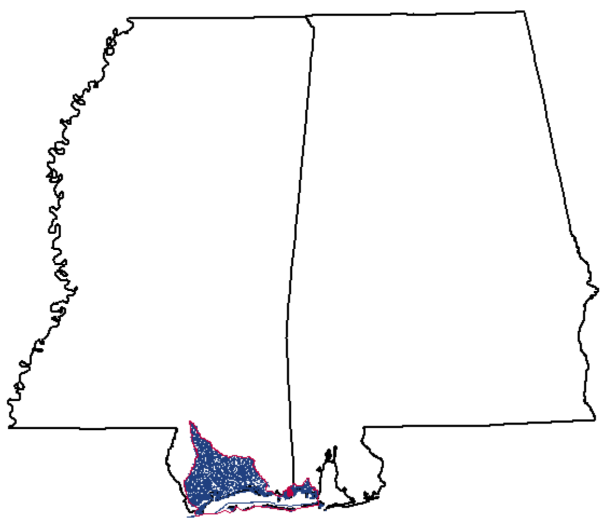
Fecal Coliform TMDL

For

Bayou Cumbest / Bangs Lake Watershed
Coastal Streams Basin
Jackson County, Mississippi

Prepared By

Mississippi State University
Coastal Research & Extension
Center



Prepared For

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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 segments addressed are comprised of monitored segments that have data indicating impairment. However, the report may also include evaluated segments with insufficient data to indicate impairment. The evaluated waterbody segments in this report were included because they are hydrologically linked to the monitored segment. 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.

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TABLES

MONITORED SEGMENT IDENTIFICATION

Name:	Bayou Cumbest
Waterbody ID:	MS109BCUM
Location:	Near Orange Grove: from county road east of Orange Grove to mouth at Pt aux Chenes Bay
County:	Jackson
USGS HUC Code:	03170009
NRCS Watershed:	070
Length:	3 miles of Bayou Cumbest plus 2 miles within Pt aux Chenes Bay
Use Impairment:	Shellfishing
Cause Noted:	Fecal Coliform, an indicator for the presence of pathogenic bacteria
Priority Rank:	6 – 1998, (No. 1 – 1996)
NPDES Permits:	None
Pollutant Standard:	For shellfish harvest season, (September – April), fecal coliform colony counts shall not exceed a median or geometric mean MPN of 14 per 100 ml, and not more than 10 percent of the samples shall exceed an MPN of 43 for a 5-tube decimal dilution test or an MPN of 49 per 100 ml for a 3-tube decimal dilution test.
Waste Load Allocation:	The TMDL prohibits any permitted discharges to this waterbody due to the classification as a shellfish harvest area.
Load Allocation:	All sources considered combined.
Margin of Safety:	Implicit model assumption – use of line intercept component of regression equation.
Total Maximum Daily Load (TMDL):	205 colonies per 100 ml (dry season) 83 colonies per 100 ml (wet season)

MONITORED SEGMENT IDENTIFICATION

Name:	Bayou Cumbest
Waterbody ID:	MS109BCUM
Location:	Near Orange Grove: from county road east of Orange Grove to mouth at Pt aux Chenes Bay
County:	Jackson
USGS HUC Code:	03170009
NRCS Watershed:	070
Length:	4 miles of Bayou Cumbest
Use Impairment:	<u>Contact Recreation</u>
Cause Noted:	Fecal Coliform, an indicator for the presence of pathogenic bacteria
Priority Rank:	6 – 1998, (No. 1 – 1996)
NPDES Permits:	None
Pollutant Standard:	Fecal coliform colony counts shall not exceed a geometric mean of 200 per 100 ml, nor shall more than 10 percent of the samples examined during any month exceed a colony count of 400 per 100 ml.
Waste Load Allocation:	The TMDL prohibits any permitted discharges to this waterbody due to the classification as a shellfish harvest area.
Load Allocation:	All sources considered combined.
Margin of Safety:	Implicit model assumption – use of line intercept component of regression equation.
Total Maximum Daily Load (TMDL):	205 colonies per 100 ml (dry season) 83 colonies per 100 ml (wet season)

EVALUATED SEGMENT IDENTIFICATION

Name:	Bayou Cumbest
Waterbody ID:	MS109BCUE
Location:	Near Orange Grove: from county road east of Orange Grove to mouth at Pt aux Chenes Bay
County:	Jackson
USGS HUC Code:	03170009
NRCS Watershed:	070
Use Impairment:	<u>Secondary Contact Recreation</u>
Cause Noted:	Fecal Coliform, an indicator for the presence of pathogenic bacteria
NPDES Permits:	None
Pollutant Standard:	For the summer months, fecal coliform colony counts shall not exceed a geometric mean of 200 per 100 ml, nor shall more than ten percent of the samples examined during any month exceed a colony count of 400 per 100 ml. In winter months, the limits are 2000 and 4000, respectively.
Waste Load Allocation:	The TMDL prohibits any permitted discharges to this waterbody due to the classification as a shellfish harvest area.
Load Allocation:	All sources considered combined.
Margin of Safety:	Implicit model assumption – use of line intercept component of regression equation.
Total Maximum Daily Load (TMDL):	205 colonies per 100 ml (dry season) 83 colonies per 100 ml (wet season)

SEGMENT IDENTIFICATION

Name:	Bangs Lake
Waterbody ID:	MS109E02M
Location:	Near Pascagoula: from inland boundary to the mouth of Pt aux Chenes Bay
County:	Jackson
USGS HUC Code:	03170009
NRCS Watershed:	070
Use Impairment:	Shellfishing
Cause Noted:	Fecal Coliform, an indicator for the presence of pathogenic bacteria
Priority Rank:	Not listed on the current Section 303(d) list for this pollutant
NPDES Permits:	None
Pollutant Standard:	For shellfish harvest season, (September – April) fecal coliform colony counts shall not exceed a median or geometric mean MPN of 14 per 100 ml, and not more than 10 percent of the samples shall exceed an MPN of 43 for a 5-tube decimal dilution test or an MPN of 49 per 100 ml for a 3-tube decimal dilution test.
Waste Load Allocation:	The TMDL prohibits any permitted discharges to this waterbody due to the classification as a shellfish harvest area.
Load Allocation:	All sources considered combined.
Margin of Safety:	Implicit model assumption – use of line intercept component of regression equation.
Total Maximum Daily Load (TMDL):	199 colonies per 100 ml (dry season) 81 colonies per 100 ml (wet season)

EXECUTIVE SUMMARY

The Bayou Cumbest / Bangs Lake watershed is highly ranked on the Mississippi 1996 Section 303(d) List of Waterbodies based on elevated levels of fecal coliform bacteria. This watershed is classified for shellfish harvest, with an approval limit of no greater than 14 colonies of fecal coliform per 100 ml, and not more than 10 percent of samples exceeding 43 colonies per 100 ml for a 5-tube decimal dilution test or 49 colonies per 100 ml for a 3-tube decimal dilution test. Shellfish beds in this watershed are commonly closed to harvest due to elevated levels of coliform bacteria.

This relatively small coastal watershed is located in the southeastern corner of Jackson County and includes the 3.5 mile channel of Bayou Cumbest and its approximately 8-10 square mile drainage area and the adjacent 10-12 square mile area of inter-tidal marsh and shallow-waters of Point aux Chenes Bay. The TMDL was developed using bi-weekly monitoring data collected at stations across the watershed over a 1-year period from May 1995 to May 1996. Data collected as part of this monitoring included cumulative rainfall (measured at a site within the watershed) and tidal conditions at the time of sample collection. These data were used to describe the critical conditions affecting fecal coliform transport across the watershed. TMDL values were generated using linear regression analysis of data collected from stations ranging from the suspected source areas to the target shellfish beds.

Fecal coliform loading within this watershed is exclusively from nonpoint sources, particularly from poorly operating and failing individual onsite wastewater treatment systems and wildlife. There are no known NPDES Permitted point sources of fecal coliform within the watershed. The major nonpoint sources of fecal contamination are approximately 45 single-family residences located along the upper reaches of Bayou Cumbest. The TMDL assumes a direct relationship between levels of bacteria introduced at the source and those measured at the target area. A series of regression models were calculated using data from 14 stations located between the source and target areas. Two sets of models were generated to reflect conditions for the two major shellfish areas within the watershed: the Point aux Chenes Bay and Bangs Lake areas. TMDL values were determined by identifying those sampling dates, which reflected near critical levels of coliform over designated shellfish beds. The TMDL was designated as the line intercept component of the regression equation for that date. Two TMDLs were designated for each shellfish area in order to reflect conditions during the wet and dry seasons of the year. The Bayou Cumbest TMDL values are 205 and 83 colonies per 100 ml for the dry and wet season, respectively. Bangs Lake TMDL values are 199 and 81 colonies per 100 ml for the dry and wet season, respectively. These TMDL values correspond to the water quality standard for shellfish harvesting in Point aux Chenes Bay and Bangs Lake.

Recommendations for load reduction within the watershed focus on reducing input of fecal contamination from the septic systems associated with residences along Bayou Cumbest and other portions of the watershed. Apart from better maintenance of septic systems, the ultimate solution along Bayou Cumbest would be the establishment of a community wastewater collection and treatment system for all residences and/or the removal of residences through buy-out programs. A possible solution to continued contamination from a second site within the watershed would include the construction of a wetland that would intercept and treat effluent after rain events.

1.0 INTRODUCTION

1.1 Background

As part of the process of implementing a Total Maximum Daily Load (TMDL) program for the State of Mississippi (pursuant to Section 303(d) of the Clean Water Act), the Mississippi Department of Environmental Quality (MDEQ) selected the Bayou Cumbest / Bangs Lake watershed as a candidate site for TMDL development. This relatively small coastal watershed was ranked first on Mississippi's priority list of impaired waterbodies (MDEQ 1996) based on data that showed elevated levels of pathogens (i.e., fecal coliform bacteria). This watershed (Figure 1) includes the 3.5 mile channel of Bayou Cumbest and its approximately 8-10 square mile drainage area and the adjacent 10-12 square mile area of inter-tidal marsh and shallow-waters of Point aux Chenes Bay. An active shellfish growing area is located in the Bangs Lake portion of Point aux Chenes Bay. The entire watershed is the abandoned delta of the Escatawpa River, prior to its capture by the Pascagoula River within the past three thousand years.

Although primarily a rural area of Jackson County, approximately 50-60 residences are located within the Bayou Cumbest watershed, with 40-45 of these located directly adjacent to Bayou Cumbest. All of these homes have individual onsite wastewater treatment systems, many if not all of which fail to adequately treat wastewater, leading to direct discharge of fecal coliform into Bayou Cumbest and the adjacent Point aux Chenes Bay (including the Bangs Lake shellfish area). The frequent closure of this shellfish growing area was the basis of the Gulf of Mexico Program's (GMP) funding of a demonstration project as part of its Shellfish Growing Waters Restoration Demonstration Program in 1994. The Bangs Lake Shellfish Growing Water Restoration Project[1] consisted of the replacement of 39 non-functioning individual on-site wastewater treatment systems along Bayou Cumbest with rock-reed filter systems. A rock-reed filter system consists of a shallow, plastic lined linear trough filled with washed gravel and planted with wetland vegetation. These filters are installed in place of the typical field lines that consist of buried perforated plastic pipe. Subsequent monitoring of three of these filter systems and the surface waters of Bayou Cumbest and Point aux Chenes Bay by Mississippi State University (LaSalle 1997) showed that these replacements appear to provide some improvement in fecal coliform levels within this watershed. Results of this study also identified at least one additional source of fecal coliform contamination into this area that appears to affect the Bangs Lake shellfish area. The TMDL described here targets pollution from fecal coliform bacteria and was developed using water quality data reported in LaSalle (1997).

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[1]Primary funding from the Gulf of Mexico Program, with supplemental funding from the Mississippi Department of Marine Resources and the Jackson County Soil & Water Conservation District with technical support from the Mississippi Department of Health and the Mississippi State University Coastal Research & Extension Center.

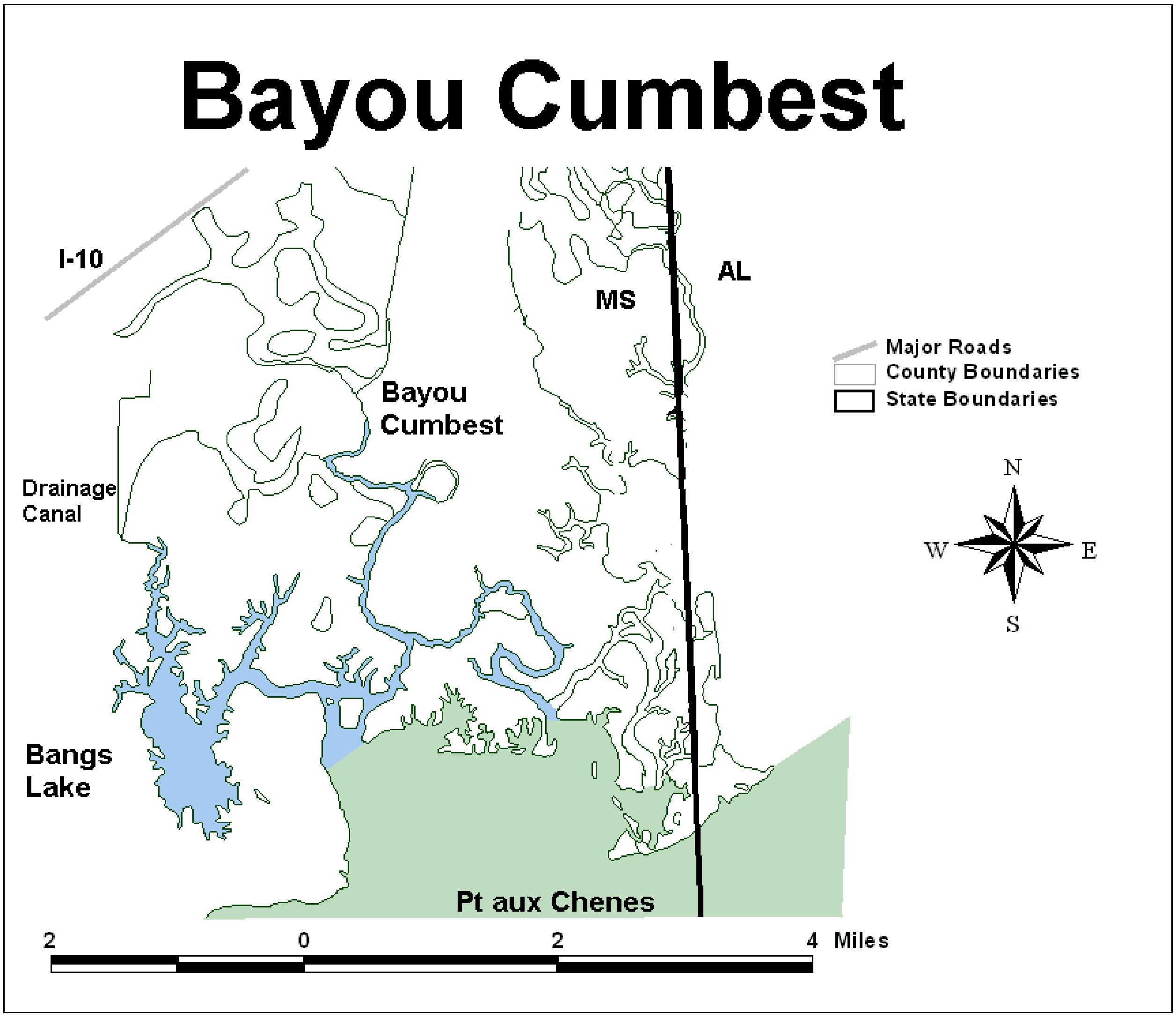

Figure 1. Vicinity map of Bayou Cumbest/Point aux Chenes Bay/Bangs Lake watershed area.

1.2 Applicable Waterbody Segment Use

The Bayou Cumbest and Bangs Lake basins were classified for shellfish harvesting by MDEQ (1995) in the *State of Mississippi Water Quality Criteria for Intrastate, Interstate and Coastal Waters* regulations. Bayou Cumbest was identified as the Number 1 ranked waterbody in the Mississippi 1996 Section 303(d) List of Impaired Waterbodies (MDEQ 1996) based on uses for aquatic life support, shellfishing, and contact recreation. For the purposes of this TMDL, fecal coliform is considered based on Mississippi's criteria for shellfish harvesting.

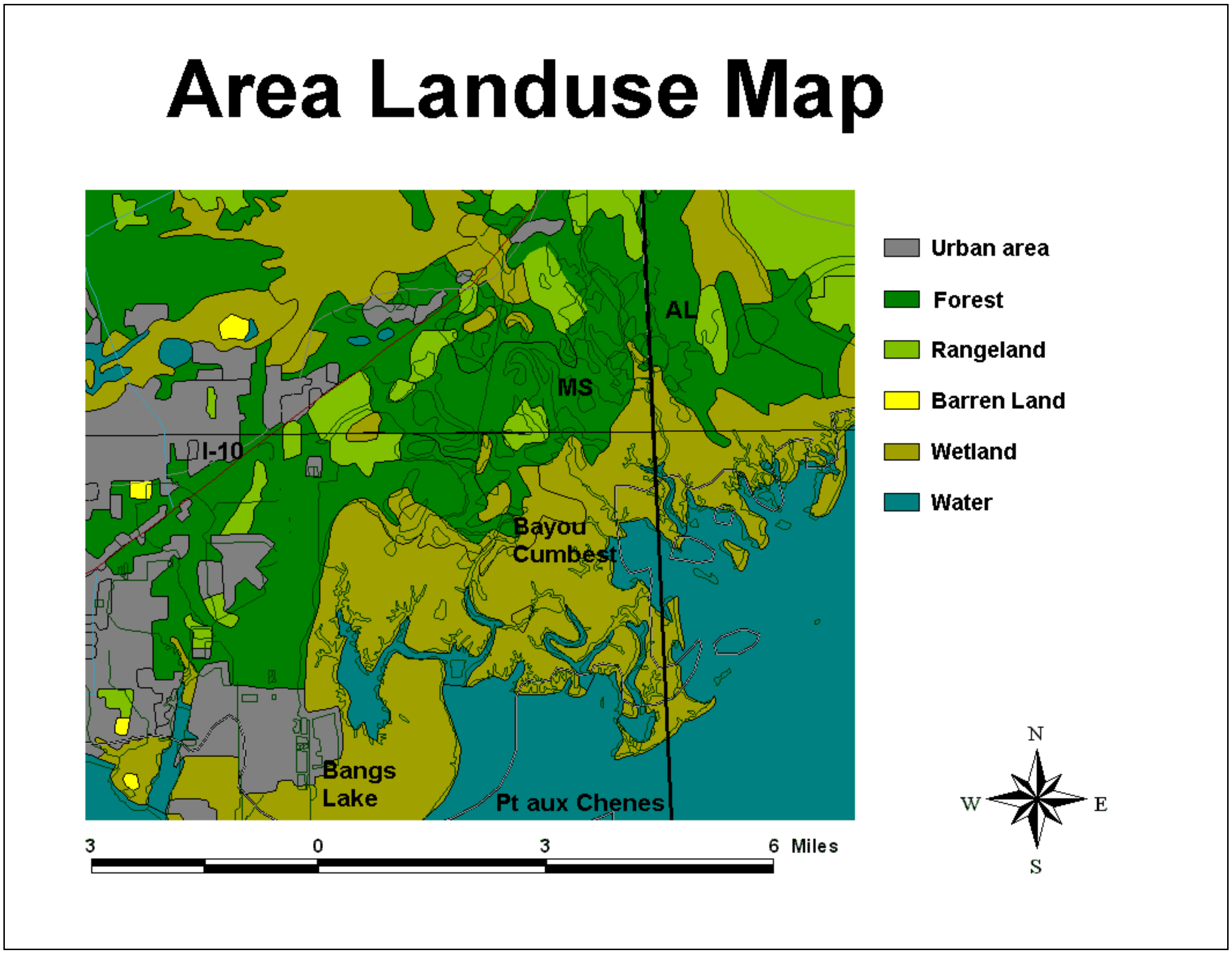

Figure 2. Landuse map for Bayou Cumbest / Bangs Lake Watershed area.

1.3 Applicable Waterbody Segment Standard

The water quality standard applicable to the use of this waterbody (i.e., shellfish harvest) is based on the Mississippi Department of Marine Resources (MDMR) Shellfish Sanitation Program, as detailed in MDMR Ordinance No. 1.014 (adopted 19 April 1999). The MDMR recognizes four levels of use for any given shellfish growing area relative to the established oyster season, including approved, conditionally approved, restricted, and prohibited (defined below). These designations are based on a number of factors relative to known or suspected sources of fecal coliform contamination within designated areas. The water quality standard defined for an "approved area" will be used as the target endpoints in the development of these TMDLs.

> Approved Area: An area is approved for oyster harvest during the established season when bacteriological quality of the water of every sampling station does not exceed a fecal coliform median or geometric mean MPN of 14 per 100 ml, and not more than 10 percent of the samples exceed an MPN of 43 for a 5-tube decimal dilution test or an MPN of 49 per 100 ml for a 3-tube decimal dilution test. An area can be closed when the above stated limits are not meet or upon the occurrence of a predetermined level of precipitation within any 24

consecutive hour period. The area remains closed until such time that microbiological analysis of two consecutive samples separated by a 48 hour period from each station in the area meets the above stated minimum level for approval.

Conditionally Approved Area: Defined as Waters that meet approved area criteria for a predictable period. The period is conditional upon established performance standards specified in a management plan.

Prohibited Area: Defined as Waters that are prohibited for harvest of shellfish for any purpose except depletion. A prohibited shellfish growing area is a closed area for the harvesting of shellfish at all times.

Restricted Area: Defined as Waters from which shellfish may be harvested only if permitted and subjected to a suitable and effective purification process as determined and permitted by the Mississippi Commission of Marine Resources.

2.0 TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Selection of a TMDL Endpoint and Critical Condition

A major component of a TMDL is the identification of numeric endpoints that can be used to evaluate the TMDL and restoration of water quality in the listed waterbody. These endpoints represent the water quality goals that are to be achieved by implementing the load and waste load reductions specified in the TMDL. These endpoints allow for a comparison between ambient conditions and conditions that are expected to restore designated areas. The fecal coliform target for this TMDL is the approved area standard, as defined by the MDMR for this watershed (see section 1.3).

Fecal coliform contamination may be attributed to both nonpoint and point sources. In non-tidal waters the critical conditions used for modeling and evaluating a TMDL may be different for both sources, given that point discharges are delivered directly into the waterbody, while nonpoint sources are typically delivered with stormwater runoff. Although similar for tidally influenced waterbodies, both sources may also be affected by tidal action within the watershed. Tidal movement of water within the waterbody and associated inter-tidal zone can serve to distribute the fecal coliform load in a bi-directional fashion. This load can include nonpoint sources from wildlife that are deposited directly on the inter-tidal marsh surfaces and exposed to the alternating rise and fall of tides.

Rainfall has a direct impact on the transport of nonpoint sources of fecal coliform largely through surface runoff from both upland and wetland areas, including the inter-tidal marsh surfaces. The data reported by LaSalle (1997) for this watershed were collected across the ranges of both conditions and are used to define critical conditions for this TMDL.

2.2 Discussion of Water Quality

Very little is directly known about the water quality within the Bayou Cumbest / Bangs Lake watershed. The area is largely rural with no known point source discharges of any kind. All of the fecal coliform load into this watershed must come from nonpoint sources.

2.2.1 Inventory of Available Water Quality Monitoring Data

Water quality data for the Bayou Cumbest / Bangs Lake watershed includes the periodic monitoring associated with the MDMR Shellfish Sanitation Program and the results of monitoring associated with the Bangs Lake Shellfish Growing Water Restoration Project (LaSalle 1997). Although used to monitor the fecal coliform conditions within the shellfish growing areas of this watershed, the data collected by MDMR is collected on an irregular basis that is tied to rainfall events and is conducted only during the harvest season (September through April). The Bayou Cumbest and Bangs Lake areas are located with Area VIIIA, as designated by MDMR. A total of 18 sample stations are located within this area. Rainfall is measured for this area from a station located seven miles to the west.

In the case of the more intensive sampling conducted by LaSalle (1997), a total of 14 stations were used to monitor water quality in the Bayou Cumbest / Point aux Chenes Bay / Bangs Lake area. This included 11 established MDMR stations and three additional stations located in the immediate vicinity of residences along the bayou. For the purposes of comparison of parameters across the entire watershed, these stations were assigned to the following five regions. These correspond to somewhat arbitrary, but logical regions of Bayou Cumbest and the open-water areas of the Point aux Chenes Bay and Bangs Lake: upper bayou stations (BR, RR, SR), mid bayou stations (CB-1, CB-2), lower bayou stations (8-2, 8-5, 8-3), Point aux Chenes Bay Stations (8-4, 8-10A, 7-13), and Bangs Lake stations (8-7, 8-8, 8-9). See Figure 3 on Page 7.

Sampling occurred at two-week intervals over a 52-week period between May 1995 and May 1996. Observations and sampling on each sample date occurred between the hours of 8:00 a.m. and 12:00 midnight and included the recording of weather and tidal conditions, measurements of salinity, water temperature and dissolved oxygen, and the collection of surface water samples for water quality analysis. Fecal coliform levels were measured using the membrane filter procedure, following standard methods for sample collection, storage, transport, and analysis (APHA 1992). Rainfall for the study period within the local area was measured using an additional electronic recording rain gauge installed and maintained at a residence located within 2 miles of Bayou Cumbest. Accumulated rain levels were recorded on a daily basis.

2.2.2 Summary of Water Quality Monitoring Data

Fecal coliform levels for all sampling stations are provided in Table 1. A summary of general weather and tidal conditions experienced on each sample date and the cumulative amounts of rainfall for selected intervals between sample dates are provided in Table 2. Overall, highest values for fecal coliform were measured within the immediate vicinity of residences along Bayou Cumbest (i.e., upper bayou stations), falling rapidly with distance from this source (typically an order of magnitude lower). Seasonal fluctuations were also evident, with highest values measured in the wet winter months (e.g., 12-18-95) and lowest values recorded in summer (e.g., 08-30-95). The relationship between rainfall and levels of fecal coliform levels was evaluated through correlation analysis (Pearson Product Moment) using the rainfall totals between sampling dates shown in Table 2.

Coefficients were highest for 1-day rainfall totals across most stations, particularly those closest to the source of bacteria (0.84 - 0.90), supporting the assumption of direct transport of bacteria into water bodies following rain events. Lower coefficient values for stations located away from the source of bacteria (0.54 - 0.81) reflect a presumed dilution of coliform with distance from the source and, therefore, weaker correlation.

A pattern of declining values for correlation coefficients for 1, 3, 7, and 14-day events supported observed patterns of gradual declines in bacterial levels with time following rain events, presumably through a combination of dilution and mortality of bacteria with time. Correlation values were highest for 1-day events (0.54 - 0.90) with values of 3-day events being nearly 50% lower (0.27 - 0.60). Based on these trends, the dilution models described below were developed for 1-day rainfall totals, which also corresponds to the established time period for rainfall totals used by MDMR.

Discrepancies in the patterns of fecal coliform levels between the mouth of Bayou Cumbest and Bangs Lake also led to the discovery of an alternative source of bacteria into this part of the watershed. Coliform levels observed after major rain events showed that levels of bacteria within Bangs Lake were typically higher than those near the mouth of Bayou Cumbest (station 8-5), located between the presumed source (Bayou Cumbest) and the Bangs Lake stations (stations 8-7, 8-8, and 8-9). These observations led to further sampling and the determination that a human-constructed drainage ditch that emptied into the upper region of Bangs Lake (Figure 1) served as an avenue for fecal contamination from homes in the northwestern most portion of the watershed that was not directly associated with Bayou Cumbest. The levels of bacteria measured at this second site were similar to those recorded in the upper reaches of Bayou Cumbest on that sampling date, leading to the assumption that the levels of contamination were similar for both source areas.

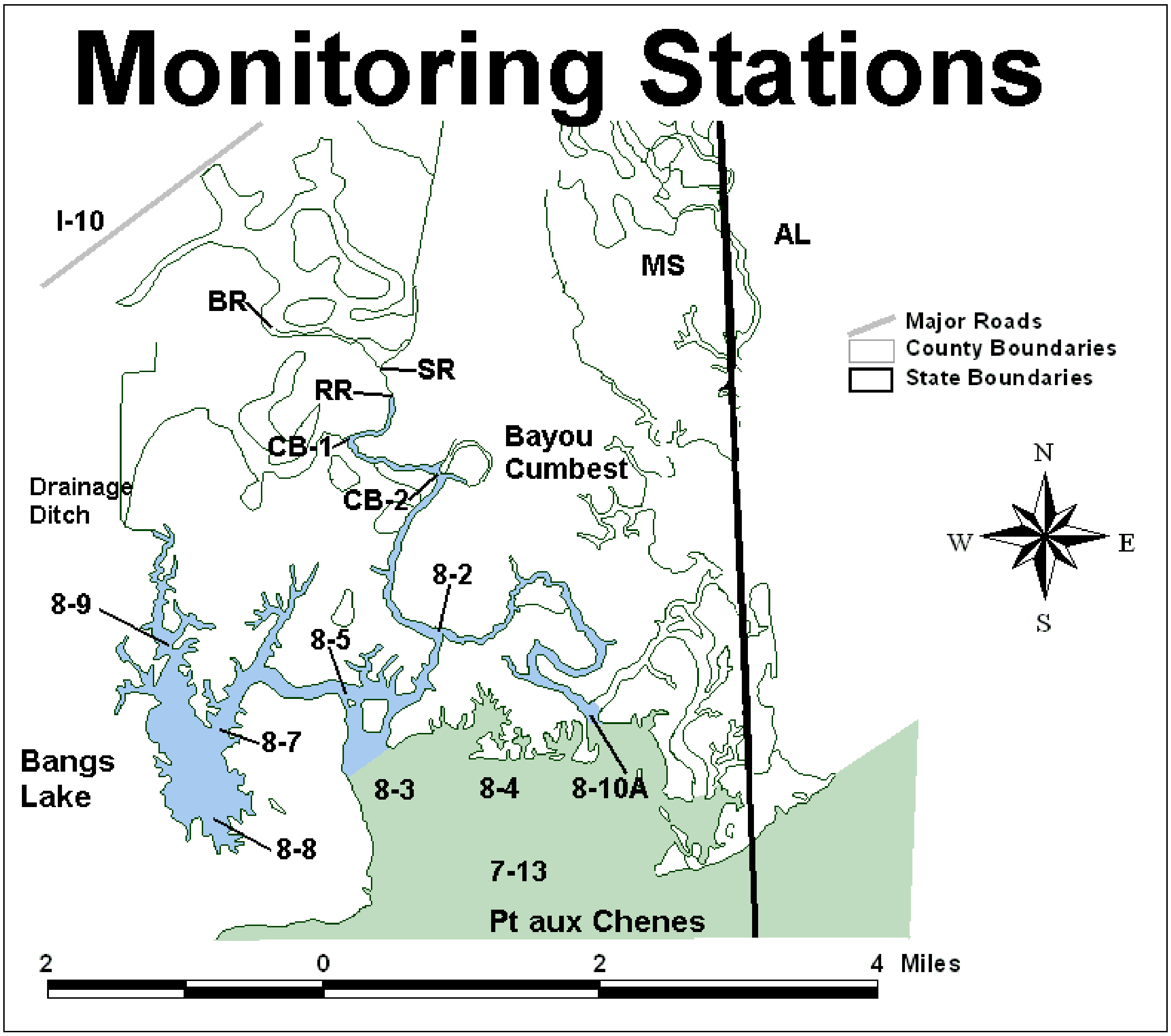

Figure 3. Vicinity map of Bayou Cumbest / Bangs Lake area showing sample station locations.

Table 1. Fecal coliform values (colonies per 100 ml) for all Bayou Cumbest, Point aux Chenes Bay, and Bangs Lake sample stations. Dates marked with an asterix indicate those immediately following major rain events (> 0.5 in within 3 days). (From LaSalle 1997).

	Upper Bayou			Mid Bayou		Lower Bayou			Bay			Bangs Lake		
Date	**BR**	**RR**	**SR**	**CB-1**	**CB-2**	**8-2**	**8-5**	**8-3**	**8-4**	**8-10A**	**7-13**	**8-7**	**8-8**	**8-9**
05-24-95	62	83	193	27		4		2	22	1	0		0	173
06-07-95	69	127	131	134	33	2								59
06-21-95	149	130	94	8	6	2	9	1	3	17	0	13	29	35
07-05-95	51	45	120	6	11	21	12	9	10	7	11	3	1	9
07-19-95	151	172	136	247	36	15	24	6	14	22	0	11	7	25
08-02-95	103	278	420	226	209	141	19	12	10	19	19	4	45	23
*08-16-95	339	1584	220	168	48	5	3	0	1	0	3	0	0	1
08-30-95	47	420	78	119	25	5	5	0	0	0	0	1	0	0
09-13-95	127	81	130	50	12	0	2	3	1	5	2	1	6	15
09-27-95	421	84	182	77	9	6	4	2	1	4	2	5	8	2
10-11-95	395	304	275	201	62	52	3	19	5	30	1	3	1	28
10-25-95	154	184	122	67	35	5	3	0	4	1	0	5	11	13
11-07-95	258	385	401	458	539	190	81					96	41	170
11-20-95	1296	720	576	576	62	41	3	0	3	21	49	7	16	32
12-06-95	344	224	263	292	193	58	19	0	8	119	0	31	4	49
*12-18-95	6912	7200	6912	4032	3168	120	144	32	146	192		282	172	184
*01-03-96	325	280	165	415	320	423	55	1	0	11	13	24	3	166
01-16-96	655	80	245	25	25	9	2	0	0	6	2	7	8	11
01-30-96	355	420	255	540	335	164	3	2		4		0	0	3
02-13-96	315	105	40	60	15	4	1	0	0	0	0	0	2	1
02-27-96	160	50	29	25	5	3	0	0	0	4	0	2	0	6
03-12-96	55	40	5	0	5	0	0	0	0	0	0	0	0	0
*03-26-96	1340	1435	795	2365	2105	39	6	4	3	15	1	7	35	112
04-09-96	140	260	85	340	335	169	35	7	1	5	4	53	10	26
04-24-96	215	95	90	65	15	6	4	2	1	3	0	2	2	8
*05-29-96	160	145	80	40	5	21	5	1	4	12	2	0	3	10

Table 2. Tidal and weather conditions and cumulative rainfall amounts for each sample date. Cumulative totals include only rain amounts that fell on days prior to the sampling date and not rain that may have fallen on the sample date (see footnotes). From LaSalle (1997).

Date (Sample No)	Tidal Condition	Weather	1-Day Rainfall	3-Day Rainfall	7-Day Rainfall	14-Day Rainfall	No. Days Between Samples
05-25-95 (1)	High	Partly Cloudy					
06-07-95 (2)	High	Partly Cloudy					13
06-21-95 (3)	High	Partly Cloudy					14
07-05-95 (4)	High	Partly Cloudy	0	0.29	1.08	1.08	14
07-19-95 (5)	Outgoing	Clear	0	0.19	2.15	3.99	14
08-02-95 (6)	Outgoing	Clear	0	2.44	4.03	4.36	14
08-16-95 (7)	Outgoing	Clear	0	0	0.59	2.62	14
08-30-95 (8)	Outgoing	Clear	0	0	0	0.87	14
09-13-95 (9)	Outgoing	Partly Cloudy	0	0	0	0.76	14
09-27-95 (10)	Outgoing	Clear	0	0	0.01	1.45	14
10-11-95 (11)	Low	Cloudy	0[1]	0	3.01	4.66	14
10-25-95 (12)	Low	Partly Cloudy	0.11	0.26	0.26	0.32	14
11-07-95 (13)	High	Raining	0[2]	0.03	4.61	4.93	13
11-20-95 (14)	Outgoing	Raining	0.04[3]	0.04	0.14	1.39	13
12-06-95 (15)	Very Low	Cloudy	0	0.16	0.16	0.71	16
12-18-95 (16)	Low	Heavy Rain	1.49[4]	1.49	1.49	1.52	12
01-03-96 (17)	Very Low	Overcast	0	2.13	2.13	3.31	16
01-16-96 (18)	Low	Partly Cloudy	0	0	0	0.19	13
01-30-96 (19)	Low	Overcast	0.01	0.01	1.38	1.56	14
02-13-96 (20)	Low	Clear	0	0	0	2.69	14
02-27-96 (21)	Incoming	Overcast	0	0	0	0.99	14
03-12-96 (22)	Incoming	Clear	0	0	0.36	1.37	14
03-26-96 (23)	Incoming	Raining	0.87[5]	0.91	0.91	1.38	14
04-09-96 (24)	Incoming	Clear	0	0	1.02	5.62	14
04-24-96 (25)	Incoming	Clear	0.15	0.15	0.35	7.39	15
05-29-96 (26)	Outgoing	Overcast	0.58[6]	0.58	0.58	0.58	35

[1] - light rain on sample date (0.01 in);
[2] - light rain on sample date (0.19 in);
[3] - light rain on sample date (0.04 in);
[4] - heavy rain on sample date (1.49 in);
[5] - heavy rain on sample date (1.85 in);
[6] - light rain on sample date (0.19 in)

3.0 SOURCE ASSESSMENT

Fecal coliform may originate from both point and nonpoint sources. Within the context of a TMDL, point sources are referred to as wasteload allocations (WLAs) and nonpoint sources as load allocations (LAs). The major point source of fecal coliform is treated effluent from municipal treatment plants. Nonpoint sources are more numerous and include both rural and urban examples. Typically nonpoint sources enter receiving bodies of water as part of stormwater runoff from both pervious and impervious surfaces.

Urban sources of fecal coliform may include failing septic tanks and field lines, leakage from sanitary sewer systems (i.e., sewer lines), deposition from domestic pets, and deposition from wildlife. In rural areas, sources of nonpoint may include failing septic tanks and field lines, animal pastures and feedlots, concentrated animal operations (e.g., dairies and hog barns), and direct deposition of feces from pets and wildlife.

3.1 Assessment of Point Sources

In the case of Bayou Cumbest, there are no point sources (WLAs) of fecal coliform within the watershed. All known residences and commercial establishments within the watershed have individual onsite wastewater treatment systems. Except for those systems along Bayou Cumbest that were fitted with rock reed filters as part of the previously discussed demonstration project, the remaining systems within the watershed consist of septic tanks and field lines.

3.2 Assessment of Nonpoint Sources

Nonpoint sources include those associated with failing septic systems and direct deposition from pets and wildlife. There are no known pastures or confined animal operations within the watershed. Approximately 70 single-family residences and one commercial establishment are located in the watershed. Of these, 45 are located directly along the banks of the bayou or along constructed canals. Prior to 1995, all of these establishments had typical septic systems consisting of a buried septic tank and shallow, underground leach fields.

3.2.1 Failing Septic Systems

A survey of these systems by the Mississippi Department of Health (MDH), conducted as part of the Bangs Lake Shellfish Growing Water Restoration Project, revealed that most of these systems were either failing or poorly operating. Of the 45 sites along Bayou Cumbest, 39 were selected as part of the program to replace the failing leach fields with rock-reed filter systems.

The objective of this program was to reduce the level of fecal coliform contamination from known or suspected failing systems by replacing them with more efficient systems. A rock-reed filter system consists of a shallow, plastic lined linear trough filled with washed gravel and planted with wetland vegetation. These filters serve to isolate effluent from the surrounding saturated soils and allow for removal of organic and inorganic compounds and suspended materials through a combination of physical filtration, deposition, infiltration, adsorption, absorption, decomposition (through microbial activity), and volatilization (Dillaha et al 1989, EPA 1993). MDH requires effluent from these beds to be further treated with chlorine (a chlorinating chamber) to kill any remaining bacteria, prior to discharge. In almost all cases in the Bayou Cumbest area, the surface discharge point of the systems was within 50 ft of the bayou or associated dredged canals.

Results of the monitoring study of selected rock-reed systems at Bayou Cumbest (LaSalle 1997) suggested that they were capable of removing as much as 98 -100 percent of fecal coliform bacteria from septic tank effluent with an overall mean reduction of 91%. Chlorinating chambers that were adequately supplied with chlorine were shown to effectively kill all remaining bacteria. Chlorine was not, however, consistently used by homeowners in the area; presumably resulting in the release of live bacteria onto the ground and subsequently into Bayou Cumbest.

The level of fecal contamination from this source can be estimated by applying the mean reduction rate of 91% across a filter to the mean influent level into the filter from the septic tank of about 424E+3 colonies per 100 ml. Using these figures, each system may contribute as much as 38.1E+3 colonies per 100 ml of fecal coliform bacteria to the environment at any given time.

3.2.2 Wildlife

Non-human sources of fecal coliform contamination from pets and wildlife are not directly known for the Bayou Cumbest area, nor are they well documented elsewhere. The levels of bacteria measured as part of the MDMR's shellfish monitoring program would be a potential source of estimates of this component of the LA for the watershed, however, appropriate reference areas or stations are not available or reliable. The adjacent watershed (Bayou Heron), although less developed compared to Bayou Cumbest, nonetheless has known sources of fecal contamination from failing septic systems. The same is true across Mississippi and adjacent coastal areas.

An attempt to identify a reference sampling station for the Bayou Cumbest monitoring study was abandoned for these reasons as well as the realization that tidal action serves to distribution any contamination across a wide area, making any potential site suspect as a reference. There is however, a limited data set for non-human fecal coliform levels collected by the authors of this TMDL as part of a water quality assessment of a non-tidal area near Ocean Springs, Mississippi, located about 15 miles west of Bayou Cumbest. Surface water samples collected from a presumed non-impacted wet pine savanna wetland area ranged from a low of 35 to a high of 867 colonies per 100 ml following rain events.

4.0 MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Defining a linkage between the selected targets and the identified sources is a critical component of a TMDL. The linkage is defined as the cause and effect relationship between the selected endpoint and the identified sources. This linkage can be derived from data analysis, best professional judgement, and previously documented relationships. The linkage is used in determining what loading is acceptable to achieve the target values. A margin of safety is also considered in the linkage or modeling effort.

4.1 Modeling Approach

The availability of monitoring data for the Bayou Cumbest watershed allows for direct evaluations of cause and effect relationships (i.e., linkages) between the presumed major source of fecal coliform bacteria (residences along the bayou) and the target levels for shellfish beds. Data were collected bi-weekly from 14 stations throughout the watershed over a 12-month period, including data from all seasons of the year and during multiple tidal conditions and wet weather events. Direct comparisons of the data from source and target areas can, therefore, form the basis of establishing a TMDL or series of TMDLs for the watershed. TMDLs for this site can be established by comparing coliform levels measured near the source (i.e., Bayou Cumbest) with those recorded at the target area (i.e., shellfish beds in Point aux Chenes Bay and Bangs Lake), using those values at the source (plus a margin of safety) that correspond to the target value of 14 colonies of fecal coliform per 100 ml at the target site. This approach assumes a direct relationship between levels of bacteria introduced at the source and those measured at the target area. Correlation analyses of data between all 14 sampling stations (Table 3) confirm strong links between levels of fecal coliform measured at upper bayou stations (BR, RR, SR, CB-1, CB-2) with those measured at Point aux Chenes Bay (8-3, 8-4, 8-10A, 7-13) and Bangs Lake stations (8-5, 8-7, 8-8, 8.9).

A series of simple linear regression models are presented below to both support this assumption and describe the range of conditions representative of dynamic changes within this tidally influenced watershed. These dilution models are based on data collected under combinations of rainfall and tidal conditions experienced within the study area during the course of monitoring. Rainfall levels are used by MDMR to trigger the automatic closures of shellfish growing waters at predetermined levels within any 24 consecutive hour period. In the case of the Bayou Cumbest and Bangs Lake areas, MDMR uses a trigger level of 1 inch of rain within 24 hours. Tidal action may act to delay or accelerate the distribution of water borne material depending upon its direction. High or low slack tide conditions, for example, may act to delay transport of material, while flooding or ebbing tide may accelerate distribution, but in opposite directions.

The following tide condition and rainfall level categories were used for the purposes of assigning models to major categories, based on these conditions.

Tidal Condition:	1) high slack, 2) low slack, 3) ebbing tide, 4) flooding tide
Rainfall Amounts (within 24 hours):	1) no rain, 2) $\leq$ 1 inch, 3) > 1 inch.

Table 3. Correlation coefficients (Pearson Product Moment) for relationships on fecal coliform levels between samples stations within the Bayou Cumbest / Bangs Lake watershed. Generated from data reported by LaSalle (1997).

Station	BR	RR	SR	CB-1	CB-2	8-2	8-5	8-3	8-4	8-10A	7-13	8-7	8-8	8-9
BR	1.0000													
RR	0.9723	1.0000												
SR	0.9873	0.9766	1.0000											
CB-1	0.9188	0.9138	0.8983	1.0000										
CB-2	0.8767	0.8795	0.8653	0.9890	1.0000									
8-2	0.1361	0.1424	0.1550	0.2229	0.2367	1.0000								
8-5	0.7673	0.7752	0.8145	0.7244	0.7287	0.5346	1.0000							
8-3	0.7487	0.7478	0.7957	0.6905	0.6730	0.2017	0.7536	1.0000						
8-4	0.9443	0.9386	0.9783	0.8332	0.8146	0.1422	0.9101	0.8081	1.0000					
8-10A	0.8283	0.8018	0.8453	0.7415	0.7068	0.1616	0.8070	0.6860	0.8443	1.0000				
7-13	0.5035	0.1992	0.4952	0.1393	-0.0324	0.2803	0.1390	0.0544	0.0179	0.0401	1.0000			
8-7	0.8988	0.8943	0.9311	0.8149	0.8051	0.2981	0.9448	0.7765	0.9709	0.8643	0.0285	1.0000		
8-8	0.9242	0.9152	0.9489	0.8772	0.8658	0.1985	0.8451	0.7902	0.9328	0.8035	0.3054	0.9246	1.0000	
8-9	0.4848	0.4808	0.5092	0.5720	0.7055	0.5327	0.8445	0.4222	0.5970	0.5053	0.0769	0.7157	0.5522	1.0000

4.2 Model Setup

Linear regression models were generated from 23 of the 26 data sets (i.e., sampling dates) shown in Table 1. The first three data sets shown in Table 1 were not used because of the lack of cumulative rainfall data (Table 2). Each set of models incorporates data from a subset of the sampling stations used in the study and which represent the logical direct path for any fecal coliform between the major source (i.e., homes along Bayou Cumbest) and the target area. Each model was derived using data on fecal coliform from each station against the linear distance of that station from the most upstream site (station BR). The intent of these linear models is to mathematically describe the change in fecal coliform levels along the presumed line between the major source of contamination and the receiving body of water. For comparative purposes, each regression model was assigned to one of the 12 possible tidal condition and rain event combinations listed in section 4.2.

The Point aux Chenes models include data from the major stations along Bayou Cumbest itself (BR, RR, CB-1, CB-2, 8-2) and stations in a direct line out into Point aux Chenes Bay (8-3, 8-4, 7-13). Station SR was excluded because of its relative location along a secondary source canal that feeds into Bayou Cumbest directly upstream from station RR (Figure 2). Levels of coliform from this site would logically be represented in the levels measured at station RR. Station 8-10A was not included in these models because it is not in direct line with other stations.

The Bangs Lake models include data from the major stations along Bayou Cumbest (BR, RR, CB-1, CB-2, 8-2) and stations in a direct line into Bangs Lake (8-5, 8-7, 8-8). Station 8-9 was excluded from these models because of the previously discussed link between this station and an alternate source of fecal contamination that appears to directly impact this site. Correlation data from this station and that of the upper bayou stations (Table 3) reflect an apparent weaker relationship for station 8-9 compared to other stations in the lake.

4.3 Models

The Point aux Chenes Bay models are listed in Table 4. The Bangs Lake models are listed in Table 5. Graphs of the models are shown in Figure 4. The effect of tidal condition and rain can been seen by comparing the strength of the regression models as reflected in R^2 values and the slopes of each model. Models for low slack tidal conditions tended to have higher overall R^2 values (> 0.7000), regardless of rainfall levels, presumably because the fecal coliform load had been distributed more equally downstream from the source prior to the collection of samples. Models for ebbing tides also showed strong relationships (R^2 > 0.6000), presumably for similar reasons. Models for flooding and high tides, although at times having relatively strong relationships (> 0.6000 for flooding tides), tended to have lower slopes compared to low and ebbing tide conditions which may be reflective of an relatively equal distribution of fecal coliform across the watershed. The influx of cleaner water into the bayou from the bay under flooding and high tide conditions, particularly during periods of no or low levels of rain (< 1 inch) may serve to dilute already low fecal coliform levels. The effect of rain on these models is indicated by the slope of each model, with highest values occurring during periods of heavy rain (> 1 inch).

Although these trends may be roughly indicative of these basic tide and rainfall conditions, the movement of water at the time of collection of samples may not reflect stable conditions relative to the source of pollution, in part, explaining some of the weak relationships in these models. Further, the strength of each tide event (i.e., the height of the tide) was not recorded and may help to explain some of the variation in R^2 values for events under similar conditions (e.g., low and ebb tide events with no rain). Any high tide event that is strong enough to flood the marsh surfaces within the watershed may act to distribute any fecal coliform that may have accumulated from wildlife sources. This contamination may affect the strength of a model regardless of the level of rainfall.

4.4 TMDL Development

A TMDL is defined as the total amount of pollutant that can be assimilated by the receiving water body in order to achieve the target water standard. Conceptually, TMDLs are comprised of the sum of all identifiable wasteload allocations from point sources, load allocations from nonpoint sources including natural background levels, and a margin of safety (MOS) designed to account for uncertainty in the relation between pollutant loads and water quality. Mathematically, a TMDL is denoted as:

$$\text{TMDL} = \Sigma \text{ WLAs} + \Sigma \text{ LAs} + \text{MOS}$$

In the case of the Bayou Cumbest watershed, the TMDL is based on the allowable limit of 14 colonies of fecal coliform per 100 ml for approved shellfish harvest, as set by the MDMR. As previously discussed, there are no WLAs in this watershed and no accurate estimates of relative proportions of measured levels of LA attributable to human-induced and natural background sources. Historical monitoring of fecal coliform in this watershed is limited to the shellfish monitoring program conducted by MDMR. As with the data set used in this TMDL, these data reflect total fecal coliform loads from all sources. For the purposes of this TMDL, therefore, these two apparent LAs are considered as a combined source. The MOS for this study was incorporated implicitly as part of the conservative selection of model output values (i.e., line intercept values of regression equations, explained below).

As previously discussed a TMDL for this watershed can be based on direct comparison of the levels of fecal coliform observed at the source and target areas. Seasonal variations in these patterns can also be incorporated into this process. For the purposes of this TMDL, values for maximum daily loads were determined by identifying those sampling dates which reflected near critical levels of coliform over designated shellfish beds (Tables 4 and 5): i.e., those dates for which fecal levels were at or below the target level of 14 colonies per 100 ml at all stations considered to be in the designated shellfish harvesting area (the decision criteria used by MDMR). For these samples, a TMDL is determined to be the line intercept component of the regression equation for that date.

For the Point aux Chenes portion of the watershed, four dates meet the criteria for approved shellfish harvest: two dates in the fall (09-13-95 and 09-27-95) and two dates in the late winter/early spring (02-27-96 and 03-12-96), all of which were under conditions of no rain within the previous 24-hour period. These dates also correspond to the dry and wet seasons of the year for coastal Mississippi, respectively. Three additional dates had fecal coliform levels that were nearly at the approved levels for shellfish harvest (07-05-95, 02-13-96, 04-24-96): one from the dry season, two from the wet season. Based on these dates, a dry season TMDL would be 205 fecal coliform per 100 milliliters (09-27-95). Although the model for this date had a lower R^2 value compared to the previous date (09-13-95), the levels of fecal coliform at stations within the shellfish harvest area were closer to the limit for harvest and, therefore, are more indicative of the definition of the TMDL. A wet season TMDL would be 83 fecal coliform per 100 milliliters (02-27-96) compared to a somewhat lower value 34 for the following date (03-12-96). As with the dry season TMDL, the level of coliform on this date was closer to the limit for harvest. This trend of a higher TMDL value for the dry weather period of the year logically reflects the higher levels of fecal coliform that can be assimilated within the watershed under these conditions.

For the Bangs Lake portion of the watershed, the same four dates as listed above meet the criteria for approved shellfish harvest. Six additional dates had fecal coliform levels that were nearly at the approved levels for shellfish harvest (07-05-95, 01-16-96, 02-13-96, 10-25-95, 05-29-96, 04-24-96): two from the dry season, two from the wet season and two from the moderately wet spring season. Based on these dates, a dry season TMDL would be 199 fecal coliform per 100 milliliters (09-27-95) and a wet season TMDL would be 81 fecal coliform per 100 milliliters. As for the Point aux Chenes Bay values, these TMDLs were chosen because they reflected levels that were closer to the limits for harvest within the shellfish areas.

In summary, the TMDLs established for Bayou Cumbest and Bangs Lake portions of the Bayou Cumbest / Bangs Lake watershed are:

	Bayou Cumbest	Bangs Lake
Dry Season:	205	199
Wet Season:	83	81

Values for both portions of the watershed were similar and could be averaged to establish a TMDL for the entire watershed. These values represent the target fecal coliform maximum load in Bayou Cumbest and in Bangs Lake at the upper reaches that maintain the water quality standard for shellfish harvesting within the shellfish areas.

Table 4. Pt aux Chenes dilution models for the Bayou Cumbest / Point aux Chenes Watershed arranged by major combinations of tidal and rainfall conditions (see text for explanation). ** - Dates when levels of fecal coliform over shellfish beds (stations 8-2, 8-3, 8-4, 7-13) meet standards for approved shellfish harvest (all stations ≤ 14 colonies per 100 ml). * - Dates when levels of fecal coliform over shellfish beds nearly meet standards for approval (< 1 station above 14 colonies per 100 ml).

Tide / Rain Conditions	Date	Sample Stations (Distance in Miles from BR)								Model	R^2	n
		BR (0.0)	RR (0.7)	CB-1 (1.3)	CB-2 (2.1)	8-2 (3.5)	8-3 (4.6)	8-4 (5.3)	7-13 (6.0)			
High Tide (no rain) *	07-05-95	51	45	6	11	21	9	10	11	Y = 36.03 - 5.28 (X)	0.4533	8
High Tide (< 1 inch)	11-07-95	258	385	458	539	190				Y = 390.98 - 16.43 (X)	0.0241	5
Low Tide (no rain)	10-11-95	395	304	201	62	52	19	5	1	Y = 309.67 - 61.20 (X)	0.8166	8
	12-06-95	344	224	292	193	58	0	8	0	Y = 315.82 - 59.89 (X)	0.9119	7
	01-03-96	325	280	415	320	423	1	0	13	Y = 410.59 - 64.15 (X)	0.5938	8
	01-16-96	655	80	25	25	9	0	0	2	Y = 279.95 - 61.43 (X)	0.3700	8
*	02-13-96	315	105	60	15	4	0	0	0	Y = 168.68 - 36.19 (X)	0.5534	8
Low Tide (< 1 inch)	10-25-95	154	184	67	35	5	0	4	0	Y = 139.14 - 28.26 (X)	0.7344	8
	01-30-96	355	420	540	335	164	2			Y = 491.34 - 92.79 (X)	0.7129	6
Low Tide (> 1 inch)	12-18-95	6912	7200	4032	3168	120	32	146		Y = 6759.04-1468.76(X)	0.8864	8
Ebbing Tide (no rain)	07-19-95	151	172	247	36	15	6	14	0	Y=181.63 - 34.55 (X)	0.6563	8
	08-02-95	103	278	226	209	141	12	10	19	Y = 232.72 - 36.75 (X)	0.6023	8
	08-16-95	339	1584	168	48	5	0	1	3	Y = 674.11 - 138.08 (X)	0.3217	8
	08-30-95	47	420	119	25	5	0	0	0	Y = 185.15 - 36.81 (X)	0.3255	8
**	09-13-95	127	81	50	12	0	3	1	2	Y = 87.51 - 18.04 (X)	0.7216	8
**	09-27-95	421	84	77	9	6	2	1	2	Y = 204.54 - 44.01 (X)	0.4682	8
Ebbing Tide (< 1 inch)	11-20-95	1296	720	576	62	41	0	3	49	Y = 865.61 - 177.78 (X)	0.6949	8
	05-29-96	160	145	40	5	21	1	4	2	Y = 117.21 - 23.81 (X)	0.6447	8
Flooding Tide (no rain)**	02-27-96	160	50	25	5	3	0	0	0	Y = 82.76 - 17.83 (X)	0.5217	8
**	03-12-96	55	40	0	5	0	0	0	0	Y = 33.88 - 7.28 (X)	0.5465	8
	04-09-96	140	260	340	335	169	7	1	4	Y = 300.19 - 48.74 (X)	0.5688	8
Flooding Tide (< 1 inch) *	04-24-96	215	95	65	15	6	2	1	0	Y = 129.81 - 27.21 (X)	0.6516	8
Flooding Tide (> 1 inch)	03-26-96	1340	1435	2365	2105	39	4	3	1	Y = 1979.28 - 363.50(X)	0.6403	8

Table 5. Bangs Lake dilution models for the Bayou Cumbest / Bangs Lake Watershed arranged by major combinations of tidal and rainfall conditions (see text for explanation). ** - Dates when levels of fecal coliform over shellfish beds (stations 8-2, 8-3, 8-4, 7-13) meet standards for approved shellfish harvest (all stations ≤ 14 colonies per 100 ml). * - Dates when levels of fecal coliform over shellfish beds nearly meet standards for approval (< 1 station above 14 colonies per 100 ml).

Tide / Rain Conditions	Date	Sample Stations (Distance in Miles from BR								Model	R^2	n
		BR (0.0)	RR (0.7)	CB-1 (1.3)	CB-2 (2.1)	8-2 (3.5)	8-5 (4.5)	8-7 (5.6)	8-8 (6.2)			
High Tide (no rain) *	07-05-95	51	45	6	11	21	12	3	1	Y = 37.49 - 6.27 (X)	0.5752	8
High Tide (< 1 inch)	11-07-95	258	385	458	539	190	81	96	41	Y = 439.31 - 61.35 (X)	0.5776	8
Low Tide (no rain)	10-11-95	395	304	201	62	52	3	3	1	Y = 305.13 - 59.41 (X)	0.8015	8
	12-06-95	344	224	292	193	58	19	31	4	Y = 309.13 - 54.73 (X)	0.8907	8
	01-03-96	325	280	415	320	423	55	24	3	Y = 407.81 - 59.30 (X)	0.6114	8
*	01-16-96	655	80	25	25	9	2	7	8	Y = 272.91 - 57.41 (X)	0.3484	8
*	02-13-96	315	105	60	15	4	1	0	2	Y = 165.21 - 34.29 (X)	0.5339	8
Low Tide (< 1 inch) *	10-25-95	154	184	67	35	5	3	5	11	Y = 135.26 - 25.86 (X)	0.6860	8
	01-30-96	355	420	540	335	164	3	0	0	Y = 477.45 - 83.79 (X)	0.8213	8
Low Tide (> 1 inch)	12-18-95	6912	7200	4032	3168	120	144	282	172	Y = 6353.10 - 1204.80 (X)	0.8322	8
Ebbing Tide (no rain)	07-19-95	151	172	247	36	15	24	11	7	Y = 178.35 - 31.95 (X)	0.6306	8
	08-02-95	103	278	226	209	141	19	4	45	Y = 228.09 - 33.46 (X)	0.5703	8
	08-16-95	339	1584	168	48	5	3	0	0	Y = 663.25 - 132.17 (X)	0.3151	8
	08-30-95	47	420	119	25	5	5	1	0	Y = 182.25 - 34.98 (X)	0.3162	8
**	09-13-95	127	81	50	12	0	2	1	6	Y = 85.46 - 16.93 (X)	0.6870	8
**	09-27-95	421	84	77	9	6	4	5	8	Y = 199.46 - 41.07 (X)	0.4413	8
Ebbing Tide (< 1 inch)	11-20-95	1296	720	576	62	41	3	7	16	Y = 854.17 - 172.06 (X)	0.6893	8
*	05-29-96	160	145	40	5	21	5	0	3	Y = 115.40 - 22.77 (X)	0.6317	8
Flooding Tide (no rain) **	02-27-96	160	50	25	5	3	0	2	0	Y = 81.00 - 16.86 (X)	0.5015	8
**	03-12-96	55	40	0	5	0	0	0	0	Y = 33.23 - 6.94 (X)	0.5313	8
	04-09-96	140	260	340	335	169	35	53	10	Y = 293.17 - 41.98 (X)	0.5389	8
Flooding Tide (< 1 inch) *	04-24-96	215	95	65	15	6	4	2	2	Y = 127.15 - 25.65 (X)	0.6270	8
Flooding Tide (> 1 inch)	03-26-96	1340	1435	2365	2105	39	6	7	35	Y = 1951.29 - 346.37 (X)	0.6279	8

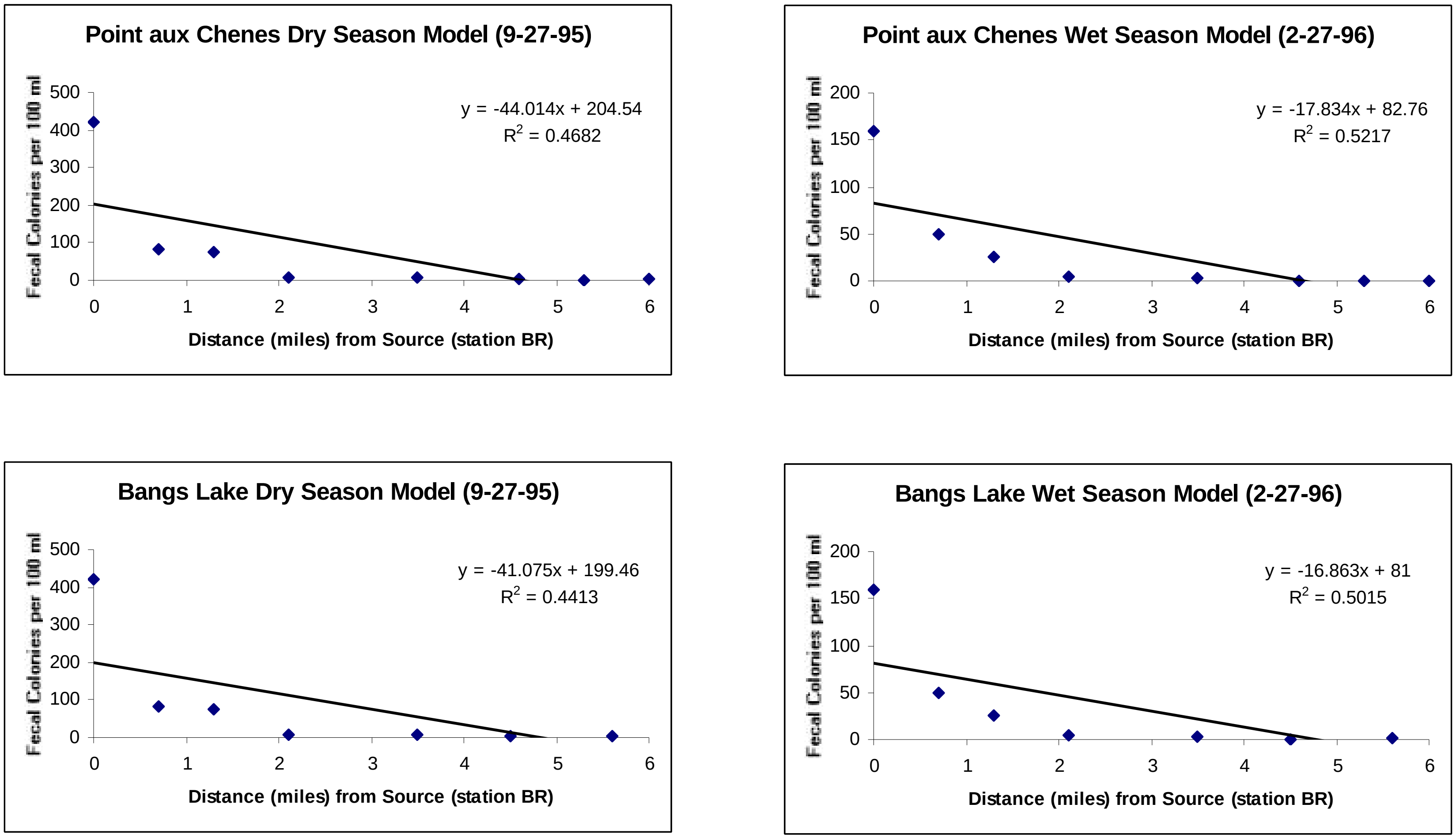

Figure 4. Point aux Chenes Bay and Bangs Lake wet and dry season TMDL models.

5.0 ALLOCATION

5.1 Load Allocations

In the absence of NPDES dischargers, the load allocation for this waterbody system is the same as the TMDL. Recommendations for load reduction in this watershed therefore focus on reducing or eliminating input of fecal coliform from individual onsite wastewater treatment systems associated with residences along Bayou Cumbest and other portions of the watershed.

The maximum limit of fecal coliform determined in this model is 205 colonies per 100ml (dry season) and 83 colonies per 100ml (wet season) in the Bayou Cumbest area. Load reductions needed vary greatly depending on weather conditions and sample station location due to the transport and fate of the fecal coliform bacteria. A sample analysis of the load reduction indicated by the monitoring of two stations is shown in Table 6. These points were selected for comparison based on station location. Data used in this example are found in Table 4 on page 17. This is based on the TMDL target of 205 dry and 83 wet.

Table 6 Load Reduction Sample Calculation

Station	Wet data	Dry data	Wet Avg.	Dry Avg.	Reduction	Reduction
BR	8 points	15 points	1336	241	93.8%	14.9%
RR	8 points	15 points	1323	267	93.7%	23.2%

Along the bayou itself, LaSalle (1997) reported somewhat lower levels of fecal coliform contamination into Bayou Cumbest after the failing septic systems were replaced with rock-reed systems. However, LaSalle (1997) also reported that homeowners did not consistently use chlorine in the associated chlorinating chambers, resulting in lower, but nonetheless continuing, release of fecal coliform into Bayou Cumbest.

5.2 Margin of Safety

The TMDL values defined for this watershed are based on direct analysis of existing data for the watershed, using linear regression equations. The MOS was incorporated implicitly by designating the line intercept value of each equation as the TMDL instead of the higher actual value for the source station (i.e., station BR).

5.3. Seasonality

In the case of shellfish beds within the coastal zone, fecal coliform limits are in effect during the approved harvest season of the year that extends from September through May. This period includes portions of both the dry and wet seasons of the year. As shown by analysis of existing monitoring data for this watershed, fecal coliform levels fluctuate seasonally, as affected by rainfall. The two proposed TMDL models reflect this seasonality.

6.0 CONCLUSION

Substantial resources have already been expended in the attempt to restore the shellfish harvesting in this waterbody system. A full-chlorine test was performed by LaSalle (1997), in which chlorine was added to all 39 rock-reed systems along Bayou Cumbest in an attempt to observe whether maximum management of these systems would lead to an observable reduction in the bayou. This test did demonstrate an apparent reduction in fecal coliform contamination following a rain event (data set for 05-29-96, Table 1). However, reluctance by local homeowners to add chlorine and/or actively maintain these rock-reed systems remains a problem in this community. These systems are also prone to clogging and subsequent surface overflow by the rapid growth of the plants that are placed in them. These systems have to be actively managed to avoid problems.

Short of some method of mandating the use of chlorine and/or active management of these systems, little additional improvements can be expected with continued use of the individual onsite wastewater treatment systems. More permanent possible solutions include the establishment of a community wastewater collection and treatment system that requires connection by each resident, and/or the removal in the number of residences in this area by federal and/or state buy-out programs. A recently discussed Federal Emergency Management Agency (FEMA) plan calls for a buy-out of many of the residences within this watershed to reduce future damages from hurricanes.

In the case of residences located in other parts of the watershed, similar measures can be attempted to reduce nonpoint contamination. Short of a buy-out of homes or the establishment of a community wastewater system, these residences could be fitted with rock-reed systems. As previously discussed, however, this measure does have its limitations. A plan to reduce the previously reported contamination of the Bangs Lake portion of the watershed via a drainage ditch that connects this waterbody to a residential area includes the construction of a wetland that would intercept and treat the effluent during rain events. This option is, however, currently limited by the lack of available land where an appropriately sized wetland could be placed.

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 yearlong cycle, MDEQ resources for water quality monitoring will be focused on one of the basin groups. During the next monitoring phase in the Coastal Streams Basin, the Bayou Cumbest Watershed may receive follow-up monitoring to identify the future improvements in water quality from the implementation of the best management practices identified in this TMDL.

6.2 Reasonable Assurance

In order to achieve the standards for shellfishing, the State should investigate all apparent means of reducing the reported sources of fecal coliform contamination listed in the previous sections. The levels of fecal contamination during the shellfish-growing season of September through April also correspond to the rainy season of the year and associated high levels of runoff from residential and natural sources within this watershed. Despite the measures taken to date to control fecal contamination from residential sources (LaSalle 1997), the watershed will likely continue to exceed the standards for shellfishing during these rainy periods.

Reasonable assurance for the implementation of the TMDL has been considered for both point and nonpoint source contributors. Currently, there are no NPDES permits in the area. In the future, there will be no permitted NPDES dischargers allowed in these waters due to the proximity of shellfish beds. Education projects that teach best management practices for septic disinfection are ongoing and should be used as a tool for reducing nonpoint source contributions. These projects have been funded by CWA Section 319 nonpoint source grants in the past.

6.3 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 and a newspaper in Pascagoula. The public will be given an opportunity to review the TMDL and submit comments. 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 received during the public notice period and at any public hearings become a part of the record of this TMDL. All comments will be considered in the ultimate approval of this TMDL by the Commission on Environmental Quality and for submission of this TMDL to EPA Region IV for final approval.

REFERENCES

American Public Health Association. 1992. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, American Water Works Association, Water Environment Federation, 18th Ed. Washington, D.C.

Dillaha, T. A., R. B. Renear, S. Mostaghimi, and D. Lee. 1989. Vegetative filter strips for agricultural nonpoint source pollution control. Transactions of the American Society of Agricultural Engineers. 32:513-519.

Environmental Protection Agency (EPA). 1991. Guidance for Water Quality-Based Decisions: the TMDL Process. 440/4-91-001, U.S. EPA, Office of Water, Washington, D.C.

Environmental Protection Agency (EPA). 1993. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. 840-B-92-002, U.S. EPA., Office of Water, Washington, D.C.

Hollomon, C. Z. and M. W. LaSalle. 1995. Modification of septic tanks requirements. Report to the Mississippi Department of Marine Resources, Biloxi, MS. 110 pp.

Mississippi Department of Environmental Quality. 1995. State of Mississippi Water Quality Criteria for Intrastate, Interstate and Coastal Waters (1995). Prepared by the Mississippi Department of Environmental Quality, Office of Pollution Control, Jackson, MS.

Mississippi Department of Environmental Quality. 1996. State of Mississippi List of Impaired Waterbodies 1996. Prepared by the Mississippi Department of Environmental Quality, Office of Pollution Control, Jackson, MS. 165 pp.

Mississippi Department of Marine Resources. 1999. Ordinance No. 1.015I: An ordinance to establish regulation for shellfish harvesting, landing, unloading, transporting, processing, sale, opening, relaying, other shellfish related activities, and the leasing of territorial waters under the jurisdiction of the state of Mississippi for shellfish activities. April 19, 1999. Mississippi Department of Marine Resources, Biloxi, MS. 56 pp.

LaSalle, M. W. 1997. Water quality monitoring of shellfish growing waters and residential rock-reed wastewater treatment systems at Bayou Cumbest, Mississippi. Final Report to the Gulf of Mexico Program. 58 pp.

DEFINITIONS

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.

Calibrated model: a model in which reaction rates and inputs are significantly based on actual measurements using data from surveys on the receiving waterbody.

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.

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.

Fecal coliform bacteria: a group of bacteria that normally live within the intestines of mammals, including humans. Fecal coliform bacteria are used as an indicator of the presence of pathogenic organisms in natural water.

Geometric mean: the *n*th root of the product of *n* numbers. A 30-day geometric mean is the 30th

root of the product of 30 numbers.

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. The load allocation is the value assigned to the summation of all cattle and land applied fecal coliform that enter a receiving waterbody. It also contains a portion of the contribution from septic tanks.

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

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.

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.

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.

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.

Scientific Notation (Exponential Notation): mathematical method in which very large numbers or very small numbers are expressed in a more concise form. The notation is based on powers of ten. Numbers in scientific notation are expressed as the following: *4.16 x 10^(+b)* and *4.16 x 10^(-b) [same as 4.16E4 or4.16E-4]*. In this case, *b* is always a positive, real number. The *10^(+b)* tells us that the decimal point is *b* places to the right of where it is shown. The *10^(-b)* tells us that the decimal point is *b* places to the left of where it is shown.

For example: $2.7X10^4$ = 2.7E+4 = 27000
$2.7X10^{-4}$ = 2.7E-4 = 0.00027
One Million = 1.0E+6
One Billion = 1.0E+9
One Trillion = 1.0E+12

Sigma (S): shorthand way to express taking the sum of a series of numbers. For example, the sum or total of three amounts 24, 123, 16, ($\mathbf{d}_l$, $\mathbf{d}_2$, $\mathbf{d}_3$) respectively could be shown as:

$$\sum_{\mathbf{i=1}}^{\mathbf{3}} d_i = d_1+d_2+d_3 = 24+123+16 = 163$$

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. It also contains a portion of the contribution from septic tanks

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

ADEM... Alabama Department of Environmental Management

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

BMP ....Best Management Practice

CWA ....Clean Water Act

DMR .... Discharge Monitoring Report

EPA .... Environmental Protection Agency

FEMA ....Federal Emergency Management Agency

GIS .... Geographic Information System

HUC ....Hydrologic Unit Code

LA ....Load Allocation

LDEQ..Louisiana Department of Environmental Quality

MARIS.. State of Mississippi Automated Information System

MDEQ... Mississippi Department of Environmental Quality

MDH .... Mississippi Department of Health

MDMR.. Mississippi Department of Marine Resources

MOS .... Margin of Safety

NRCS ....National Resource Conservation Service

NPDES... National Pollution Discharge Elimination System

NPSM...Nonpoint Source Model

USGS .... United States Geological Survey

WLA ....Waste Load Allocation