FINAL REPORT
September 2003

Phase 1 Total Maximum Daily Load

For Organic Enrichment/Low DO and Nutrients

The Bear Creek Watershed Including Blue, Four Mile, Three Mile, Six Mile, Wasp, Macon, Mossy, and Sky Lakes

Yazoo River Basin

Leflore, Humphreys, and Sunflower Counties, Mississippi

Prepared By

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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 waterbody segments found on Mississippi's 1996 Section 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.

Prefixes for fractions and multiples of SI units

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	µ	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

Conversion Factors

To convert from	To	Multiply by	To Convert from	To	Multiply by
Acres	Sq. miles	0.0015625	Days	Seconds	86400
Cubic feet	Cu. Meter	0.028316847	Feet	Meters	0.3048
Cubic feet	Gallons	7.4805195	Gallons	Cu feet	0.133680555
Cubic feet	Liters	28.316847	Hectares	Acres	2.4710538
cfs	Gal/min	448.83117	Miles	Meters	1609.344
cfs	MGD	.6463168	mg/l	ppm	1
Cubic meters	Gallons	264.17205	µg/l * cfs	Gm/day	2.45

CONTENTS

FOREWORD 1
CONTENTS 2
TMDL INFORMATION PAGE 4
EXECUTIVE SUMMARY 6
INTRODUCTION 9
1.1 Background 9
1.2 Applicable Waterbody Segment Use 10
1.3 Applicable Waterbody Segment Standard 10
1.4 Selection of a TMDL Endpoint 11
WATERBODY ASSESSMENT 12
2.1 Discussion of Instream Water Quality Data 12
2.2 Assessment of Point Sources 18
2.3 Assessment of Nonpoint Sources 18
2.4 Critical Condition 19
TMDL Calculation 20
4.1. Phase 1 Mass Balance Approach 20
4.2 Calculation of Flows 20
4.3. Calculation of Loads 21
ALLOCATION 22
5.1 Wasteload Allocation 22
5.2 Load Allocation 22
5.3 Incorporation of a Margin of Safety 22
5.4 Calculation of the TMDL 23
5.5. Seasonality 24
5.6 Reasonable Assurance 24
CONCLUSION 25
6.1 Future Monitoring 25
6.2 Public Participation 25
REFERENCES 26
DEFINITIONS 27
ABBREVIATIONS 32

PHOTOS

Photo 1. Wasp Lake Upstream of Control Structure 7
Photo 2. Yazoo River at the Confluence of Wasp Lake 7
Photo 3. Wasp Lake at Station 7287260 14
Photo 4. Bear Creek near Swiftown 17

FIGURES

Figure 1. Bear Creek Watershed 8
Figure 2. Bear Creek Watershed 303(d) Listed Segments 9
Figure 3. Water Quality Monitoring Stations in the Bear Creek Watershed 13
Figure 4. Landuse Distribution Map for Bear Creek Watershed 19
Figure 5. Head-Discharge Curve for the Wasp Lake Control Structure 21

TABLES

i. Listing Information 4
ii. Water Quality Standard 4
iii. NPDES Facilities 4
iv. Total Maximum Daily Load for TBODu 5
Table 1. Water Quality Monitoring Stations in the Bear Creek Watershed 14
Table 2. In-Situ Data, Surface Depth 15
Table 3. In-Situ Data, Multiple Depths 16
Table 4. Landuse Distribution, Acres 18
Table 5. Load Allocation 22
Table 6. Explicit Margin of Safety 23
Table 7. TMDLs for TBODu 23

TMDL INFORMATION PAGE

i. Listing Information

Name	ID	County	HUC	Cause	Mon/Eval
Bear Creek	MS354M1	Leflore	08030206	Nutrients	Monitored
At Swiftown, from Six Mile Lake to Four Mile Lake					
Bear Creek	MS354M2	Leflore, Humphreys	08030206	Nutrients	Monitored
Near Swiftown, from Four Mile Lake to Wasp Lake					
Bear Creek - DA	MS354E	Leflore, Sunflower, Humphreys	08030206	Organic Enrichment/Low DO and Nutrients	Evaluated
Drainage Area near Four Mile					
Blue Lake	MS354BLM	Leflore	08030206	Organic Enrichment/Low DO and Nutrients	Monitored
Lake Near Itta Bena from Headwaters to Bear Creek					
Four Mile Lake	MS354FLE	Leflore	08030206	Nutrients	Evaluated
Near Swiftown, from Bear Creek MS354M1 to MS254M2					
Macon Lake	MS354ML2E	Sunflower	08030206	Nutrients	Evaluated
Near Inverness					
Mossy Lake	MS354ML1E	Leflore	08030206	Organic Enrichment/Low DO and Nutrients	Evaluated
Near Swiftown					
Six Mile Lake	MS354SL1E	Leflore, Sunflower	08030206	Nutrients	Evaluated
Near Swiftown					
Sky Lake	MS354SL2E	Humphreys	08030206	Nutrients	Evaluated
Near Jake Town					
Three Mile Lake	MS354TMLE	Sunflower	08030206	Organic Enrichment/Low DO and Nutrients	Evaluated
Near Swiftown					
Wasp Lake	MS354WLM	Humphreys	08030206	Organic Enrichment/Low DO and Nutrients	Monitored
Lake near Belzoni from Bear Creek to the Yazoo 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

iii. NPDES Facilities

There are no permanent, direct discharges from NPDES permitted facilities in these water bodies.

iv. Total Maximum Daily Load for TBODu

Flow at Wasp Lake Structure (cfs)	TMDL (lbs/day)	TMDL (lbs/acre-day)
0	0	0.00
500	20,217	0.27
1000	40,433	0.55
1500	60,650	0.82
2000	80,866	1.09
2500	101,083	1.37
3000	121,299	1.64
3500	141,516	1.91
4000	161,732	2.19
4500	181,949	2.46
5000	202,166	2.73

EXECUTIVE SUMMARY

Segments of Bear Creek have been placed on the Mississippi 1998 Section 303(d) List of Waterbodies as monitored water body segments, due to organic enrichment/low dissolved oxygen. Blue Lake and Wasp Lake, which are contained in a system of lakes connected by Bear Creek, have also been placed on the 303(d) list as monitored lakes due to organic enrichment/low dissolved oxygen and nutrients. In addition, there are several evaluated lakes in the Bear Creek watershed that are listed for organic enrichment/low dissolved oxygen and nutrients; Four Mile Lake, Macon Lake, Mossy Lake, Six Mile Lake, Sky Lake, and Three Mile Lake. The applicable state standard specifies that the 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. 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.

The Bear Creek Watershed is located in west-central Mississippi, within Leflore, Humphreys, and Sunflower Counties. Bear Creek flows for approximately 50 miles, from its headwaters south of Itta Bena to its confluence with the Yazoo River approximately 5 miles south of Belzoni. The 50-mile reach consists of a series of lakes connected by small segments of the creek. The most upstream creek, Blue Lake is fed by Gayden Brake, a 1645-acre Cypress-Tupelo swamp located on the southwestern edge of Itta Bena. Bear Creek Begins at the lower end of Blue Lake and flows for 19 miles before reaching One Mile Lake. In this region, Bear Creek is shallow, slow flowing and stagnant at times. Brush and large trees are found along the banks and within the creek. The creek width is typically 50 ft or less in this area. One Mile Lake is connected to Mossy Lake during periods of high water. Bear Creek continues from the lower end of One Mile Lake for approximately 3 miles before reaching Three Mile Lake. Macon Lake is located near Three Mile Lake and is connected when the water level of either lake rises above 115 ft mean sea level. Other segments of Bear Creek connect Three Mile Lake to Six Mile Lake, Six Mile Lake to Four Mile Lake, and Four Mile Lake to Wasp Lake. Sky Lake is located just West of Four Mile Lake, and is connected to the Bear Creek system during high flow periods (Pennington et al, 1991). The Bear Creek Watershed is shown in Figure 1.

Discharge from the lower end of Wasp Lake into the Yazoo River is regulated by a control structure built to prevent backwater flooding from the Yazoo River. This structure was completed in 1983. Prior to its construction, the lower lakes of the Bear Creek watershed (Three Mile, Four Mile, Six Mile, and Wasp Lake) were periodically flooded by backwaters from the Yazoo River. The control structure was built at an elevation of 95 ft. The structure has a gate that is closed during high flow conditions on the Yazoo River. The gate is operated by the Vicksburg District Corps of Engineers. Photos 1 and 2 show the control structure at the confluence of Wasp Lake and the Yazoo River. These photos show high water conditions with the structure gate closed.

Photo 1. Wasp Lake Upstream of Control Structure

Photo 2. Yazoo River at the Confluence of Wasp Lake

The construction and operation of the Wasp Lake control structure represents a significant change from the natural hydrology of the Bear Creek Watershed. In Wasp Lake, the elevation of the inlet of the control structure allows water to flow only when the water level is above 95 ft. Records of stage for a Corps of Engineers gage located in the lake at the control structure show

that the water level usually falls below the 95 ft level during the summer low-flow period each year. Also, the operation of the backwater gate holds water in Wasp Lake while preventing backwater from the Yazoo River during high flow conditions. Because of these changes, it is not possible to create a hydrological model of this system without a detailed data set that could be used to define the channel geometry, velocity, and flow quantity under various flow and control structure management conditions. These data are not available. Due to this significant limitation, MDEQ has determined that model development is not an appropriate approach for this TMDL. A simplified mass balance method, based on a varying flow condition and target values for oxygen demanding material, has been used to calculate this phase 1 TMDL.

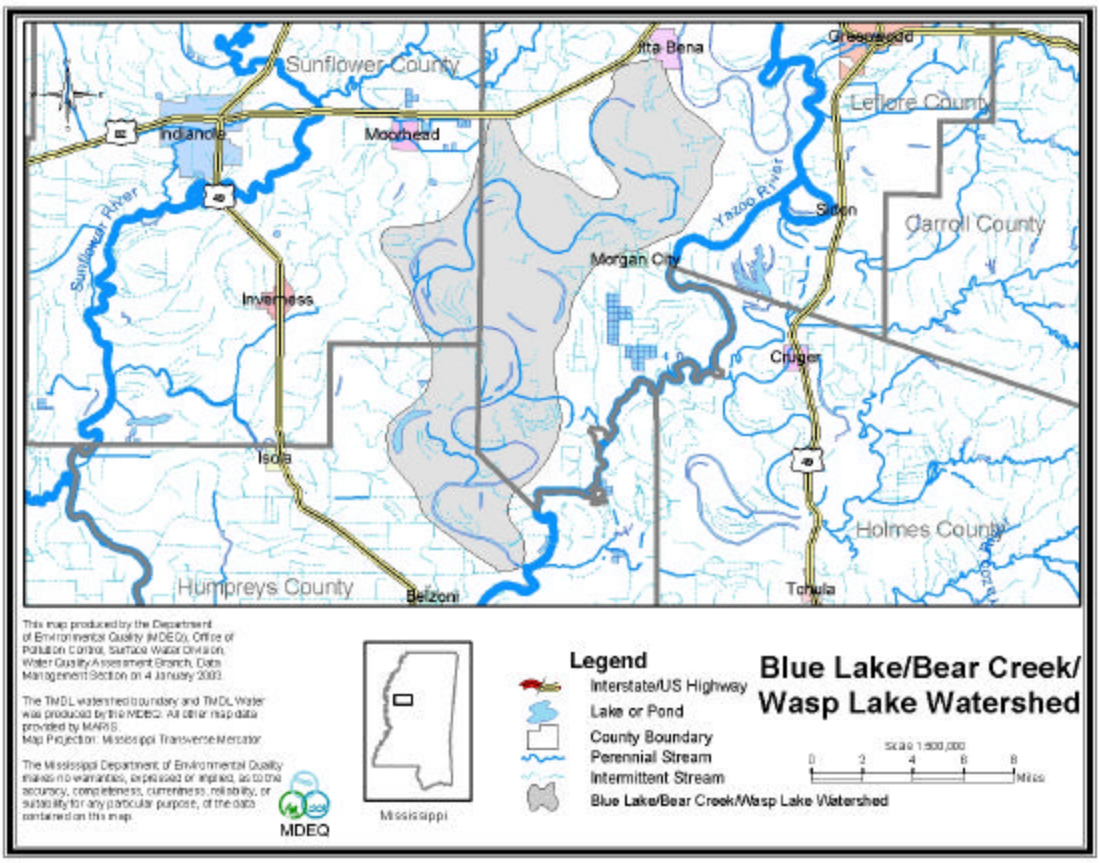

Figure 1. Bear Creek Watershed

INTRODUCTION

1.1 Background

The identification of waterbodies not meeting their designated use and the development of total maximum daily loads (TMDLs) for those waterbodies are required by Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR part 130). The TMDL process is designed to restore and maintain the quality of those impaired waterbodies through the establishment of pollutant specific allowable loads. The impairment is caused by reduced levels of dissolved oxygen (DO) in the creek and connecting lakes due to nutrient enrichment and oxidation of organic material. Thus, this TMDL has been developed for organic enrichment. This TMDL was developed for the 303(d) listed segments shown in Figure 2.

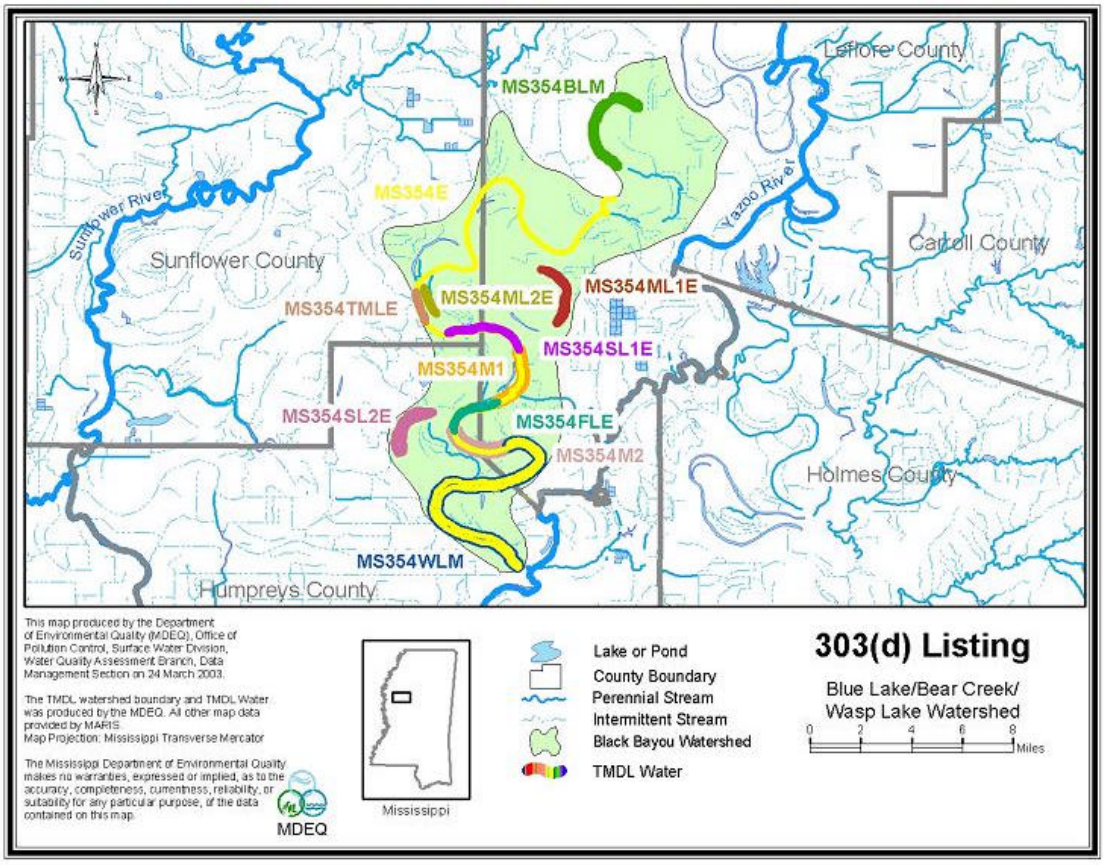

Figure 2. Bear Creek Watershed 303(d) Listed Segments

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.

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

Organic material in a stream 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. Because the water quality target for organic material is written in terms of BOD_5 while this TMDL will be expressed using TBODu, a ratio between the two terms is needed, Equation 2. Values of this ratio, called the 5-day to ultimate ratio, are specified in MDEQ regulations.

$$\textbf{TBODu} = \textbf{BOD}_5 * \textbf{Ratio} \qquad \textbf{(Equation 2)}$$

1.2 Applicable Waterbody Segment Use

The water use classification for the listed segments in the Bear Creek Watershed, as established by the State of Mississippi in the *Water Quality Criteria for Intrastate, Interstate and Coastal Waters* regulation, is Fish and Wildlife Support. The designated beneficial uses for Bear Creek and the connecting lakes located in the Bear Creek Watershed are Secondary Contact and Aquatic Life Support.

1.3 Applicable Waterbody Segment Standard

The water quality standard applicable to the use of the waterbody and the pollutant of concern is defined in the *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters*. 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. The water quality standard will be replaced with the surrogate of TBODu, and DO will not be used as an endpoint to establish this TMDL because water quality modeling has not been conducted. An instream target condition for organic material in the water body will be used as the surrogate for the DO standard. It is estimated that both portions of the DO standard will be attained if the amount of organic material in the water body is below the target condition.

The Bear Creek watershed contains several segments that are listed for impairment due to nutrients. These water bodies were listed based on a comparison of available nutrient data to target levels for specific nutrient species. MDEQ no longer uses nutrient target levels in the water body assessment process. A task force has been formed to develop nutrient water quality standards for water bodies in Mississippi. However, MDEQ will not develop TMDLs for specific nutrient species until the nutrient standards development process is complete and approved.

TMDLs for water bodies listed for nutrients will be developed using the dissolved oxygen standard of a daily average of not less and 5.0 mg/l. TMDL endpoints will not be developed for specific nutrient species. Nutrients are linked to the dissolved oxygen standard, however, through biological processes involving algae growth and respiration. EPA guidance[1] states that

1 USEPA, 2000. Stressor Identification Guidance Docoument. EPA/822/B-00/025.

"excess nutrients, … may affect water quality by promoting algal blooms. In this scenario, an overabundance of plant nutrients such as phosphorous is delivered to stream, and over stimulates algal growth (a process known as eutrophication)." The guidance further states that "If the algal growth is severe, the resulting detritus becomes a source of BOD, reducing dissolved oxygen levels in the river." Thus, the impact of nutrients in water bodies is evaluated through the use of the TMDL endpoint for organic material.

1.4 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 endpoint for this TMDL is based on target levels for organic material given in Mississippi's 1998 Section 305(b) report. The target concentration for $TBOD_5$ is less than 5.0 mg/L. In order to express the TMDL target in terms of total ultimate biochemical oxygen demand (TBODu), a 5-day to ultimate ratio of 1.5 was used. The use of this ratio is specified in MDEQ regulations. Thus, the endpoint for this TMDL will be an instream concentration of TBODu that is less than 7.5 mg/l. It is our estimate that this target level will protect the water quality standard for dissolved oxygen. The TBODu target value for this TMDL takes into account both the carbonaceous (CBODu) and nitrogenous (NBODu) components of the oxygen demanding material.

WATERBODY ASSESSMENT

This TMDL Report includes an analysis of available water quality data and the identification of all known potential pollutant sources in the Bear Creek watershed. The potential point and nonpoint pollutant sources were characterized by the best available information, monitoring data, and literature values. This section documents the available information for Bear Creek and the lakes in the Bear Creek Watershed.

2.1 Discussion of Instream Water Quality Data

The State's 1998 Section 305(b) Water Quality Assessment Report was reviewed to assess water quality conditions and data available for the watershed. Limited water quality data are available for Bear Creek. According to the report, Bear Creek is threatened for the use of aquatic life support. These conclusions were based on instantaneous water chemistry data collected at station 07287195.

There have been two major water quality studies conducted in the Bear Creek Watershed. The first study was conducted by the National Sedimentation Laboratory during the late 1970's, prior to the construction of the control structure on Wasp Lake. This study involved the establishment of twelve monitoring stations within the Bear Creek system. Sampling was conducted at each of these stations over a four-year period. The sampling involved an analysis of the stream flow, sediment movement, nutrients, DO levels, pesticides, and fecal coliform bacteria. This study also included recommendations for future management of the watershed, including a recommendation to install the Wasp Lake structure at an elevation of 95 ft.

The second water quality study in the Bear Creek Watershed was conducted by the Vicksburg District Corps of Engineers, in conjunction with several other studies in the Upper Yazoo Project Area. This study involved sampling at the stations that were included in the Sedimentation Laboratory Study. The stations were sampled at least four times in 1990. This study was conducted after the construction of the Wasp Lake control structure, and included a discussion of some of the changes caused by the structure. The water levels in the upper portion of the system (the area above Three Mile Lake) were unaffected by the structure. In the lower portion of the system, the most significant effect was the change in the source of water during the sampling events. After the construction of the structure, the water in the lower system originated from within the Bear Creek Watershed, not from backwater from the Yazoo River. The locations of the stations included in this study are shown in Figure 3. Table 1 shows the 303(d) listed segments that correspond with each monitoring station. The table also gives an alternative station number, which corresponds to the numbers that were assigned to each station during the Sedimentation Laboratory Study. Station 07287260 is shown below, Photo 3.

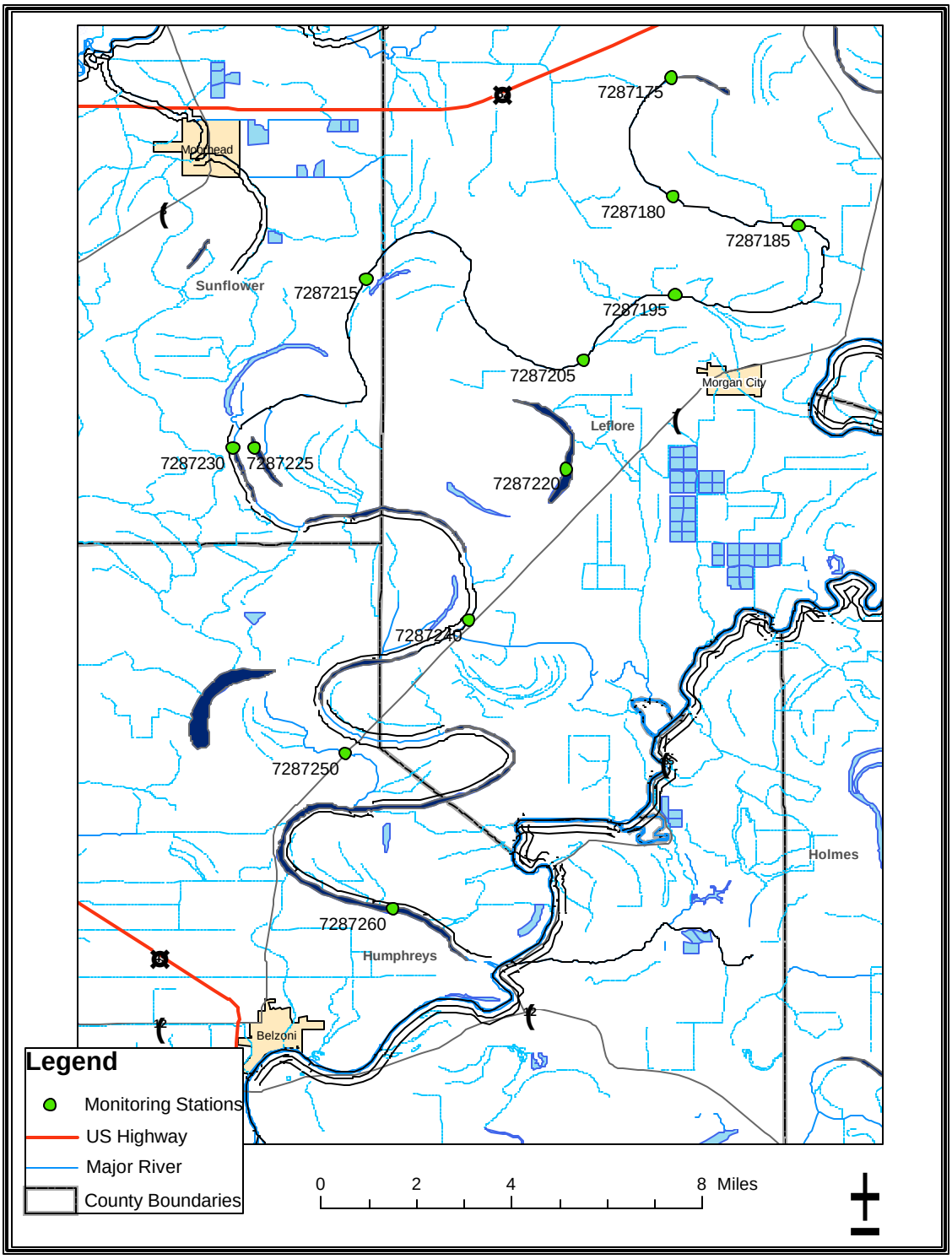

Figure 3. Water Quality Monitoring Stations in the Bear Creek Watershed

Table 1. Water Quality Monitoring Stations in the Bear Creek Watershed

Station Number	Alternate Station Number	Location	303(d) Segment
7287175	1	Blue Lake at Berclair	MS354BLM
7287180	2	Blue Lake near Quito	MS354BLM
7287185	3	Bear Creek near Quito	MS354E
7287195	4	Bear Creek near Morgan City	MS354E
7287205	5	Bear Creek near Colony Town	MS354E
7287215	5A	Bear Creek near Moorhead	MS354E
7287220	6	Mossy Lake near Swiftown	MS354M1LE
7287225	7	Macon Lake near Swiftown	MS354ML2E
7287230	8	Three Mile Lake near Swiftown	MS354TMLE
7287240	9	Bear Creek at Swiftown	MS354M1
7287250	10	Sky Lake near Jaketown	MS354SL2E
7287260	11	Wasp Lake near Belzoni	MS354WLM

In-situ data collected during the COE study are summarized in Tables 2 and 3 below. These tables are from Water Quality Studies in the Upper Yazoo Project Area, Mississippi (Pennington et al, 1991). Table 2 shows the in-situ data collected during the four sampling events. Table 3 shows the depth varying data that were collected at some of the stations.

Photo 3. Wasp Lake at Station 7287260

Table B1

Bear Creek Water Quality - Field Data

Station	Date	Temp (°C)	DO (mg/l)	pH	Cond (umhos/cm)	Turb (ntu)	Barometer (mm of Hg)
1	4-18-90	17.5	4.6	7.05	68	27	767
	6-07-90	29.0	12.0	7.76	76	6	760
	8-29-90	32.0	7.5	6.75	102	8	755
	10-11-90	19.5	2.8	6.44	96	30	760
2	4-18-90	14.5	3.3	7.05	72	25	767
	6-07-90	28.0	3.3	6.7	81	10	760
	8-29-90	27.0	1.0	7.2	92	12	755
	10-11-90	13.0	1.8	6.5	99	18	760
3	4-18-90	14.0	5.2	7.1	65	27	765
	6-07-90	28.0	5.2	6.5	76	11	760
4	4-18-90	15.0	5.3	7.3	63	55	765
	6-07-90	29.0	6.0	7.0	75	45	760
	8-29-90	28.5	2.5	7.2	345	6	757
	10-11-90	14.5	3.4	7.04	228	15	760
5	4-17-90	16.5	8.4	7.1	63	140	760
5a	4-18-90	13.0	4.2	7.3	88	150	765
	6-07-90	30.0	6.3	6.8	81	110	760
	8-29-90	30.0	3.0	7.45	360	10	757
	10-10-90	18.0	4.6	6.78	282	35	760
6	4-17-90	16.5	6.7	7.4	50	85	760
	6-07-90	27.0	6.2	6.75	76	95	760
	8-29-90	32.0	5.9	7.2	179	5	757
	10-10-90	20.4	7.2	6.64	193	20	760
7	4-17-90	18.0	8.5	7.5	43	45	760
	6-07-90	29.0	8.1	7.0	50	23	760
	8-29-90	31.5	8.9	7.6	51	7	757
	10-10-90	21.5	6.5	6.52	44	35	760
8	4-17-90	17.5	5.3	7.1	80	75	760
	6-07-90	27.0	5.2	6.16	74	175	760
	8-29-90	31.0	3.6	7.45	323	8	757
	10-10-90	17.5	6.4	6.94	242	32	760
9	4-17-90	17.0	5.0	6.95	66	65	760
	6-07-90	27.0	6.6	6.45	74	90	760
	8-29-90	31.0	5.2	7.35	149	25	757
	10-10-90	18.5	7.2	6.52	157	38	760
10	4-17-90	17.5	6.3	7.05	80	100	760
	6-07-90	26.0	5.4	6.3	85	85	760
	8-29-90	31.0	5.5	6.46	108	25	757
	10-10-90	20.5	4.7	7.15	111	50	760
11	4-17-90	20.0	7.9	7.0	70	105	760
	6-07-90	28.5	8.3	6.05	78	130	760
	8-29-90	31.5	6.7	7.40	99	18	757
	10-10-90	20.6	7.4	6.48	90	70	760

Table 2. In-Situ Data, Surface Depth

Table B2

Bear Creek Water Quality - Field Data with Depth

Station	Date	Time	Depth (ft)	pH	Cond (µmhos/cm)	Temp (°C)	DO (mg/l)
1	4-18-90	12:31	1.0	7.0	68	17.5	4.6
		12:32	15.0	6.9	90	15.0	2.0
		12:33	20.0	6.9	115	14.5	0.4
	6-07-90	18:01	1.0	7.8	76	29.0	12.0
		18:02	16.0	6.8	181	19.0	0.4
	8-29-90	15:46	1.0	6.8	102	32.0	7.5
		15:47	5.0	6.7	115	31.0	6.0
		15:48	12.0	6.6	186	27.0	0.0
	10-11-90	9:31	1.0	6.4	96	19.5	2.8
		9:32	12.0	6.3	96	20.5	1.8
6	6-07-90	13:46	1.0	6.8	76	27.0	6.2
		13:47	10.0	6.6	93	24.5	1.7
	8-29-90	13:31	1.0	7.2	179	32.0	5.9
		13:32	7.0	7.2	205	29.5	0.1
	10-10-90	15:46	1.0	6.6	193	20.5	7.2
		15:47	7.0	6.8	193	20.5	6.5
7	6-07-90	12:31	1.0	7.0	50	29.0	8.1
		12:32	9.0	6.2	60	23.5	0.3
	8-29-90	12:01	1.0	7.6	51	31.5	8.9
		12:02	5.0	7.6	51	31.0	5.4
	10-10-90	17:31	1.0	6.5	44	21.5	6.5
		17:32	7.0	6.4	43	21.0	5.8
8	6-07-90	13:01	1.0	6.2	74	27.0	5.2
		13:02	3.0	6.2	74	27.0	5.2
9	6-07-90	11:31	1.0	6.4	74	27.0	6.6
		11:32	5.0	6.4	75	26.0	4.1
10	6-07-90	11:01	1.0	6.3	85	26.0	5.4
		11:02	7.0	6.2	87	24.5	0.9
	8-29-90	11:01	1.0	7.2	111	31.0	4.7
		11:02	3.0	7.1	111	31.0	3.3
	10-10-90	12:31	1.0	6.5	108	20.5	5.5
		12:32	3.0	6.5	108	20.5	4.6
11	4-17-90	11:31	1.0	7.0	70	20.0	7.9
		11:32	10.0	7.0	74	16.5	4.7
	6-07-90	9:31	1.0	6.1	78	28.5	8.3
		9:32	7.0	6.1	80	24.0	0.5
	8-29-90	10:01	1.0	7.4	99	31.5	6.7
		10:02	5.0	7.0	105	31.0	0.9
	10-10-90	11:46	1.0	6.5	90	20.5	7.4
		11:47	5.0	6.5	90	21.5	6.5

Table 3. In-Situ Data, Multiple Depths

As indicated in Table 2, DO violations were reported more frequently in the upper part of the system. As seen in Photo 4 of Bear Creek near Swiftown, the upper and middle parts of the watershed are much more wooded and narrow compared to the open lakes in the lower part of the watershed. The depth profiles in Table 4 show that the DO decreased with depth at all of the stations sampled.

Photo 4. Bear Creek near Swiftown

2.2 Assessment of Point Sources

The first step in assessing pollutant sources in the Bear Creek Watershed was locating the NPDES permitted sources. There is currently only one facility with a direct discharge into the Bear Creek Watershed. This facility, Confish Inc (MS0043346), presently discharges into an interim outfall, Ditch No 21 thence into Wasp Lake. The facility is presently completing construction of its final discharge site in the Yazoo River[2]. Because the discharge from this facility will be removed from Wasp Lake before the summer of 2003, it was not included as a source of organic material in this TMDL. The removal of this source, however, represents a decrease in the current load of organic material and may result in some water quality improvement in Wasp Lake. The only other NPDES permitted discharger located in the Bear Creek Watershed is the Itta Bena POTW (MS0020915). This facility discharges into Gayden Brake, a large Cypress-Tupelo swamp. Since the discharge point is a significant distance upstream from the point where Gayden Brake meets the headwaters of Blue Lake, it is assumed that the discharge has little or no direct impact on Blue Lake or the downstream waterbodies.

2.3 Assessment of Nonpoint Sources

Nonpoint loading of TBODu in a waterbody results from the transport of the pollutants into receiving waters by overland surface runoff and groundwater infiltration. Landuse activities within the drainage basin, such as agriculture, and urbanization contribute to nonpoint source loading. Other nonpoint pollution sources include atmospheric deposition and natural weathering of rocks and soil.

The 74,000-acre drainage area of Bear Creek contains many different landuse types, including urban, forest, cropland, pasture, water, and wetlands. The landuse information 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. The majority of the land in the watershed is used for farming, with cotton and soybeans being the most common crops. The landuse distribution within the Bear Creek Watershed is shown in Table 4 and Figure 4.

Table 4. Landuse Distribution, Acres

Urban	Agriculture	Water	Forest	Wetland	Total
89	50,122	4,240	12,054	7,496	74,001
0%	68%	6%	16%	10%	100%

2 Personal Communication. Carey Hardin, Clearwater Consultants. March 2003.

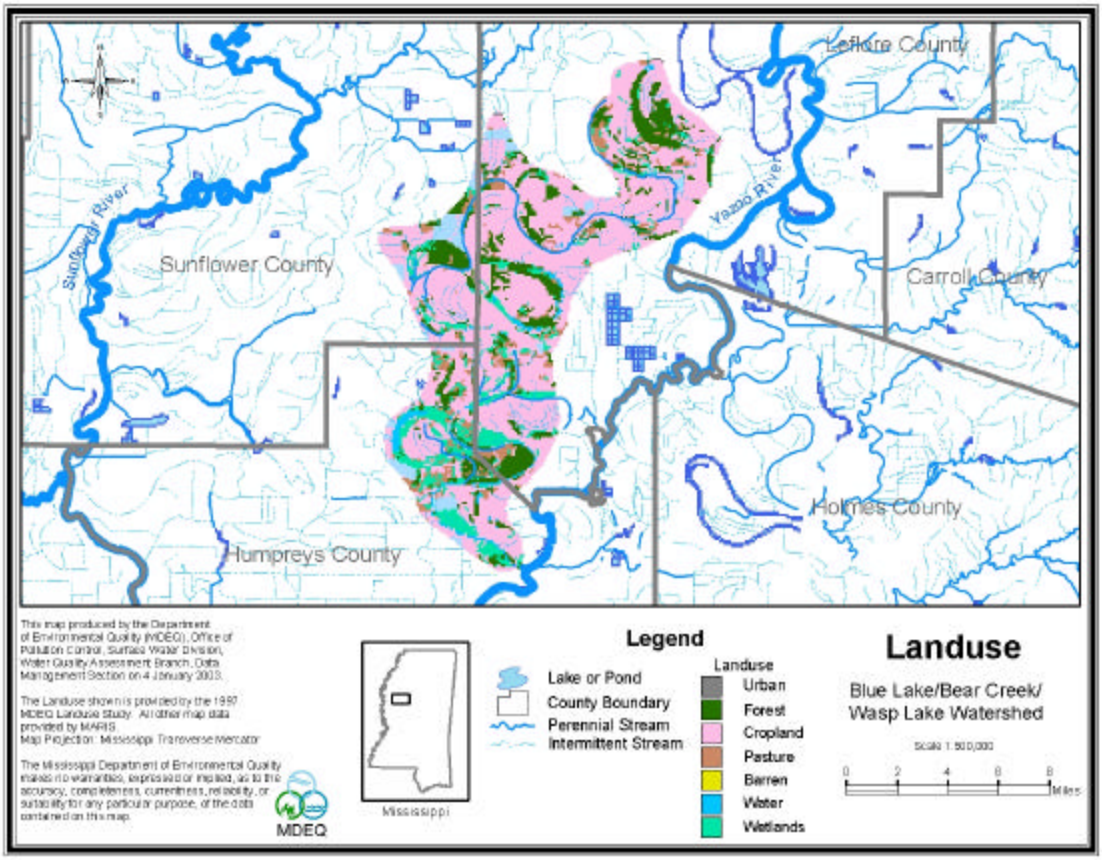

Figure 4. Landuse Distribution Map for Bear Creek Watershed

2.4 Critical Condition

Based on the information given in this section, the worst-case, critical condition of the water bodies can not be determined. This is because the critical condition is related to both the environmental conditions and the management of the control structure. Because the majority of the land in the watershed is used for agriculture, critical events will likely occur following rainfall/runoff events. However, low-flow conditions, in which there is not flow in the water body may also be described as critical events. Since this TMDL will vary based on the flow condition, it will apply to both types of critical events and all seasons.

TMDL Calculation

Establishing the relationship between the instream water quality target and the source loading is a significant component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. For this Phase 1 TMDL, this link will be established using a simple mass balance approach.

4.1. Phase 1 Mass Balance Approach

For this TMDL, there is not enough data to calibrate a model of the system with any level of accuracy. For this reason, this TMDL has been developed as a phase 1 report. The phase 1 TMDL has been calculated by using a simple mass-balance approach, based on a water quality target and varying flow. Using this approach, the TMDL will be presented as an equation that can be applied to a range of flow conditions, instead of a single number.

4.2 Calculation of Flows

There are not continuous records of flow available for the Bear Creek Watershed. The flows, however, can be estimated using the stage gages that were installed on both sides of the Wasp Lake Control Structure. A rating curve for the structure that relates the head above 95 ft on the Wasp Lake side of the structure to the discharge was provided by the COE, along with the daily stage records for a twelve-year period, from 1990 to 2002. This rating curve is shown in Figure 5. It should be noted that this curve only applies when the water level on the Yazoo River side of the structure is lower than the water level on the Wasp Lake side. The structure gate is closed when the river elevation rises above the lake elevation, so there is no flow out of Wasp Lake. Based on Figure 5 and a review of the stage data from the Wasp Lake Structure, the range of flows expected for Wasp Lake are from 0 to 5000 cfs.

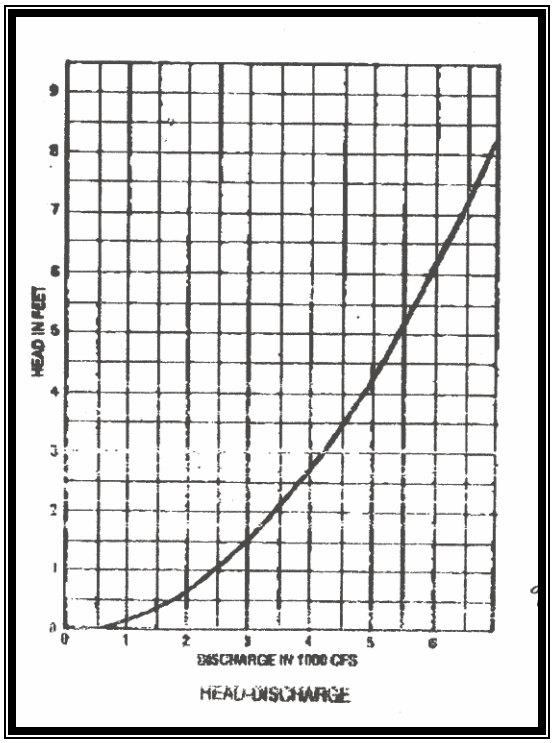

Figure 5. Head-Discharge Curve for the Wasp Lake Control Structure
From Wasp Lake Drainage Structure and Levee Gap Closure, Hydrologic Data, U.S Army Engineer District, Vicksburg Corps of Engineers

4.3. Calculation of Loads

The mass balance approach uses the conservation of mass principle. Loads can be calculated by multiplying the target TBODu concentration in the water body by each flow value in the range 0 to 5000 cfs. Because nonpoint sources are the only contributors represented in this TMDL, the loads have then been divided by the drainage area of the watershed. This allows the TMDL to be expressed in the units of lbs/acre-day. This method of calculation, however, does not allow the loads to be attributed to separate landuse categories such as cropland and forested areas. Instead, the allowable loads are distributed evenly over the watershed. The loads can be calculated using the following relationship.

Load (lbs/acre-day) = [Concentration (mg/L) * Flow (cfs) * (1 MGD/1.547 cfs) * 8.34 (lb-L/Mgal-mg)]/Drainage Area (acre) **(Equation 3)**

Where: cfs = cubic feet per second
MGD = million gallons per day
Mgal = million gallons

ALLOCATION

The allocation for this TMDL involves an allocation for nonpoint sources necessary for attainment of water quality standards in the Bear Creek Watershed.

5.1 Wasteload Allocation

The WLA for this TMDL has been set to zero. This is because there are no permanent dischargers of organic material present in the Bear Creek Watershed. The only exception is the Itta Bena POTW, which discharges into Gayden Brake but does not directly impact Blue Lake or the downstream water bodies. The addition of new sources in the Bear Creek Watershed is not recommended at this time. This is because the flow of water through Bear Creek and its connected lakes is often slow and is stagnant during low water level periods and times when the Wasp Lake control structure is closed. Low-flow and no-flow conditions limit the assimilative capacity of the receiving water body. Thus, the addition of point sources may have negative impacts on the water quality of the water body, and should not be permitted without additional monitoring and modeling in the watershed.

5.2 Load Allocation

The LA for the Bear Creek system was calculated using the target value of 7.5 mg/l TBODu and the flow condition. In calculating the LA component of the TMDL, the target value was reduced by a 20 percent explicit MOS. The resulting LA, based on equation 1 has a lower limit of 0.00 and an upper limit of 2.19 lbs/acre-day at a flow of 5,000 cfs at the Wolf Lake Structure. The LA, in terms of both lbs/day and lbs/acre-day of TBODu, calculated in increments of 500 cfs is given in Table 5.

Table 5. Load Allocation

Flow at Wasp Lake Structure (cfs)	LA (lbs/day)	LA (lbs/acre-day)
0	0	0.00
500	16,173	0.22
1000	32,347	0.44
1500	48,520	0.66
2000	64,693	0.87
2500	80,866	1.09
3000	97,040	1.31
3500	113,213	1.53
4000	129,386	1.75
4500	145,559	1.97
5000	161,732	2.19

5.3 Incorporation of a Margin of Safety

The margin of safety is another required component of a TMDL and accounts for the uncertainty about the relationship between pollutant loads and the quality of the receiving waterbody. 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. Since a model was

not used, the MOS selected for this model is explicit. Reducing the TMDL by 20% explicitly specifies the MOS. The MOS, in terms of both lbs/day and lbs/acre-day of TBODu, calculated in increments of 500 cfs is given in Table 6.

Table 6. Explicit Margin of Safety

Flow at Wasp Lake Structure (cfs)	MOS (lbs/day)	MOS (lbs/acre-day)
0	0	0.00
500	4,043	0.05
1000	8,087	0.11
1500	12,130	0.16
2000	16,173	0.22
2500	20,217	0.27
3000	24,260	0.33
3500	28,303	0.38
4000	32,347	0.44
4500	36,390	0.49
5000	40,433	0.55

5.4 Calculation of the TMDL

The TMDL was calculated based on Equation 3, where the WLA is the wasteload allocation (the load from the point sources), the LA is the load allocation (the load from the nonpoint sources), and MOS is the margin of safety.

$$\mathbf{TMDL = WLA + LA + MOS} \qquad \textbf{(Equation 3)}$$

The WLA portion of this TMDL is equal to zero, since there are no permanent point sources present in the waterbody, and reservation of future assimilative capacity for point sources is not recommended. Thus, this TMDL is simply a sum of the LA and MOS. The TMDLs for TBODu for flows of 0 to 5000 cfs are given in Table 7. Due to the lack of monitoring data for TBODu and flow, the existing load of organic material could not be calculated. Thus, a percent reduction from the present loading is not included in this TMDL.

Table 7. TMDLs for TBODu

Flow at Wasp Lake Structure (cfs)	LA (lbs/day)	MOS (lbs/day)	TMDL (lbs/day)	LA (lbs/acre-day)	MOS (lbs/acre-day)	TMDL (lbs/acre-day)
0	0	0	0	0.00	0.00	0.00
500	16,173	4,043	20,217	0.22	0.05	0.27
1000	32,347	8,087	40,433	0.44	0.11	0.55
1500	48,520	12,130	60,650	0.66	0.16	0.82
2000	64,693	16,173	80,866	0.87	0.22	1.09
2500	80,866	20,217	101,083	1.09	0.27	1.37
3000	97,040	24,260	121,299	1.31	0.33	1.64
3500	113,213	28,303	141,516	1.53	0.38	1.91
4000	129,386	32,347	161,732	1.75	0.44	2.19
4500	145,559	36,390	181,949	1.97	0.49	2.46
5000	161,732	40,433	202,166	2.19	0.55	2.73

5.5. Seasonality

Seasonal variation has been addressed in the TMDL by using an equation that varies with the flow condition to represent the TMDL. Thus, this TMDL will ensure attainment of water quality standards for both high and low flow conditions. Temperature was not considered in calculating this TMDL.

5.6 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 Load Allocation components and reductions.

CONCLUSION

This Phase 1 TMDL will place restrictions on NPDES permitting activities in the Bear Creek Watershed such that additional point sources are not recommended without additional monitoring and modeling. Steps need to be taken to ensure that the overall load of TBODu placed in this waterbody from the nonpoint sources does not exceed the assimilative capacity of the Bear Creek and its connecting lakes.

6.1 Future Monitoring

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 Yazoo Basin, Bear Creek may receive additional monitoring to identify any change in water quality. The additional monitoring may allow refinements of the assumptions and water quality target used to calculate the phase 1 TMDL.

6.2 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.

All comments received during the public notice period and at any public meetings become a part of the record of this TMDL. All comments will be considered in the submission of this TMDL to EPA Region 4 for final approval.

REFERENCES

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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 waterbody may be based upon a similar, unaltered or least impaired, waterbody or on historical pre-alteration data.

Biological Impairment: Condition in which at least one biological assemblages (e.g. , fish, macroinvertabrates, or algae) indicates less than full support with moderate to severe modification of biological community noted.

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 waterbody.

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 waterbody 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 waterbody 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 waterbody 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 Waterbody: Any waterbody 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 nonpoint source pollution from the land surface to the receiving stream.

Load Allocation (LA): The portion of a receiving water's loading capacity attributed to or assigned to nonpoint 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.

Nonpoint 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 waterbodies 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 waterbody 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 waterbody 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+ NO_3 ..... Nitrite Plus Nitrate

NPDES .....National Pollution Discharge Elimination System

$TBOD_5$ .....5-Day Total Biochemical Oxygen Demand

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

WWTP ..... Wastewater Treatment Plant