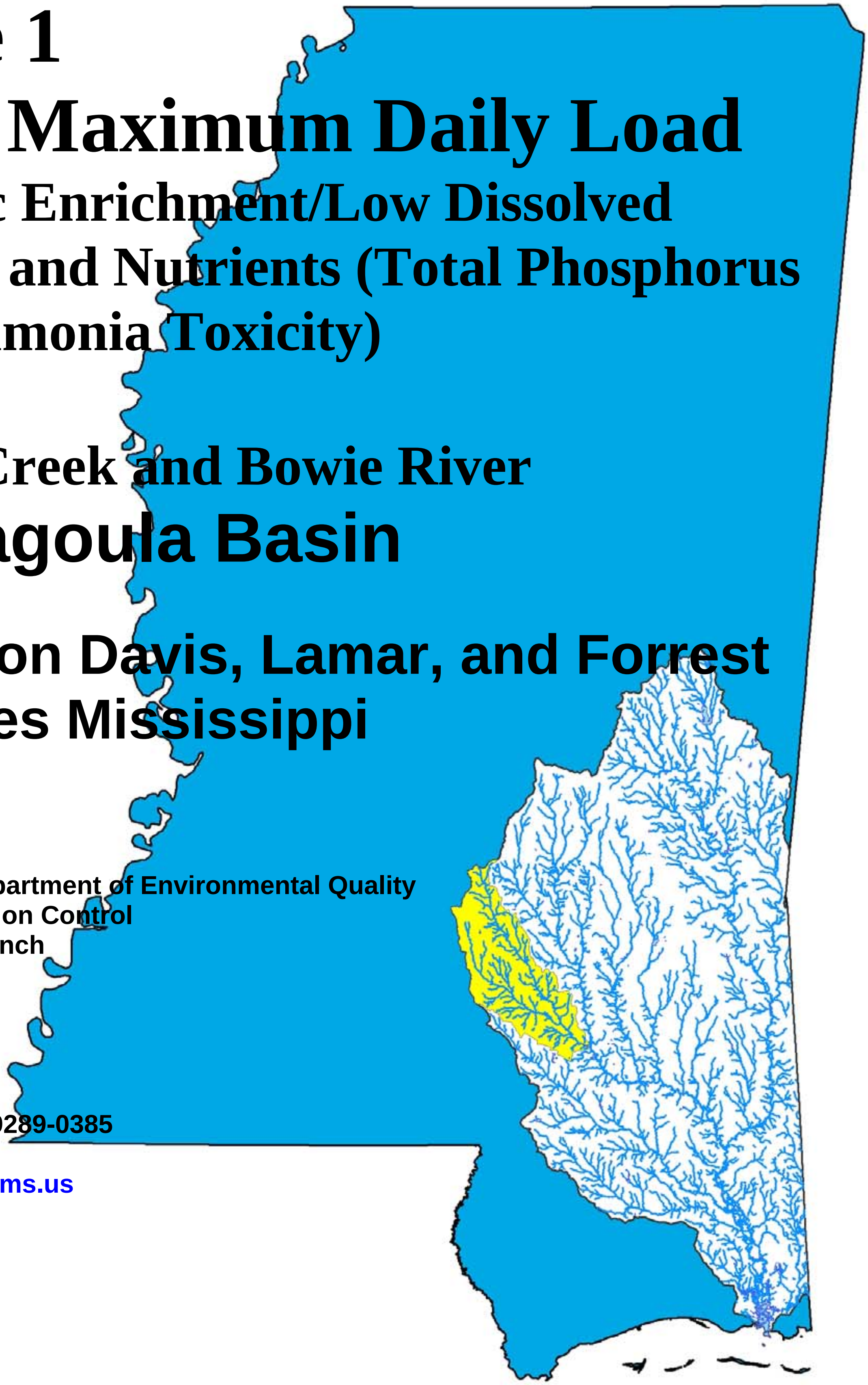
FINAL REPORT
June 2005
ID: 405063002

Phase 1
Total Maximum Daily Load
Organic Enrichment/Low Dissolved Oxygen and Nutrients (Total Phosphorus and Ammonia Toxicity)

Bowie Creek and Bowie River
Pascagoula Basin

Jefferson Davis, Lamar, and Forrest Counties Mississippi



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FOREWORD

This report has been prepared in accordance with the schedule contained within the federal consent decree dated December 22, 1998. The report contains one or more Total Maximum Daily Loads (TMDLs) for water body segments found on Mississippi's 1996 §303(d) List of Impaired Waterbodies. Because of the accelerated schedule required by the consent decree, many of these TMDLs have been prepared out of sequence with the State's rotating basin approach. The implementation of the TMDLs contained herein will be prioritized within Mississippi's rotating basin approach.

The amount and quality of the data on which this report is based are limited. As additional information becomes available, the TMDLs may be updated. Such additional information may include water quality and quantity data, changes in pollutant loadings, or changes in landuse within the watershed. In some cases, additional water quality data may indicate that no impairment exists.

Conversion Factors

To convert from	To	Multiply by	To convert from	To	Multiply by
mile^2	acre	640	acre	ft^2	43560
km^2	acre	247.1	days	seconds	86400
m^3	ft^3	35.3	meters	feet	3.28
ft^3	gallons	7.48	ft^3	gallons	7.48
ft^3	liters	28.3	hectares	acres	2.47
cfs	gal/min	448.8	miles	meters	1609.3
cfs	MGD	0.646	tonnes	tons	1.1
m^3	gallons	264.2	µg/l * cfs	gm/day	2.45
m^3	liters	1000	µg/l * MGD	gm/day	3.79

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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TMDL INFORMATION PAGE

i. Listing Information

Name	ID	County	HUC	Cause	Mon/Eval
Bowie Creek	MS083E	Jefferson Davis	03170004	Organic Enrichment/Low DO and Nutrients	Evaluated
At Dean, from confluence with Dry Creek to confluence with Terrible Creek					
Bowie River	MS085E	Lamar and Forrest	03170004	Organic Enrichment/Low DO and Nutrients	Evaluated
Near Hattiesburg, from the confluence of Okatoma Creek to mouth at Leaf River					

ii. Water Quality Standard

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
Nutrients	Aquatic Life Support	Waters shall be free from materials attributable to municipal, industrial, agricultural or other discharges producing color, odor, taste, total suspended or dissolved solids, sediment, turbidity, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation or to aquatic life and wildlife or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated use.

iii. NPDES Facilities

NPDES ID	Facility Name	Permitted Discharge (MGD)	Receiving Water
MS0038792	Lakewood Estates Subdivision	0.128	Big Creek
MS0039004	Creekwood Subdivision	0.063	Big Creek
MS0022314	North Haven Subdivision	0.160	Tributary of Mineral Creek
MS0031801	Westover West Subdivision	0.140	Mixon Creek
MS0020826	Hattiesburg North	4.000	Bowie River
MS0055140	Trace Subdivison Number 4	0.043	Tributary of Cross Creek
MS0050172	Serene Hills Subdivision	0.028	Mineral Creek
MS0051080	The Trace Subdivision First Addition	0.102	Tributary of Mixon Creek
MS0053660	Great Southern National Bank	0.0005	Tributary of Mixon Creek
MS0047473	Pecan Grove Trailer Park	0.004	Tributary of Mixon Creek
MS0037176	Al Casco Custom Cutting and Wrap	0.003	Unnamed Tributary of Bowie Creek
MS0039331	A1 Trailer Park	0.005	Tributary of Mixon Creek
MS0035874	Lamar Villa Apartments	0.010	Tributary of Mixon Creek
MS0056413	Crossland Road Subdivision	0.043	Tributary of Tick Creek thence Bowie Creek

iv. Phase 1 Total Maximum Daily Loads for TBODu and Total Phosphorus

WLA (lbs/day)	LA (lbs/day)	MOS	TMDL (lbs/day)
2,145 TBODu	**2,577 TBODu**	**24,226 TBODu**	**28,948 TBODu**

EXECUTIVE SUMMARY

This TMDL has been developed for segments of Bowie Creek and Bowie River that have been placed on the Mississippi 2004 §303(d) List of Water Bodies as evaluated water body segments. Segments of Bowie Creek and Bowie River were originally placed on the §303(d) List based on anecdotal information. Mississippi conducted a survey of district conservationists (DC) in 1988 and 1989 to find candidate watersheds for future §319 funding opportunities. MDEQ requested each DC identify the watersheds of concern in their county based on available information including land use. Numerous DCs responded to the survey, and MDEQ created Mississippi's §319 list based on these surveys.

Bowie Creek and Bowie River are listed due to organic enrichment/low dissolved oxygen and nutrients. The applicable state standard specifies that the 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. Mississippi currently does not have standards for allowable nutrient concentrations, so a TMDL specifically for nutrients will not be developed. However, because elevated levels of nutrients may cause low levels of dissolved oxygen, the TMDL developed for dissolved oxygen also addresses the potential impact of elevated nutrients in the water bodies. In addition, recently collected data indicate that elevated nutrients may not be a significant concern in Bowie River. Ammonia nitrogen levels will be evaluated in this TMDL using criteria established for ammonia nitrogen toxicity. Additionally this TMDL will estimate the total phosphorus load in the stream and a preliminary breakpoint between point and nonpoint sources. This TMDL has been developed as a phase 1 TMDL so that when more data are available and nutrient water quality standards are developed phase 2 could address nitrogen and/or phosphorus loads as needed.

The Bowie River Watershed is located in southeastern Mississippi in HUC 03170004. The headwaters of Bowie Creek begin near Magee, MS in Simpson County. The creek flows for approximately 40 miles in a southeastern direction. The Bowie River is formed in Forrest County, north of the city of Hattiesburg, with the confluence of Okatoma Creek and Bowie Creek. It continues in a southeastern direction for approximately 10 miles to its confluence with the Leaf River east of Hattiesburg. The 303(d) listed segment of Bowie Creek begins at the confluence of Dry Creek in Covington County and ends approximately 9 miles downstream at the confluence of Terrible Creek. The listed segment of the Bowie River, Photo 1, begins at the confluence Okatoma Creek in Forrest County and ends approximately 10 miles downstream at the confluence with the Leaf River. The locations of the watershed and §303(d) listed segments are shown in Figure 1.

Photo 1. Bowie River near Hattiesburg

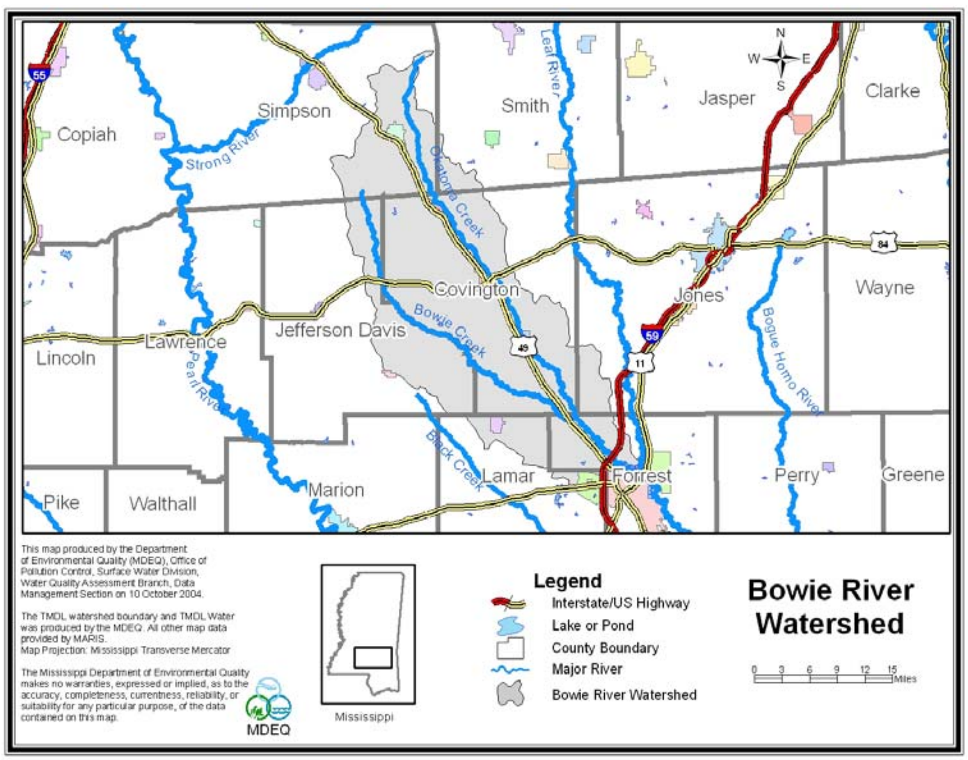


Figure 1. Bowie River Watershed

The predictive model used to calculate this TMDL is based on limited water quality data from a recent study along with assumptions described in MDEQ Regulations. A modified Streeter-Phelps dissolved oxygen sag model was selected as the modeling framework for developing the TMDL allocations for this study. A mass-balance approach was used to ensure that the instream concentration of ammonia nitrogen (NH_3-N) did not exceed the water quality criteria. The critical modeling period was determined to occur during the hot, dry summer period.

The TMDL for organic enrichment was quantified in terms of total ultimate biochemical oxygen demand (TBODu). The model used in developing this TMDL included both non-point and point sources of TBODu in the Bowie River Watershed. TBODu loading from non-point sources in the watershed was accounted for by using an estimated background concentration of TBODu. There are several NPDES Permitted discharges located in the watershed that are included as point sources in the model. The model results showed that the DO levels in Bowie Creek and Bowie River are above water quality standards. However, model results indicated that water quality standards for dissolved oxygen are not met during critical condition in two unnamed tributaries of Mineral Creek and Mixon Creek thence the Bowie River as a result of two existing point source dischargers. Because there are no data available for these tributaries, this TMDL recommends that additional monitoring be conducted to determine the actual condition of the unnamed tributaries. Expansions of the existing facilities or construction of additional facilities in these tributaries should not be allowed until additional data are available.

INTRODUCTION

1.1 Background

Segments of Bowie Creek and Bowie River were originally placed on the §303(d) List based on anecdotal information. Mississippi conducted a survey of district conservationists (DC) in 1988 and 1989 to find candidate watersheds for future §319 funding opportunities. MDEQ requested each DC identify the watersheds of concern in their county based on available information including land use. Numerous DCs responded to the survey, and MDEQ created Mississippi's §319 list based on these surveys.

In 1992, MDEQ compiled a §303(d) List based, in part, on the §319 List of watersheds of concern. Therefore, water bodies were included on the §303(d) List based on speculation and not water quality monitoring. MDEQ uses the term "evaluated" to describe these water bodies that were placed on the §303(d) List without monitoring data. At the time, MDEQ considered the evaluated listings from the §319 survey as a placeholder for future monitoring to determine if there was impairment in the watershed.

The surveys asked for the presence of agriculture, urban areas, or forestry in the watershed. MDEQ interpreted potential pollutants present on these land uses and listed several broad potential pollutant categories based on the survey results. Every watershed, for which agriculture was checked, was listed for several pollutants, including sediment, pesticides, organic enrichment/low dissolved oxygen, and nutrients. Segments of Bowie Creek and Bowie River were listed for organic enrichment/low DO, nutrients, and siltation based on the survey results.

To further complicate the situation, nutrients were listed as an impairment even though there are no state criteria in Mississippi for nutrients. These criteria are currently being developed by the Mississippi Nutrient Task Force (NTF) in agreement with EPA Region 4. MDEQ has a work plan for nutrient criteria development approved by EPA and is on schedule according to the approved plan in development of nutrient criteria (MDEQ, 2004). Data have been collected for wadeable streams to be used to calculate the criteria.

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 §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 restore and maintain the quality of those impaired water bodies through the establishment of pollutant specific allowable loads. This TMDL has been developed for the 303(d) listed segments shown in Figure 2.

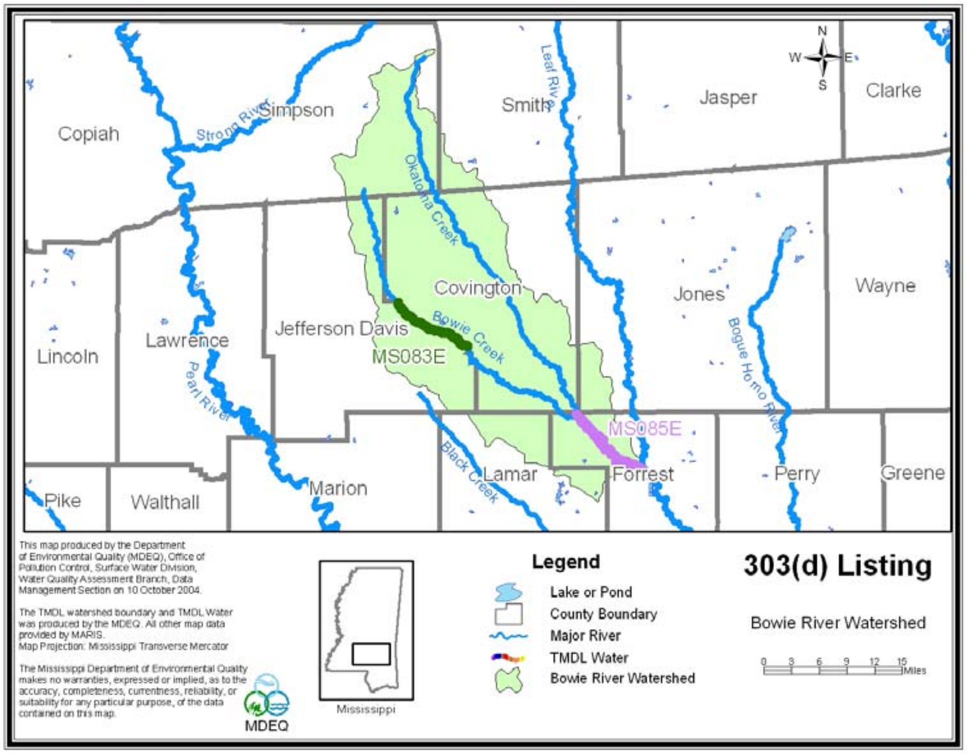


Figure 2. Bowie River Watershed 303(d) Listed Segments

1.2 Applicable Water Body Segment Use

The water use classifications are established by the State of Mississippi in the document *Water Quality Criteria for Intrastate, Interstate and Coastal Waters* (MDEQ, 2002). The designated beneficial use for part of the listed segment of Bowie Creek is fish and wildlife support. Bowie Creek beginning at Highway 589 is classified for use as recreation. Bowie River is also classified for use as recreation from the confluence of Bowie Creek to Highway 59. The segment downstream of Highway 59 is designated for use as fish and wildlife support.

1.3 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* (MDEQ, 2002). The applicable standard specifies that the dissolved oxygen (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. This water quality standard will be used as a targeted endpoint to evaluate impairments and establish this TMDL.

The water quality standard for ammonia nitrogen toxicity is also included in this TMDL. Ammonia nitrogen concentrations can be evaluated using the criteria given in 1999 Update of Ambient Water Quality Criteria for Ammonia (EPA-822-R-99-014). The maximum allowable instream ammonia nitrogen (NH_3-N) concentration at a pH of 7.0 and stream temperature of 26°C is 2.82 mg/l.

Mississippi's NTF is currently in the process of developing numeric criteria for nutrients. The current standards only contain a narrative criteria that can be applied to nutrients which states that *"Waters shall be free from materials attributable to municipal, industrial, agricultural, or other discharges producing color, odor, taste, total suspended or dissolved solids, sediment, turbidity, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation or to aquatic life and wildlife or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated use."*

In the *1999 Protocol for Developing Nutrient TMDLs,* EPA suggests several methods for the development of numeric criteria for nutrients (EPA, 1999). In accordance with the 1999 Protocol, *"The target value for the chosen indicator can be based on: comparison to similar but unimpaired waters; user surveys; empirical data summarized in classification systems; literature values; or best professional judgment"*. MDEQ believes the most economical and scientifically defensible method for use in Mississippi is a comparison between similar but unimpaired waters within the same region. This method is dependent on adequate data which are being collected in accordance with the EPA approved plan.

1.4 Selection of a Critical Condition

The critical condition represents the hydrologic and atmospheric conditions in which the pollutants causing impairment of a water body have their greatest potential for adverse effects. Low DO due to elevated levels of nutrients and organic material typically occurs during seasonal low-flow, high-temperature periods during the late summer and early fall. Elevated oxygen demand and ammonia nitrogen is of primary concern during low-flow periods because the effects of minimum dilution and high temperatures combine to produce the worst-case potential effect on water quality (USEPA, 1997). The flow at critical conditions is typically defined as the 7Q10 flow, which is the lowest flow for seven consecutive days expected during a 10-year period. The low flow condition for the Leaf River was determined based on data from several USGS gages and information given in *Techniques for Estimating 7-Day, 10-Year Low-Flow Characteristics on Streams in Mississippi* (Telis, 1992).

1.5 Selection of a TMDL Endpoint

One of the major components of a TMDL is the establishment of instream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. Instream numeric endpoints, therefore, represent the water quality goals that are to be achieved by meeting the load and wasteload allocations specified in the TMDL. The endpoints allow for a comparison between observed instream conditions and conditions that are expected to restore designated uses. The instream DO target for this TMDL is a daily average of not less than 5.0 mg/l. The instantaneous minimum portion of the DO standard was considered when establishing the instream target for this TMDL. However, it was determined that using the daily average standard with the conservative modeling assumptions would protect the instantaneous minimum standard. The daily average choice is supported by the use of the existing modeling tools in a desktop modeling exercise such as this. More specific modeling and calibration are needed in order to obtain diurnal oxygen levels with any expectation of accuracy. Therefore, based on the limited data available and the relative simplicity of the model, the daily average target is appropriate.

The maximum impact of oxidation of organic material is generally not at the location of the sources, but at some distance downstream, where the maximum DO deficit occurs. The DO deficit is defined as the difference between the DO concentration at 100% saturation and the actual DO. The point of maximum DO deficit, also called the DO sag, will be used to define the endpoint required for this TMDL. The endpoint for this TMDL will be based on a daily average of not less than 5.0 mg/l at the DO sag location during critical conditions.

The TMDL for DO will be quantified in terms of organic enrichment. Organic enrichment is measured in terms of total ultimate biochemical oxygen demand (TBODu). TBODu represents the oxygen consumed by microorganisms while stabilizing or degrading carbonaceous and nitrogenous compounds under aerobic conditions over an extended time period. The carbonaceous compounds are referred to as CBODu, and the nitrogenous compounds are referred to as NBODu. TBODu is equal to the sum of NBODu and CBODu, Equation 1.

$$\mathbf{TBODu = CBODu + NBODu} \qquad \textbf{(Equation 1)}$$

WATER BODY ASSESSMENT

This TMDL Report includes an analysis of available water quality data and the identification of all known potential pollutant sources in the Bowie River Watershed. The potential point and non-point pollutant sources were characterized by the best available information, monitoring data, and literature values.

2.1 Discussion of Instream Water Quality Data

Data for the Bowie River Watershed are available for several routine monitoring stations as well as special studies. There were several historical special studies as well as a recently-conducted water quality study for a segment of the Bowie River near Hattiesburg. The data are discussed in the following sections.

2.1.1 Monitoring Data

There are several sources of data available for Bowie Creek and Bowie River. The most recent available data were collected by MDEQ at Bowie Creek near Sumrall at Highway 589 (02472420). Data collected from February 1997 through December 2001 are available at this station. The location of this monitoring station along with several others is shown in Figure 3. The data for dissolved oxygen and ammonia nitrogen for station 02472420 are given in Table 1. Note that none of the values in Table 1 show violations of water quality standards for dissolved oxygen. However, this may be due to the samples being collected once per day and may not reflect the diurnal DO variations that naturally occur in water bodies.

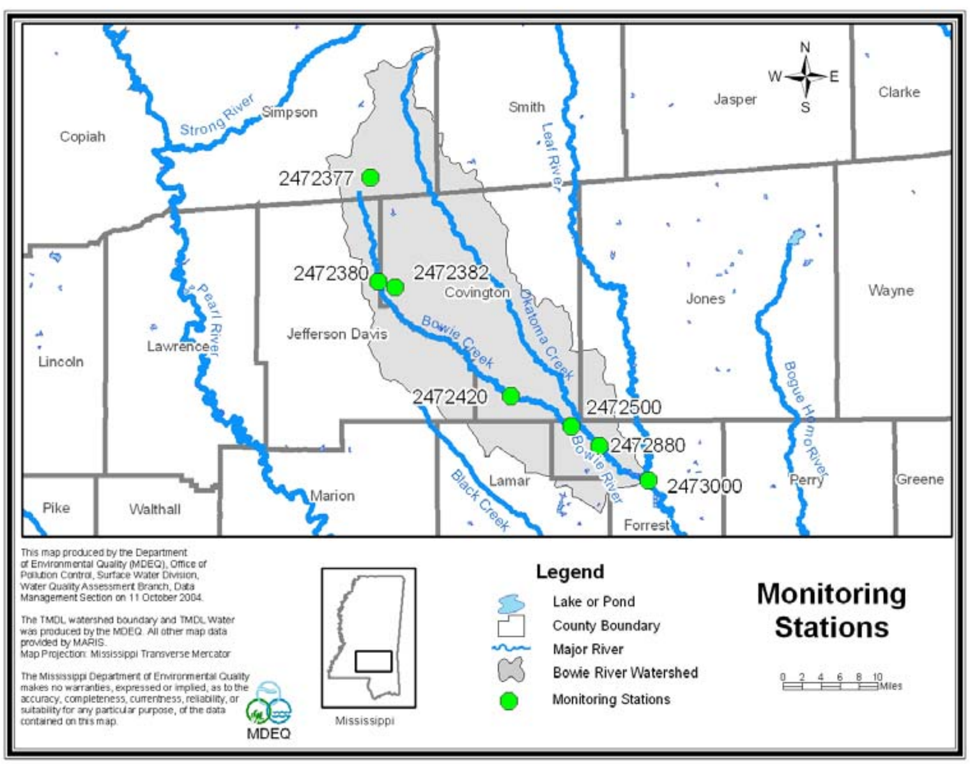


Figure 3. Bowie River Monitoring Stations

Table 1. Water Quality Data Collected at Bowie Creek near Sumrall (02472420)

Sample Date	Time	Dissolved Oxygen (mg/l)	Total Phosphorus (mg/l)	Ammonia Nitrogen (mg/l)
6-Feb-97	9:02	9.40	0.04	0.20
6-Mar-97	9:15	9.20	0.1	0.18
7-Apr-97	9:08	8.02	0.05	0.19
8-May-97	10:17	9.40	0.06	0.14
4-Jun-97	9:25	7.10	0.02	0.15
2-Jul-97	10:30	6.60	0.21	0.12
5-Aug-97	10:02	8.27	0.06	0.10
3-Sep-97	10:47	7.73	0.01	0.21
1-Oct-97	10:28	8.42	0.03	0.08
12-Nov-97	10:45	8.17	0.04	0.22
3-Dec-97	9:59	9.84	0.01	0.10
5-Jan-98	11:13	9.41	0.23	0.43
2-Feb-98	10:32	11.01	0.08	0.10
2-Mar-98	10:42	9.03	0.06	0.24
7-Apr-98	11:28	9.33	0.03	0.14
1-Jun-98	10:21	7.92	0.05	0.12
7-Jul-98	10:33	7.95	0.05	0.10
12-Aug-98	10:47	8.04	0.06	0.10
14-Sep-98	10:41	8.05	0.04	0.10
6-Oct-98	11:05	7.86	0.24	0.11
9-Nov-98	10:34	10.58	0.05	0.10
3-Dec-98	9:40	8.65	0.02	0.10
25-Jan-99	11:02	9.97	0.05	0.23
17-Feb-99	10:12	9.95	0.03	0.11
9-Mar-99	10:05	8.73	0.12	0.31
29-Mar-99	10:36	9.39	0.03	0.10
5-May-99	10:00	9.17	0.14	0.10
3-Jun-99	9:53	8.10	0.08	0.10
1-Jul-99	10:40	7.70	0.09	0.25
4-Aug-99	11:50	8.76	0.01	0.32
16-Sep-99	11:45	8.73	0.03	0.59
11-Oct-99	10:33	7.24	0.11	0.80
23-Nov-99	11:35	10.84	0.03	0.78
13-Dec-99	10:41	9.25	0.01	0.14
10-Jan-00	10:10	8.84	0.1	0.18
17-Feb-00	10:00	9.44	0.06	0.12
4-Apr-00	10:45	7.82	0.14	0.29
2-May-00	10:35	9.55	0.03	0.10
15-Jun-00	10:20	8.33	0.05	0.10
12-Jul-00	11:20	8.07	0.04	0.43
26-Sep-00	10:49	8.82	0.04	0.18
12-Oct-00	10:51	10.43	0.02	0.16
8-Nov-00	10:30	12.21	0.02	0.13
5-Dec-00	11:02	11.11	0.01	0.21
9-Apr-01	11:17	8.18	0.05	0.18
7-May-01	11:12	9.20	0.05	0.16
4-Jun-01	11:25	8.24	0.08	0.14
9-Jul-01	11:25	7.85	0.02	--
25-Sep-01	13:08	8.71	0.05	0.10
11-Oct-01	11:27	8.81	0.01	0.10
6-Dec-01	10:47	9.66	0.03	0.10

Additional monitoring data are available for MDEQ stations located at Bowie Creek near Mt Carmel (02472380) and Bowie Creek near Hattiesburg (02472500). Data from Bowie Creek near Mt Carmel are available from June 1997 and December 1997. Data at the Bowie Creek near Hattiesburg were collected by MDEQ beginning in January 1994 and ending in December 1997. The recently collected data from these stations are given in Tables 2 and 3.

Table 2. Water Quality Data Collected at Bowie Creek near Mt Carmel (02472380)

Sample Date	Time	Dissolved Oxygen (mg/l)	Total Phosphorus (mg/l)	Ammonia Nitrogen (mg/l)
23-Jun-97	10:38	8.22	.01	0.10
10-Dec-97	10:32	8.20	.10	0.18

Table 3. Water Quality Data Collected at Bowie Creek near Hattiesburg (02472500)

Sample Date	Time	Dissolved Oxygen (mg/l)	Total Phosphorus (mg/l)	Ammonia Nitrogen (mg/l)
12-Jan-94	12:50	10.30	0.01	--
6-Mar-94	12:09	11.00	0.06	--
5-May-94	12:37	7.50	0.07	--
20-Jun-94	12:00	6.40	0.05	--
23-Aug-94	12:45	7.90	0.04	--
7-Nov-94	12:20	9.30	0.01	--
9-Jan-95	12:10	11.20	0.08	--
6-Mar-95	11:50	9.90	0.09	--
17-Apr-95	11:30	8.30	0.01	--
10-Jul-95	11:45	7.50	0.03	--
11-Sep-95	11:30	7.60	0.01	--
8-Nov-95	11:50	7.70	0.03	--
9-Jan-96	12:10	10.20	0.05	--
4-Mar-96	11:40	8.00	0.05	--
6-May-96	12:30	7.80	0.08	--
9-Jul-96	11:00	7.70	0.09	--
10-Sep-96	12:45	6.70	0.02	--
9-Dec-96	11:44	7.60	0.03	0.10
9-Jan-97	8:33	12.00	0.1	0.10
23-Jun-97	15:40	7.56	0.14	0.11
16-Dec-97	12:50	12.23	0.03	0.13

USGS collected data at several locations including the Bowie River at Rawls Springs (02472880). Most of the data at this station were collected during the 1970's. Historical data from EPA's Storet Database are also available for several additional sites in the Bowie River Watershed. The station locations, dates of data collection for the historical monitoring stations are given in Table 4 below. These historical data are not included in this report.

Table 4. Historical Monitoring Stations

Station Number	Location	Agency	Dates
275220	Bowie River near Hattiesburg at I-59	EPA Region 4	May 1965 – August 1965
275350	Bowie Creek northwest of Hattiesburg on US 4	EPA Region 4	May 1965 – September 1965
2472880	Bowie River at Rawls Springs	USGS	August 1975 – June 1977

2.1.2 Special Studies

In preparation for the development of the TMDL, MDEQ conducted a study on the Bowie River on September 27 – 29, 2004. The study focused on the area of Bowie River near Hattiesburg, from the Interstate 59 Bridge to just below the confluence of Mixon Creek. The data collected were used in setting up the water quality model of Bowie River near the outfall of the Hattiesburg North POTW.

During the study, monitoring data were collected at three stations on the Bowie River; 1) upstream of the Hattiesburg North POTW, 2) downstream of the Hattiesburg North POTW, and 3) above the gravel pit area near Hattiesburg, just downstream from the confluence of Mixon Creek (labeled as “ponded area” on Figure 4). The monitoring station locations are shown in Figure 4. In-situ measurements of DO, DO saturation, pH, temperature, and conductivity were collected for a 24-hour period at each station. Water samples for BOD_5, NH_3-N, total phosphorous, total Kjeldahl nitrogen, nitrite + nitrate nitrogen, total organic carbon, and turbidity were collected from the three instream monitoring stations and from the Hattiesburg North POTW. A 24-hour composite sample from the Hattiesburg North POTW was analyzed for ultimate BOD. The study also included a time-of-travel study to estimate water velocity. Data collected during this study were used in calibrating the water quality model for this section of the Bowie River.

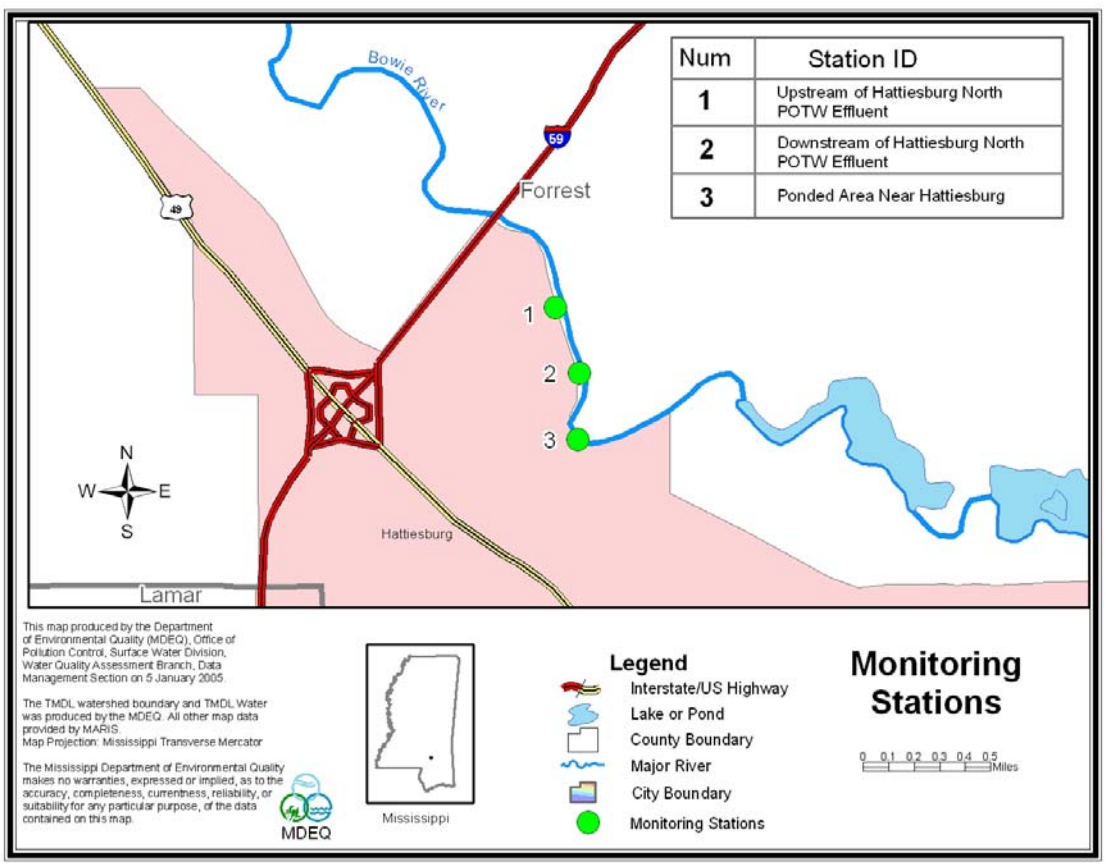


Figure 4. Monitoring Station Locations, September 2004

Flow and precipitation during the study were monitored at two USGS gaging stations located on Bowie Creek near Hattiesburg (02472500) and Okatoama Creek at Sanford (02472850). The gage on Bowie Creek is located just above the confluence of Bowie Creek with Okatoma Creek. The gage on Okatoma Creek is located near the mouth of Okatoma Creek. The average flows during the study period from these two gages (Bowie Creek = 137.8 cfs, Okatoma Creek = 98.7 cfs) were summed to estimate the flow in the Bowie River below the confluence of Bowie River and Okatoma Creek, approximately 236.5 cfs. There was no precipitation measured during the study period. The flows at both gages were steady and varied less than 3 cfs during the study period.

Data collected at the instream monitoring stations are given below. Table 5 contains a summary of the in-situ parameters dissolved oxygen and temperature. The DO values ranged between 80 and 100 percent saturation over the 24-hour period in which they were measured. The DO values measured during the study were above the water quality standard for DO. Water chemistry data are given in Table 6. Four water chemistry samples were collected at each station at mid-depth during the study. All of the samples for BOD_5 and NH_3-N were below the minimum detection levels. The nutrient levels measured at all of the stations were similar, and did not increase below the Hattiesburg North POTW outfall. The low levels of TKN, Nitrite + Nitrate Nitrogen, and Total Phosphorous measured during the study indicate that this section of the Bowie River may not be impaired due to nutrients. However, because the data were collected over a single 24-hour period under one flow condition, this conclusion cannot be applied to all flow conditions.

Table 5. In-Situ Monitoring Data, Bowie River Near Hattiesburg, September 28-29, 2004

Station	Average DO (mg/l)	Maximum DO (mg/l)	Minimum DO (mg/l)	Average Temp. (°C)	Maximum Temp (°C)	Minimum Temp. (°C)
Upstream of Hattiesburg North POTW	8.2	9.0	7.5	23.5	24.3	22.1
Downstream of Hattiesburg North	8.2	9.0	7.7	23.6	24.6	22.2
Below the Confluence with Mixon Creek	7.7	8.7	7.3	23.6	24.6	22.3

Table 6. Instream Monitoring Data, Bowie River Near Hattiesburg, September 28-29, 2004

Station	Date/Time	BOD_5 (mg/l)	NH_3-N (mg/l)	TKN (mg/l)	Nitrite + Nitrate N (mg/l)	Total Phosphorous (mg/l)
Upstream of Hattiesburg North POTW Effluent	9/28/04 9:00	< 2	< 0.10	0.25	0.64	0.08
	9/28/04 17:00	< 2	< 0.10	0.34	0.63	0.07
	9/28/04 0:00	< 2	< 0.10	0.32	0.61	0.05
	9/29/04 9:00	< 2	< 0.10	0.39	0.57	0.08
Downstream of Hattiesburg North POTW Effluent	9/28/04 8:30	< 2	< 0.10	0.25	0.62	0.08
	9/28/04 16:30	< 2	< 0.10	0.33	0.60	0.09
	9/28/04 23:15	< 2	< 0.10	0.38	0.61	0.05
	9/29/04 8:30	< 2	< 0.10	0.35	0.64	0.08
Above Ponded Area near Hattiesburg	9/28/04 7:30	< 2	< 0.10	0.20	0.64	0.07
	9/28/04 15:30	< 2	< 0.10	0.39	0.62	0.07
	9/28/04 23:00	< 2	< 0.10	0.38	0.62	0.09
	9/29/04 8:00	< 2	< 0.10	0.32	0.66	0.07

Data from the Hattiesburg North POTW effluent are given in Table 7 and Table 8. The data in Table 8 are based on analysis of a 24-hour composite sample of effluent. The study is described in detail, and all of the available data are given in the report *Waste Load Allocation Studies: Bowie River Near Hattiesburg (September 27 -29, 2004)* (MDEQ, 2005).

Table 7. Effluent Monitoring Data, Hattiesburg POTW, September 29, 2004

Station	Date/Time	DO (mg/l)	Temp. (°C)
Hattiesburg POTW Effluent	9/29/04 07:15	5.7	23.8

Table 8. Effluent Monitoring Data, Hattiesburg POTW, September 28-29, 2004

Station	Date/Time	BOD_5 (mg/l)	CBODu (mg/l)	NH_3-N (mg/l)	TKN (mg/l)	Nitrite + Nitrate N (mg/l)	Total Phosphorous (mg/l)
Hattiesburg POTW Effluent	9/28/04 08:30 through 9/29/04 08:30	14	22	0.13	3.02	4.06	4.01

There are two additional studies that were conducted in this section of the Bowie River during the 1990's. The first was a site investigation related to the industry Hercules, Inc, which was discharging into an unnamed tributary of Bowie River downstream from Glendale Road. The location of Glendale Road is shown on Figure 5. The study, conducted in November 1996, was in response to a complaint regarding odors and discoloration in the unnamed tributary due to effluent discharged to the tributary from the industry. During the study, it was found that water quality in the unnamed ditch was poor due to low dissolved oxygen and elevated solids and turbidity. Since this time, however, the wastewater treatment process used by the industry has been improved. The industrial wastewater from this facility is now treated through the City of Hattiesburg's POTWs. Presently, only non-contact cooling water and stormwater from the site are discharged into the unnamed tributary.

The second study of the Bowie River focused on the water quality and biological effects of the sand and gravel mining operations in Hattiesburg. American Sand and Gravel (now called Standard Gravel) has been in operation for many years. Instream mining conducted by this company created a series of pits both within the river and beside the river with depths up to 60 ft. EPA and the Corps of Engineers conducted a study of this area in June and July 1995 in response to concern for the environmental effects of the mining operations. An aerial photograph of the area of the river modified by the mining activities is shown in Figure 5.

Data collected during this study included measurement of in-situ parameters, water chemistry sampling, and biological monitoring at stations upstream and downstream of the mined areas. Sampling also included gravel pits that were located within the river and beside the river (not directly aligned with the river channel). The pits not aligned with the river channel, however, are not natural water bodies because they were created by the mining activities. Data showed that gravel pits beside the river were stratified with respect to temperature and DO. Exceedences of the DO standards occurred only in the pits that were not aligned with the river channel. Elevated nutrients and increased algal production were also detected in the gravel mining areas that were separated from the river channel. The biological evaluation showed a decline in habitat quality and diversity of benthic macroinvertebrates in the stations downstream of the mining areas due to the effects of excess sedimentation (EPA Region IV, 1996).

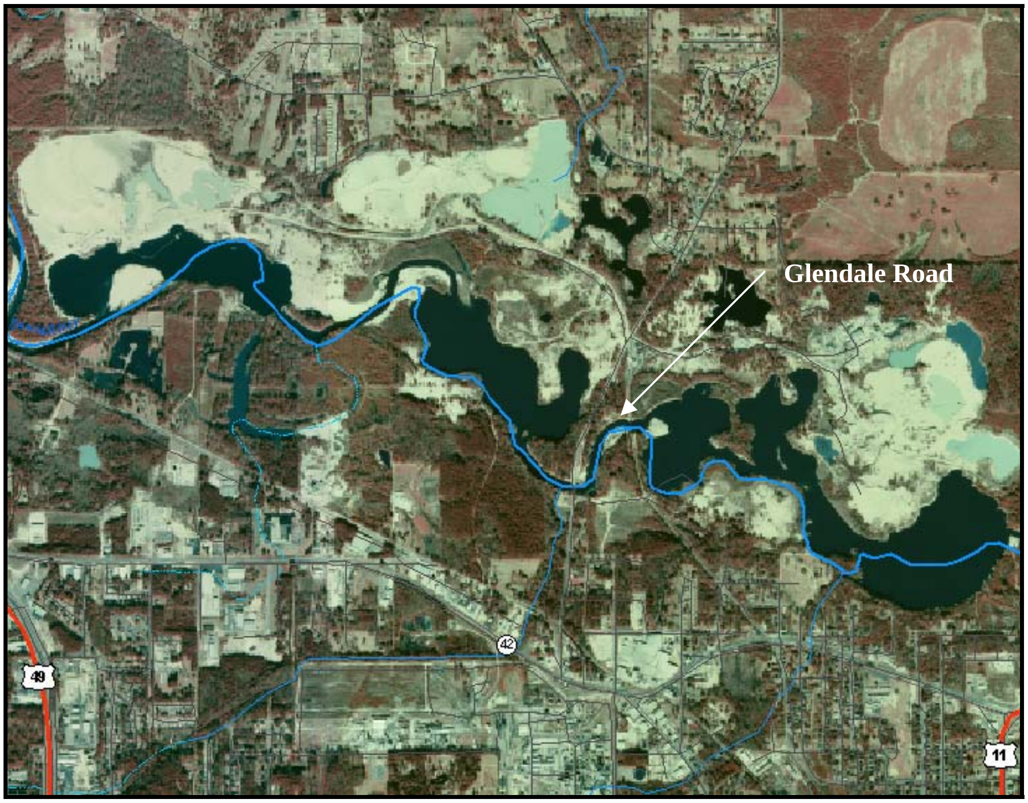


Figure 5. Sand and Gravel Pits in the Bowie River near Hattiesburg

The lower section of the Bowie River has also been the subject of extensive study by scientists from the University of Southern Mississippi, Department of Biological Sciences and the Mississippi Department of Wildlife Fisheries and Parks Museum of Natural Science (Ross, et al, 2004). The Bowie River between Glendale Road and the confluence with the Leaf River, is a spawning area for Gulf Sturgeon. The Gulf Sturgeon is listed as threatened under the Federal Endangered Species Act and listed as endangered in Mississippi. The Gulf Sturgeon use the slower moving, cooler water in the gravel pits for spawning. Thus, the maintenance of clean substrate with sufficient DO is important to support the Gulf Sturgeon in this area (personal communication, Paul Hartsfield, April 2004).

2.2 Assessment of Point Sources

An important step in assessing pollutant sources in the Bowie River watershed is locating the NPDES permitted sources. There are 14 facilities permitted to discharge organic material into the Bowie Creek, Bowie River, and its tributaries, Table 9. These facilities serve a variety of activities in the watershed, including municipalities, industries, and other businesses. The locations of the facilities are shown in Figure 6. The Hattiesburg North outfall location is shown in Photo 2.

Number	Name	NPDES Permit	Treatment Type	Permitted Discharge (MGD)	TP concentration estimate (mg.l)	TP Load estimate (lbs/day)
1	Lakewood Estates Subdivision	MS0038792	aerated lagoon	0.128	5.2	5.55
2	Creekwood Subdivision	MS0039004	aerated lagoon	0.063	5.2	2.71
3	North Haven Subdivision	MS0022314	aerated lagoon	0.160	5.2	6.94
4	Westover West Subdivision	MS0031801	aerated lagoon	0.140	5.2	6.07
5	Hattiesburg North	MS0020826	aerated lagoon	4.000	4.01	133.77
6	Trace Subdivison Number 4	MS0055140	conventional lagoon	0.043	5.2	1.86
7	Serene Hills Subdivision	MS0050172	aerated lagoon	0.028	5.2	1.21
8	The Trace Subdivision First Addition	MS0051080	aerated lagoon	0.102	5.2	4.43
9	Great Southern National Bank	MS0053660	activated sludge plant	0.001	5.8	0.02
10	Pecan Grove Trailer Park	MS0047473	conventional lagoon	0.004	5.2	0.16
11	Al Casco Custom Cutting and Wrap	MS0037176	conventional lagoon	0.003	5.2	0.12
12	A1 Trailer Park	MS0039331	conventional lagoon	0.005	5.2	0.22
13	Lamar Villa Apartments	MS0035874	conventional lagoon	0.010	5.2	0.43
14	Crossland Road Subdivision	MS0056413	conventional lagoon	0.043	5.2	1.87
Total				4.729		165.4

Table 9. NPDES Permitted Facilities Treatment Types

Photo 2. Hattiesburg North POTW Outfall Location

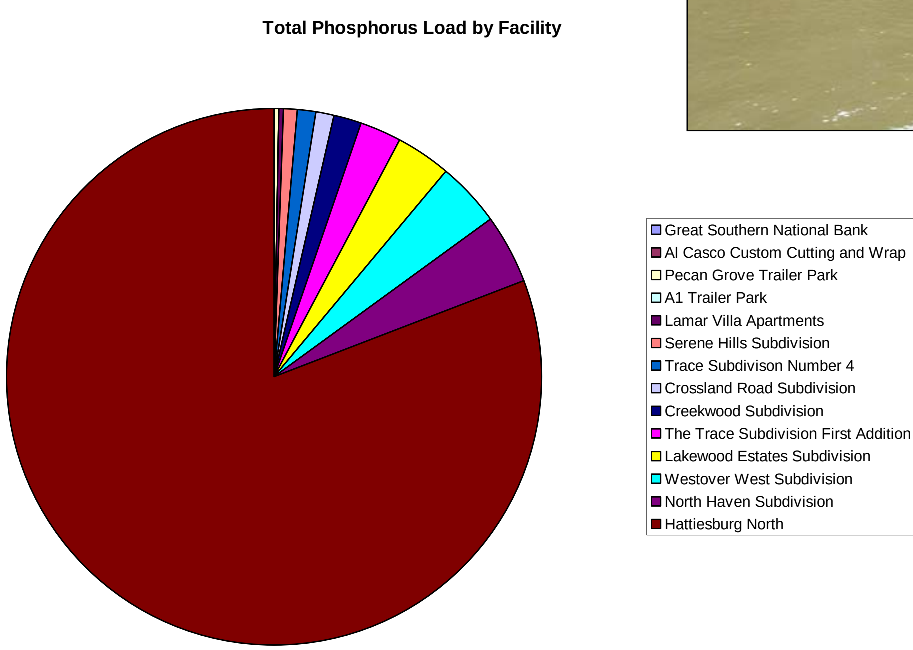
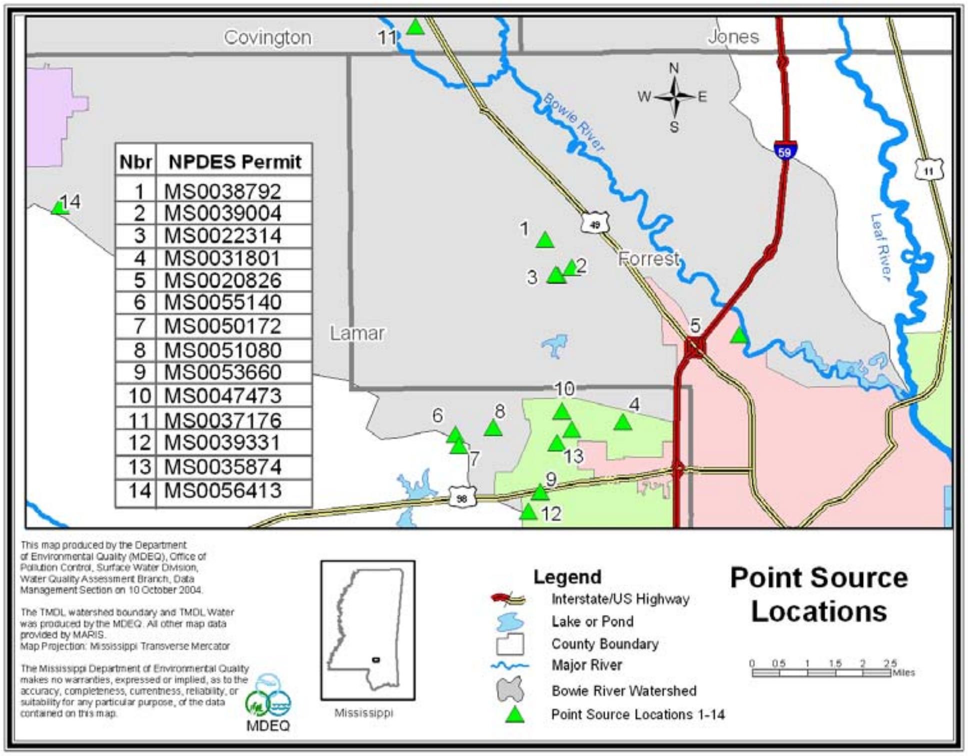


Figure 6. Point Source Location Map



In order to accommodate growth, the city of Hattiesburg has requested an expansion of their permitted flow of 2 MGD to a current design flow of 4 MGD at the north facility (Facility #5 in Table 9). This facility produces the majority of total phosphorus being discharged into this stream. This expansion would allow the city to offer sewer service to several hundred homes and businesses that are currently using septic tanks and individual, onsite wastewater treatment systems in Lamar County. The water quality impact of the proposed expansion will be evaluated in this TMDL report. MDEQ supports this concept to provide centralized sewer service to the unsewered areas of Hattiesburg.

The current condition of the effluent from each facility was characterized based on all available data including information on each facility's wastewater treatment system, permit limits, and discharge monitoring reports. The permit limits as well as the average flows and BOD_5 concentrations, as reported in available discharge monitoring reports (DMRs) for the past five years (1998 through 2003), are given in Table 10. Ammonia nitrogen and total phosphorus permit limits and monitoring are not required for most of the facilities.

Table 10. Identified NPDES Permitted Facilities

Name	NPDES Permit	Permitted Discharge (MGD)	Actual Average Discharge (MGD)	Permitted Average BOD_5 (mg/L)	Actual Average BOD_5 (mg/L)	Permitted NH_3-N (mg/l)	Actual Average NH_3-N (mg/l)
Lakewood Estates Subdivision	MS0038792	0.1280	0.1280	30	7.8	--	--
Creekwood Subdivision	MS0039004	0.0625	No data	30	*11.0	--	--
North Haven Subdivision	MS0022314	0.1600	0.1600	30	10.3	--	--
Westover West Subdivision	MS0031801	0.1400	0.0040	30	*51.0	--	--
Hattiesburg North	MS0020826	2.0000	1.6200	30	20.4	--	--
Trace Subdivison Number 4	MS0055140	0.0428	No discharge	30	No discharge	--	--
Serene Hills Subdivision	MS0050172	0.0280	0.0100	30	22.7	--	--
The Trace Subdivision First Addition	MS0051080	0.1022	0.0190	30	15.3	--	--
Great Southern National Bank	MS0053660	0.0005	No discharge	30	No discharge	--	--
Pecan Grove Trailer Park	MS0047473	0.0038	0.0240	30	25.0	--	--
Al Casco Custom Cutting and Wrap	MS0037176	0.0028	No discharge	.312 lbs/day	No discharge	0.52 lbs/day	--
A1 Trailer Park	MS0039331	0.0050	No data	30	No data	--	--
Lamar Villa Apartments	MS0035874	0.0100	0.0100	30	13.9	--	--
Crossland Road Subdivision	MS0056413	0.0432	No data	45	No data	--	--

*Only one measurement reported

2.3 Assessment of Non-Point Sources

Non-point loading of nutrients and organic material in a water body results from the transport of the pollutants into receiving waters by overland surface runoff and groundwater infiltration. Phosphorous is typically seen as the limiting nutrient in most freshwater environments. Therefore, this TMDL will only address total phosphorus. Phosphorus is primarily transported by runoff when it has been sorbed by eroding sediment. Phosphorous may not be immediately released from sediment and can sometimes reenter the water column from deposited sediment. Most non-point sources of phosphorous will have build up and then wash off during rain events. Table 11 presents typical nutrient loading ranges for various land uses.

Table 11. Nutrient Loadings for Various Land Uses

Landuse	Total Phosphorus [lb/acre-y]			Total Nitrogen [lb/acre-y]		
	Minimum	Maximum	Median	Minimum	Maximum	Median
Roadway	0.53	1.34	0.98	1.2	3.1	2.1
Commercial	0.61	0.81	0.71	1.4	7.8	4.6
Single Family-Low Density	0.41	0.57	0.49	2.9	4.2	3.6

Single Family-High Density	0.48	0.68	0.58	3.6	5.0	5.2
Multifamily Residential	0.53	0.72	0.62	4.2	5.9	5.0
Forest	0.09	0.12	0.10	1.0	2.5	1.8
Grass	0.01	0.22	0.12	1.1	6.3	3.7
Pasture	0.01	0.22	0.12	1.1	6.3	3.7

Landuse	Total Phosphorus [lb/acre-y]			Total Nitrogen [lb/acre-y]		
	Minimum	**Maximum**	**Median**	**Minimum**	**Maximum**	**Median**
Roadway	0.53	1.34	0.98	1.2	3.1	2.1
Commercial	0.61	0.81	0.71	1.4	7.8	4.6
Single Family-Low Density	0.41	0.57	0.49	2.9	4.2	3.6
Single Family-High Density	0.48	0.68	0.58	3.6	5.0	5.2
Multifamily Residential	0.53	0.72	0.62	4.2	5.9	5.0
Forest	0.09	0.12	0.10	1.0	2.5	1.8
Grass	0.01	0.22	0.12	1.1	6.3	3.7
Pasture	0.01	0.22	0.12	1.1	6.3	3.7

The drainage area of the Bowie River is approximately 427,939 acres. The watershed contains many different landuse types, including urban, forest, cropland, pasture, water, and wetlands. The landuse information given below is based on data collected by the State of Mississippi's Automated Resource Information System (MARIS) 1997. This data set is based on Landsat Thematic Mapper digital images taken between 1992 and 1993. Forest is the dominant landuse within this watershed. The landuse distribution within the Bowie River Watershed is shown in Table 12 and Figure 7.

Table 12 Landuse Distribution, Bowie River Watershed

	Urban	Forest	Cropland	Pasture	Scrub/Barren	Water	Wetlands
Area (acres)	6,910	197,201	16,940	125,468	74,809	2,602	4,009
Percentage	1.6%	46.1%	4.0%	29.3%	17.5%	0.6%	1.0%

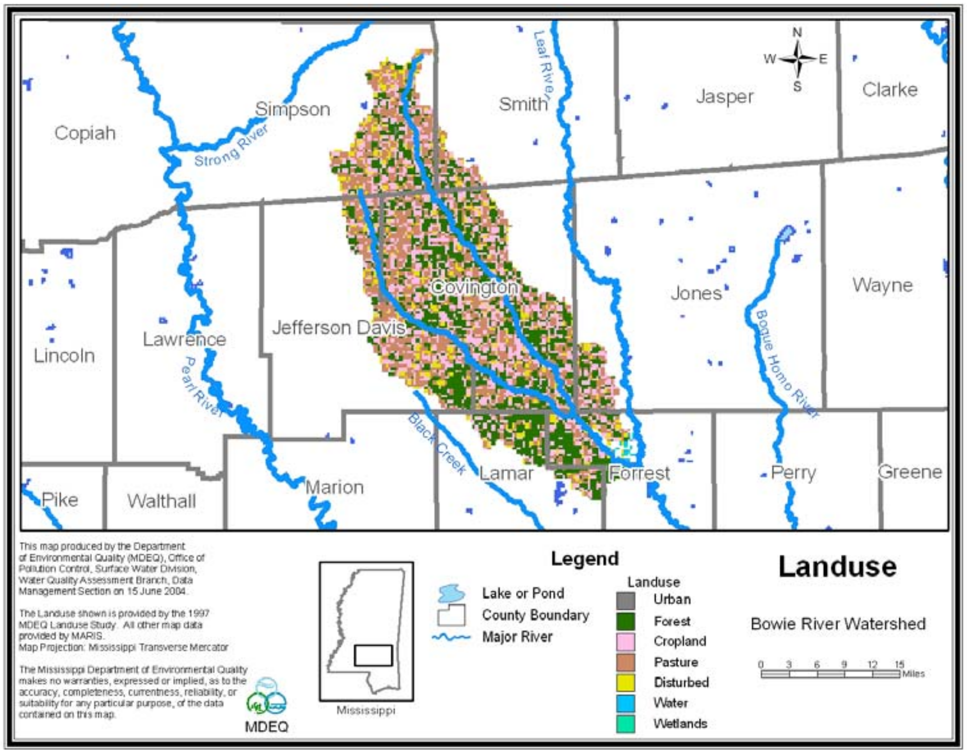


Figure 7. Landuse Distribution for the Bowie River Watershed

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

A mathematical model, STeady Riverine Environmental Assessment Model (STREAM), for DO distribution in freshwater streams was used for developing the TMDL. STREAM is an updated version of the AWFWUL1 model, which had been used by MDEQ for many years. The use of AWFWUL1 is promulgated in the *Wastewater Regulations for National Pollutant Discharge Elimination System (NPDES) Permits, Underground Injection Control (UIC) Permits, State Permits, Water Quality Based Effluent Limitations and Water Quality Certification* (MDEQ, 1994). This model has been approved by EPA and has been 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 non-point source loadings.

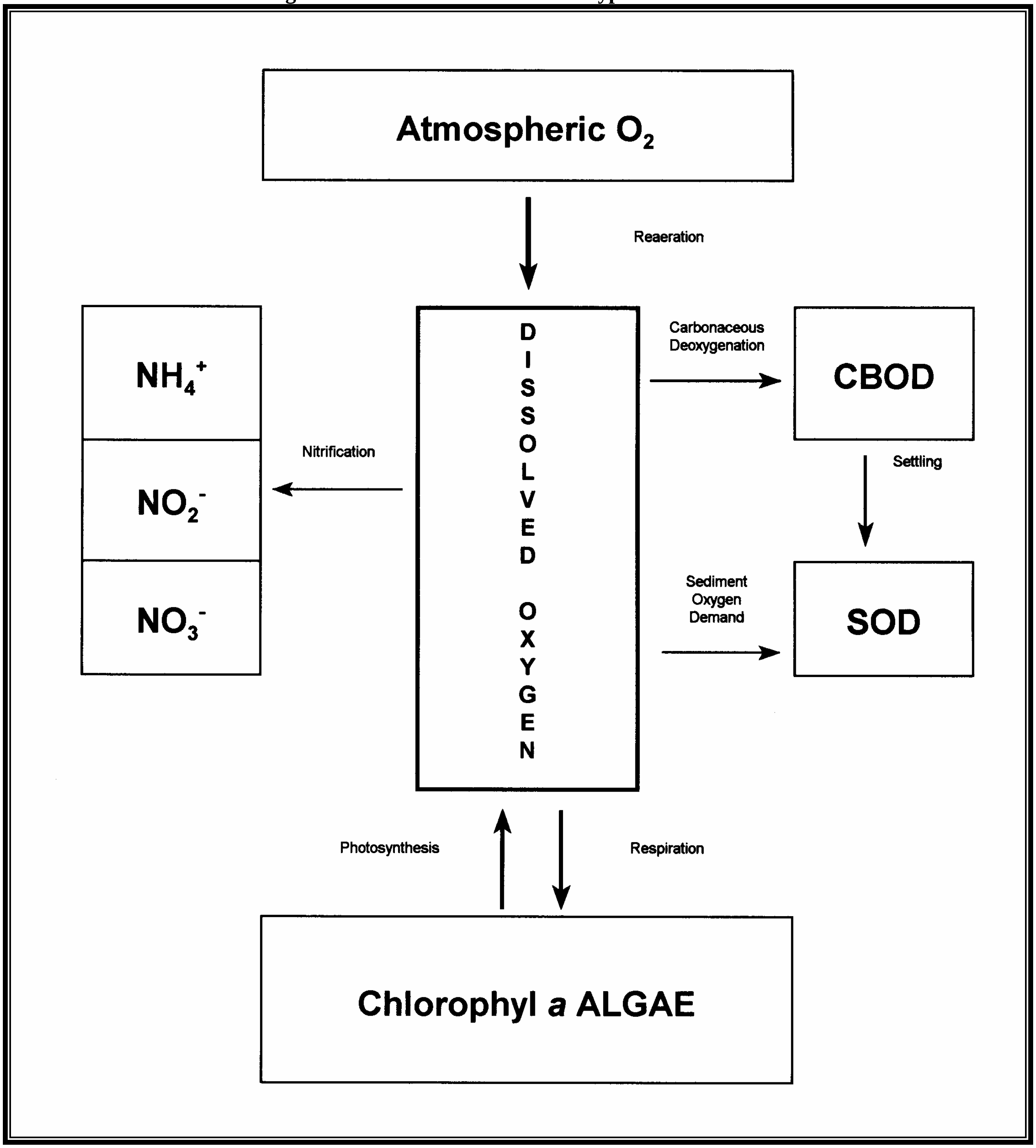
STREAM is a steady-state, daily average computer model that utilizes a modified Streeter-Phelps DO sag equation. Instream processes simulated by the model include CBODu decay, nitrification, reaeration, sediment oxygen demand, and respiration and photosynthesis of algae. Figure 8 shows how these processes 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 NH_3-N concentrations. The hydrological processes simulated by the model include stream velocity and flow from point sources and spatially distributed inputs.

The model was set up to calculate 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 2.

$$K_a = C*S*U \qquad \textbf{(Equation 2)}$$

C is the escape coefficient, U is the reach velocity in mile/day, and S is the average reach slope in ft/mile. The value of the escape coefficient is assumed to be 0.11 for streams with flows less than 10 cfs and 0.0597 for streams with flows greater than 10 cfs. Reach velocities were measured in the lower reaches of the Bowie River with the time of travel study. In other reaches, velocities were calculated using an equation based on slope. Slopes for the main stem of Bowie Creek and the Bowie River typically range from 1 to 9 ft/mile. Tributaries of the Bowie River had steeper slopes.

Figure 8. Instream Processes in a Typical DO Model

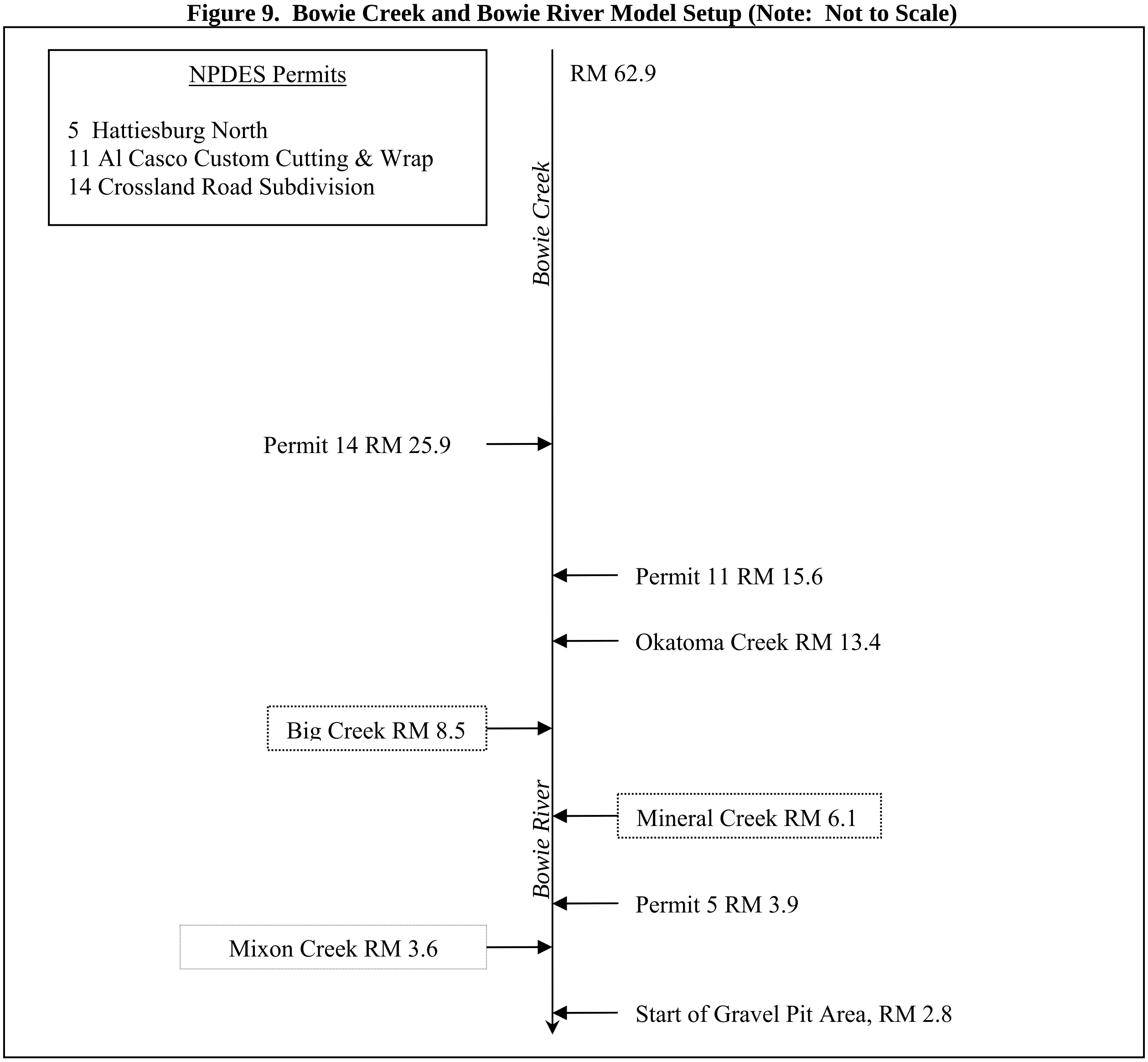


3.2 Model Setup

The model for this TMDL includes Bowie Creek, Bowie River, and several tributaries. The model begins at the headwaters of Bowie Creek and continues to the gravel pit area of the Bowie River, at river mile 2.8. The gravel pit area was not modeled because it contains deep pits with irregular depths of up to 60 ft. The flow pattern through the gravel pits will differ from the flow pattern in the riverine section of Bowie River. The STREAM model assumes steady-state flow conditions in water bodies. Thus, the model is not capable of simulating water quality conditions at multiple depths. It is not appropriate to apply the STREAM model to the gravel pit segments of the Bowie River.

A diagram showing the model setup for Bowie Creek and Bowie River is shown in Figure 9. The locations of the confluence of point sources and significant tributaries are shown. The point sources are labeled with numbers assigned in Table 9 and repeated on the figure below. Arrows represent the direction of flow in each segment. Okatoma Creek is the largest tributary of Bowie Creek. The contribution from this water body was included as a point load in the appropriate location of Bowie Creek. The numbers on the figure represent approximate river miles (RM). River miles are assigned to water bodies with the highest number at the upstream point and decreasing to zero at the mouth.

Figure 9. Bowie Creek and Bowie River Model Setup (Note: Not to Scale)



Three smaller tributaries located near Hattiesburg; Big Creek, Mineral Creek, and Mixon Creek, were also included in the model. These tributaries contain NPDES permitted point sources. The model diagrams for Big Creek, Mineral Creek, and Mixon Creek are shown in Figures 10 through 12.

Figure 10. Big Creek Model Setup

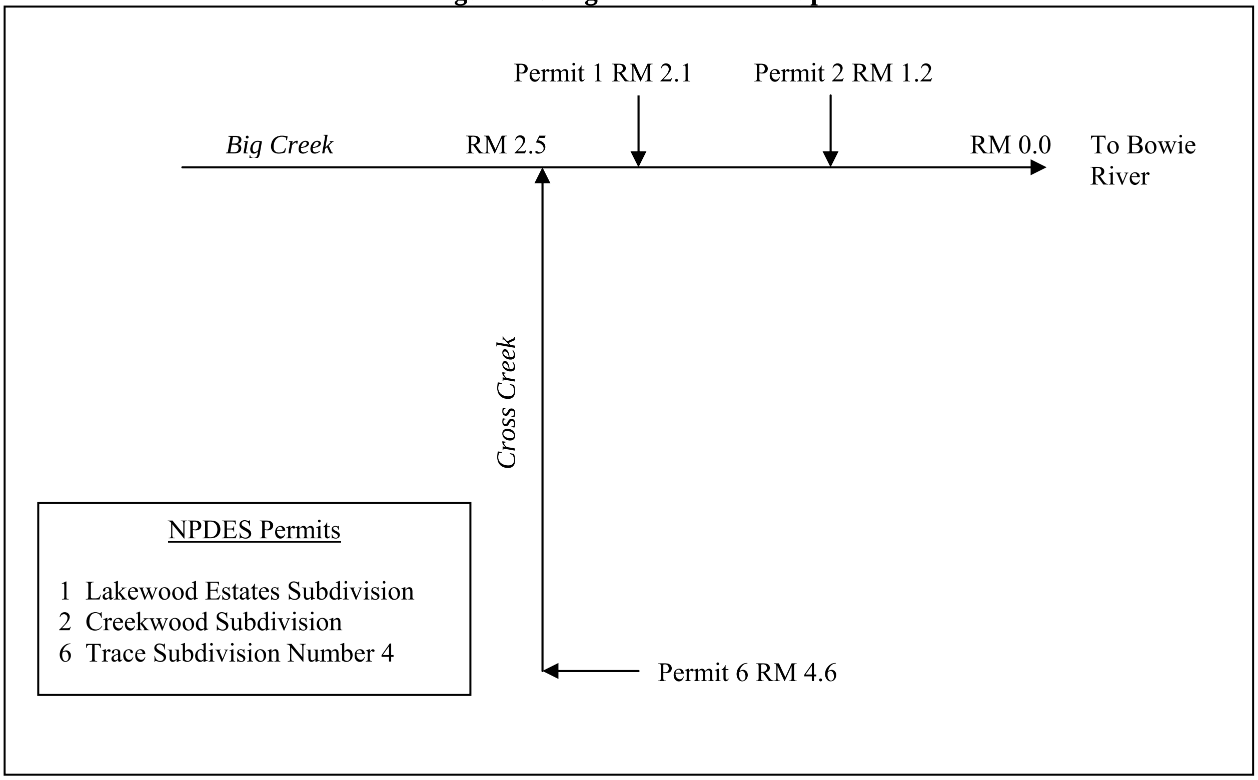


Figure 11. Mineral Creek Model Setup

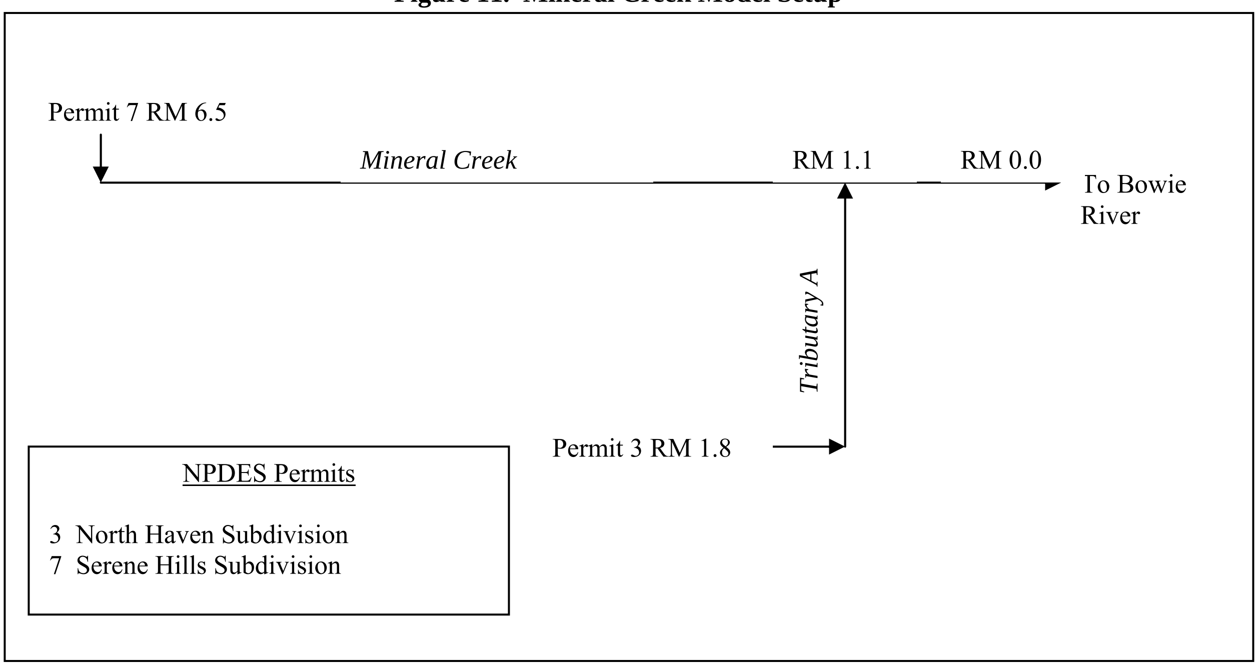
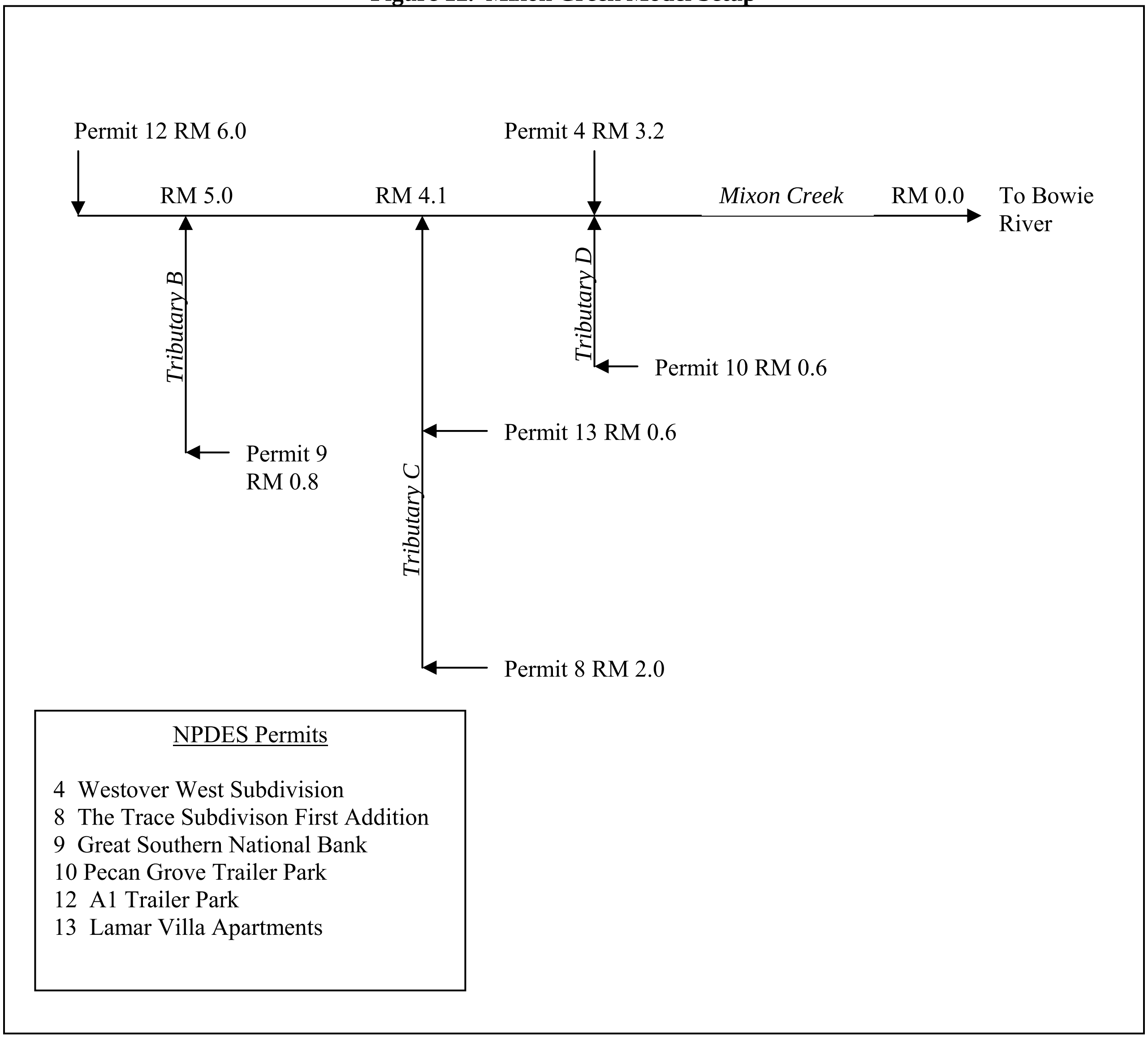


Figure 12. Mixon Creek Model Setup



The modeled water bodies are divided into reaches for modeling purposes. Reach divisions are made at locations where there is a significant change in hydrological and water quality characteristics, such as the confluence of a point source or tributary. Within each reach, the modeled segments are divided into computational elements of 0.1 mile. The simulated hydrological and water quality characteristics are calculated and output by the model for each computational element.

The STREAM model was initially set up to simulate flow and temperature conditions that were measured during the September 2004 study in the segment from I-59 to the confluence with Mixon Creek. The flow in Bowie River was based on the flows measured at the USGS gages at Bowie Creek and Okatoma Creek. The average flows during the study period from these two gages, Bowie Creek (USGS gage 02472500) = 137.8 cfs and Okatoma Creek (USGS gage 02472850) = 98.7 cfs were summed to estimate the flow in the Bowie River below the confluence of Bowie River and Okatoma Creek, approximately 236.5 cfs. The temperature was set at 24°C, which was the average of the temperatures measured at each of the monitoring stations. The instream CBODu and NH_3-N decay rates were based on values given in MDEQ Regulations because the decay rates were not measured during the study.

The model was then set at flow and temperature conditions that which were determined to be the critical condition for this TMDL. The critical condition temperature used in the model varies with flow. In accordance with MDEQ regulations, the temperature is set to 26°C for flows less than 50 cfs and 28°C for flows between 50 and 300 cfs. The headwater instream DO was assumed to be 85% of saturation at the stream temperature. Values for instream CBODu and NH_3-N decay rates were based on MDEQ Regulations. The instream CBODu decay rate is dependent on temperature, according to Equation 3.

$$\mathbf{K_{d(T)} = K_{d(20°C)}(1.047)^{T-20}} \qquad \textbf{(Equation 3)}$$

In the above equation, 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 at critical conditions are required by the *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). Also based on MDEQ Regulations, the rates for photosynthesis, respiration, and sediment oxygen demand were set to zero because data for these model parameters were not available.

The flow in the Bowie River system at critical conditions is based on data available from the USGS (Telis, 1992). There are several partial record flow gauging stations located in the Bowie River Watershed. The stations and their 7Q10 flows are given in Table 13. The critical condition model was set up so that the modeled flow was approximately equal to the 7Q10 flow at monitoring locations in the system.

Table 13. 7Q10 Flow Data for the Bowie River Watershed

Station	Location	Drainage Area (square miles)	7Q10 Flow (cfs)
02472850	Okatoma Creek at Sanford	257.0	90
02472900	Big Creek near Hattiesburg	31.9	2
02472500	Bowie Creek near Hattiesburg (above confluence of Okatoma Creek	304.0	100
02472940	Bowie Creek near Hattiesburg (below the confluence of Okatoma Creek)	646.0	182

3.3 Source Representation

Both point and non-point sources were represented in the model. The loads from NPDES permitted sources were added as direct inputs into the appropriate reach of the modeled water bodies as a flow in cfs and concentration of $CBOD_5$ and ammonia nitrogen in mg/L. Spatially distributed loads, which represent non-point sources of flow, $CBOD_5$, and ammonia nitrogen were distributed evenly into each computational element of the modeled water bodies.

Organic material discharged to a stream from an NPDES permitted point source is typically quantified as 5-day biochemical oxygen demand (BOD_5). BOD_5 is a measure of the oxidation of carbonaceous and nitrogenous material over a 5-day incubation period. However, oxidation of nitrogenous material, called nitrification, usually does not take place within the 5-day period because the bacteria that are responsible for nitrification are normally not present in large numbers and have slow reproduction rates (Metcalf and Eddy, 1991). Thus, BOD_5 is generally considered equal to $CBOD_5$. Because permits for point source facilities are written in terms of BOD_5 while TMDLs are typically developed using CBODu, a ratio between the two terms is needed, Equation 4.

$$\textbf{CBODu} = \textbf{CBOD}_5 * \textbf{Ratio} \qquad \textbf{(Equation 4)}$$

The CBODu to $CBOD_5$ ratios are given in *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). These values are recommended for use by MDEQ regulations when actual field data are not available. The value of the ratio depends on the treatment type of wastewater. For secondary treatment systems (conventional and aerated lagoons), this ratio is 1.5. A CBODu to $CBOD_5$ ratio of 1.5 is appropriate for all of the facilities in the Bowie River Watershed, with the exception of Great Southern National Bank (MS0053660). A ratio of 2.3 was used for this facility. MDEQ regulations specify that a ratio of 2.3 should be used for activated sludge facilities.

In order to convert the ammonia nitrogen (NH_3-N) loads to an oxygen demand, a factor of 4.57 pounds of oxygen per pound of ammonia nitrogen (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 point source load of TBODu. The maximum permitted loads of TBODu from each of the existing point sources are given in Table 13. Note that most of the permitted $CBOD_5$ concentrations are greater than the actual concentrations, as reported in the DMR data, Table 14.

There are no concentrations given from Al Casco Cutting and Wrap because this facility reports in units of lbs/day. Because most the facilities are not required to report values for ammonia nitrogen an assumed value of 2.0 mg/L was used to calculate the NBODu loads. There were no monitoring data available for some of the facilities. In these cases, the maximum permit limits were used to estimate the actual loads. Comparison of Tables 14 and 15 shows that the actual TBODu load is approximately one-half that of the maximum permitted load.

Table 14. Point Sources, Maximum Permitted Loads

Facility	Flow (MGD)	$CBOD_5$ (mg/l)	NH_3-N (mg/L)	$CBOD_u$:$CBOD_5$ Ratio	CBODu (lbs/day)	NH_3-N (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
Lakewood Estates Subdivision	0.1280	30	2	1.5	48.0	2.1	9.8	57.8
Creekwood Subdivision	0.0625	30	2	1.5	23.5	1.0	4.8	28.2
North Haven Subdivision	0.1600	30	2	1.5	60.0	2.7	12.2	72.2
Westover West Subdivision	0.1400	30	2	1.5	52.5	2.3	10.7	63.2
Hattiesburg North	2.0000	30	2	1.5	750.6	33.4	152.5	903.1
Trace Subdivison Number 4	0.0428	30	2	1.5	16.1	0.7	3.3	19.3
Serene Hills Subdivision	0.0280	30	2	1.5	10.5	0.5	2.1	12.6
The Trace Subdivision First Addition	0.1022	30	2	1.5	38.4	1.7	7.8	46.1
Great Southern National Bank	0.0005	30	2	2.3	0.3	0.0	0.0	0.3
Pecan Grove Trailer Park	0.0038	30	2	1.5	1.4	0.1	0.3	1.7
Al Casco Custom Cutting and Wrap	0.0028	--	--	1.5	0.3	0.5	2.3	2.6
A1 Trailer Park	0.0050	30	2	1.5	1.9	0.1	0.4	2.3
Lamar Villa Apartments	0.0100	30	2	1.5	3.8	0.2	0.8	4.5
Crossland Road Subdivision	0.0432	45	2	1.5	24.3	0.7	3.3	27.6
	2.7288				**1,031.6**	**46.0**	**210.1**	**1,241.7**

Table 15. Point Sources, Loads Based on Averages of DMR Data

Facility	Flow (MGD)	$CBOD_5$ (mg/l)	NH_3-N (mg/L)	$CBOD_u$:$CBOD_5$ Ratio	CBODu (lbs/day)	NH_3-N (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
Lakewood Estates Subdivision	0.1280	7.8	2	1.5	12.5	2.1	9.8	22.2
Creekwood Subdivision	**0.0625*	11.0	2	1.5	8.6	1.0	4.8	13.4
North Haven Subdivision	0.1600	10.3	2	1.5	20.6	2.7	12.2	32.8
Westover West Subdivision	0.0040	51.0	2	1.5	2.6	0.1	0.3	2.9
Hattiesburg North	1.6200	20.4	2	1.5	413.4	27.0	123.5	536.9
Trace Subdivison Number 4	0.0000	0.0	2	1.5	0.0	0.0	0.0	0.0
Serene Hills Subdivision	0.0100	22.7	2	1.5	2.8	0.2	0.8	3.6
The Trace Subdivision First Addition	0.0190	15.3	2	1.5	3.6	0.3	1.4	5.1
Great Southern National Bank	0.0000	0.0	2	2.3	0.0	0.0	0.0	0.0
Pecan Grove Trailer Park	0.0240	25.0	2	1.5	7.5	0.4	1.8	9.3
Al Casco Custom Cutting and Wrap	0.0000	--	--	1.5	0.0	0.0	0.0	0.0
A1 Trailer Park	**0.0050*	*30.0*	2	1.5	1.9	0.1	0.4	2.3
Lamar Villa Apartments	0.0100	13.9	2	1.5	1.7	0.2	0.8	2.5
Crossland Road Subdivision	**0.0432*	*45.0*	2	1.5	24.3	0.7	3.3	27.6
	2.0857				**499.6**	**34.8**	**159.0**	**658.6**

**Permitted flow was used because no DMR data are available*

Background concentrations of CBODu and NH_3-N were based on available water quality monitoring data and recently collected data from the Bowie River near Hattiesburg. As a conservative assumption, the background concentration of CBODu was set at 2 mg/l, because of the instream measurements of $CBOD_5$ were less than the detection limit of 2 mg/l. Instream measurements of CBODu were not available. The background concentration of NH_3-N was set at 0.1 mg/l, because the instream measurements of NH_3-N were less than the detection limit of 0.1 mg/l. These assumptions are consistent with concentrations given in *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). According to these regulations, the background concentrations used in modeling are CBODu = 2.0 mg/L and NH_3-N = 0.1 mg/l.

Non-point source flows entering Bowie Creek were included in the model to account for water entering due to groundwater infiltration, overland flow, and small, unmeasured tributaries. The non-point source flows were assumed to be distributed evenly throughout the modeled reaches. Non-point source flows were represented in the models developed for the September 2004 study conditions and at the 7Q10 critical conditions.

Flows were based on data obtained during the September 2004 study for the study condition model. A ratio was calculated using the average flow measured at gage 02472500, 137.8 cfs. This gage is located at Bowie Creek at RM 14.1. This flow was divided by the length of the modeled section of Bowie Creek from its headwaters (at RM 62.9) to the gage 02472500 (located at RM 14.1). This ratio is equal to 2.82 cfs/river mile (137.8 cfs/48.8 river miles = 2.82 cfs/river mile). Then, the ratio was used to determine the amount of non-point source flow entering each reach from the headwaters (RM 62.9) to the confluence of Okatoma Creek (RM 13.4). This flow is equal to 139.6 cfs (2.82 cfs/river mile * 49.5 miles = 139.6 cfs). The flow from Oaktoma Creek was measured at an average of 98.7 cfs at gage 02472850. The flow from Okatoma Creek was added as a point source to Bowie Creek at RM 13.4.

For the 7Q10 condition model, a ratio was calculated in a similar manner, by dividing the 7Q10 flow at gage 02472500 (100 cfs) by the length of the modeled section of the Bowie Creek from its headwaters (at RM 62.9) to the gage 02472500 (located at RM 14.1). This ratio is equal to 2.05 cfs/river mile (100 cfs/48.8 river miles = 2.05 cfs/river mile). Then, the ratio was used to determine the amount of non-point source flow entering each reach from the headwaters (RM 62.9) to the confluence of Okatoma Creek (RM 13.4). This flow is equal to 101.5 cfs (2.05 cfs/river mile * 49.5 miles = 101.5 cfs). The flow from Okatoma Creek has a 7Q10 flow of 90 cfs. The flow from Okatoma Creek was added as a point source to Bowie Creek at RM 13.4.

For both the study condition and the 7Q10 condition model, non-point source flows entering Bowie River downstream for the confluence of Okatoma Creek were accounted for by modeling the tributaries Big Creek, Mineral Creek, and Mixon Creek at the 7Q10 flow conditions. Flows from these tributaries were not measured during the September 2004 study.

The 7Q10 for Big Creek (2 cfs) was based on the USGS gage at Big Creek 02472900. The flows for Mineral Creek and Mixon Creek were estimated based on a drainage area ratio. A drainage area ratio is the total flow expected during 7Q10 flow conditions per square mile of drainage area (cfs/square mile). Based on the USGS Report 91-4130, the drainage area ratio for the Bowie River near Hattiesburg is 0.06 cfs/square mile. The 7Q10 flow for Mineral Creek was calculated as 0.4 cfs (0.06 cfs/square mile * 6.4 square miles). The 7Q10 flow for Mixon Creek was calculated as 0.7 cfs (0.06 cfs/square mile * 11.3 square miles). The flows were multiplied by the background concentrations of CBODu and NH_3-N to calculate the non-point source loads for the study conditions, Table 16, and 7Q10 flow conditions, Table 17.

Table 16. Non-Point Source Loads Input into the Model, Study Flow Condition

Water Body	Flow (cfs)	$CBOD_u$ (mg/L)	CBODu (lbs/day)	NH_3-N (mg/l)	NBODu (lbs/day)	TBODu (lbs/day)
Bowie Creek	139.6	2.0	1,504.9	0.1	343.9	1,848.8
Big Creek	2.0	2.0	21.6	0.1	4.9	26.5
Mineral Creek	0.4	2.0	4.3	0.1	1.0	5.3
Mixon Creek	0.7	2.0	7.5	0.1	1.7	9.3
Okatoma Creek	98.7	2.0	1,064.0	0.1	243.1	1,307.1
			2,602.3		**594.6**	**3,196.9**

Table 17. Non-Point Source Loads Input into the Model, 7Q10 Flow Condition

Water Body	Flow (cfs)	$CBOD_u$ (mg/L)	CBODu (lbs/day)	NH_3-N (mg/l)	NBODu (lbs/day)	TBODu (lbs/day)
Bowie Creek	101.5	2.0	1,094.2	0.1	250.0	1,344.2
Big Creek	2.0	2.0	21.6	0.1	4.9	26.5
Mineral Creek	0.4	2.0	4.3	0.1	1.0	5.3
Mixon Creek	0.7	2.0	7.5	0.1	1.7	9.3
Okatoma Creek	90.0	2.0	970.2	0.1	221.7	1,191.9
			2,097.8		**479.3**	**2,577.1**

3.4 Model Calibration

There are not sufficient data available to fully calibrate the model of Bowie Creek and Bowie River. However, the model output from the model set up for the study conditions was compared to instream data that were collected during the recent study of the Bowie River near Hattiesburg. Comparison of the available data shows that the predicted daily average dissolved oxygen levels and instream $CBOD_5$ and NH_3-N concentrations are in the same range as recently collected data. The model was run with the loads from NPDES permitted point sources were set at their current loads as determined from the discharge monitoring reports, Table 14, with the exception of Hattiesburg North. The loads from Hattiesburg North POTW were set at the levels measured during the September 2004 study. The CBODu concentration from the facility was 22 mg/l and the ammonia nitrogen concentration was 0.13 mg/l. The flow measured during the month of September 2004 from this facility, 1.19 MGD, was also used in the model.

The figures below show comparisons of the model output and the data collected during the September 2004 study. The model output is shown for the area studied, beginning at river mile 5.1 and ending at river mile 2.8. Figure 13 shows the modeled concentrations of CBODu. All of the modeled concentrations are less than the measured value of less than 2.0 mg/l BOD_5. Figure 14 shows the modeled concentrations of NH_3-N. All of the modeled concentrations are less than the measured value of less than 0.1 mg/l NH_3-N. Figure 15 shows the modeled DO compared to the measured daily average DO concentration for the 3 instream monitoring locations. Though the DO values do not match exactly, they show that the model predictions are close to the measured values.

Figure 13. Modeled CBODu Concentrations at Study Conditions

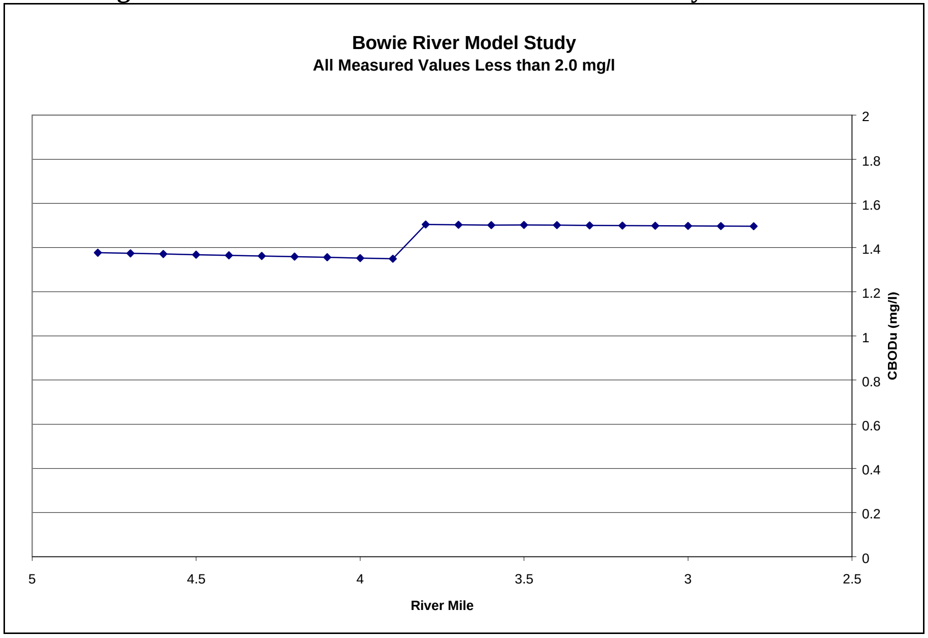


Figure 14. Modeled NH_3-N Concentrations at Study Conditions

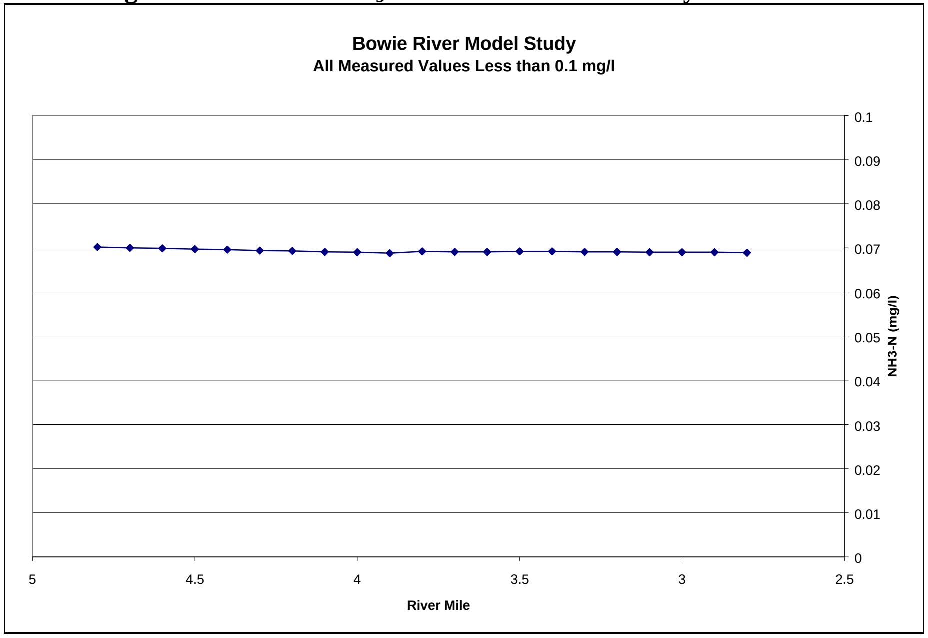
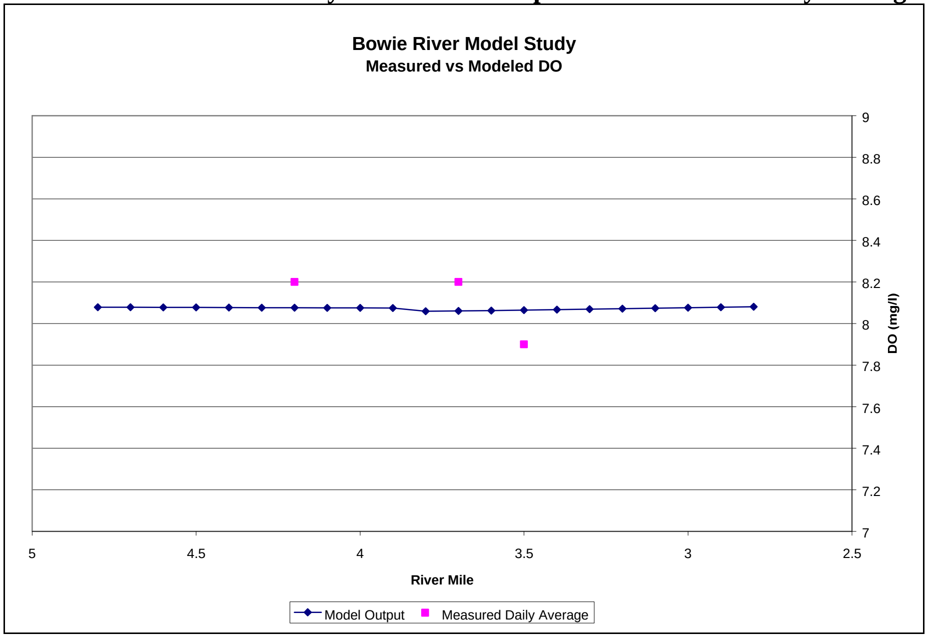


Figure 15. Modeled DO at Study Conditions Compared to Measured Daily Average DO



3.5 Model Results

Once the model setup and calibration were complete, the model was used to predict water quality conditions in Bowie Creek and Bowie River under critical conditions. The model was run at 7Q10 flow conditions with the permits set at the maximum loads allowed in the NPDES permits. Model runs with permits at maximum permitted loads showed that the water quality standard for dissolved oxygen was not violated at any point in Bowie Creek or Bowie River. Finally, the maximum allowable load was determined by increasing the non-point source loads. The model was run using a trial-and-error process to determine the maximum TBODu loads that would not violate water quality standards for DO. These model results are called the maximum load scenario.

3.5.1 Critical Condition Model Results

The critical condition model results are shown in the figures below. The red line on the figures represents the TMDL endpoint of 5.0 mg/l DO. Figure 16 shows the daily average instream DO concentrations, beginning with river mile 62.9 in Bowie Creek and ending with river mile 2.8 in Bowie River. As shown, the predicted DO stays well above the water quality standard of 5.0 mg/l. The decrease in DO at RM 13.4 is due to the confluence of Okatoma Creek, which was modeled with the assumption that the background DO is 6.9 mg/l or 85% of the DO saturation at 28°C in accordance with MDEQ Regulations. The model output does not show a DO sag in Bowie Creek and the Bowie River due to the point source dischargers.

The model output for modeled tributaries of the Bowie River is shown in Figures 17 through 24. The DO in most of the modeled tributaries meets water quality standards during critical conditions. However, the modeled DO in Tributary A, an unnamed tributary of Mineral Creek, and Tributary C, an unnamed tributary of Mixon Creek, falls below 5.0 mg/l due to the influence of the point source dischargers. The point source discharging into Tributary A is North Haven Subdivision. Tributary C carries effluent from two point sources, the Trace Subdivision First

Addition and Lamar Villa Apartments. However, the DO falls below water quality standard due to only one of these sources, the Trace Subdivision First Addition, and recovers before the outfall of Lamar Villa Apartments. Because model results show that water quality standards are not attained in these tributaries, this TMDL recommends further study of the tributaries below two point sources, North Haven Subdivision and Trace Subdivision First Addition.

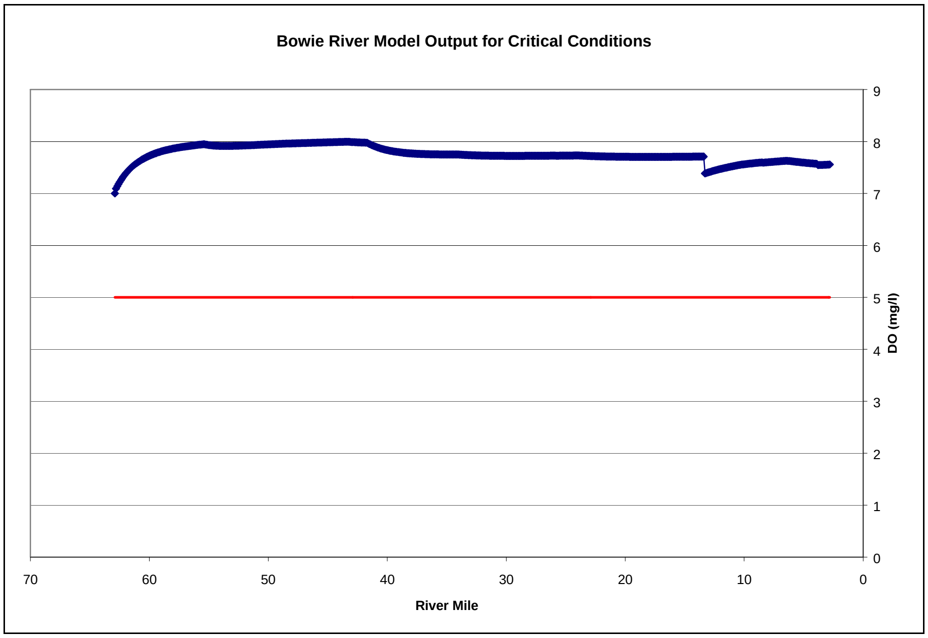


Figure 16. Critical Condition Model Output for DO in Bowie River

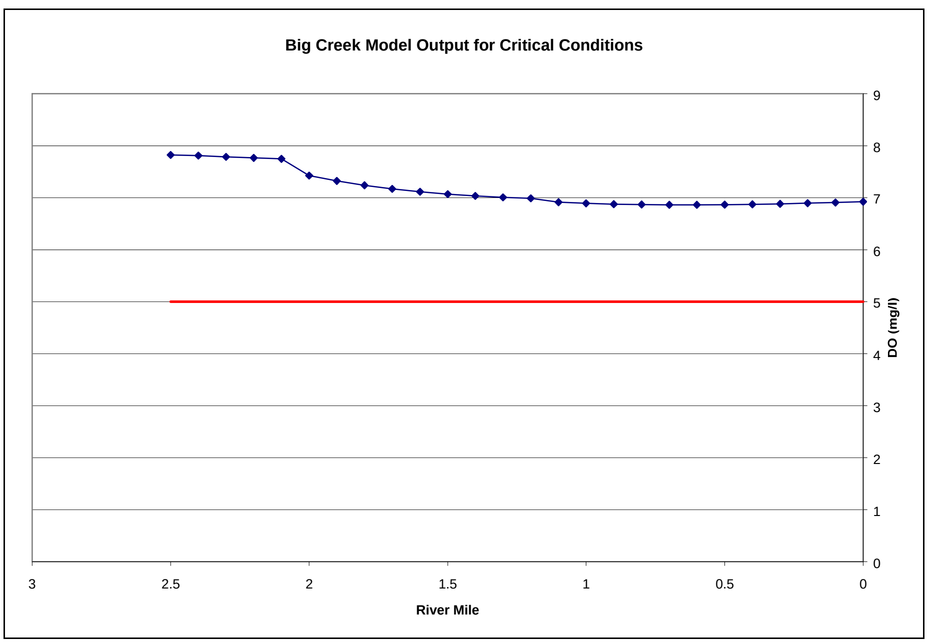


Figure 17. Critical Condition Model Output for DO in Big Creek

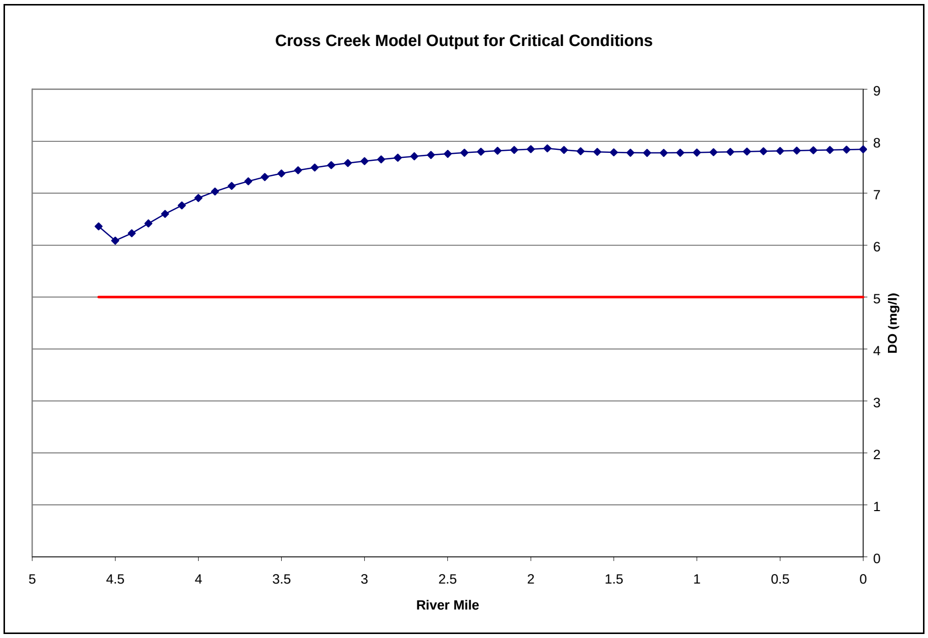


Figure 18. Critical Condition Model Output for DO in Cross Creek

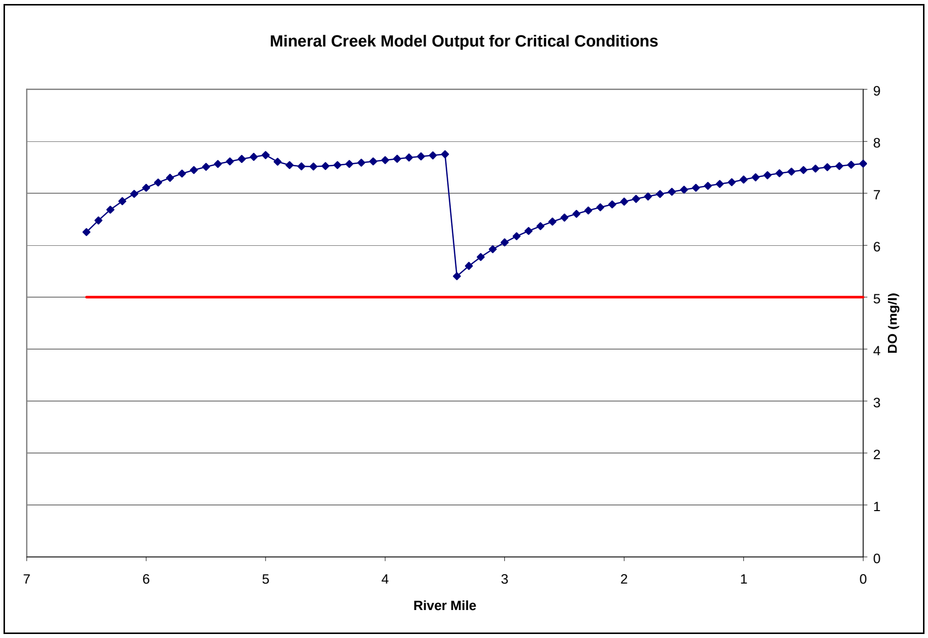


Figure 19. Critical Condition Model Output for DO in Mineral Creek

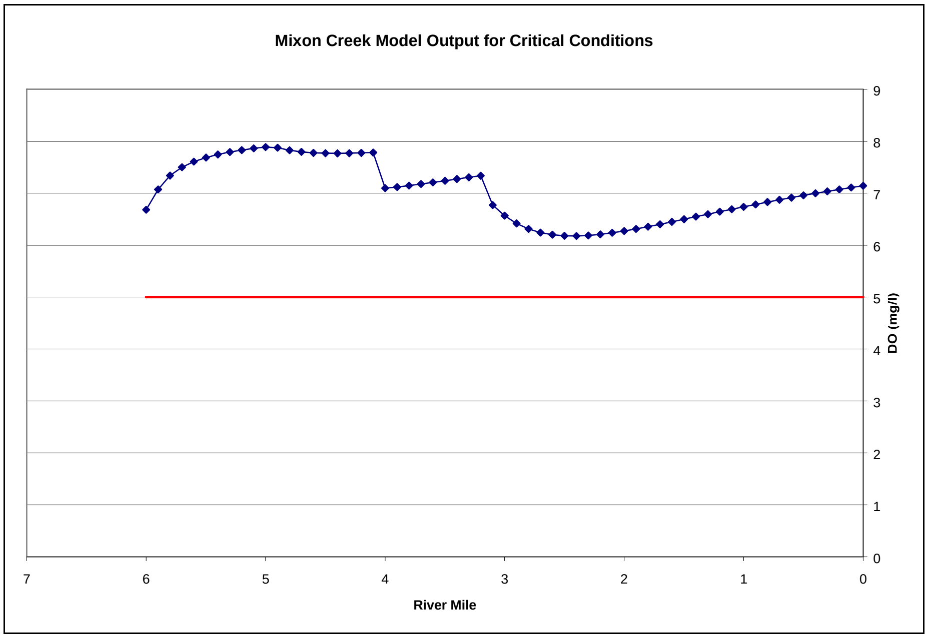


Figure 20. Critical Condition Model Output for DO in Mixon Creek

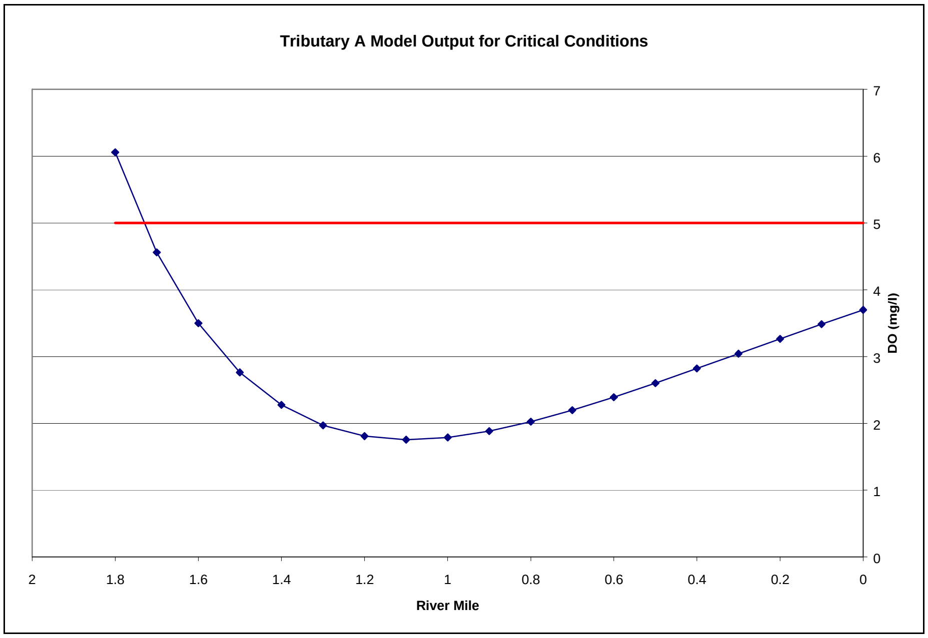


Figure 21. Critical Condition Model Output for DO in Tributary A

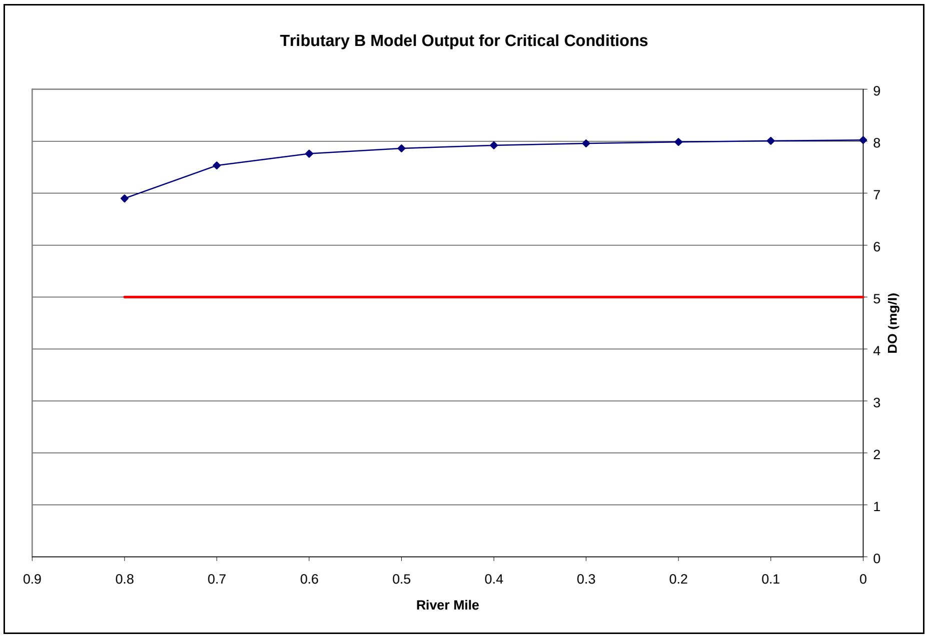


Figure 22. Critical Condition Model Output for DO in Tributary B

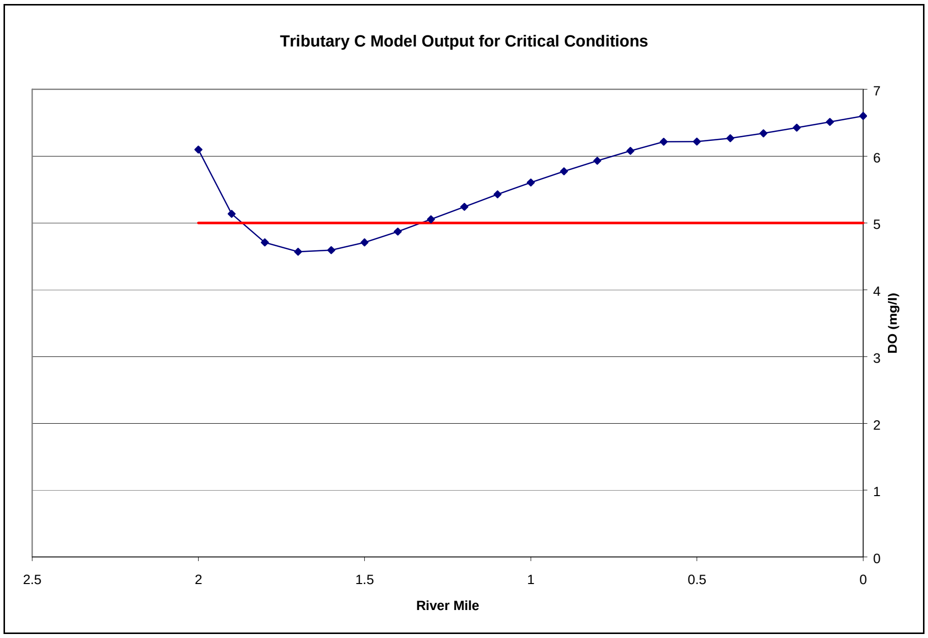


Figure 23. Critical Condition Model Output for DO in Tributary C

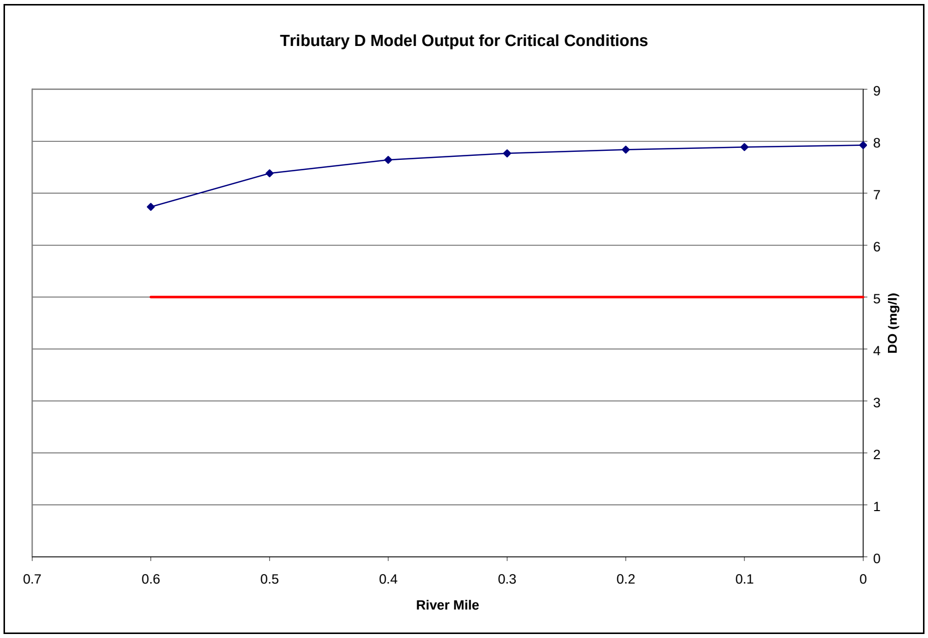


Figure 24. Critical Condition Model Output for DO in Tributary D

An additional model run was completed in order to predict the dissolved oxygen in the Bowie River with the proposed expansion of the Hattiesburg North POTW from 2 MGD to 4 MGD. The results of this model run are shown in Figure 25. As shown, the modeled DO is approximately 7.5 mg/l downstream of the increased point source load. The increased load is well within the assimilative capacity of Bowie River. The water body has remaining assimilative capacity beyond the increased loading. Thus, this TMDL allows the proposed expansion of the Hattiesburg North POTW.

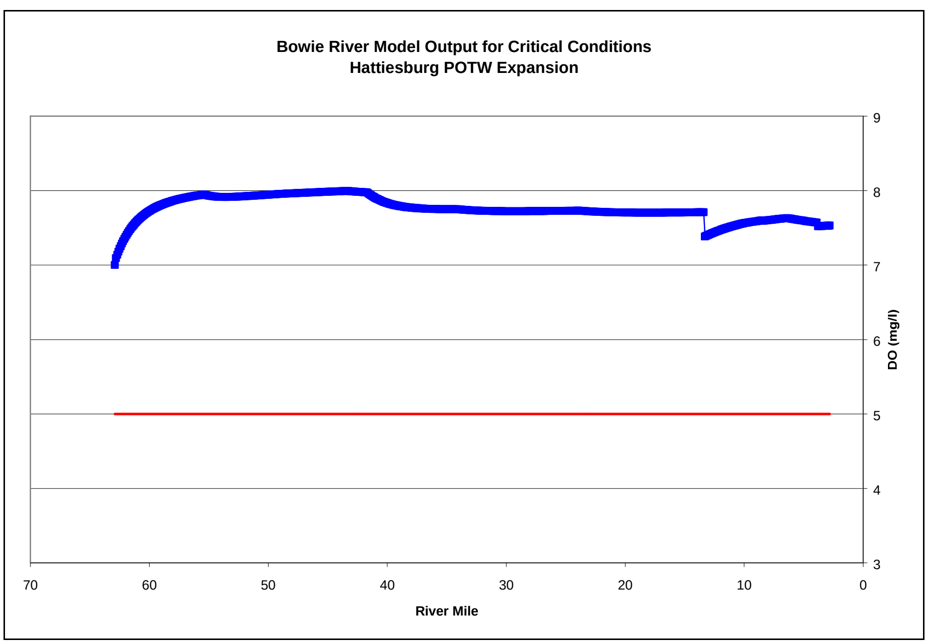


Figure 25. Model Output for the Bowie River with Hattiesburg North Expansion

The TBODu loads for point sources are included in the maximum load scenario, Table 18. As discussed in the critical condition model results, the model indicated that there may be water quality problems in the unnamed tributaries below the discharge points of North Haven Subdivision (MS0022314) and The Trace Subdivision First Addition (MS0051080) when the facilities are discharging at their maximum permitted loads. However, the actual discharges from the facilities (based on DMR data) are much less than the maximum loads. The model does not show violations in water quality standards below these sources when they are discharging at their current levels. Because of this changes to the permits of these facilities are not necessary at the present time. Instead, this TMDL will require monitoring in the unnamed tributaries below these two facilities. There are no reductions from current NPDES permits recommended in this TMDL. Thus, the current permitted loads were used to develop the waste load allocation proposed in this TMDL.

Table 18. Maximum Load Scenario, Critical Conditions

Facility	Flow (MGD)	$CBOD_5$ (mg/l)	NH_3-N (mg/L)	$CBOD_u$:$CBOD_5$ Ratio	CBODu (lbs/day)	NH_3-N (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
Lakewood Estates Subdivision	0.128	30	2	1.5	48.0	2.1	9.8	57.8
Creekwood Subdivision	0.0625	30	2	1.5	23.5	1.0	4.8	28.2
North Haven Subdivision	0.16	30	2	1.5	60.0	2.7	12.2	72.2
Westover West Subdivision	0.14	30	2	1.5	52.5	2.3	10.7	63.2
Hattiesburg North	4	30	2	1.5	1,501.2	66.7	304.9	1,806.1
Trace Subdivison Number 4	0.0428	30	2	1.5	16.1	0.7	3.3	19.3
Serene Hills Subdivision	0.028	30	2	1.5	10.5	0.5	2.1	12.6
The Trace Subdivision First Addition	0.1022	30	2	1.5	38.4	1.7	7.8	46.1
Great Southern National Bank	0.0005	30	2	2.3	0.3	0.0	0.0	0.3
Pecan Grove Trailer Park	0.0038	30	2	1.5	1.4	0.1	0.3	1.7
Al Casco Custom Cutting and Wrap	0.0028	--	--	1.5	0.3	0.5	2.3	2.6
A1 Trailer Park	0.005	30	2	1.5	1.9	0.1	0.4	2.3
Lamar Villa Apartments	0.01	30	2	1.5	3.8	0.2	0.8	4.5
Crossland Road Subdivision	0.0432	45	2	1.5	24.3	0.7	3.3	27.6
	4.7288				**1,782.2**	**79.3**	**362.5**	**2,144.7**

3.5.2 Maximum Load Scenario

Calculating the maximum allowable load of TBODu involved increasing the non-point loads and running the model using a trial-and-error process until the modeled DO was just above 5.0 mg/l in Bowie Creek. The maximum loads from the point sources were not increased. However, the critical condition non-point source loads were increased by a factor of 18.5. The increased non-point source loads are shown in Table 19. Note that the flows were not increased, and the load for Okatoma Creek was not increased because this water body was modeled as a point source going into Bowie Creek. The increased loads were used to develop the allowable maximum daily load for Bowie Creek and the Bowie River. The difference between the critical condition and maximum non-point source loads was used to calculate the margin of safety. The model output for DO in Bowie Creek and Bowie River with the increased loads is shown in Figure 26. As shown, the DO sag reaches 5.0 mg/l.

Table 19. Non-Point Source Loads Input into the Model, Maximum Load Scenario

Water Body	Flow (cfs)	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
Bowie Creek	101.5	20,237.2	4,624.2	24,861.4
Big Creek	2.0	399.3	91.2	490.5
Mineral Creek	0.4	76.1	17.4	93.5
Mixon Creek	0.7	135.0	30.8	165.8
Okatoma Creek	90.0	970.2	221.7	1,191.9
		21,817.8	**4,985.4**	**26,803.1**

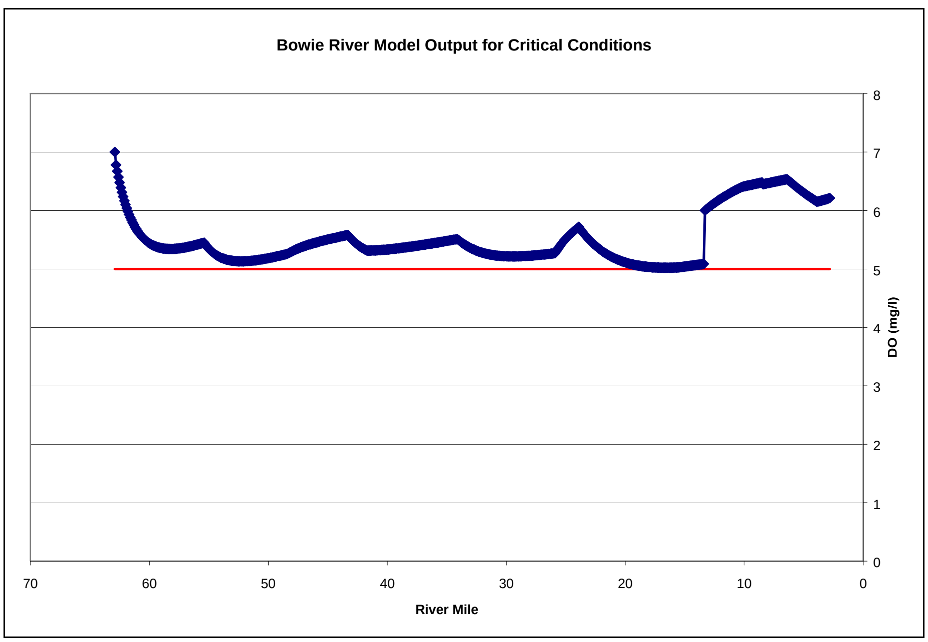


Figure 26. Model Output for the Bowie River, Maximum Load Scenario

3.6 Evaluation of Ammonia Toxicity

Ammonia must not only be considered due to its effect on dissolved oxygen in the receiving water, but also its toxicity potential. Ammonia nitrogen concentrations can be evaluated using the criteria given in 1999 Update of Ambient Water Quality Criteria for Ammonia (EPA-822-R-99-014). The maximum allowable instream ammonia nitrogen (NH_3-N) concentration at a pH of 7.0 and stream temperature of 26°C is 2.82 mg/l. Based on the model results for the maximum load scenario, Figure 27, this standard was not exceeded in Bowie Creek or Bowie River under the current NH_3-N loads with the proposed expansion of the Hattiesburg North POTW.

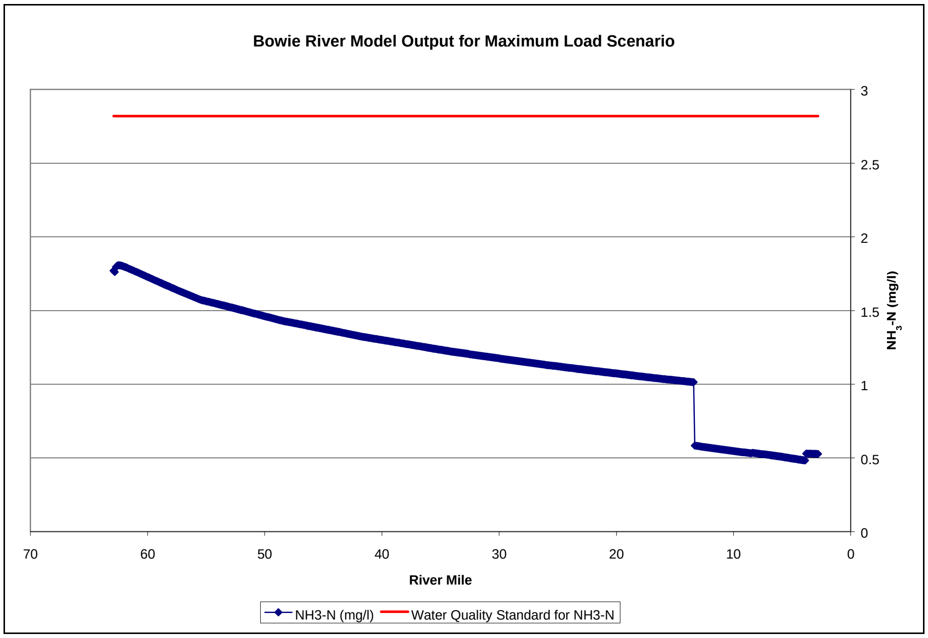


Figure 27. Model Output for Ammonia Nitrogen in Bowie Creek and Bowie River

3.6 Total Phosphorus Estimates

For the Bowie River total phosphorus should be the limiting nutrient. Therefore, the nutrient estimates within this TMDL are focusing on total phosphorus. There are some data available in this stream as shown in Section 2.1. The data were collected in this segment. Table 20 shows the average annual total phosphorus concentration in the stream. The annual average total phosphorus concentration is 0.052 mg/l. This average value is below but near the range of the total phosphorus concentrations measured for the least-disturbed wadeable streams for all seasons in the same bioregion, 0.07 to 0.11 mg/l. While there are not enough data to assess, nor is there a criterion to measure these results against, the concentration values appear to be inline with expected values.

Table 20 Average Annual Total Phosphorus Loads

Year	Samples Collected	Annual Average TP mg/l
1997	2	0.055
1999	12	0.061
2000	10	0.051
2001	7	0.041

The annual average flow in the Bowie River is 639 MGD. The annual average total phosphorus concentration is 0.052 mg/l. The estimated total phosphorus concentration from a lagoon system is 5.2 mg/l and from a mechanical treatment plant is 5.8 mg/l. The load of total phosphorus coming from point sources is estimated using the following equation.

$$TP = \sum flows * 8.34 conversion * [Effluent] mg / l$$

The maximum averaged TP point source load is estimated to be 165.4 pounds per day. This calculation assumes full flow at all of the point sources including the recent increase to Hattiesburg North POTW. The annual average total load based on data from 1997 to 2001 is 277.2 pounds per day. The point source load on average is 59% of the total load..

ALLOCATION

The allocation for this TMDL involves a load allocation for point sources and non-point sources necessary for attainment of water quality standards in the Bowie River. The allocations are given in terms of TBODu for this Phase 1 TMDL. Additionally this TMDL recommends monitoring at the Hattiesburg North POTW for nutrient loads (total phosphorus and total nitrogen). When water quality standards and additional information become available, a phase 2 TMDL may be developed for the Bowie River that includes a nutrient target and reduction scenario.

Nutrients were listed based on anecdotal information, not data that could be compared to a criterion. Therefore, without the “mark on the wall” to make a comparison, it is impossible to establish any TMDL limits at this time. MDEQ is making progress on this however with the Nutrient Task Force’s work. In agreement with EPA Region 4 MDEQ is continuing work on a six year plan to establish criteria for nutrients in wadeable streams, non-wadeable rivers, lakes, and estuaries. Data collection efforts are well underway at this time.

MDEQ does not anticipate adverse downstream impacts from phosphorus loads based on the phosphorus data that are currently available for this water body. Since this water body flows into the Leaf River and thence into the Pascagoula River, which was used as a reference condition for the Escatapwa River study, there does not appear to be any significant "far field" nutrient impacts in the River Basin. In addition, the River dissolved oxygen (DO) data indicate there were no severely depressed DO levels in morning samples or supersaturated DO levels in the afternoon samples. Therefore, it is reasonable to infer that there is no indication of severe diurnal DO sags occurring during the periods sampled by MDEQ. This assessment supports the contention that existing nutrient loadings are not likely causing severe impacts, but further study is necessary to ensure the current nutrient loads are not impairing the aquatic community.
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4.1 Wasteload Allocation

Federal regulations require that effluent limits developed to protect water quality criteria are consistent with the assumptions and requirements of any available wasteload allocation prepared by the state and approved by EPA. The NPDES Permitted facilities that discharge BOD_5 and ammonia nitrogen in the Bowie River watershed are included in the wasteload allocation, Table 21. No reduction of the permitted TBODu load is needed in order for the model to show compliance with the TMDL endpoint in Bowie Creek and the Bowie River. However, instream monitoring requirements should be added to the permits for North Haven Subdivision and The Trace Subdivision First Addition.

Table 21. Wasteload Allocation

Facility	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
Lakewood Estates Subdivision	48.0	9.8	57.8
Creekwood Subdivision	23.5	4.8	28.2
North Haven Subdivision	60.0	12.2	72.2
Westover West Subdivision	52.5	10.7	63.2
Hattiesburg North	1,501.2	304.9	1,806.1

Trace Subdivison Number 4	16.1	3.3	19.3
Serene Hills Subdivision	10.5	2.1	12.6
The Trace Subdivision First Addition	38.4	7.8	46.1
Great Southern National Bank	0.3	0.0	0.3
Pecan Grove Trailer Park	1.4	0.3	1.7
Al Casco Custom Cutting and Wrap	0.3	2.3	2.6
A1 Trailer Park	1.9	0.4	2.3
Lamar Villa Apartments	3.8	0.8	4.5
Crossland Road Subdivision	24.3	3.3	27.6
	1,782.2	**362.5**	**2,144.7**

4.2 Load Allocation

The headwater and spatially distributed loads calculated for the critical condition are included in the load allocation for each water body, Table 21. No reductions of the non-point source loads are required for this TMDL.

Table 21. Load Allocation

Water Body	Flow (cfs)	$CBOD_u$ (mg/L)	CBODu (lbs/day)	NH_3-N (mg/L)	NBODu (lbs/day)	TBODu (lbs/day)
Bowie Creek	101.5	2.0	1,094.2	0.1	250.0	1,344.2
Big Creek	2.0	2.0	21.6	0.1	4.9	26.5
Mineral Creek	0.4	2.0	4.3	0.1	1.0	5.3
Mixon Creek	0.7	2.0	7.5	0.1	1.7	9.3
Okatoma Creek	90.0	2.0	970.2	0.1	221.7	1,191.9
			2,097.8		**479.3**	**2,577.1**

4.3 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 includes both an implicit and explicit component. Conservative assumptions which place a higher oxygen demand on the water body than may actually be present are considered part of the implicit margin of safety. The assumption that all of the ammonia nitrogen present in the water body is oxidized to nitrate nitrogen, for example, is a conservative assumption. In addition, the TMDL is based on the critical condition of the water body represented by the low-flow, high-temperature condition. Modeling the water body at this flow provides protection during the worst-case scenario.

The explicit MOS for this report is the difference between the non-point loads calculated in the maximum load scenario and the critical condition non-point loads. The critical condition non-point source loads represent an approximation of the loads currently going into Bowie Creek, Bowie River, and its tributaries at low-flow conditions based on flow data and regulatory assumptions. The maximum non-point source loads are the maximum TBODu loads that allow maintenance of water quality standards in Bowie Creek under 7Q10 flow conditions. MDEQ has set the MOS as the difference in these loads to account for the uncertainty in the desktop model that was used to develop this phase 1 TMDL. There were limited data available to set up the model, and many assumptions based on regulations and literature values were used. The rate of sediment oxygen demand, for example, was set to zero due to lack of monitoring data. Sediment oxygen demand, however, can be a significant factor in the DO balance of a large water body such as the Bowie River. The STREAM model is a steady state, daily average model that assumes complete mixing throughout the water column. There is some uncertainty in applying this type of model to large rivers such as the Bowie River. Due to the uncertainty in the model, MDEQ set a large, explicit MOS instead of increasing either the WLA or LA to express the maximum assimilative capacity determined for the water body.

For this TMDL the explicit MOS will be set as the difference between these two load scenarios, 24,226 lbs/day TBODu. The calculation of the MOS is shown in Table 22. The MOS is flexible and available for revision of future permitting needs assessed on a case-by-case basis.

Table 22. Calculation of the Explicit Margin of Safety

	Maximum Non-Point Load	Critical Conditoin Non-Point Load	Margin of Safety (Maximum – Baseline)
CBODu (lbs/day)	**21,817.8**	**2,097.8**	19,720.0
NBODu (lbs/day)	**4,985.4**	**479.3**	4,506.1
TBODu (lbs/day)	**26,803.2**	**2,577.1**	**24,226.1**

4.4 Seasonality

Seasonal variation may be addressed in the TMDL by using seasonal water quality standards or developing model scenarios to reflect seasonal variations in temperature and other parameters. Mississippi's water quality standards for dissolved oxygen, however, do not vary according to the seasons. This model was set up to simulate dissolved oxygen during the critical condition period, the low-flow, high-temperature period that typically occurs during the summer season. Since the critical condition represents the worst-case scenario, the TMDL developed for critical conditions is protective of the water body at all times. Thus, this TMDL will ensure attainment of water quality standards for each season

4.5 Calculation of the TMDL

The TMDL was calculated based on Equation 5.

$$\mathbf{TMDL = WLA + LA + MOS} \qquad \textbf{(Equation 5)}$$

Where WLA is the wasteload allocation, LA is the load allocation, and MOS is the margin of safety. All units are in lbs/day of TBODu. The Phase 1 TMDL for TBODu was calculated based on the current loading of point and non-point sources in Bowie Creek and Bowie River. The TMDL calculation is shown in Table 23. As shown in the table, TBODu is the sum of CBODu and NBODu. The wasteload allocation incorporates the CBODu and NH_3-N contributions from identified NPDES Permitted facilities. The load allocations include the background and non-point sources of TBODu and NH_3-N from surface runoff and groundwater infiltration. The implicit margin of safety for this TMDL is derived from the conservative assumptions used in setting up the model.

Table 23. Phase 1 TMDL for TBODu in the Bowie River Watershed

	WLA (lbs/day)	LA (lbs/day)	MOS	TMDL (lbs/day)
CBODu	1,782.2	2,097.8	19,720.0	**23,600.0**
NBODu	362.5	479.3	4,506.1	**5,347.9**
TBODu	**2,144.7**	**2,577.1**	**24,226.1**	**28,947.9**

The Phase 1 TMDL presented in this report represents the current maximum daily load of a pollutant allowed in a water body. Although it has been developed for critical conditions in the water body, the allowable load is not tied to any particular combination of point and non-point source loads. The LA given in the TMDL applies to all non-point sources, and does not assign loads to specific sources. Also, the WLA does not dictate a specific distribution of the loads among individual point sources.

4.6. Reasonable Assurance

This component of TMDL development does not apply to this TMDL report. There are no point sources (WLA) requesting a reduction based on promised LA components and reductions.

CONCLUSION

This Phase 1 TMDL is based on a desktop model calibrated with limited water quality monitoring data. The monitoring results indicate that Bowie Creek and Bowie River are meeting the water quality standard for dissolved oxygen at the present loading of TBODu. Also, monitoring data indicate that nutrients are not causing water quality impairment in the Bowie River. The TMDL allows for the expansion of the Hattiesburg North wastewater treatment facility. In addition, this TMDL also does not limit the issuance of new NPDES permits in the watershed as long as new facilities do not cause or contribute to impairment in Bowie Creek or Bowie River.

The water quality modeling results indicate that there may be water quality problems in two unnamed tributaries of Mineral Creek and Mixon Creek thence the Bowie River. Because there are no data available for these tributaries, this TMDL recommends that additional monitoring be conducted to determine their condition. Specifically, monitoring of the instream water quality condition of the unnamed tributaries below the outfalls of North Haven Subdivision (MS0022314) and The Trace Subdivision First Addition (MS0051080) should be required by the NPDES permits. Expansions of the existing facilities or construction of additional facilities in these tributaries should not be allowed until additional data are available.

This TMDL recommends quarterly nutrient monitoring for the Hattiesburg North POTW to develop information for the Nutrient Task Force development of criteria and a phase 2 TMDL. Additionally, it is recommended that the Bowie River watershed be considered a priority for stream bank and riparian buffer zone restoration and any nutrient reduction BMPs, especially for agricultural activities. The implementation of these BMP activities should reduce the nutrient load entering the Bowie River. This will provide improved habitat for the support of aquatic life in the water body and will result in the attainment of the applicable water quality standards.

This TMDL has been developed as a phase 1 TMDL so that specific nutrient species may be evaluated, if necessary, when more data are available and water quality standards are developed for nutrients. The TMDL may also be revised when water quality data on the unnamed tributaries become available.

5.1 Future Monitoring

Additional monitoring may be prioritized by the local stakeholders, MDEQ, and EPA. MDEQ has adopted the Basin Approach to Water Quality Management, a plan that divides Mississippi's major drainage basins into five groups. During each year-long cycle, MDEQ's resources for water quality monitoring will be focused on one of the basin groups. During the next monitoring phase in the Pascagoula Basin, the Bowie River Watershed will receive additional monitoring to identify any change in water quality.

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 TMDL 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. TMDL mailing list members may request to receive the TMDL reports through either, email or the postal service. Anyone wishing to become a member of the TMDL mailing list should contact Greg Jackson at (601) 961-5098 or Greg_Jackson@deq.state.ms.us.

At the end of the 30-day period, MDEQ will determine the level of interest in the TMDL and make a decision on the necessity of holding a public hearing. If a public hearing is deemed appropriate, the public will be given a 30-day notice of the hearing to be held at a location near the watershed. That public hearing would be an official hearing of the Mississippi Commission on Environmental Quality, and would be transcribed.

All comments should be directed in writing to Greg Jackson at Greg_Jackson@deq.state.ms.us or Greg Jackson, MDEQ, PO Box 10385, Jackson, MS 39289. 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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DEFINITIONS

5-Day Biochemical Oxygen Demand: Also called BOD_5, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous or nitrogenous compounds under aerobic conditions over a period of 5 days.

Activated Sludge: A secondary wastewater treatment process that removes organic matter by mixing air and recycled sludge bacteria with sewage to promote decomposition

Aerated Lagoon: A relatively deep body of water contained in an earthen basin of controlled shape which is equipped with a mechanical source of oxygen and is designed for the purpose of treating wastewater.

Ammonia: Inorganic form of nitrogen (NH_3); product of hydrolysis of organic nitrogen and denitrification. Ammonia is preferentially used by phytoplankton over nitrate for uptake of inorganic nitrogen.

Ammonia Nitrogen: The measured ammonia concentration reported in terms of equivalent ammonia concentration; also called total ammonia as nitrogen (NH_3-N)

Ammonia Toxicity: Under specific conditions of temperature and pH, the unionized component of ammonia can be toxic to aquatic life. The unionized component of ammonia increases with pH and temperature.

Ambient Stations: A network of fixed monitoring stations established for systematic water quality sampling at regular intervals, and for uniform parametric coverage over a long-term period.

Assimilative Capacity: The capacity of a body of water or soil-plant system to receive wastewater effluents or sludge without violating the provisions of the State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters and Water Quality regulations.

Background: The condition of waters in the absence of man-induced alterations based on the best scientific information available to MDEQ. The establishment of natural background for an altered water body may be based upon a similar, unaltered or least impaired, water body or on historical pre-alteration data.

Carbonaceous Biochemical Oxygen Demand: Also called CBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous compounds under aerobic conditions over an extended time period.

Calibrated Model: A model in which reaction rates and inputs are significantly based on actual measurements using data from surveys on the receiving water body.

Conventional Lagoon: An un-aerated, relatively shallow body of water contained in an earthen basin of controlled shape and designed for the purpose of treating water.

Critical Condition: Hydrologic and atmospheric conditions in which the pollutants causing impairment of a water body have their greatest potential for adverse effects.

Daily Discharge: The “discharge of a pollutant” measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling. For pollutants with limitations expressed in units of mass, the "daily discharge" is calculated as the total mass of the pollutant discharged over the day. For pollutants with limitations expressed in other units of measurement, the "daily average" is calculated as the average.

Designated Use: Use specified in water quality standards for each water body or segment regardless of actual attainment.

Discharge Monitoring Report: Report of effluent characteristics submitted by a NPDES Permitted facility.

Dissolved Oxygen: The amount of oxygen dissolved in water. It also refers to a measure of the amount of oxygen that is available for biochemical activity in a water body. The maximum concentration of dissolved oxygen in a water body depends on temperature, atmospheric pressure, and dissolved solids.

Dissolved Oxygen Deficit: The saturation dissolved oxygen concentration minus the actual dissolved oxygen concentration.

DO Sag: Longitudinal variation of dissolved oxygen representing the oxygen depletion and recovery following a waste load discharge into a receiving water.

Effluent Standards and Limitations: All State or Federal effluent standards and limitations on quantities, rates, and concentrations of chemical, physical, biological, and other constituents to which a waste or wastewater discharge may be subject under the Federal Act or the State law. This includes, but is not limited to, effluent limitations, standards of performance, toxic effluent standards and prohibitions, pretreatment standards, and schedules of compliance.

Effluent: Treated wastewater flowing out of the treatment facilities.

First Order Kinetics: Describes a reaction in which the rate of transformation of a pollutant is proportional to the amount of that pollutant in the environmental system.

Groundwater: Subsurface water in the zone of saturation. Groundwater infiltration describes the rate and amount of movement of water from a saturated formation.

Impaired Water body: Any water body that does not attain water quality standards due to an individual pollutant, multiple pollutants, pollution, or an unknown cause of impairment.

Land Surface Runoff: Water that flows into the receiving stream after application by rainfall or irrigation. It is a transport method for non-point source pollution from the land surface to the receiving stream.

Load Allocation (LA): The portion of receiving water's loading capacity attributed to or assigned to non-point sources (NPS) or background sources of a pollutant

Loading: The total amount of pollutants entering a stream from one or multiple sources.

Mass Balance: An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving a defined area, the flux in must equal the flux out.

Non-point Source: Pollution that is in runoff from the land. Rainfall, snowmelt, and other water that does not evaporate become surface runoff and either drains into surface waters or soaks into the soil and finds its way into groundwater. This surface water may contain pollutants that come from land use activities such as agriculture; construction; silviculture; surface mining; disposal of wastewater; hydrologic modifications; and urban development.

Nitrification: The oxidation of ammonium salts to nitrites via *Nitrosomonas* bacteria and the further oxidation of nitrite to nitrate via *Nitrobacter* bacteria.

Nitrogenous Biochemical Oxygen Demand: Also called NBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading nitrogenous compounds under aerobic conditions over an extended time period.

NPDES Permit: An individual or general permit issued by the Mississippi Environmental Quality Permit Board pursuant to regulations adopted by the Mississippi Commission on Environmental Quality under Mississippi Code Annotated (as amended) §§ 49-17-17 and 49-17-29 for discharges into State waters.

Photosynthesis: The biochemical synthesis of carbohydrate based organic compounds from water and carbon dioxide using light energy in the presence of chlorophyll.

Point Source: Pollution loads discharged at a specific location from pipes, outfalls, and conveyance channels from either wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving stream.

Pollution: Contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the State, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or other substance, or leak into any waters of the State, unless in compliance with a valid permit issued by the Permit Board.

Publicly Owned Treatment Works (POTW): A waste treatment facility owned and/or operated by a public body or a privately owned treatment works which accepts discharges which would otherwise be subject to Federal Pretreatment Requirements.

Reaeration: The net flux of oxygen occurring from the atmosphere to a body of water across the water surface.

Regression Coefficient: An expression of the functional relationship between two correlated variables that is often empirically determined from data, and is used to predict values of one variable when given values of the other variable.

Respiration: The biochemical process by means of which cellular fuels are oxidized with the aid of oxygen to permit the release of energy required to sustain life. During respiration, oxygen is consumed and carbon dioxide is released.

Sediment Oxygen Demand: The solids discharged to a receiving water are partly organics, which upon settling to the bottom decompose aerobically, removing oxygen from the surrounding water column.

Storm Runoff: Rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate than rainfall intensity, but instead flows into adjacent land or water bodies or is routed into a drain or sewer system.

Streeter-Phelps DO Sag Equation: An equation which uses a mass balance approach to determine the DO concentration in a water body downstream of a point source discharge. The equation assumes that the stream flow is constant and that CBODu exertion is the only source of DO deficit while reaeration is the only sink of DO deficit.

Total Ultimate Biochemical Oxygen Demand: Also called TBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous or nitrogenous compounds under aerobic conditions over an extended time period.

Total Kjeldahl Nitrogen: Also called TKN, organic nitrogen plus ammonia nitrogen.

Total Maximum Daily Load or TMDL: The calculated maximum permissible pollutant loading to a water body at which water quality standards can be maintained.

Waste: Sewage, industrial wastes, oil field wastes, and all other liquid, gaseous, solid, radioactive, or other substances which may pollute or tend to pollute any waters of the State.

Wasteload Allocation (WLA): The portion of a receiving water's loading capacity attributed to or assigned to point sources of a pollutant.

Water Quality Standards: The criteria and requirements set forth in *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters*. Water quality standards are standards composed of designated present and future most beneficial uses (classification of waters), the numerical and narrative criteria applied to the specific water uses or classification, and the Mississippi antidegradation policy.

Water Quality Criteria: Elements of State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports the present and future most beneficial uses.

Waters of the State: All waters within the jurisdiction of this State, including all streams, lakes, ponds, wetlands, impounding reservoirs, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and all other bodies or accumulations of water, surface and underground, natural or artificial, situated wholly or partly within or bordering upon the State, and such coastal waters as are within the jurisdiction of the State, except lakes, ponds, or other surface waters which are wholly landlocked and privately owned, and which are not regulated under the Federal Clean Water Act (33 U.S.C.1251 et seq.).

Watershed: The area of land draining into a stream at a given location.

ABBREVIATIONS

7Q10 .... Seven-Day Average Low Stream Flow with a Ten-Year Occurrence Period

BASINS ....Better Assessment Science Integrating Point and Nonpoint Sources

BMP ....Best Management Practice

$CBOD_5$ .... 5-Day Carbonaceous Biochemical Oxygen Demand

CBODu .... Carbonaceous Ultimate Biochemical Oxygen Demand

CWA ....Clean Water Act

DMR .... Discharge Monitoring Report

DO...Dissolved Oxygen

EPA ....Environmental Protection Agency

GIS .... Geographic Information System

HUC ....Hydrologic Unit Code

LA .... Load Allocation

MARIS...Mississippi Automated Resource Information System

MDEQ.. Mississippi Department of Environmental Quality

MGD .... Million Gallons per Day

MOS... Margin of Safety

NBODu .... Nitrogenous Ultimate Biochemical Oxygen Demand

NH_3 .... Total Ammonia

NH_3-N ....Total Ammonia as Nitrogen

NO_2-N+ NO_3-N...Nitrite Plus Nitrate Nitrogen

NPDES.. National Pollution Discharge Elimination System

POTW ....Public Owned Treatment Works

RBA .... Rapid Biological Assessment

TBODu...Total Ultimate Biochemical Oxygen Demand

TKN .... Total Kjeldahl Nitrogen

TN .... Total Nitrogen

TOC.. Total Organic Carbon

TP .... Total Phosphorous

USGS .... United States Geological Survey

WLA .... Waste Load Allocation