion values for reaches 10 through 13 were obtained from the model of Bayou Queue de Tortue South of Crowley, LA (Smythe and Waldon, 1991). These two values were used as guidance when estimating the values for the remaining reaches.

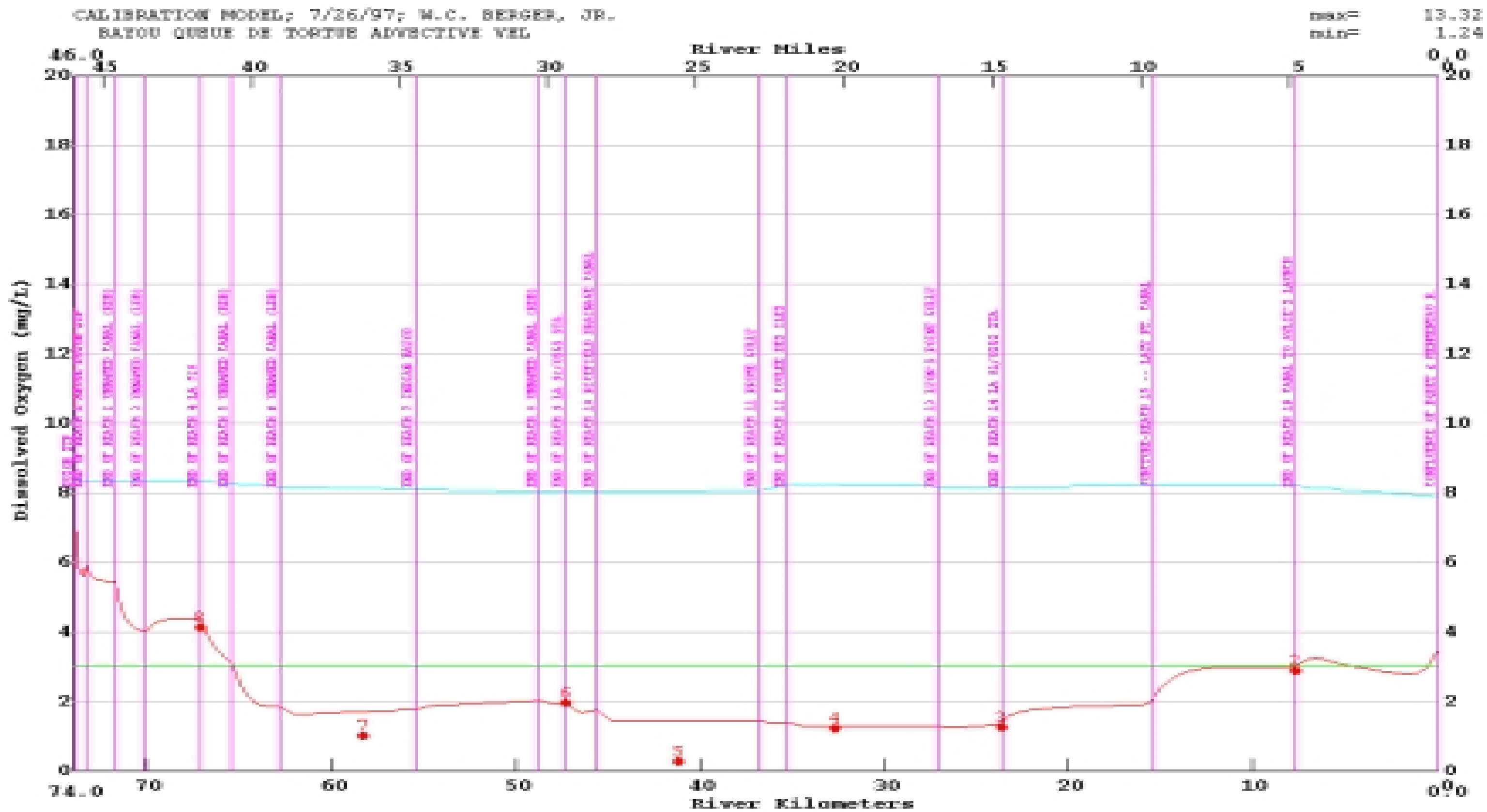

Figure 2. Dissolved Oxygen vs. River Kilometer Plot for the Bayou Queue de Tortue Calibration Model

c. Reaeration Rates

The Isaacs and Gaudy Reaeration Equation was used in reaches 1 through 6 of the watershed model since this portion of the model was developed from the calibrated model of Bayou Queue de Tortue near Duson (Smythe, 1992). The Owens, Edwards, and Gibbs Equation was used for the remaining reaches (Owens, Edwards, and Gibbs, 1964).

The Isaacs and Gaudy equation is applicable to streams with velocities between 0.6 and 1.6 ft/sec (0.18 and 0.49 m/sec) and depths between 0.5 and 1.5 feet (0.15 and 0.46 meters). This equation was applicable to reaches 1 through 6 based upon the depth criteria but not the velocity criteria. The velocities produced by the calibration model were lower than the velocity range for which the equation was developed (Isaacs and Gaudy, 1968).

The Owens, Edwards, and Gibbs equation is applicable to streams with velocities between 0.1 and 1.8 ft/sec (0.03 and 0.55 m/sec) and depths between 0.4 and 11 feet (0.12 and 3.35 meters). Based upon the depth criteria, this equation was applicable to all of the reaches except reach 16. The equation was not applicable based upon the velocity criteria. The velocities in reaches 7 through 17 were lower than the range for which the equation was developed.

However, the ranges of applicability for these equations were more applicable to the conditions of Bayou Queue de Tortue than the ranges for other available reaeration equations. These reaeration equations also provided reaeration rates that were similar to values that were measured during previous surveys of the bayou (Pilione, 1992). They also enabled the model to be calibrated. Therefore, the reaeration equations were considered to be appropriate.

c. Decay Rates, Settling Rates, and SOD Rates

Decay and settling rates were taken from the existing models for Bayou Queue de Tortue near Duson and Bayou Queue de Tortue south of Crowley (Smythe, 1992) (Smythe and Waldon, 1991). The SOD rates were determined by calibration.

d. Chlorophyll

Algal production was not simulated in the calibration or projection models.

e. Incremental Loads (with flow)

The model designates incremental concentrations as being associated with incremental flow. Since incremental flow had to be used to calibrate the model, water quality data had to be estimated to use as input for the model. The incremental flows and concentrations were meant to represent tributary and hydrostatic groundwater flows from the ricefields that could not be detected during the survey.

The previous survey of Bayou Queue de Tortue south of Crowley (Smythe and Waldon, 1991) had obtained water quality data for a tributary receiving ricefield discharges. The data included values for $CBOD_U$, $NBOD_U$, chlorides, and sulfates, but not dissolved oxygen.

A survey conducted on Bayou Blanc near Rayne (Pilione, 1994) obtained measurements of $CBOD_U$, $NBOD_U$, dissolved oxygen, chlorides, and sulfates. However the model could not be calibrated using the chloride data. The primary landuse within the Bayou Blanc watershed is rice production with a minimal amount of urban areas. Since Bayou Queue de Tortue has similar landuse characteristics and geology, loading concentrations obtained from the headwater site of the Bayou Blanc survey was used to represent the incremental $CBOD_U$, $NBOD_U$, and dissolved oxygen concentrations in the Bayou Queue de Tortue calibration model.

The chloride and sulfate concentrations from the Bayou Queue de Tortue tributary data (Pilione, 1992) were used to represent the incremental chloride and sulfate concentrations.

f. Nonpoint Loads (without flow)

   Nonpoint $CBOD_U$ and $NBOD_U$ were added to calibrate the model. This loading is assumed to represent the combined impact of resuspension of benthic material and other loading entering the water column without an associated flow.

g. Lower boundary conditions

   Lower boundary condition values for the calibration model were taken from site 8 of the watershed survey conducted on May 24 – 26, 1999. This site was located midstream of the Mermentau River at the mouth of Bayou Queue de Tortue.

3.3.3 Water quality projections

Projections were developed for the summer critical (March-November) and winter critical (December-February) seasons. The only parameters changed from the calibration model were headwater flow, wasteload flow, wasteload concentrations, initial conditions temperature, initial conditions dissolved oxygen concentration, incremental concentrations, and nonpoint concentrations. Projection models were also created to simulate summer and winter critical conditions without man-made loading.

Spreadsheets, reports, and plots developed to estimate the nonpoint and incremental load input data required for the projection models are presented in Appendix F. They are presented in the order in which they are explained in the following text.

1. Reference Stream Nonpoint Loading
   It is the purpose of the projections to produce wasteload allocations (WLAs) for point source dischargers and percent reductions of anthropogenic loading (LAs) for nonpoint sources. In order to differentiate anthropogenic nonpoint loading from natural background nonpoint loading, some measure of natural background nonpoint loading is needed. Toward that end, the available calculated loading from the reference stream program is listed. From this spreadsheet, the total natural benthic load was estimated to be 2.0 g O_2/m^2/day (Smythe, 1999).

2. Calibration Model Nonpoint Input Equivalent Load Determinations
   Also needed for the calculation of percent reduction of man-made nonpoint loading is the calibration benthic loading. The benthic loading was calculated for each reach in this spreadsheet.

3. Calculation of Background and Anthropogenic (Man-Made) Incremental Water Quality (Summer)
   The spreadsheet calculates the concentrations used in the projection model with a 60 % reduction of the man-made concentrations. The calculations were based on three assumptions. The first assumption was that incremental flow would be the same as the incremental flow determined during development of the calibration model. The second assumption was that the reduction would be obtained with lower concentrations based upon the calibration concentrations, not reduced incremental flows. The third assumption is that all of the incremental load (flows and concentrations) are man-made due to rice production and agriculture. Therefore, there would be no incremental flow with a 100 percent reduction of the man-made incremental load. The third assumption applies to the no load simulation.

4. Calculation of Background and Anthropogenic (Man-Made) Incremental Water Quality (Winter)
   The explanation is the same as for item 3.

5. Summer Projection Nonpoint Load Model Input Determinations
   This spreadsheet estimates the nonpoint and SOD loads used in the projection model, based on a 60 % reduction of the man-made nonpoint and SOD loading, calibration values, and the total benthic loading estimated from the reference stream values.

6. Winter Projection Nonpoint Load Model Input Determinations
   The explanation is the same as for item 5.

7. Summer No Load Projection Nonpoint Load Model Input Determinations
   This spreadsheet estimates the nonpoint and SOD loads used in the projection model, based on a 100 % reduction of the man-made nonpoint and SOD loading, calibration values, and the total benthic loading estimated from the reference stream values.

8. Winter No Load Projection Nonpoint Load Model Input Determinations
   The explanation is the same as for item 7.

9. Bayou Queue de Tortue Total Natural Background Loads: Summer Incremental and Nonpoint
   A summary of the natural background incremental and nonpoint loads for summer critical conditions are provided in this spreadsheet. The loads are in lbs./day.

10. Bayou Queue de Tortue Total Natural Background Loads: Winter Incremental and Nonpoint
    The spreadsheet provides the same information for winter critical conditions that item 9 provides for summer critical conditions.

The following spreadsheets, reports, and plots present the input data justifications and the projection results. They are presented in Appendix F1 in the order in which they are explained.

1. Summer Projection Model Output and Plots (Treatment Level: 10 mg/L $CBOD_U$/5 mg/l $NBOD_U$/ 6 mg/L D.O. & 60 % reduction of Man-Made Incremental & Nonpoint Loading)
   The output file for the summer projection model is provided. It includes a summary of the input data. Plots produced by the model are also provided. The plot for dissolved oxygen is also presented in Figure 3.

2. Bayou Queue de Tortue Water Quality Summer Projection Model Input Description
   The input data and data sources or justifications are provided in spreadsheet format.

3. Summer No Load Projection Model Output and Plots
   The output file for the summer no load projection model is provided. The term “no load” means no man-made load. Included is a summary of the input data. Plots produced by the model are also provided.

4. Bayou Queue de Tortue Water Quality Summer No Load Projection Model Input Description

   The input data and data sources or justifications are provided in spreadsheet format.

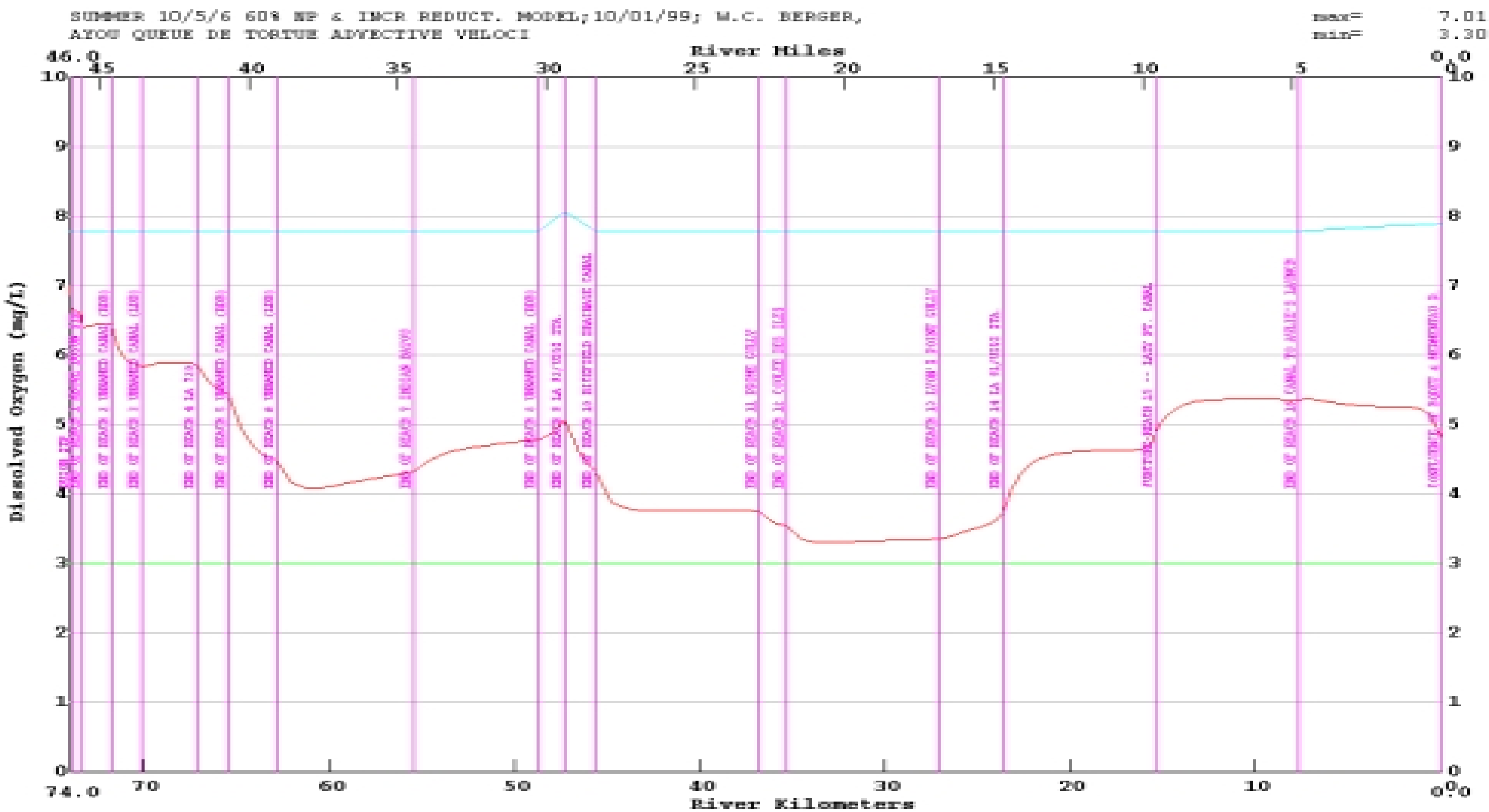

Figure 3. Dissolved Oxygen vs. River Kilometer Plot for the Summer Projection Model

5. Plots for Additional Summer Projections

An additional summer projection was made to demonstrate that a 50 % reduction in the man-made incremental and nonpoint loading did not meet criteria.

The following spreadsheets, reports, and graphs are presented in Appendix F2.

1. Winter Projection Model Output and Plots (Treatment Level: 30 mg/L $CBOD_U$/15 mg/l $NBOD_U$/5 mg/L D.O. & 60 % reduction of Man-Made Incremental & Nonpoint Loading

    The output file for the winter projection model is provided. It includes a summary of the input data. Plots produced by the model are also provided. The dissolved oxygen plot is presented in Figure 4 for convenience. The lower boundary condition card was turned off for the winter models because applicable data was not available.

    Assumptions were made when determining the percent reductions of man-made incremental and nonpoint loading. LA DEQ has documented that the incremental loading occurs throughout the year, but has its greatest effect during summer critical conditions in the form of benthic loads (SOD) and nonpoint loads (resuspension). Recognizing this fact, and the fact that LA DEQ cannot implement percentage load reductions on a seasonal basis, the percentage load reductions for the winter critical conditions were set equivalent to the percentage load reductions that protected the dissolved oxygen criteria for the summer critical conditions.

2. Bayou Queue de Tortue Water Quality Winter Projection Model Input Description.

    The input data and data sources or justifications are provided in spreadsheet format.

3. Winter No Load Projection Model Output and Plots

    The output file for the winter no load projection model is provided. The term “no load” means no man-made load. Included is a summary of the input data. Plots produced by the model are also provided. The lower boundary condition card was turned off for the winter models because applicable data was not available.

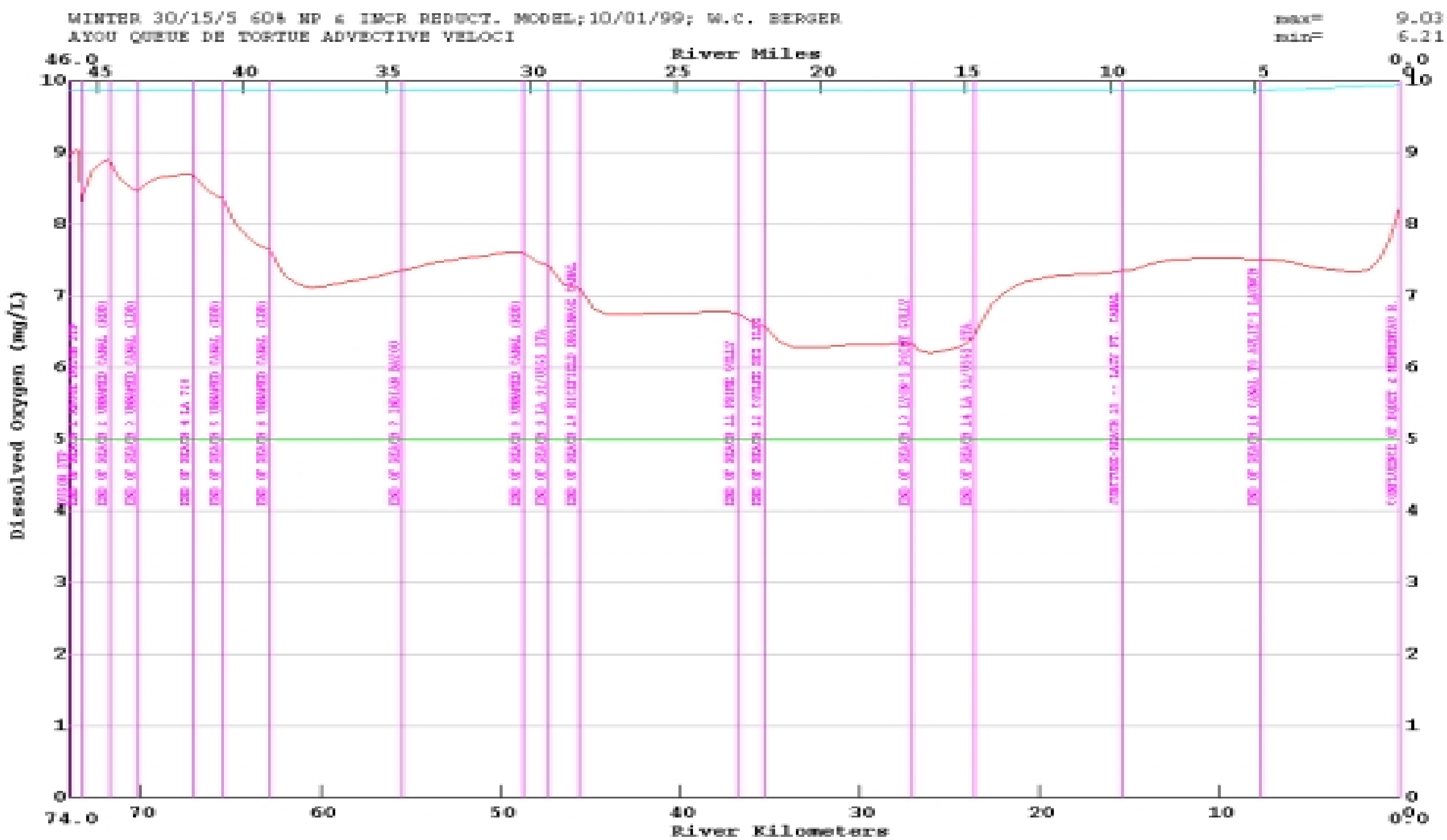

Figure 4. Dissolved Oxygen vs. River Kilometer Plot for the Winter Projection Model

4. Bayou Queue de Tortue Water Quality Winter No Load Projection Model Input Description

    The input data and data sources or justifications are provided in spreadsheet format.

The following spreadsheets are in Appendix G.

Summer and Winter TMDL Calculations

    Land use in the Bayou Queue de Tortue watershed is fairly homogeneous, comprising principally rice farming and row crops. Summer and winter TMDLs have therefore been calculated for the entire watershed. The spreadsheets sum loading from headwaters, point sources, incremental (nonpoint associated with flow), nonpoint (not associated with flow), and SOD.

3.3.4 Sensitivity Analysis

Sensitivity analysis was performed for the calibration model. A spreadsheet presenting the results of the analysis is provided in Appendix E. The results are grouped into reaches 1 through 4 and reaches 5 through 17. This was done in order to differentiate between the D.O. sag due to the Duson STP in the headwaters and the D.O. sag due to the incremental, SOD and nonpoint loadings in the lower reaches.

In reaches 1 through 4 the model was most sensitive to the reaeration, benthal (SOD), temperature, depth, and aerobic BOD decay parameters. Since the reaeration and benthal parameters are related to depth, we can say that the upper reaches of the model are highly sensitive to depth.

In reaches 5 through 17, the model was most sensitive to the reaeration, velocity, benthal, aerobic BOD decay, and temperature parameters. Once again, since the reaeration, velocity, and benthal parameters are related to depth, we can also say that the lower reaches are highly sensitive to depth. It is especially important, therefore, that stream hydrologic data be reasonably good.

4. TMDLs and Allocations

Land use in the Bayou Queue de Tortue watershed is fairly homogeneous, comprising principally rice and soybean farming. Dissolved oxygen TMDLs have therefore been calculated for the entire watershed. A nonpoint source margin of safety was not calculated because a reduction is required to meet dissolved oxygen criteria.

The summer TMDL was higher than the winter TMDL. A percent reduction, which met the summer critical season criteria was determined with the summer projection. An equivalent percent reduction was then applied to the winter conditions because the loading occurs annually, although the greatest impact is felt during the summer. Also, LA DEQ cannot implement seasonal Best Management Practices (BMPs). Therefore the summer and winter TMDLs were approximately the same except for two areas, the Duson STP and the SOD loading. The Duson STP produced a higher loading in the winter projection due to higher limits, but it did not have a significant impact on the model. When considering SOD, the percent reduction for both the summer and winter models were based upon the same calibration SOD value at 20 degrees. After this value was reduced, it was put into the summer and winter projections, which were at different stream temperatures. The models then corrected the SOD values for stream temperature. The temperature-corrected SODs were then used in the TMDL calculations, producing a higher summer TMDL value.

The following text contains a brief outline of the projection and TMDL calculations. It will help explain some of the calculations in the Appendices. The TMDLs and allocations are summarized in Table 5 on page 24. The point source allocations for the City of Duson STP are summarized in Table 6 on page 24.

1. The natural background benthic loading was estimated from reference stream NBOD, CBOD, and SOD data.
2. The calibration anthropogenic (man-made) benthic loading was determined as follows:
   - Calibration non-point CBOD and NBOD (resuspension), and SOD were summed for each reach as gm/m^2d to get the total calibration benthic loading.
   - The natural background benthic loading was subtracted from the total calibration benthic loading to get the total anthropogenic (man-made) calibration benthic loading.
3. Projection runs were made with:
   - Point sources represented at 125% of design flow (based on Department of Health design criteria) to provide an explicit 20% margin of safety for point source loading.
   - Headwater flows at seasonal 7Q10 or 0.1(summer)/1.0(winter) cfs, whichever was greater.
   - Headwater concentrations of CBOD, NBOD, and DO at calibration levels.
5. For each reach, the non-point CBOD and NBOD (resuspension), SOD, and point source limitations were adjusted to bring the projected in-stream dissolved oxygen in compliance with criteria. No additional explicit margin of safety was employed for non-point loading. The loading capacity and percent reduction of anthropogenic non-point were calculated as follows:
   - The total projection benthic loading at 20^oC was calculated as the sum of projection NBOD, CBOD, and SOD expressed as gm/m^2d.
   - The natural background benthic loading was subtracted from the total projection benthic loading to get the total anthropogenic (man-made) projection benthic loading.

- The total anthropogenic projection benthic loading was subtracted from the total calibration anthropogenic benthic loading and that number divided by the total calibration anthropogenic benthic loading to obtain the percent reduction of anthropogenic non-point loading needed to achieve the in-stream dissolved oxygen criteria.

6. The total projection benthic loading for each reach was calculated as follows:
   - The projection SOD at 20°C was adjusted to stream critical temperature.
   - The projection CBOD, NBOD, and SOD were summed to get the total benthic loading at stream temperature critical in lb/d for each reach.
7. The total stream loading capacity at stream critical temperature was calculated as the sum of:
   - Headwater CBOD and NBOD loading in lb/d.
   - Projection benthic loading for all reaches of the stream in lb/d.
   - Total point source CBOD and NBOD loading in lb/d.
   - The facility margin of safety.

The TMDL for the Bayou Queue de Tortue watershed was set equal to the total stream loading capacity.

Table 6. Total Maximum Daily Loads

	Summer season (Mar – Nov)		Winter season (Dec – Feb)	
Point source allocations (WLA)	Load lbs./day	% of TMDL	Load lbs./day	% of TMDL
Total point source allocations (WLA)	79.8	0.16	239.5	0.63
Point source margin of safety (MOS)	20.0	0.04	59.9	0.16
Headwater/Tributary Loads	4.5	0.009	45	0.12
Benthic Loads	48,339.9	99.79	37,857.3	99.10
Reduction of man-made nonpoint	60 %		60 %	
Nonpoint source margin of safety (MOS)	0.0	0.0	0.0	0.0
Total maximum daily load (TMDL)	48,444	100.0	38,202	100.0

Table 7. Point Source Allocations

		Permit limitations (BOD_5/TSS)		Projected limits (BOD_5/NH_3-N/DO)	
Facility	Flow (MGD)	Summer	Winter	Summer	Winter
City of Duson STP	0.190	10/15	10/15	10/5/6	30/15/5

8. Conclusion

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 has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a five-year cycle with two targeted basins sampled each year. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the five-year cycle. Sampling is conducted on a monthly basis or more frequently if necessary to yield at least 12 samples per site each year. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, targeted basins follow the TMDL priorities. In this manner, the first TMDLs will have been implemented by the time the first priority basins will be monitored again in the second five-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. The sampling schedule for the first five-year cycle is shown below.

1998 - Mermentau and Vermilion-Teche River Basins
1999 - Calcasieu and Ouachita River Basins
2000 - Barataria and Terrebonne Basins
2001 - Lake Pontchartrain Basin and Pearl River Basin
2002 - Red and Sabine River Basins

(Atchafalaya and Mississippi Rivers will be sampled continuously.)
Mermentau and Vermilion-Teche Basins will be sampled again in 2003.

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