Approved TMDL
December 15, 2000

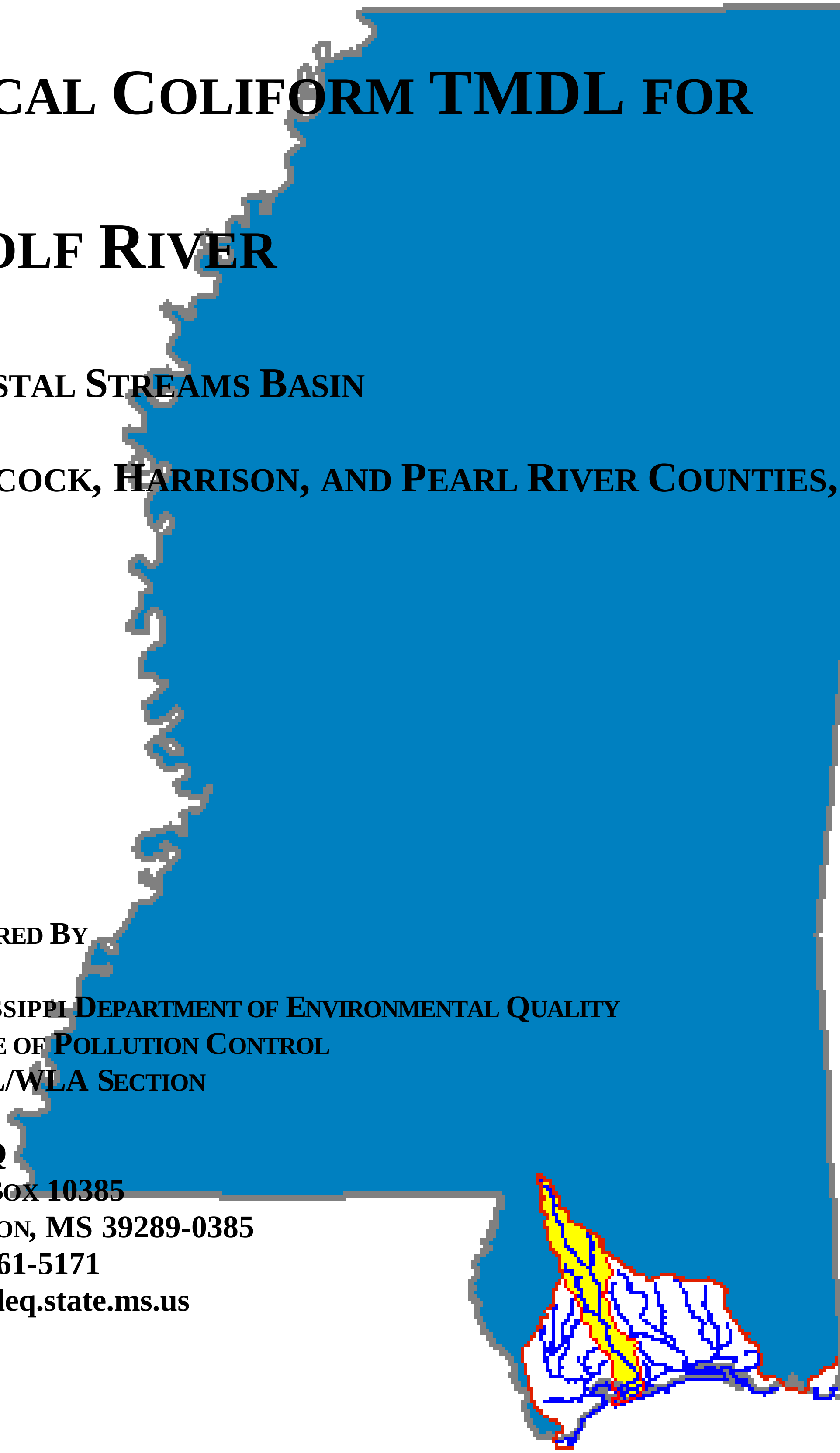
Phase One

Fecal Coliform TMDL for

Wolf River

Coastal Streams Basin

Hancock, Harrison, and Pearl River Counties, Mississippi



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FOREWORD

This report has been prepared in accordance with the schedule contained within the federal consent decree dated December 22, 1998. The report contains one or more Total Maximum Daily Loads (TMDLs) for waterbody segments found on Mississippi's 1996 Section 303(d) List of Impaired Waterbodies. The implementation of the TMDLs contained herein will be prioritized within Mississippi's rotating basin approach.

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

Prefixes for fractions and multiples of SI units

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

Conversion Factors

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

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TABLES

CHARTS

MONITORED SEGMENT MS111M1 IDENTIFICATION

Name:	Wolf River
Waterbody ID:	MS111M1
Location:	Near Lizana (Landon): From county road at Sellers to the mouth at St. Louis Bay
County:	Harrison County, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	090
Length:	31 miles
Use Impairment:	Contact Recreation
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
Priority Rank:	30
NPDES Permits:	There are no NPDES Permits issued for facilities that potentially discharge fecal coliform in the watershed
Standards Variance:	None
Pollutant Standard:	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
Waste Load Allocation:	Assigning 50 percent of the allocated septic tank failures to this category (all future dischargers must meet water quality standards for disinfection)
Load Allocation:	Assigning all of the loads contributing to surface runoff and the direct sources, including the other 50 percent of the failing septic tanks and all of the animals in the stream, to this category
Margin of Safety:	Implicit modeling assumptions
Total Maximum Daily Load (TMDL):	Summation of the loads from the sources listed above that result in the water quality standard of a geometric mean of 200 fecal coliform colony counts per 100 ml being met

EXECUTIVE SUMMARY

Several waterbodies and waterbody segments, including St. Louis Bay itself, in the St. Louis Bay watershed are on the Mississippi 1998 Section 303(d) List of Waterbodies as impaired due to pathogens, which are indicated by the presence of fecal coliform bacteria. The TMDLs for these waterbodies were developed through one monitoring and modeling project. However the TMDLs are being presented in two phases due to the diversity of the systems and processes involved. Phase One is comprised of TMDLs for the Wolf River and the Jourdan River, which are the primary fresh water sources for St. Louis Bay. Phase Two will follow with TMDLs for the Bay itself and the near shore watersheds, which drain directly to the saltwater of the Bay. The phased approach is beneficial not only because different model were used to represent the saltwater and the freshwater systems, but also because the different systems have different targets. This TMDL, which is for a segment of the Wolf River, is part of Phase One of the St. Louis Bay Watershed Fecal Coliform TMDL Modeling Project. The modeling for this project was conducted by the Civil Engineering Department at Mississippi State University.

The Wolf River is recognized to be an especially important stream to the citizens of the State of Mississippi. The Wolf River has the distinction of being the first stream in the State of Mississippi designated for the Scenic Streams Stewardship Program, which is conducted by the Mississippi Department of Wildlife, Fisheries, and Parks. The Wolf River is also one of only a few streams in the state with an organization dedicated to it's conservation, the Wolf River Conservation Society. The Wolf River Conservation Society was started in 1998 with the mission to conserve, manage, and protect the Wolf River and its watershed (SCS, 2000).

The Wolf River flows in a southeasterly direction from its headwaters in Pearl River County through Hancock and Harrison Counties, where it flows into St. Louis Bay. The BASINS Nonpoint Source Model (NPSM) and the Environmental Fluid Dynamics Code (EFDC) model were selected as the models for performing the TMDL allocations for this study. The weather data used for this model were collected at several locations in the study area. The representative hydrologic period used for this TMDL was a wet year, 1995, and a dry year, 1968, as determined by an analysis of mean annual rainfall distributions at several stations including Poplarville, Gulfport, Picayune, and Bay St. Louis. Bacteria data MDEQ collected at ambient station 02481510, located near Lizana (Landon), indicate a violation of the water quality standards for contact recreation for fecal coliform bacteria in the waterbody.

Fecal coliform loadings from nonpoint sources in the watershed were calculated based upon wildlife populations, livestock populations, information on livestock and manure management practices, and urban development for the Wolf River Basin. The estimated fecal coliform production and accumulation rates due to nonpoint sources that would runoff from the watershed were incorporated into the model. Also represented in the model were the nonpoint sources that would be directly deposited in the stream, such as failing septic systems and other animals that have direct access to the main stem and tributaries of the Wolf River. A 50% failure rate of septic tanks in the drainage area was assumed for input into the model. There are no NPDES Permitted discharges included as point sources in the model. Under existing, or baseline, conditions, output from the model indicates a violation of the geometric mean fecal coliform standard. After applying a TMDL reduction scenario, there were no violations of the standard according to the model.

The model accounted for seasonal variations in hydrology, climatic conditions, and watershed activities. The use of the continuous simulation model allowed for consideration of the seasonal aspects of rainfall and temperature patterns within the watershed. Calculation of the fecal coliform accumulation parameters and source contributions on a monthly basis accounted for seasonal variations in watershed activities such as livestock grazing and land application of manure.

The Phase One TMDL scenario for the fecal coliform load from the Wolf River Watershed involves a reduction in the total fecal coliform load of approximately 2 percent. That reduction could be achieved through many different scenarios, which are not specifically addressed in this TMDL, but will be included in an implementation plan at a later date. The categories of loads that may be reduced include those that contribute to surface runoff and those that reach the stream directly. Additional monitoring and information is necessary to verify the specific sources that need to be controlled. Because the Phase Two results will provide a more comprehensive picture of sources affecting the entire St. Louis Bay System, the individual TMDL components will not be assigned until Phase Two.

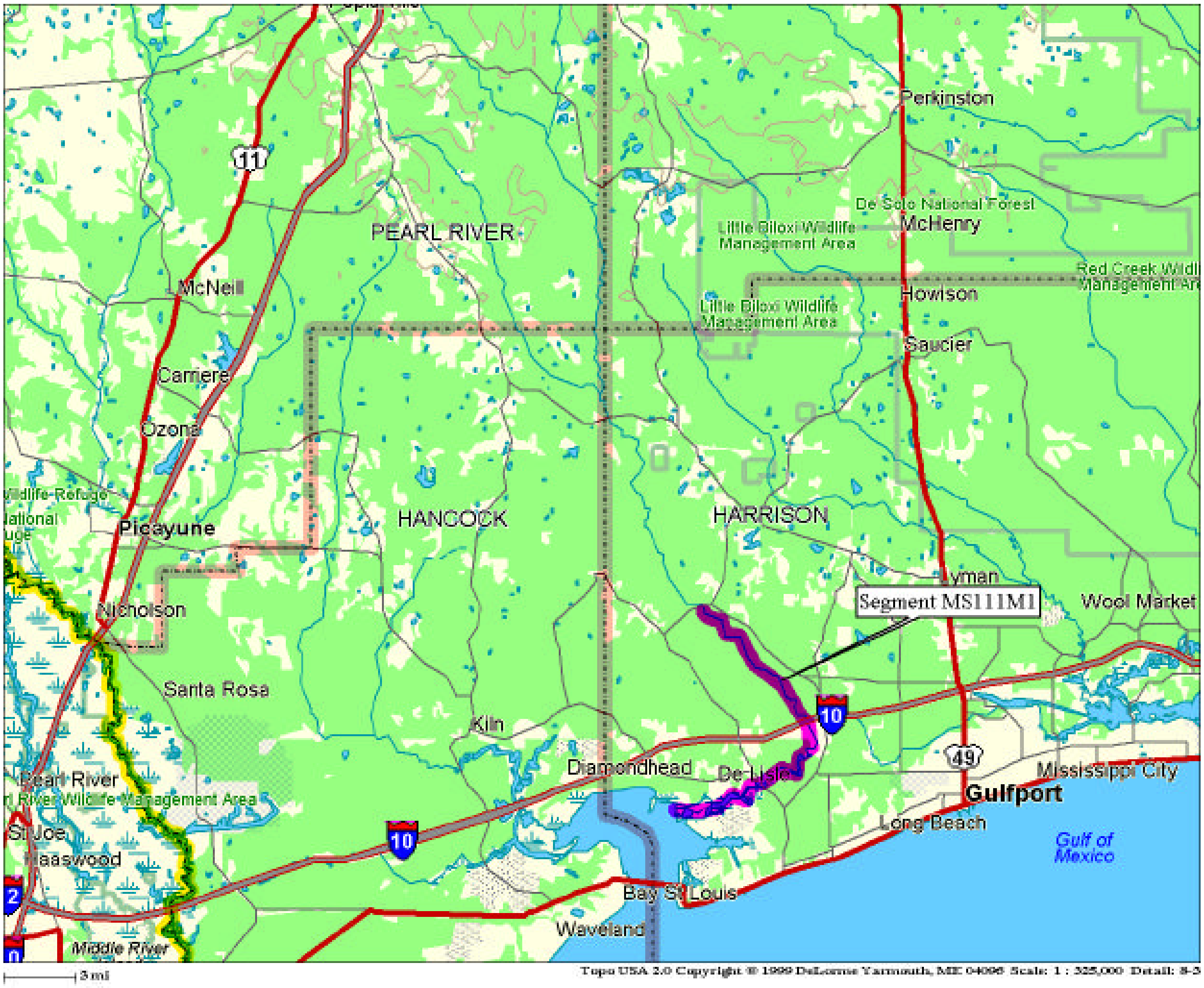
1.0 INTRODUCTION

1.1 Background

The identification of waterbodies not meeting their designated use and the development of total maximum daily loads (TMDLs) for those waterbodies are required by Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR part 130). The TMDL process is designed to restore and maintain the quality of those impaired waterbodies through the establishment of pollutant specific allowable loads. The pollutant of concern for this TMDL is pathogens. Fecal coliform bacteria are used as indicator organisms for pathogens. They are readily identifiable and indicate the possible presence of other pathogenic organisms in the waterbody. The TMDL process can be used to establish water quality based controls to reduce pollution from both point and nonpoint sources, and restore and maintain the quality of water resources.

The Mississippi Department of Environmental Quality (MDEQ) has identified a segment of the Wolf River as being impaired by fecal coliform bacteria for a length of 31 miles as reported in the Mississippi 1998 Section 303(d) List of Waterbodies. This segment is listed as impaired because historical monitoring data was available to show that there was a violation of the water standard for pathogens in this segment. The listed segment is near Lizana and Landon, from Cable Bridge Road to the mouth at St. Louis Bay. The monitored section of the Wolf River is shown in Figure 1.1a.

Figure 1.1a Wolf River Impaired Segment

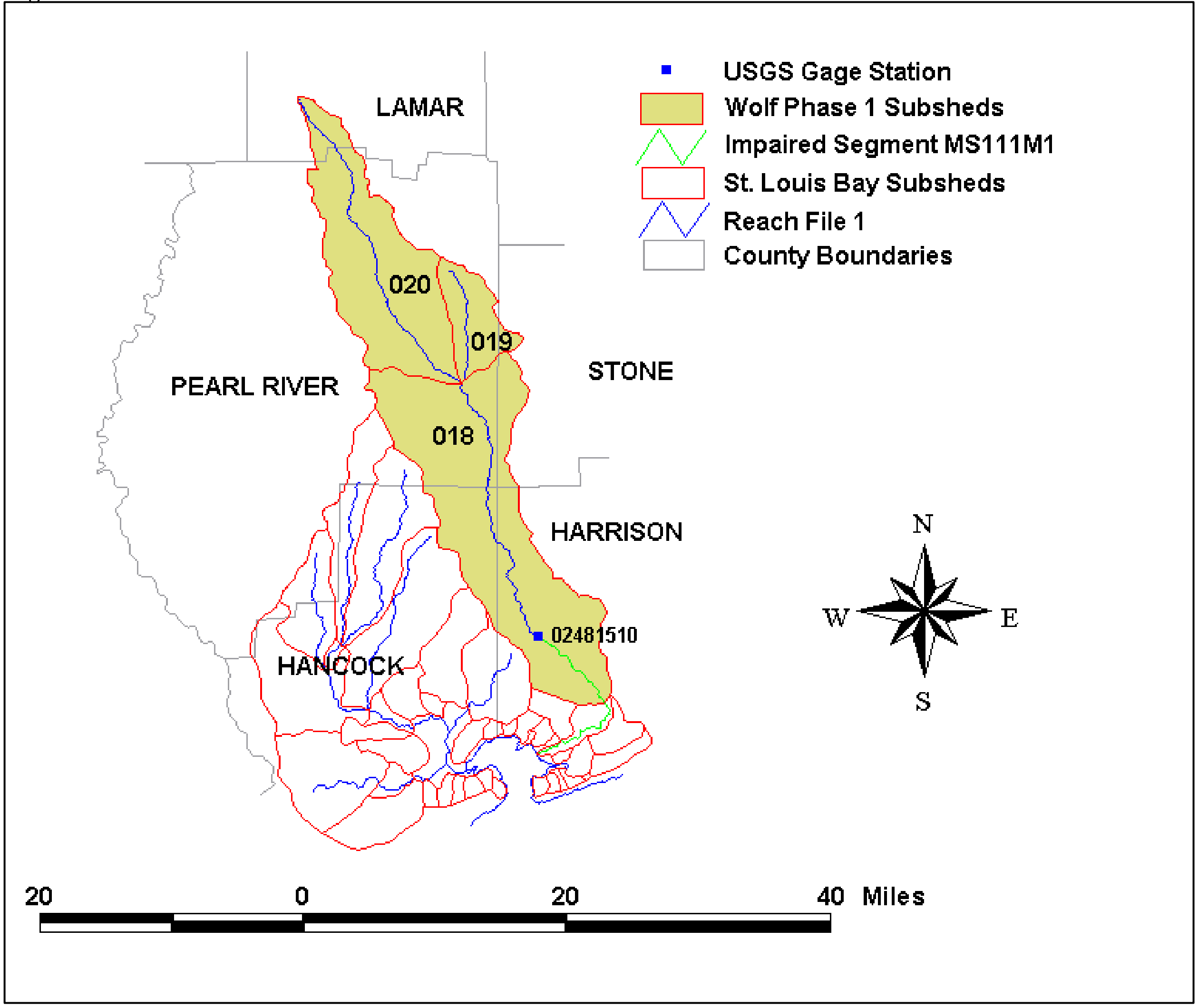


The impaired segment of the Wolf River is in the Coastal Streams Basin Hydrologic Unit Code (HUC) 03170009 in southwest Mississippi. The drainage area of the monitored segment represented in this TMDL is approximately 345 square miles. As shown in yellow in Figure 1.1b, the drainage area lies within portions of Pearl River, Hancock, Harrison, Stone, and Lamar Counties. The watershed is predominately forested and rural with the urban area shown being shown below predominately composed of transportation acres. Forest is the dominant landuse within the watershed. The land distribution is shown in Table 1.1.

Table 1.1 Landuse Distribution in Acres for the Wolf River Watershed

	Urban	Forest	Cropland	Pasture	Barren	Wetland	Total
Area (Acres)	605	191,590	5,164	21,859	630	12	219,860
% Area	0	87	2	10	0	0	100

Figure 1.1b Wolf River Subwatersheds



The drainage area represented in this phase of the TMDL has been divided into three subwatersheds based on the major tributaries and topography. Figure 1.1b shows the subwatersheds of the Wolf River represented in this TMDL in yellow and identifies them with a three-digit identification number. Six subwatersheds in the Upper Jourdan River Watershed will be represented in another Phase One TMDL, while the remaining subwatersheds delineated in Figure 1.1b will be addressed in Phase Two of the St. Louis Bay Fecal Coliform TMDL Modeling Project. The impaired segment of the Wolf River, MS111M1, is shown in green.

1.2 Applicable Waterbody Segment Use

The water use classification for the Wolf River, as established by the State of Mississippi in the *Water Quality Criteria for Intrastate, Interstate and Coastal Waters* regulation, is Recreation. The designated beneficial use for the Wolf River is Contact Recreation. The designation of the Wolf River for the Scenic Streams Stewardship Program and the activities of the Wolf River Conservation Society indicate the high level of public use and concern for the quality of the Wolf River.

1.3 Applicable Waterbody Segment Standard

The water quality standard applicable to the use of the waterbody and the pollutant of concern is defined in the *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters*. The standard states that for the use of contact recreation the 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. This water quality standard will be used as targeted endpoints to evaluate impairments and to establish this TMDL. The TMDLs which will be addressed in Phase Two will be for the designated use of Shellfish Harvesting.

2.0 TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Selection of a TMDL Endpoint and Critical Condition

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 waste load allocations specified in the TMDL. The endpoints allow for a comparison between observed instream conditions and conditions that are expected to restore designated uses. The instream fecal coliform target for this TMDL is a 30-day geometric mean of 200 colony counts per 100 ml.

Because fecal coliform may be attributed to both sources that are runoff dependent and sources that are constantly discharging to the stream, the critical condition must account for both high 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. While the watershed model was run for a full eleven year period to capture various high and low flow situations, most of the 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 stations in the area.

2.2 Discussion of Instream Water Quality

According to the State's 1998 Section 305(b) Water Quality Assessment Report, this 31 mile long segment of the Wolf River is not supporting the use of Contact Recreation. This conclusion is based on instantaneous data collected approximately bimonthly at station 02481510, which is the Wolf River near Lizana (Landon).

2.2.1 Inventory of Available Water Quality Monitoring Data

Monitoring for flow and fecal coliform was performed on a bimonthly basis (six per year) at station 02481510 through MDEQ's Ambient Monitoring Program. Then in 1997 the monitoring frequency at that station was increased to a monthly basis. The data resulting in the latest 303(d) listing, from October of 1991 through September of 1996, is shown in Table 2.2a. More recent data is shown in Table 2.2b, and data from the 1997 and 1998 intensive surveys are shown in Table 2.2c.

Through the development of a Data Compendium for St. Louis Bay some additional historical water quality data sources on the Wolf River were identified and evaluated. Two intensive surveys were also conducted for the St. Louis Bay Fecal Coliform TMDL Project that included stations on the Wolf River. The results from those intensive surveys were used for model calibration.

Mississippi Power Company adopted the Wolf River through the Adopt-A-Stream Program in 1993, then later in 1993 enlisted biologists from Southern Company Services (SCS) Earth Science and Environmental Engineering Group to conduct physical, chemical, and biological data at 12 stations on the Wolf River. Fecal Coliform monitoring was added at selected stations in 1998 (SCS, 2000). The results are shown in Table 2.2d.

Table 2.2a Fecal Coliform Data used in latest 303(d) from the Wolf River near Lizana (Landon), Station 02481510

Date	**Flow (cfs)**	**Fecal Coliform (counts/100ml)**
11/4/1991	127	80
1/6/1992	164	130-MF
3/4/1992	356	70
5/4/1992	210	80
7/13/1992	56	1300
9/14/1992	110	80
11/2/1992	640	9000
1/12/1993	4200	2800
3/8/1993	422	20
5/3/1993	1280	2300
7/12/1993	628	300
9/13/1993	146	40
11/2/1993	612	1700
1/10/1994	200	20
3/7/1994	412	210
5/4/1994	2170	7000
6/21/1994	188	230
8/22/1994	98	800
11/8/1994	600	3000
1/10/1995	281	800
3/7/1995	642	90
4/18/1995	512	230
7/11/1995	99	20
9/12/1995	67	40
11/6/1995	307	800
1/10/1996	308	500
3/6/1996	329	500
5/7/1996	177	20
7/10/1996	139J	1700
9/9/1996	106J	70

***All data in MPN (Most Probable Number), unless noted by MF (Membrane Filtration)**

Table 2.2b More Recent Fecal Coliform Data from the Wolf River near Lizana (Landon), Station 02481510

Date	**Flow (cfs)**	**Fecal Coliform (counts/100ml)**
12/11/1996	119	60-MF
1/8/1997	1880	5300-MF
2/5/1997	2450	1600-MF
3/5/1997	0.8	56-MF
4/3/1997	315	97-MF
5/6/1997	206	60-MF
6/10/1997	529	70-MF
7/7/1997	366	1900-MF
8/11/1997	392	528-MF
9/4/1997	82	200-MF
10/8/1997	Not Available	70-MF
11/17/1997	Not Available	200-MF
1/12/1998	Not Available	3200-MF
2/9/1998	Not Available	27-MF
3/18/1998	Not Available	1910-MF
4/9/1998	Not Available	200-MF
6/15/1998	Not Available	100-MF
7/13/1998	Not Available	230-MF
8/17/1998	Not Available	17-MF
9/15/1998	Not Available	320-MF
10/20/1998	Not Available	74-MF
11/3/1998	Not Available	400-MF
12/1/1998	Not Available	46-MF

***All data in MPN (Most Probable Number), unless noted by MF (Membrane Filtration)**

Table 2.2c Fecal Coliform Data from the Wolf River (02481510) during two Intensive Surveys

July 1998 Water Quality Study					
Station #	Date	Time	Sample Depth (ft)	FC - MPN (#/100 ml)	FC - MF (#/100 ml)
WR2 (02481510)	07/14/1998	18:15	0.5	1600.0	2100.0
WR2 (02481510)	07/15/1998	13:10	1.0	350.0	200.0
WR2 (02481510)	07/16/1998	12:15	1.0	110.0	100.0
April 1999 Water Quality Study					
Station #	Date	Time	Sample Depth (ft)	FC - MPN (#/100 ml)	FC - MF (#/100 ml)
WR2 (02481510)	04/19/1999	14:55	1.0	7.8	3.0
WR2 (02481510)	04/21/1999	14:30	1.0	6.8	10.0
WR2 (02481510)	04/22/1999	13:20	1.0	13.0	10.0

Table 2.2d Fecal Coliform Data from the Wolf River from the Mississippi Power Company Environmental Monitoring Program

Station	Date	Counts/100 ml (MF Method)
WR2 (upper reaches near Poplarville)	10/09/1998	62.0
WR9 (middle reaches)	10/09/1998	28.0
WR10 (lower reaches)	10/09/1998	28.0

2.2.2 Analysis of Instream Water Quality Monitoring Data

A statistical summary of the water quality data that resulted in the 303(d) Listing is presented in Table 2.2e. Samples are compared to the instantaneous maximum standard of 400 counts per 100 ml. The percent exceedance was calculated by dividing the number of exceedances by the total number of samples and does not represent the amount of time that the water quality is in violation.

Table 2.2e Statistical Summary for Station 02481510 (Oct. 1991 – Sept. 1996) corresponding to 303(d) Listing

Season	Number of Samples	Minimum Value (counts/100ml)	Maximum Value (counts/100ml)	Number of Exceedances	Percent Instantaneous Exceedance
Annual	29	20	9000	13	45%

A statistical summary of all of the data shown in Table 2.2a, 2.2b, and 2.2c is provided in Table 2.2f.

Table 2.2f Statistical Summary for Station 02481510 (Oct. 1991 – April 1999) corresponding to all available data

Season	Number of Samples	Minimum Value (counts/100ml)	Maximum Value (counts/100ml)	Number of Exceedances	Percent Instantaneous Exceedance
Annual	59	3	9000	20	34%

3.0 SOURCE ASSESSMENT

The TMDL evaluation summarized in this report examined all known potential fecal coliform sources in the Wolf River Watershed. The source assessment was used as the basis of development for the model and ultimate analysis of the TMDL allocation options. In evaluation of the sources, loads were characterized by the best available information, monitoring data, literature values, and local management activities. This section documents the available information and interpretation for the analysis. The representation of the following sources in the model is discussed in Section 4.0, Modeling Procedure: Linking the Sources to the Endpoint.

3.1 Assessment of Point Sources

Typically, point sources of fecal coliform bacteria have their greatest potential impact on water quality during periods of low flow. There are no point sources permitted for fecal coliform bacteria in the Wolf River Watershed. Point sources discharging in the tidally influenced area were considered to be a direct discharge to the Bay and were not included as part of the watershed model input data.

3.2 Assessment of Nonpoint Sources

There are many potential nonpoint sources of fecal coliform bacteria for the Wolf River, including:

- Wildlife
- Land application of hog and cattle manure
- Grazing animals
- Land application of poultry litter
- Urban development
- Direct Inputs

The 220,000 acre drainage area of the Wolf River contains many different landuse types, including urban, forest, cropland, pasture, barren, and wetlands. The modeled landuse information for the watershed is based on two different data sets which are representative of different time periods. Geographic Information Retrieval and Analysis System (GIRAS) land use data from the 1970s, which is available on the EPA BASINS web site, was used for this project. The BASINS default land use data, originally obtained from USGS, uses the Anderson Level I and Level II classifications. This data was applied to simulations for the period 1965 through 1985. Updated land use data from 1992-1993 were obtained from the Mississippi Automated Resources Information System (MARIS) data set and merged with the BASINS data by using the EPA Watershed Characterization System (WCS) utility program. This landuse information is based on data collected by the State of Mississippi's Automated Information System. This dataset is based on Landsat Thematic Mapper digital images taken between 1992 and 1993. The MARIS data are classified on a modified Anderson level I and II system. The MARIS landuse dataset was used for the hydrologic calibration period of 1987 through 1999. For modeling purposes the landuse categories were grouped into the landuse categories of urban, forest, cropland, pasture, barren, and wetlands. The contributions of

each of these land types to the fecal coliform loading of the Wolf River was considered on a subwatershed basis. Figure 3.2 and Table 3.2 show the landuse distribution for the watershed.

The nonpoint fecal coliform contribution from each landuse was estimated using the latest information available. The MARIS landuse data for Mississippi was utilized by the WCS to extract landuse sizes, populations, and agriculture census data. Several agencies were contacted and the watershed was visited to refine the assumptions made in determining the fecal coliform loading. The GAP Study provided information on wildlife density in the Wolf River Watershed. The Mississippi State Department of Health was contacted regarding the failure rate of septic tank systems in this portion of the state. Mississippi State University researchers provided information on manure application practices and loading rates for hog farms and cattle operations. The Natural Resources Conservation Service also provided information on manure treatment practices and land application of manure.

Figure 3.2 Landuse Distribution

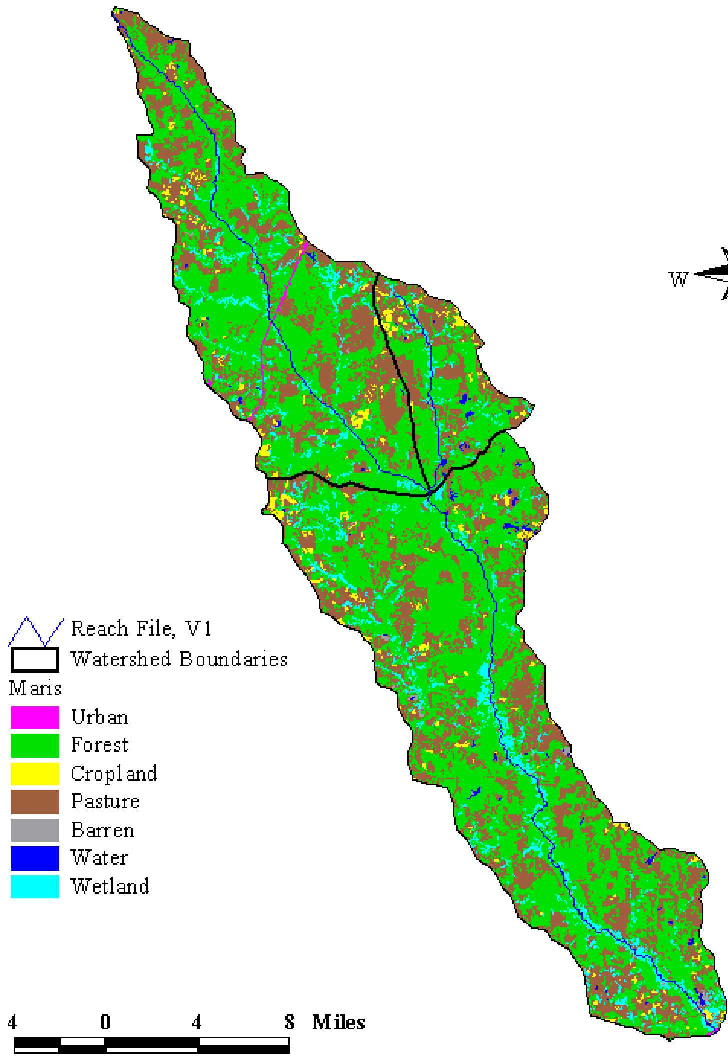


Table 3.2 Landuse Distribution for the Entire Wolf River Watershed Represented in Phase One in Number of Acres

Subwatershed	Urban	Forest	Cropland	Pasture	Barren	Wetland	Total
03170009018	61	109,916	2,591	9,645	496	12	**122,721**
03170009019	0	16,236	888	2,301	24	0	**19,449**
03170009020	544	65,438	1,685	9,913	110	0	**77,690**
Total	**605**	**191,590**	**5,164**	**21,859**	**630**	**12**	**219,860**

3.2.1 Wildlife

Wildlife present in the Wolf River Watershed contributes to fecal coliform bacteria on the land surface and as a direct input to the stream. In the Wolf River model, all wildlife was represented by considering contributions from deer. Estimates of deer population were designed to account for the deer combined with all of the other wildlife, such as ducks and geese, contributing to the area. An upper limit of 30 deer per square mile was used as the estimate. The wildlife population was modeled as a constant variable throughout the year.

3.2.2 Land Application of Hog and Cattle Manure

In the Wolf River Watershed processed manure from confined hog and dairy cattle operations is assumed to be collected in lagoons and routinely applied to pastureland during April through October. This manure is a potential contributor of bacteria to receiving waterbodies due to runoff produced during a rain event. Hog farms in the Wolf River Watershed operate by either keeping the animals confined or by allowing hogs to graze in a small pasture or pen. For this model, it was assumed that all of the hog manure produced by either farming method was applied evenly to the available pastureland. Application rates of hog manure to pastureland from confined operations varied monthly according to management practices currently used in this area.

The dairy farms that are currently operating in the Wolf River Watershed only confine the animals for a limited time during the day. The model assumed a confinement time of four hours per day, during which time the cattle are milked and fed. The manure collected during confinement is applied to the available pastureland in the watershed. Like the hog farms, application rates of dairy cow manure to pastureland vary monthly according to management practices currently used in this area.

3.2.3 Grazing Beef and Dairy Cattle

Grazing cattle deposit manure on pastureland where it is available for wash-off and delivery to receiving waterbodies. The dairy farms that are currently operating in the Wolf River Watershed only confine the animals for a limited time during the day. The model assumed a confinement time of four hours per day. During all other times, dairy cattle are assumed to graze on pasturelands. Beef cattle have access to pastureland for grazing all of the time. The manure produced by grazing cattle was modeled as a fecal coliform load to available pastureland in the watershed.

3.2.4 Land Application of Poultry Litter

Like hog and cattle manure, poultry litter is modeled by applying only to pastureland and not to cropland. Poultry litter is a potential contributor of pathogens to streams in the watershed when a rain event washes a portion of it to a receiving waterbody. It is assumed that all of the poultry litter from chicken houses is applied evenly to the available pastureland. While there are some alternative uses of poultry litter, such as utilization as cattle feed, almost all of the litter in the state is currently used for fertilizer.

Predominantly two kinds of chickens are raised on farms in the Wolf River Watershed, broilers and layers. The growth time of the broiler chickens from when the chicken is born to when it is sold off the farm is approximately 48 days, which is about 1/7 of a year. Conversely, layer chickens remain on farms for ten months or longer. To estimate the number of chickens in the watershed on any given day, the census number of broiler chickens sold is divided by seven and added to the number of layers.

3.2.5 Urban Development

Urban areas include land classified as urban and barren. Only a small percentage of the Wolf River Watershed is classified as urban. It is primarily concentrated around the Bay and will be addressed in the Phase Two TMDL report for the tidally influenced area. However, the contribution of the urban areas in the other parts of the watershed to fecal coliform loading in the Wolf River was considered.

3.2.6 Direct Inputs

Failing septic systems, illicit dischargers, and animals with access to the stream are nonpoint sources that have the potential to directly deposit in the stream with no time or mechanism for die off of the organisms. Therefore, these sources account for a large percentage of the actual load in the stream.

Septic systems have a potential to deliver fecal coliform bacteria loads to surface waters due to malfunctions, failures, and direct pipe discharges. Properly operating septic systems treat wastewater and dispose of the water through a series of underground field lines. The water is applied through these lines into a rock substrate, thence into underground absorption. The systems can fail when the field lines are broken, or when the underground substrate is clogged or flooded. A failing septic system's discharge can reach the surface, where it becomes available for wash off into the stream. Also, a potential problem is an illicit direct pipe bypassing the septic system or the field lines and discharging directly to a stream in an effort to keep the waste off the land.

Another consideration is the use of individual onsite wastewater treatment plants. These treatment systems are in wide use in Mississippi. They can adequately treat wastewater when properly maintained. However, these systems may not receive the maintenance needed for proper, long-term operation. These systems require disinfection to properly operate. When this expense is ignored, the water is discharged with higher pathogenic concentrations than intended.

Cattle and other animals often have direct access to flowing and intermittent streams that run through pastureland. These small pasture streams are tributaries of larger streams. Fecal coliform bacteria deposited in the streams are modeled as a direct input of bacteria to the Wolf River. In order to estimate the amount of bacteria introduced into streams from animals, it was assumed that four percent of the manure load produced by cattle represents the available load. This four percent represents manure loading by all animals in the watershed.

4.0 MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between the instream water quality target and the source loading is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load allocations. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses to flow and loading conditions. In this section, the selection of the modeling tools, setup, and model application are discussed.

4.1 Modeling Framework Selection

As described earlier, the impaired segment of the Wolf River and the Wolf River Watershed are included within the St. Louis Bay Fecal Coliform TMDL Modeling Project. However, this Phase One Wolf River TMDL is addressing only the freshwater portion of the system. The St. Louis Bay Fecal Coliform TMDL Modeling Project utilizes two computer simulation models. The NPSM model, described below, was used to model the watershed hydrology and load washoff of the entire St. Louis Bay Watershed. It was also used to model the hydraulic response and water quality of the freshwater rivers and streams in the watershed including the Wolf. The watershed model was linked with the Environmental Fluid Dynamics Code (EFDC) model to simulate hydrodynamics, salinity, temperature, and water quality in the Bay and tidally influenced portions of the freshwater systems. The Bay model will be described in more detail in the MSU report and Phase Two of the St. Louis Bay Fecal Coliform TMDL Modeling Project.

Several stormwater models were considered for use in the freshwater portion of this project (MSU, 2000). The Non-Point Source Model (NPSM) within the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) platform was chosen due to its superior water quality routines as applied to large, complex basins. The BASINS model platform and the NPSM model were used to predict the significance of fecal coliform sources to fecal coliform levels in the Wolf River Watershed. BASINS is a multipurpose environmental analysis system for use in performing watershed 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 discharges, and stream descriptions. The NPSM model simulates nonpoint source runoff from selected watersheds, as well as the transport and flow of the pollutants through stream reaches. 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.

4.2 Model Setup

The freshwater portion of the Wolf River, located in HUC 03170009, was modeled within the watershed modeling system. The results for the freshwater portion of the Wolf River impaired segment are presented separately in this Phase One TMDL. The freshwater portion of the Wolf River Watershed was divided into three 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.

At least the first 12 months of the model results were considered a stabilization period and disregarded.

4.3 Hydrologic Calibration

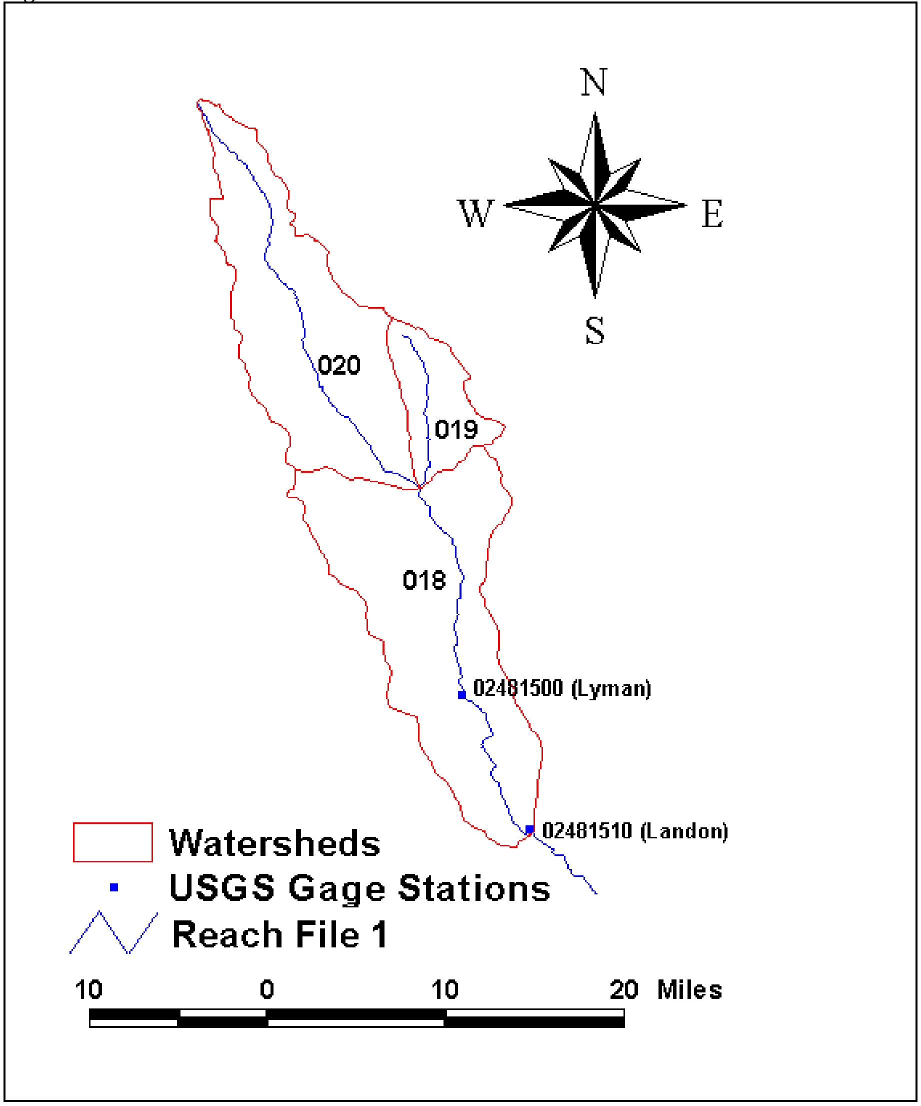
Hydrologic calibration has been achieved by comparing predicted flow to historical flow data at two USGS Stations, 02481510 and 02481500, which are shown in Figure 4.3. The most significant factors to develop a well calibrated computational NPSM model include: (1) accurate sub-watershed delineation, (2) stream data assessment, (3) representative precipitation data, (4) land use data, and (5) proper selection of modeling parameters. Some of the factors found to be most influential in this calibration were storage, infiltration and interception of the lower and upper soil zones, and the friction and hydrograph parameters for stream reaches.

Hydrological calibration was conducted at Lyman and Landon to best utilize the available data, which is shown in Table 4.3a. The methods used for hydrological calibration at both stations are similar. The Landon calibration will be described in this TMDL.

4.3.1 Subwatershed Delineation

The watershed delineation for the Wolf River calibration at Landon is depicted in Figure 4.3. The Landon gauging station reflects a drainage area of 308 square miles. This drainage area was subdivided into three subwatersheds for development of the NPSM calibration simulation. Delineation was based upon Reach File 1 resolution river data and watershed topography. Reach characteristics, drainage areas, and applied weather station data source for each river segment is summarized in Tables 4.3a and 4.3b.

Figure 4.3 Wolf River Calibration Subwatersheds



4.3.2 Stream Data Assessment

The location of gaging stations, available data, time period of availability and sampling frequency are summarized in Table 4.3a. Daily discharge measurements are available for the Wolf River from a USGS gage station that has been maintained near Landon from August 1, 1971 to September 2000. These data were obtained from the USGS web site and converted into a format required for input into the NPSM model. The river characteristics for the Wolf River subwatersheds used in calibration are shown in Table 4.3b. A similar modeling process was completed for the gage at Lyman.

Table 4.3a Hydrologic and Water Quality Data for the Wolf River Watershed

Location	USGS Station	Available Data	Duration	Frequency
Wolf River at Landon	02481510	Stage, Discharge	8/1/1971-Present	Daily
Wolf River at Landon	02481510	Fecal Coliform	1978-1986	~ Monthly
Wolf River at Lyman	02481500	Stage, Discharge	10/1/1964-9/30/1971	Daily

Table 4.3b River Characteristics for Hydrologic Calibration on Wolf River at Landon

Subwatershed	Stream Name	River Length (mile)	Delta h (ft)	River Elevation (ft)
03170009018	Wolf River	25.00	84.00	84.00
03170009019	Murder Creek	10.00	157.87	209.94
03170009020	Wolf River	28.70	222.76	242.38

4.3.3 Precipitation Data

Precipitation and other meteorological data are available from several climatological stations in the area. Although the data would be considered extensive for many purposes, it is very limited within the context of developing a computational watershed model. The most relevant data were obtained from the Wiggins Ranger Station, Poplarville Experimental Station, Saucier Experiment Forest, Picayune, Bay St Louis NASA, White Sand, Standard, and Slidell weather stations.

A reasonable computational model requires that hourly boundary data (primarily precipitation) be supplied to the model. However, Saucier Experiment Forest, White Sand, Wiggins, and Slidell are the only regional weather stations for which hourly data were recorded. Daily data were obtained from the remaining stations. The daily data were disaggregated into hourly data by using the METCMP and WDMutil programs obtained from the USGS and EPA, respectively. Disaggregation was based upon the hourly precipitation patterns data at Saucier Experiment Forest, Wiggins Ranger Station, or White Sand as appropriate. Table 4.3c summarizes the location, frequency, duration, and disaggregation station for the available meteorological data.

As with other hydrologic models, NPSM applies spatially uniform precipitation at the subwatershed level. Unfortunately, none of the weather stations are located within the Landon subwatershed. Consequently, precipitation data of primary importance must be extrapolated from nearest available weather stations. The applied weather stations for hydrologic calibration on the Wolf River watershed are listed in Table 4.3d along with the landuse information.

Table 4.3c St. Louis Bay Watershed Meteorological Data

Station Name	COOPID	Location (Lat, Long)	Frequency	Available Data	Station for Dissaggregation
Saucier Experiment Forest	MS227840	30° 38' N 89° 03' W	Hourly	5/1/1954-Present	-
Wiggins/ Wiggins Ranger Station	MS229639 MS229648	30° 51' N 89° 09' W	Hourly Hourly	1/1/1948-1982 10/1/1973-Pres	-
White Sand	MS229617	30° 48' N 89° 41' W	Hourly	1/1/1940-Present	-
Poplarville Exp Station	MS227128	30° 51' N 89° 33' W	Daily	1/1/1948-Present	White Sand
Standard	MS228352	30° 32' N 89° 22' W	Daily	1/1/1948-1988	Saucier Exp Forest
Picayune	MS226921	30° 31' N 89° 42' W	Daily	7/1/1962-Present	White Sand
Bay St Louis/ Bay St Louis NASA	MS220519 MS220521	30° 18' N 89° 20' W 30° 22' N 89° 35' W	Daily Daily	4/1/1931-1979 8/1/1969-Pres	White Sand
Gulfport Naval Center	MS223671	30° 23' N 89° 08' W	Daily	6/1/1956-Present	Saucier Exp Forest
Slidell WSFO	LA168539	30° 20' N 89° 49' W	Hourly	4/1/1974-Present	-

4.3.4 Land Use Data for Hydrologic Calibration

GIRAS land use data from 1970s is made available by EPA through BASINS and was obtained from the BASINS web site for this project. The BASINS default land use data were originally obtained from USGS Geographic Information Retrieval and Analysis System (GIRAS) and use the Anderson Level I and Level II classifications. This data was applied to simulations for the period 1965 through 1985.

Updated land use data from 1992-1993 were obtained from the MARIS data set and merged with the BASINS data by using the USEPA Watershed Characterization System (WCS) utility program. This landuse information is based on data collected by the State of Mississippi's Automated Resource Information System. This dataset is based on Landsat Thematic Mapper digital images taken between 1992 and 1993. The MARIS data are classified on a modified Anderson level I and II system. The MARIS landuse dataset was used for hydrologic calibration period 1987 through 1999.

Table 4.3d Landuse Distribution in Acres for the Portion of the Wolf River Watershed used for Hydrologic Calibration at Landon

Landuse Type	Sub-Watershed	Stream Name	Urban, Built-up	Agriculture	Forest	Wetland	Barren	Total Area	Applied Weather Station
GIRAS	03170009018	Wolf River	32	16,441	80,288	0	213	96,974	Standard
	03170009019	Murder Creek	0	4,590	14,896	76	77	19,639	Wiggins
	03170009020	Wolf River	721	13,277	63,316	0	371	77,685	Poplarville
	All							194,298	
MARIS	03170009018	Wolf River	0	9,403	86,962	0	347	96,712	Saucier
	03170009019	Murder Creek	0	3,189	16,236	0	24	19,449	Wiggins
	03170009020	Wolf River	544	11,598	65,437	0	111	77,690	Poplarville
	All							193,851	

4.3.5 Hydrologic Calibration Parameters

Initial hydrologic calibration on Wolf River at Landon was accomplished utilizing historical data for period 1971 to 1985. Final hydrologic calibration on Wolf River at Landon was accomplished utilizing historical data for period 1987 to 1999. Hydrologic parameters found in the initial hydrologic calibration at Lyman were used in the hydrologic calibration at Landon.

4.3.6 Hydrologic Calibration Results

Using the boundary data and watershed delineation described, the Landon watershed was modeled from 1971 to present. As expected simulation results were most sensitive to the applied precipitation data. Simulations were made for four scenarios of precipitation strategies. Each scenario represents a reasonable application of available measured precipitation to the defined Landon sub-watersheds. The applied stations shown on Table 4.3d represent the best scenario. Comparisons with stream gage data have been made graphically and by calculation of integral stream volumetric flux on both seasonal and individual storm variations. The integral stream quantities were calculated following the procedure outlined by EPA for TMDL studies.

Results are illustrated in Graphs A-1 through A-4 in Appendix A and Table 4.3e for selected times and events within the modeled period. The results presented indicate that the applied precipitation provides the best correlation with stream data measured at Landon. This is illustrated by comparing simulations for different NPSM parameter values with the measured data.

Measured versus calculated stream volume, using the optimal NPSM parameters and the preferred precipitation scenario is depicted in Appendix A for various time periods between 1972 and 1999. The overall trend of the comparisons is quite good with many of the major storm events captured.

Table 4.3e Percent Error and Comparison of Observed and Computed Flow and Volume

	Simulated			Observed		
	1972	**1979**	**1983**	**1972**	**1979**	**1983**
Total In-stream Flow	31.35	43.27	49.56	27.15	39.39	41.35
Total of highest 10% flow	14.11	18.26	21.49	13.63	17.99	20.18
Total of lowest 50% flow	3.29	5.76	6.75	2.38	5.30	4.63
Summer flow volume (months 7-9)	1.77	10.59	5.45	1.34	10.13	3.85
Fall flow volume (months 10-12)	7.79	7.67	9.25	5.43	5.40	7.50
Winter flow volume (months 1-3)	13.40	16.08	20.42	13.59	15.22	15.49
Spring flow volume (months 4-6)	8.38	8.92	14.45	6.79	8.64	14.51
Total storm volume	29.43	40.87	43.78	25.19	36.61	37.55
Summer storm volume (7-9)	1.29	9.99	3.99	0.84	9.43	2.90
Errors (Simulated - Observed)	**1972**	**1979**	**1983**			
Error in total volume	13.38	8.97	16.57			
Error in 50% lowest volume	27.80	8.58	31.35			
Error in 10% highest flows	3.35	1.50	6.12			
Seasonal volume error -Summer	24.55	4.40	29.28			
Seasonal volume error - Fall	30.30	29.56	18.89			
Seasonal volume error - Winter	-1.42	5.33	24.15			
Seasonal volume error - Spring	18.94	3.24	-0.42			
Error in storm volumes	14.43	10.41	14.22			
Error in summer storm volumes	34.75	5.61	27.45			

As expected, there are isolated storm events for which data correlation is less than desired. For such events, it is instructive to examine the temporal and spatial storm variation in the watershed to determine whether discrepancies are most likely attributable to model deficiencies or data deficiencies.

4.4 Selection of Representative Modeling Period

The model was run from 1965-1985 and from 1987-1999 for calibration at Landon. However, representative wet and dry years were also used. Because these large time spans are used, a margin of safety is implicitly applied. Seasonality and critical conditions are accounted for during the extended time frame of the simulation.

The critical condition for fecal coliform impairment from nonpoint source contributors occurs after a heavy rainfall that is preceded by several days of dry weather. The dry weather allows a build up of fecal coliform bacteria, which is then washed off the ground by a heavy rainfall. By using the 11-year time period, many such occurrences are captured in the model results. Critical conditions for point sources, which occur during low-flow and low-dilution conditions, are simulated as well.

4.5 Source Representation

Both point and nonpoint sources can be represented in the model. Since there are no permitted point sources in the freshwater portion of the Wolf River Watershed, only nonpoint sources are identified in this Phase One TMDL. However, the contribution from failing septic tanks is divided equally between the waste load allocation and the load allocation to represent the potential for that portion of the failing septic tank load to become a permitted point source in the future. A fecal coliform spreadsheet was utilized for quantifying the nonpoint sources of bacteria in each of the subwatersheds. This spreadsheet calculates the model inputs for fecal coliform loading due to nonpoint sources using local and literature values, along with some assumptions, about land management, septic systems, farming practices, and permitted point source contributions. Each of the potential bacteria sources is covered in the fecal coliform spreadsheet.

Nonpoint sources of fecal coliform bacteria can be grouped into two components: urban and non-urban areas. The Phase One TMDLs on the Wolf River and the Jourdan River primarily address non-urban nonpoint sources, while the Phase Two TMDLs primarily address urban nonpoint sources.
Fecal coliform loadings from non-urban nonpoint sources in the watershed were calculated based upon wildlife populations, livestock populations, information on livestock and manure management practices, and failing septic tanks and illicit dischargers for the Wolf River Watershed. The phasing of the TMDLs is not only a benefit in differentiating between the areas contributing to freshwater and saltwater, but the phasing also provides a benefit in being able to concentrate on the different types of nonpoint sources.

The nonpoint sources are represented in the model with two different methods. The first of these methods is a direct fecal coliform loading to the waterbodies in the Wolf River Watershed. Other nonpoint sources are represented as an application rate to the land in the Wolf River Watershed, which enter the waterbody as a distributed source. For these sources, fecal coliform accumulation rates in counts per acre per day were calculated for each subwatershed on a monthly basis and input to the model for each landuse. Fecal coliform contributions from forests and wetlands were considered to be equal. Urban and barren areas were also considered to produce equal loads. The fecal coliform accumulation rate for pastureland is the sum of accumulation rates due to litter application, wildlife, processed manure, and grazing animals. For cropland, the accumulation rate is only due to wildlife. Accumulation rates for pastureland are calculated on a monthly basis to account for seasonal variations in manure and litter application.

4.5.1 Wildlife

Based on information provided by the Department of Wildlife and Fisheries at Mississippi State University the deer population throughout the Wolf River Watershed was estimated to be 20 to 30 animals per square mile. For the model, the upper limit of 30 deer per square mile was used to account for the deer and all other wildlife contributing to fecal coliform accumulation in the area. The wildlife contribution in counts per acre per day is calculated by multiplying a loading rate by the number of animals. The loading rate used in the model was estimated to be 5.00E+08 counts per day per animal. The per acre loading rate applied to the landuses is 2.34E+07 counts per acre per day.

4.5.2 Land Application of Hog and Cattle Manure

The fecal coliform spreadsheet was used to estimate the fecal coliform loadings contributed by hog and cattle from each subwatershed. Fecal coliform production rates of 1.08E+08 count per day per hog and 5.40E+09 counts per day per cow were used to quantify the fecal coliform loadings (ASAE, 1998 and Metcalf and Eddy, 1991). Manure application rates to pastureland vary on a monthly basis. Data from Pascagoula River Basin study were used to estimate the manure application rates.

4.5.3 Grazing Beef and Dairy Cattle

Manure produced by grazing beef and dairy cattle is assumed to be evenly spread on pastureland throughout the year. The number of grazing cattle is computed by subtracting the number of confined cattle from the total number of cattle on each sub-watershed. The cattle population was determined from the 1997 Census of Agriculture Data. The fecal coliform content of manure produced by grazing cattle is estimated by multiplying the number of grazing cattle by a fecal coliform production rate of 5.40E+09 counts per day per animal (Metcalf and Eddy, 1991). No manure was applied to cropland area in the model.

4.5.4 Land Application of Poultry Litter

The fecal coliform spreadsheet was used to estimate the concentration of bacteria, which accumulates in the dry litter where poultry waste is collected. The fecal coliform production rate of 6.75E+07 MPN/day/chicken (ASAE, 1998) was used to calculate the concentration of fecal coliform. The chicken population was determined from the 1997 Census of Agriculture Data for the number of chickens sold for each county per year. The chicken population was assumed to be normalized by watershed area. Variable monthly loading rates of litter were applied to pastureland. No litter was applied to cropland area in the model.

4.5.5 Urban Development

The urban and barren areas in the Wolf River Watershed were combined and classified as high density, low density, or transportation. Fecal coliform buildup rates for each classification were determined from the following literature rates of 1.54E+07 counts per acre per day for high density areas, 1.03E+07 counts per acre per day for low density areas, and 2.00E+05 counts per acre per day for transportation areas (Horner, 1992).

4.5.6 Direct Inputs

The number of failing septic systems used in the model was derived from the watershed area normalized county populations. The percentage of the population on septic systems was determined from 1990 United States Census Data. A failure rate of 50 percent was estimated based on the coastal environmental conditions of a high ground water table and saturated geologic material. This information was used to calculate the estimated number of failing septic tanks per watershed. The number of failing septic tanks also incorporates an estimate for the failing individual onsite wastewater treatment systems and illicit dischargers in the area. Discharges from failing septic systems were quantified based on several factors including the estimated population served by the septic systems, an average daily discharge of 70 gallons per person per day, and a septic system effluent fecal coliform concentration of 10^4 counts per 100 ml. The septic system contribution in the model is based on the assumption that all fecal coliform bacteria discharged from failing septic systems directly reaches the stream. Additionally, these failing septic system discharges were assumed to be constant throughout the whole simulation.

The direct contribution of fecal coliform from animals to a stream is also represented as a direct source to the stream in the model. The fecal coliform loading is estimated by using a representative number of cattle and a bacteria production rate of 5.40E+09 counts per animal per day (Metcalf and Eddy, 1991).

4.6 Water Quality Calibration Process

Water quality calibration was begun after completion of the hydrology calibration described in Section 4.3. Whereas, flow modeling deals with a single constituent, water quantity, and a single primary source, precipitation, water quality must consider numerous constituents, various forms or species, and multiple sources. Fecal coliform contributions from all sources are estimated or measured, hydrologic transport processes are superimposed, and then water quality modeling is performed to allow adjustments in parameters and sources as part of the calibration process.

Water quality calibration is an iterative process; the model predictions are the integrated results of all the assumptions used in developing the model input and in representing the modeled process. Difference in model predictions and the observations require the model user to re-evaluate these assumptions, in terms of both the estimated model input and model parameters, and consider the accuracy and uncertainty in the observations.

To develop a representative linkage between the sources and the instream water quality response in all the reaches in the St. Louis Bay Watershed, model parameters were adjusted until reasonable nonpoint and point source loading rates were found. Parameters related to fecal coliform surface loading as well as background concentrations in the reaches were adjusted by comparing the modeled in-stream concentrations to available observed data. This process was limited by the absence of continuous data for high flow and storm flow conditions.

4.6.1 Comparison of Expected and Simulated Nonpoint Loading Rates

How nonpoint source loading rate changes as a function of land use, climate, soil characteristics, topography, management practices, and other human activities has been a major topic of environmental concern and investigation for more than twenty years. However, in spite of this concern, exact quantitative predictions of expected loading rates for site specific conditions are difficult to derive from available field monitoring due to the wide variations observed even within a specific land use under similar soils, topographic, and climatic (Donigian et al, 1994).

The goal of this section is to define the expected range of loading rates from available literature, as a basis for evaluating and calibrating the model predicted loading rates, and determine if any changes or adjustments to the original nonpoint parameters could be justified. Unfortunately, there is no available loading rate data for the St. Louis Bay Watershed. The values of loading rates recommended for nonpoint source modeling in Georgia and other studies are shown in Table 4.6a. The table provides a brief summary of results from previous studies with ranges of loading rates for fecal coliform for the major land use categories in the NPSM watershed model.

Table 4.6a Literature Values of Landuse Loading Rates

Symbol	Definition	Units	Landuse Type	Tallahala Creek, MS	Red Creek, MS	South Fork South Branch Potomac River, West Virginia
ACQOP	Rate of accumulation of FC	Cfu/ac.day	Urban	1.01E+08 – 8.09E+10	1.94E+08 – 1.06E+10	5.01E+08
			Agriculture	1.76E+09 – 1.13E+11	2.11E+09 – 5.99E+10	1.89E+09 – 9.46E+09
			Pastureland	2.61E+12 – 2.86E+13	1.69E+12 – 1.68E+13	1.89E+09 – 9.46E+09
			Forest	2.12E+11 – 2.10E+12	1.99E+12 – 1.86E+13	3.26E+07 – 6.87E+07
			Barren	1.01E+08 – 8.09E+10	1.94E+08 – 1.06E+10	5.01E+08
SQOLIM	Maximum Storage	Cfu/ac	Urban	-	-	4.51E+09
			Agriculture	-	-	1.70E+10 – 8.51E+10
			Pastureland	-	-	1.70E+10 – 8.51E+10
			Forest	-	-	2.93E+08 – 6.18E+08
			Barren	-	-	4.51E+09

The total accumulation for each landuse type was determined by combining the contributions from each subwatershed. The loading rates are constant throughout the year for forest, cropland, and urban land. However, the loading rates for pastureland vary monthly. Generally, the simulated loading rates for the St. Louis Bay Watershed are within the range of available literature values shown.

4.6.2 Instream Water Quality Concentrations

Once nonpoint and point source loading rates were deemed to be reasonable, the instream water quality calibration focused on adjustments to selected instream parameters to improve agreement with observed concentrations. The primary parameter of concern was the decay rate for fecal coliform.

Ideally, fecal coliform decay rate should be determined in-situ. This, however, would require an extensive monitoring effort under controlled environmental and loading conditions. For purposes of this modeling project, an extensive search of the literature was conducted to determine the magnitude and the range of fecal coliform decay rates in fresh water and marine environments. Mancini (1978) recommended a fresh water mortality rate of 0.80/day at 20° C. Mitchell and Chamberlin (1978) provided a listing of in-situ measured decay rates, provided in Table 4.6b.

For modeling of the St. Louis Bay, decay rates of 0.3/day - 0.8/day were investigated. Based on the available field data for calibration, a decay rate of 0.5/day at 20°C, in combination with a temperature correction factor of 1.07, were selected for fresh water. Graph A-3 shows the water quality simulation results for one major station in the St. Louis Bay Watershed. In this figure, daily simulated and observed values of fecal coliform were compared. The simulation results for fecal coliform are generally quite good and within the range of observed values.

Table 4.6b Freshwater Decay Rates of Coliform Bacteria

System	Temperature Indication	T_{90} [h]	k [d^{-1}]
Cumberland River	Summer	10	5.52
Glatt River	-	2.1	26.4
Groundwater stream	10°C	110	0.504
Leaf River (Mississippi)	-	135	0.408
Lower Illinois River	June - September October and May December - March April - November	27 63 90 80	2.04 0.888 0.624 0.696
Missouri River	Winter	115	0.48
Ohio River	Summer (20°C) Winter (5°C)	47 51	1.176 1.08
Sacramento River	Summer	32	1.728
"Shallow turbulent stream"	-	3.6	15.12
Tennessee River (Chattanooga)	Summer	42	1.32
Tennessee River (Knoxville)	Summer	53	1.032
Upper Illinois River	June - September October and May December - March April and November	27 22 95 53	2.04 2.52 0.596 1.032
Maturation ponds	- 19°C	28 33	1.992 1.68
Oxidation ponds	20°C	21.3	2.592
Wastewater lagoon	7.9 - 25.5°C	79-276	0.696 - 0.1992

4.7 Existing Loading

Appendix A includes graphs of the model results showing the instream fecal coliform concentrations for reach 0317009018 of the Wolf River. Graph A-6 shows the fecal coliform levels during the wet year. Graph A-7 shows the fecal coliform levels during the dry year. Graph A-8 shows the fecal coliform levels during the 11-year modeling period. The graphs show a 30-day geometric mean of the data. The straight line at 200 counts per 100 ml indicates the water quality standard for the stream.

Graphs A-9 through A-11 show the 30-day geometric mean of the fecal coliform levels after the TMDL scenario has been modeled. The scale matches the previous graph for comparison purposes. The graph indicates that there are no violations of the water quality standard for the monitored segment after the TMDL scenario is applied.

5.0 ALLOCATION

The allocation for this TMDL includes a waste load allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources, and an implicit margin of safety (MOS) which will result in a total load reduction of approximately 40 percent. That 40 percent reduction can be achieved through the application of various scenarios. Those scenarios will be described in more detail in an implementation plan to be developed at a later date when more information is available. While this TMDL does not specify the specific scenario which may be applied, it does describe the potential sources in detail.

5.1 Wasteload Allocations

There are no NPDES dischargers in the modeled watersheds, therefore no point sources were included in the model. However, a wasteload allocation for each subwatershed should be based on the load from 50 percent of the failing septic tanks. Septic tank failures in reality are both point and nonpoint contributions and have been calculated as equal contributors to the wasteload allocation component and load allocation component of the TMDL calculation. Future facility permits will require end-of-pipe criteria equivalent to the water quality standard of 200 fecal coliform colony counts per 100 ml.

5.2 Load Allocations

The load allocation for this TMDL could involve the two different types of 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, with a flow and fecal coliform concentration in counts per hour. 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 geometric mean water quality standard of 200 fecal coliform colony counts per 100 ml.

5.3 Incorporation of a Margin of Safety (MOS)

The two types of MOS development are to implicitly incorporate the MOS using conservative model assumptions or to explicitly specify a portion of the total TMDL as the MOS. The MOS selected for this model is implicit. Running the model for 11 years with no violations of the water quality standard provides the primary component of the MOS. Ensuring compliance with the standard throughout all of the critical condition periods represented during the 11 years is a conservative practice. Another component of the MOS is the conservative assumption that in the model 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 filtration and die off during transport. The use of a die-off rate lower than that suggested by EPA is another conservative assumption.

5.4 Calculation of the TMDL

The St. Louis Bay Facal Coliform TMDL Modeling Project is based on a complex three dimensional model that represents fecal coliform levels in St. Louis Bay. The complexity of the modeling project would be over-simplified and compromised by an attempt to represent a number of bacteria in Phase One. A more meaningful calculation method is determining the percent reduction needed to achieve the water quality standard of 200 fecal coliform colony counts per 100 ml. The total percent reduction needed for the Wolf River Watershed was determined based on a 30 day critical period according to the model results.

As shown below, the waste load allocation is based only on 50 percent of the failing septic load since there are no NPDES permitted sources in this watershed. The load allocation includes the fecal coliform contributions from surface runoff and direct sources, such as animals in the stream and the other 50 percent of the contribution from failing septic tanks. The margin of safety for this TMDL is implicit and derived from the conservative loading assumptions used in setting up the model. Values will be assigned to the waste load allocation and the load allocation in Phase Two of the St. Louis Bay Modeling Project after all sources are considered. This will allow MDEQ to establish meaningful reduction targets for the overall concentration of fecal coliform in the Wolf River Watershed which are commensurate with MDEQ's fecal coliform standard.

WLA = 50 percent of the Septic Tank Failures

LA = Surface Runoff + Direct Sources (50 percent of the Septic Tank Failures
+ Animals in Stream)

MOS = Implicit

TMDL= Geometric Mean of 200 fecal coliform colony counts per 100 ml

5.5 Seasonality

For many streams in the state, fecal coliform limits vary according to the seasons. This stream is designated for the use of contact recreation. For this use, the pollutant standard is not seasonal.

The model was run for a representative wet and dry year to save on computer run time, then it was also established for an 11-year time span. It took into account all of the seasons within the calendar years from 1987 to 1998. The extended time period allowed the simulation of many different atmospheric conditions such as rainy and dry periods and high and low temperatures. It also allowed seasonal critical conditions to be simulated.

6.0 CONCLUSION

The St. Louis Bay Fecal Coliform TMDL Modeling Project is very comprehensive. This Wolf River TMDL is only a part of the first phase. The TMDLs are being presented in two phases due to the diversity of the systems, processes, and targets involved. Phase One is comprised of TMDLs for the Wolf River and the Jourdan River, which are the primary fresh water sources for St. Louis Bay and have a designated use of contact recreation for which the fecal coliform standard is a geometric mean of 200 counts per 100 ml. Phase Two will follow with TMDLs for the Bay itself and the near shore watersheds, which drain directly to the saltwater of the Bay that has a designated use of shellfish harvesting for which the fecal coliform standard is a median of 14 counts per 100 ml. The phased approach is beneficial not only because different model were used to represent the saltwater and the freshwater systems, but also because the different systems have different targets. The conclusions of this TMDL are applicable to the subwatersheds and processes discussed herein, but more comprehensive conclusions will be provided with the final phase of the project.

6.1 Current Conservation Activities

Several programs and organizations focus conservation activities in the Wolf River Watershed. The Wolf River Conservation Society was described earlier as having a mission to conserve, manage, and protect the Wolf River and its watershed (SCS, 2000). In September 1999 International Paper donated a conservation easement to the Wolf River Conservation Society. The 950 acre easement permanently limits tree cutting and bans development along both sides of the river, creating a 15 mile long by 300 foot wide buffer zone (SCS, 2000). The goal of the Scenic Streams Stewardship Program is to foster voluntary private conservation efforts by riparian land owners (SCS,2000). In coordination with easement donation and the Wolf River Conservation Society NASA has agreed to use the Wolf River as a laboratory for testing applications of high resolution satellite imagery for conservation endeavors and commercial enterprises.

Also, several agencies, including the USDA Natural Resources Conservation Service (NRCS) and the Consolidated Farm Services Agency (CFSA), the Mississippi Department of Environmental Quality (MDEQ), the Mississippi Soil and Water Conservation Commission (MSWCC), the Hancock County Soil and Water Conservation District (SWCD) , the Pearl River County Soil and Water Conservation District (SWCD) and the Harrison County Soil and Water Conservation District (SWCD), are cooperating in an effort to promote the implementation of nonpoint source pollution control best management practices (BMPs).

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

6.2 Future Monitoring

Some monitoring programs are already in place in the Wolf River Watershed including a Wet-Weather Monitoring Program and an annual effort by the Wolf River Conservation Society. MDEQ has adopted the Basin Approach to Water Quality Management, a plan that divides Mississippi's major drainage basins into five groups. During each year long cycle, MDEQ resources for water quality monitoring will be focused on one of the basin groups. During the next monitoring phase in the Coastal Streams Basin, Wolf River will receive additional monitoring to identify any improvements in water quality.

6.3 Public Participation

The public has been very involved and aware of the TMDL work ongoing in the St. Louis Bay Watershed, which includes the Wolf River Watershed. Several public and agency meetings have been held. This TMDL was also published for a 30-day public notice. The public was given an opportunity to review the TMDL and submit comments.

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.

Disaggregate: breaking down into smaller time steps

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 direst sources 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 and $2.7X10^{-4}$ = 2.7E-4=0.00027.

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, ($\mathbf{d_1}$, $\mathbf{d_2}$, $\mathbf{d_3}$) respectively could be shown as:

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

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

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

BMP ....Best Management Practice

CFSA .... Consolidated Farm Services Agency

CWA ....Clean Water Act

DMR..Discharge Monitoring Report

EFDC..Environmental Fluid Dynamics Code

EPA .... Environmental Protection Agency

GAP .... Geographic Approach to Planning

GIRAS ....Geographic Information Retrieval and Analysis System

GIS ....Geographic Information System

HUC ....Hydrologic Unit Code

LA.. Load Allocation

MARIS .... State of Mississippi Automated Information System

MDEQ .... Mississippi Department of Environmental Quality

MOS.. Margin of Safety

MSWCC...Mississippi Soil and Water Conservation Commission

NRCS .... National Resource Conservation Service

NPDES ....National Pollution Discharge Elimination System

NPSM...Nonpoint Source Model

RF3...Reach File 3

SWCD.. Soil and Water Conservation District

TMDL...Total Maximum Daily Load

USGS..United States Geological Survey

WCS..Watershed Characterization System

WLA..Waste Load Allocation

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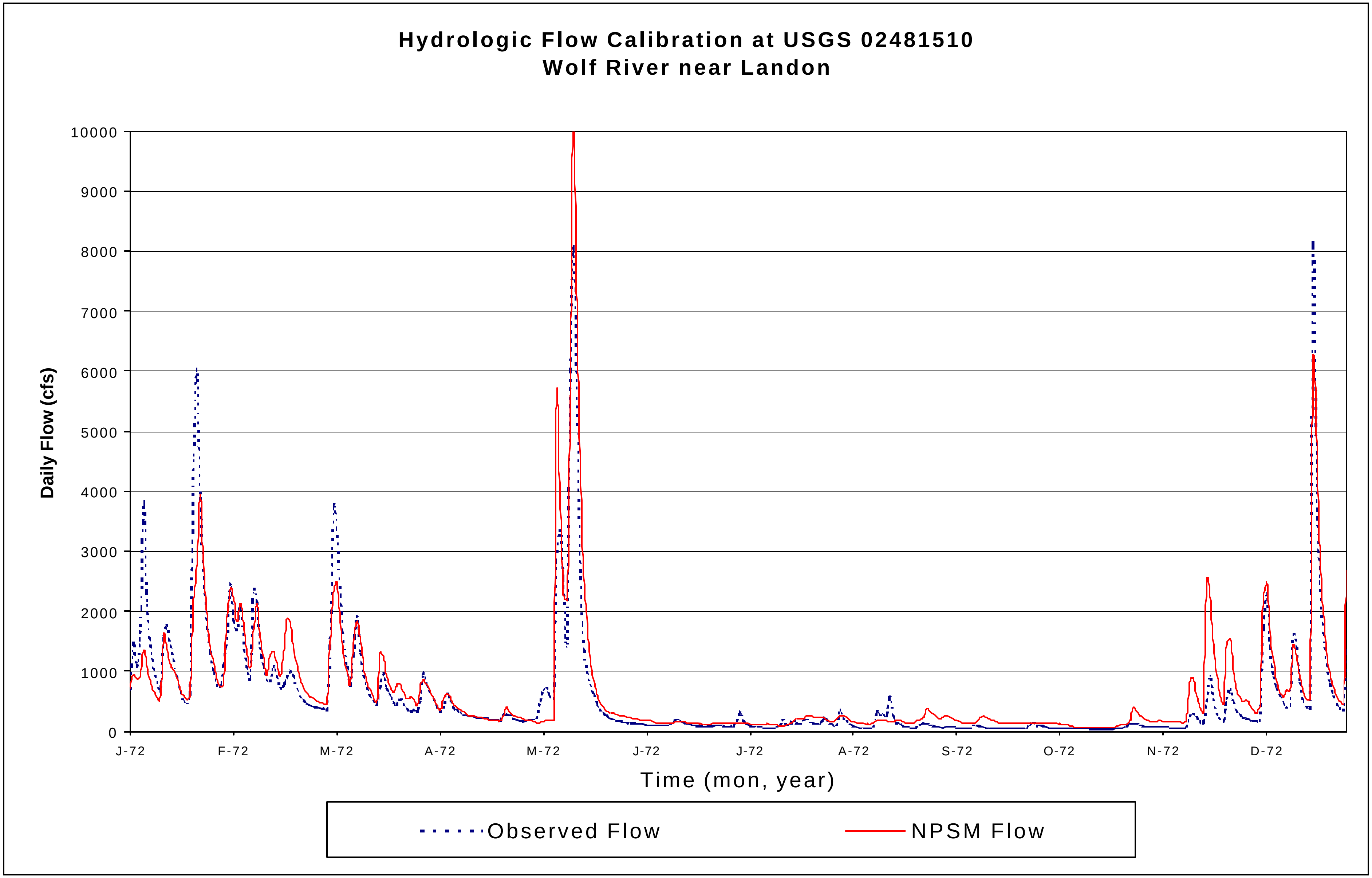
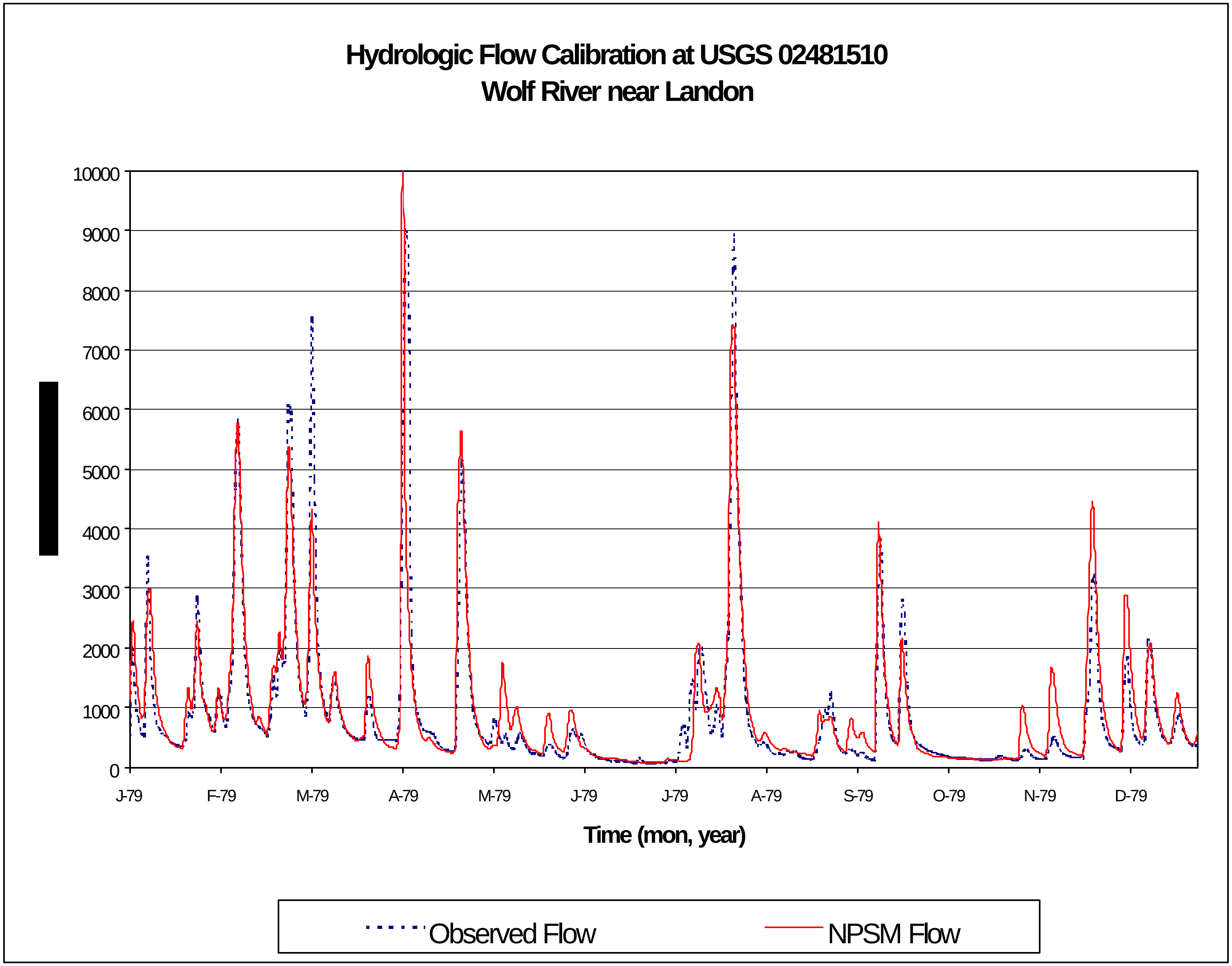
APPENDIX A

This appendix contains printouts of the various model run results. Graphs A-1 through A-4 show the modeled flow, in cubic feet per second, through reach 03170009018 compared to the USGS flow readings from the Wolf River, station 02481510. Graph A-5 shows a water quality calibration graph. The following graphs, A-6 through A-8, show the 30-day geometric mean for fecal coliform concentrations in counts per 100 ml in the listed section of the Wolf River. The graphs contain a reference line at 200 counts per 100 ml. Graphs A-6, A-7, and A-8 show the fecal coliform levels in reach 03170009018 during the wet year, dry year, and 11-year modeling period respectively. Graphs A-9, A-10, and A-11 show the modeled fecal coliform levels in reach 03170009018 during the wet year, dry year, and 11-year modeling period, respectively, after the TMDL scenario has been applied.

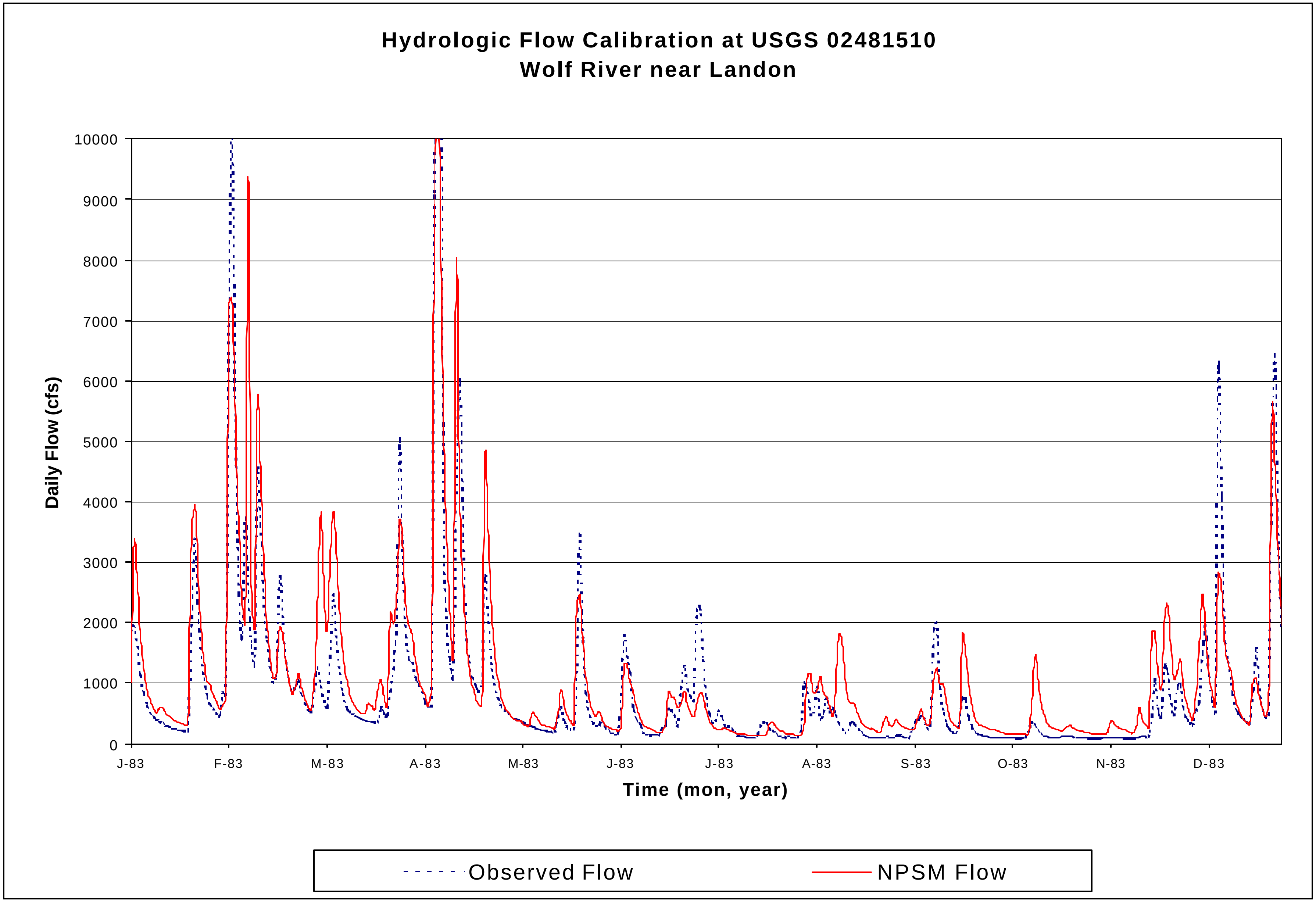
Graph A-1 Hydrologic Flow Calibration at USGS 02481510 Wolf River at Landon–1972 (GIRAS Landuse)



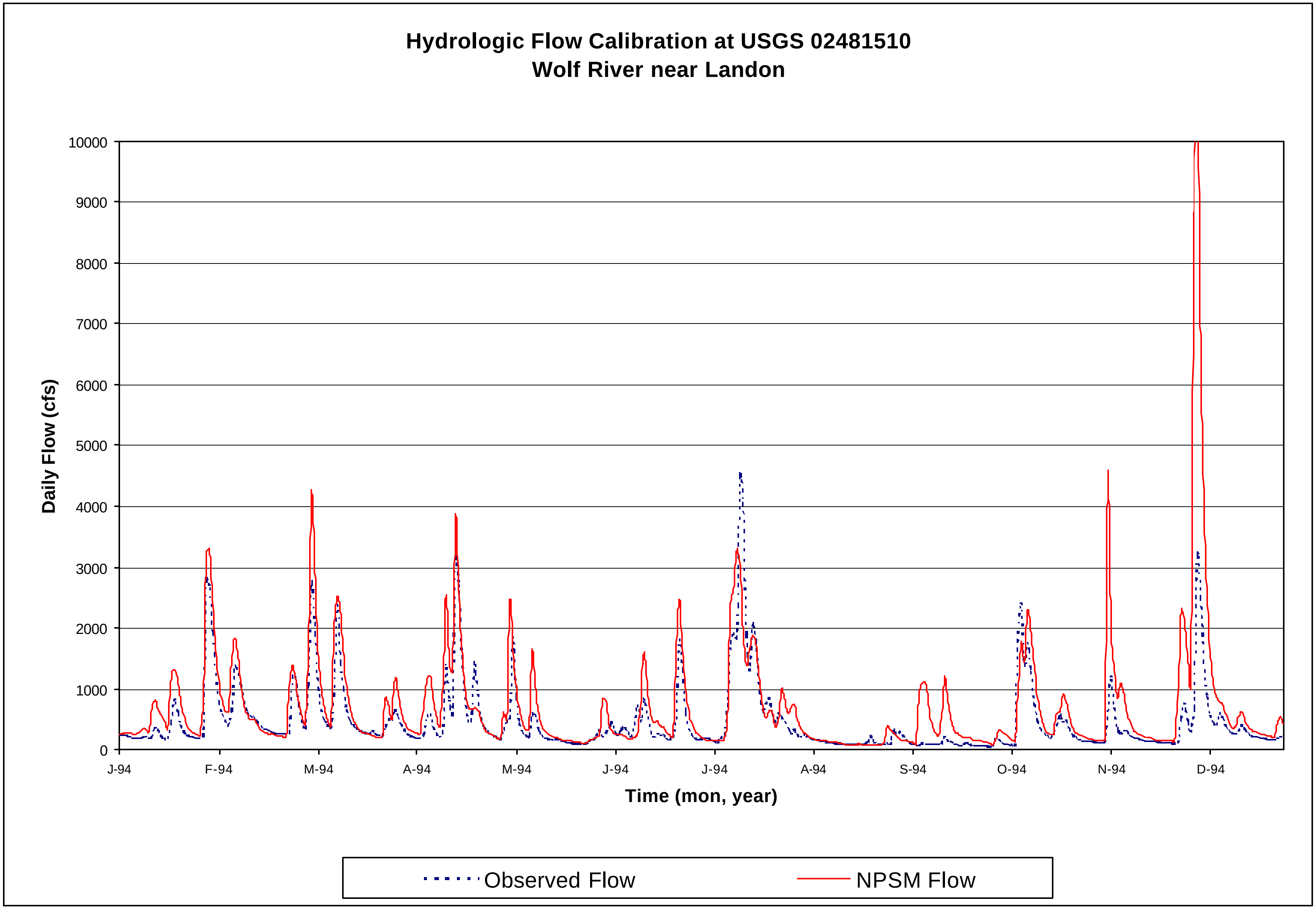
Graph A-2 Hydrologic Flow Calibration at USGS 02481510 Wolf River at Landon–1979 (GIRAS Landuse)



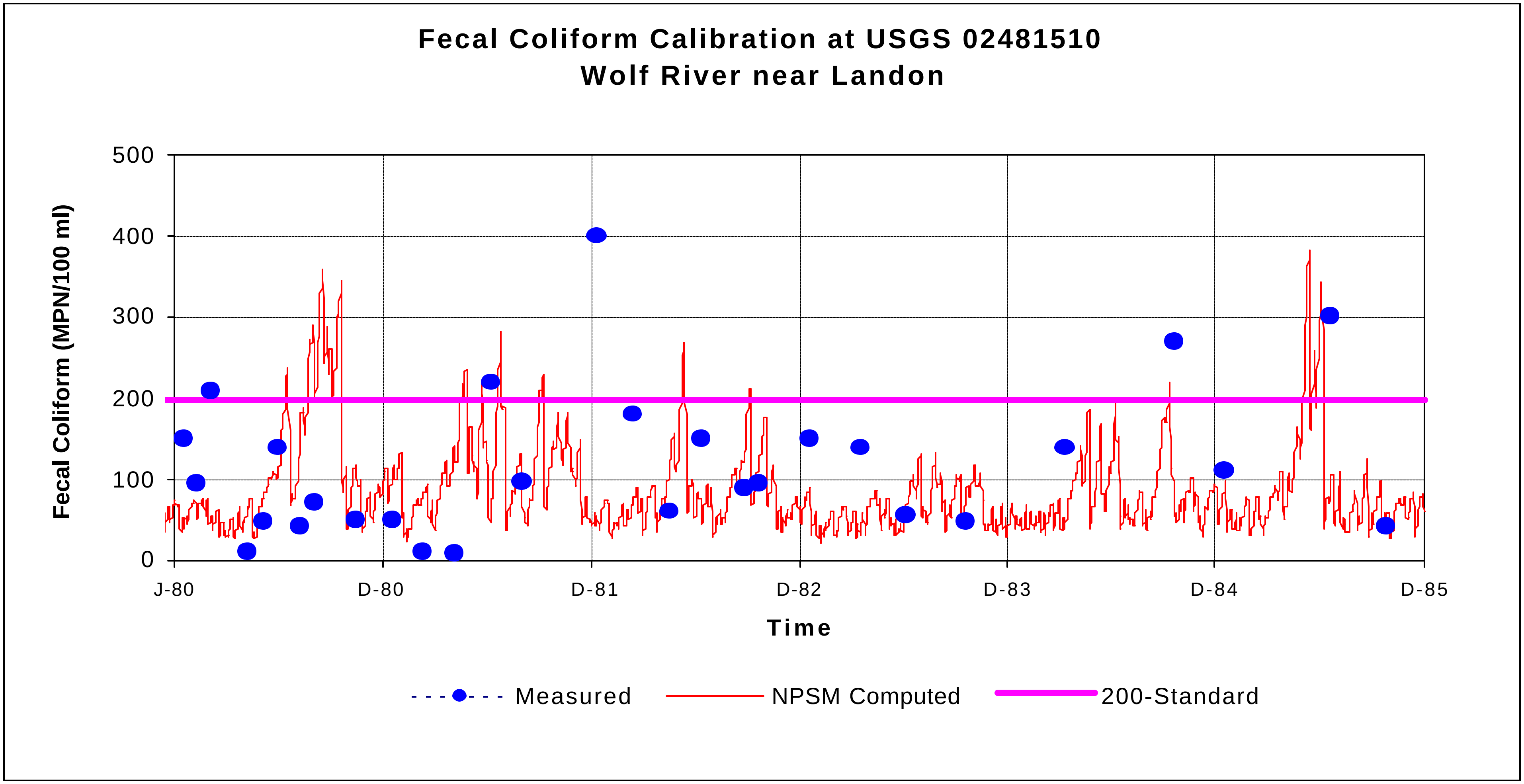
Graph A-3 Hydrologic Flow Calibration at USGS 02481510 Wolf River at Landon–1983 (GIRAS Landuse)



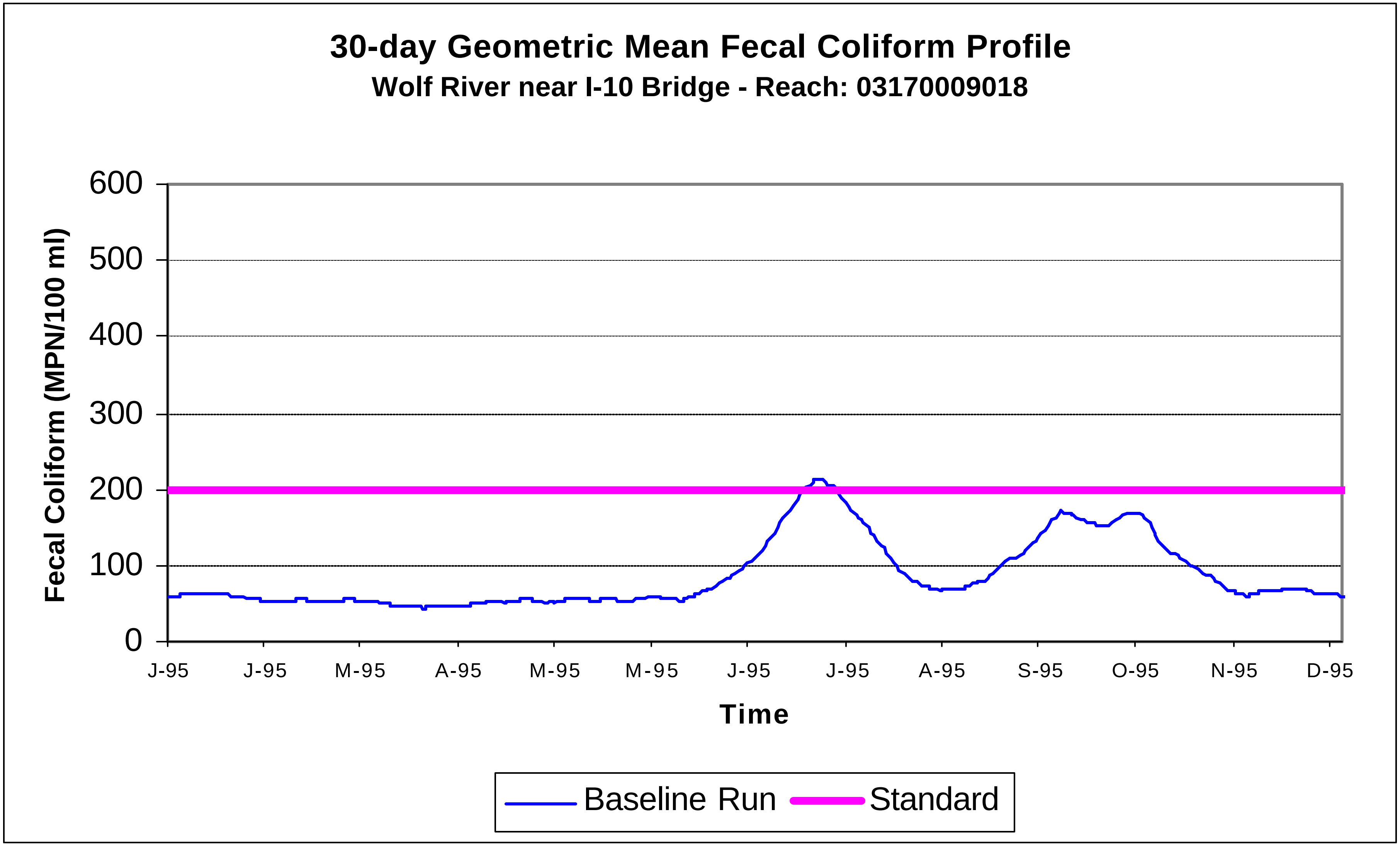
Graph A-4 Hydrologic Flow Calibration at USGS 02481510 Wolf River at Landon–1994 (MARIS Landuse)



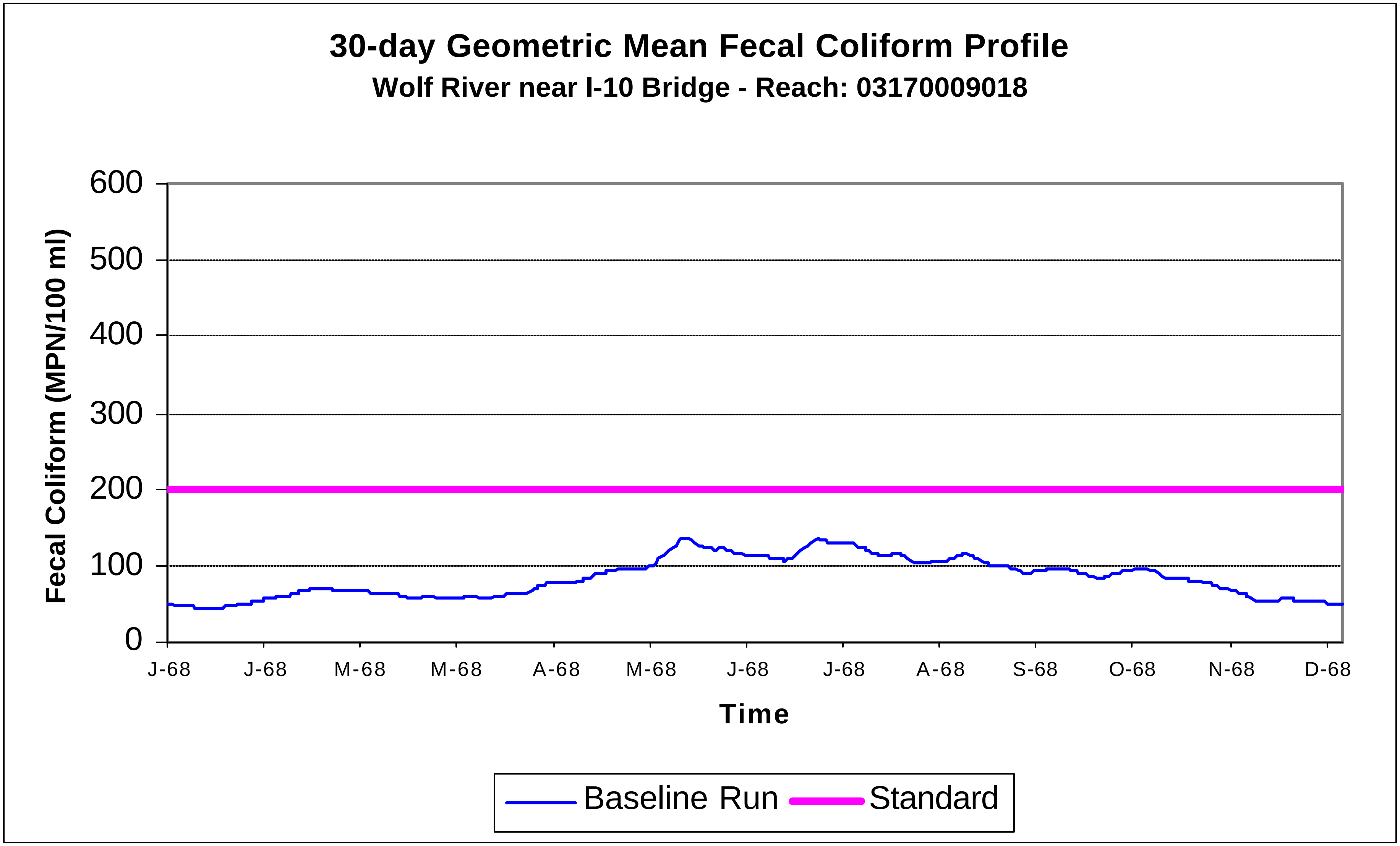
Graph A-5 Computed and Observed Fecal Coliform Profile at USGS Gage 02481510



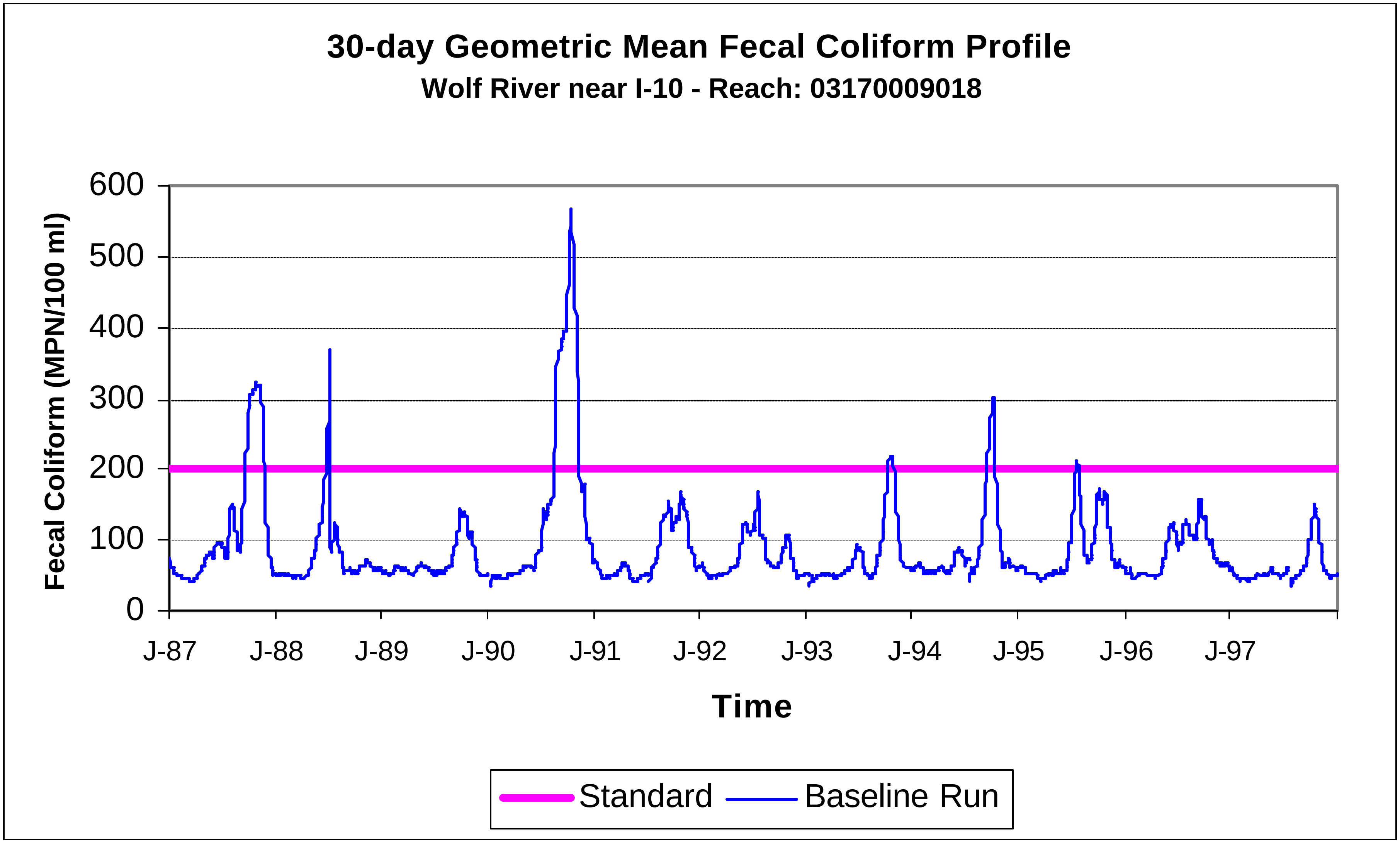
Graph A-6 Model Output Under Baseline Conditions for Reach 03170009018 (Wet Year)



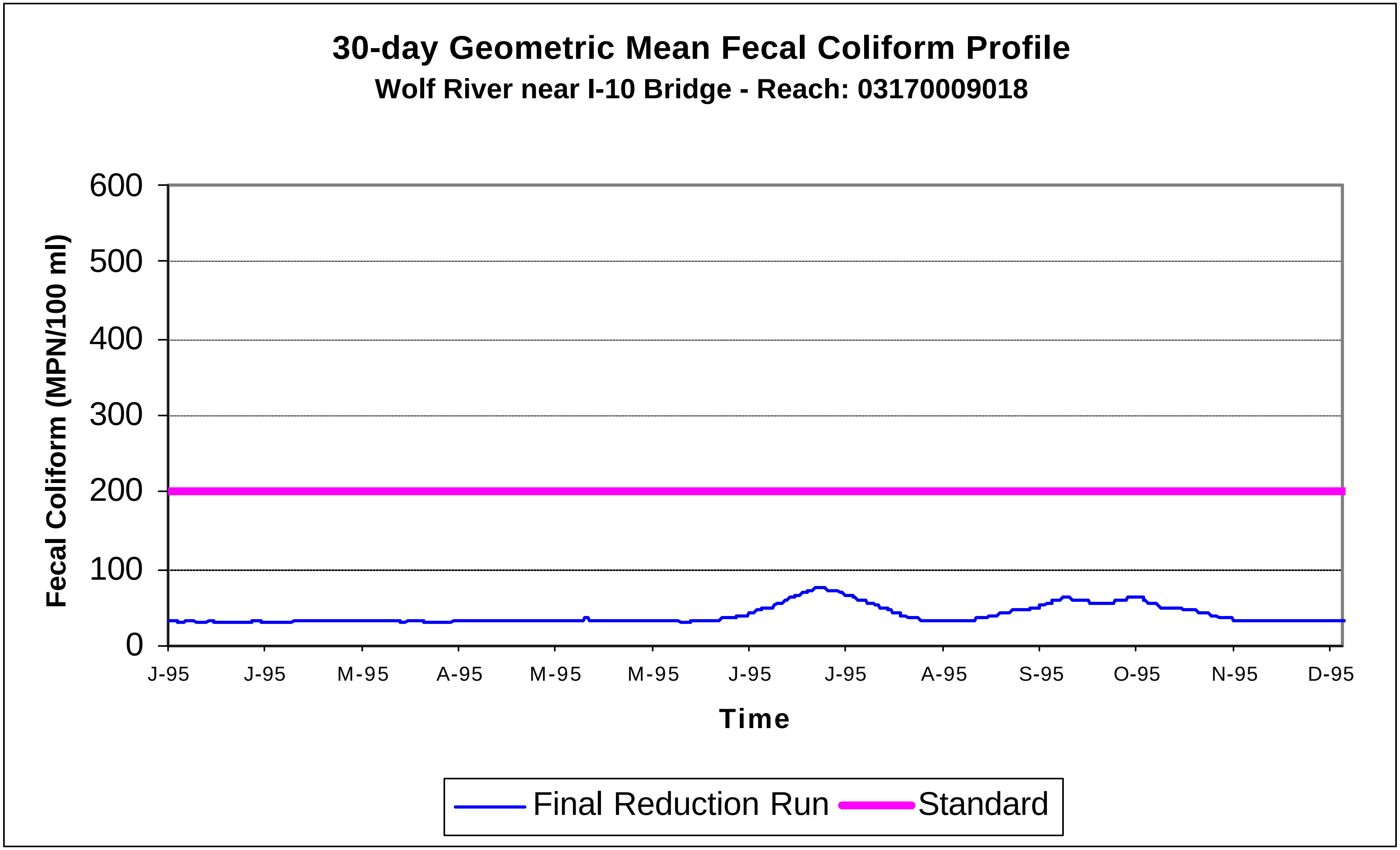
Graph A-7 Model Output Under Baseline Conditions for Reach 03170009018 (Dry Year)



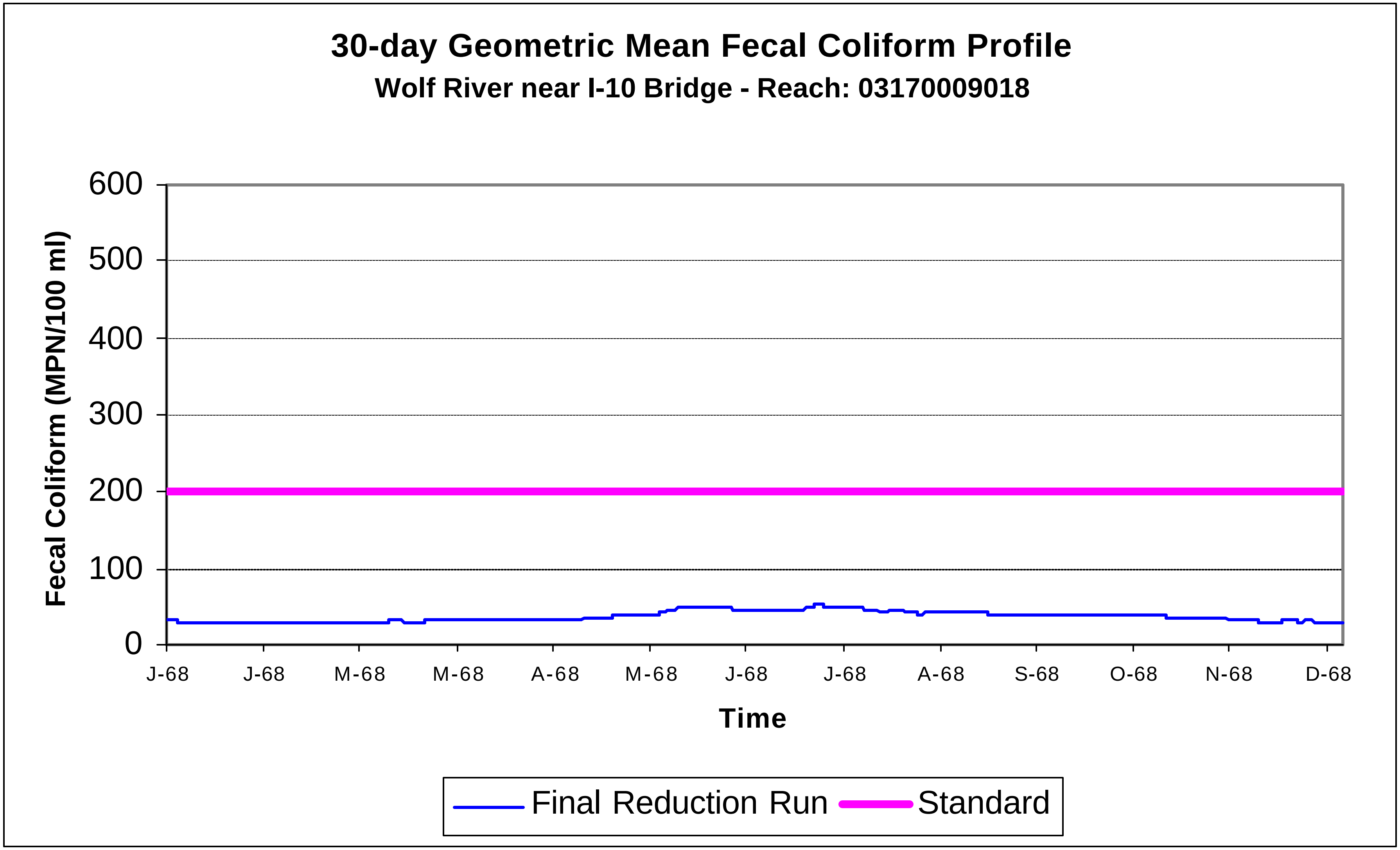
Graph A-8 Model Output Under Baseline Conditions for Reach 03170009018 (11 Year Span)



Graph A-9 Model Output After TMDL Scenario for Reach 03170009018 (Wet Year)



Graph A-10 Model Output After TMDL Scenario for Reach 03170009018 (Dry Year)



Graph A-11 Model Output After TMDL Scenario for Reach 03170009018 (11 Year Span)