DEVELOPING A TOTAL MAXIMUM DAILY LOAD (TMDL) FOR FECAL COLIFORM BACTERIA IN A MISSISSIPPI COASTAL ESTUARY

Kim S. Caviness
Mississippi Department of Environmental Quality, Jackson, MS

INTRODUCTION

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. The TMDL process is designed to restore and maintain the quality of those waterbodies through the establishment of pollutant specific allowable loads.

The Mississippi Department of Environmental Quality (MDEQ) has identified several segments within the Biloxi Bay Watershed as being impaired by fecal coliform bacteria as reported in the Mississippi 1998 Section 303(d) List of Waterbodies (Figure 1, Table 1). The listing of these waterbody segments was influenced by both water quality monitoring data and shellfish classifications.

The TMDLs for these waterbody segments were developed through a monitoring and modeling project. The development of a water quality model for this project was conducted under contract by the Civil Engineering Department at Mississippi State University (Huddleston, et. al., 2001).

BILOXI BAY WATERSHED DESCRIPTION

Watershed Characterization

The Biloxi Bay Watershed is located along the Mississippi Gulf Coast in Harrison, Jackson, and Hancock Counties. The watershed includes Biloxi Bay, Back Bay of Biloxi, Bernard Bayou, Big Lake, Old Fort Bayou, Tidewater Bayou, Heron Bayou, and many other tributaries.

The metropolitan areas of Biloxi, Gulfport, Ocean Springs, and D'Iberville are included in the watershed. These urban areas represent a small percentage of the Biloxi Bay Watershed and are primarily concentrated around the Back Bay of Biloxi and Biloxi Bay (Figure 2).

The listed waterbody segments are in Coastal Streams Basin Hydrologic Unit Code (HUC) 03170009 in southern Mississippi. The drainage area of the watershed is approximately 400,000 acres. Forest and wetland areas represent the largest percentage of landuses within the watershed. The landuse distribution of the watershed is provided in Figure 3.

The Back Bay of Biloxi and Biloxi Bay provide convenient navigation and transportation services to the economic activities of the area. Besides navigation, these waterbodies provide recreational opportunities, as well as stimulate industrial development within the region. This industrialization, in turn, tends to promote population growth and economic development within the adjoining communities. Growth has also been stimulated by resort facilities and casinos, by the presence of abundant fresh and saltwater fisheries, and by the establishment or expansion of military installations. Unfortunately, population growth and industrial development are accompanied by an increased potential for water quality degradation.

Waterbody Uses and Standards

The water use classifications of shellfish harvesting and secondary contact are both applicable in the Biloxi Bay watershed (MDEQ, 1995). The water quality standards for shellfish harvesting apply to Biloxi Bay. These standards are the most stringent, requiring a median fecal coliform most probably number (MPN) of the water not to exceed 14 per 100 ml (MDEQ, 1995). The classification of the Biloxi Bay waters for shellfish harvesting is determined by the Mississippi Department of Marine Resources (MDMR). These classification definitions are fully explained in the National Shellfish Sanitation Program (NSSP) Ordinance which is available on the Interstate Shellfish Sanitation Conference (ISSC) website, http://www.issc.org.

The waters of Biloxi Bay are classified as restricted and prohibited for shellfish harvesting. Past guidance has dictated that any water classified as restricted or prohibited for shellfish

harvesting by the NSSP and MDMR must be listed on the 303(d) List of Waterbodies as impaired. New guidance from EPA now states that "prohibited" classifications set as a precautionary measure due to the proximity of wastewater dischargers are not appropriate to consider in the listing of impaired waterbodies (EPA, 2000). The new guidance along with verification with water quality samples may provide the opportunity to upwardly reclassify more of the Biloxi Bay shellfish growing areas to conditionally approved so that shellfish can be transported and used as seed oysters or possibly harvested and processed. Seasonal conditionally approved classifications are also a possibility if MDMR determines that the water quality is consistently adequate during certain portions of the year. The ultimate goal of this fecal coliform TMDL is to improve water quality to allow for upward classification where appropriate.

Water Quality Assessment

According to Mississippi's 1998 305(b) Water Quality Assessment Report, Biloxi Bay is partially supporting the use of shellfish harvesting due to past guidance. Historical and current data from several MDEQ ambient monitoring stations were also considered in the development of this TMDL. In addition, MDMR collects data extensively in shellfish growing areas. MDEQ recently received a new 10-year data set collected by MDMR, which includes data collected through 1999. This data set was used as part of the most recent MDEQ water quality assessment (MDEQ, 2001), which indicated an improvement in water quality in the Biloxi Bay watershed.

Two intensive surveys were also conducted on the Back Bay of Biloxi during 1994 and 1995. The results from those intensive surveys were used for model calibration and verification.

TMDL DEVELOPMENT

TMDL Endpoint and Critical Conditions

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 implementing the load and wasteload reductions specified in the TMDL. The endpoints allow for a comparison between observed instream conditions and conditions that are expected to restore designated uses.

While there are various designated uses in the Biloxi Bay watershed, the use with the most stringent water quality standards is shellfish harvesting. Reductions utilized to meet this target will be sufficient to meet all other standards.

Because fecal coliform may be attributed to both sources that are runoff dependent and sources that are constantly discharging into the stream, the critical condition must account for both high-flow and low-flow conditions. Critical conditions for waters impaired by nonpoint sources that are runoff related generally occur during periods of wet-weather and high surface runoff. But critical conditions for nonpoint and point sources that continually discharge generally occur during low-flow, low-dilution conditions.

The watershed modeling was done using a wet year and a dry year that were determined to be representative through the evaluation of precipitation records for the period of record of several precipitation stations in the area. The wet year (1995) was determined to be the most critical for the water quality in the bay.

Source Assessment

All known potential fecal coliform sources in the Biloxi Bay Watershed were evaluated. The source assessment was used as the basis of development for the model and the ultimate analysis of the TMDL allocation options.

Point Sources. Typically point sources of fecal coliform bacteria have their greatest potential impact on water quality during periods of low-flow. There are 48 facilities permitted to discharge fecal coliform within the Biloxi Bay watershed. These 48 facilities serve a variety of activities including residential subdivisions, schools, industries, and municipalities. Marinas and shipyards located in the study area were assumed to discharge to the municipalities.

All identified National Pollutant Discharge Elimination System (NPDES) permitted facilities are given in Table 2. As a conservative approach, facilities were modeled at 200 counts/100 ml for the entire year. Seafood

processors, which do not have fecal coliform limits in their NPDES permits, were modeled at 58 counts/100 ml. This discharge number represents the average fecal discharge from seafood processors measured during the 1994-95 Back Bay of Biloxi Study.

Nonpoint Sources. Potential nonpoint sources of pollution for the Biloxi Bay watershed include: failing septic systems, wildlife, land application of animal manure, grazing animals, and urban development.

The nonpoint sources of fecal coliform bacteria have their greatest potential impact on water quality during periods of high runoff. The 400,000 acre drainage area of Biloxi Bay contains many different landuse types including urban, forest, cropland, pasture, barren, and wetlands. The modeled landuse information for the entire watershed is based on the 1997 State of Mississippi's Automated Resource Information System (MARIS). This data set is based on Landsat Thematic Mapper digital images taken between 1992 and 1993. For modeling purposes the landuse categories were grouped into the landuses of urban, forest, cropland, and pasture. Figure 3 shows the landuse distribution within the Biloxi Bay watershed.

The nonpoint fecal coliform contribution from each of these sources was estimated using the best available information, such as population data, agriculture census data, agency estimates of wildlife density, septic tank system failure rates, and manure application practices and loading rates for animal manure.

Approximately 22,560 acres of the Biloxi Bay watershed are classified as urban. Even though this area represents only 5.6% of the total watershed area, it is a significant source of the fecal coliform loadings to the Bay. The urban areas are primarily concentrated around Biloxi Bay and the Back Bay of Biloxi.

Fecal coliform contributions from urban and residential areas may include the activities of domestic pets, wildlife, septic systems, illicit connections and landfills. The bay supports both recreational and commercial boating activities. Therefore, waste from those boats is also a likely source in the bay.

Modeling Procedure

Establishing the relationship between the instream water quality target and the source loading is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses to flow and loading conditions.

The Back Bay of Biloxi and Biloxi Bay Fecal Coliform TMDL Modeling Project utilizes two computer simulation models. The BASINS Non-Point Source Model (NPSM) was used to model the watershed hydrology of the entire Biloxi Bay watershed. It was also used to model the water quality of the freshwater rivers and streams in the watershed. The watershed model (NPSM) was linked with the Water Quality Analysis Simulation Program – 5 (WASP5) to simulate hydrodynamics, salinity, temperature, and water quality in the Back Bay of Biloxi, Biloxi Bay, and the tidally influenced portions of the freshwater systems.

NPSM has the capability to run a single watershed or a system of multiple watersheds that have been delineated through the BASINS environment. BASINS is a multipurpose environmental analysis system used in performing watershed-based and water quality-based studies. A geographic information system (GIS) provides the integrating framework for BASINS and allows for the display and analysis of a wide variety of landscape information such as landuses, monitoring stations, point source dischargers, and stream descriptions. A key reason for using BASINS as the modeling framework is its ability to integrate both point and nonpoint sources in the simulation, as well as its ability to assess instream water quality response.

The NPSM model simulates nonpoint source runoff from selected watersheds, as well as the transport and flow of the pollutants through stream reaches. The freshwater portion of the Biloxi Bay watershed (the portion that is not tidally influenced) was divided into subwatersheds in order to isolate the major stream reaches and to allow for the relative contribution of nonpoint sources to be addressed within each subwatershed. A

calibrated NPSM model was used to simulate the flow and fecal coliform loadings from each subwatershed in the freshwater study area. The output from this NPSM model was used to provide boundary condition input into the Bay model.

The NPSM model was linked with WASP5 to simulate conditions in the Back Bay of Biloxi, Biloxi Bay and the tidally influenced portions of the freshwater systems. The WASP5 model contains two stand-alone water quality models, EUTRO5 and TOXI5. EUTRO5 was developed to simulate eutrophication kinetics for eight different variables: Ammonia (NH3), Nitrate Nitrogen (NO3), Orthophosphorus (PO4), Phytoplankton, Carbonaceous Biochemical Oxygen Demand (CBOD), Dissolved Oxygen (DO), Organic Nitrogen (ON), and Organic Phosphorus (OP). TOXI5 was specifically created to predict dissolved oxygen and sorbed chemical concentrations in the bed and overlying layers (Ambrose, et. al., 1993).

EUTRO5 can be applied in one, two, or three dimensions and is designed for linkage with a hydrodynamic model. DYNHYD5 is the default hydrodynamic model linked with EUTRO5 and was the hydrodynamic model chosen for this application (Shoemaker, et. al., 1997).

The hydrodynamics program, DYNHYD5, simulates the movement of water, while the water quality program, EUTRO5, simulates the movement and interaction of pollutants within the water.

As previously stated, EUTRO5 is capable of modeling eight different kinetic processes. The current problem for the Biloxi Bay watershed lies in pathogen concentration. In most applications, fecal coliform modeling considers only decay through a simple first-order kinetics approach. Since EUTRO5 has no explicit state variable for bacteria modeling, the CBOD model was altered to conform to the simplified coliform model presented below.

$$\frac{\delta C}{\delta t} = -KC\theta^{T-20}$$

Where: C = coliform concentration, MPN/100 ml
K = overall decay rate constant, d^{-1}
t = exposure time
T = temperature, °C
θ = temperature correction factor for K

The decay rate takes into consideration such factors as die-off, predation, sunlight, and salinity.

Allocation

The allocation for this TMDL involves a wasteload allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and an implicit margin of safety (MOS) which would provide the reduction necessary for attainment of water quality standards.

Wasteload Allocation. The wasteload allocation for the Biloxi Bay watershed is based on the sum of the loads from the NPDES permitted dischargers. The modeled contribution of each discharger was based on the facility's discharge monitoring data and other records of past performance. For most facilities, the discharge limits for the NPDES permitted facilities were modeled as equivalent to the water quality standard of 200 counts per 100 ml.

No reduction in the current wasteload allocation was necessary to establish this TMDL. Future facility permits will require end-of-pipe criteria equivalent to the water quality standard of 200 fecal coliform colony counts per 100 ml. It is important that facilities potentially discharging bacteria disinfect their effluent as well as monitor their effluent for compliance.

Load Allocation. The load allocation for this TMDL involves the two different types on nonpoint sources described earlier: those modeled as direct sources to the stream and those modeled as diffuse runoff to the stream. While some nonpoint sources, such as animals in the stream and failing septic tanks were modeled as direct inputs to the stream, other nonpoint source contributions were applied to land area on a counts per day per acre basis and available for transport to the stream in runoff from a rain event.

Contributions from direct sources are input into the model in a manner similar to point source input. The fecal coliform bacteria deposited on the land, either through land application or grazing, are subject to a die-off rate and an absorption rate before entering the stream. Therefore, the sources that runoff into the stream are not as predominant of a source as the direct sources. The load allocation is the load resultant from all of the aforementioned

sources, direct sources and distributed, which result in meeting the appropriate water quality standard for each waterbody's designated use.

According to the model under existing conditions, only Bernard Bayou (segment 2) and Biloxi Bay showed impairment. A 60 percent reduction in septic tank failures within the drainage area of Bernard Bayou was necessary in order for this segment to meet the water quality standards for Secondary Contact.

Because over 97% of the allocated load for Biloxi Bay is due to nonpoint sources, those loads were the focus for reductions. The load allocation necessary for Biloxi Bay to meet the water quality standards for Shellfishing involves a reduction in the urban nonpoint source runoff from the watersheds surrounding the Back Bay of Biloxi and Biloxi Bay. A 35 percent reduction in the concentration of urban runoff was necessary from each of these small watersheds (Graphs 1 and 2).

Margin of Safety. 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. For this study, the MOS is incorporated into the modeling process by utilizing a conservative fecal coliform decay rate, conservative loading and environmental conditions, and running a dynamic simulation to calculate fecal coliform values in the Back Bay of Biloxi and Biloxi Bay every two hours.

In addition, ensuring compliance with the standard throughout all of the critical periods represented during the modeling period is a conservative practice. Another component of the implicit MOS is the conservative assumption in the model that all of the fecal coliform bacteria discharged from failing septic tanks reaches the stream, while it is likely that only a portion of the bacteria will reach the stream due to die-off during transport.

TMDL Calculation

This TMDL is calculated based on the following equation:

$$TMDL = WLA + LA + MOS$$

The TMDL was calculated based on the 15-day critical period for the Biloxi Bay watershed according to the model. Each of the loading rates was converted to the 15-day equivalent.

As stated earlier, the wasteload allocation incorporates the fecal coliform contributions from identified NPDES permitted facilities. The load allocation includes the contributions from nonpoint sources. The margin of safety for this TMDL is implicit and is derived through conservative loading assumptions used in setting up the model.

Public Participation and EPA Approval

Upon completion, this TMDL was published for a 30-day public notice. During this time, the public was notified by publication in a statewide newspaper and a newspaper in the area of the watershed. This provides the public with the opportunity to review the TMDL and submit comments. Private meetings were held with representatives of many organizations including the Gulf of Mexico Program Office, the Mississippi Department of Health, the Gulf Restoration Network, and the Gulf Islands Conservancy. In addition, a public meeting was held in Biloxi, Mississippi. This meeting was a public forum style, open meeting where any concerns regarding the TMDL could be addressed. MDEQ proposed the Fecal Coliform TMDL for the Back Bay of Biloxi and Biloxi Bay in November 2001. EPA approved the TMDL document in January 2002.

FUTURE MONITORING AND ACTIVITIES

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, additional monitoring is needed to identify any change in water quality within the Biloxi Bay watershed.

The Gulf of Mexico Program Office is facilitating efforts to evaluate options for future wastewater treatment needs in Hancock County (URS, 2001). Recommendations include consolidating the wastewater treatment in the county under one authority, Southern Regional Wastewater Management District (SRWWMD), and building collection and transport systems for rural parts of the county. The consolidated facility might

utilize innovative approaches to treatment and disposal including land application. Harrison and Jackson Counties could undertake similar efforts.

Numerous other management practices could be implemented to reduce bacteria loadings within the Biloxi Bay watershed. These include improving stormwater treatment practices, repairing sanitary sewers, and getting pet owners to clean up after their pets either through implementation of an aggressive pet waste education program or city ordinances. Also, the counties could establish ordinances for inspection, maintenance, and repair of septic systems and individual onsite wastewater treatment systems in the area

Additional Monitoring

Additional monitoring is needed within the Biloxi Bay watershed to quantify the bacteria loadings entering the bay. This data could be used to validate the loadings predicted by the models used for this TMDL.

Bacterial source tracking (BST) involves identifying the sources of the bacteria present in surface water through various monitoring and analytical techniques including biochemical profiling and DNA. This technique could be used to determine the sources of the bacteria entering the Back Bay of Biloxi and Biloxi Bay.

Funding Sources

MDEQ guidance for future 319 project funding will encourage NPS restoration projects that attempt to address TMDL related issues within Section 303(d)/TMDL watersheds in Mississippi.

An additional potential funding source for future activities in this watershed is the Coastal Impact Assistance Program (CIAP). CIAP is a program recently formed to provide funds for projects that deal with environmental resources on the Mississippi Coast.

CONCLUSION

The ultimate goal of a TMDL is to improve and restore water quality to the polluted stream or waterbody. Another goal of this TMDL is to improve the water quality within Biloxi Bay to allow for upward re-classification of the waters to once again allow shellfish harvesting when appropriate. Additional stakeholder input is the key to the development of a successful implementation plan for this watershed.

Additional details about the model setup, calibration, and verification are available in the *Fecal Coliform TMDL for the Back Bay of Biloxi and Biloxi Bay* (MDEQ, 2002). Interested persons may obtain a copy of this document by contacting the author.

Acknowledgements

MDEQ would like to acknowledge the Gulf of Mexico Program, the Mississippi State University Civil Engineering Department, the Mississippi Department of Marine Resources, EPA Region 4, and all of the other agencies and individuals that have participated in the Back Bay of Biloxi and Biloxi Bay Fecal Coliform TMDL project.

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Figure 1. Biloxi Bay Watershed 303(d) Listed Segments

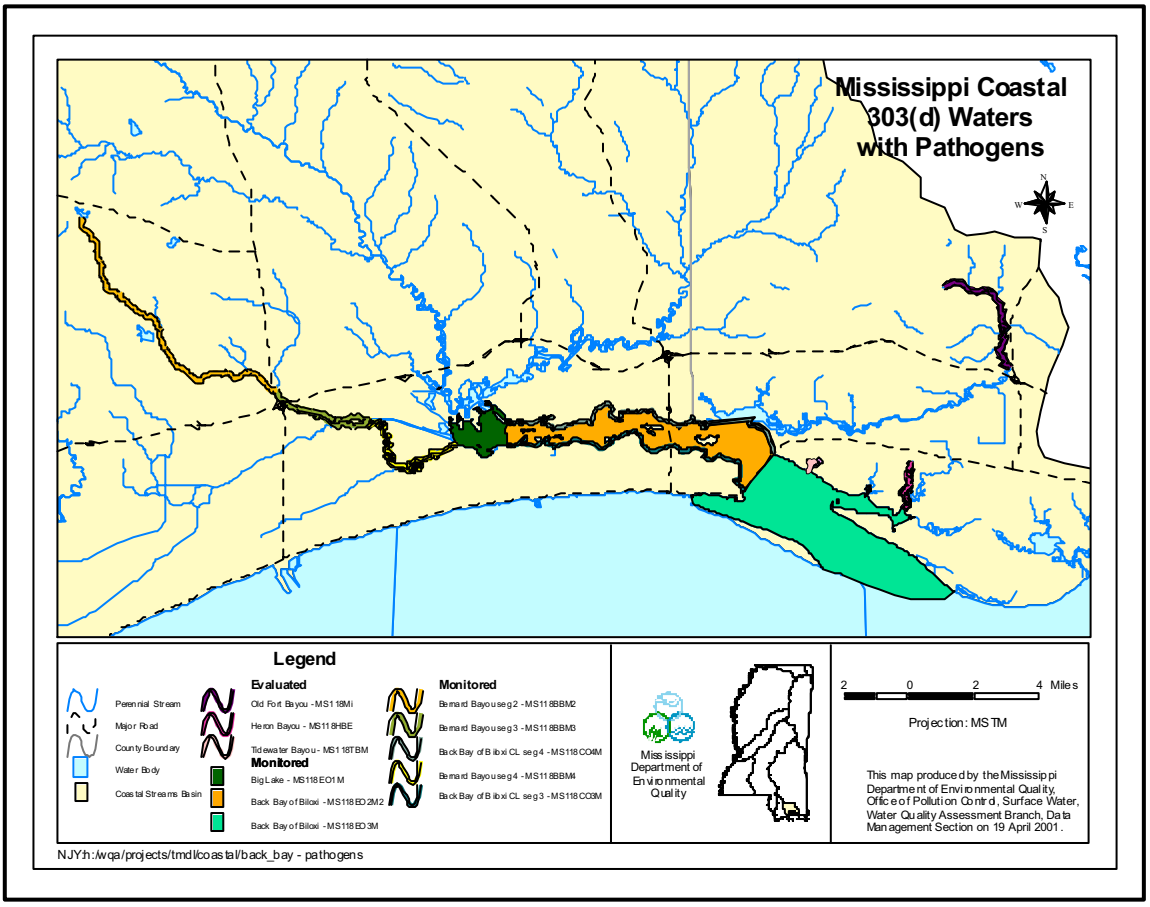


Table 1. Waterbodies included in the Back Bay of Biloxi Fecal Coliform TMDL

Waterbody Name	Waterbody ID	Use Impairment	Cause of Impairment
Biloxi Bay	MS118E03M	Shellfishing	Pathogens
Back Bay of Biloxi	MS118E02M2	Secondary Contact	Pathogens
Back Bay of Biloxi Coastline segment 3	MS118C03M	Secondary Contact	Pathogens
Back Bay of Biloxi Coastline segment 4	MS118C04M	Secondary Contact	Pathogens
Big Lake	MS118E01M	Secondary Contact	Pathogens
Bernard Bayou segment 2	MS118BBM2	Secondary Contact	Pathogens
Bernard Bayou segment 3	MS118BBM3	Secondary Contact	Pathogens
Bernard Bayou segment 4	MS118BBM4	Secondary Contact	Pathogens
Heron Bayou	MS118HBE	Secondary Contact	Pathogens
Old Fort Bayou	MS118M1	Secondary Contact	Pathogens
Tidewater Bayou	MS118TBM	Secondary Contact	Pathogens

Figure 2. Area Map for the Biloxi Bay Watershed

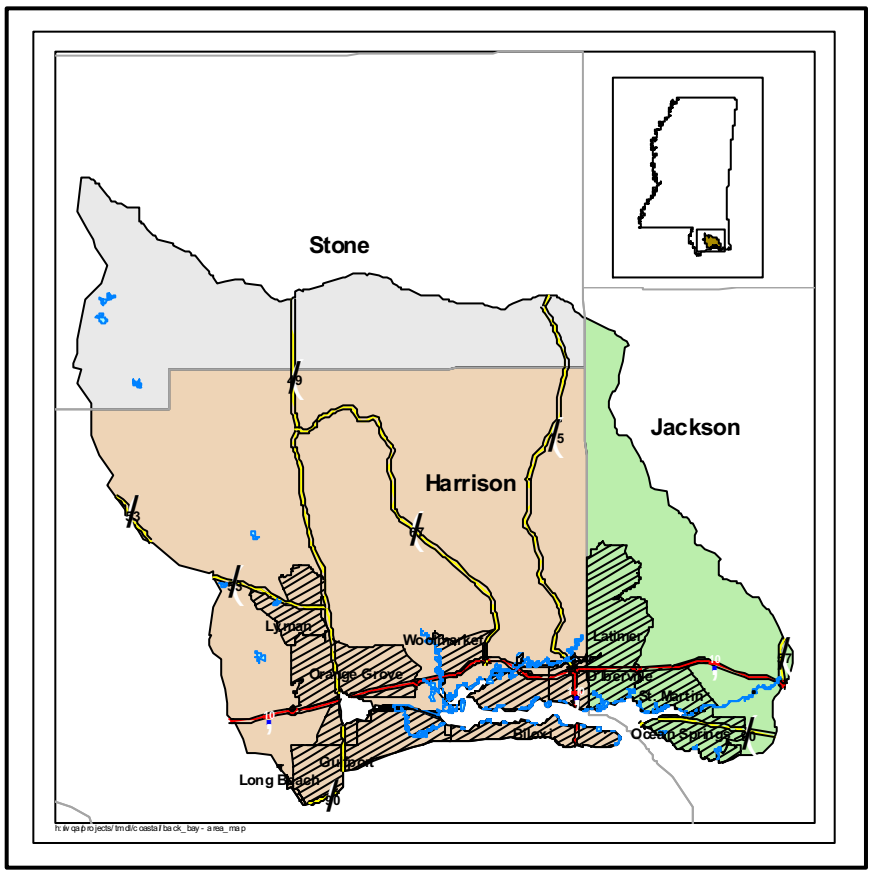


Figure 3. Landuse Distribution for the Biloxi Bay Watershed

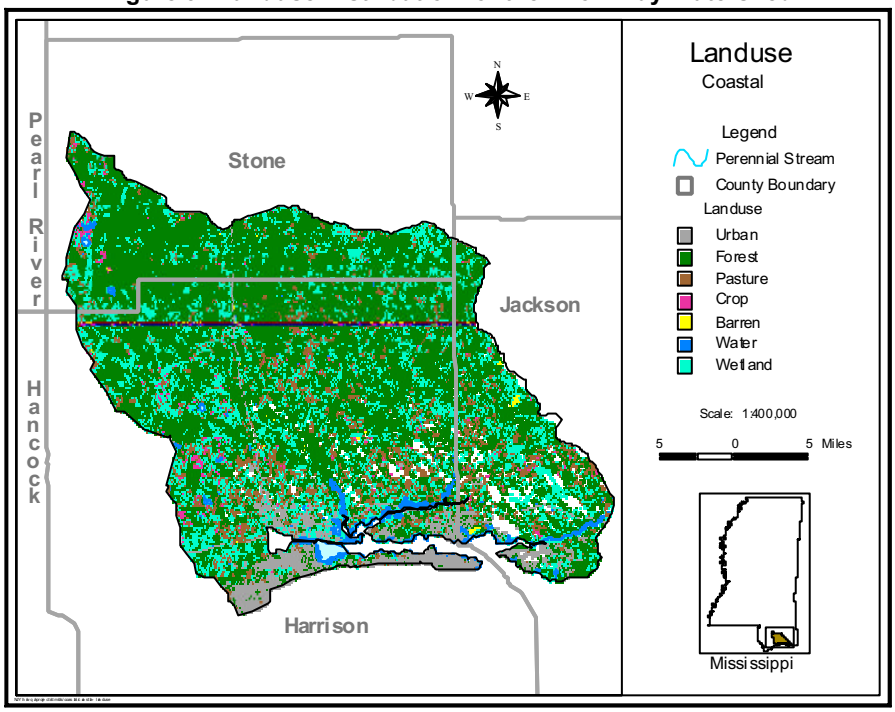
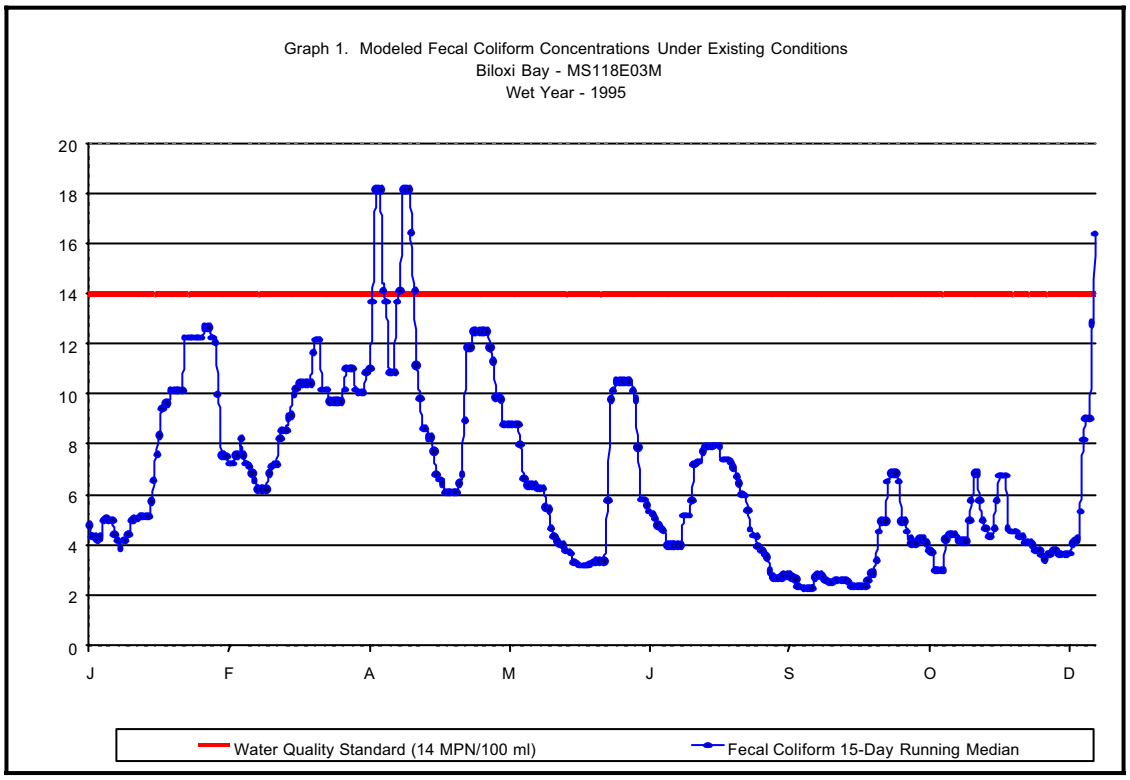
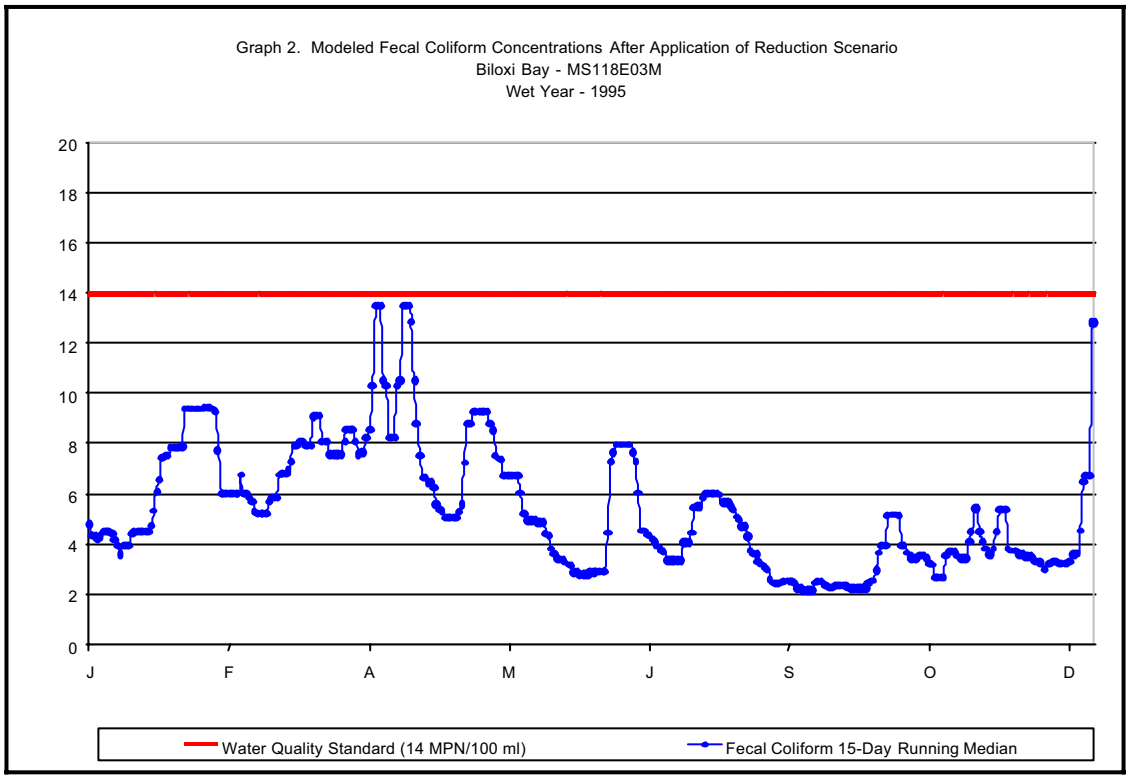


Table 2. Inventory of Identified NPDES Permitted Facilities

Facility Name	NPDES Permit	Receiving Waterbody
Reichhold Inc.	MS0001520	Big Lake
Harrison County/West Biloxi POTW	MS0030333	Back Bay of Biloxi
D'Iberville POTW	MS0042340	Back Bay of Biloxi
Harrison County/East Biloxi POTW	MS0023159	Keegan Bayou to Back Bay
Fast Lane #735	MS0047201	Back Bay of Biloxi
Gollott Brothers Seafood	MS0047597	Back Bay of Biloxi
Coast to Coast Seafood	MS0047520	Back Bay of Biloxi
R. Fournier & Sons Seafood Inc.	MS0001562	Back Bay of Biloxi
C. F. Gollott & Sons Seafood Co.	MS0002861	Back Bay of Biloxi
Seymour & Sons Seafood Inc.	MS0036315	Back Bay of Biloxi
R. A. Fayard Seafood Company Inc.	MS0001589	Back Bay of Biloxi
R. A. Lesso Seafood	MS0037656	Back Bay of Biloxi
Golden Gulf Coast Packing Co.	MS0040142	Back Bay of Biloxi
Gulf Pride Enterprises Inc.	MS0039276	Back Bay of Biloxi
M & M Shrimp Company Inc.	MS0044466	Back Bay of Biloxi
J & W Seafood	MS0045012	Back Bay of Biloxi
David Gollot Seafood	MS0045799	Back Bay of Biloxi
G & R Seafood L.L.C.	MS0046493	Back Bay of Biloxi
David Gollot Seafood Inc.	MS0052400	Back Bay of Biloxi
Weems Brothers Seafood	MS0001759	Back Bay of Biloxi
AC Foods Inc.	MS0044431	Back Bay of Biloxi
Custom Pack	MS0045004	Back Bay of Biloxi
Seven Oaks Gulf Hills Resort	MS0031143	Old Fort Bayou
KOA Kampground	MS0041629	Old Fort Bayou
Ocean Springs Seafood Company	MS0037001	Biloxi Bay
1st Am Printing and Direct Mail	MS0041700	Old Fort Bayou
St. Martin High School	MS0038008	Bayou Talla
Schmidt Apartments	MS0047554	St. Martin Bayou
Gulfcoast 7th Day Adventist Church	MS0050504	Parker Creek
Parker's Landing RV Park Alt	MS0052159	Tchoutacabouffa River
Pine Haven Mobile Home Park	MS0036854	Parker Creek
Mazalea RV Park	MS0039594	Tchoutacabouffa River
Country Living Mobile Home Park	MS0042218	Howard Creek
North Woolmarket Village Estates	MS0049298	Howard Creek
Gutierrez RV Park	MS0050938	Howard Creek
Destination RV Park	MS0039250	Tuxachanie Creek
West Jackson Artificial Wetlands	MS0045446	Costapia Bayou
Oaklawn Mobile Home Park	MS0050717	Tchoutacabouffa River
Clark Oil Company #11 - Exxon	MS0046418	Fritz Creek
Jig's Fish Camp	MS0052230	Biloxi River
Harrison County/Eagle Point POTW	MS0034436	Biloxi River
Apple Valley Trailer Park	MS0040169	Biloxi River
Woolmarket Elementary School	MS0030899	Biloxi River
Harrison County WWM	MS0023345	Bernard Bayou
Bernard Bayou Industrial Park	MS0027537	Bernard Bayou
Harrison County/Gulport POTW –	MS0051756	Bernard Bayou (Gulfport Lake)
Homestead Trailer Village	MS0051373	Flat Branch
Walters Trailer Park	MS0046086	Bernard Bayou





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