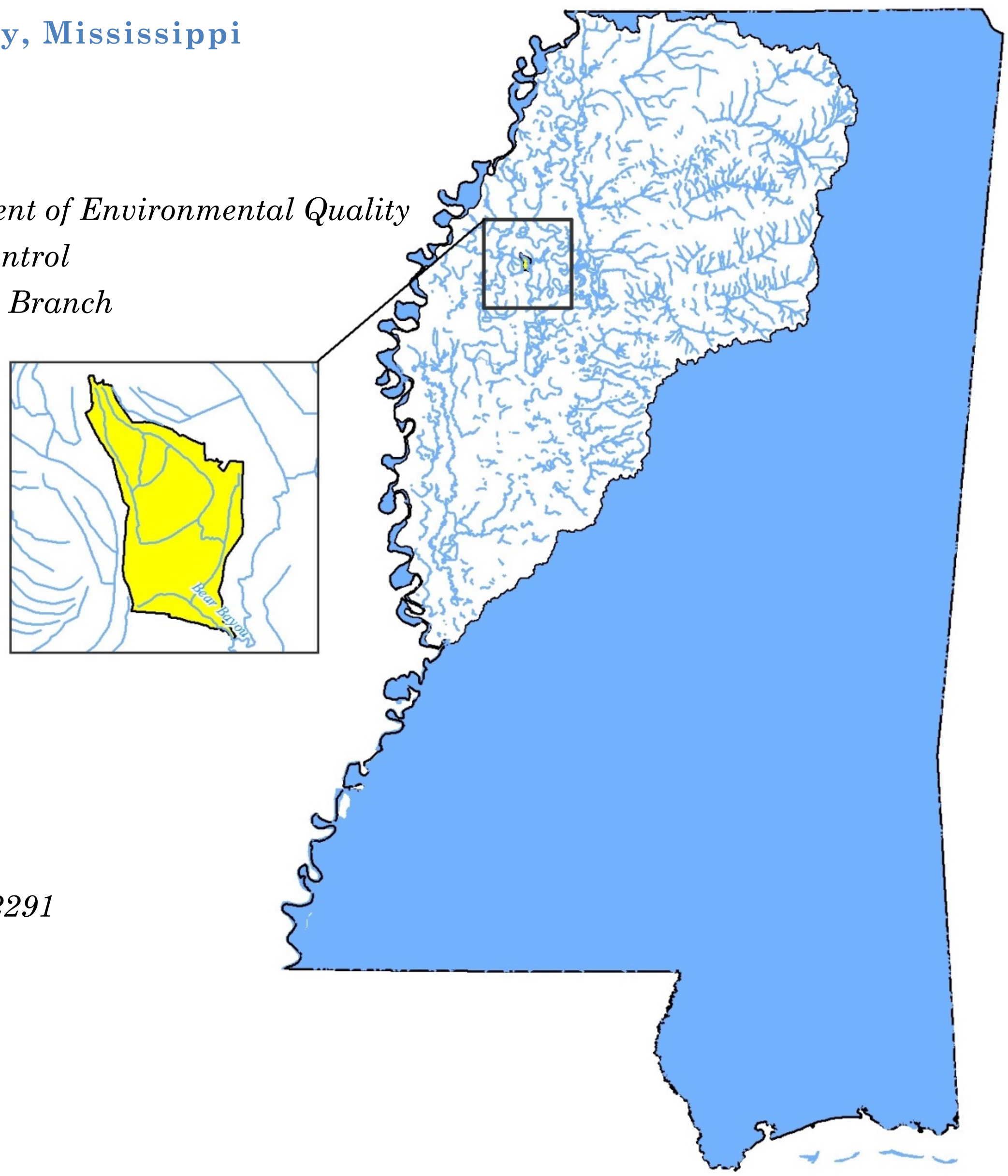
FINAL REPORT
December 2014

Organic Enrichment / Low DO TMDL for Bear Bayou Watershed

Yazoo River Basin
Sunflower County, Mississippi

Prepared By

Mississippi Department of Environmental Quality
Office of Pollution Control
Modeling and TMDL Branch



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FOREWORD

The report contains one or more Total Maximum Daily Loads (TMDLs) for water body segments found on Mississippi's 2012 Section 303(d) List of Impaired Water Bodies. The implementation of the TMDLs contained herein will be prioritized within Mississippi's rotating basin approach.

As additional information becomes available, the TMDLs may be updated. Such additional information may include water quality and quantity data, changes in pollutant loadings, modifications to the water quality standards or criteria, or changes in landuse within the watershed. In some cases, additional water quality data may indicate that no impairment exists.

Table 1. Conversion Factors

From	To	multiply by	From	To	multiply by	From	To	multiply by
mi^2	$feet^2$	27,878,400	$meter^3$	liter	1,000	miles	feet	5,280
km^2	$feet^2$	10,763,911	$Feet^3$/sec	gallons/min	448.8312	km	feet	3,280.84
hectares	$feet^2$	107,639	$meter^3$	gallons	264.1721	miles	meters	1,609.34
acre	$feet^2$	43,560	$meter^3$	$Feet^3$	35.3147	meters	feet	3.2808
mi^2	acre	640	$Feet^3$	Liter	28.3168	km	miles	0.6214
km^2	acre	247.1044	$Yard^3$	$Feet^3$	27	days	seconds	86,400
km^2	hectares	100	$Feet^3$	gallons	7.4805	mg/l * MGD	lbs/day	8.3454
hectares	acre	2.4710	$Yard^3$	$meter^3$	0.7646	µg/l * cfs	gm/day	2.4500
km^2	mi^2	0.3861	$Feet^3$/sec	MGD	0.6463	tonnes	ton	1.1

Table 2. Prefix Symbols

Fraction	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	d	10	deka	da
10^{-2}	centi	c	10^2	hecto	h
10^{-3}	milli	m	10^3	kilo	k
10^{-6}	micro	:	10^6	mega	M
10^{-9}	nano	n	10^9	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f	10^{15}	peta	P
10^{-18}	atto	a	10^{18}	exa	E

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EXECUTIVE SUMMARY

Bear Bayou is a Mississippi Delta stream located just northeast of Parchmen Prison southwest of Tutwiler, Mississippi in Sunflower County, Figure 1. The length of the water body is approximately 7.5 miles from the headwaters to the Quiver River. There are no NPDES permitted point sources or MS4s in the watershed. The landuse of the watershed is predominantly (85%) agriculture.

Table 3. Listing Information

Name	ID	County	Impaired Use	Impairment
Bear Bayou	951412	Sunflower	Fish and Wildlife	Organic Enrichment / Low Dissolved Oxygen

MDEQ collected water quality monitoring data in 2014 which indicate impairment of the dissolved oxygen water quality standard. This TMDL will provide an allocation for TBODu for the watershed to meet the current water quality standard. According to the data, the TBODu load in the water body exceeds the assimilative capacity of Bear Bayou for organic material. Therefore, either reductions in TBODu are required, or the designated use classification of the stream could be modified.

Table 4. Water Quality Standards

Parameter	Beneficial use	Water Quality Criteria
Dissolved Oxygen	Aquatic Life Support	DO concentrations shall be maintained at a daily average of not less than 5.0 mg/l with an instantaneous minimum of not less than 4.0 mg/l

MDEQ modeled this water body with the STREAM model to determine the reductions needed for this stream to meet the water quality standards. MDEQ will also consider modification of the designated use classification of this and similar Delta streams based in part on this analysis.

Changes to water quality standards would require Commission Action, public review, and EPA approval. This document will inform that process should MDEQ proceed toward water quality standards modification.

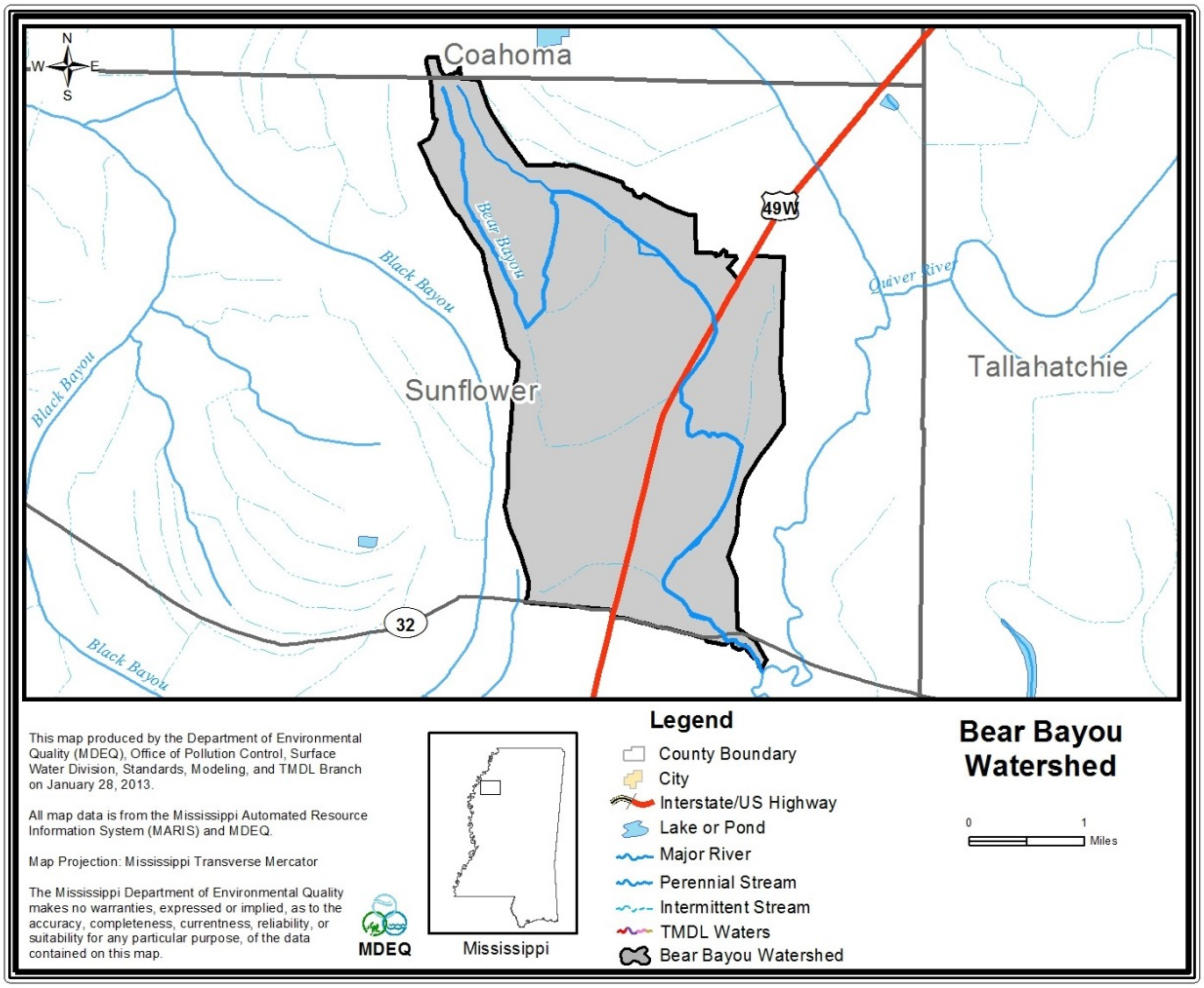

Figure 1. Bear Bayou Watershed

INTRODUCTION

1.1 Background

The identification of water bodies not meeting their designated use and the development of total maximum daily loads (TMDLs) for those water bodies are required by Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR part 130). The TMDL process is designed to identify impairment and restoration alternatives, and maintain the quality of those impaired water bodies through the establishment of pollutant specific allowable loads. This TMDL is for the 2012 §303(d) listed segment shown in Figure 2. The impaired segment of the stream is shown in green.

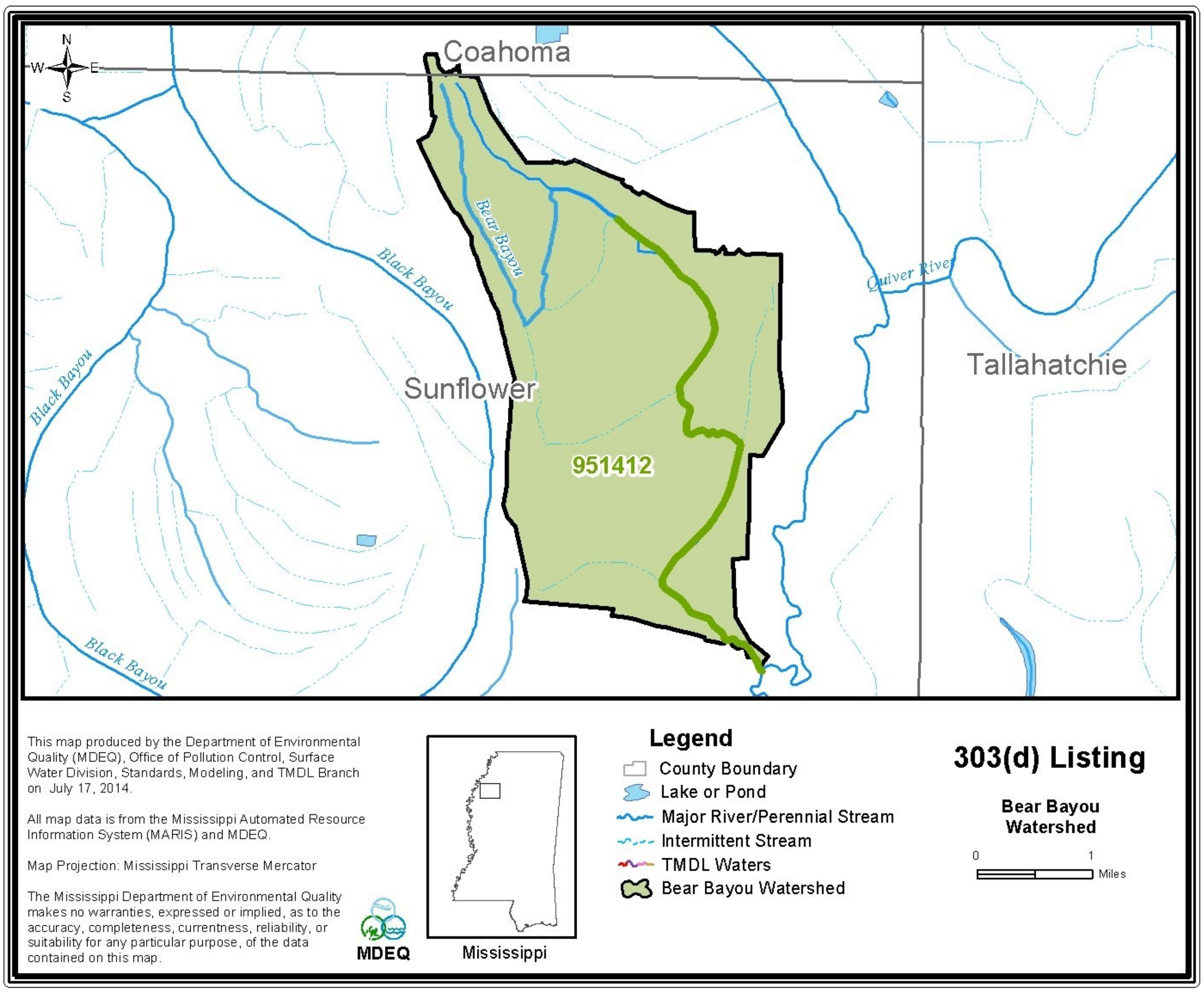

Figure 2. Bear Bayou Impaired Segment

1.2 Listing History

The impaired segment was first listed on the 2010 § 303(d) List of Impaired Water Bodies. The organic enrichment / low dissolved oxygen impairment was assessed based on diel DO data collected during a water quality study on Bear Bayou in 2007. These data indicate impairment, however, further research indicated the data were not valid due to equipment malfunction. The stream was monitored again in 2014 for this TMDL.

1.3 Applicable Water Body Segment Use

The water use classifications are established by the State of Mississippi in the document *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters WPC-2* (MDEQ, 2012). The designated beneficial use for the listed segment is fish and wildlife.

1.4 Applicable Water Body Segment Standard

The water quality standard applicable to the use of the water body and the pollutant of concern is defined in the *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters WPC-2* (MDEQ, 2012).

The applicable standard specifies:

"<u>Dissolved Oxygen</u>: Dissolved oxygen concentrations shall be maintained at a daily average of not less than 5.0 mg/l with an instantaneous minimum of not less than 4.0 mg/l. When possible, samples should be taken from ambient sites according to the following guidelines:

For water bodies that are not stratified, samples should be taken: At mid-depth if the total water column depth is 10 feet or less. At 5 feet from the water surface if the total water column depth is greater than 10 feet.

For water bodies that are stratified, samples should be taken: At mid-depth of the epilimnion if the epilimnion depth is 10 feet or less; At 5 feet from the water surface if *the epilimnion depth is greater than 10 feet."*[1]

Future standards modification may rely on the natural condition clause within WPC-2 to consider the site specific modification of the designated use for this stream. It may be feasible to modify the water quality standards for dissolved oxygen based on the natural dissolved oxygen levels found in this stream. The natural conditions statement says:

"Natural conditions are defined as background water quality conditions due only to non-anthropogenic sources. The criteria herein apply specifically with regard to substances attributed to sources (discharges, nonpoint sources, or instream activities) as opposed to natural phenomena. Waters may naturally have characteristics outside the limits established by these criteria. Therefore, naturally occurring conditions that fail to meet criteria should not be interpreted as violations of these criteria."[2]

Figure 3. Bear Bayou

1 (Mississippi Department of Environmental Quality, June 28, 2012), page 8.

2 Ibid. page 3

WATER BODY ASSESSMENT

2.1 Bear Bayou Water Quality Data

Water quality data for Bear Bayou were gathered in 2007. These data indicated stream impairment, however, further research indicates there was an equipment failure at this monitoring event. The stream was monitored again in 2014 which confirmed the impairment classification of this water body. Bear Bayou is not supporting the use of aquatic life support and indicates violations of the dissolved oxygen (DO) standard. The data are shown in Figures 4 through 7 below.

2.2 Assessment of Data

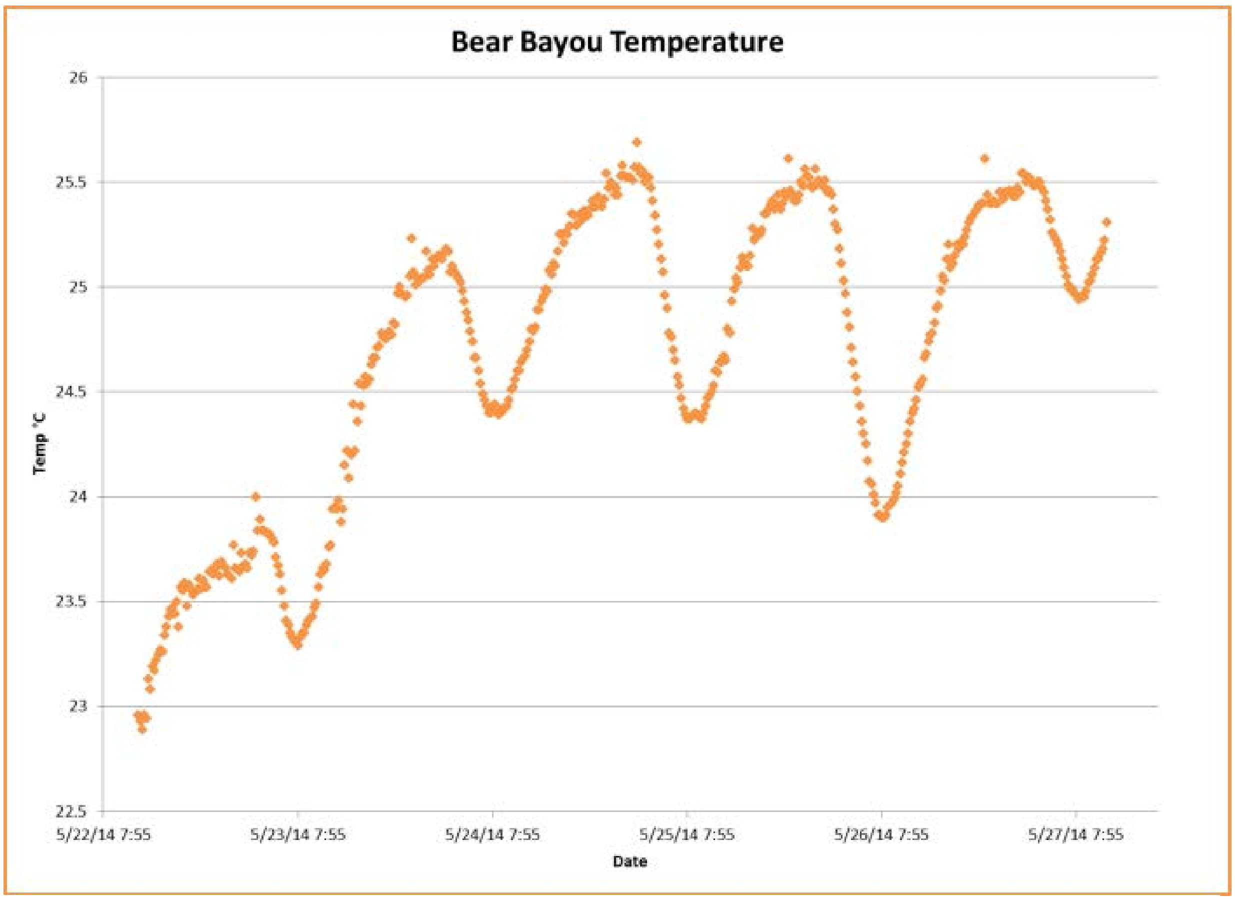

Figure 4. Temperature Data

The average temperature for the deployment was 24.7 °C. This value was used in the STREAM models for temperature in this water body.

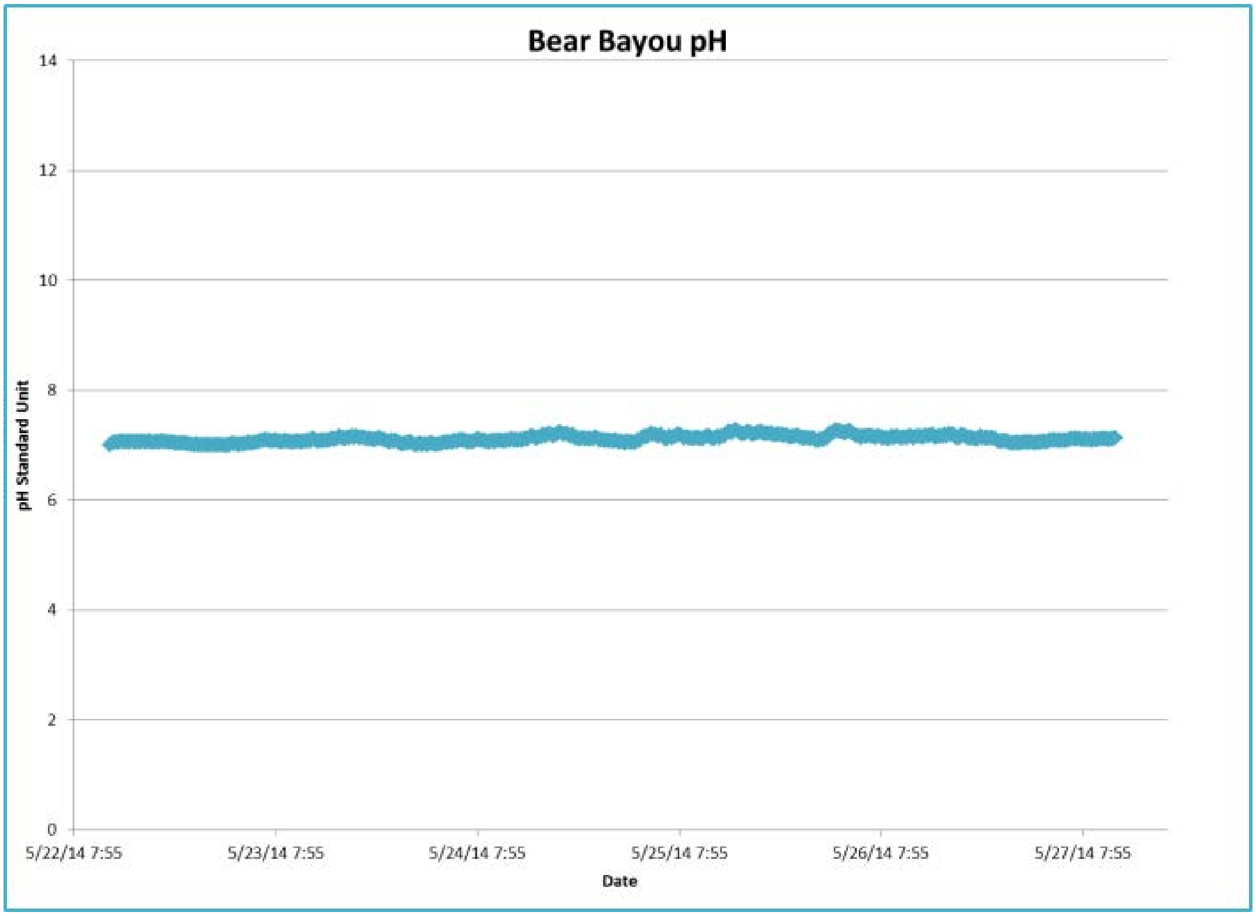

Figure 5. pH Data

The pH values in the stream were as suspected with little variation. The average pH value is 7.11 standard units.

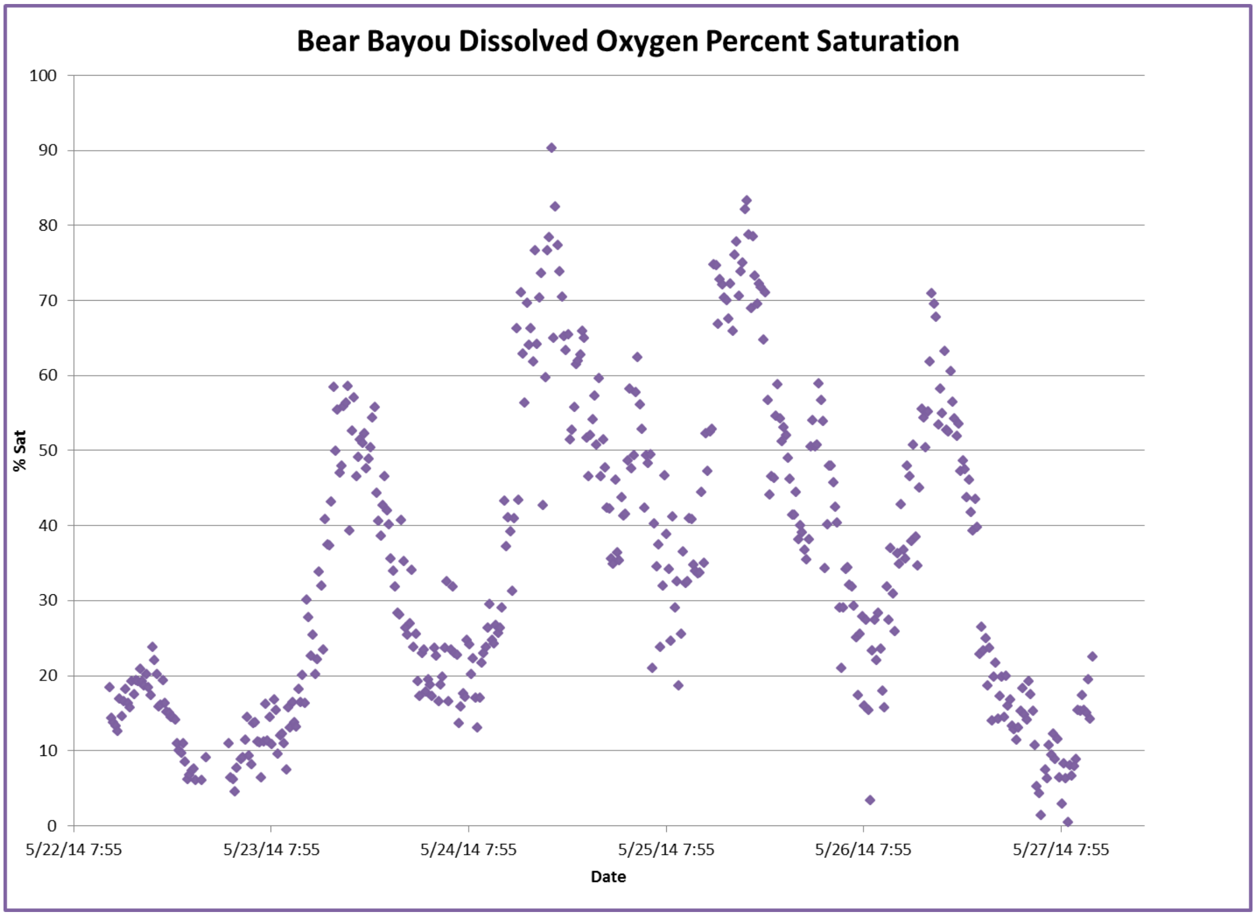

Figure 6. Dissolved Oxygen Percent Saturation Data

The percent saturation readings were lower than anticipated. This could have been caused by the very slow velocity of the stream during the deployment. There is a good diurnal swing indicating a response to the sunshine and respiratory production of oxygen in the stream.

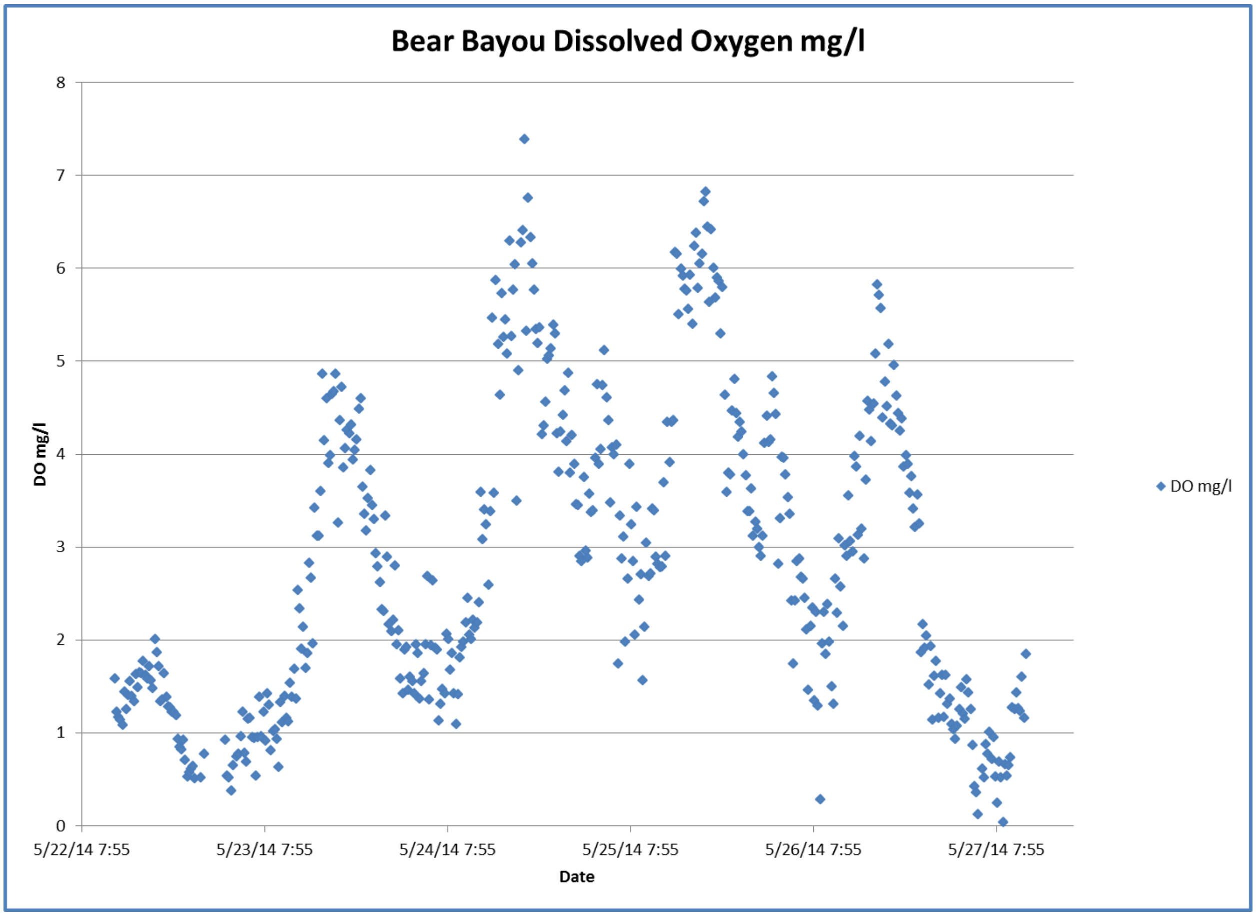

Figure 7. Diel Dissolved Oxygen Data

The average DO value was 2.89 mg/l for the 5 days deployed. This is below the water quality standard of 5.0 mg/l. This confirms the impairment listing decision.

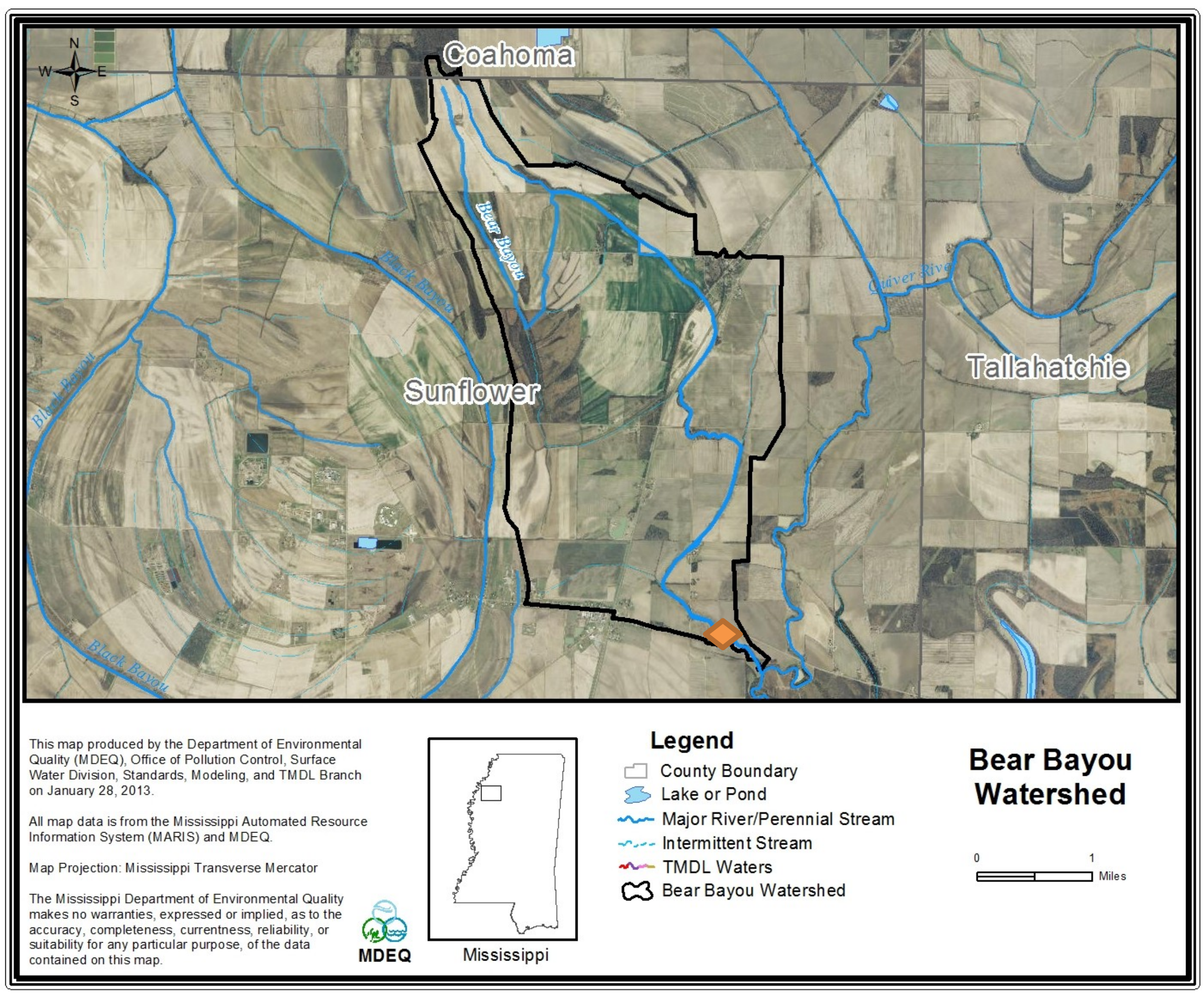

Figure 8. Satellite Image Showing Sample Station

2.3 Assessment of Point Sources

An important part of the TMDL analysis is the identification of individual sources, source categories, or source subcategories in the watershed and the amount of pollutant loading contributed by each of these sources. Under the CWA, sources are broadly classified as either point or nonpoint sources. Under 40 CFR §122.2, a point source is defined as a discernible, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters.

The National Pollutant Discharge Elimination System (NPDES) program regulates point source discharges. Point sources can be described by two broad categories: 1) NPDES regulated municipal, commercial, and industrial wastewater treatment plants (WWTPs) and 2) NPDES regulated activities, which include construction activities and municipal storm water discharges (Municipal Separate Storm Sewer Systems [MS4s]).

The Bear Bayou Watershed has no NPDES permitted point sources. There are no MS4s in this area. Therefore the WLA will be set to zero for this TMDL. This WLA may be revised based on new information in the future.

2.3 Assessment of Nonpoint Sources

Nonpoint loading of organic material in a water body results from the transport of the pollutants into receiving waters by overland surface runoff, groundwater infiltration, and atmospheric deposition.

The Bear Bayou watershed landuse is primarily agricultural. The land use information for the watershed is based on the 2006 National Land Cover Database (NLCD). The landuse distribution for the Bear Bayou Watershed is shown in Table 5 and Figure 9.

Table 5. 2006 NLC Landuse Distribution

Area	Water	Urban	Forest	Pasture	Cropland	Wetland	Total
Acres	4.0	601.4	13.6	13.6	4899.1	230.6	5762.3
Percentage	0.1%	10.4%	0.2%	0.2%	85.0%	4.0%	

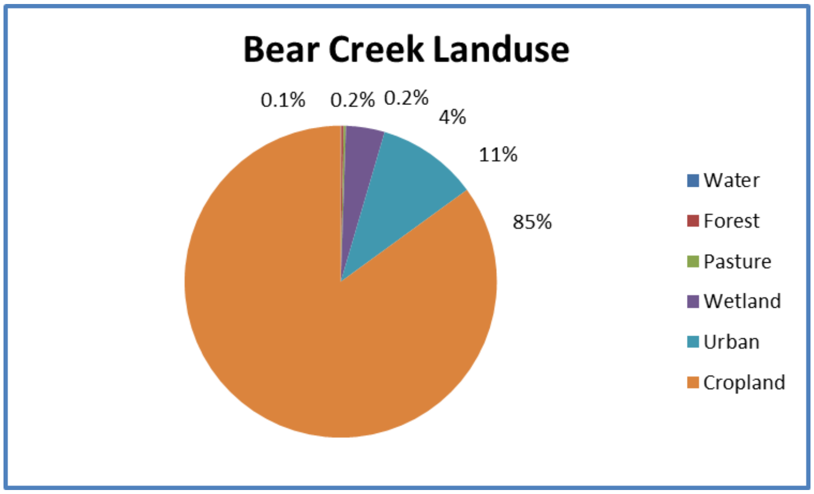

Figure 9. Landuse Pie Chart

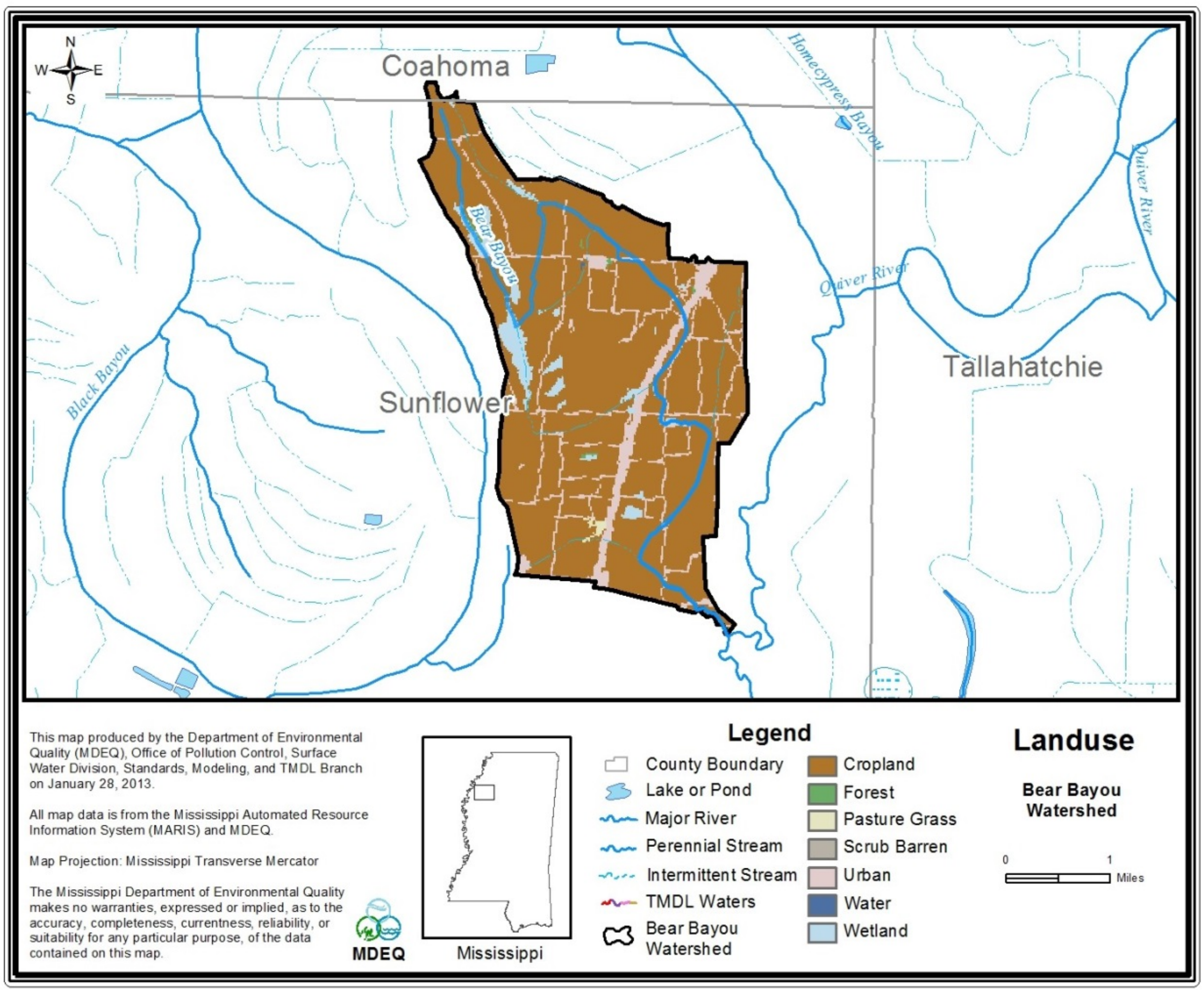

Figure 10. Landuse in Bear Bayou Watershed

MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between the instream water quality target and the source loading is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain water body responses to flow and loading conditions. In this section, the selection of the modeling tools, setup, and model application are discussed.

3.1 Modeling Framework Selection

MDEQ's steady state water quality model, STeady Riverine Environmental Assessment Model (STREAM), for DO distribution in freshwater streams was used for developing the TMDL. The use of STREAM is promulgated in the *Title 11: Mississippi Department of Environmental Quality Part 6: Wastewater Pollution Control Regulations Part 6, Chapter 9: Mississippi Commission on Environmental Quality.(MDEQ, 2012)* (Regulations) This model is approved by EPA and used extensively at MDEQ. A key reason for using the STREAM model in TMDL development is its ability to assess instream water quality conditions in response to point and nonpoint source loadings.

3.2 Model Setup

The STREAM model for this TMDL was created with 6 stream segments based on the NHDplus stream coverage. Table 6 STREAM Model Variables on page 22 below provides the model inputs used.

Segment divisions were made at locations where there is a change in hydrological and water quality characteristics, such as the confluence of a point source or tributary or change in slope. The modeled segments were divided into computational elements of 0.1 mile. The simulated hydrological and water quality characteristics were calculated and output by the model for each computational element.

3.2.1 Base Equations

STREAM is a steady-state, daily average computer model that solves the partial differential modified Streeter-Phelps Dissolved Oxygen (DO) sag equation. Instream processes simulated by the model include Carbonaceous Biochemical Oxygen Demand ultimate (CBODu) decay, nitrification (Nitrogenous Biochemical Oxygen Demand ultimate (NBODu) load expresses as oxygen), reaeration, sediment oxygen demand (SOD), and respiration and photosynthesis of algae. Figure 11 shows how these processes are related in a typical DO model. Reaction rates for the instream processes are input by the user and corrected for temperature by the model. The model output includes water quality conditions in each computational element for DO, CBODu, and ammonia as nitrogen (NH_3-N) concentrations. The hydrological processes simulated by the model include stream velocity in feet per second (f/s) and flow in cubic feet per second (cfs) from point sources, if present, and spatially distributed inputs.

3.2.2 Reaeration

The model calculates reaeration within each reach using the Tsivoglou formulation. The Tsivoglou formulation calculates the reaeration rate, K_a (day^{-1} base *e*), within each reach according to Equation 1.

$$K_a = C*S*U \qquad \textbf{(Eq. 1)}$$

C is the escape coefficient, U is the reach velocity in mile/day, and S is the average reach slope in feet per mile. The value of the Tsivoglou escape coefficient is assumed to be 0.11 for streams with flows less than 10 cfs and 0.0597 for stream flows equal to or greater than 10 cfs.

Reach velocities were calculated using an empirical equation based on stream slope and flow. The regulatory minimum velocity of 0.1 ft/sec was used in this model. The slope of each reach elevation were measured with 2010 LIDAR coverage and input into the model in units of feet per mile.

3.2.3 Temperature and Flow

The STREAM model simulates the critical flow and temperature conditions, which were determined to be the critical condition for this TMDL. MDEQ Regulations state that when the flow in a water body is less than 50 cfs, the temperature used in the model is 26°C. However, to match the measured data, 24.7 °C was used. The instream CBODu decay rate at K_d at 20°C was input as 0.3 day^{-1} (base e) as specified in MDEQ regulations. The model adjusts the K_d rate based on temperature, according to Equation 2.

$$\mathbf{K_{d(T)} = K_{d(20^\circ C)}(1.047)^{T-20}} \qquad \textbf{(Eq. 2)}$$

Where K_d is the CBODu decay rate and T is the assumed instream temperature. The assumptions regarding the instream temperatures, background DO saturation, and CBODu decay rate are required by MDEQ regulations

Also based on MDEQ Regulations, the rates for photosynthesis, respiration, and sediment oxygen demand were set to zero because data for these model parameters are not available.

There are no USGS gages located on Bear Bayou. The flow for the model was taken from average flow estimates for incremental flow in the NHDplus database.

3.2.4 Organic Enrichment Loading

Organic enrichment sources were represented in the model by adding CBODu and NBODu loads. The spatially distributed loads were distributed evenly into each computational element of the modeled water body. The dissolved oxygen level was initiated at 6.0 mg/l.

Direct measurements of background concentrations of CBODu were not available for the Bear Bayou Watershed. Because there were no background data available, the background concentrations of CBODu and NH_3-N were estimated based on the measured data.

3.2.5 Nitrogen Loading

In order to convert the NH_3-N loads to an oxygen demand, a factor of 4.57 pounds of oxygen per pound of NH_3-N oxidized to nitrate nitrogen (NO_3-N) was used. Using this factor is a conservative modeling assumption because it assumes that all of the ammonia is converted to nitrate through nitrification. The oxygen demand caused by nitrification of ammonia is equal to the NBODu load. The sum of CBODu and NBODu is equal to the load of TBODu. The loads of TBODu from the calibrated STREAM model are given in Table 7 Calibrated Model Loads .

TBODu = CBODu + NBODu **(Eq. 3)**

3.2.6 STREAM Model Identification

There are two STREAM models in this study. The first is the calibrated model. The calibrated model setup was based on the critical condition measured during deployment in May, 2014. The measured average dissolved oxygen value of 2.89 mg/l was matched with the data output of the model at river mile 1.1 where the monitoring station was located.

The second model takes the conditions established in the calibrated model and adjusts the loads to meet the water quality standard. This second model is the pollutant reduction model.

Table 6. STREAM Models Variables Used

River Mile	Temp °C	Slope Ft/mile	Kr Day^{-1}	Kd Day^{-1}	Kn Day^{-1}	Escape Coeff	Velocity fps
7.5	24.7	1.83	0.3	0.3	0.3	0.11	0.1
6.2	24.7	0.80	0.3	0.3	0.3	0.11	0.1
5.6	24.7	1.95	0.3	0.3	0.3	0.11	0.1
3.6	24.7	1.61	0.3	0.3	0.3	0.11	0.1
2.7	24.7	0.55	0.3	0.3	0.3	0.11	0.1
1.2	24.7	4.26	0.3	0.3	0.3	0.11	0.1

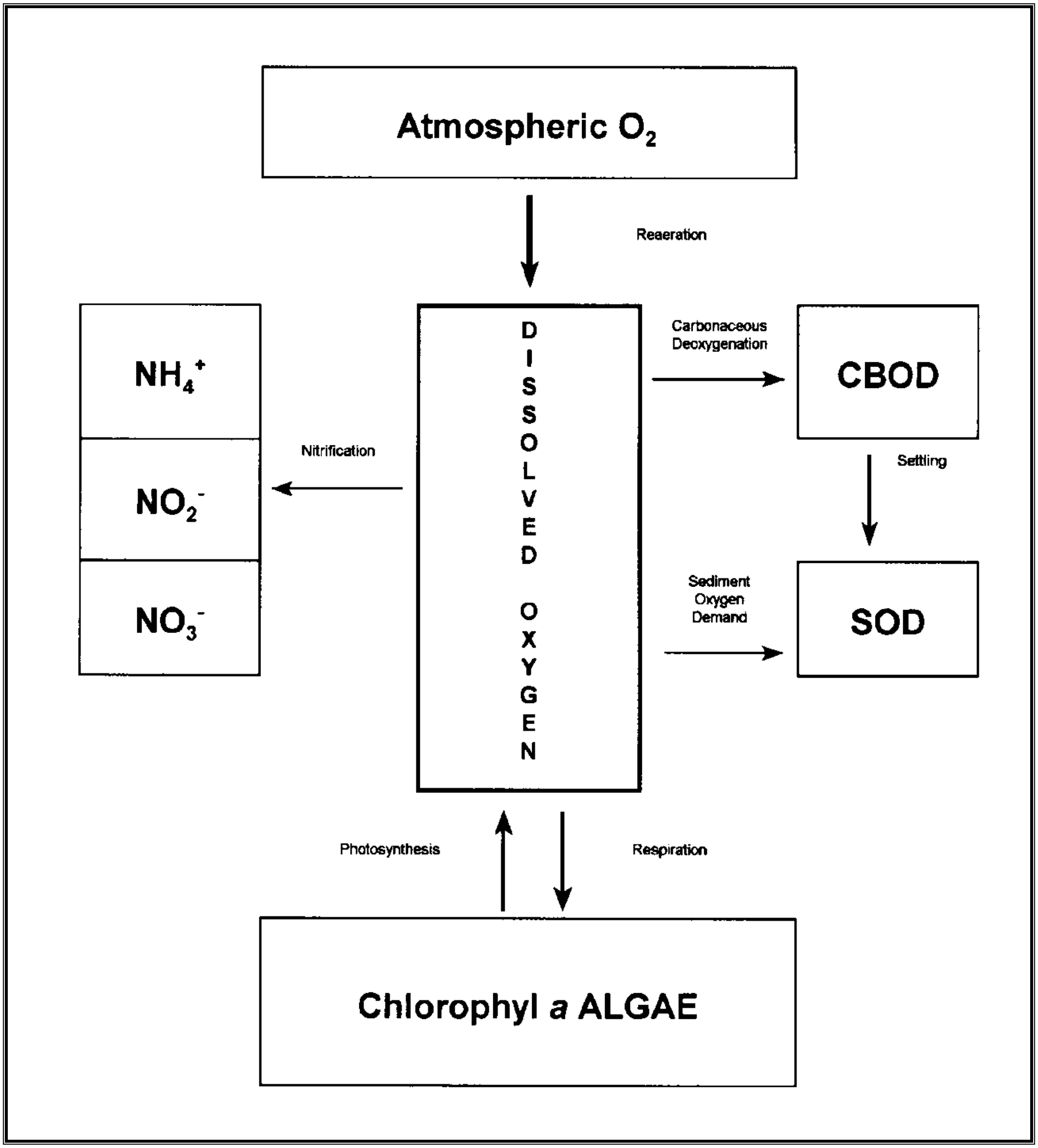

Figure 11. Instream Processes in a Typical DO Model

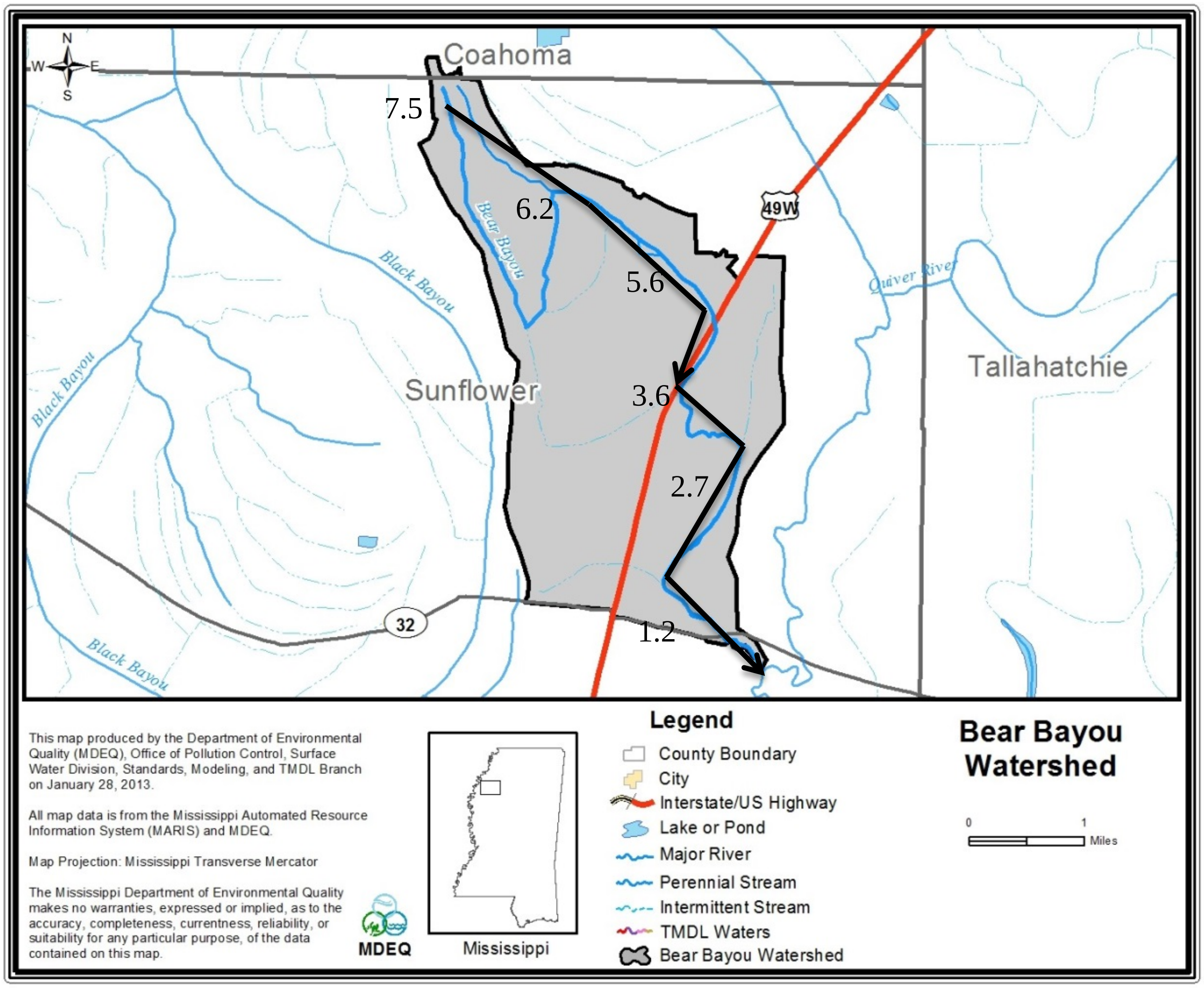

Figure 12. Model Segment with River Miles Shown

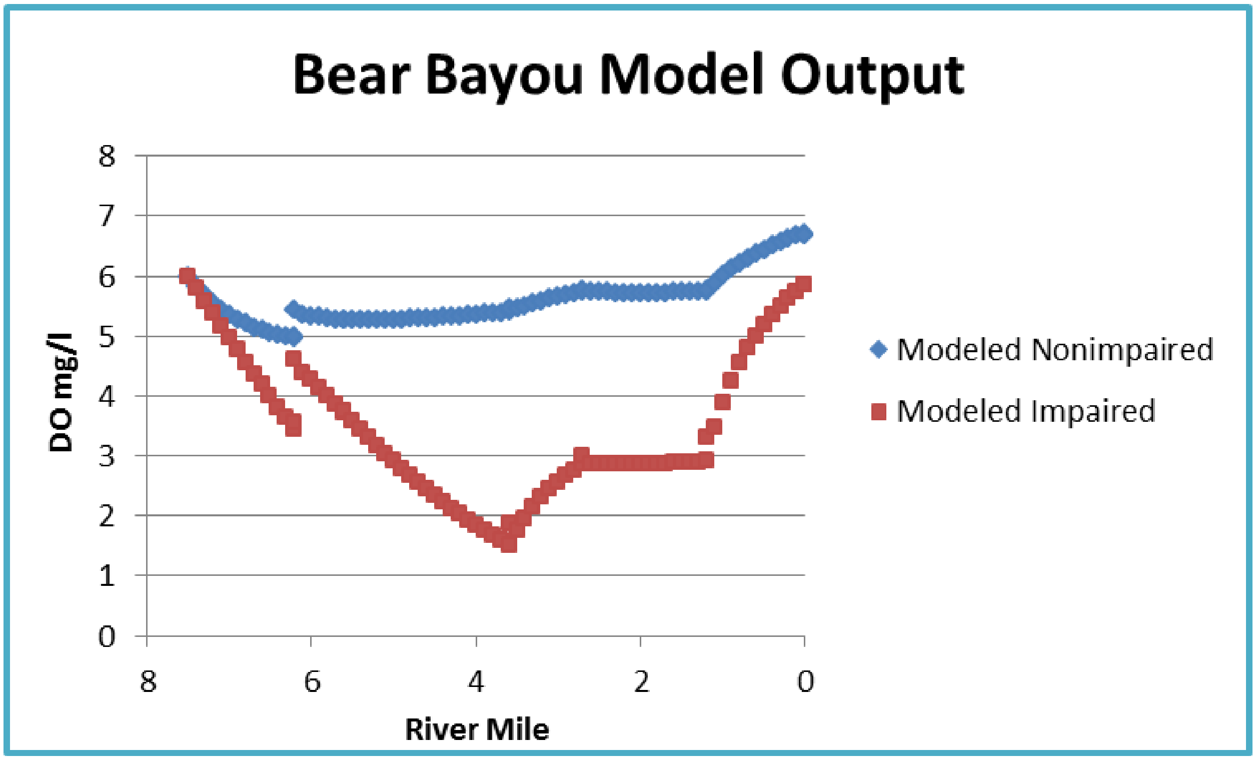

Figure 13, Output From Both Models

3.3 Source Representation

The background concentration used in modeling for $CBOD_5$ is 1.33 mg/l and for NH_3-N is 0.1 mg/l. These concentrations are used as estimates for the $CBOD_5$ and NH_3-N levels of water entering the water bodies through nonpoint source flow and tributaries. It is noted that because there were DO violations indicated, higher values of $CBOD_5$ and NH_3-N for the nonpoint source concentrations were used to reflect the measured instream average DO value. This was done to calibrate the model to the data.

Nonpoint source flows were included in the model to account for water entering due to groundwater infiltration, overland flow, and small, tributaries. The nonpoint source loads were assumed to be distributed evenly throughout the modeled reaches.

3.4 Model Results

As shown in Figure 13 above, the calibrated model (orange line) was below the water quality standard target of 5.0 mg/l of dissolved oxygen. The pollutant reduction model was set to match the standard (model output shown with the blue line). Table 7 shows the loads used in the calibrated model. Table 8 shows the pollutant reduction model loads. The TBODu shown in Table 8 is the TMDL for this stream, 30.09 lbs. per day. The percent reduction in the loads from Table 7 to Table 8 is 73.6%. This is the targeted reduction for this TMDL.

CBODu is calculated by multiplying the concentration in mg/L by the flow in cfs and a conversion factor of 5.39.

$$\text{CBODu (lbs/day)} = \text{CBODu mg/L} * \text{Flow (cfs)} * 5.39 \qquad \text{(Eq. 4)}$$

NBODu is similarly calculated with the addition of a multiplier of 4.57 which converts the equivalent oxygen load.

$$\text{NBODu (lbs/day)} = \text{NBODu mg/L} * \text{Flow (cfs)} * 5.39 * 4.57 \text{ lbs } O_2 \qquad \text{(Eq. 5)}$$

Table 7 Calibrated Model Loads

Segment	Flow (cfs)	CBODu (lbs/day)	NH3-N (mg/l)	NBODu (lbs/day)	TBODu (lbs/day)
7.5	0.21	22	0.11	0.57	22.57
6.2	0.26	17	0.11	0.70	17.70
5.6	0.04	16	0.1	0.10	16.10
3.6	0.45	16	0.1	1.11	17.11
2.7	0.65	16	0.1	1.60	17.60
1.2	2.84	16	0.1	6.77	22.77
Totals	4.36				113.86

Table 8 TMDL Loads

Segment	Flow (cfs)	CBODu (lbs/day)	NH3-N (mg/L)	NBODu (lbs/day)	TBODu (lbs/day)
7.5	0.21	8	0.11	0.57	8.57
6.2	0.26	3	0.11	0.70	3.70
5.6	0.04	2	0.1	0.10	2.10
3.6	0.45	2	0.1	1.11	3.11
2.7	0.65	2	0.1	1.60	3.60
1.2	2.75	2	0.1	7.01	9.01
Totals	4.36				30.09

ALLOCATION

The allocation for this TMDL involves the load reduction necessary for attainment of water quality standards in the Bear Bayou Watershed.

4.1 Wasteload Allocation

There is no point source included in the model for the Bear Bayou Watershed. The WLA is therefore zero.

4.2 Wasteload Allocation Stormwater

There is no MS4 designation in this watershed. The WLA for stormwater is zero.

4.3 Load Allocation

The load allocation for the TBODu TMDL is shown in Table 8 TMDL Loads. Because the water body indicates DO standard violations, loadings should be reduced to meet the standard.

4.4 Incorporation of a Margin of Safety

The margin of safety is a required component of a TMDL and accounts for the uncertainty about the relationship between pollutant loads and the quality of the receiving water body. The two types of MOS development are to implicitly incorporate the MOS using conservative model assumptions or to explicitly specify a portion of the total TMDL as the MOS. The MOS selected for this TMDL is implicit.

4.5 Calculation of the TMDL

The TMDL is calculated based on the following equation.

$$\text{TMDL} = \text{WLA} + \text{WLA}_{sw} + \text{LA} + \text{MOS} \qquad \text{(Eq. 6)}$$

where WLA is the Wasteload Allocation, WLAsw is Wasteload Allocation from stormwater activities, LA is the Load Allocation, and MOS is the Margin of Safety.

Table 9. TBODu TMDL

	WLA (lbs/day)	WLAsw (lbs/day)	LA (lbs/day)	MOS (lbs/day)
CBODu	0	0	19.0	Implicit
NBODu	0	0	11.09	Implicit
TBODu	0	0	30.09	Implicit

4.6 Seasonality and Critical Condition

This TMDL accounts for seasonal variability by requiring allocations that ensure year-round protection of water quality standards, including during critical conditions.

CONCLUSION

A 73.6% reduction of organic enrichment loading is necessary to meet the dissolved oxygen water quality standard based on the STREAM model. This reduction may not be possible due to the land use in this agricultural watershed. There are no point sources to be reduced. The reduction has to come from nonpoint sources. Best management practices are encouraged to reduce sediment and nutrients from leaving the fields. These will help reduce the organic load as well.

The natural condition of this watershed may be better defined in the future with a modified designated use for this stream. Aquatic life were observed in the stream and it is believed that the stream is supportive of aquatic life in its current condition, but due to MDEQ's water quality standard, the stream will be unable to ever meet a minimum of 4.0 mg/l of dissolved oxygen during the hot summer conditions. Recognition of this fact and a more appropriate designation of this stream as an agricultural drainage stream may return this stream to a fully supporting designation.

5.1 Best Management Practices

For land disturbing activities related to silviculture, construction, and agriculture, it is recommended that practices, as outlined in "Mississippi's BMPs: Best Management Practices for Forestry in Mississippi" (MFC, 2008), "NPS Field Manual For Erosion And Sediment Control Version 2." (MDEQ, et. al, 2011), and "Field Office Technical Guide" (NRCS, 2012), be followed, respectively.

5.2 Public Participation

This TMDL will be published for a 30-day public notice. During this time, the public will be notified by publication in the statewide newspaper. The public will be given an opportunity to review the TMDLs and submit comments. MDEQ also distributes all TMDLs at the beginning of the public notice to those members of the public who have requested to be included on a TMDL mailing list. Anyone wishing to become a member of the TMDL mailing list should contact Greg Jackson at Greg_Jackson@deq.state.ms.us.

All comments should be directed to Greg_Jackson@deq.state.ms.us or Greg Jackson, MDEQ, PO Box 2261, Jackson, MS 39225. All comments received during the public notice period and at any public hearings become a part of the record of this TMDL and will be considered in the submission of this TMDL to EPA Region 4 for final approval.

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