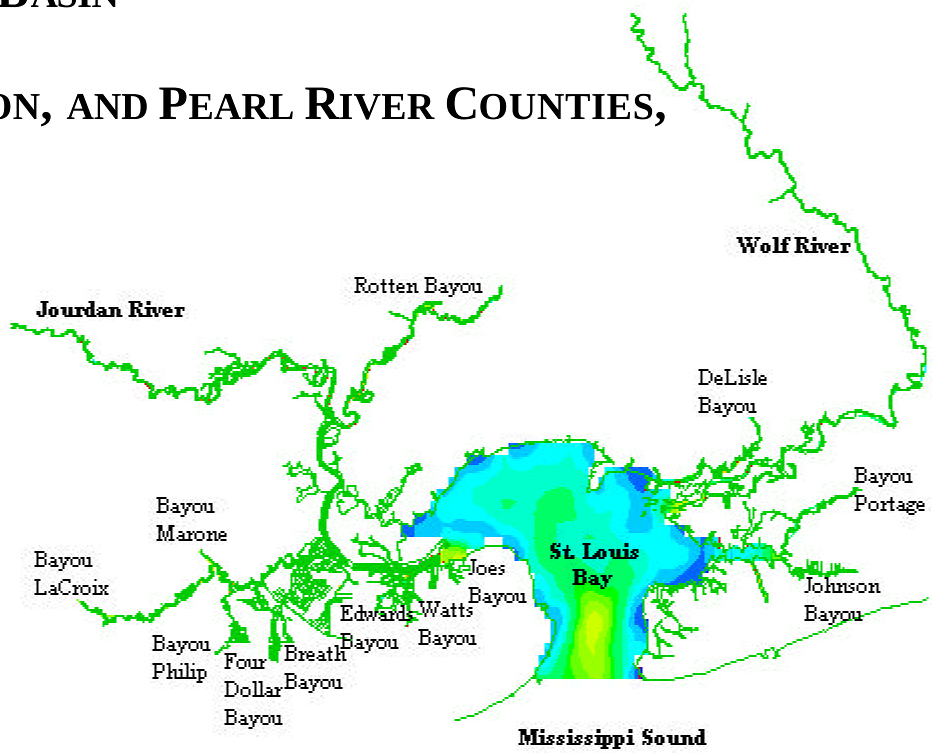
Approved TMDL
July 2, 2001

FECAL COLIFORM TMDL FOR

ST. LOUIS BAY, JOURDAN RIVER (PHASE TWO), AND WOLF RIVER (PHASE TWO)

COASTAL STREAMS BASIN

HANCOCK, HARRISON, AND PEARL RIVER COUNTIES, MISSISSIPPI



PREPARED BY

MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY
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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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FIGURES

TABLES

MONITORED SEGMENT MSSTLUBAYM IDENTIFICATION

Name:	St. Louis Bay
Waterbody ID:	MSSTLUBAYM
Location:	At Bay St. Louis: From inland boundary to Highway 90 bridge
County:	Hancock and Harrison Counties, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	114
Length:	15 miles
Use Impairment:	Shellfish Harvesting and Contact Recreation*
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
Priority Rank:	7
NPDES Permits:	There are 12 NPDES Permits issued for facilities that potentially discharge fecal coliform in the watershed (Table 3.1)
Standards Variance:	None
Pollutant Standard:	Median fecal coliform MPN (most probable number) colony counts shall not exceed 14 per 100 ml, nor shall more than ten percent of the samples examined ordinarily exceed an MPN colony count of 43 per 100 ml in those portions or areas most probably exposed to fecal contamination during most unfavorable hydrographic and pollutional conditions
Waste Load Allocation:	3.07E+12 MPN/15 days (all dischargers must meet water quality standards for disinfection)
Load Allocation:	6.85E+14 MPN/15 days
Margin of Safety:	Implicit modeling assumptions
Total Maximum Daily Load (TMDL):	6.88E+14 MPN/15 days

* For MSSTLUBAYM the controlling standard is that for shellfish harvesting, which is the most stringent. MDEQ intends to delist the contact recreation use.

MONITORED SEGMENT MS115CO4M IDENTIFICATION

Name:	St. Louis Bay Coastline
Waterbody ID:	MS115CO4M
Location:	At Bay St. Louis: From Highway 90 bridge to Jourdan River
County:	Hancock and Harrison Counties, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	130
Length:	4 miles
Use Impairment:	Shellfish Harvesting and Contact Recreation*
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
Priority Rank:	1
NPDES Permits:	There are 12 NPDES Permits issued for facilities that potentially discharge fecal coliform in the watershed (Table 3.1)
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

* It is illegal to harvest shellfish within 750 yards of a coastline, therefore the contact recreation use controls for MS115CO4M.

MONITORED SEGMENT MS114CO1M IDENTIFICATION

Name:	St. Louis Bay Coastline near Delisle
Waterbody ID:	MS114CO1M
Location:	Near Delisle: From Jourdan River to Wolf River
County:	Hancock and Harrison Counties, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	120
Length:	14 miles
Use Impairment:	Shellfish Harvesting and Contact Recreation*
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
Priority Rank:	2
NPDES Permits:	There are 12 NPDES Permits issued for facilities that potentially discharge fecal coliform in the watershed (Table 3.1)
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

* It is illegal to harvest shellfish within 750 yards of a coastline, therefore the contact recreation use controls for MS114CO1M.

MONITORED SEGMENT MS118CO1M IDENTIFICATION

Name:	St. Louis Bay Coastline near Pass Christian
Waterbody ID:	MS118CO1M
Location:	At Pass Christian: From Wolf River to Highway 90 bridge
County:	Harrison County, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	160
Length:	9 miles
Use Impairment:	Shellfish Harvesting and Contact Recreation*
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
Priority Rank:	3
NPDES Permits:	There are 12 NPDES Permits issued for facilities that potentially discharge fecal coliform in the watershed (Table 3.1)
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

* It is illegal to harvest shellfish within 750 yards of a coastline, therefore the contact recreation use controls for MS118CO1M.

MONITORED SEGMENT MS112M1 IDENTIFICATION

Name:	Jourdan River
Waterbody ID:	MS112M1
Location:	Near Kiln: From confluence of Catahoula Creek and Bayou Bacon to confluence with Rotten Bayou
County:	Hancock County, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	100
Length:	13 miles
Use Impairment:	Contact Recreation
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
Priority Rank:	78
NPDES Permits:	There is 1 NPDES Permit issued for a facility that potentially discharges fecal coliform in the watershed (Table 3.1)
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:	5.68E+9 MPN/15 days (all dischargers must meet water quality standards for disinfection)
Load Allocation:	6.09E+13 MPN/15 days
Margin of Safety:	Implicit modeling assumptions
Total Maximum Daily Load (TMDL):	6.10E+13 MPN/15 days

The loads provided above are based on the same 15 day critical period as the loads provided for MSSTLUBAYM and represent the portion of the MSSTLUBAYM loads that are discharged directly into both the freshwater and saltwater portions of MS112M1. The loads provided above shall replace the narrative loads provided in Phase One.

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 is 1 NPDES Permit issued for a facility that potentially discharges fecal coliform in the watershed (Table 3.1)
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:	9.09E+8 MPN/15 days (all dischargers must meet water quality standards for disinfection)
Load Allocation:	4.22E+13 MPN/15 days
Margin of Safety:	Implicit modeling assumptions
Total Maximum Daily Load (TMDL):	4.22E+13 MPN/15 days

The loads provided above are based on the same 15 day critical period as the loads provided for MSSTLUBAYM and represent the portion of the MSSTLUBAYM loads that are discharged directly into both the freshwater and saltwater portions of MS111M1. The loads provided above shall replace the narrative loads provided in Phase One.

EVALUATED WATERBODY MS114DLE IDENTIFICATION

Name:	Bayou Delisle
Waterbody ID:	MS114DLE
Location:	Near Delisle
County:	Harrison County, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	120
Use Impairment:	Secondary Contact Recreation
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
NPDES Permits:	There is 1 NPDES Permit issued for a facility that potentially discharges fecal coliform in the watershed (Table 3.1)
Standards Variance:	None
Pollutant Standard:	May through October - geometric mean colony count of 200 per 100 ml and less than 10 percent may exceed 400 per 100 ml November through April - geometric mean of 2000 per 100 ml, and less than 10 percent may exceed 4000 per 100 ml

EVALUATED WATERBODY MS115BLCE IDENTIFICATION

Name:	Bayou La Croix
Waterbody ID:	MS115BLCE
Location:	Near Waveland
County:	Hancock County, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	130
Use Impairment:	Secondary Contact Recreation
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
NPDES Permits:	There are 0 NPDES Permits issued for facilities that potentially discharge fecal coliform in the watershed (Table 3.1)
Standards Variance:	None
Pollutant Standard:	May through October - geometric mean colony count of 200 per 100 ml and less than 10 percent may exceed 400 per 100 ml November through April - geometric mean of 2000 per 100 ml, and less than 10 percent may exceed 4000 per 100 ml

EVALUATED WATERBODY MS115EBE IDENTIFICATION

Name:	Edwards Bayou
Waterbody ID:	MS115EBE
Location:	At Waveland
County:	Hancock County, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	130
Use Impairment:	Secondary Contact Recreation
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
NPDES Permits:	There is 1 NPDES Permit issued for a facility that potentially discharges fecal coliform in the watershed (Table 3.1)
Standards Variance:	None
Pollutant Standard:	May through October - geometric mean colony count of 200 per 100 ml and less than 10 percent may exceed 400 per 100 ml November through April - geometric mean of 2000 per 100 ml, and less than 10 percent may exceed 4000 per 100 ml

EVALUATED WATERBODY MS115JOBE IDENTIFICATION

Name:	Joes Bayou
Waterbody ID:	MS115JOBE
Location:	Near Bay St. Louis
County:	Hancock County, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	130
Use Impairment:	Secondary Contact Recreation
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
NPDES Permits:	There are 0 NPDES Permits issued for facilities that potentially discharge fecal coliform in the watershed (Table 3.1)
Standards Variance:	None
Pollutant Standard:	May through October - geometric mean colony count of 200 per 100 ml and less than 10 percent may exceed 400 per 100 ml November through April - geometric mean of 2000 per 100 ml, and less than 10 percent may exceed 4000 per 100 ml

EVALUATED SEGMENT MS115M1 IDENTIFICATION

Name:	Jourdan River
Waterbody ID:	MS115M1
Location:	Near Kiln: From 115J Boundary near Edwards Bayou to mouth at St. Louis Bay
County:	Hancock County, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	130
Use Impairment:	Contact Recreation
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
NPDES Permits:	There are 2 NPDES Permits issued for facilities that potentially discharge fecal coliform in the watershed (Table 3.1)
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:	5.62E+11 MPN/15 days (all dischargers must meet water quality standards for disinfection)
Load Allocation:	1.52E+14 MPN/15 days
Margin of Safety:	Implicit modeling assumptions
Total Maximum Daily Load (TMDL):	1.52E+14 MPN/15 days

The loads provided above are based on the same 15 day critical period as the loads provided for MSSTLUBAYM and represent the portion of the MSSTLUBAYM loads that are discharged directly into both the freshwater and saltwater portions of MS115M1. The loads provided above shall replace the narrative loads provided in Phase One.

EVALUATED WATERBODY MS113JE IDENTIFICATION

Name:	Rotten Bayou
Waterbody ID:	MS113JE
Location:	Near Kiln
County:	Hancock County, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	110
Use Impairment:	Secondary Contact Recreation
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
NPDES Permits:	There is 1 NPDES Permit issued for a facility that potentially discharges fecal coliform in the watershed (Table 3.1)
Standards Variance:	None
Pollutant Standard:	May through October - geometric mean colony count of 200 per 100 ml and less than 10 percent may exceed 400 per 100 ml November through April - geometric mean of 2000 per 100 ml, and less than 10 percent may exceed 4000 per 100 ml

EVALUATED WATERBODY MS114JE IDENTIFICATION

Name:	Cutoff Bayou
Waterbody ID:	MS114JE
Location:	Near Kiln
County:	Hancock County, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	120
Use Impairment:	Secondary Contact Recreation
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
NPDES Permits:	There are 0 NPDES Permits issued for facilities that potentially discharge fecal coliform in the watershed (Table 3.1)
Standards Variance:	None
Pollutant Standard:	May through October - geometric mean colony count of 200 per 100 ml and less than 10 percent may exceed 400 per 100 ml November through April - geometric mean of 2000 per 100 ml, and less than 10 percent may exceed 4000 per 100 ml

EVALUATED SEGMENT MS115JM1 IDENTIFICATION

Name:	Jourdan River
Waterbody ID:	MS115JM1
Location:	Near Kiln: From Confluence of Rotten Bayou to boundary of 115J near Edwards Bayou
County:	Hancock County, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	130
Use Impairment:	Contact Recreation
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
NPDES Permits:	There is 1 NPDES Permit issued for a facility that potentially discharges fecal coliform in the watershed (Table 3.1)
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:	5.68E+9 MPN/15 days (all dischargers must meet water quality standards for disinfection)
Load Allocation:	1.18E+14 MPN/15 days
Margin of Safety:	Implicit modeling assumptions
Total Maximum Daily Load (TMDL):	1.18E+14 MPN/15 days

The loads provided above are based on the same 15 day critical period as the loads provided for MSSTLUBAYM and represent the portion of the MSSTLUBAYM loads that are discharged directly into both the freshwater and saltwater portions of MS115JM1. The loads provided above shall replace the narrative loads provided in Phase One.

EVALUATED WATERBODY MS118MBE IDENTIFICATION

Name:	Mallini Bayou
Waterbody ID:	MS118MBE
Location:	At Pass Christian
County:	Harrison County, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	160
Use Impairment:	Shellfishing
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
NPDES Permits:	There are 0 NPDES Permits issued for facilities that potentially discharge fecal coliform in the watershed (Table 3.1)
Standards Variance:	None
Pollutant Standard:	Median fecal coliform MPN (most probable number) colony counts shall not exceed 14 per 100 ml, nor shall more than ten percent of the samples examined ordinarily exceed an MPN colony count of 43 per 100 ml in those portions or areas most probably exposed to fecal contamination during most unfavorable hydrographic and pollutional conditions

EVALUATED WATERBODY MS115WBE IDENTIFICATION

Name:	Watts Bayou
Waterbody ID:	MS115WBE
Location:	Near Waveland
County:	Hancock County, Mississippi
USGS HUC Code:	03170009
NRCS Watershed:	130
Use Impairment:	Secondary Contact Recreation
Cause Noted:	Fecal Coliform, an Indicator for the Presence of Pathogens
NPDES Permits:	There are 0 NPDES Permits issued for facilities that potentially discharge fecal coliform in the watershed (Table 3.1)
Standards Variance:	None
Pollutant Standard:	May through October - geometric mean colony count of 200 per 100 ml and less than 10 percent may exceed 400 per 100 ml November through April - geometric mean of 2000 per 100 ml, and less than 10 percent may exceed 4000 per 100 ml

EXECUTIVE SUMMARY

Several waterbody segments 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 was comprised of TMDLs for the portion of the Wolf River and the Jourdan River watersheds that drain to freshwater. The Wolf River and the Jourdan River are the primary fresh water sources for St. Louis Bay. The results from Phase One for the freshwater portion of the Wolf River and Jourdan River watersheds were used as input at the appropriate boundaries for Phase Two, which includes the remaining portion of the Wolf River and Jourdan River watersheds that drain to saltwater. This report includes TMDLs for the Bay, it's coastlines, the near shore watersheds, which drain directly to the saltwater portion of the Bay, and the Phase Two portion of the Wolf River and Jourdan River TMDLs. The phased approach is beneficial not only because different models were used to represent the saltwater and the freshwater systems, but also because the different systems have different end point targets.

St. Louis Bay is a vital waterbody in the Mississippi Gulf Coast Region with designated uses of shellfish harvesting and primary contact recreation. The western half of the Coastal Streams Hydrologic Unit Code, HUC, 03170009, drains into St. Louis Bay. The total area of the St. Louis Bay Watershed is approximately 800 square miles. The Phase One Jourdan River and Wolf River TMDLs covered 217 and 345 square miles, respectively. The remaining portion of the St. Louis Bay Watershed drains directly to the Bay or other tidally influenced portions of the system and is covered in this Phase Two document.

The modeling to support the development of this TMDL report was conducted by the Civil Engineering Department at Mississippi State University. The modeling system selected for this study, which includes the BASINS Nonpoint Source Model (NPSM) and the Environmental Fluid Dynamics Code (EFDC), combined the hydrology, in-stream hydrodynamic, and environmental quality of the estuary system while considering both point source and nonpoint source loadings. The Mississippi Department of Environmental Quality (MDEQ) and the Environmental Protection Agency (EPA) have conducted intensive field data acquisition projects to provide additional data to facilitate better understanding of this complex estuarine system and to provide data for model calibration and validation. Intensive surveys during July 1998 and April 1999 were used for model calibration and verification.

The models accounted for seasonal variations in hydrology, climatic conditions, and watershed activities. The use of the continuous simulation models 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 urban runoff and watershed activities such as livestock grazing and land application of manure.

The weather data used for this model were collected at several locations in the study area. The representative hydrologic period used for this modeling project 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.

The water quality data available were not sufficient for assessment. However, the violation of the shellfish harvesting and contact recreation uses was based upon harvesting classification restrictions. The prohibited classification was not reflective of water quality, but due to proximity to a waste source. The existence of new guidance and additional water quality for the areas where the classifications are reflective of water quality could allow for upward classification of areas of St. Louis Bay where appropriate.

Fecal coliform loadings from nonpoint sources in the Jourdan River and Wolf River Watersheds were calculated based upon wildlife populations, livestock populations, information on livestock and manure management practices, and urban development for the Phase One TMDLs. However, for the small watersheds surrounding St. Louis Bay, the fecal coliform loadings from nonpoint sources were estimated based on literature values and calibration. The estimated fecal coliform production and accumulation rates due to nonpoint sources that would runoff from the watersheds were incorporated into the model. Pollutant loadings from the major rivers and small bayous are simulated as input into the Bay model. There are 12 NPDES Permitted discharges included as point sources in the model.

Under existing, or baseline, conditions output from the model indicates a violation of the median fecal coliform standard for shellfish harvesting and the geometric mean fecal coliform standard for contact recreation due to both nonpoint and point sources. After applying a TMDL reduction scenario, there were no significant violations of the standard according to the model.

The Phase One TMDL scenarios for reduction of the fecal coliform loads from the Jourdan River and Wolf River Watersheds were represented in the scenario for Phase Two, which invloves a reduction in the total fecal coliform load of approximately 27 percent. Because over 99 percent of the allocated load is due to nonpoint sources, those were focused on for reductions. Also, the permitted dischargers in the watershed are currently required to disinfect and to discharge at levels equivalent to the contact recreation water quality standard. The 27 percent reduction could be achieved through many different scenarios, which might include addressing urban nonpoint source issues in the small watersheds around the Bay and addressing other issues in the Phase One Jourdan River and Phase One Wolf River TMDLs. The categories of loads that may be reduced include those that contribute to surface runoff and those that reach the stream directly. The waters of St. Louis Bay are in various stages of restriction for shellfish harvesting and one of the goals of this TMDL is to improve water quality to allow for upward classification of the waters to once again allow shellfish harvesting where appropriate. Additional stakeholder input should be sought to develop an appropriate implementation plan for this watershed.

1.0 INTRODUCTION

1.1 Background

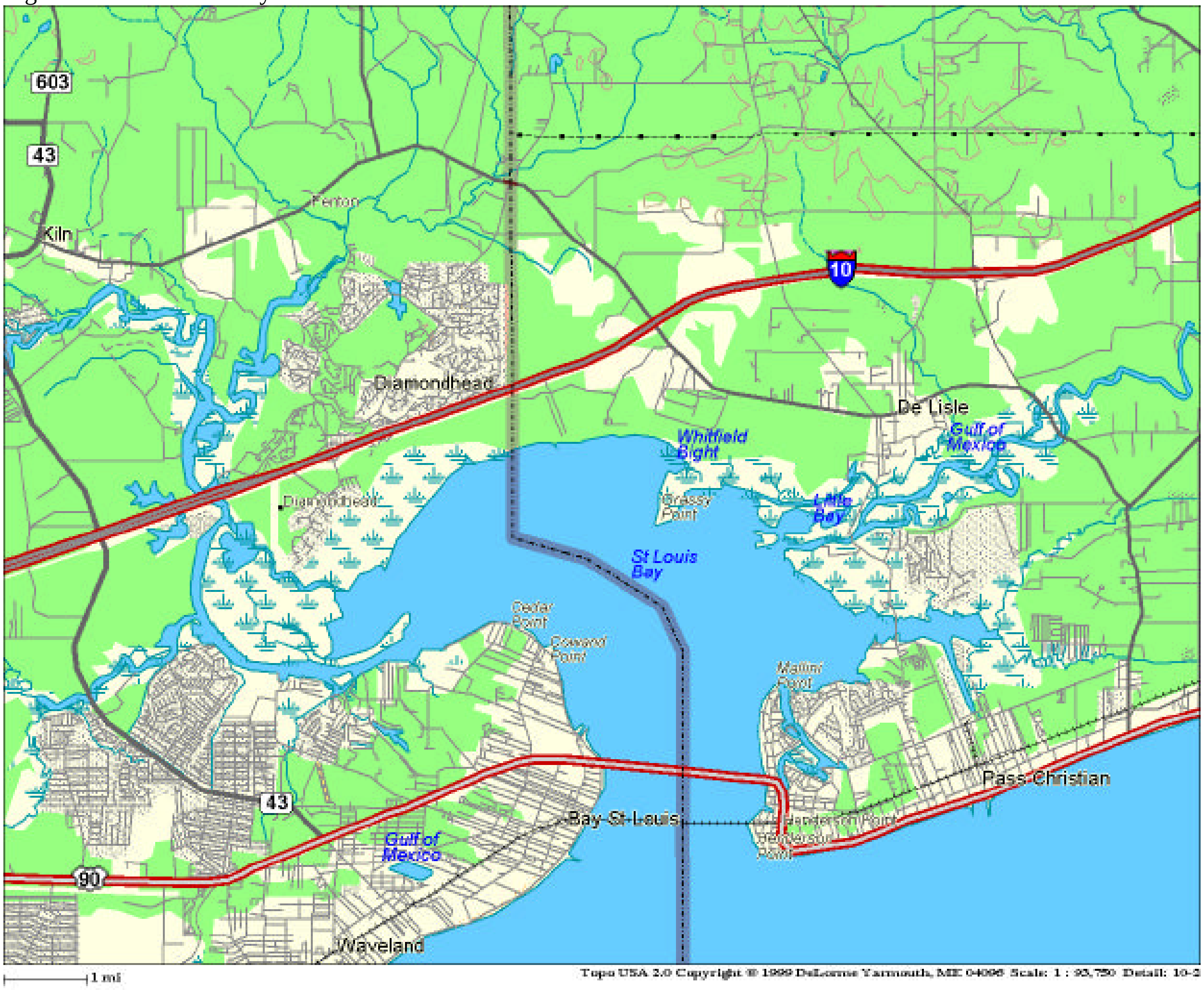
The identification of waterbodies not meeting their designated use and the development of total maximum daily loads (TMDLs) for those waterbodies are required by Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 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 St. Louis Bay as being impaired by fecal coliform bacteria as reported in the Mississippi 1998 Section 303(d) List of Waterbodies. The St. Louis Bay coastline, which has been split into three segments, has also been identified as being impaired by fecal coliform bacteria. The aforementioned four segments are listed on the monitored portion of the Mississippi 1998 Section 303(d) List of Waterbodies. Phase Two of the monitored portions of the Jourdan River and Wolf River are also included in this TMDL. In addition, this TMDL includes 10 waterbody segments in the St. Louis Bay Watershed that are on the evaluated portion of the Mississippi 1998 Section 303(d) List of Waterbodies for pathogens. The 10 evaluated segments are: Bayou Delisle, Bayou LaCroix, Edwards Bayou, Joes Bayou, Jourdan River from Edwards Bayou to mouth, Rotten Bayou, Cutoff Bayou, Jourdan River from Rotten Bayou to Near Edwards Bayou, Mallini Bayou at Pass Christian, and Watts Bayou. The St. Louis Bay area is shown in Figure 1.1a.

The listing of the segments was influenced by several factors, including shellfish classifications, water quality data, and anecdotal evidence. The St. Louis Bay and it's coastlines were automatically listed as impaired for shellfish harvesting due to the prohibited and restricted classification of the shellfish beds in the Bay by MDMR. While the prohibited classification was possibly due to proximity to a NPDES point source discharge, the restricted classification was more likely water quality related. The monitored segments of the Jourdan River and the Wolf River were listed due to water quality data, which is presented in their Phase One TMDL reports. The evaluated segments were listed due to anecdotal evidence. All segments included in this report are shown in Figure 1.1b.

According to the U.S. Fish and Wildlife Service there are no threatened or endangered species that occur in the waters in the St. Louis Bay Watershed.

Figure 1.1a St. Louis Bay Area



St. Louis Bay and the other impaired segments addressed in this TMDL are in the Coastal Streams Basin Hydrologic Unit Code (HUC) 03170009 in southwest Mississippi. The area of the entire St. Louis Bay Watershed is approximately 800 square miles. As shown in Figure 1.1c the St. Louis Bay Watershed area lies within portions of Pearl River, Hancock, Harrison, Stone, and Lamar Counties. Figure 1.1c also shows the portion of the watershed in the Phase One Jourdan River TMDL in green, the portion of the watershed in the Phase One Wolf River TMDL in yellow, and the remaining portion of the watershed in blue, which is covered in this TMDL. The Jourdan and Wolf watersheds are predominately forested and rural, containing the majority of the agricultural activities. Detailed descriptions of their landuse distributions are provided in those TMDLs. However, the majority of the urban area in the St. Louis Bay Watershed is included in the area covered in this TMDL. The land use distribution for the entire St. Louis Bay Watershed is shown in Table 1.1.

Table 1.1 Landuse Distribution in Acres for the St. Louis Bay Watershed

	Urban	Forest	Cropland	Pasture	Barren	Wetland	Total
Area (Acres)	11,726	303,729	14,319	45,541	874	132,609	522,593
% Area	2	58	3	9	0	25	100

Figure 1.1b St. Louis Bay Waterbody Segments

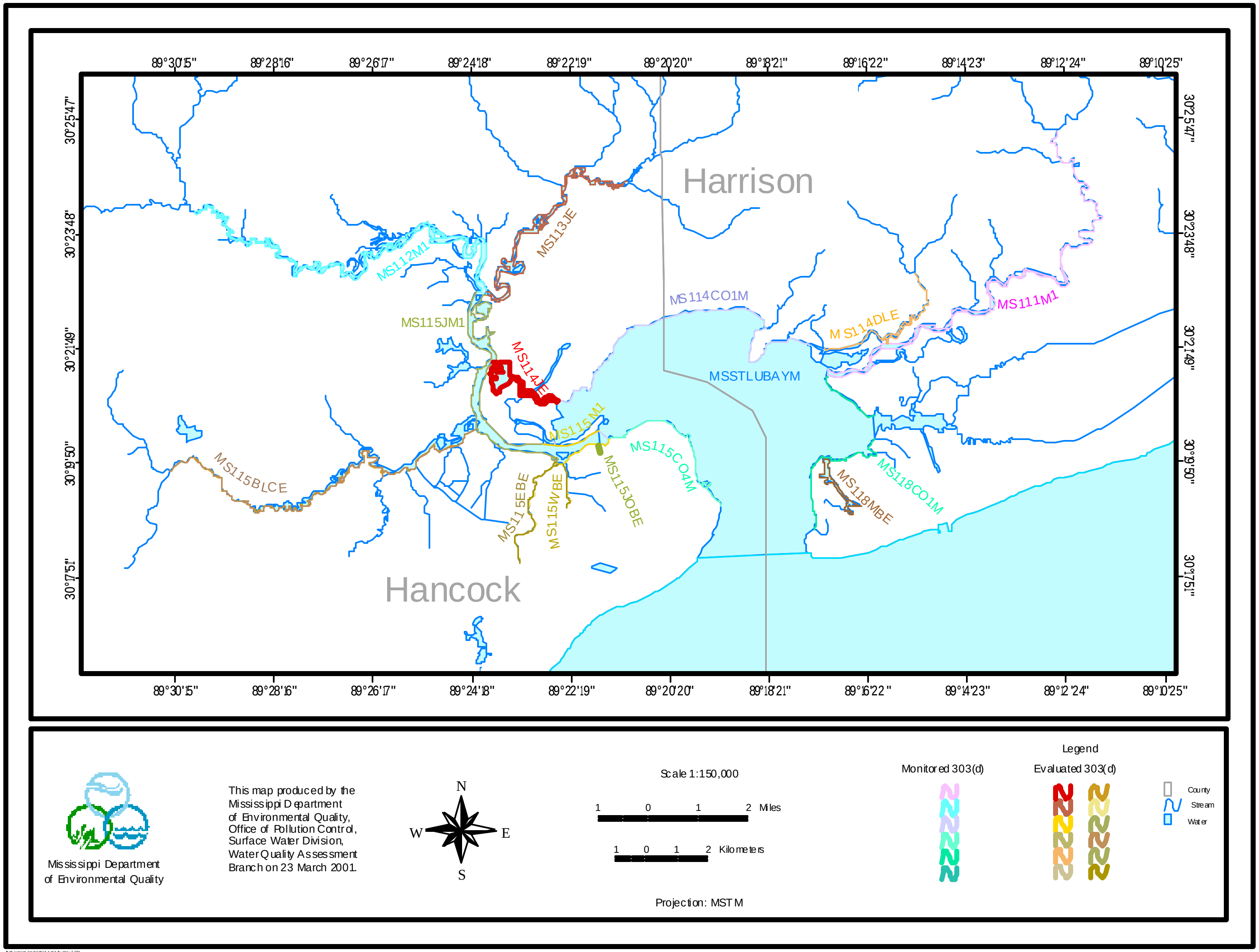
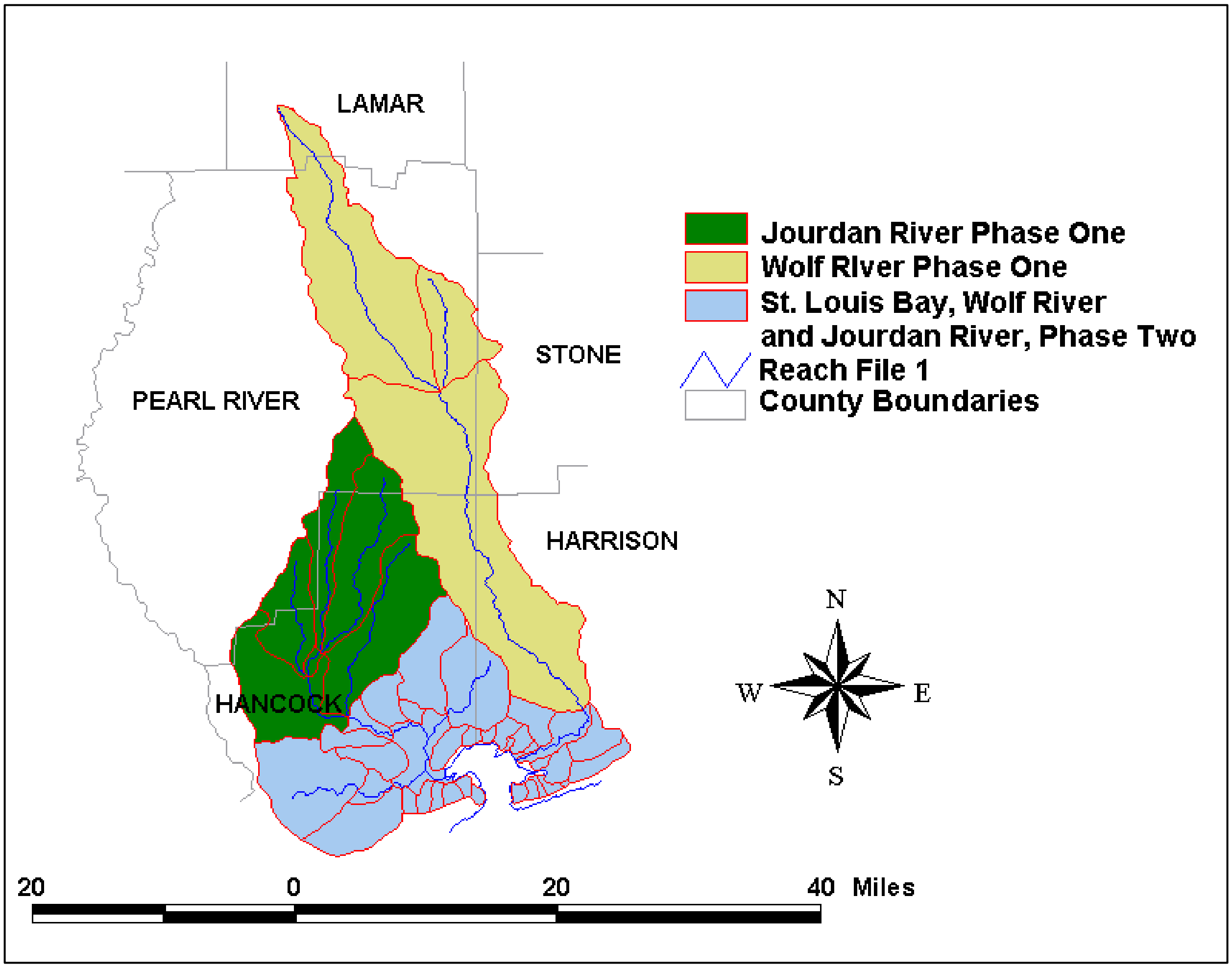
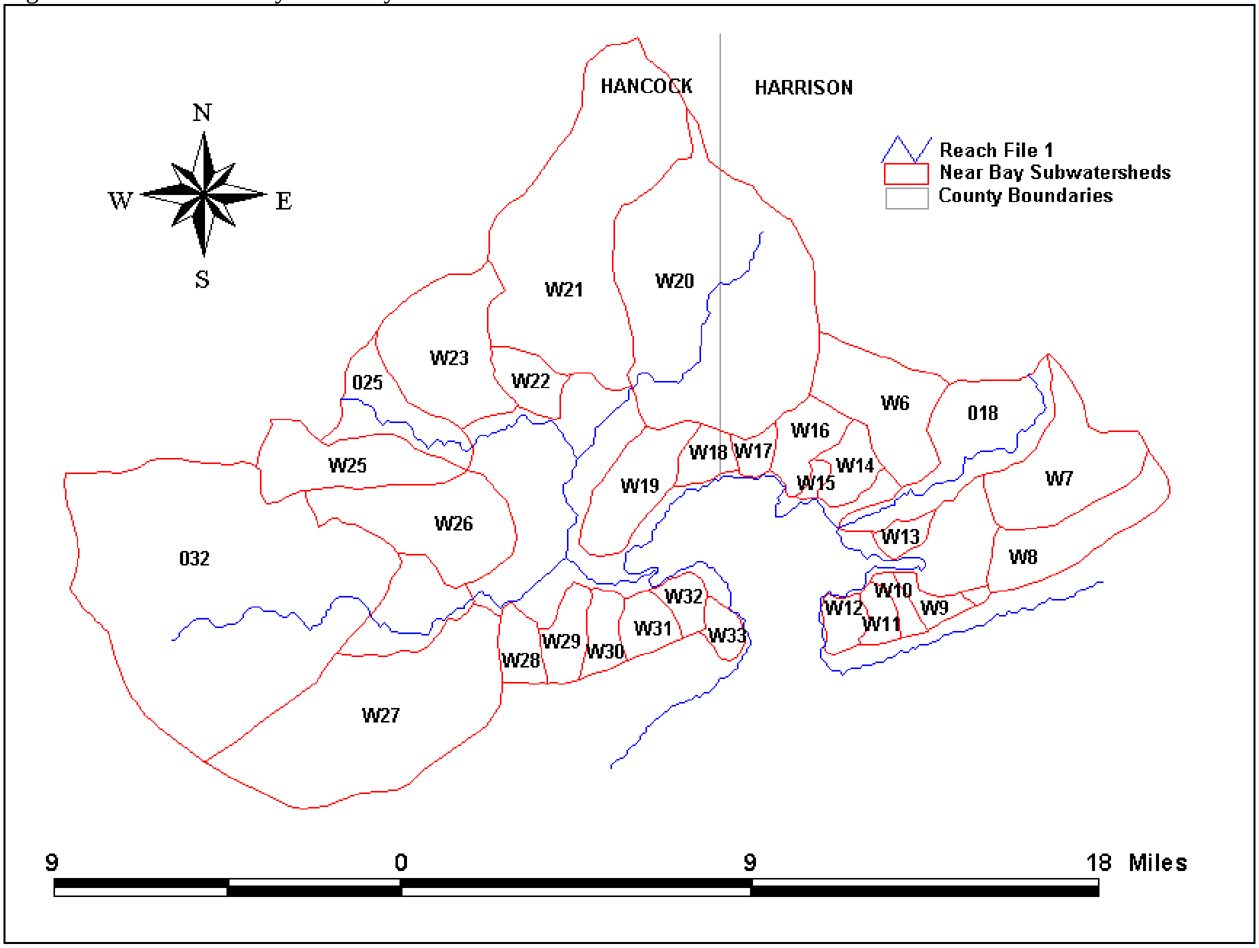


Figure 1.1c St. Louis Bay Subwatersheds



The St. Louis Bay Watershed has been divided into 37 subwatersheds based on the major tributaries and topography. Figure 1.1c also shows the portion of the watershed in the Phase One Jourdan River TMDL in green, the portion of the watershed in the Phase One Wolf River TMDL in yellow, and the remaining portion of the watershed in blue, which is covered in this TMDL. Figure 1.1d shows a more detailed view of the subwatersheds of St. Louis Bay represented in this TMDL and identifies them with a three-digit identification number. The three subwatersheds in the Upper Wolf River Watershed and the six subwatersheds in the Upper Jourdan River Watershed were represented in Phase One TMDLs.

Figure 1.1d St. Louis Bay Near Bay Subwatersheds



1.2 Applicable Waterbody Segment Use

The water use classification for St. Louis Bay, as established by the State of Mississippi in the *Water Quality Criteria for Intrastate, Interstate and Coastal Waters* regulation, is Shellfish Harvesting. Because the regulations state that "waters that meet the Shellfish Harvesting Area Criteria shall also be suitable for recreational purposes," St. Louis Bay and it's coastlines have the designated beneficial uses of both, Shellfish Harvesting and Contact Recreation. The water use classification for the other monitored waterbodies is Recreation, which means they have the designated beneficial use of Contact Recreation. The evaluated waterbodies have the water use classification of Fish and Wildlife with a designated beneficial use of Secondary Contact Recreation related to pathogens.

The classification of the St. Louis Bay waters for shellfish harvesting is shown in Figure 1.2a. These classifications are determined by the Mississippi Department of Marine Resources (MDMR) and are fully explained in the National Shellfish Sanitation Program (NSSP) Model Ordinance which is available on the Interstate Shellfish Sanitation Conference (ISSC) website, http://www.issc.org/. Figure 1.2b shows the location of the reefs in St. Louis Bay. The waters of St. Louis Bay are in various stages of restriction and the goal is to improve water quality to allow for upward classification where appropriate.

Figure 1.2a Shellfish Harvesting Classifications in St. Louis Bay (MDMR)

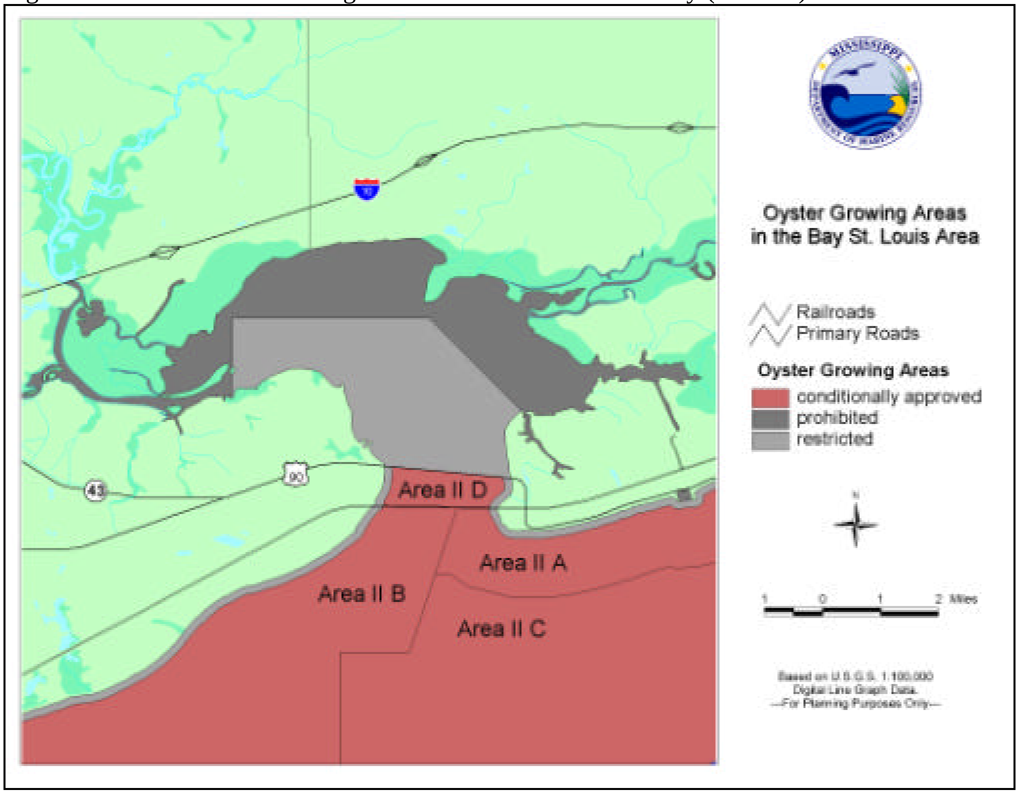
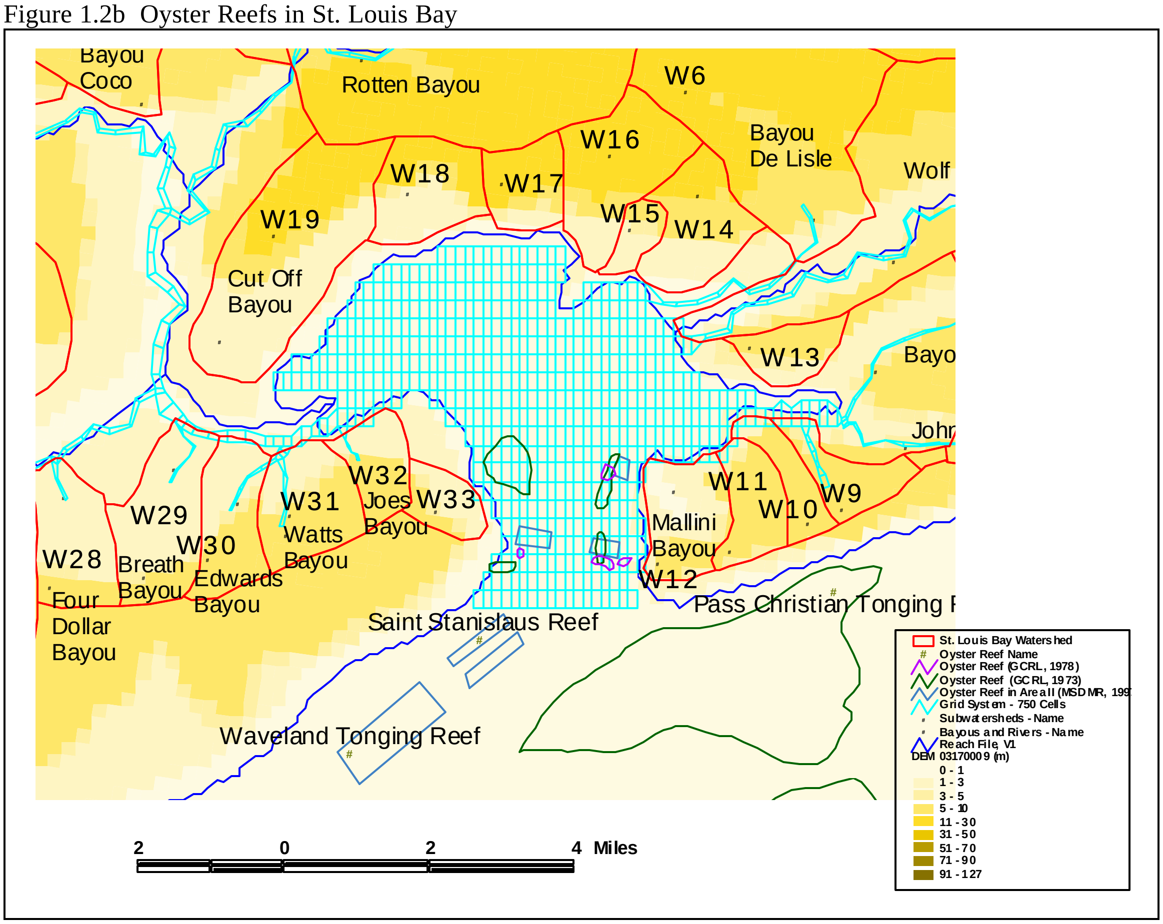


Figure 1.2b Oyster Reefs in St. Louis Bay



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 standards are shown in Table 1.3. These water quality standards will be used as targeted endpoints to evaluate impairments and to establish this TMDL.

Table 1.3 Water Quality Standards

Water Use	Purpose	Water Standards
Shellfishing Harvesting	Waters for this use are for propagation and harvesting shellfish for sale or use as a food product.	The median fecal coliform most probable number (MPN) of the water shall not exceed 14 per 100 ml, and not more than ten percent (10%) of the samples shall ordinarily exceed an MPN of 43 per 100 ml in those portions or areas most probably exposed to fecal contamination during most unfavorable hydrographic and pollutional conditions.
Recreation	The quality of waters in this classification is to be suitable for recreational purposes, including such water contact activities as swimming and water skiing.	Fecal coliform shall not exceed a geometric mean of 200 per 100 ml nor shall more than ten percent (10%) of the samples examined during any month exceed 400 per 100 ml.
Fish and Wildlife	Waters in this classification are intended for fishing and for propagation of fish, aquatic life, and wildlife. Waters that meet Fish and Wildlife Criteria shall also be suitable for secondary contact recreation. Secondary contact recreation is defined as incidental contact with the water, including wading and occasional swimming.	For the months of May through October, when water contact recreation activities may be expected to occur, fecal coliform shall not exceed a geometric mean of 200 per 100 ml nor shall more than 10 percent (10%) of the samples examined during any month exceed 400 per 100 ml. For the months of November through April, when incidental recreational contact is not likely, fecal coliform shall not exceed geometric mean of 2000 per 100 ml, nor shall more than ten percent (10%) of the samples examined during any month exceed 4000 per 100 ml.

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. While there are various designated uses in the St. Louis Bay system, the use with the most stringent standards is that for shellfish harvesting, which requires an instream fecal coliform target of a median of 14 MPN counts per 100 ml. Reductions utilized to meet this target should 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 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 models were 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. The wet year has been determined to be the most critical for the fecal coliform water quality in the Bay.

2.2 Discussion of Instream Water Quality

According to the State's 1998 Section 305(b) Water Quality Assessment Report, St. Louis Bay is partially supporting the uses of Shellfish Harvesting and Contact Recreation. MDEQ had limited data available to support this assessment. However, in the past guidance dictated that any water classified as restricted or prohibited for shellfish harvesting by the NSSP and MDMR must be listed as impaired. Figure 1.2a shows that the northern portion of St. Louis Bay is classified as prohibited, the southern half is classified as restricted, and the portion between the bridges at the mouth is classified as conditionally approved. New guidance from EPA is now available that states "Prohibited" classifications set as a precautionary measure due to the proximity of wastewater discharges are not appropriate to consider in the listing of impaired waterbodies (Grubbs and Wayland Letter, October, 2000). The new guidance along with verification with water quality samples may provide for the opportunity to upwardly classify more of the St. Louis 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 the water quality is determined by MDMR to be consistently adequate during certain portions of the year.

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 on the Wolf River and at station 02481660 on the Jourdan River through MDEQ's Ambient Monitoring Program. Then in 1997 the monitoring frequency at that station was increased to a monthly basis. These data along with even more recent data, including that from the Wolf River Conservation Society, are displayed in their respective Phase One reports.

Historically only one station in Bayou Portage, a tributary to St. Louis Bay, was monitored through the Ambient Monitoring Program. While three stations were added in 1997 in St. Louis Bay, the data are only collected quarterly and therefore not of sufficient frequency to assess for fecal coliform. However, that data is provided below in Table 2.2b, while Table 2.2a provides a description of the station names and locations for the stations in Table 2.2b and Table 2.2c.

Through the development of a Data Compendium for St. Louis Bay some additional historical water quality data sources were identified and evaluated. Two intensive surveys were also conducted for the St. Louis Bay Fecal Coliform TMDL Project. The results from those intensive surveys were used for model calibration, and even though the frequency is still insufficient for assessment the data is provided in Table 2.2c.

Mississippi Department of Marine Resources (MDMR) collects data extensively in shellfish growing areas. MDEQ is using MDMR data for the 2000 assessment of meeting the contact recreation designated use.

Table 2.2a Station Locations

Station ID	Waterbody Name	Station Location
BB1	BREATHS BAYOU	OFF OF JOURDAN RIVER
BLC1	BAYOU LA CROIX	NEAR MOUTH AT JOURDAN RIVER
BLC2	BAYOU LA CROIX	COUNTY ROAD WEST OF HWY 43
BLT1	BAYOU LA TERRE	COUNTY ROAD EAST OF KILN, NEAR MOUTH, SEC 37
BP1	BAYOU PORTAGE	COUNTY ROAD NEAR PASS CHRISTIAN
BP2	BAYOU PORTAGE	COUNTY ROAD (MENGE AVE) AT CUEVAS
CB1	CUTOFF BAYOU	NEAR DIAMONDHEAD MARINA
CC1	CATAHOULA CREEK	CROSSING NEAR SANTA ROSA, SEC 30
DLB1	DE LISLE BAYOU	AT CHANNEL CUT TO WOLF RIVER
DLB2	DE LISLE BAYOU	COUNTY ROAD AT DELISLE
EB1	EDWARDS BAYOU	OFF OF JOURDAN RIVER
FDB1	FOUR DOLLAR BAYOU	OFF OF BAYOU LA CROIX
JB1	JOES BAYOU	OFF OF JOURDAN RIVER
JNB1	JOHNSON BAYOU	NEAR MOUTH AT BAYOU PORTAGE
JR1	JOURDAN RIVER	MOUTH AT ST LOUIS BAY
JR2	JOURDAN RIVER	AT INTERSTATE 10
JR3	JOURDAN RIVER	HWY 43/603 AT KILN
MB1	MALLINI BAYOU	NORTHERN END NEAR MALLINI POINT
MS1	MISSISSIPPI SOUND	CHANNEL MARKER RED 4 SOUTH OF RR BRIDGE
RB1	ROTTEN BAYOU	NEAR MOUTH AT JOURDAN RIVER, ABOVE I-10
SLB1	ST LOUIS BAY	HWY 90 BRIDGE
SLB2	ST LOUIS BAY	CHANNEL MARKER GREEN 5 OFF MALLINI POINT
SLB3	ST LOUIS BAY	CHANNEL MARKER GREEN 3 OFF COWAND POINT
SLB4	ST LOUIS BAY	CHANNEL MARKER GREEN 5 OFF WOLF RIVER
SLB5	ST LOUIS BAY	OFF CEDAR POINT, NEAR JOURDAN RIVER
SLB6	ST LOUIS BAY	WEST OF GRASSY POINT NEAR DUPONT
SLB7	ST LOUIS BAY	NORTHEAST OF CUTOFF BAYOU
WB1	WATTS BAYOU	OFF OF JOURDAN RIVER
WR1	WOLF RIVER	ROUSE BRIDGE NEAR CUEVAS
WR2	WOLF RIVER	COUNTY ROAD NEAR LANDON

Table 2.2b Ambient Program Fecal Coliform Data (MPN/100 ml)

WR1		SLB1		SLB2		SLB3		MS1	
Date	FC	Date	FC	Date	FC	Date	FC	Date	FC
3/3/1998	46	8/19/1998	1.8	4/16/1997	5	4/16/1997	17	4/16/1997	7.8
8/3/1998	350			7/15/1997	49	7/5/1997	11	7/15/1997	2
				10/9/1997	2	10/9/1997	2	10/9/1997	2
				1/28/1998	540	1/28/1998	920	1/28/1998	49
				4/6/1998	13	4/6/1998	33	4/6/1998	2
				8/19/1998	1.8	8/19/1998	13	8/19/1998	1.8
				10/26/1998	4.5	10/26/1998	4.5		

Table 2.2c Intensive Study Fecal Coliform Data (MPN/100 ml)

Station ID	July 1998 Study				April 1999 Study		
	7/14/1998 Afternoon	7/15/1998 Midday	7/15/1998 Midnight	7/16/1998 Midday	4/19/1999 Afternoon	4/21/1999 Morning	4/22/1999 Afternoon
BB1	79	350	49		110	240	220
BLC1	33	79	13		4.5	33	33
BLC2	540	540		33	13	23	22
BLT1	920	920		350	46	110	350
BP1	240	23	7.8		33	17	7.8
BP2	1600	1600		540	79	49	33
CB1		49	23		22	49	4.5
CC1	79	240		11	13	46	17
DLB1	350	49			740		1600
DLB2		920		540	49	79	240
EB1	1600	140	540		49	920	1600
FDB1		70	23		140		350
JB1	360	130			70	350	79
JNB1	1600	170			140		13
JR1		79	23		7.8	6.8	17
JR2		23	23		13	33	33
JR3	350	240		33	23	7.8	46
MB1	540	33	23		22	170	130
MS1		1.8	1.8		1.8	4.5	2
RB1	130	33	130		13	4	23
SLB1		1.8	1.8		2	6.8	7.8
SLB2		14	1.8		2	79	7.8
SLB3		1.8	1.8		4.5	11	4
SLB4		1.8	1.8		4.5	110	4.5
SLB5		2	2		7.8	17	13
SLB6		2	1.8		2	79	79
SLB7		13	1.8		11	23	21
WB1	540	920	170		79	160	540
WR1	130	350		350	33	23	79
WR2	1600	350		110	7.8	6.8	13

2.2.2 Analysis of Instream Water Quality Monitoring Data

Because the St. Louis Bay 303(d) Listings were due to guidance and not the data provided above, no statistical summaries are provided.

3.0 SOURCE ASSESSMENT

The TMDL evaluation summarized in this report examined all known potential fecal coliform sources in the St. Louis Bay 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 12 facilities permitted to discharge fecal coliform included in the St. Louis Bay model. The 12 facilities serve a variety of activities including residential subdivisions, schools, industries, and municipalities. Marinas and shipyards located in the study area were considered to be discharging to the municipalities.

Samples were collected at the point sources during the July 1998 calibration study and again in the April 1999 verification study. Flow and fecal coliform values from the July 1998 study were used as input into the Bay model for calibration. For subsequent application runs of the model the maximum permitted limits were used for each facility. Every facility included in the model is listed in Table 3.1.

Table 3.1 shows the existing dischargers. However, the Gulf of Mexico Program Office (GMPO) 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 treatment and disposal approaches including land application, which would remove the discharge from the waterbody altogether. Similar efforts may be undertaken by Harrison and Jackson counties.

Table 3.1 Inventory of Point Source Dischargers

Name of Facility	NPDES #	Receiving Stream	Flow (MGD)	Permit Limit (mg/L)
Waveland Regional Wastewater Mgt. Dist.	MS0027847	Edwards Bayou	4.900	200
Diamondhead Water/Sewer Dist.	MS0046078	St. Louis Bay	0.180	200
Long Beach/Pass Christian Sewage Treatment Plant	MS0043141	Bayou Portage	1.560	200
Coast Episcopal High School	MS0028321	Canal No. 3	0.008	200
DeLisle Elem. School	MS0022799	Bayou Delisle	0.008	200
Discovery Bay	MS0021865	Bayou Portage	0.015	200
Dupont Outfall: 1N (Process WW)	MS0027294	St. Louis Bay	4.200	200
Dupont Outfall: 2A (Sanitary)	MS0027294	St. Louis Bay	0.034	200
Dupont Outfall: 3A (Storm)	MS0027294	St. Louis Bay	10.300	200
Five-Star Resort	MS0035131	Wolf River	0.008	200
Jourdan River Shores	MS0022870	Jourdan River	0.050	200
Long Beach Industrial Park	MS0022373	Canal No. 1	0.250	200

3.2 Assessment of Nonpoint Sources

There are many potential nonpoint sources of fecal coliform bacteria in the St. Louis Bay Watershed, including:

- Failing septic systems
- Wildlife
- Land application of hog and cattle manure
- Grazing animals
- Land application of poultry litter
- Other Direct Inputs
- Urban development
- Domestic Pets
- Boat Pumpout

The 523,000 acre drainage area of St. Louis Bay contains many different landuse types, including urban, forest, cropland, pasture, barren, and wetlands. The sources of failing septic systems, wildlife, land application of hog and cattle manure, grazing animals, land application of poultry litter, and other direct inputs are addressed in detail in the Phase One Jourdan River and Phase One Wolf River TMDLs. Because the Jourdan River and Wolf River drain into St. Louis Bay those sources could potentially impact the Bay. However, the area near the Bay is primarily urban and residential, including the activities of domestic pets, wildlife, septic systems, illicit connections, and landfills. Because St. Louis Bay supports both recreational and commercial boating, waste from those boats is also considered a likely source in the Bay.

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. These data were 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 dataset is 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. Figure 3.2 and Table 3.2 show the landuse distribution for the watershed.

Figure 3.2 Landuse Distribution

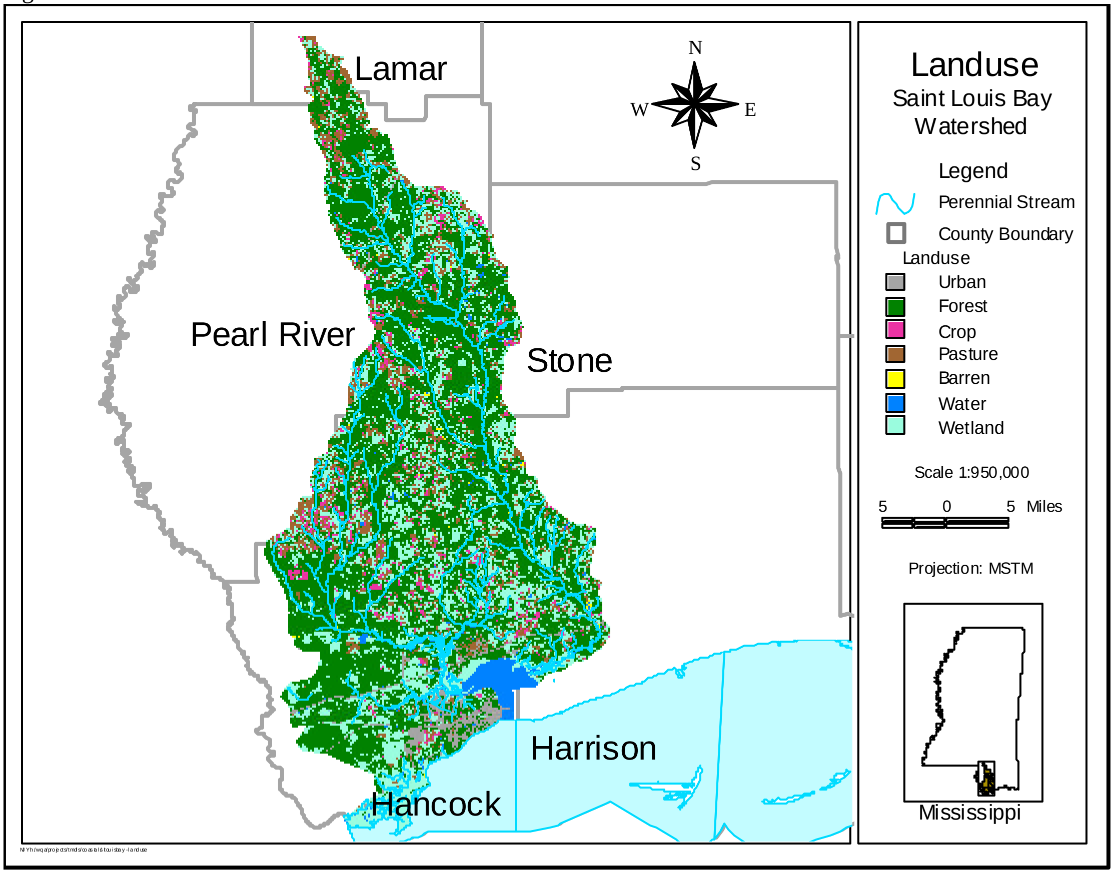


Table 3.2 Landuse Distribution in Acres for the St. Louis Bay Watershed

	Urban	Forest	Cropland	Pasture	Barren	Wetland	Total
Area (Acres)	11,726	303,729	14,319	45,541	874	132,609	522,593
% Area	2	58	3	9	0	25	100

For Jourdan River and Wolf River Watershed modeling purposes the landuse categories were grouped into the categories of urban, forest, cropland, pasture, barren, and wetlands. The contributions of each of these land types to the fecal coliform loading of the Jourdan River and Wolf River was considered on a subwatershed basis. 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. The output from the watershed models was input into the Bay model in order to account for watershed activities.

In the smaller watersheds near the Bay the watershed model was used only to simulate stormwater runoff. Through calibration, water quality simulation from the watershed model was found to be inadequate for the urban runoff loads entering the Bay. Event mean concentrations (EMCs) from the literature were found to be more accurate.

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

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 of the entire St. Louis Bay Watershed. It was also used to model the water quality of the freshwater rivers and streams in the watershed including the Jourdan River and the Wolf River Watersheds, which are described in their Phase One TMDL reports. 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.

4.2 Model Setup

The freshwater portions of the Jourdan River and the Wolf River Watersheds, located in HUC 03170009, were modeled within the NPSM watershed modeling system. The results for the freshwater watersheds are presented separately in Phase One TMDL reports. The freshwater portion of the Jourdan River and the Wolf River Watersheds were 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, as discussed in the Phase One reports, was used to simulate the flow and fecal coliform loadings from each subwatershed in the freshwater study area. The output from the NPSM was used to provide boundary condition input into the Bay model. At least the first 12 months of the model results were considered a stabilization period and disregarded. Flow and fecal concentrations from each subwatershed were simulated for the period March 26 to July 31, 1998 for the Bay model calibration and for the period January 1 to April 30, 1999 for the verification. The precipitation data from Poplarville, Picayune, Bay St. Louis at NASA, and Gulfport rain gauge stations were used for the model simulations. The precipitation data during the first intensive survey period (July 13-19, 1998) are shown in Figure 4.2a. The precipitation data during the second intensive survey period (April19-21, 1999) are shown in Figure 4.2b. Computed flow for the calibration period is shown in Figure 4.2c for the Wolf and upper Jourdan Rivers. Measured flow in the Wolf River is in good agreement with the computed flow at US Highway I-10. Figure 4.2d shows a sample of the computed fecal coliform concentrations at several major rivers and bayous used as input into the Bay Model calibration. Computed and observed flows for the verification period are shown in Figure 4.2e. for the Bay model boundaries. A sample of the computed fecal coliform concentrations at several major river and bayou boundaries are shown in Figure 4.2f.

Figure 4.2a Rainfall Data Distribution in St. Louis Bay (March 26-July 31, 1998)

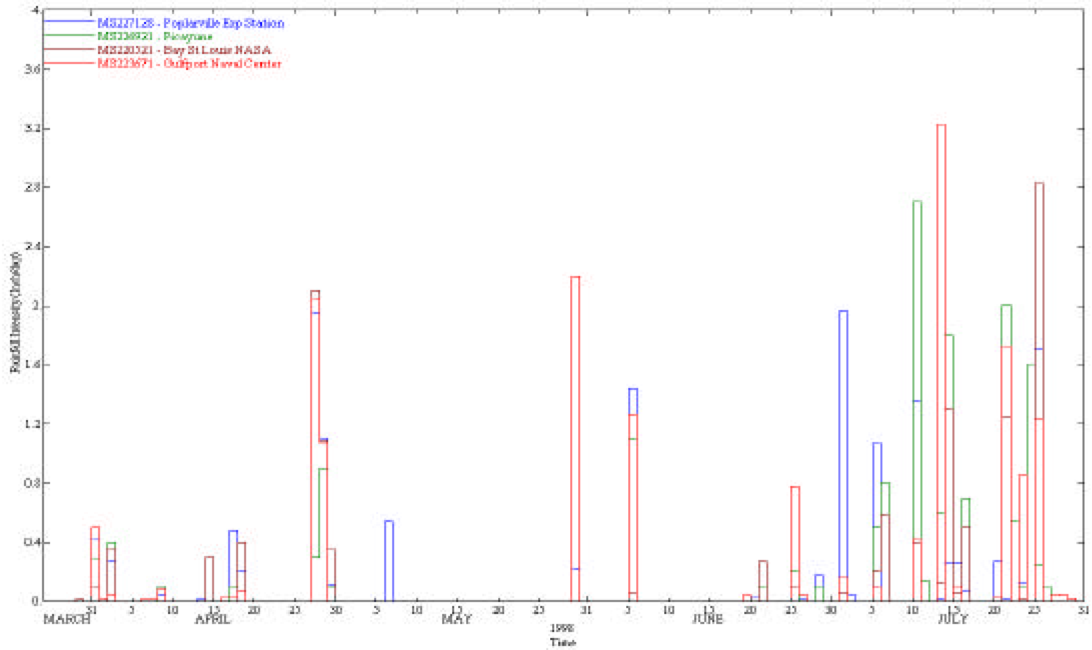


Figure 4.2b Rainfall Data Distribution in St. Louis Bay (January 1- April 30, 1999)

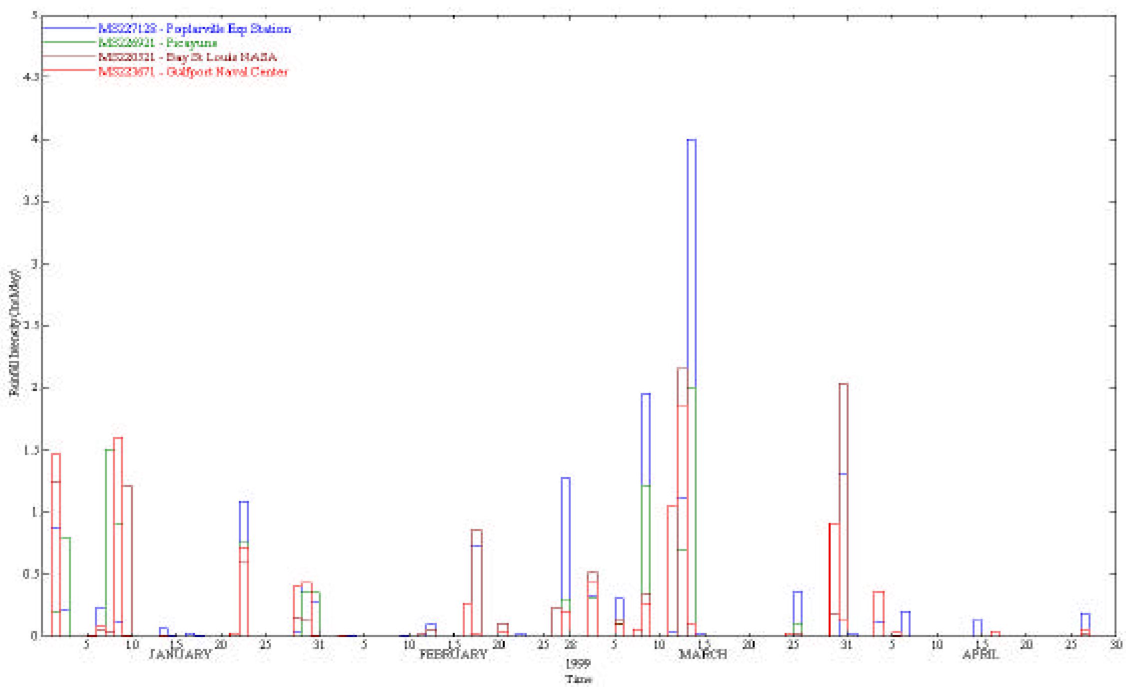
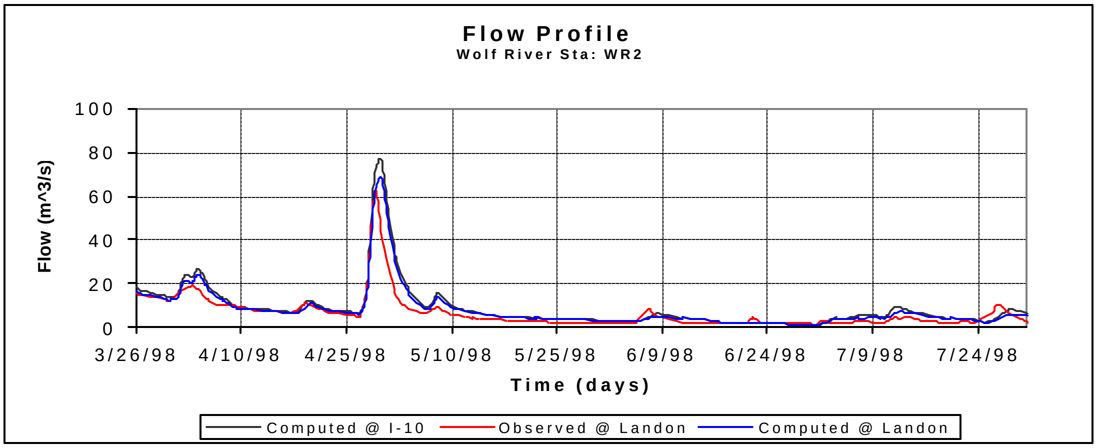


Figure 4.2c Calibration Flow Profiles for the Wolf and Jourdan River Boundaries in the Bay Model (March 26 – July 31, 1998).



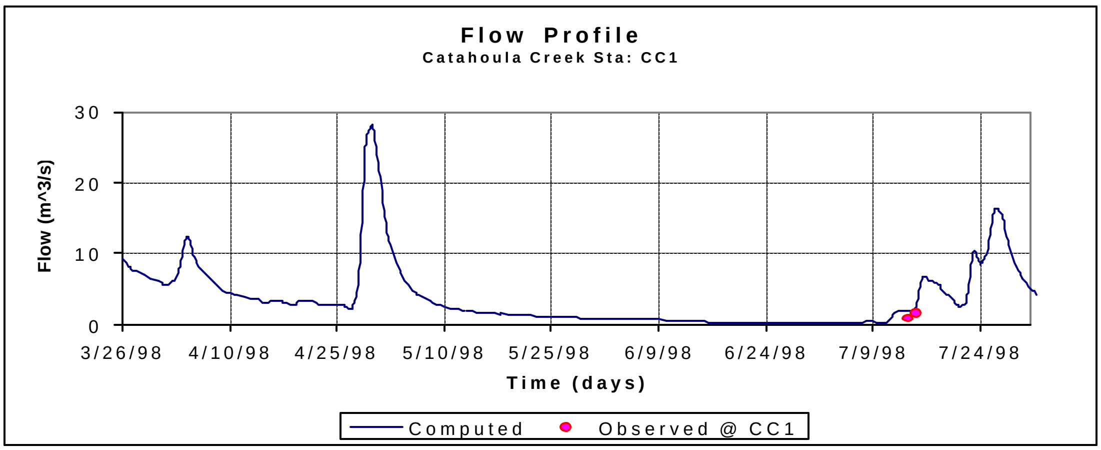
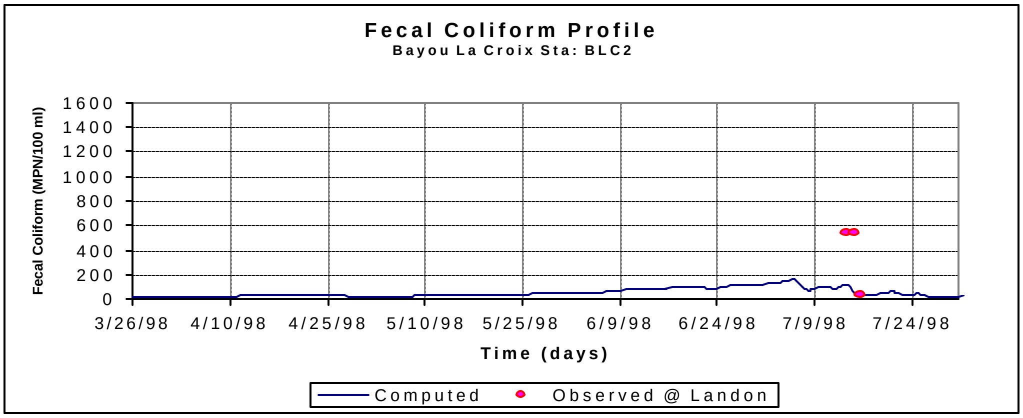
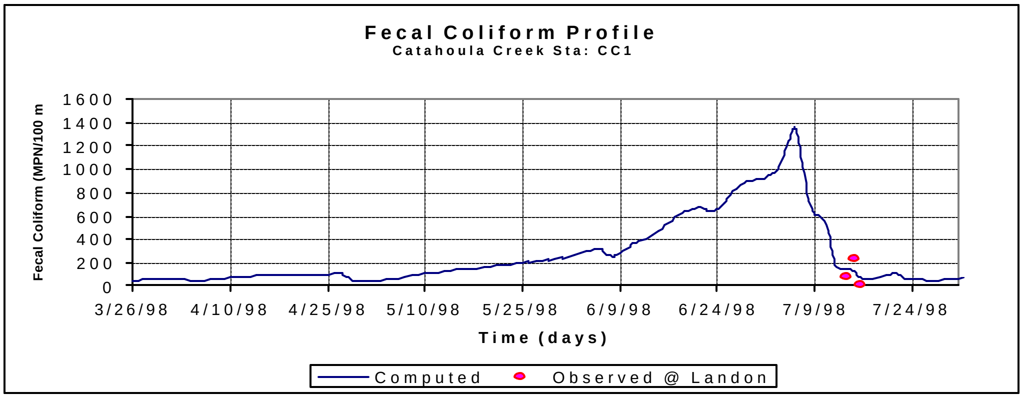
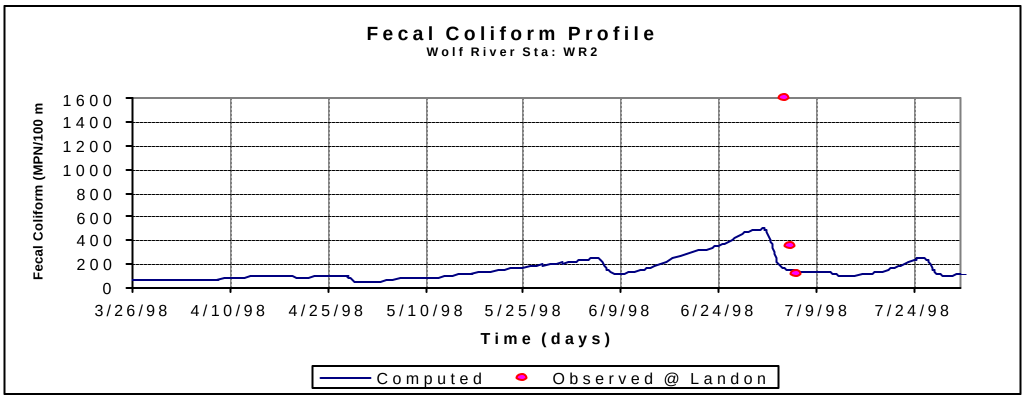


Figure 4.2d Calibration Fecal Coliform Profiles at the Bay Model Boundaries (March 26 – July 31, 1998)







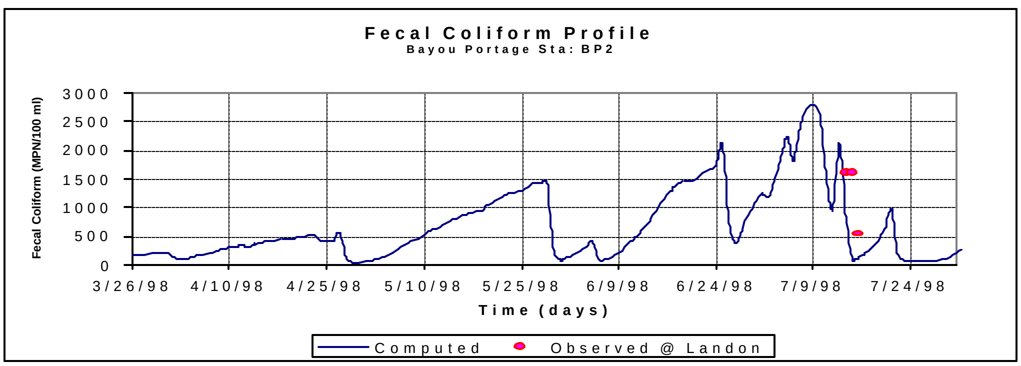
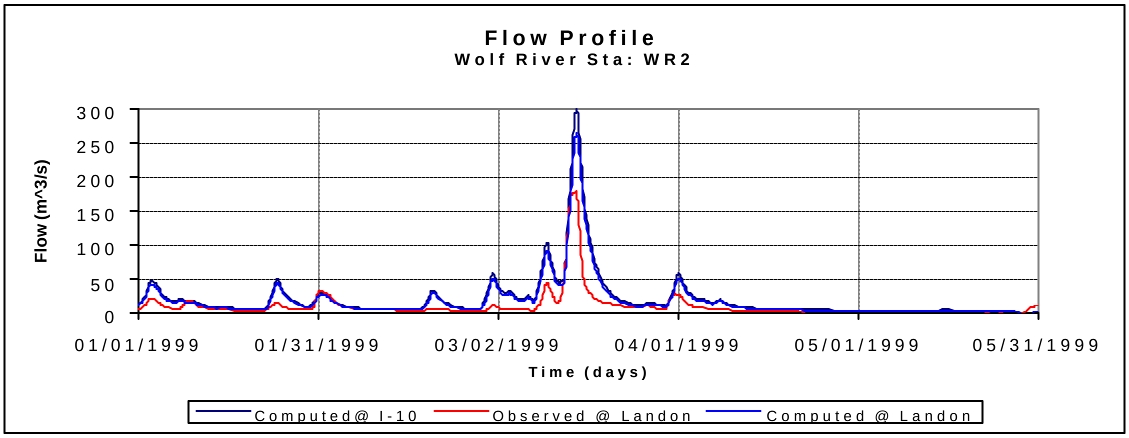


Figure 4.2e Verification Flow Profiles for the Wolf River and Jourdan River Boundaries in the Bay Model (January 1 – May 31, 1999)



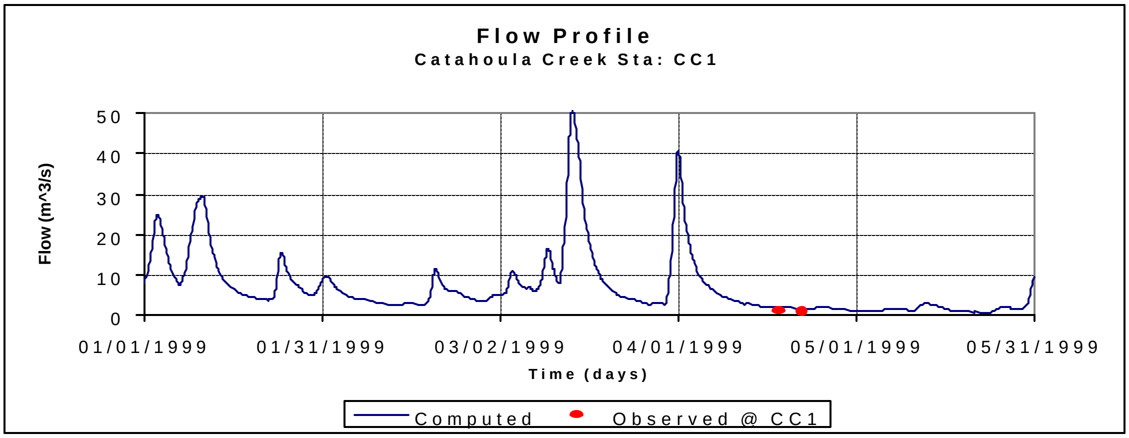
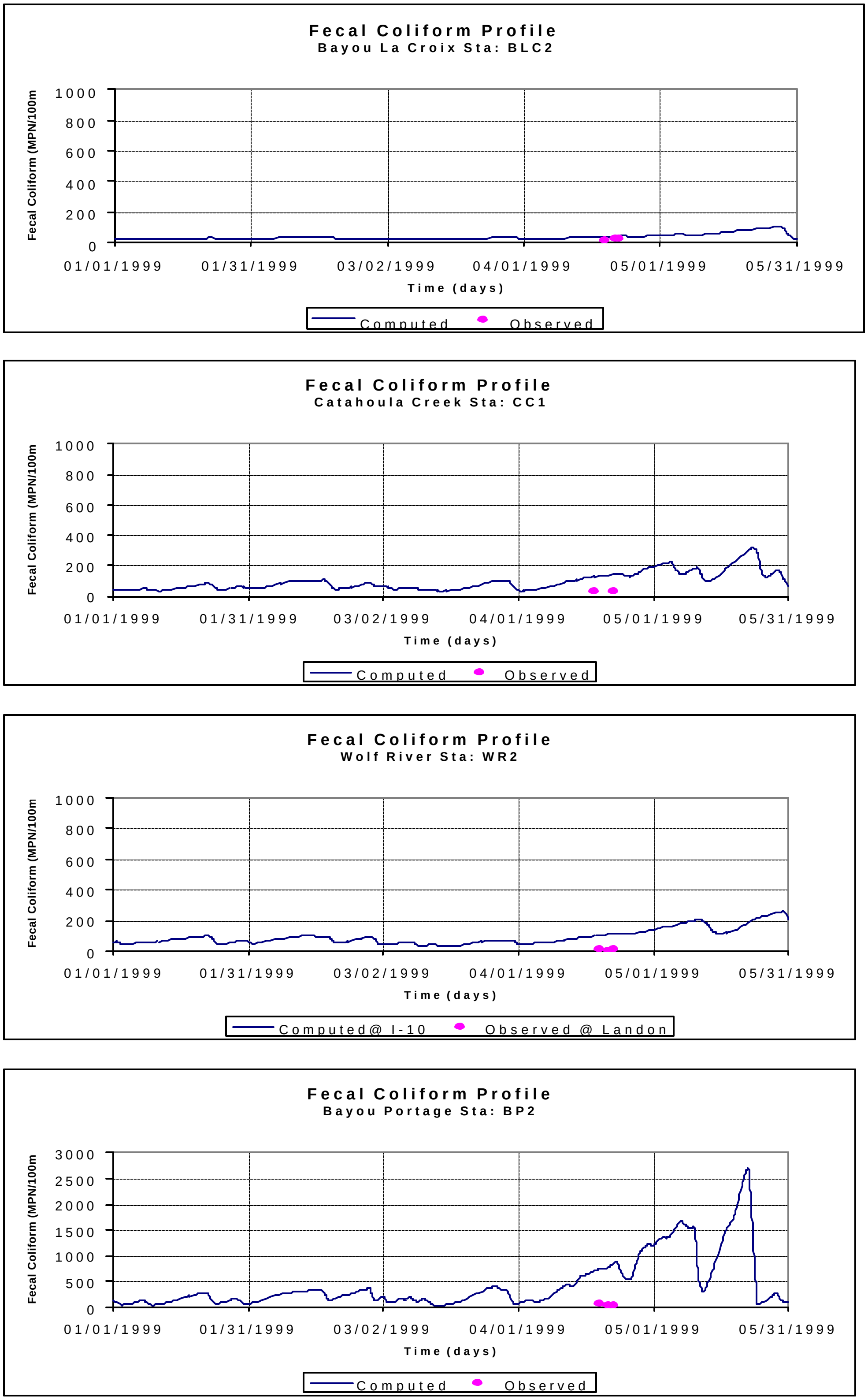


Figure 4.2f Verification Fecal Coliform Profiles at the Bay Model Boundaries (January 1 – May 31, 1999)



4.3 Hydrologic Calibration of the Bay model

Calibration results in a consistent set of model coefficients that are reasonable and reproduce the observed data for all state variables considered. All model coefficients should be consistent between the calibration period and the verification period. The method used in determining the values for the model coefficients is essentially one of trial and error. The starting point is a set of rate constants and parameter values, which have been used in previous modeling studies (King County Natural Resources, 1999; Tetra Tech, 1997).

4.3.1 Database

Water quality in St. Louis Bay has been monitored for over two decades dating back to 1966, both for shellfish harvesting and for specific studies. Historical water quality and quantity data of surveys conducted in the St. Louis Bay and/or its major tributaries are summarized in Table 4.3a and historical water level stations are given in Table 4.3b. The criteria for selecting an appropriate calibration/verification data set are adequate temporal and spatial coverage, and available data for all variables considered in the computation. An intensive survey conducted in July 13-19, 1998 was used as a calibration data set, and a second intensive survey conducted in April 19-21, 1999 was used as a verification data set. These two studies were selected because of the availability of a comprehensive set of data and adequate description of boundary conditions during the study period.

4.3.2 Boundary Data for Hydrodynamic Calibration and Verification

The hydrodynamic model (EFDC) was configured to simulate four (4) physical characteristics of the St. Louis Bay model: salinity, velocity, temperature, and water elevation. As a condition to the numerical solution of the equations used to predict the four variables, values for salinity, velocity, temperature, and water elevation must be specified at the model boundaries. Conditions at the St. Louis Bay seaward boundary was defined by water elevation, temperature, and salinity time series. Conditions at the upstream boundaries (rivers and bayous) were defined by daily averaged river flow and freshwater (zero salinity). Freshwater flows computed by the calibrated/verified watershed model (BASINS Version 2) were prescribed at the upstream boundaries.

Table 4.3a Historical Water Quality and Quantity Data for St. Louis Bay Estuarine System

SURVEY DATE	AGENCY	WATER QUALITY DATA	HYDROLOGICAL DATA	WASTE SOURCES
12/5/66-11/16/67 St. Louis Bay	MSBH	Coliform, Fecal Coliform		
April,1968-April,1969	GCRL	Monthly T, Salinity, DO, pH (surface and Bottom); Monthly P, PO4, NO3 (Surface and Bottom)	Monthly Flow Averages (Surface and Bottom)	
6/28/71-11/21/72 St. Louis Bay	GCRL	T,pH,Turb., Salinity, Coliform, Fecal Coliform, Enterococci		
8/4/72-8/6/72 (Jourdan and Wolf Rivers, Levee Canals, Johnson Bayou, Portage Bayou, St. Louis Bay)	USEPA	T, pH, Chloride, BOD5, TOC, DO, TKN, NO2+NO3, TPHO, TC, FC	Daily USGS Stream Flow Measurement near Layman, MS; Estimated Flow at Wolf River Mouth (7/20-8/20/98) Partial Tide Records at Louisville and Nashville Railroad (L&N RR) bridge and Jourdan River Tide Gauges and Predicted "Tide Stage"	Municipal Waste Sources: Long Beach #1 and #2; Bay St. Louis STP; Pass Christian STP
12/77-12/78 (St. Louis Bay, Jourdan and Wolf Rivers, and Bayous)	GCRL	T, Salinity, pH, DO, Transparency, Secchi Disk,Color (Surface, 1,2, and 3 meters), Salinity, Turb, TC, FC,NH3, NO2+NO3, Ortho_P, TP, SO4, S, OC, IOC, Alk, Chloride, SS, Turb Trace Metals	Current Magnitude and Direction 3 Tide Gage Stations (24 hrs Period 0400 3/21 – 0400 3/22/78)	
9/24/84-9/28/84 (Edwards Bayou, Watts Bayou, Joes Bayou, Jourdan River)	BPC USEPA	Secchi depth, DO, pH, Salinity, Cond, T Collected with depths BOD5, SS, N, FC, DO, T, pH, SS, TKN, NH3, ON, NO2+NO3	Predicted St. Louis Bay Tides published by Cooperative Extension Service/Sea Grant Advisory Service Dye Study	2 WWTP
1/29/86-1/30/86 (Pass Christian WWTP Tracer Study- Bayou Portage,)	FDA MSDH		Tracer Study	
8/4/88/-6/10/98 St. Louis Bay Mississippi Sound	MSDMR	Salinity, Temp., Fecal Coliform,		
7/89-10/89 (Edwards Bayou Study)	WRWMD USEPA BPC	Res.Chlorine, pH, Sal, Cond, T, DO,FC collected with Depth		Composite Waveland and Bay St. Louis (Semimonthly)
9/9/96-9/20/96 (Edwards Bayou) (No Report)	GCRL	T, DO, %Sat, Cond, pH, Salinity, Secchi Depth collected with depth pH, T, DO, Cond, Salinity, Secchi Depth, TOC, TP, TKN, NH3, NO2+NO3, DO% Sat, Chloride, Ortho_ P, BOD Waveland WLA Study Chlorophyll_a, FC Analysis		Waveland POTW

Table 4.3a Continued, Historical Water Quality and Quantity Data for St. Louis Bay Estuarine System

SURVEY DATE	AGENCY	WATER QUALITY DATA	HYDROLOGICAL DATA	WASTE SOURCES
9/19/96-9/20/96 (Jourdan River)	USGS		Tide Levels and Discharge Measurements were Made at the Measuring Site on Jourdan River Near I-10	
7/14/98-7/21/98 (St. Louis Bay, Jourdan and Wolf Rivers, and Other Bayous)	MDEQ USEPA MSDMR	Hydrographic Profiles: T,pH,Cond, DO,%Sat pH, T, DO, Cond, Sal, TP, TKN, NH3, NO2+NO3, TSS, Turb, FC, Entero_MF, Ortho_P Diurnal Water Quality (14 Stations): pH, Cond, Sal, DO % Sat, DO, T Community SOD FC and Entero_MF	Rating Curves/Tables: Catahoula Creek; Bayou Bacon; Orphan Bayou; Bayou La Terre; Rotten Bayou Water Levels (transducers): Wolf River ; Rotten Bayou; Bayou Portage; Catahoula Creek; Bayou La Terre Tidal Elevations: Jourdan River; Wolf River; US90 Crossing, Waveland Rainfall Data: US 90 Crossing, Waveland,Bay St. Louis, Pass Christian, Gulfport Base, Gulfport Harbor, Biloxi AFB, Biloxi Harbor, Pascagoula, Pearl River, Merril River, Wolf River %Cloud Wind Speed and Direction @Gulfport Harbor Time of Travel Studies @ Jourdan and Wolf Rivers Diffusion and Reaeration Rates Current Meter Data (6 Stations): Jourdan River, Wolf River and 4 Locations in the Bay)	Diamondhead, Dupont, Jourdan River Shores, Long Beach, Pass Christian, Waveland STP
6/21/99-6/29/99 (St. Louis Bay, Jourdan and Wolf Rivers, and Other Bayous)	MDEQ USEPA MSDMR	Hydrographic Profiles: T,pH,Cond, DO,%Sat pH, T, DO, Cond, Sal, TP, TKN, NH3, NO2+NO3, TSS, Turb, FC, Entero_MF, Ortho_P Diurnal Water Quality: pH, Cond, Sal, DO % Sat, DO, T Community SOD FC and Entero_MF	Rating Curves/Tables: Catahoula Creek; Bayou Bacon; Orphan Bayou; Bayou La Terre; Rotten Bayou Water Levels (transducers): Wolf River ; Rotten Bayou; Bayou Portage; Catahoula Creek; Bayou La Terre Tidal Elevations: Jourdan River; Wolf River; US90 Crossing, Waveland %Cloud Wind Speed and Direction @Gulfport Harbor Time of Travel Studies @ Jourdan and Wolf Rivers Diffusion and Reaeration Rates Current Meter Data (6 Stations): Jourdan River, Wolf River and 4 Locations in the Bay)	Diamondhead, Dupont, Jourdan River Shores, Long Beach, Pass Christian, Waveland STP

Table 4.3b CO-OPS Historical Water Level Station Index for St. Louis Bay

Station	Station Name	Install Date	Removal Date
8746724	Johnson Bayou, MS	10/31/1978	02/01/1979
8746737	Cuevas, Eastern Bayou Portage, MS	10/31/1978	02/01/1979
8746819	Pass Christian YC, Mississippi Sound, MS	06/29/1979	12/17/1980
8746908	Delisle, Delisle Bayou, MS	10/31/1978	02/01/1979
8746943	Hendersen Ave, Bayou Portage, MS	10/31/1978	02/01/1979
8747038	Hendersen Ave. Bridge, Wolf R., MS	05/31/1978	06/01/1979
8747131	Mallini Bayou North, MS	10/31/1978	02/01/1979
8747145	Mallini Bayou South, MS	10/31/1978	02/01/1979
8747398	North Shore, Bay of St. Louis, MS	10/31/1978	02/01/1979
8747437	Bay Waveland YC, Bay St. Louis, MS	05/31/1978	12/31/1996
8747437	Bay Waveland YC, Bay St. Louis, MS	01/01/1997	11/10/1997
8747438	Bay St Louis, Bay St. Louis, MS	10/31/1978	02/01/1979
8747674	Rotten Bayou East, MS	02/27/1979	06/01/1979
8747739	Jourdan River Entrance, MS	10/31/1978	02/01/1979
8747766	Waveland, Mississippi Sound, MS	10/28/1996	operating
8747819	Watts Bayou, Jourdan River, MS	10/31/1978	02/01/1979
8747934	Cutoff Bayou, MS	02/27/1979	06/01/1979
8747961	Rotten Bayou, MS	05/31/1978	06/01/1979
8748005	Breath Bayou, Jourdan River, MS	10/31/1978	02/01/1979
8748087	Lower Jourdan River, MS	05/31/1978	06/01/1979
8748145	Bayou La Croix, MS	05/31/1978	06/01/1979
8748278	Bordage’s Marina, Bayou Caddy, MS	06/30/1978	10/01/1978
8748318	Bayou Philip, MS	02/27/1979	06/01/1979
8748371	Jourdan River, MS	05/31/1978	06/01/1979
8748469	Bayou La Croix West, MS	02/27/1979	06/01/1979
8748568	Jourdan River West, MS	02/27/1979	06/01/1979

4.3.3 Hydrodynamic Calibration and Verification Database

Hydrodynamic data sources for St. Louis Bay used in the calibration are presented in Table 4.3c. The location and type of hydrodynamic sampling stations are shown in Figure 4.3a. As shown in the figure, tidal stage measurements were made at Wolf River, Jourdan River, Rotten Bayou, and within the Bay. The observed tidal information (water elevation) measured at Waveland was used at the seaward boundary. Current velocity and direction were measured at six stations within the bay. Information on wind speed and direction was obtained from the Slidell and Gulfport meteorological stations to define wind conditions within the model domain. Temporal variation of wind speed and direction was introduced at model boundary condition but no data was available describing spatial variation of wind conditions. Continuous and water column profiles of salinity and temperature were taken at several stations during the survey as indicated in Figure 4.3b.

Bathymetric features for St. Louis Bay, major rivers, and small bayous were obtained from National Oceanic and Atmospheric Administration (NOAA) bathymetric records with shore boundaries digitized from the NOAA navigational charts. Thalweg bathymetric data for the Wolf River, Jourdan River, and for the major Bayous were surveyed by MDEQ (2000) from the Bay to a point where the stream was no longer navigable. Stream locations were digitized from United States Geological Survey (USGS) 7.5 minute maps. The bathymetric contour profile of St. Louis Bay is shown in Figure 4.3c.

Measurement of stream flows at the upstream model boundaries of Wolf River, Jourdan River, Rotten Bayou, Bayou La Terre, and Bayou Bacon were conducted on July 1998 by MDEQ. Transducers were placed at these stations for continuous recording of stream stage. Continuous stage taken on the Wolf River at the USGS flow station near Landon was converted to flow by the established rating curve.

Rainfall data used in the calibration/verification and application were collected during the field survey period by MDEQ. The National Oceanic and Atmospheric Administration (NOAA) monitor hourly and daily precipitation data at four (4) meteorological stations in the area. Daily precipitation at each weather station is presented in Figure 4.3d and Figure 4.3e for the calibration and verification period, respectively.

Table 4.3c Hydrodynamic Data Sources for Calibration and Verification

Date	Agency	Project Component	Data Category
07/14-19/98 04/14-19/99		Flow Measurement	Freshwater Inflows
07/14-19/98 04/14-19/99	MDEQ	Tide Stage	Water Surface Elevation
07/14-19/98 04/14-19/99		Meteorology	Wind, Rain, & Air Temp.
07/14-19/98 04/14-19/99		Currents	Velocity & Direction
		Water Quality (Endecos)	Salinity, Temperature, Depth
04/98 – 7/98 04/99 - 7/99	NOAA	Meteorology	Precipitation, Wind Speed and Direction
04/98 – 7/98 04/99 - 7/99	USGS	Flow Measurement	Discharge at Wolf River near Landon
1972	OPC/MDEQ	* Bathymetry	Wolf River, Jourdan River, Bay
1991	NOAA	Bathymetry	Bathymetry Map
02/2000	MDEQ	Bathymetry	Wolf River, Jourdan River, Bay, Bayou Portage, Johnson Bayou, Rotten Bayou, Bayou La Croix, Edwards/Watts Bayou

Figure 4.3a Locations of Hydrodynamic Sampling Stations

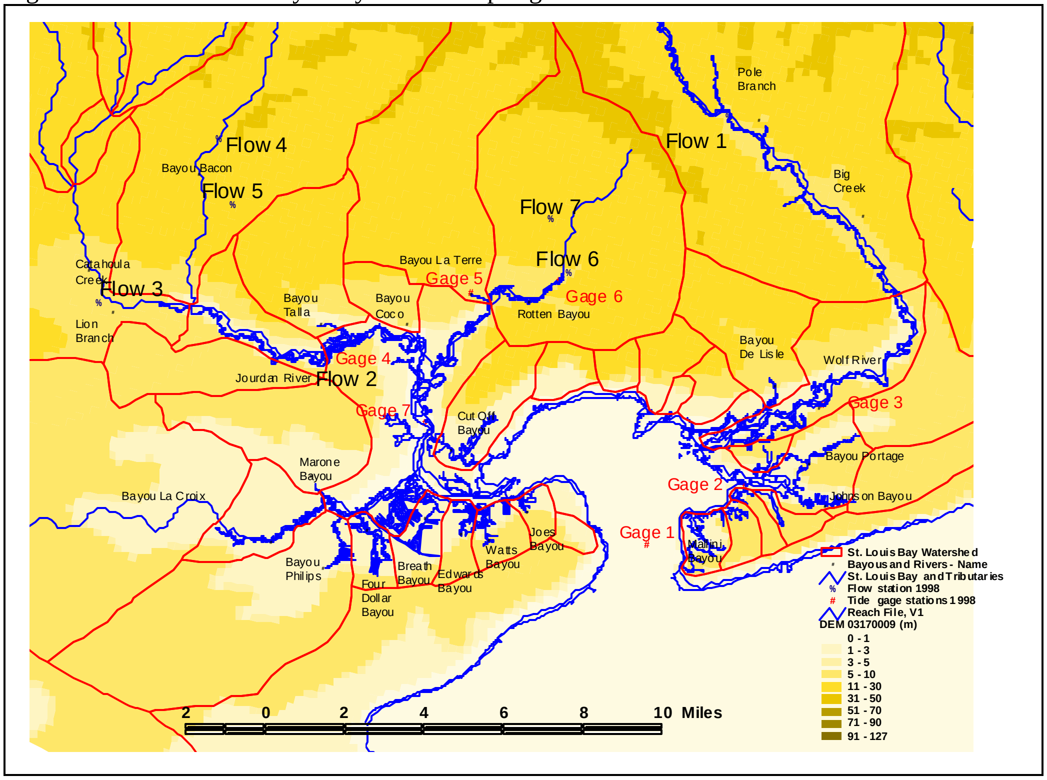


Figure 4.3b Location of Water Quality Sampling Stations

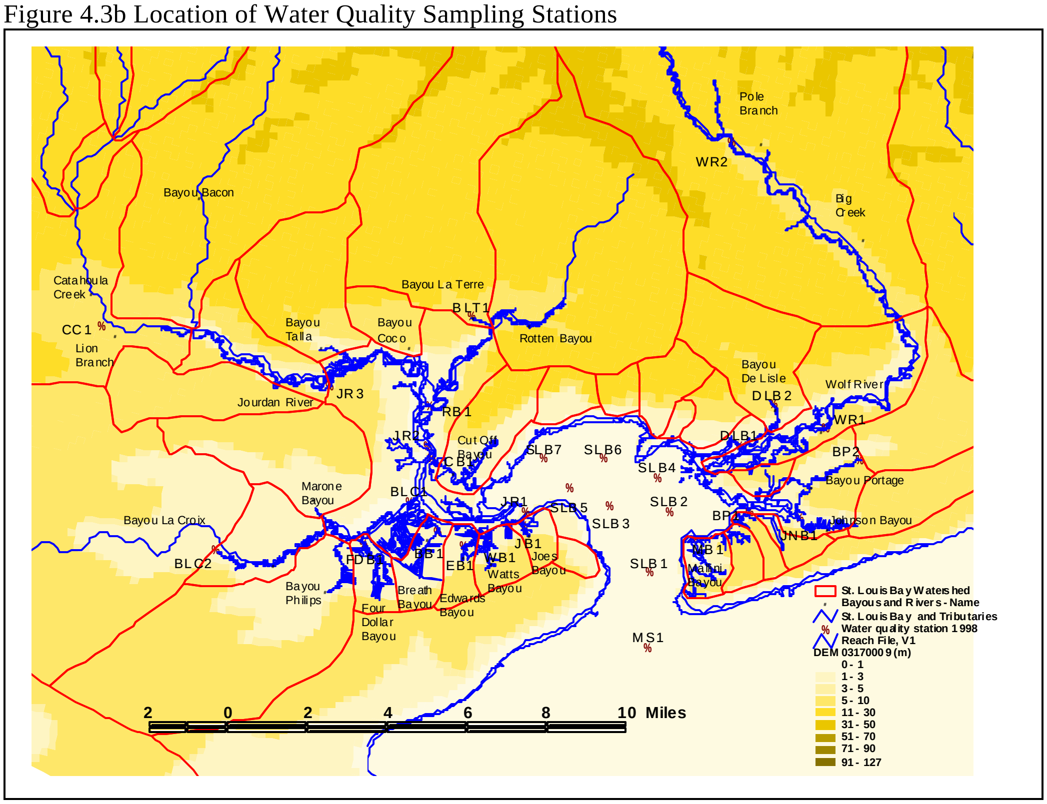


Figure 4.3c St. Louis Bay Bathymetric Contour Map

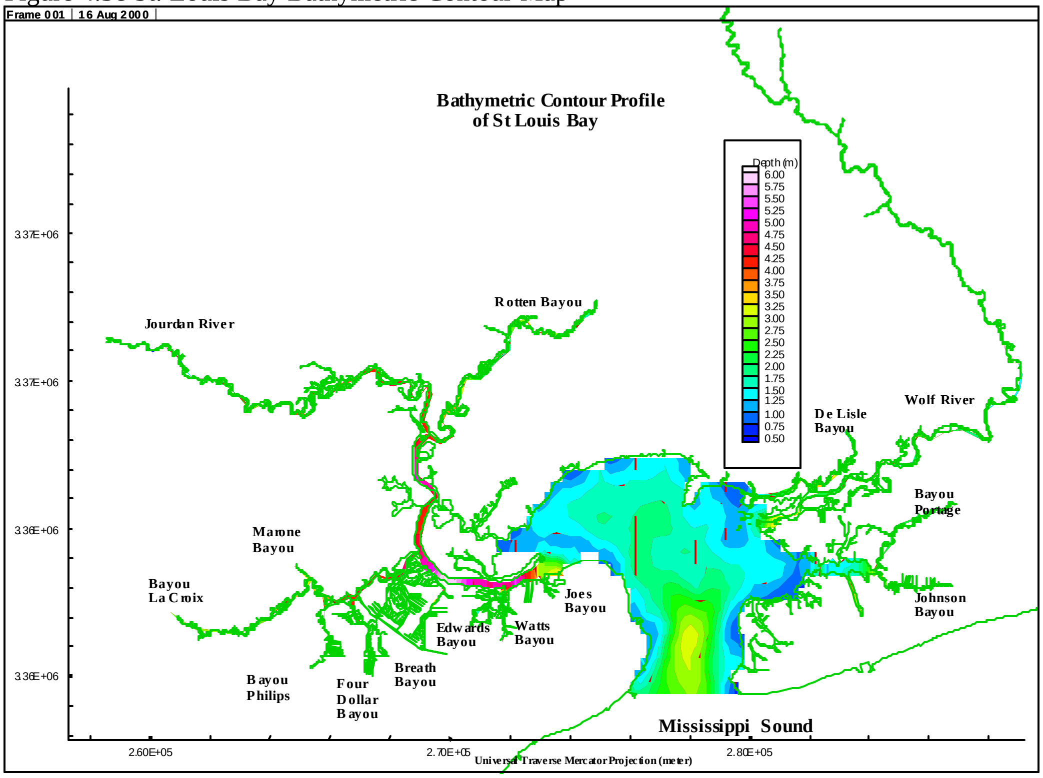


Figure 4.3d Rainfall Data during the Intensive Survey (July 1 – 30, 1998)

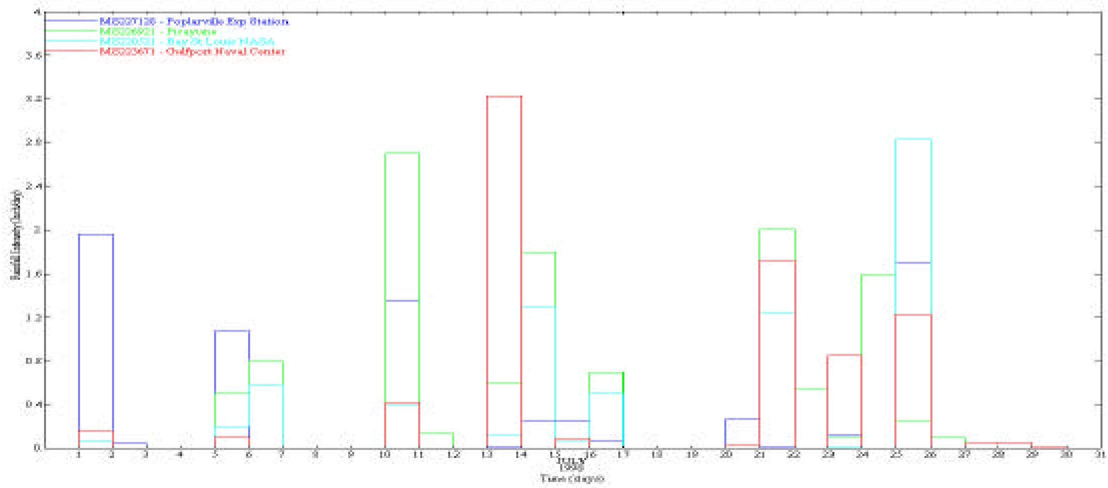
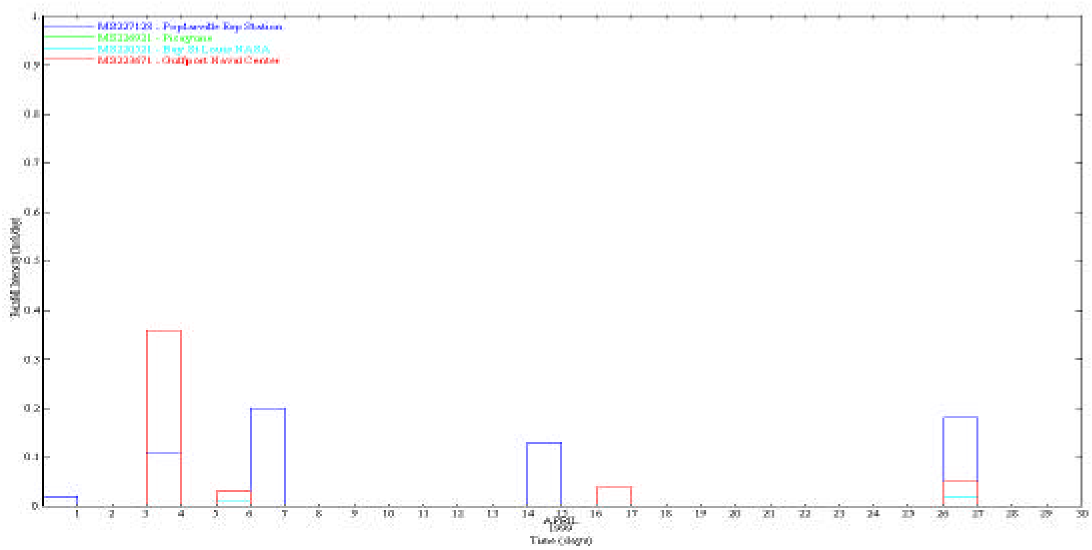


Figure 4.3e Rainfall Data during the Intensive Survey (April 1–30, 1999)



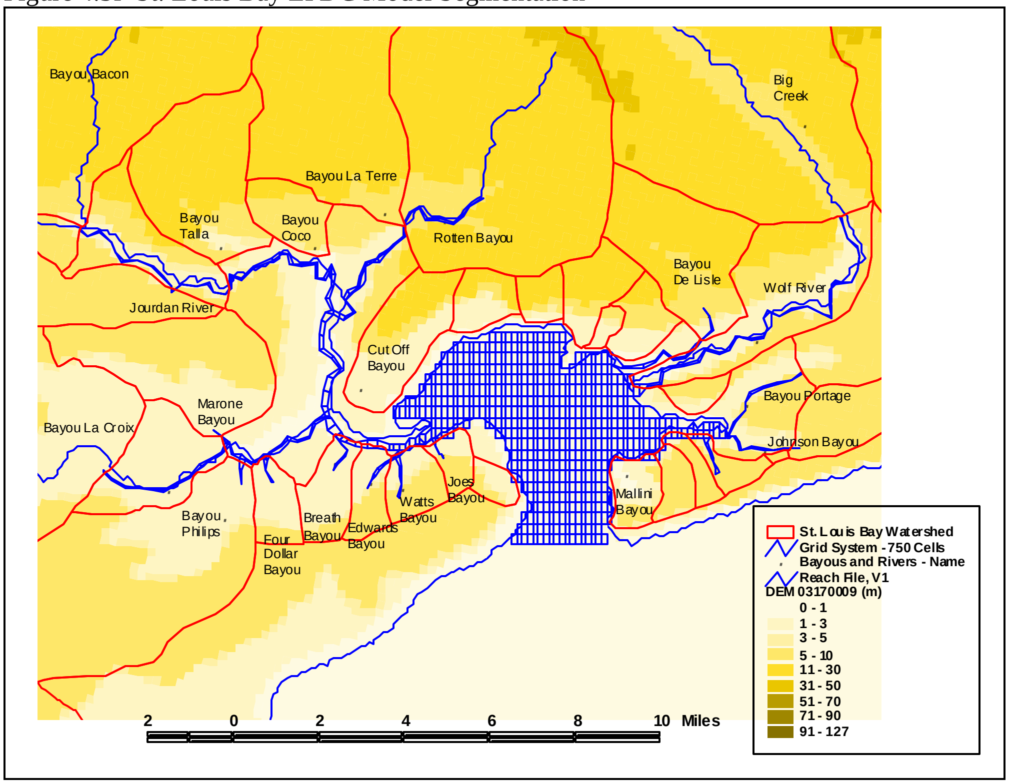
4.3.4 Bay Model Segmentation

The two fundamental types of structured grids used in numerical modeling, curvilinear, and Cartesian, are both applied in the St. Louis Bay application. The Virginia Institute of Marine Science (VIMS) grid generation code (GEFDC) processes both types, depending on input file designations. The model grid is composed of two merged "sub-grids", one of each type.

Three-dimensional segmentation in the Bay was selected to represent the spatial heterogeneity of the water bodies in longitudinal and lateral directions. By using approximately equal surface areas, this type of segmentation is capable of representing the physical shape of the water system. Lateral segmentation for the hydrodynamic model of the St. Louis Bay is illustrated in Figure 4.3f. The model simulation described herein is for both the Bay and tributaries. A Cartesian three-dimensional structured grid system generated by GEFDC grid generator was used in the Bay area of this study. An orthogonal two-dimensional structured grid system is used for the tributaries. In the transition area in the vicinity of river mouths, where the curvilinear portion is two dimensional in the horizontal, the grid coordinates produced by the grid generator are adjusted slightly by aligning the grid as much as possible to ensure orthogonality.

The EFDC hydrodynamic model consists of 750 active cells. There are eighteen downstream (seaward) boundary cells located at the junction of the St. Louis Bay with the Mississippi Sound. The upstream boundary cells include Wolf River, Jourdan River, Bayou La Croix, Rotten Bayou, Bayou La Terre, Bayou De Lisle, Bayou Portage, Johnson Bayou, Four Dollar Bayou, Breath Bayou, Edwards Bayou, Watts Bayou, Joes Bayou, Bayou Bacon, Bayou Coco, Lion Branch, Bayou Talla, Bayou Marone, Bayou Philips, Mallini Bayou, Young Bayou, Pole Branch, Big Creek, and several unnamed bayous.

Figure 4.3f St. Louis Bay EFDC Model Segmentation



4.3.5 Specification of Initial Conditions

When the EFDC model is first activated, an initial flow field of velocity, tidal height, and salinity values are required. It is important that the residual effects of any inaccurate initial spatial distribution be eliminated for each state variable (tidal elevation, velocity, salinity, and temperature) prior to comparing model results to field data. It is advantageous to restart the model with a set of values from a prior run which is as realistic as possible.

In this study, water velocities and tidal heights were initialized to zero (level free surface) everywhere. Prescribed boundary conditions were used to drive the system until an equilibrium condition. This is referred to as a "cold start", and "spinup" refers to a period of simulation before the model reaches equilibrium.

The initial conditions of salinity and temperature were specified in salt.inp and temp.inp files, respectively. Constant values were prescribed throughout the domain for each variable.

4.3.6 Geophysical Boundary Conditions

Boundary condition specification depends on the type of application at hand. In this study, the model is capable of reading separate input files for time series specifications of tidal height as well as salinity at the seaward boundary and freshwater discharges at upstream locations.

Bathymetric features for St. Louis Bay, the major rivers, and small bayous were obtained from National Oceanic and Atmospheric Administration (NOAA) and National Ocean Service (NOS) bathymetric records with shore boundaries digitized from the NOAA/NOS navigational charts (NOAA/NOS, 1991). These boundaries were compared to boundaries digitized from 7.5 minute United States Geological Survey (USGS) quad maps. Bathymetric data surveyed by MDEQ, both in the Bay and in the rivers and bayous flowing into the Bay, were used to supplement bathymetric data from NOAA/NOS. The Bay model divides the depth in each cell into two equal layers in the model domain.

The downstream boundary point for the model is located just outside of the mouth of St. Louis Bay. This downstream seaward boundary was forced by a tidal elevation series as measured at Waveland (NOAA/NOS, 1999)

The upstream boundaries of the Wolf River and Jourdan River are located outside the tidal influence, allowing the use of a simple flow time series boundary condition. Flow conditions were defined by computed flows from a calibrated/verified watershed model. The flow discharges from small bayous were computed as daily average flows at respective boundaries from the watershed model output.

Information on wind speed and direction was obtained from Slidell and Gulfport meteorological stations to define wind conditions within the model domain. The boundary conditions of surface water elevation, wind speed and direction, air temperature, atmospheric pressure, and solar radiation are shown in Figures 4.3g through 4.3k, respectively, for the 1998 calibration period. Similar boundary conditions are shown in Figures 4.3l through 4.3p for the 1999 verification period.

Figure 4.3g Calibration Surface Water Elevation at Waveland (NOAA/NOS, 1999

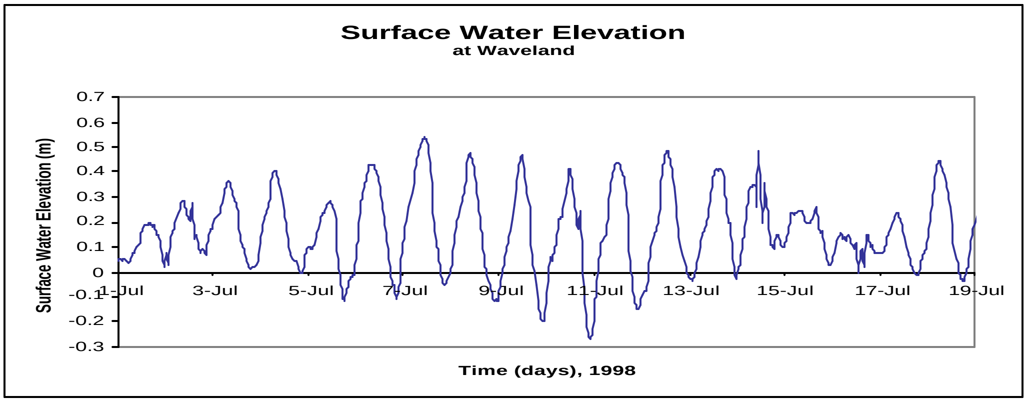


Figure 4.3h Calibration Wind Speed and Direction Profiles (NOAA, 1999)

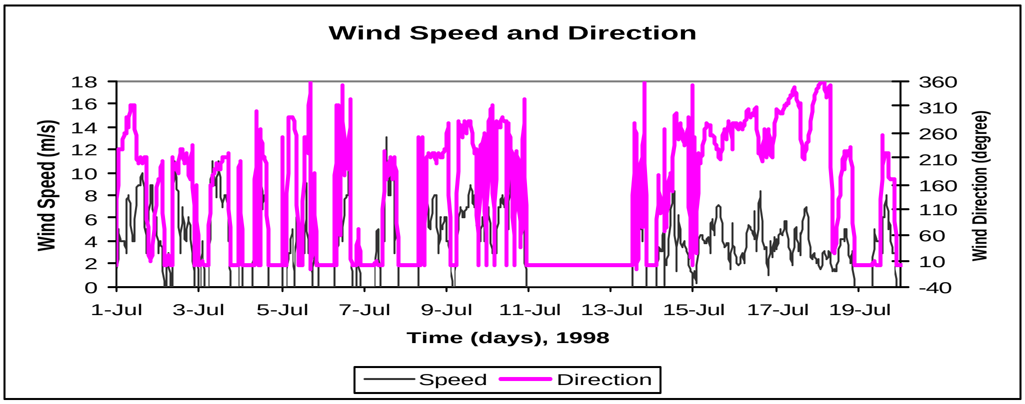


Figure 4.3i Calibration Air Temperature Profile (NOAA, 1999)

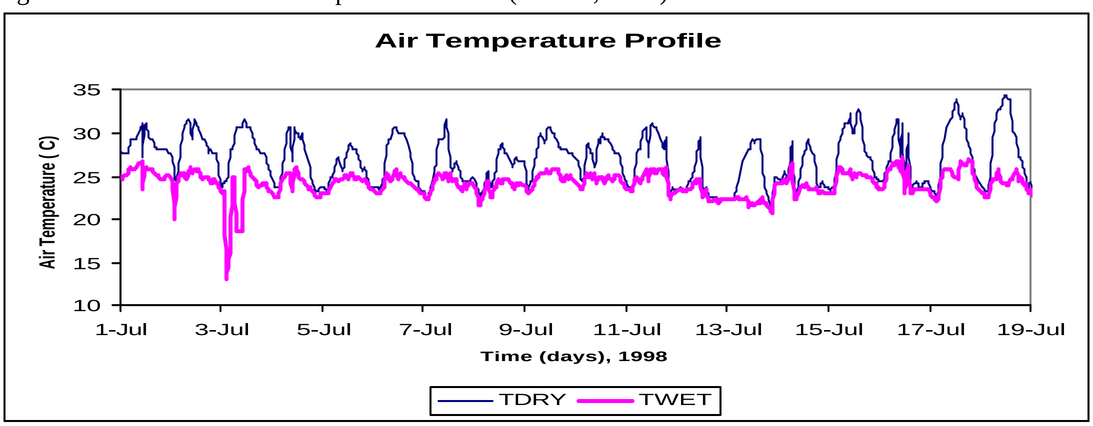


Figure 4.3j Calibration Atmospheric Pressure Profile (NOAA, 1999)

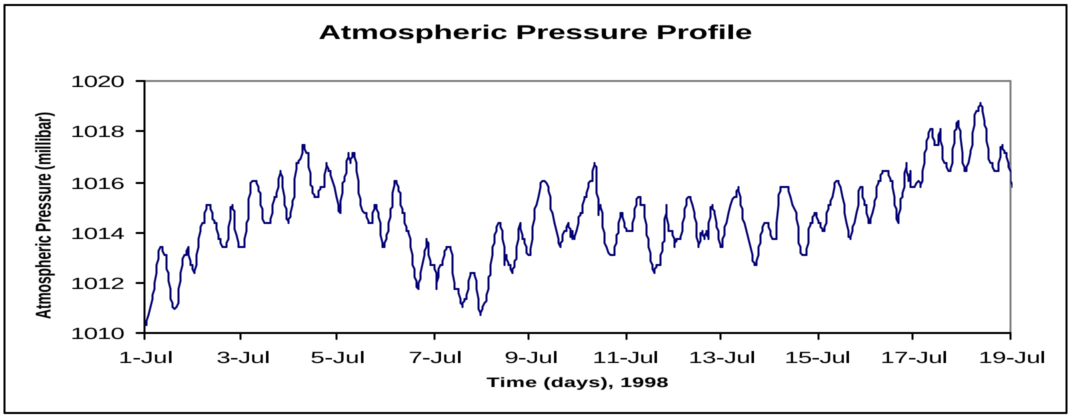


Figure 4.3k Calibration Solar Radiation Profile (NOAA, 1999)

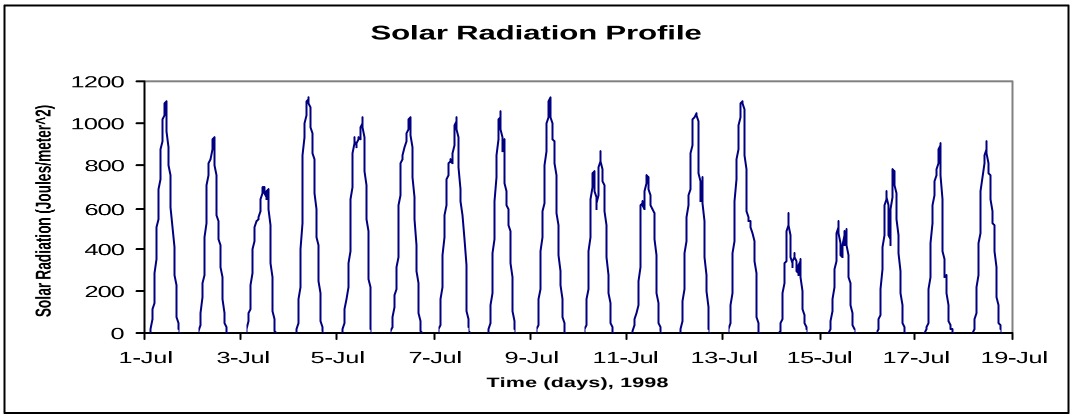


Figure 4.3l Verification Surface Water Elevation at Waveland (NOAA/NOS, 1999)

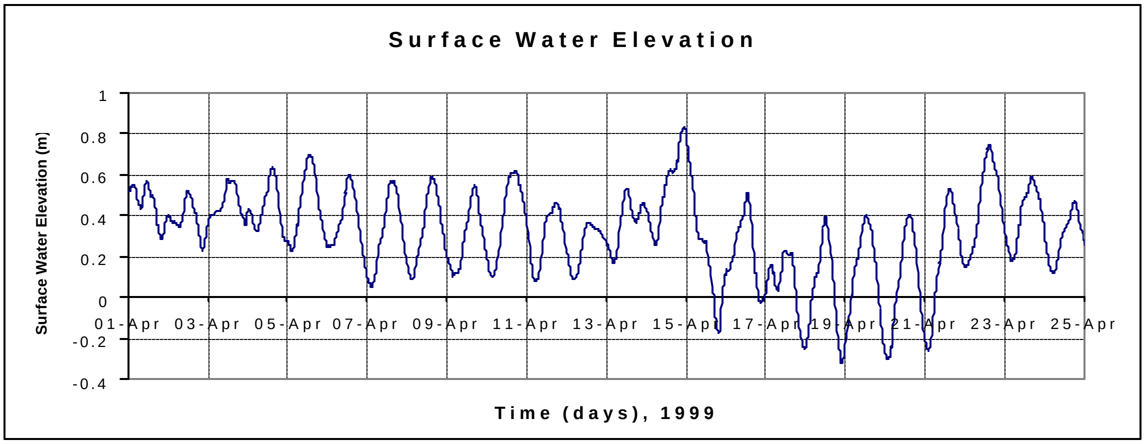


Figure 4.3m Verification Wind Speed and Direction Profiles (NOAA, 1999)

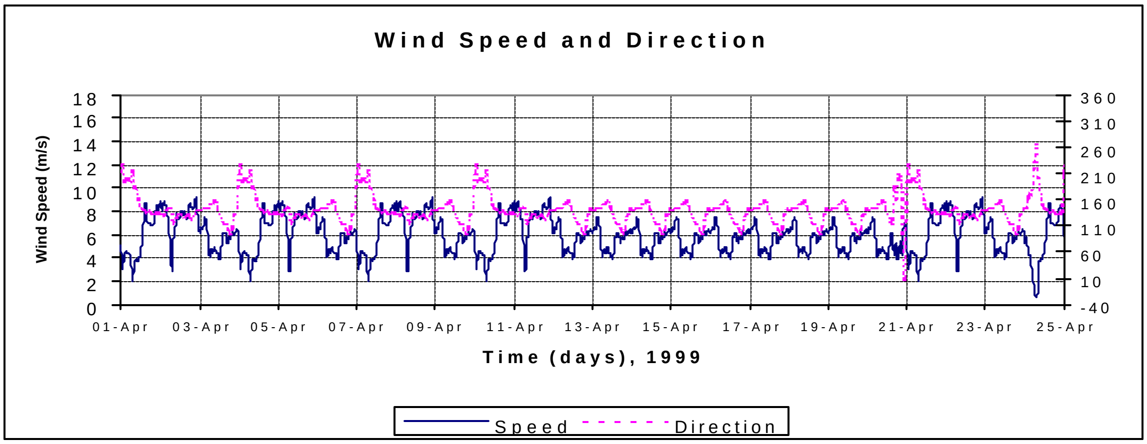


Figure 4.3n Verification Air Temperature Profile (NOAA, 1999)

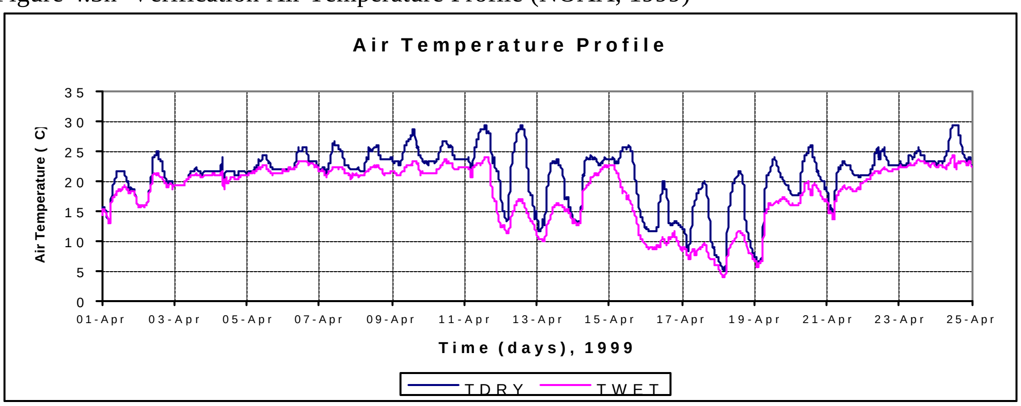


Figure 4.3o Verification Atmospheric Pressure Profile (NOAA, 1999)

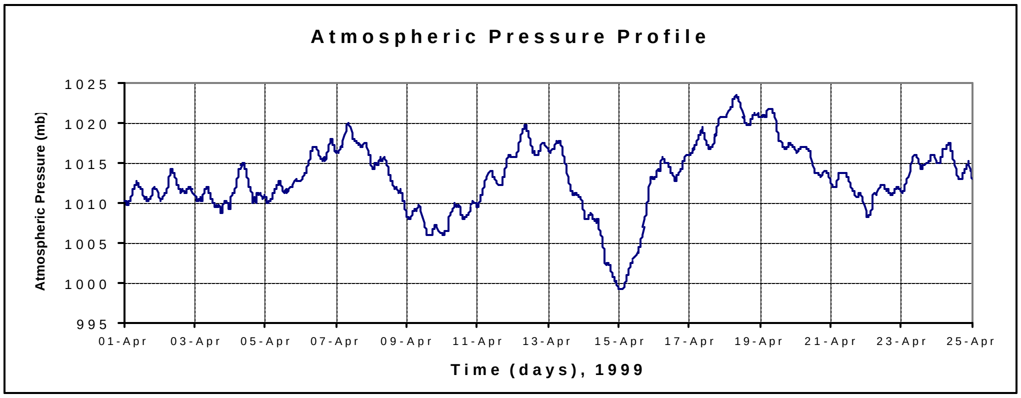
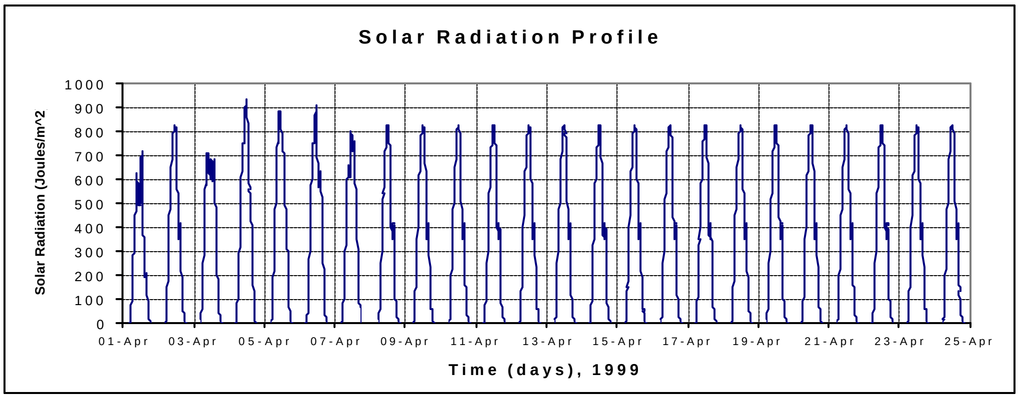


Figure 4.3p Verification Solar Radiation Profile (NOAA, 1999)



4.3.7 Geochemical Boundary Conditions

Chemical and salinity data in the water columns and continuous data collection gathered from the intensive surveys at the Mississippi Sound (MS1) field station were used at the seaward boundaries for model calibration and verification. Boundary conditions for the 1998/1999 calibration and verification periods were specified for upstream boundaries at Wolf River, Jourdan River, Bayou La Croix, Rotten Bayou, Bayou De Lisle, Bayou Portage, Four Dollar Bayou, Breath Bayou, Edwards Bayou, Watts Bayou, Joes Bayou, Johnson Bayou, and Mallini Bayou at Pass Christian, using field data collected at stations WR2, CC1, BLC2, BLT1, DLB2, BP2, FDB1, BB1, EB1, WB1, JB1, JNB1, and MB1. The location of these stations is shown in Figure 4.3b. For other small bayous, boundary concentrations were extrapolated from the closest station.

4.3.8 Results of Hydrodynamic Calibration and Verification

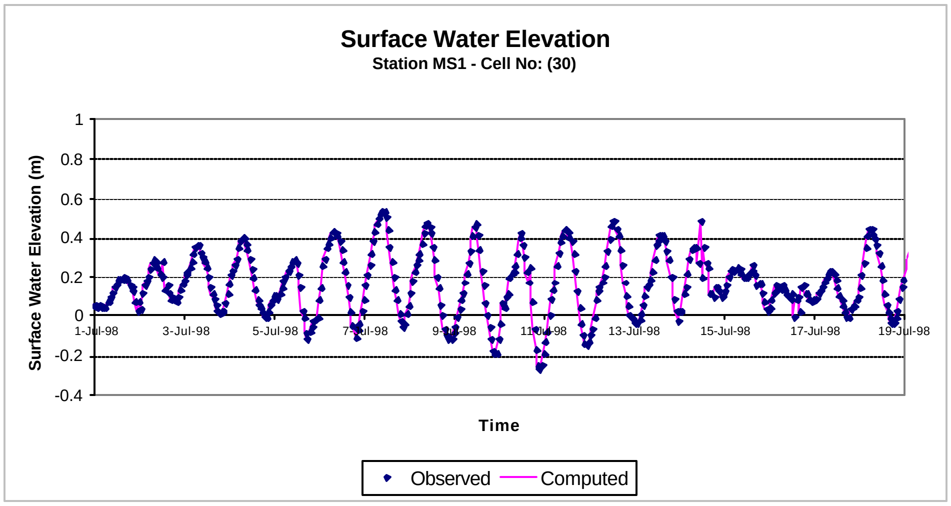
The model was executed using the boundary conditions as described above for the calibration period of 120 days (March 26-July 30, 1998). Bottom roughness was found to be the most influential modeling parameter for hydrodynamic calibration. Bottom roughness values were adjusted until the predicted results reasonably matched the observed data. After several adjustments, a bottom roughness of 2 cm was selected for use in this study. The model results were compared against observed data taken in the study period (July 14-17, 1998).

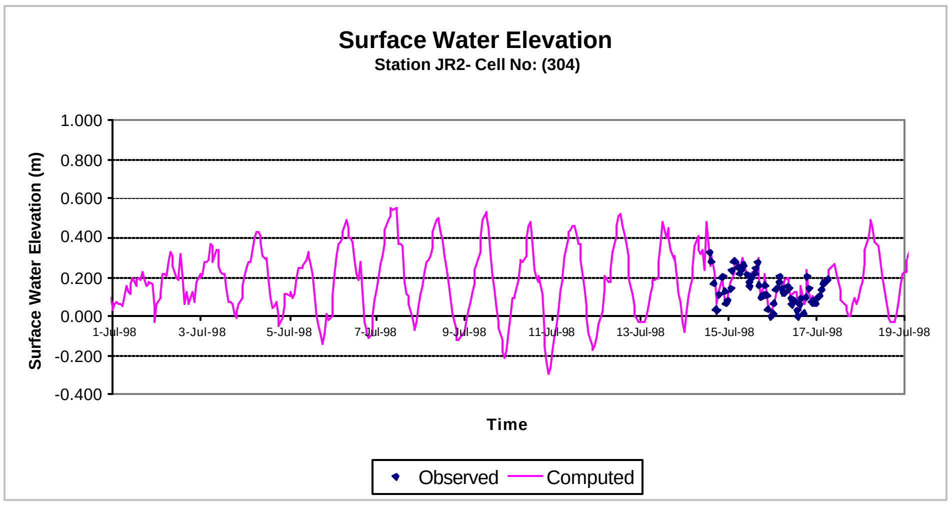
The temporal profiles of observed and predicted tide level and flow velocity are compared in Figures4.3q and Figure 4.3r, respectively for the calibration period. As shown in Figure 4.3p, the predicted tide levels reasonably matched the observed data at five sampling stations; MS1, JR2, WR1, BP1, and SLB1. These figures indicate that the model reasonably simulated the tide range and phase at a number of locations throughout St. Louis Bay. The velocity profiles at six (6) stations were compared against observed data (Figure 4.3r). The magnitude of predicted data was found to be in the range of observed data at each of the sampling stations. Similar temporal profiles of tide and velocity are shown in Figures 4.3s and 4.3t for the verification period (January 1- April 30, 1999).

The hydrograph of the Wolf River, as shown in Figure 4.2c, indicates a very wet hydrologic period for the first 45 days of the calibration period, followed by a relatively dry period with a low flow event occurring the last 75 days of simulation. This large variability in hydrology provided a good period in which to assess the capability of the model to reproduce salinity distributions during both dry and wet periods. Because the model employs a turbulent-eddy-viscosity and diffusion-solution scheme, the turbulent mixing between the fresh and saline waters cannot be adjusted directly. Constants used in the scheme are considered universal and should not be adjusted (Hamrick, 1992a). However, a minimum turbulent diffusion value is invoked in the model if the predicted value falls below the minimum turbulent value. The minimum turbulent diffusion value should not exceed $1x10^{-5}$ (m^2/s) (King County Natural Resources, 1999). In this study, the minimum turbulent diffusion value was not adjusted. Overall the salinity time-series graphs in Figures A.1 and A.2 (Appendix A) for the calibration period and Figures A.3 and A.4 (Appendix A) for the verification period, show good agreement with observations at all stations.

Water temperature in the EFDC model is a dynamic, computed physical parameter. Parameters, that impact the EFDC model water temperature include, wind speed, relative humidity, air temperature, and solar radiation. As shown in the Figures A.5 and A.6 (Appendix A) for the calibration period and Figure A.7 and A.8 for the verification period, computed water temperatures are in general agreement with observations.

Figure 4.3q Temporal Profile of Observed and Calibrated Tide Level, 1998 at MS1, JR2, and WR1





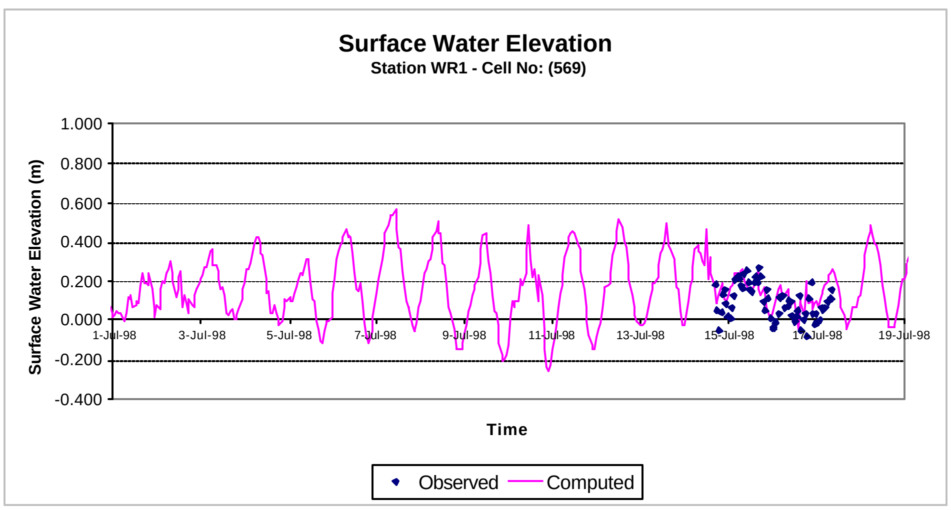
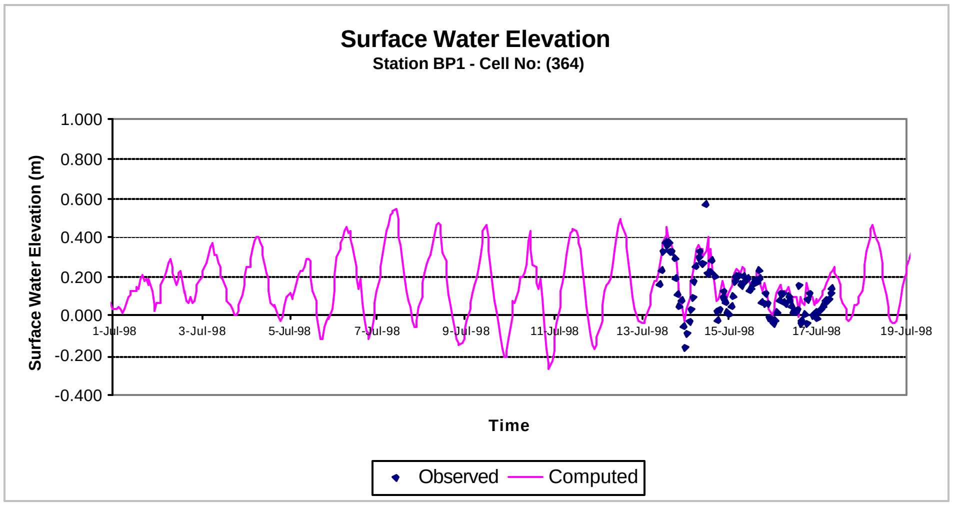


Figure 4.3q Continued Temporal Profile of Observed and Calibrated Tide Level, 1998 at BP1, and SLB1



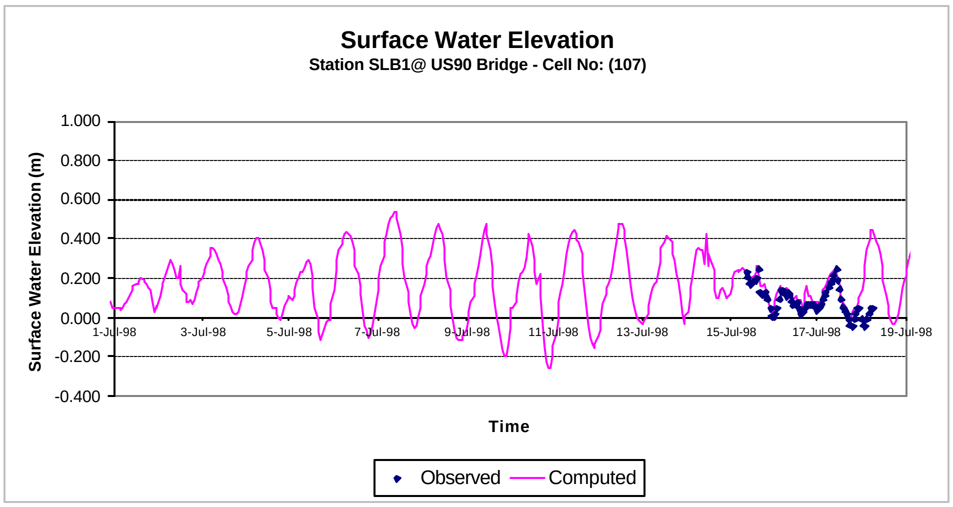
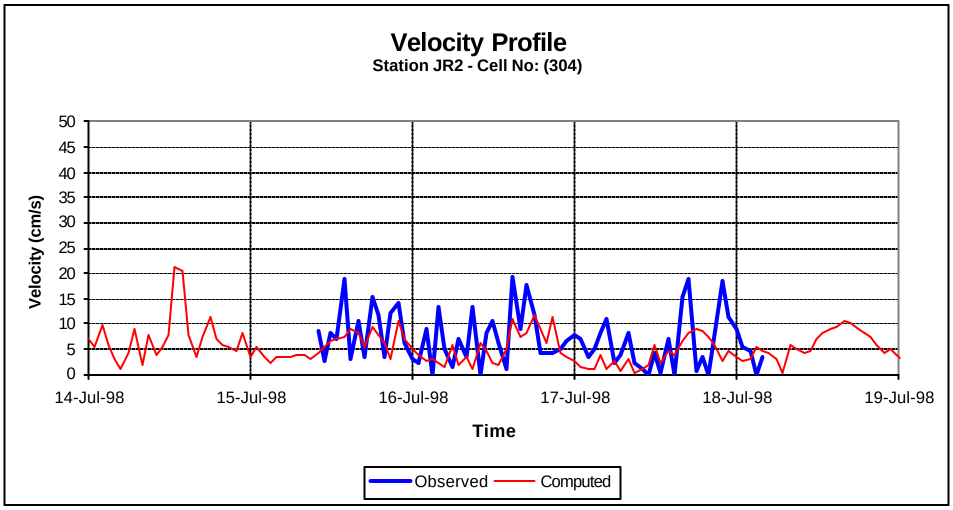
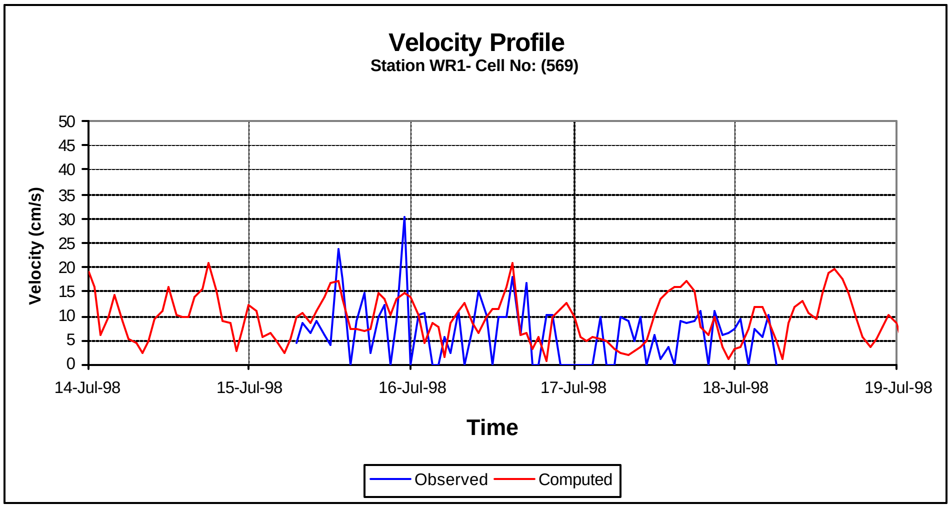


Figure 4.3r Temporal Profile of Observed and Calibrated Velocity, 1998 at JR2, WR1, and SLB1W





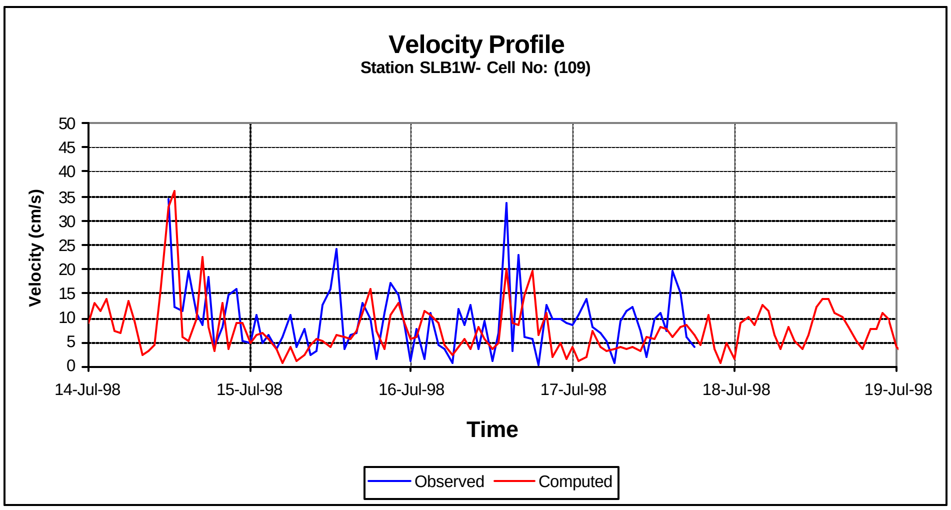
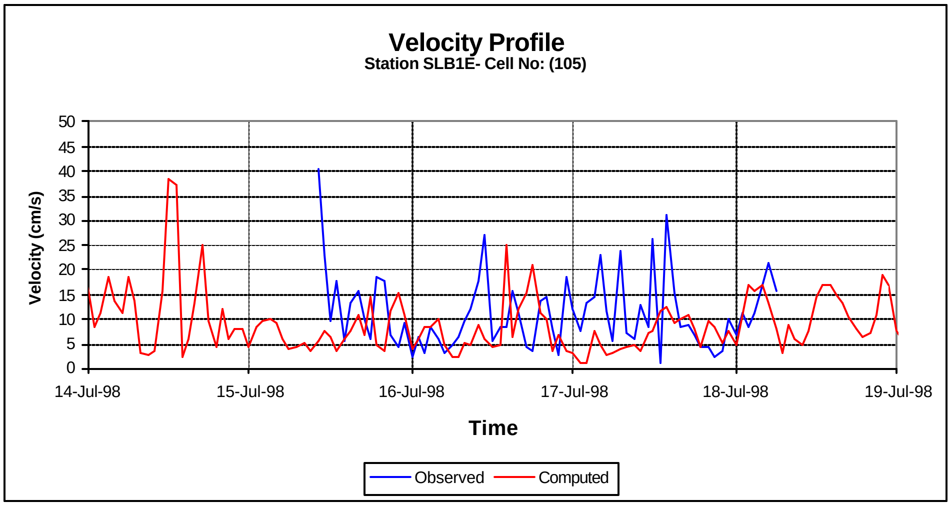
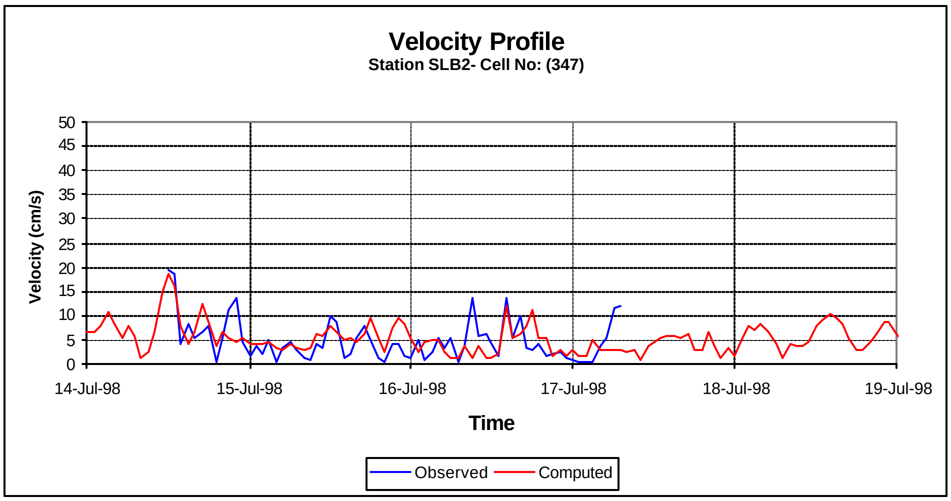


Figure 4.3r Continued Temporal Profile of Observed and Calibrated Velocity, 1998 at SLB1E, SLB2, and SLB6





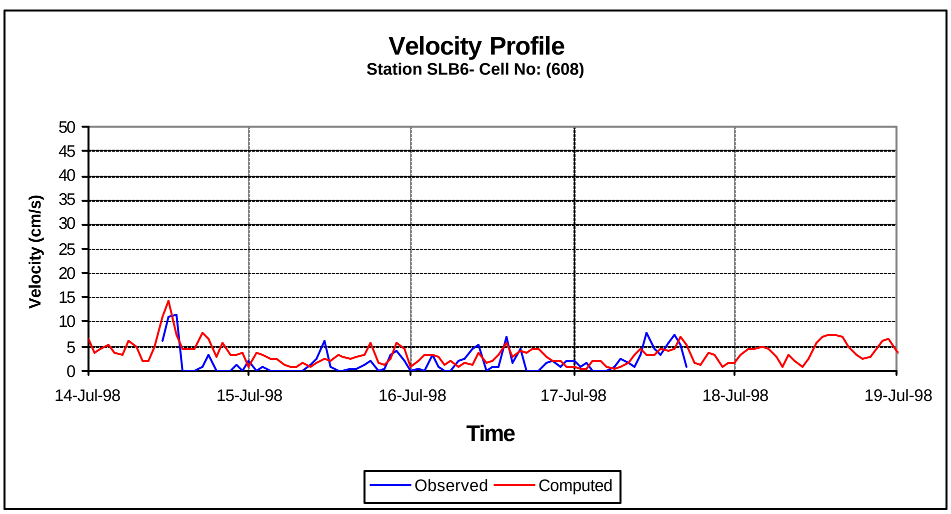
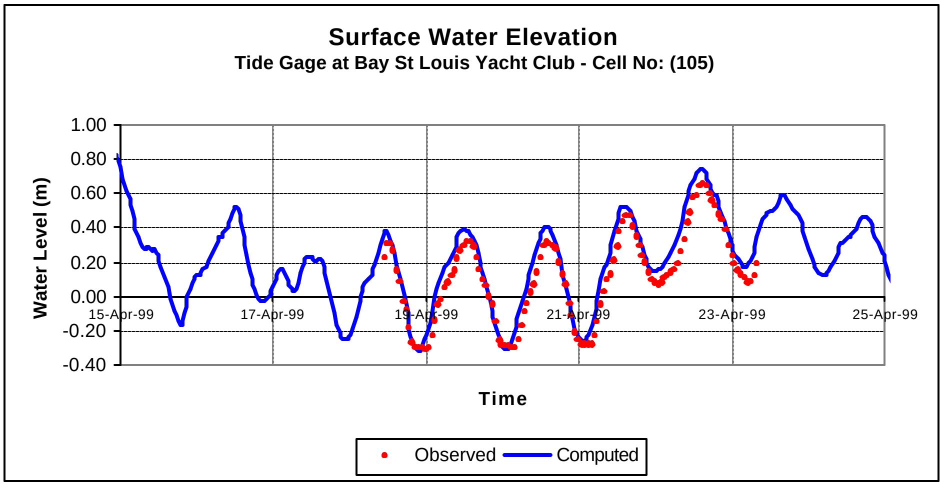
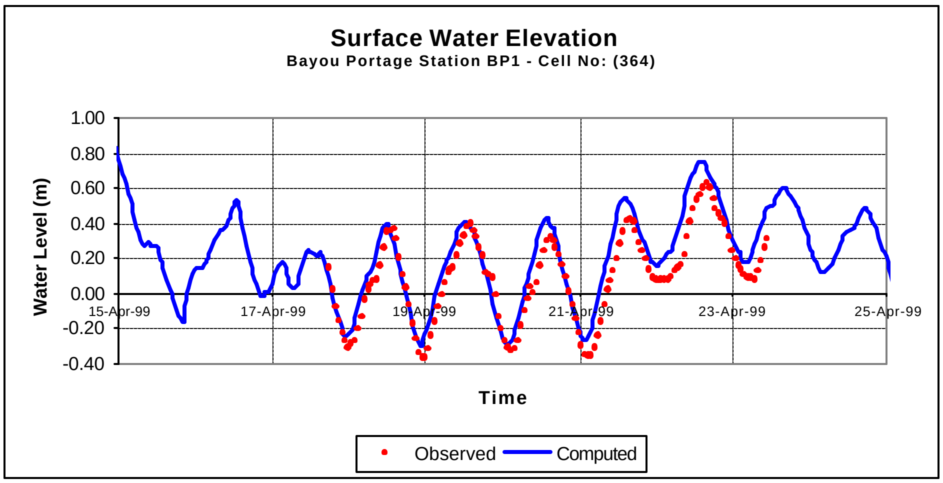


Figure 4.3s Temporal Profile of Observed and Verified Tide Level, 1999 at BSL YC, BP1 and JR2





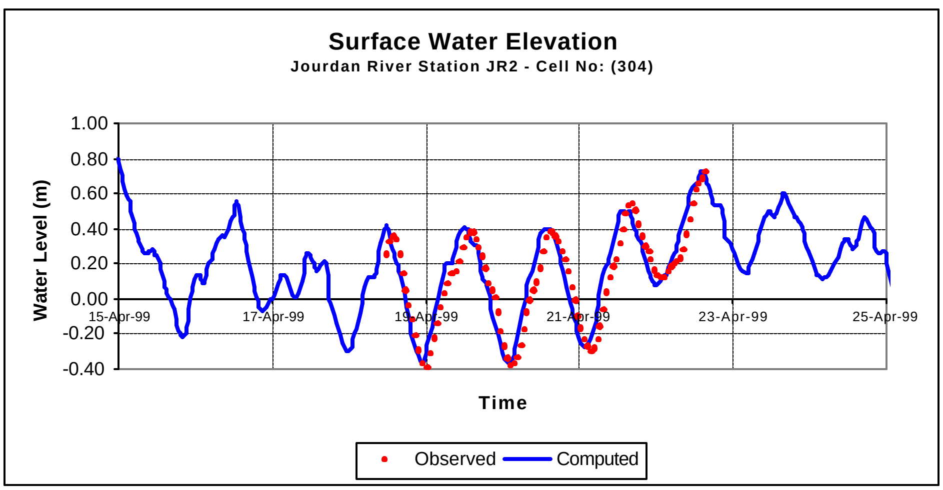
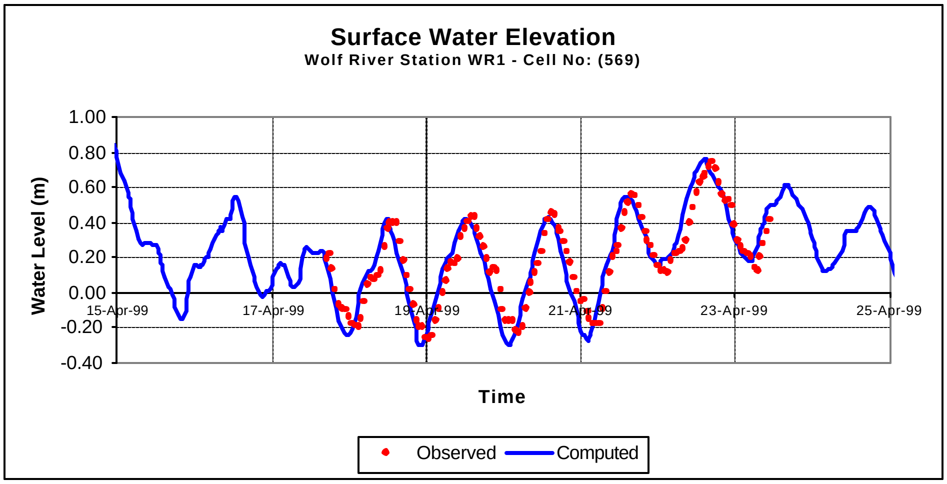
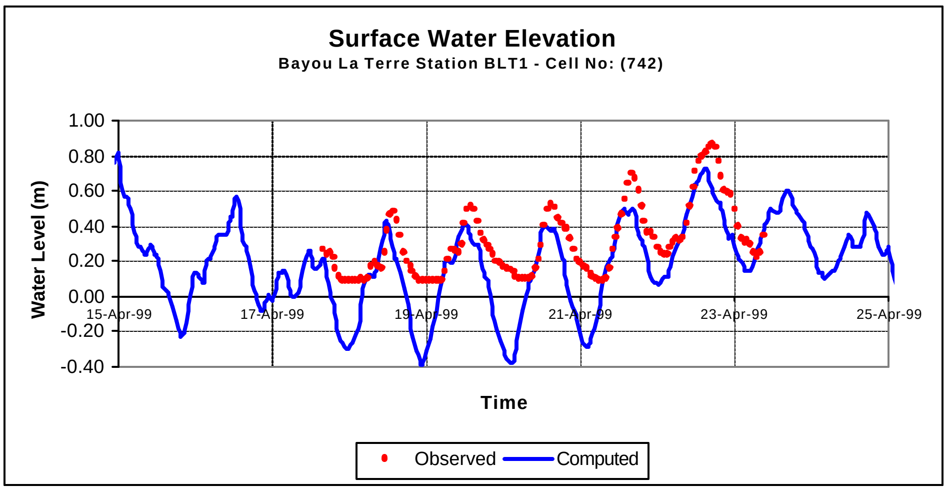


Figure 4.3s Continued Temporal Profile of Observed and Verified Tide Level, 1999 at WR1, BLT1, and Rotten Bayou





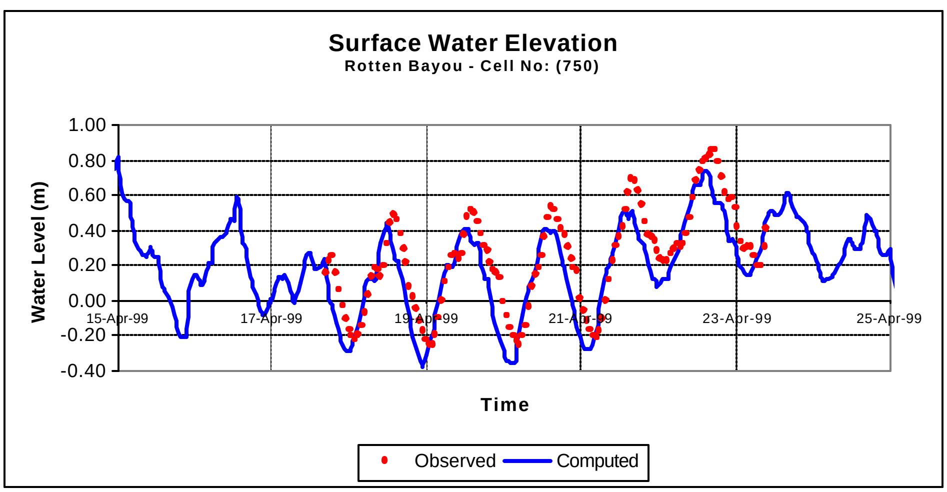
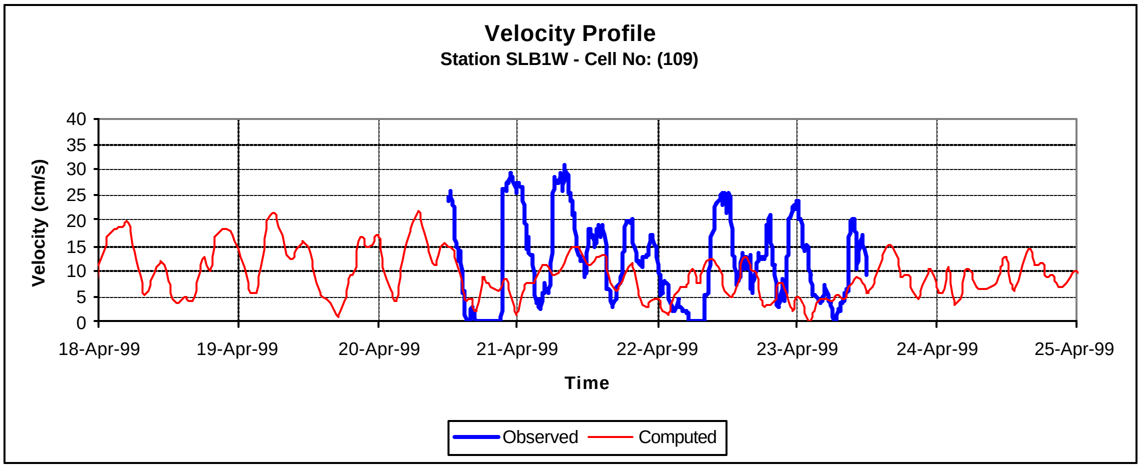
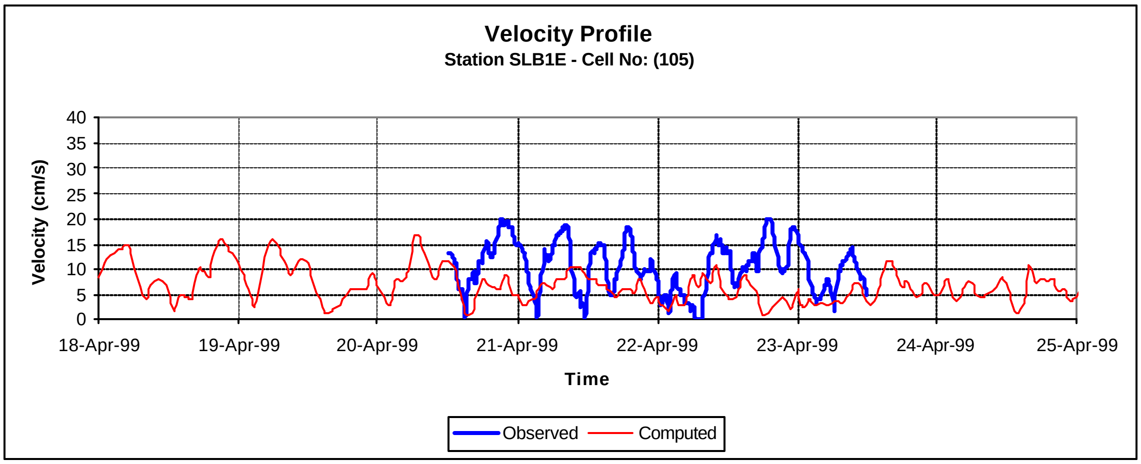


Figure 4.3t Temporal Profile of Observed and Verified Velocity, 1999 at SLB1W, SLB1E, and SLB2





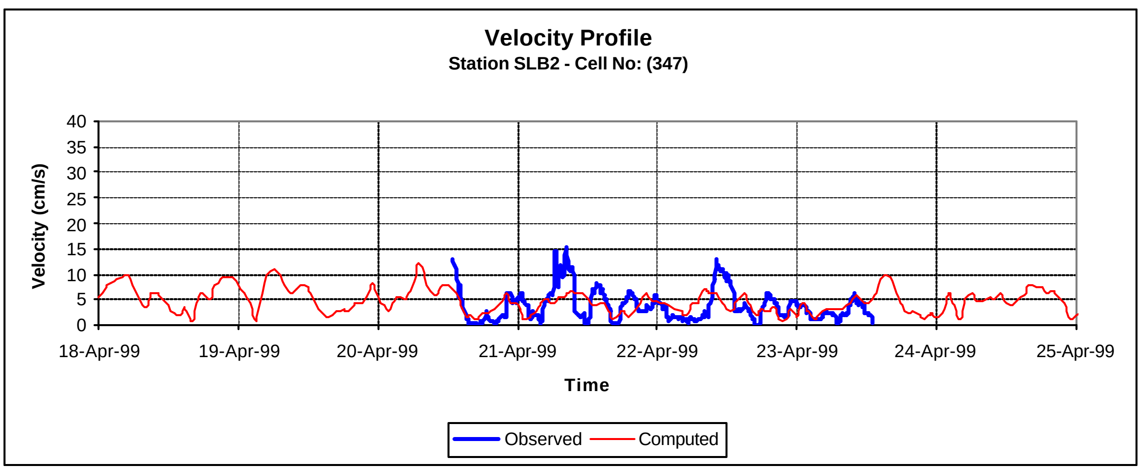
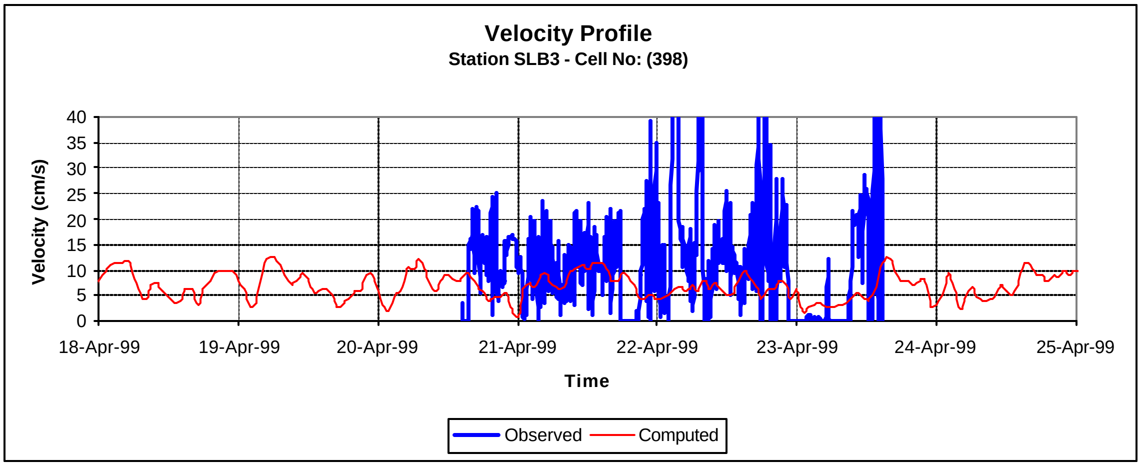
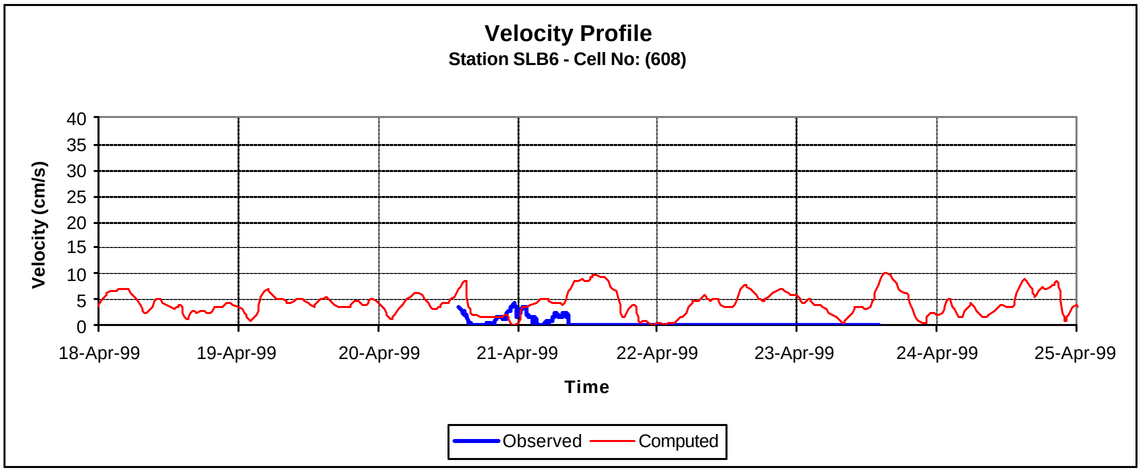


Figure 4.3t Continued Temporal Profile of Observed and Verified Velocity, 1999 at SLB3, SLB6, and WR1





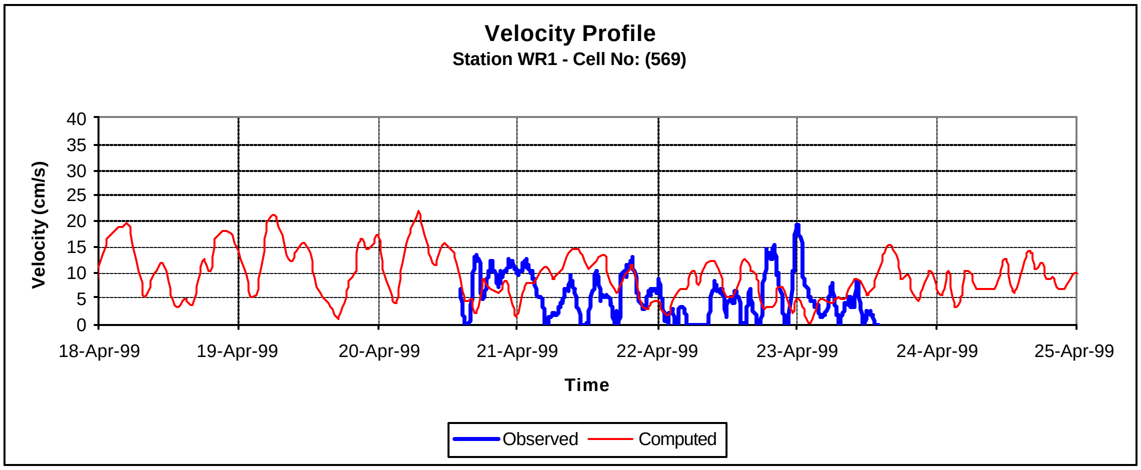
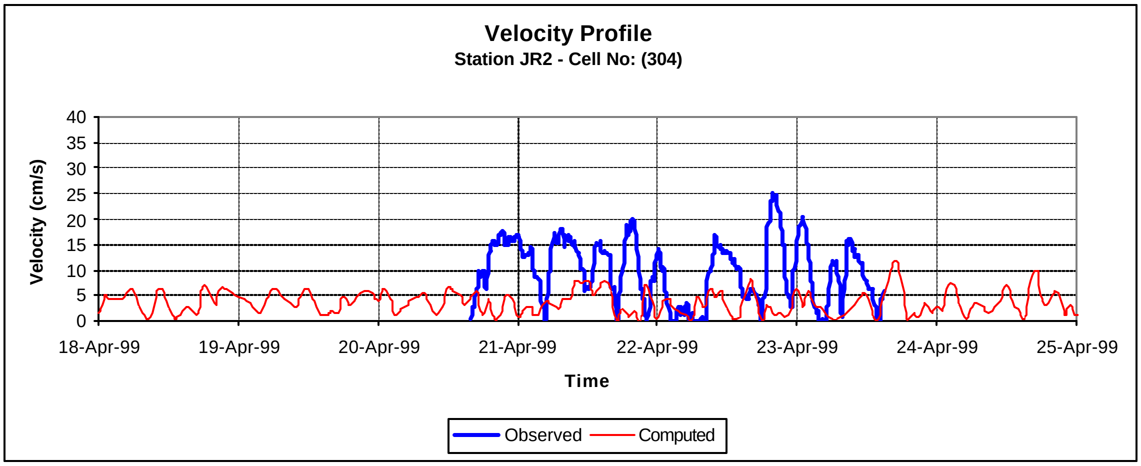


Figure 4.3t Continued Temporal Profile of Observed and Verified Velocity, 1999 at JR2



4.4 Water Quality

Water quality calibration for St. Louis Bay was accomplished utilizing the July 14-17, 1998 intensive survey data (EPA, 1998; MDEQ, 1998). An almost identical set of data was collected from April 14-19, 1999 (EPA, 1999; MDEQ, 1999). The starting point was a set of rate constants and parameter values that were used in the initial calibration (Tetra Tech, 1997). Model constants were also compared with those used in previous modeling studies (Bowie et. al., 1985).

4.4.1 Water Quality Calibration and Verification Databases

Field data jointly collected by EPA and MDEQ during the first intensive survey July 14-17, 1998 (Table 4.4a) and the second intensive survey April 19-21, 1999 (Table 4.4b) were used to calibrate and verify the model, respectively. The locations of the water quality sampling stations for the July, 1998 and April, 1999 surveys are shown in Figure 4.3b, where physical, chemical, and bacteriological parameters were collected from twenty-eight (28) stations. A water column and a diurnal (diel) monitoring survey were conducted at the water quality sampling stations.

Table 4.4a Water Quality Data Sources for St. Louis Bay Calibration, 1998 Study

Date	Agency	Project Component	Data Category
07/14-19/98	USEPA, MDEQ, MDMR	Insitu WQ Water Column Profiles (4 Sampling Runs)	DO, Salinity, Conductivity, Temperature,
		WQ Study	Ultimate BOD & Other Parameters
07/14-19/98		Continuous Dissolved Oxygen Monitoring (diel monitoring)	DO, Salinity, Conductivity, Temperature, pH
			SOD Rate
07/16-18/98		Diffusion/Reaeration Rate Measurements	Reaeration Rate
07/15-16/98		Tide-Phased bacteriological Sampling (2 Sampling Runs: High Slack and Low Slack)	Fecal Coliform
07/17-18/98		Production and Respiration Measurements (Dark Bottle & Closed Chamber Techniques)	Respiration Rate
07/13-19/98		Point Source Water Quality Sampling	Fecal Coliform, Ultimate BOD & Other Parameters

Table 4.4b Water Quality Data Sources for St. Louis Bay Verification, 1999 Study

Date	Agency	Project Component	Data Category
04/14-19/99	USEPA, MDEQ, MDMR	Insitu WQ Water Column Profiles (4 Sampling Runs)	DO, Salinity, Conductivity, Temperature,
		WQ Study	Ultimate BOD & Other Parameters
04/14-19/99		Continuous Dissolved Oxygen Monitoring (diurnal monitoring)	DO, Salinity, Conductivity, Temperature, pH
			SOD Rate
04/16-18/99		Diffusion/Reaeration Rate Measurements	Reaeration Rate
04/15-16/99		Tide-Phased bacteriological Sampling (2 Sampling Runs: High Slack and Low Slack)	Fecal Coliform
04/17-18/99		Production and Respiration Measurements (Dark Bottle & Closed Chamber Techniques)	Respiration Rate
04/13-19/99		Point Source Water Quality Sampling	Fecal Coliform, Ultimate BOD & Other Parameters

Waste sources were sampled during the July 1998 calibration study (MDEQ, 1998) and again in the April 1999 verification study (MDEQ, 1999b). The locations of the municipal and commercial waste sources, and the location of marinas and shipyards are shown in Figure 4.4a. Waste sources from these marinas and shipyards were considered to be discharging into the municipal systems in this study, which are listed in Table 3.1. Unsewered subdivisions in Bay St. Louis are listed in Table 4.4c and shown in Figure 4.9b.

Figure 4.4a Location of Waste Sources in St. Louis Bay

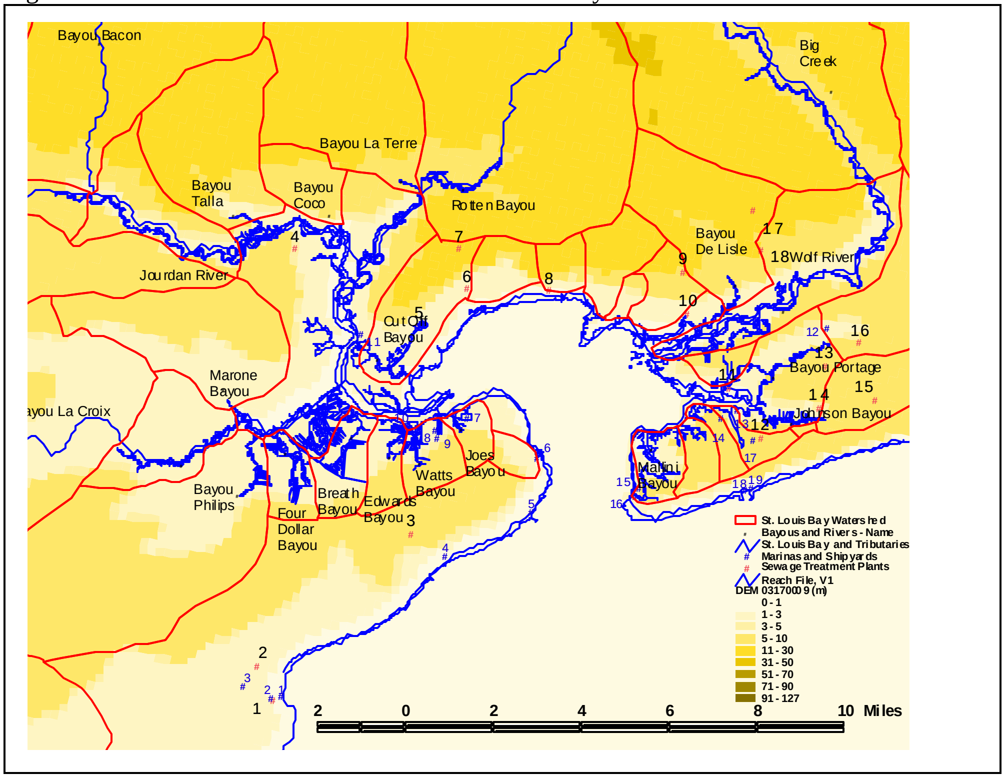


Figure 4.4b Location of Unsewered Areas in St. Louis Bay

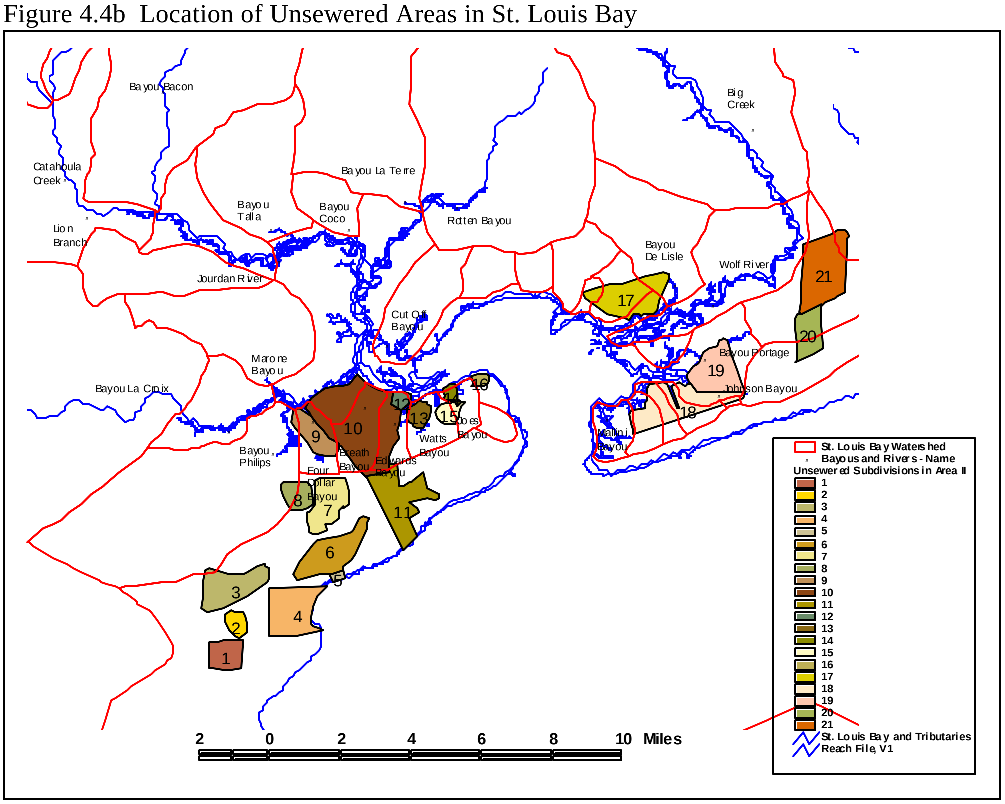


Table 4.4c Unsewered Subdivision Draining into Area II Waters (MSDMR, 1997)

SUBSECTION	SUBDIVISION	NO. DWELLINGS	AREA OF DISCHARGE
Waveland	City of Waveland	357	Jackson Marsh, Grand Bayou
	Clermont Harbor	292	Clermont Harbor
	Lakeshore	149	Clermont Harbor, Bayou Caddy
Bayside Park	Bayside Park	607	Turkey Bayou
Bay St. Louis	Shoreline park	715	Bayou La Croix, Breath Bayou, Jourdan River
	Jourdan River Estates, Jourdan Isles	300	Edwards Bayou, Joe's Bayou, Jourdan River
	City of Waveland	65	Edwards Bayou
	Shoreline Park	897	Bayou La Croix, Bayou Philip, Edwards Bayou, Jourdan River
	Cedar Point	60	Jourdan River
	Shiloh Ranch	217	Sand Bayou, Bayou Caddy
	Kline	160	Sand Bayou
W. Harrison Co.	Glad Acres, Byrnewood	120	Bayou Portage
	De Lisle	434	De Lisle Bayou, Wolf River
	Knollwood	107	Bayou Portage
	Hillcrest	79	Bayou Portage
	City of Long Beach	314	Canal #1, Canal#2, Bayou Portage

4.4.2 Water Quality Calibration and Verification Input Parameters

The water quality parameter of concern in this study is fecal coliform. The first order decay rate and temperature correction factor were specified in the input file. Pollutant discharges to the Bay are distributed spatially over the Bay in accordance with the delineation determined from the watershed model. Pollutant loadings from the major rivers and small bayous are simulated as point sources discharging into the Bay model.

4.4.3 Water Quality Calibration/Verification Initial and Boundary Conditions

Successful calibration/verification of the water quality model requires an initial condition and appropriate boundary conditions and waste loads. All of the boundary conditions incorporated in the model were either temporal or spatial variables, or both. Much of the data were approximated by a series of piecewise linear functions. The piecewise linear functions used in this model consist of a series of variables and break points either at high slack, low slack, mid-flood and mid-ebb or only high slack and low slack.

4.4.4 Boundary Concentrations

Boundary concentrations are specified at the upstream boundaries and downstream (seaward) boundary junctions with the Mississippi Sound. For the fecal coliform calibration, the July 13-19, 1998 intensive survey produced 3 data points at a station over a one-week survey period. To fill in missing data between observed field data, the model internally employed a linear interpolation scheme to estimate the boundary conditions during non-sampled periods. A constant fecal coliform concentration of 2 MPN/100 ml was specified at the seaward boundary. Daily computed fecal coliform loadings from the calibrated/verified watershed model were specified at each of the upstream boundaries. The seaward boundary conditions were also specified.

4.4.5 Initial Conditions

For dynamic simulations where the transient concentration response is desired, initial concentrations are input closely reflecting the measured values at the beginning of the simulation. In this study, initial conditions reflecting low slack condition was used since the simulation begin with low slack condition. A fecal coliform concentration of 2 MPN/100ml was used in the Bay and other tributaries. A uniform initial condition of fecal coliform in the Bay was input in wq3dwc.inp file.

4.4.6 Results of Water Quality Calibration and Verification

The water quality model was calibrated using the July 13-19, 1998 survey data. Verification used the April 14-19, 1999 data. Ideally, the 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 and seawater mortality rate of 0.8/day and 1.4/day at 20^0 C, respectively. Mitchell and Chamberlain (1978) provided a listing of in-situ measured decay rates, provided in Table 4.4d. For modeling of the St. Louis Bay, decay rates of 0.8/day – 1.4/day were investigated. Based on the available field data for calibration, a first order die-off rate 1.0/day at 20^o C and temperature correction factor 1.07 was selected for use in this calibration. As with the bay model, simulation results from several segments are presented. The results of the water quality calibration and verification for fecal coliform are shown in Figures B.1 and B.2 (Appendix B) respectively. These figures show reasonable agreement in the water quality trends between model simulation and field data for fecal coliform. Examination of the calibration and verification profiles show that the water quality model, in general, reproduces most of the observed water quality data but does not compute every data point. Despite the fact that fecal coliform data is difficult to simulate due to the high variability of bacteria in the environment, the model is capable of predicting the fecal coliform within the range of observed data.

Table 4.4d Seawater Decay Rates of Coliform Bacteria (Droste, 1997)

Location	**Previous sewage treatment**	**T_{90} [h]**	**K [h^{-1}]**
Denmark	None	2.0	1.15
England	None	0.78-3.50	0.66-2.90
Gentoffe, Denmark	None	1.16	1.98
Leaf River (Mississippi)	None	0.80-3.00	0.77-2.88
Instanbul, Turkey	None	1.78-3.45	0.67-1.30
Manila Bay, Philippines	None	2.16-2.84	0.81-1.06
Nice, France	None	1.5	1.54
Rio de Janeiro, Brazil	None	<1.0	> 2.3
Santa Barbara, California	Primary	0.37-5.47	0.42-6.01
Santa Monica, California	Secondary	6.5	0.354
Seaside Heights, New Jersey	Primary	1.05	2.2
Sidmouth and Bridport, England	-	0.57 - >> 4	<<0.56-4.04
Titahi Bay, New Zealand	None	0.65	3.54
Tema, Ghana	None	1.33	1.73

4.5 Selection of Representative Modeling Period

In development of this TMDL for St. Louis Bay, design conditions were chosen as those critical conditions that must be specified in order to determine attainment of water quality standards. In specifying conditions in the St. Louis Bay, an attempt was made to use a reasonable "worst case" scenario. In situations where nonpoint source loadings at wet weather flow conditions are more significant that the point source loadings, the use of low flow related design conditions is inappropriate (USEPA, 1991a). High flow conditions are more appropriate for analysis of nonpoint and intermittent point source discharges such as storm sewers. Other factors such as rainfall intensity and duration, time since previous rainfall, pollutant accumulation rates, and stream flow previous to rainfall should be considered in selecting design conditions for nonpoint source analysis. In general, continuous point source discharges present the greatest stress under low-flow, dry weather conditions. Since the St. Louis Bay TMDL is evaluating both point and nonpoint sources, the model was run for both a typical wet year and a dry year.

For the development of a representative wet year and dry year for St. Louis Bay, mean annual rainfall data distributions based on Saucier, Poplarville, Gulfport, Picayune, and Bay St. Louis rainfall stations were analyzed. As shown in Figure 4.5a and Table 4.5a for the five (5) meteorological stations, year 1968 was considered a typical dry weather condition, while year 1995 was considered a typical wet weather condition. Total annual precipitation in each of these years corresponds to approximately a ten-year return period, as shown by statistical analysis in Table 4.5b.

Figure 4.5a Distribution of Annual Precipitation in St. Louis Bay Watershed

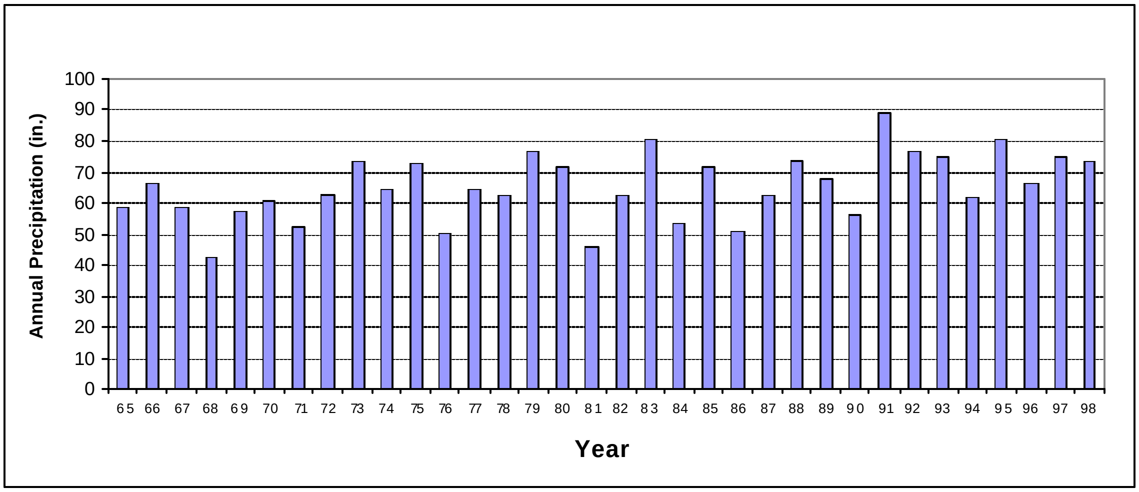


Table 4.5a Summary of Annual Rainfall Distribution in St. Louis Bay Watershed

YEAR	Month												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
65	6.87	5.46	7.08	0.94	3.62	5.66	4.92	6.25	7.20	1.55	3.34	5.31	58.20
66	10.63	12.25	4.19	5.86	4.82	3.95	5.46	6.23	2.99	2.45	2.23	5.21	66.28
67	5.51	4.41	1.57	3.52	3.21	4.39	4.57	7.48	7.58	7.09	0.59	8.43	58.34
68	2.16	2.63	2.28	2.63	3.77	3.24	4.24	3.99	4.09	1.58	5.04	7.14	42.77
69	5.02	3.33	8.16	6.18	4.33	0.54	9.63	9.31	1.13	2.01	2.04	5.65	57.32
70	3.99	4.41	7.10	1.73	5.53	5.21	6.73	8.24	3.12	6.84	1.62	6.36	60.88
71	2.36	7.32	4.10	0.84	2.40	3.60	5.51	6.65	8.95	0.62	3.02	7.32	52.69
72	10.08	4.24	6.03	1.90	10.64	2.43	5.44	3.26	2.62	2.38	5.42	8.25	62.69
73	2.71	4.33	10.76	10.19	4.63	4.17	4.26	6.24	12.13	3.24	4.24	6.33	73.23
74	6.35	5.46	5.96	9.38	5.79	3.18	4.20	6.45	6.79	0.47	5.49	4.91	64.43
75	4.66	3.01	5.31	7.56	7.09	6.64	9.46	9.43	7.48	3.75	4.11	4.38	72.89
76	1.76	3.85	4.57	1.24	6.86	5.12	4.46	2.87	3.14	5.35	5.93	5.40	50.53
77	6.43	3.68	6.84	3.89	3.97	1.75	5.33	9.95	9.00	3.06	6.74	4.11	64.75
78	10.27	2.96	3.38	3.70	10.82	6.58	7.33	5.78	3.03	0.00	3.83	4.75	62.43
79	6.15	10.95	4.28	8.81	5.57	1.83	14.40	4.25	7.46	1.71	6.58	4.78	76.76
80	4.95	1.75	14.27	13.55	14.01	2.37	5.77	1.62	4.17	4.50	3.47	1.26	71.70
81	0.73	11.12	2.81	1.07	3.17	5.37	4.50	6.03	3.00	1.33	0.79	5.85	45.76
82	3.72	7.92	5.31	6.17	2.30	4.82	7.73	5.81	2.00	2.41	6.62	7.39	62.19
83	5.23	11.53	7.13	11.46	3.92	9.26	3.55	6.50	6.32	2.16	4.55	8.92	80.52
84	4.24	5.79	4.21	3.00	4.37	4.93	6.05	9.38	1.92	3.56	2.98	3.07	53.50
85	5.62	6.13	6.02	2.14	1.81	4.25	9.41	8.42	10.19	11.20	1.78	4.71	71.67
86	2.81	3.83	4.65	2.14	3.55	3.89	2.66	4.22	4.72	4.97	8.40	4.93	50.77
87	7.83	8.43	7.88	1.95	6.79	4.29	4.55	10.82	1.13	0.21	4.25	4.04	62.17
88	3.86	10.52	10.13	5.40	1.79	1.92	8.80	12.22	10.68	1.87	2.57	3.76	73.52
89	2.98	1.23	5.12	4.04	6.45	10.73	11.88	3.10	3.84	2.31	9.21	6.70	67.60
90	6.64	10.19	6.22	3.61	7.08	3.41	3.51	2.78	2.29	2.89	2.78	4.83	56.24
91	17.28	4.11	6.15	11.29	14.04	6.42	5.20	4.95	4.86	6.11	2.76	6.10	89.26
92	11.24	8.60	6.23	3.03	1.57	8.05	6.71	8.48	4.12	0.36	11.65	6.27	76.31
93	12.88	3.17	6.94	4.33	5.52	6.41	10.41	5.33	5.41	7.05	3.61	3.61	74.66
94	4.12	1.73	5.24	4.70	3.79	6.68	10.23	3.96	5.53	6.01	4.51	4.98	61.48
95	7.16	5.97	11.80	9.07	12.88	3.71	7.34	5.01	1.91	3.64	6.30	5.55	80.34
96	6.02	3.49	8.41	9.27	4.41	5.52	7.01	6.87	3.62	2.70	2.03	6.84	66.19
97	6.81	7.73	4.69	6.13	8.43	8.00	11.15	3.62	0.76	5.01	9.55	3.02	74.90
98	16.18	5.47	9.78	3.80	0.73	1.98	8.69	3.38	14.78	1.88	4.45	2.17	73.28
Mean	6.33	5.79	6.31	5.13	5.58	4.71	6.80	6.14	5.23	3.30	4.49	5.36	65.18
	Standard Deviation												10.64

Table 4.5b Statistical Analysis of Annual Precipitation in St. Louis Bay Watershed

	Probabilities and Return Periods (Normal Distribution)					Mean	Std Dev
						65.18	10.64
				Probability of Less Than		**Probability of Exceedance**	
				Prob(P(x)=<))		Prob(P(x)=>))	
Year	Ppt, (x)	PDF, f(x)		F(x)	Tr, yrs	1-F(x)	Tr, yrs
	in				1/F(x)		1/(1-F(x))
	5	4.20929E-09		0			
	10	5.38259E-08	1.45088E-07	1.45088E-07	6892374.943	0.99999985	1.000000145
	15	5.51874E-07	1.51425E-06	1.65934E-06	602650.4294	0.99999834	1.000001659
	20	4.53685E-06	1.27218E-05	1.43812E-05	69535.46551	0.99998562	1.000014381
	25	2.99044E-05	8.61032E-05	0.000100484	9951.794738	0.99989952	1.000100494
	30	0.000158046	0.000469876	0.00057036	1753.2784	0.99942964	1.000570686
	35	0.000669725	0.002069427	0.002639787	378.8183778	0.99736021	1.002646774
	40	0.002275497	0.007363056	0.010002844	99.97157133	0.98999716	1.010103912
68	**42.8**	0.004098577	0.008923704	0.018926548	52.83583655	0.98107345	1.019291673
	45	0.006199009	0.021186267	0.031189111	32.06247232	0.96881089	1.032193188
	50	0.013540493	0.049348756	0.080537866	12.41651965	0.91946213	1.087592369
	55	0.023714439	0.093137329	0.173675195	5.757874624	0.8263248	1.21017788
	60	0.033301013	0.142538629	0.316213825	3.162417081	0.68378618	1.462445478
	65	0.037494559	0.176988929	0.493202753	2.027563702	0.50679725	1.973175676
	70	0.033848954	0.178358782	0.671561536	1.48906682	0.32843846	3.044710374
	75	0.024501263	0.145875544	0.81743708	1.223335746	0.18256292	5.477563571
	80	0.014219945	0.096803021	0.914240101	1.09380457	0.0857599	11.66046146
95	**80.3**	0.013666893	0.004183026	0.918423126	1.088822756	0.08157687	12.25837612
	85	0.006617189	0.047667593	0.966090719	1.035099479	0.03390928	29.49045119
	85.3	0.006276093	0.049857465	0.968280592	1.032758488	0.03171941	31.52643918
	90.3	0.002310868	0.021467405	0.989747996	1.010358196	0.010252	97.54190782
	95.3	0.000682224	0.007482732	0.997230729	1.002776962	0.00276927	361.1058005
	100.3	0.00016149	0.002109286	0.999340014	1.000660421	0.00065999	1515.184666
	105.3	3.065E-05	0.00048035	0.999820364	1.000179668	0.00017964	5566.820072
	110.3	4.66424E-06	8.82855E-05	0.99990865	1.000091359	9.135E-05	10946.87564
	115.3	5.69112E-07	1.30834E-05	0.999921733	1.000078273	7.8267E-05	12776.79431
	120.3	5.56776E-08	1.56197E-06	0.999923295	1.000076711	7.6705E-05	13036.97333
Note:	PDF=> Probability Density Function						
	F(x) => Cumulative Probability Density Function						
	Tr => Return Period in Years						

4.6 Source Representation

Both point and nonpoint sources were represented in the model. The discharge from point sources was added as a direct input into the appropriate cell of the bay model. The nonpoint sources in the Jourdan River and Wolf River watershed models are represented in the model since the output from those models is input into the appropriate cell of the bay model. The nonpoint sources in the near bay watersheds were not being represented adequately with the watershed model. Therefore, as stated in section 3.2, event mean concentrations (EMCs) determined through the research of literature and calibration were used for the landuses in those watersheds

4.6.1 Point Source Representation

The discharge from point sources was added as a direct input into the appropriate reach of the waterbody. There are 12 NPDES permitted facilities in the watershed which discharge fecal coliform bacteria. Fecal coliform loading rates for point sources are input to the model as flow in cubic feet per second and fecal coliform contribution in counts per hour.

4.6.2 Nonpoint Source Representation

For the small subwatersheds surrounding St. Louis Bay, the watershed model was only used to simulate the stormwater runoff. An Event Mean Concentration (EMC) value of 2,000 MPN/100 ml was used to compute the loadings from urban land use in each subwatershed for the months of January, February, and December. An EMC value of 20,000 MPN/100 ml was used to compute the loadings for the other months. These concentrations are based upon extensive field surveys that analyzed urban runoff resulting from 1600 storm runoff samples collected during the Nationwide Urban Runoff Program (NURP) in the early 1980's and 59 more recent urban stormwater monitoring studies throughout the United States (Pitt, 1998; Center of Watershed, 1999). It should be noted that fecal coliform loading from urban storm water constitutes a composite value that results from numerous sources including combined sewer overflows, sanitary sewer overflows, illegal sanitary connections to storm drains, transient wastewater dumping into storm drains, failing septic systems, domestic animals, and other small animals in urban areas. Table 4.6a shows the EMC values for various land use categories included in the model to compute the loadings from areas surrounding St. Louis Bay.

Non-point source loads from urban, forest, and agricultural runoff were incorporated into the Bay model through the calibrated and verified watershed model used to compute the flow and fecal coliform loads from small watersheds. These loads were introduced into the Bay model at the upstream freshwater boundary of major rivers and small bayous. The results from Phase One for the freshwater portions of the Wolf River and Jourdan River watersheds were used as input at the appropriate boundaries for Phase Two, which includes the remaining portion of the Wolf River and Jourdan River watersheds that drain to saltwater. The details of how the loads were estimated are explained in the Wolf River and Jourdan River Phase One Fecal Coliform TMDL reports. Non-point source loads from precipitation and atmospheric deposition of pollutants were not incorporated in the Bay model.

Table 4.6a EMC Values for Bay Model Loading Computations

Land Use Type	EMC Values for January, February, December (MPN/100ml)	EMC Values for March-November (MPN/100ml)
Urban/barren	2,000	20,000
Pastureland	250	2,500
Cropland	250	2,500
Forest	10	100

4.7 Existing Loading

The baseline simulation is defined as a simulation for existing conditions by using existing nonpoint source load, and permitted point source load. The results from the baseline run are shown in Appendix C. The baseline run shown in Phase Two differs from that shown in Phase One because the results are shown at different points in the stream. The results shown in Phase One represent the freshwater portion of the watershed, while the Phase Two results at the mouth of the Wolf River and Jourdan River at St. Louis Bay which is saltwater.

4.7.1 Wet Year Simulation

The simulation period for the wet year weather was July 1, 1994 to December 31, 1995. The six months in 1994 were used to stabilize the model. The rainfall distribution for this period is shown in Figure 4.7a. The discharge hydrographs for the two major rivers, Wolf River and Jourdan River, are shown in Figure 4.7b.

Boundary conditions such as wind speed, tidal elevation, and air and water temperature that were recorded in the St. Louis Bay Watershed were used in this base line simulation. Figure C.1 (Appendix C) shows representative computed temporal fecal coliform profiles in Wolf River, Jourdan River, and St. Louis Bay. Spatially and temporally averaged zones that corresponded with the waterbody segment and designated use were used in the statistical water quality standard analysis. An exceedance for the cells grouped over the oyster beds was defined as any day during which the fifteen-day median value exceeded the applicable fecal coliform standards. An exceedance for the coastlines, major rivers, and bayous was defined as any day during which the thirty-day geometric mean value exceeded the fecal coliform standard.

Figure C.1 in Appendix C shows the exceedances for each of the waterbody segments included in this TMDL.

Figure 4.7a Rainfall Distribution for Wet Year Existing Run – 1995

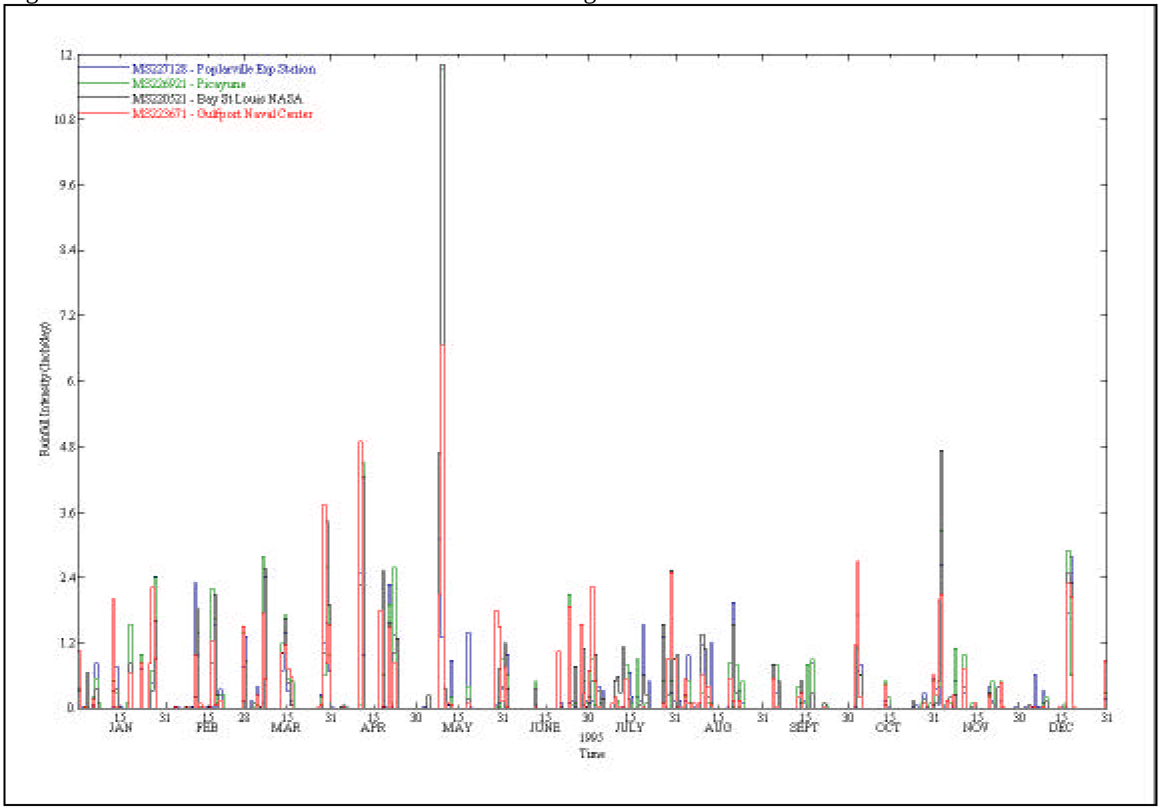
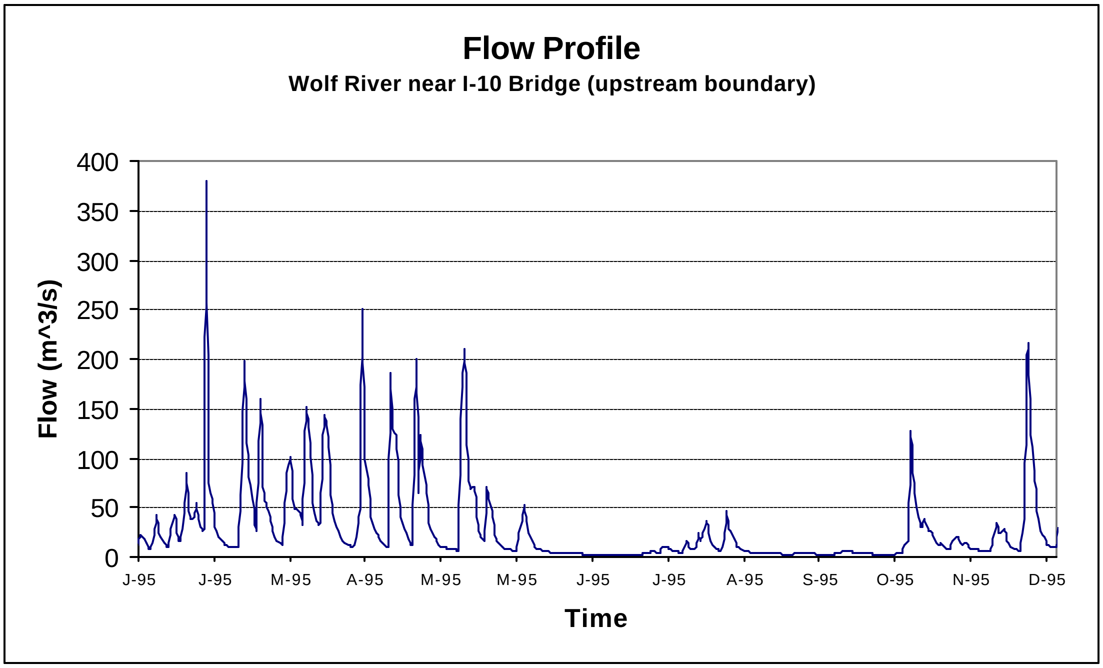
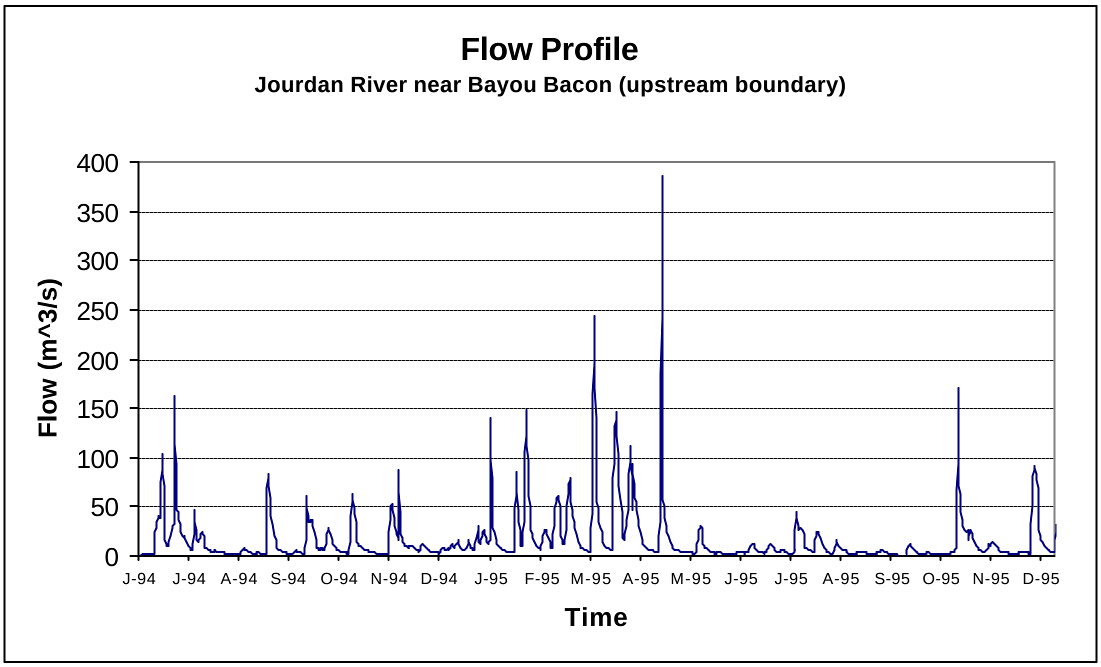


Figure 4.7b Discharge Hydrographs for Wet Year Existing Run – 1995





4.7.2 Dry Year Simulation

The simulation period for the dry year weather was July 1, 1967 to December 31, 1968. Here again, the six months in 1967 were used to stabilize the model. The rainfall distribution for this period is shown in Figure 4.7c. The discharge hydrographs for two major rivers, Wolf River and Jourdan River, are shown in Figure 4.7d. The same boundary conditions as previously described above were used in this dry weather base line simulation. No additional graphs are shown for the dry year because it was not critical. All of the critical fecal coliform violations occurred in the wet year.

Figure 4.7c Rainfall Distribution for Dry Year Existing Run - 1968

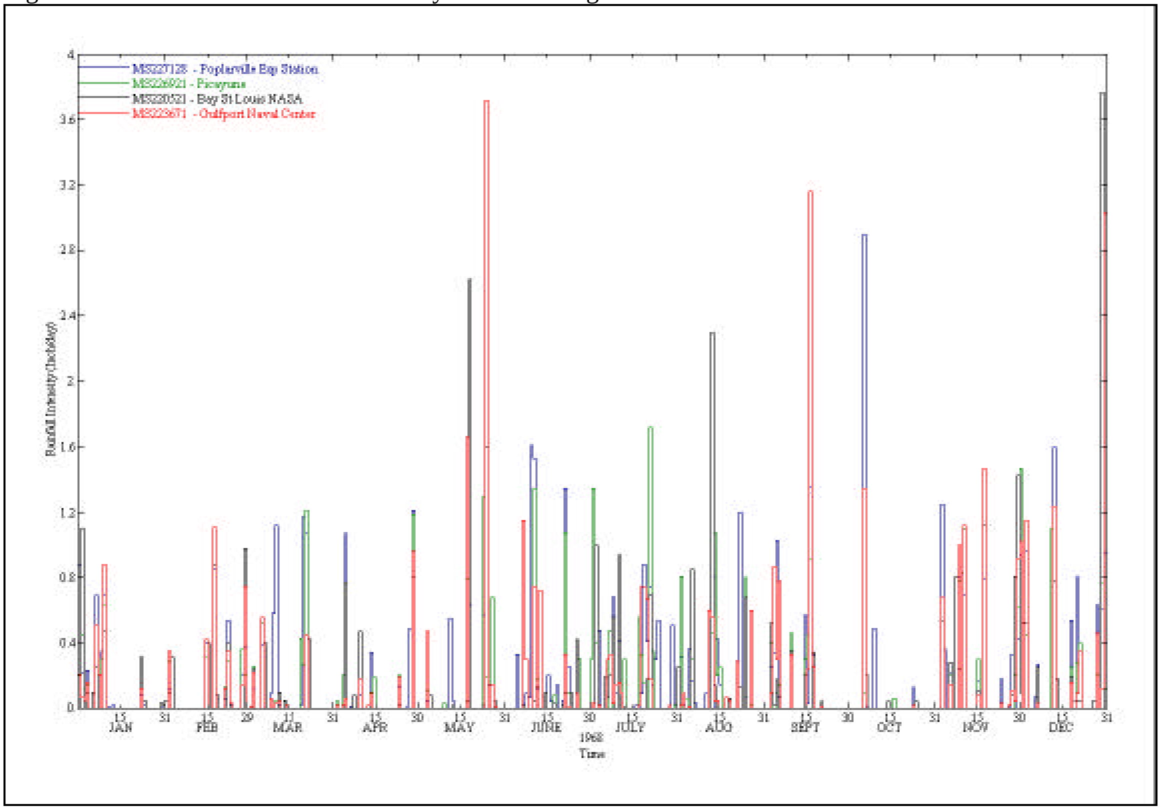
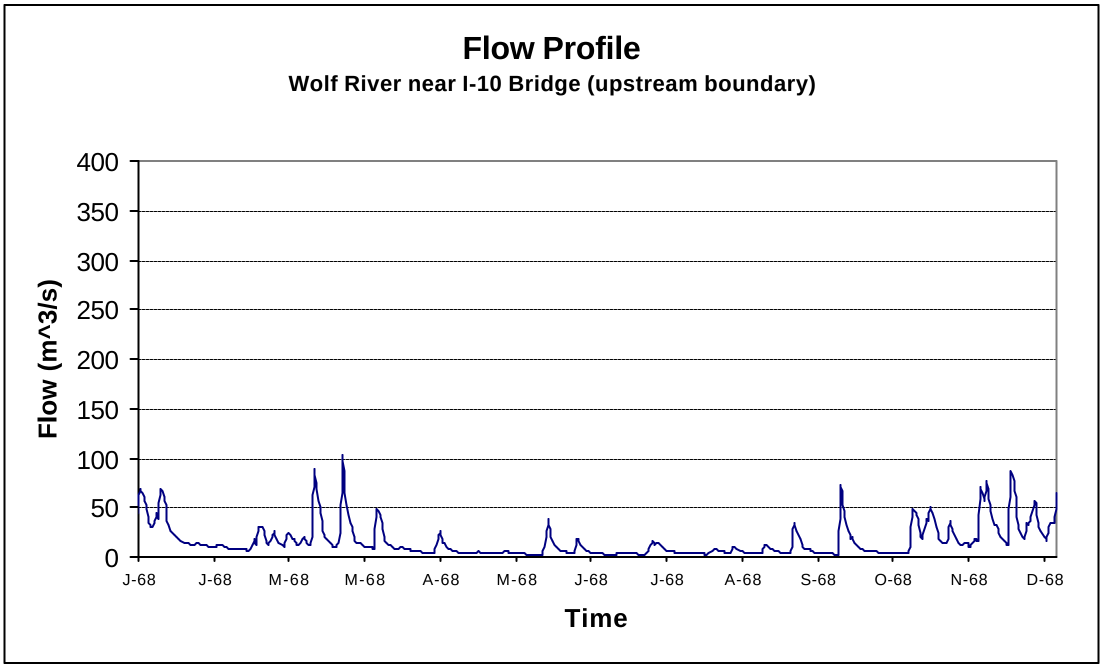
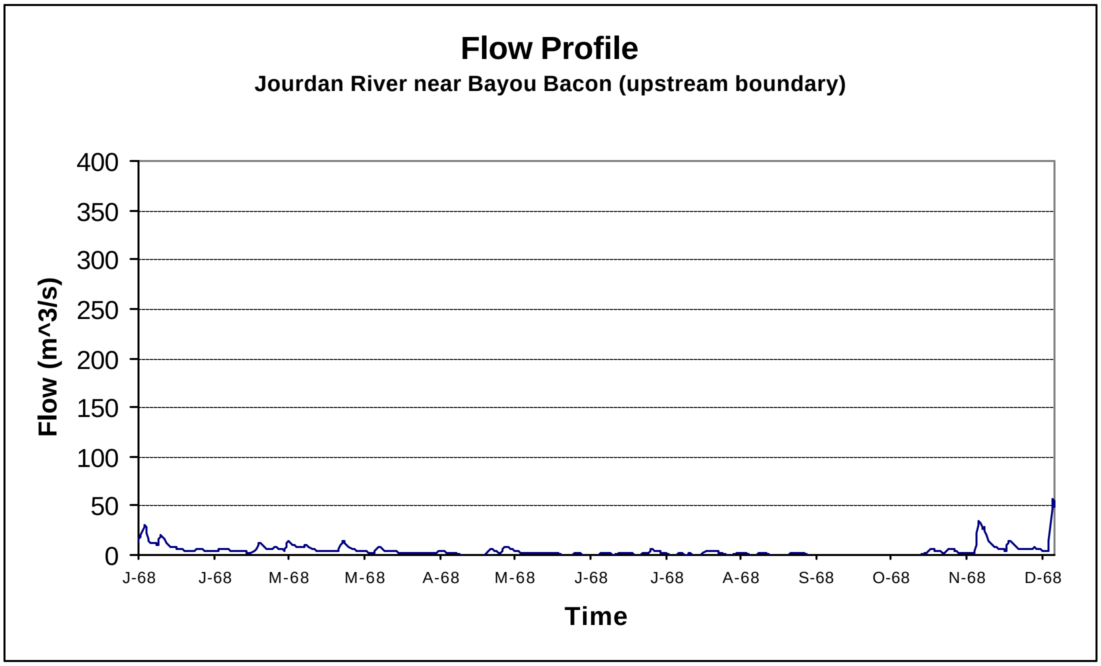


Figure 4.7d Discharge Hydrographs for Dry Year Existing Run – 1968





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 27 percent. The modeling scenario that was run to achieve that 27 percent reduction included the reduction urban nonpoint source runoff. The rural nonpoint source loads reductions were also included and are described in the Phase One TMDLs for the Jourdan River and Wolf River (DEQ, 2000). While reduction of the rural nonpoint source loads is imperative to the attainment of sufficient water quality in the monitored segments of the Wolf River and the Jourdan River, the impact of the rural watershed loads upon fecal coliform levels in St. Louis Bay is much less significant. Loads from urban runoff appear to have the greatest influence upon the Bay fecal coliform level. Figure C.2 in Appendix C shows the model results based on the allocated loads for the waterbodies included in this TMDL.

5.1 Wasteload Allocations

The wasteload allocation for the St. Louis Bay Watershed is based on the sum of the loads from the NPDES permitted dischargers. Since the permit limits for the NPDES facilities are already equivalent to the water quality standard of 200 counts per 100 ml, no reductions were required of the permitted facilities. 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 disinfect their effluent as well as monitor for their effluent for compliance. Table 5.1 lists the point source contributions, including their existing load, allocated load, and percent reduction.

Table 5.1 Wasteload Allocation

Name of Facility	Existing Flow (MGD)	Existing Load (counts/15 days)	Allocated Flow (MGD)	Allocated Load (counts/15 days)	Percent Reduction
Waveland Regional Wastewater Mgt. Dist.	4.900	5.56E+11	4.900	5.56E+11	0%
Diamondhead Water/Sewer Dist.	0.180	2.84E+11	0.180	2.84E+11	0%
Long Beach/Pass Christian STP	1.560	4.95E+11	1.560	4.95E+11	0%
Coast Episcopal High School	0.008	9.09E+08	0.008	9.09E+08	0%
DeLisle Elem. School	0.008	4.54E+09	0.008	4.54E+09	0%
Discovery Bay	0.015	3.41E+09	0.015	3.41E+09	0%
Dupont Outfall: 1N (Process WW)	4.200	4.77E+11	4.200	4.77E+11	0%
Dupont Outfall: 2A (Sanitary)	0.034	1.17E+12	0.034	1.17E+12	0%
Dupont Outfall: 3A (Storm)	10.300	3.86E+09	10.300	3.86E+09	0%
Five-Star Resort	0.008	9.09E+08	0.008	9.09E+08	0%
Jourdan River Shores	0.050	5.68E+09	0.050	5.68E+09	0%
Long Beach Industrial Park	0.250	6.81E+10	0.250	6.81E+10	0%
Total		**3.07E+12**		**3.07E+12**	**0%**

5.2 Load Allocations

The load allocation for this TMDL involves a reduction in the urban nonpoint source runoff from the small watersheds surrounding the Bay. A 25% reduction in the concentration of urban runoff was necessary from each of the small watersheds surrounding the Bay except for three watersheds, Edwards Bayou, Watts Bayou, and Joes Bayou, that were more impacted. These three watersheds required a 75% reduction in the concentration of urban runoff. These reductions in concentration resulted in an overall reduction in the load allocation of 27 percent as shown in Table 5.2.

Table 5.2 Load Allocation

Subwatershed ID/Name	Existing Load (MPN/15 days)	Allocated Load (MPN/15 days)	Percent Reduction
032/Bayou La Croix	5.27E+12	5.27E+12	0*
025/Jourdan River	5.04E+13	4.10E+13	19
026/Bayou Bacon	1.75E+13	1.42E+13	19
018/Wolf River	6.93E+13	4.22E+13	39
W6/ Bayou De Lisle	1.17E+12	1.17E+12	0*
W7/ Bayou Portage	8.96E+13	7.39E+13	17
W8/ Johnson Bayou	9.41E+13	7.45E+13	21
W9/ Unnamed Canal/Bayou Portage	4.29E+13	3.29E+13	23
W10/ Unnamed Bayou/Bayou Portage	2.56E+13	1.95E+13	24
W11/ Young Bayou/Bayou Portage	2.61E+13	1.99E+13	24
W12/ Mallini Bayou	5.71E+13	4.32E+13	24
W13/ Bayou Portage	1.44E+12	1.44E+12	0
W14/ Unnamed Bayou/Bayou De Lisle	1.57E+13	1.37E+13	13
W15/ Unnamed Bayou/Bayou De Lisle	4.17E+11	4.07E+11	2
W16/ Unnamed Bayou/Bay	2.25E+13	2.03E+13	10
W17/ Unnamed Bayou/Bay	1.24E+13	1.03E+13	17
W18/ Unnamed Bayou/Bay	2.26E+13	1.74E+13	23
W19/ Cutoff Bayou	1.23E+14	9.40E+13	24
W20/ Rotten Bayou	7.89E+12	7.89E+12	0*
W21/ Bayou La Terre/Rotten Bayou	7.12E+12	7.12E+12	0*
W22/ Bayou Coco/Jourdan River	1.08E+12	1.08E+12	0*
W23/ Bayou Talla/Jourdan River	2.86E+12	2.86E+12	0*
W25/ Unnamed Bayou/Jourdan River	1.83E+12	1.83E+12	0*
W26/ Bayou Marone/Bayou La Croix	1.44E+12	1.44E+12	0*
W27/ Bayou Philips/Bayou La Croix	3.95E+12	3.95E+12	0*
W28/ Four Dollar Bayou	8.08E+11	8.08E+11	0*
W29/ Breath Bayou	3.92E+13	3.08E+13	22
W30/ Edwards Bayou	3.44E+13	1.18E+13	66
W31/ Watts Bayou	4.32E+13	1.26E+13	71
W32/ Joes Bayou	2.46E+13	9.04E+12	63
W33/ Unnamed Bayou near Yacht Club	9.06E+13	6.83E+13	25
Total	**9.37+14**	**6.85+14**	**27**

*NPSM output for both flow and load used rather than EMCs, therefore 25 percent to urban runoff concentration not applied

5.3 Incorporation of a Margin of Safety (MOS)

The margin of safety (MOS) is part of the TMDL development process. There are two basic methods for incorporating the MOS (USEPA, 1991a):

a. Implicitly incorporate the MOS using the conservative model assumptions to develop allocations

b. Explicitly specify a portion of the total TMDL as the MOS and use the remainder for allocations.

For this study, the MOS is incorporated implicitly into the modeling process by utilizing a conservative fecal coliform decay rate, conservative loading and environmental conditions, and running a dynamic simulation to calculate the hourly fecal coliform values in the Bay and rivers. Dynamic simulation of the model was done under selected design conditions, which, are discussed in the Section 4.7.

5.4 Calculation of the TMDL

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 St. Louis Bay Watershed according to the model. Each of the loading rates has been converted to the 15-day equivalent. The wasteload allocation incorporates the fecal coliform contribution from identified NPDES Permitted facilities. The load allocation includes the fecal coliform contributions from nonpoint sources. The margin of safety for this TMDL is derived from the conservative loading assumptions used in setting up the model and is implicit. Table 5.4 gives the TMDL for the primary listed segment, MSSTLUBAYM. This overall TMDL accounts for all of the loads represented in the model.

WLA = NPDES Permitted Facilities

LA = Nonpoint Sources

MOS = Implicit

Table 5.4 TMDL Summary for Monitored Segment (MPN/ 15 days)

TMDL CALCULATION	**MSSTLUBAYM**
NPDES Discharges **WLA**	**3.07E+12**
Jourdan, Wolf, and Near Bay Watersheds Nonpoint Sources **LA**	**6.85E+14**
TMDL = WLA + LA +MOS	**6.88E+14**

5.5 Seasonality

For many streams in the state, fecal coliform limits vary according to the seasons. As discussed earlier, there are several designated uses with in the St. Louis Bay Watershed. The uses of Shellfish Harvesting and Contact Recreation are not seasonal. Many of the evaluated segments included in this TMDL are classified for Secondary Contact Recreation, which is seasonal. However, these waterbodies were held to the Contact Recreation standards in order to add an additional margin of safety and eliminate model complexity.

The model was run for a representative wet and dry year, which allowed seasonal critical conditions to be simulated.

6.0 CONCLUSION

The St. Louis Bay Fecal Coliform TMDL Modeling Project is comprehensive. This TMDL is the second 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 includes 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 15 day median of 14 counts per 100 ml. The phased approach is beneficial not only because different models were used to represent the saltwater and the freshwater systems, but also because the different systems have different targets.

6.1 Current Conservation Activities

Several programs and organizations focus conservation activities in the St. Louis Bay Watershed. The Wolf River Conservation Society has 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), 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).

The Gulf of Mexico Program Office (GMPO) 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. Similar efforts may be undertaken by Harrison and Jackson counties.

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 Activities

Some monitoring programs are already in place in the St. Louis Bay 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, St. Louis Bay will receive additional monitoring to identify any improvements in water quality.

The wet-weather monitoring results are being utilized along with data from the intensive studies to expand the model developed for this TMDL to include nutrient and dissolved oxygen capabilities.

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. MDEQ is investigating the utility of employing such techniques.

A potential funding source for future activities is the Coastal Infrastructure Assistance Program (CIAP). CIAP is a program recently formed to administer funds to projects which air and water resources on the Mississippi Coast.

6.3 Public Participation

The public has been very involved and aware of the TMDL work ongoing in the St. Louis Bay 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

GEFDC...Grid Environmental Fluid Dynamics Code

GIRAS..Geographic Information Retrieval and Analysis System

GIS .... Geographic Information System

GMPO ....Gulf of Mexico Program Office

HUC ....Hydrologic Unit Code

ISSC ....Interstate Shellfish Sanitation Conference

LA ....Load Allocation

MARIS ....State of Mississippi Automated Information System

MDEQ ....Mississippi Department of Environmental Quality

MDMR.. Mississippi Department of Marine Resources

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

NSSP..National Shellfish Sanitation Program

RF3...Reach File 3

SWCD..Soil and Water Conservation District

TMDL ....Total Maximum Daily Load

USGS ....United States Geological Survey

VIMS...Virginia Institute of Marine Science

WCS...Watershed Characterization System

WLA..Waste Load Allocation

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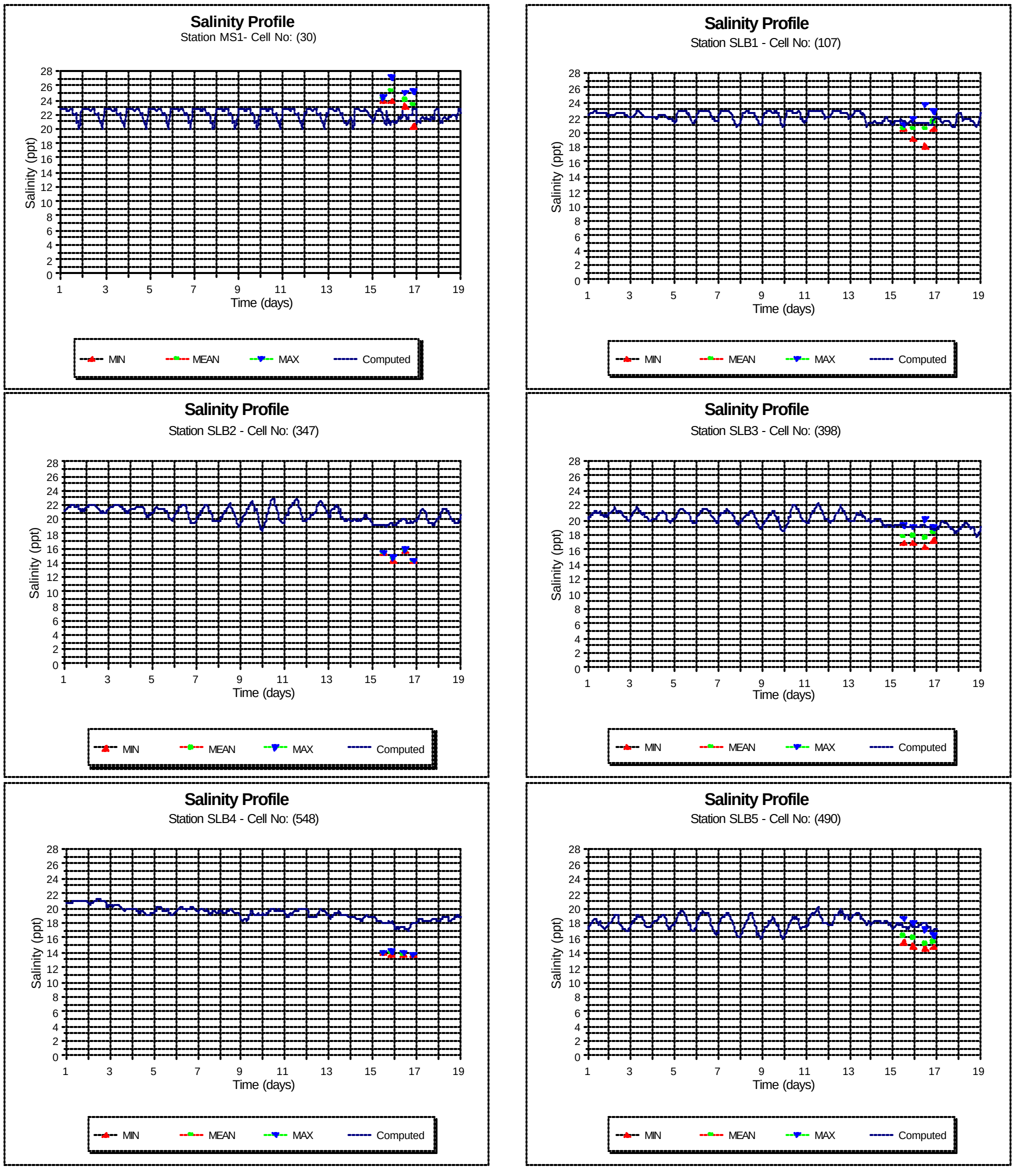
APPENDIX A

Calibration and Verification Profiles of Salinity and Temperature

Figure A.1 Calibration Temporal Salinity Profiles, July 1-19, 1998



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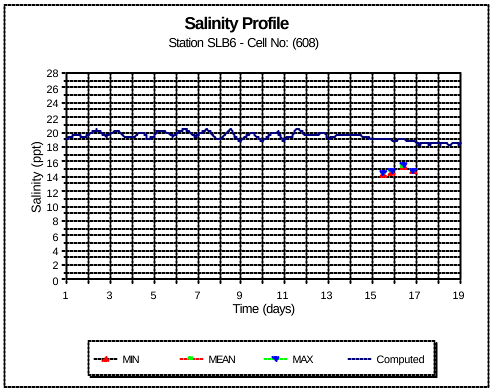
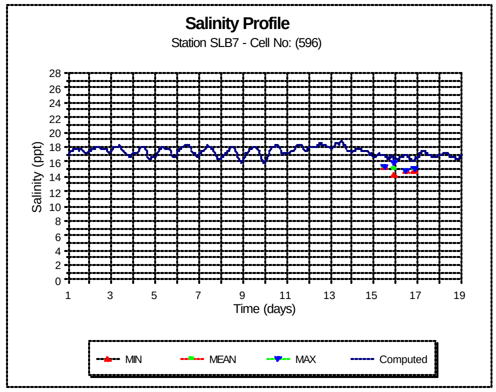
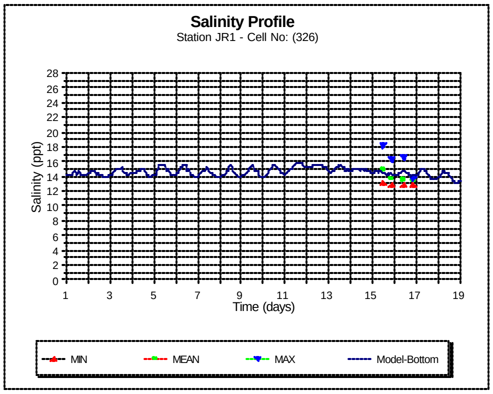
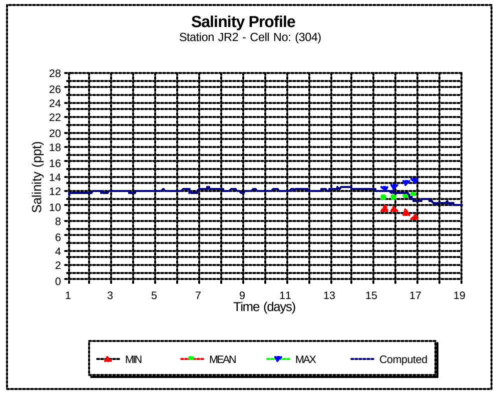
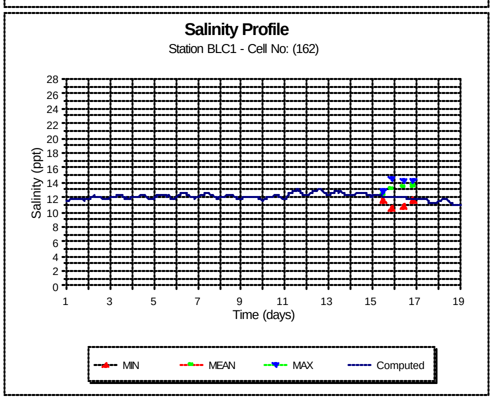
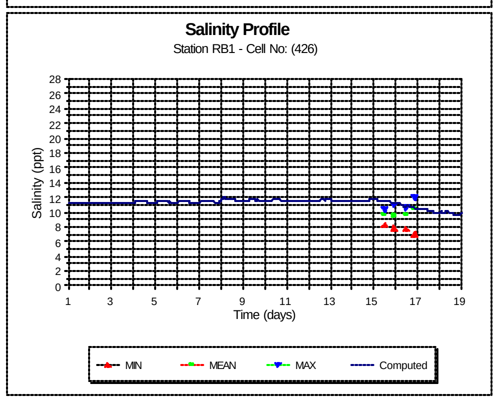












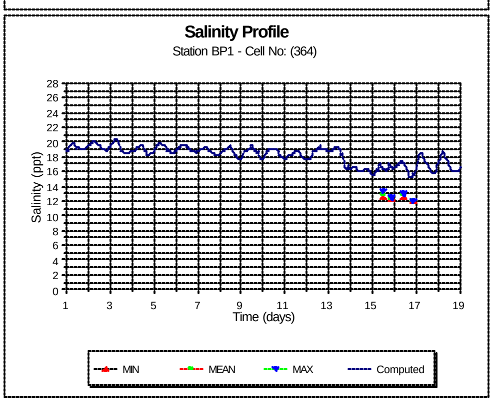
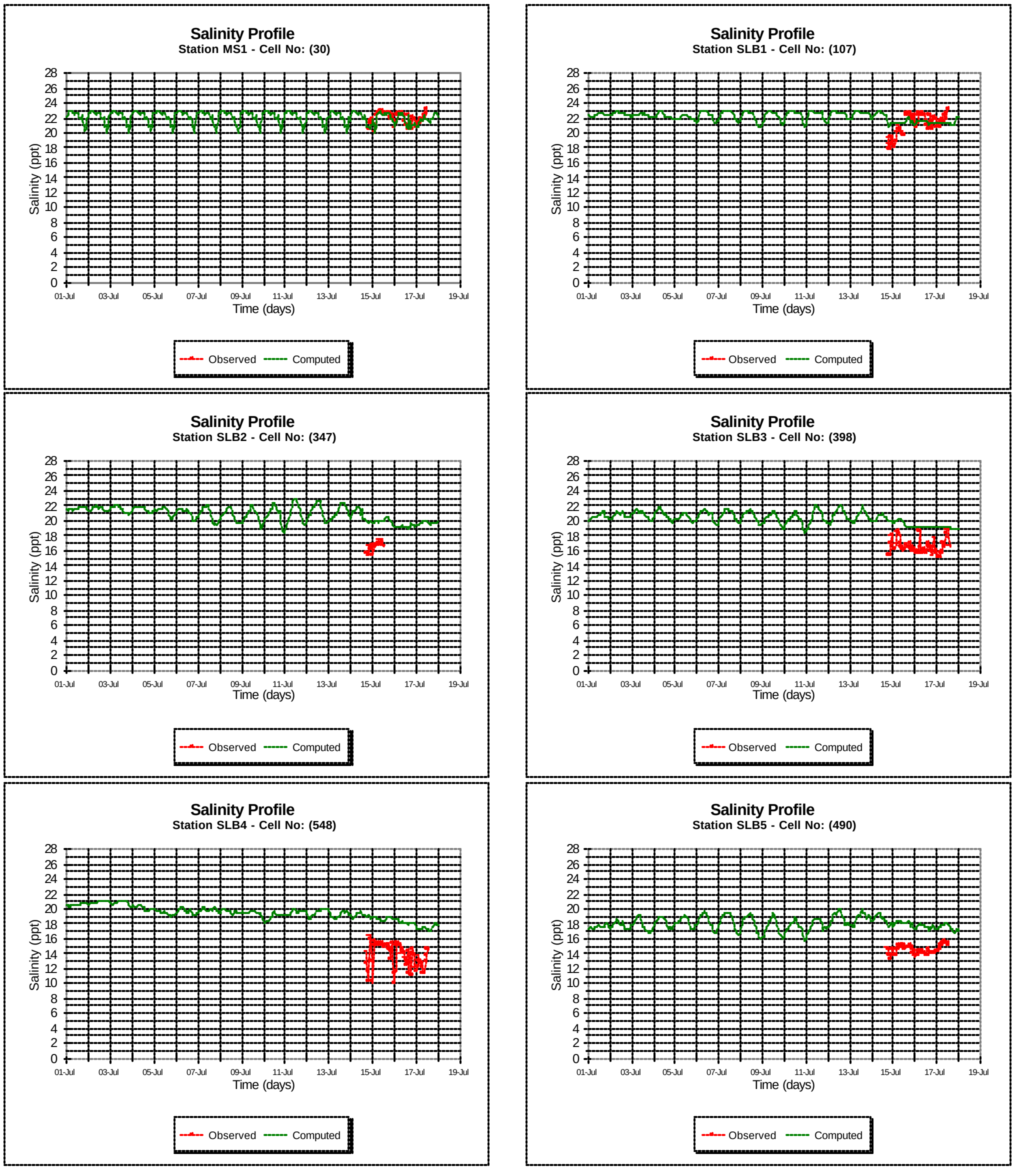


Figure A.2 Calibration Diurnal Salinity Profiles, July 1-19, 1998



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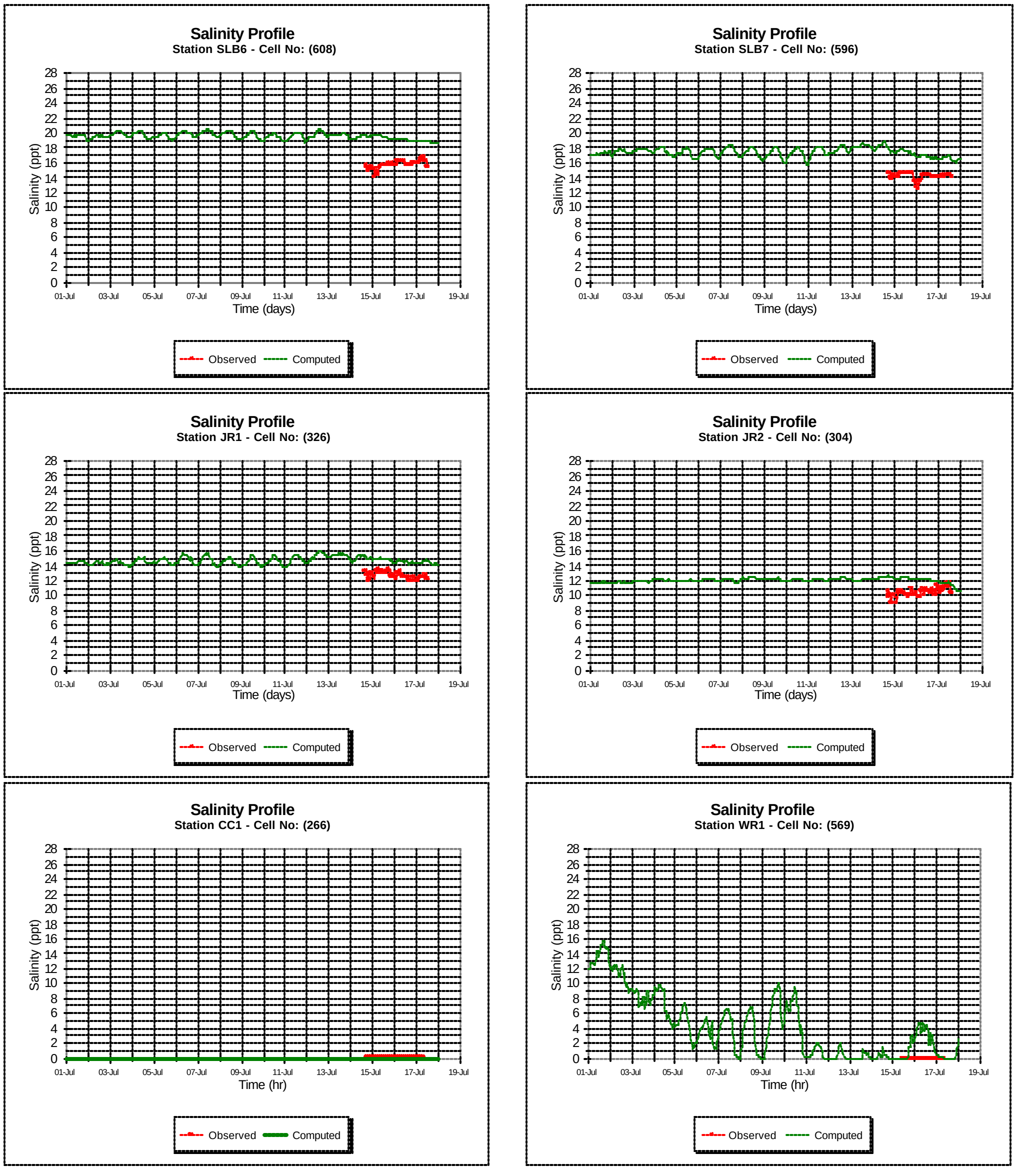
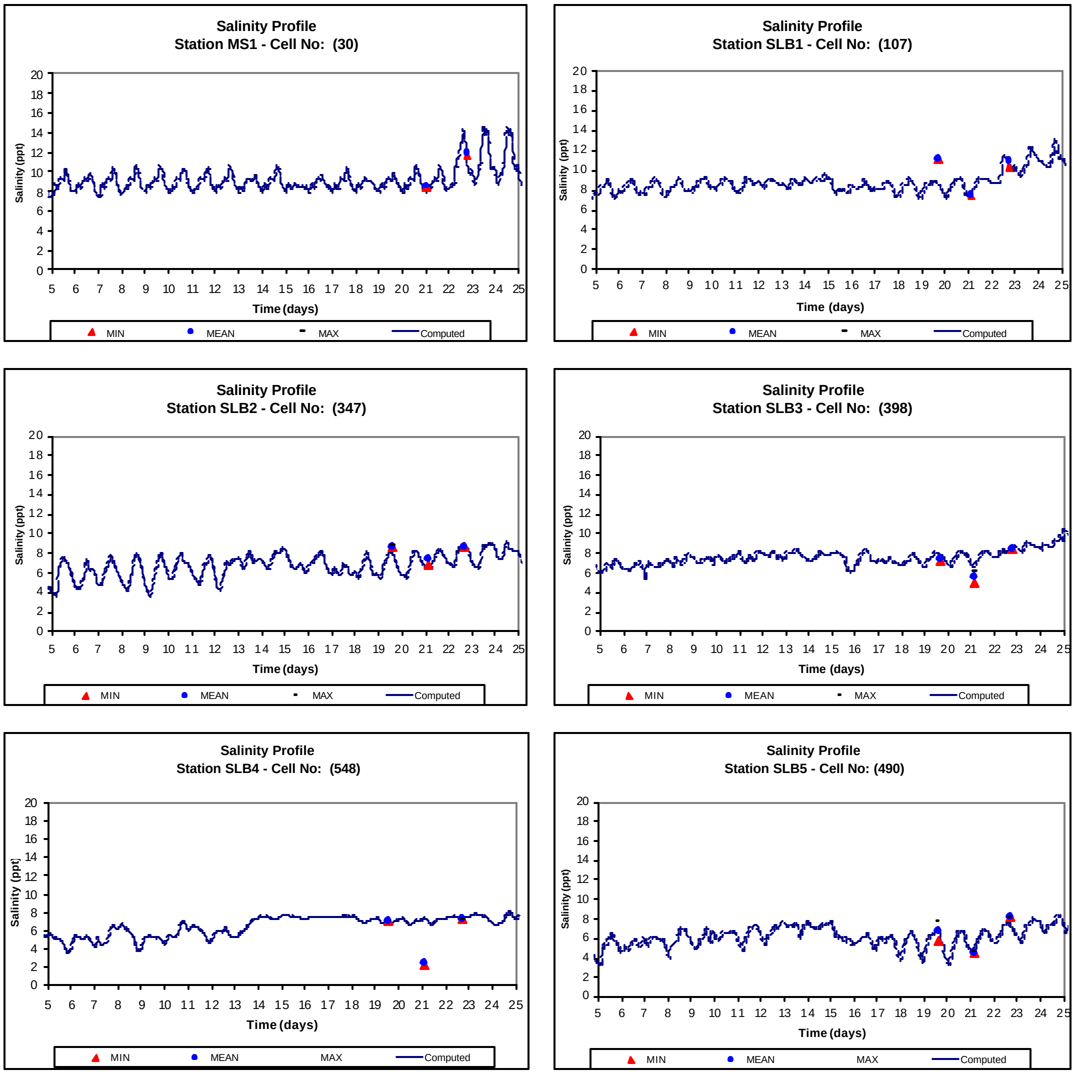


Figure A.3 Verification Temporal Salinity Profiles at St. Louis Bay, April 5-25, 1999



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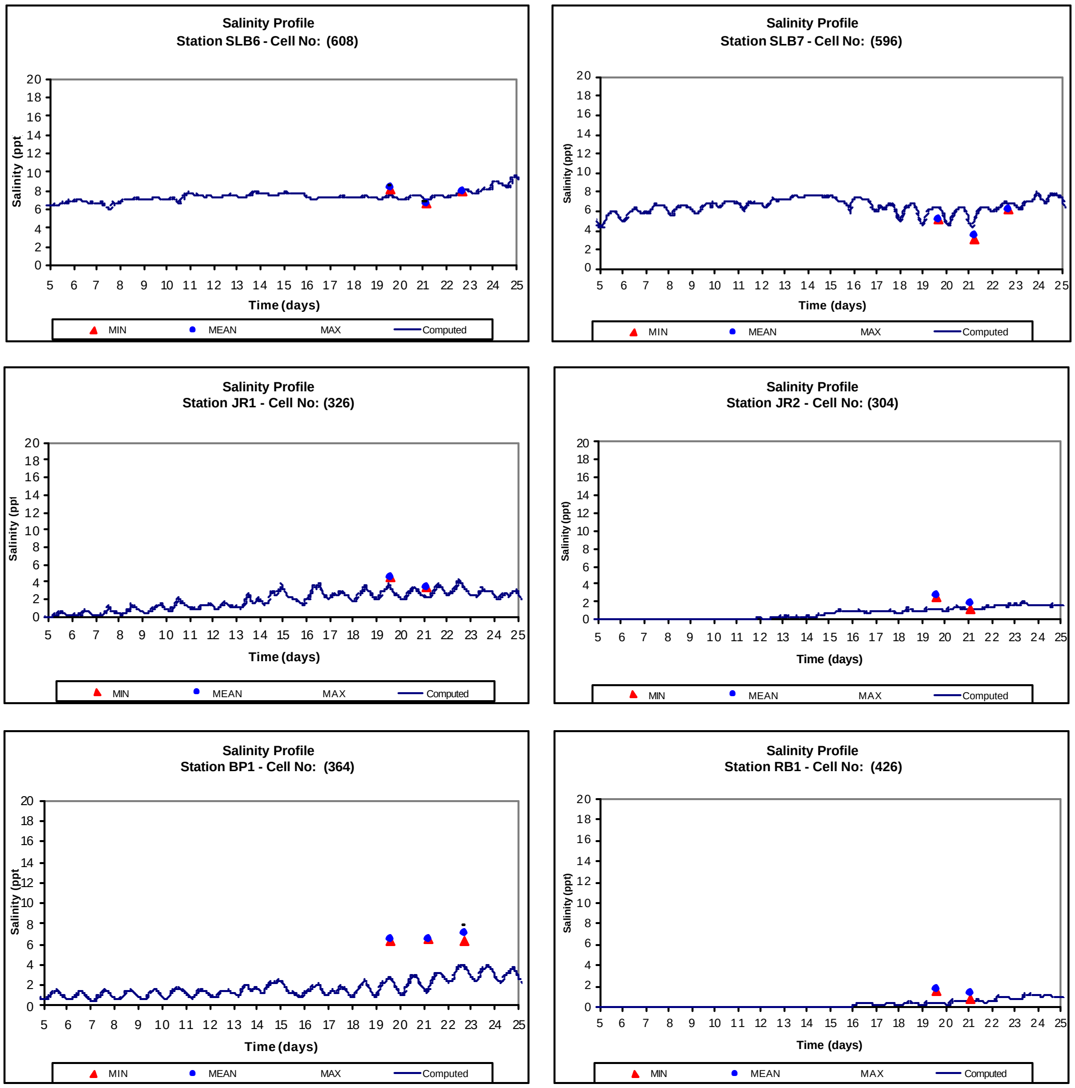

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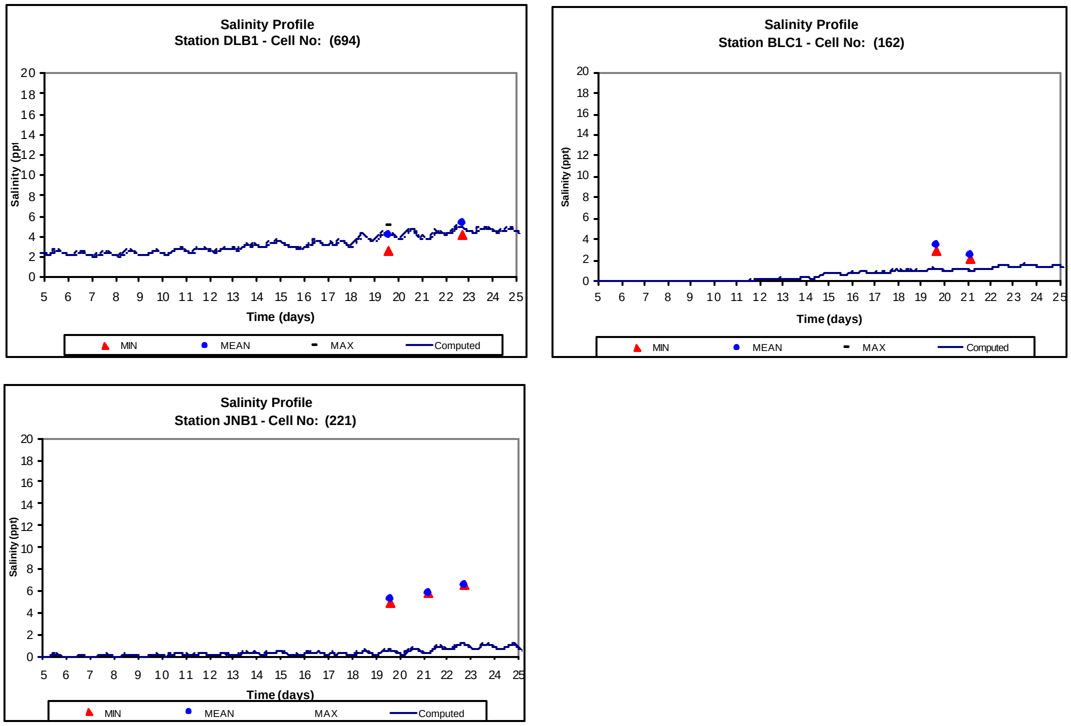
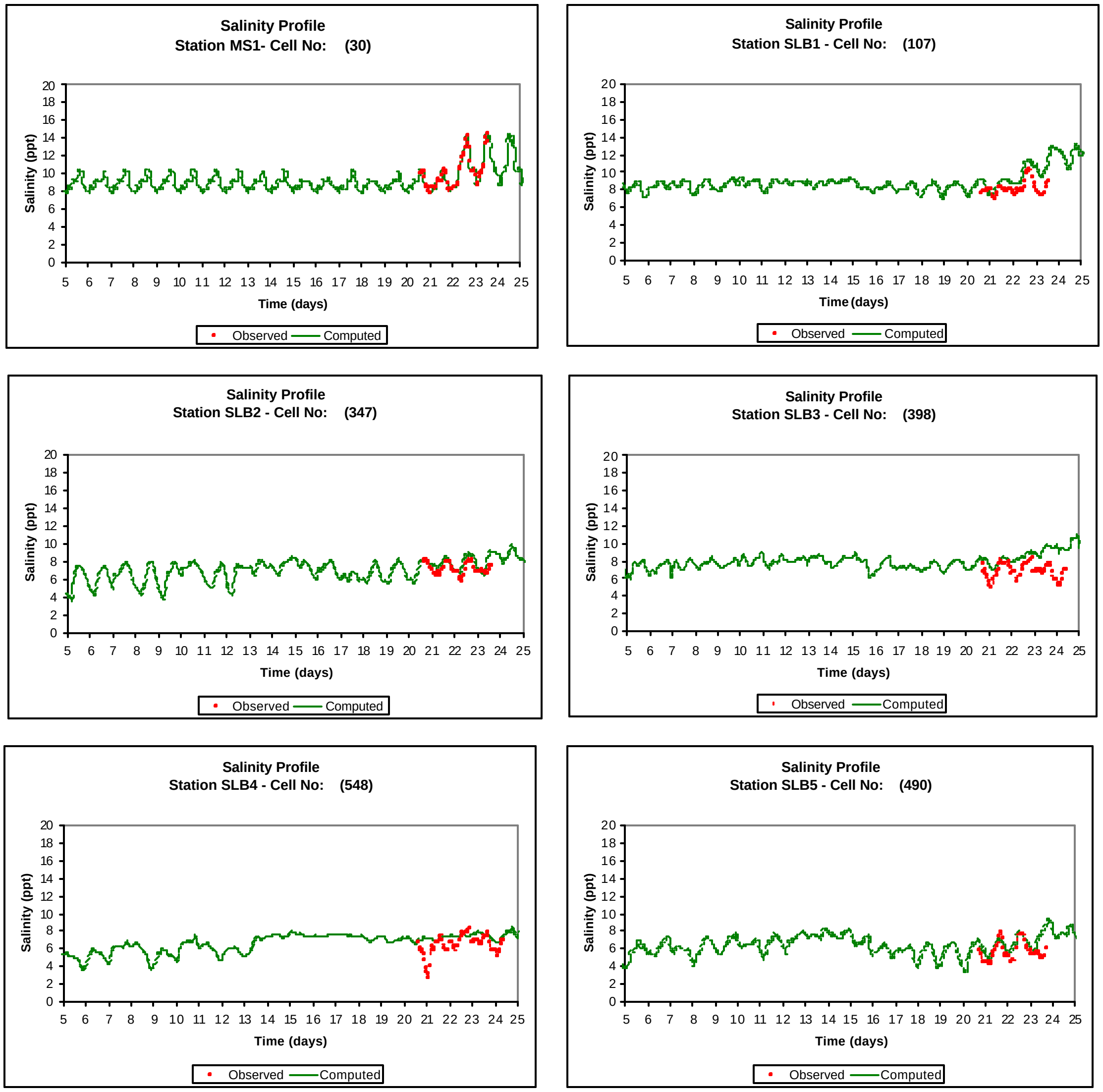


Figure A.4 Verification Diurnal Salinity Profiles at St. Louis Bay, April 5-25, 1999



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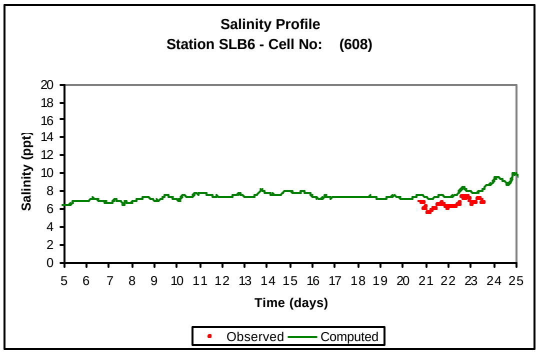

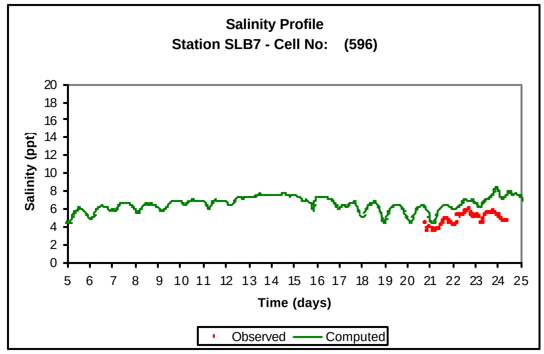

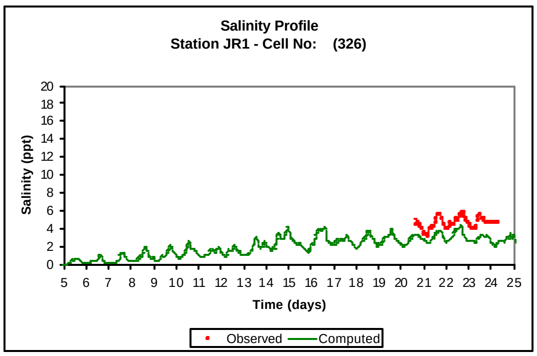

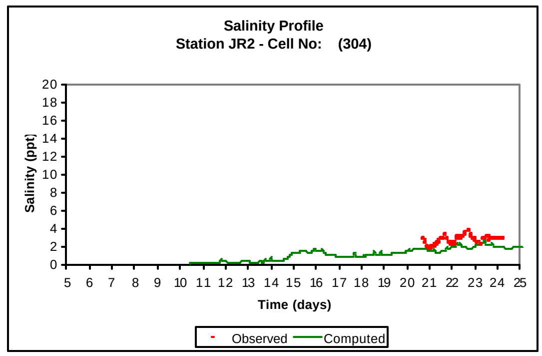

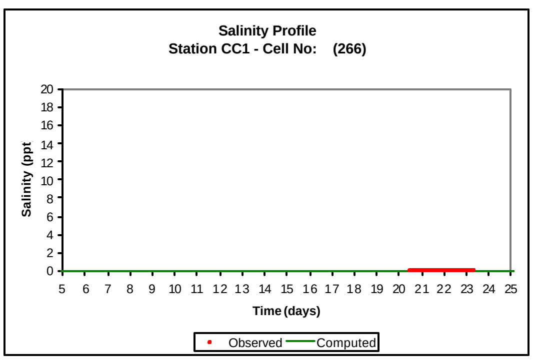

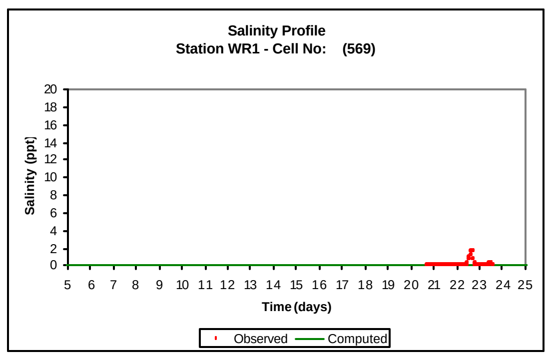

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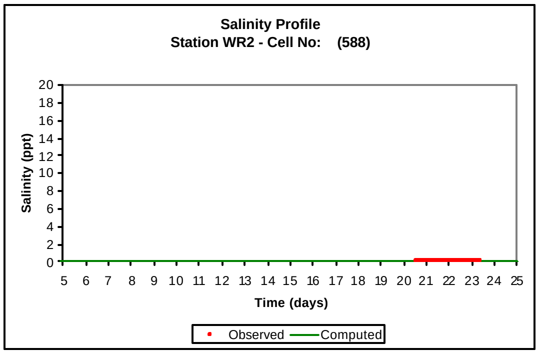


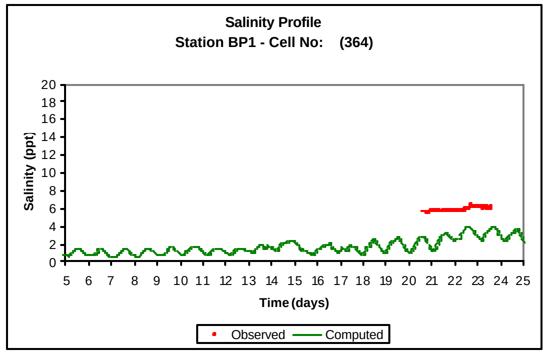
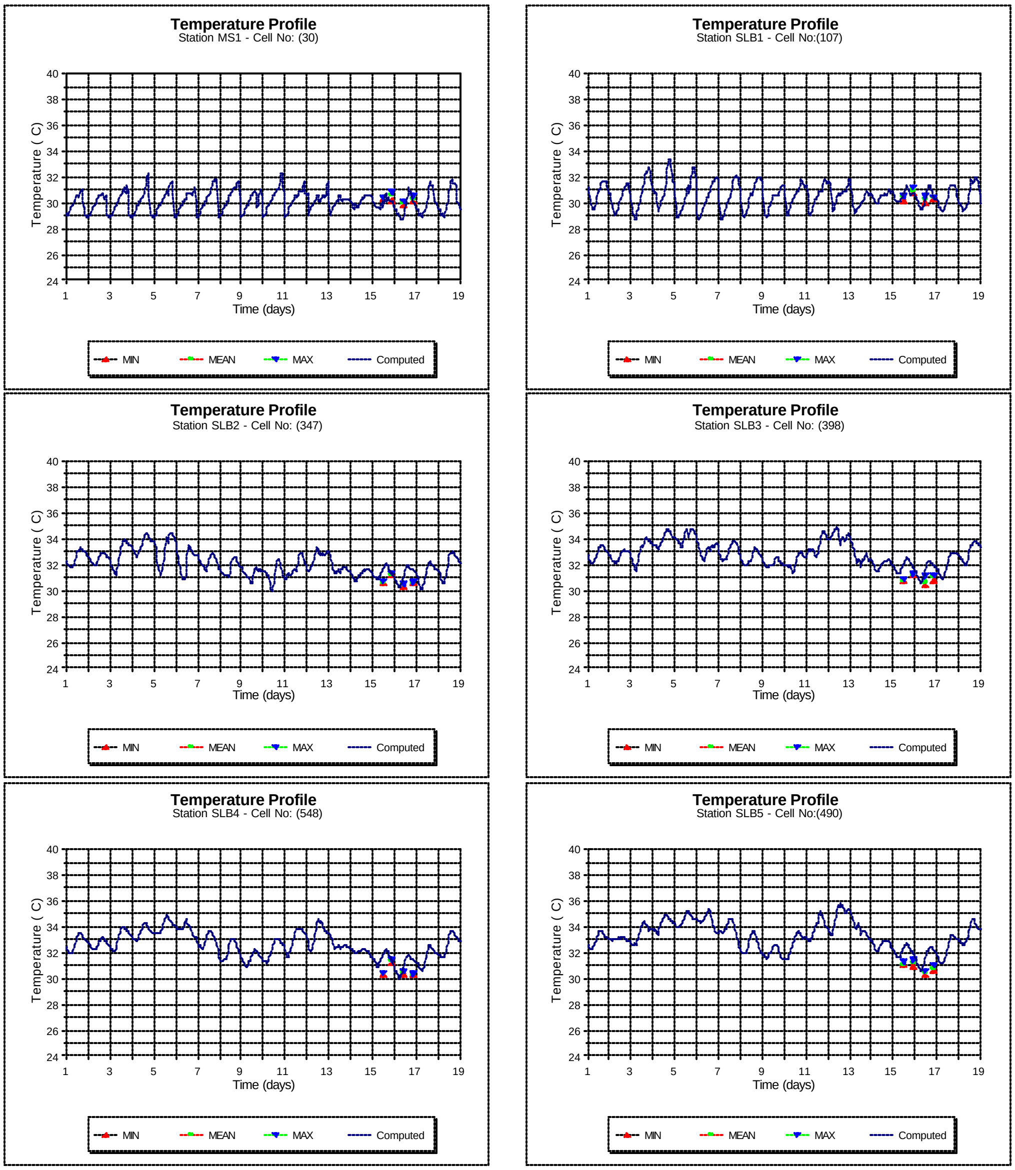


Figure A.5 Calibration Temporal Temperature Profiles at St. Louis Bay, July 1- 19, 1998



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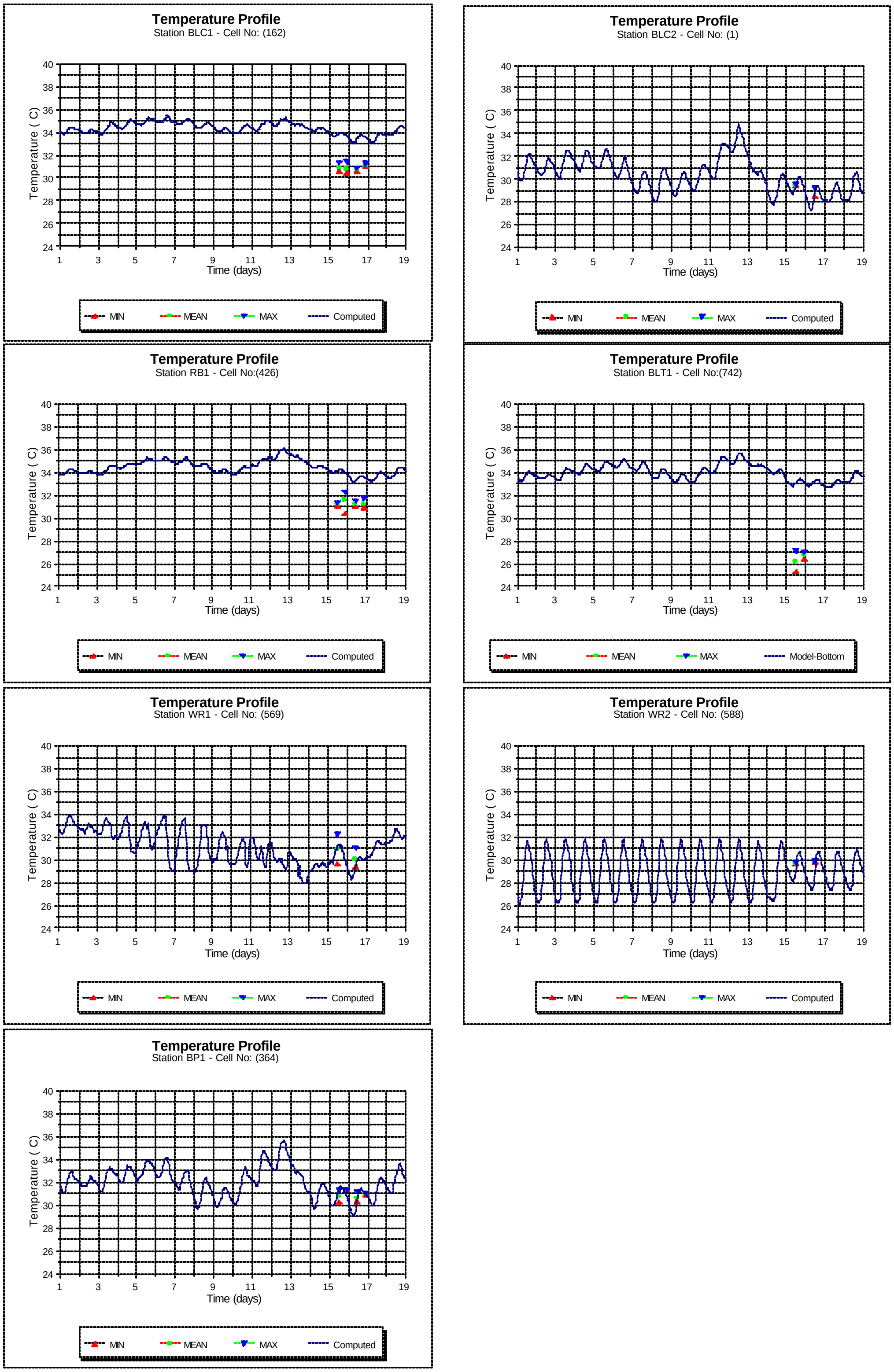
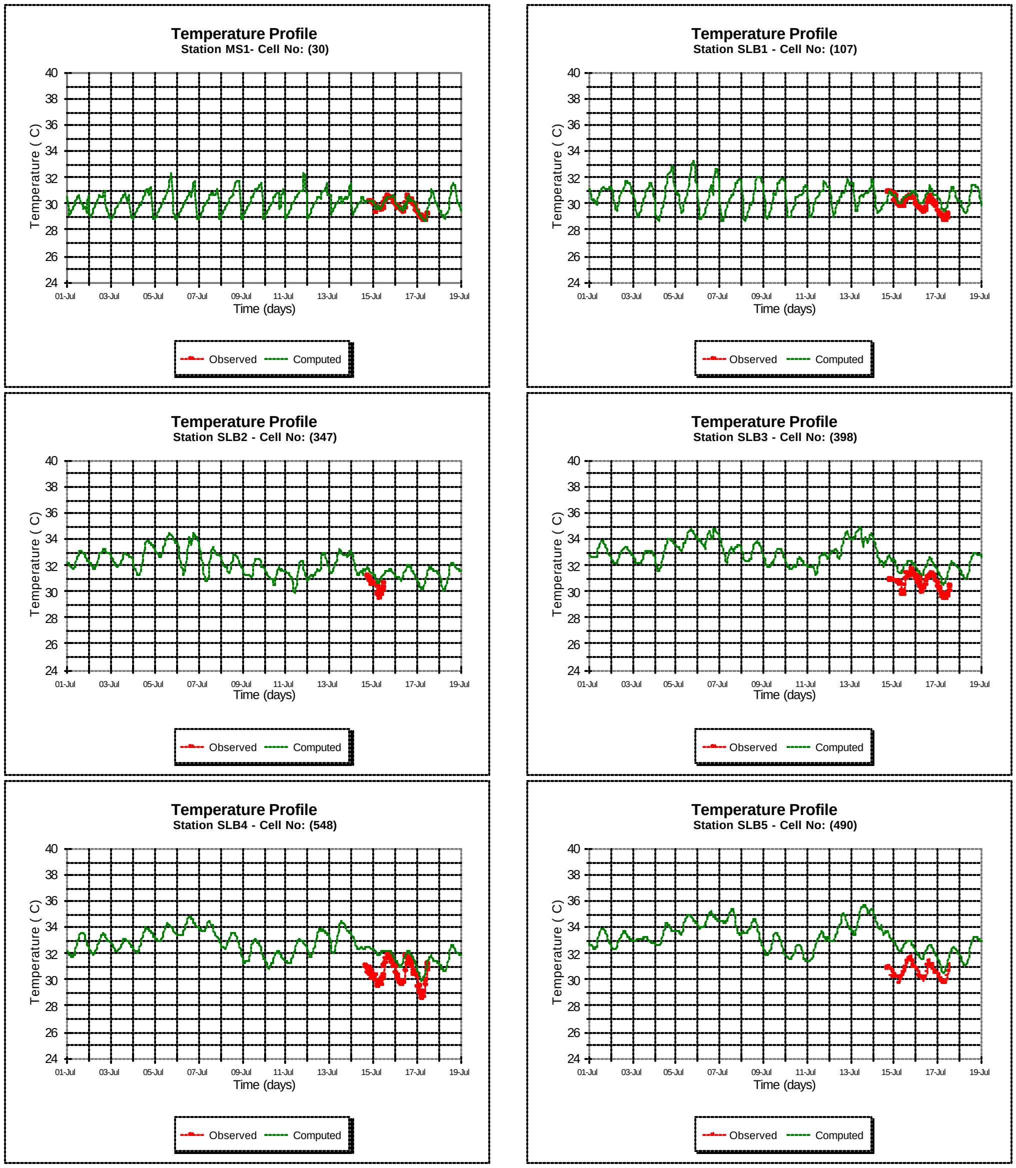


Figure A.6: Calibration Diurnal Temperature Profiles at St. Louis Bay, July 1-19, 1998



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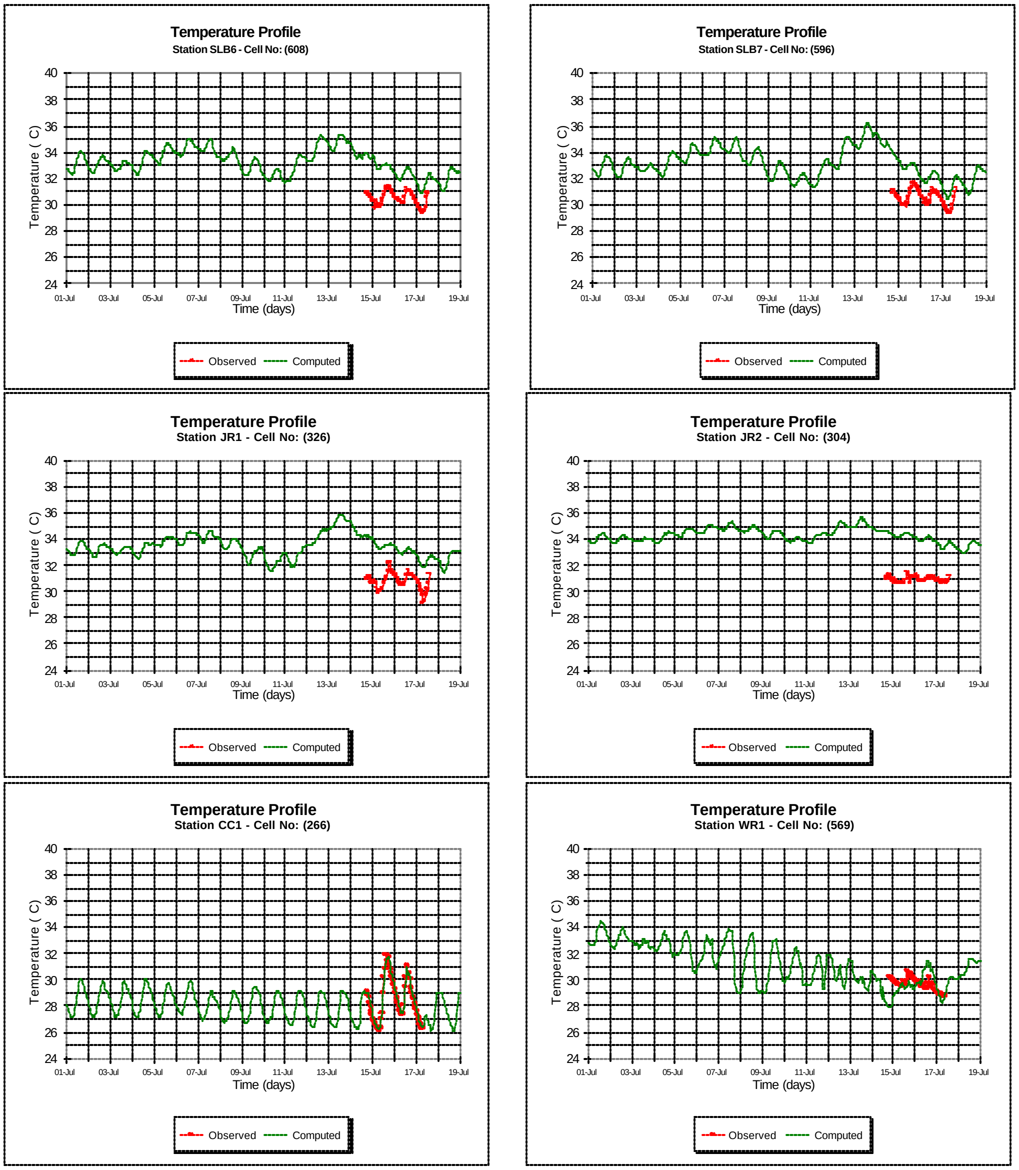

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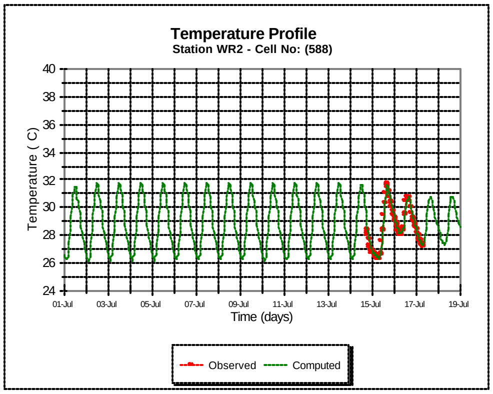


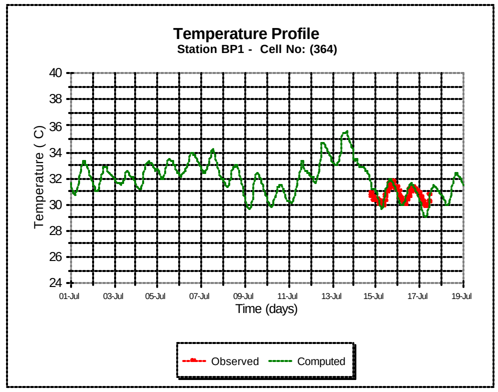
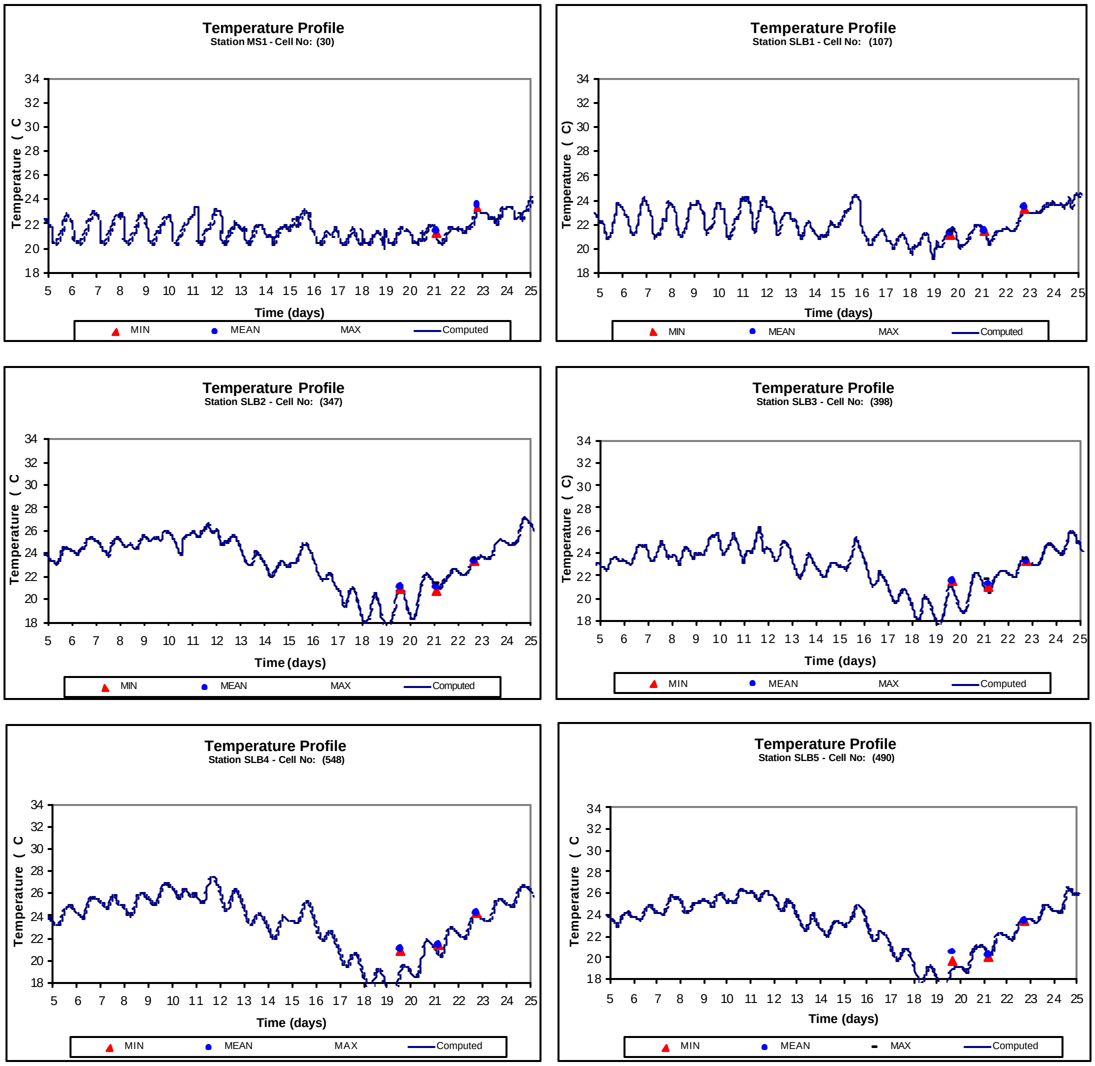


Figure A.7 Verification Temporal Temperature Profiles at St. Louis Bay, April 5-25, 1999



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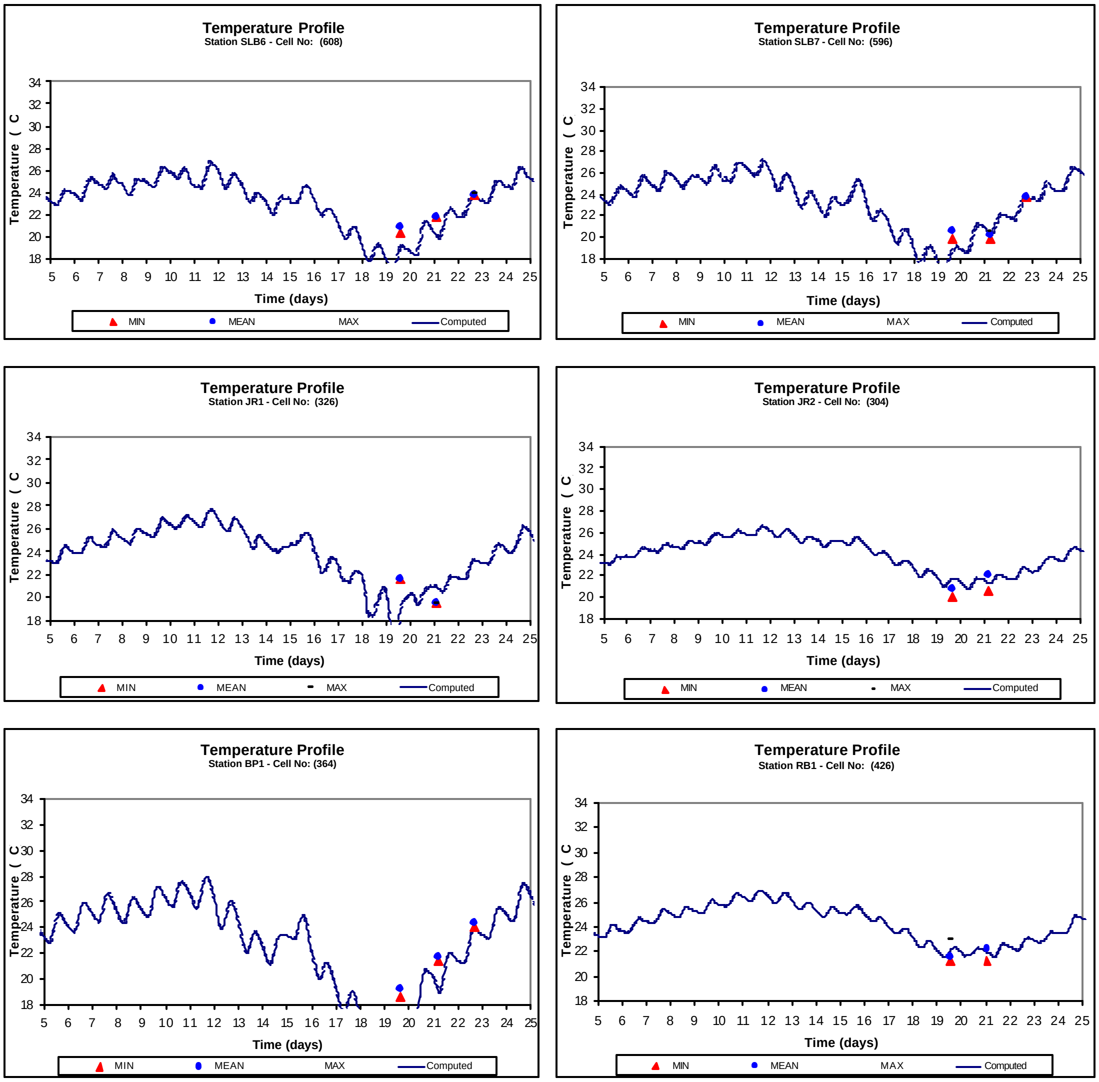

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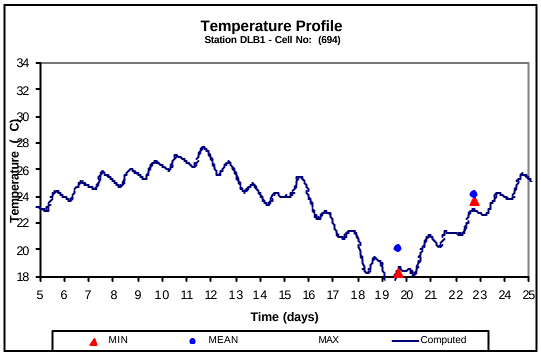
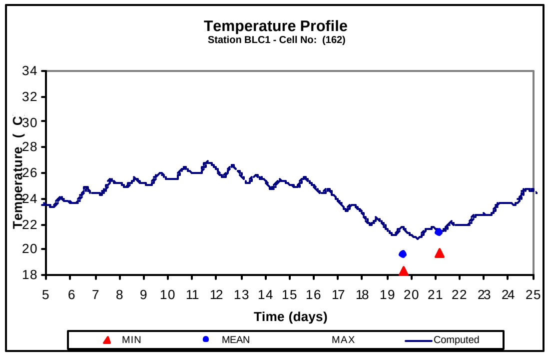




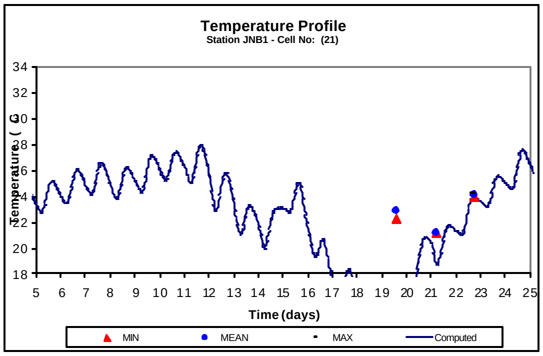
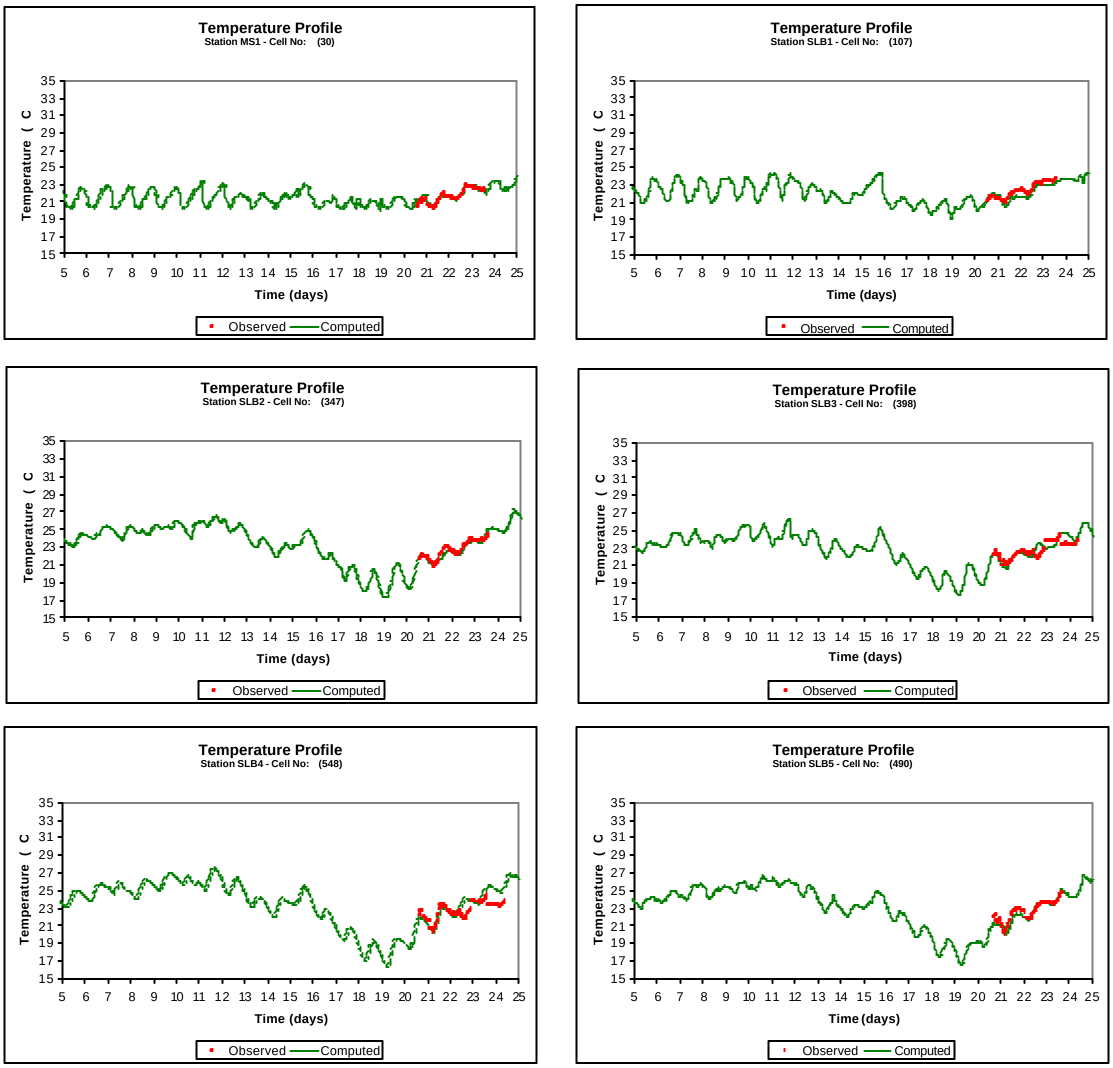


Figure A.8 Verification Diurnal Temperature Profiles at St. Louis Bay, April 5-25, 1999



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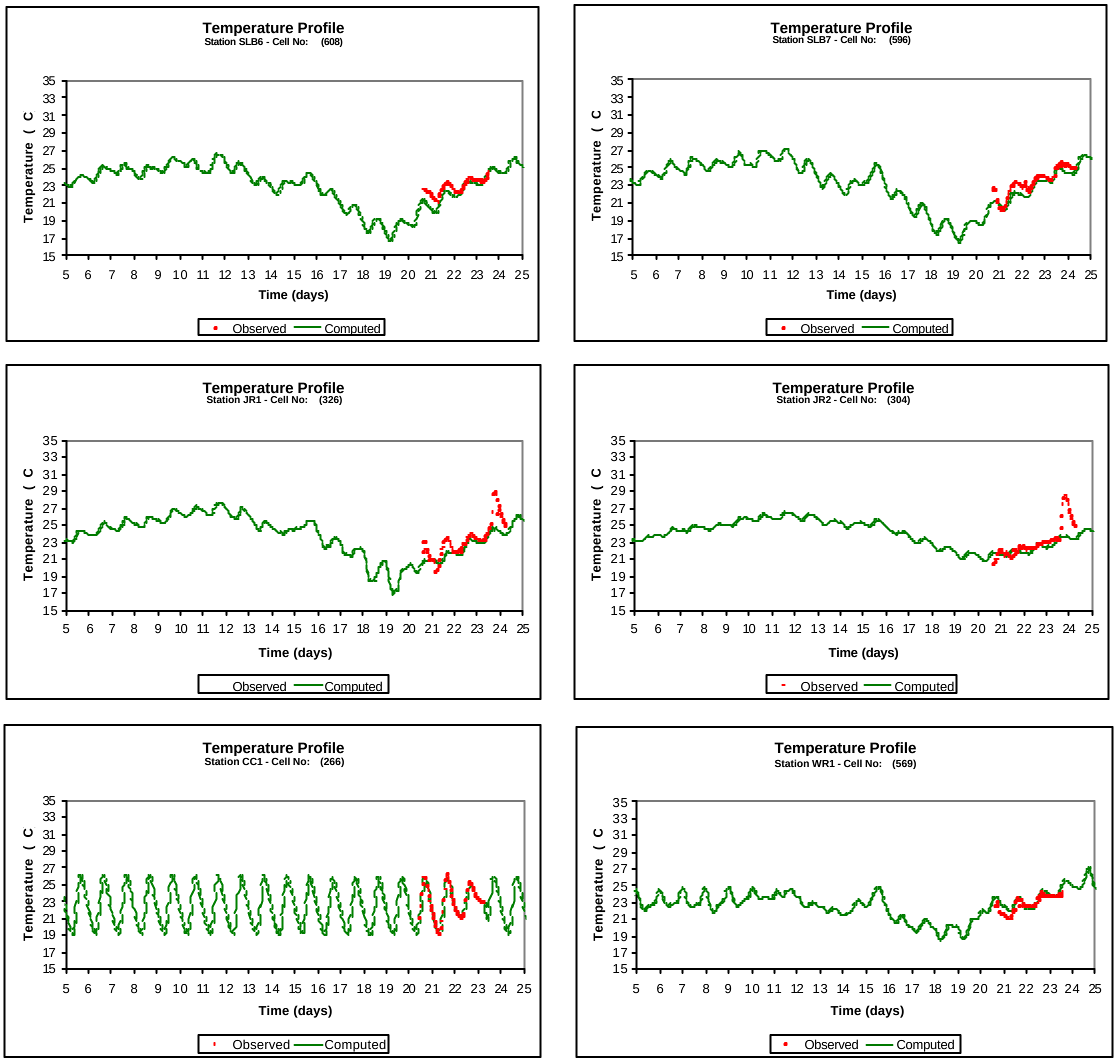

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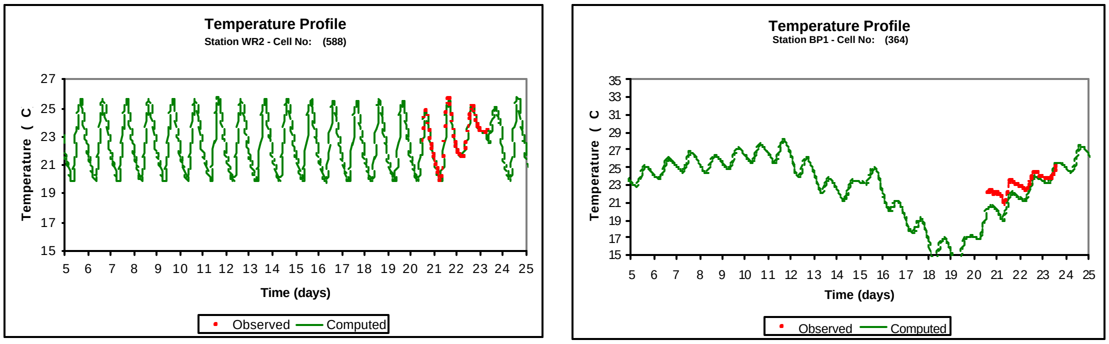
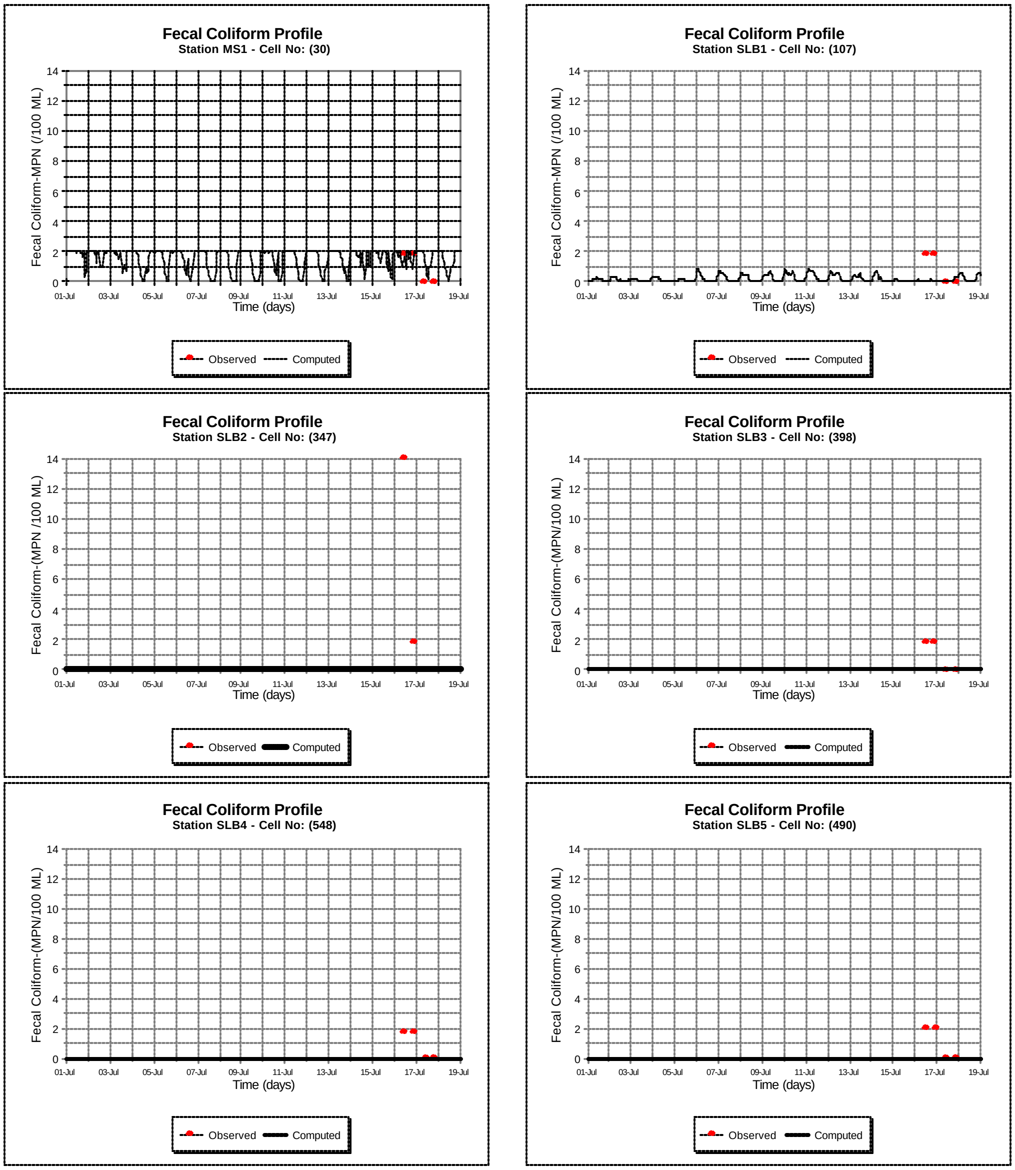


APPENDIX B

Calibration and Verification of Water Quality

Figure B.1 Calibration Temporal Fecal Coliform Profiles at St. Louis Bay, July 1-19, 1998



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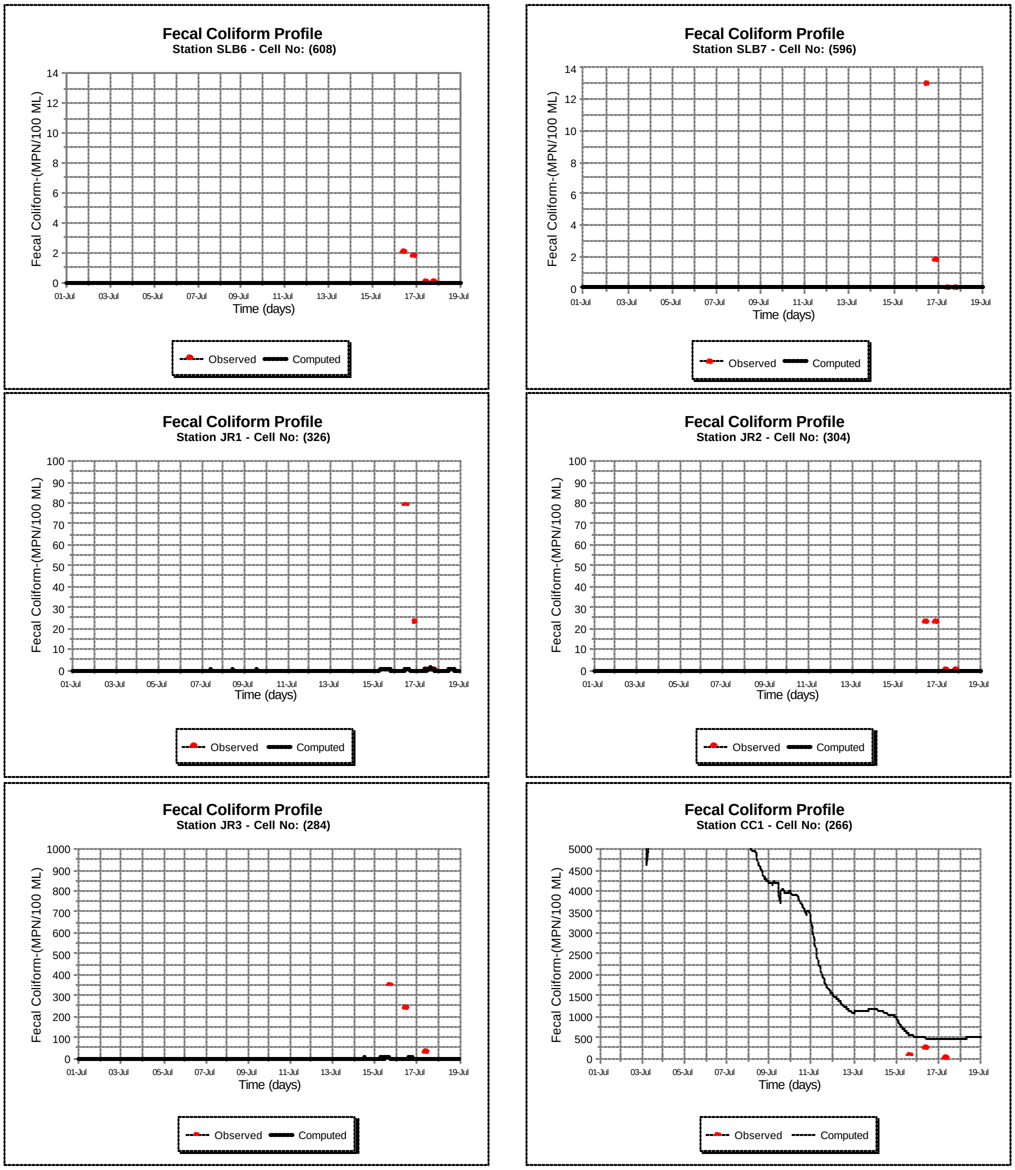

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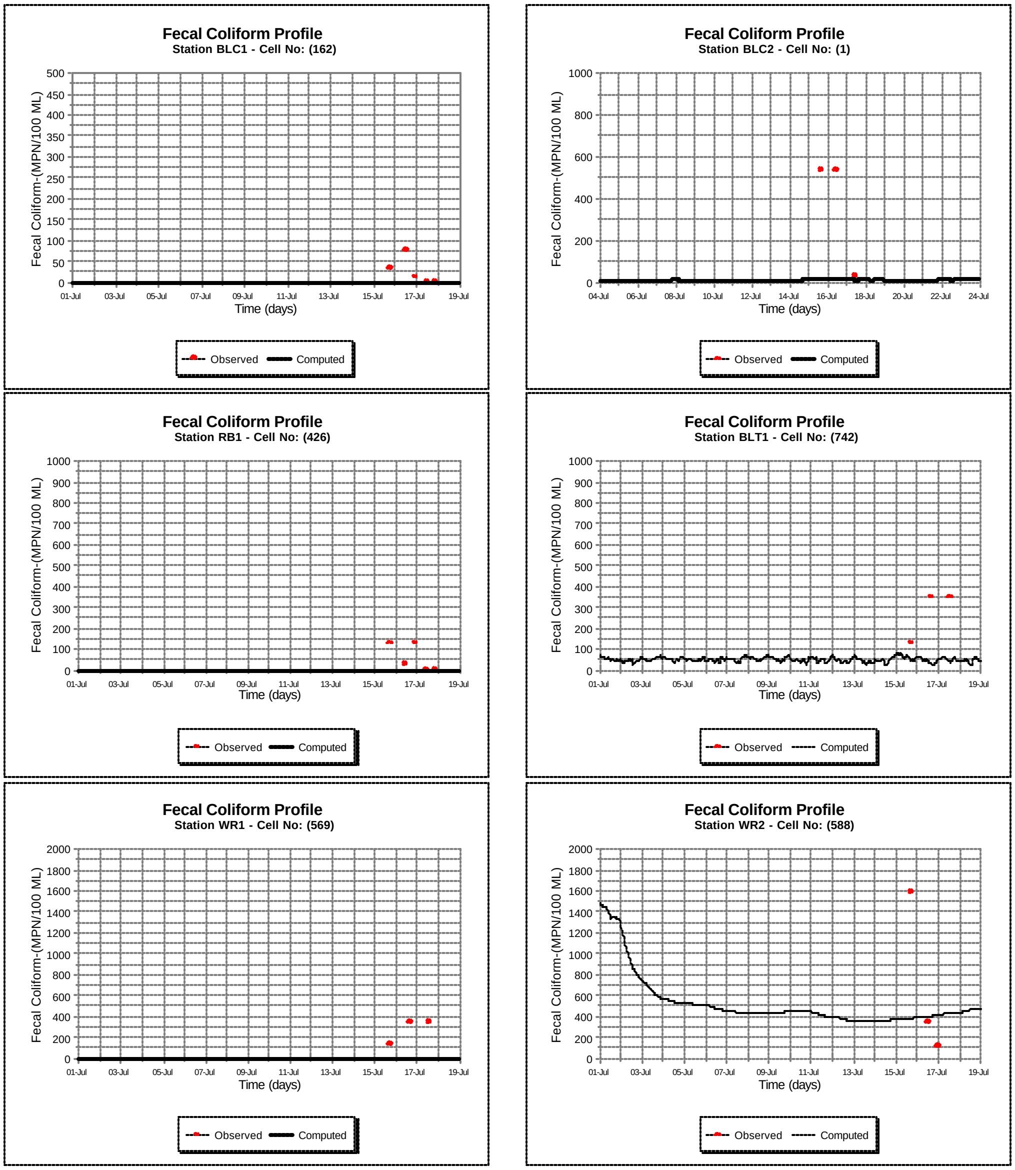

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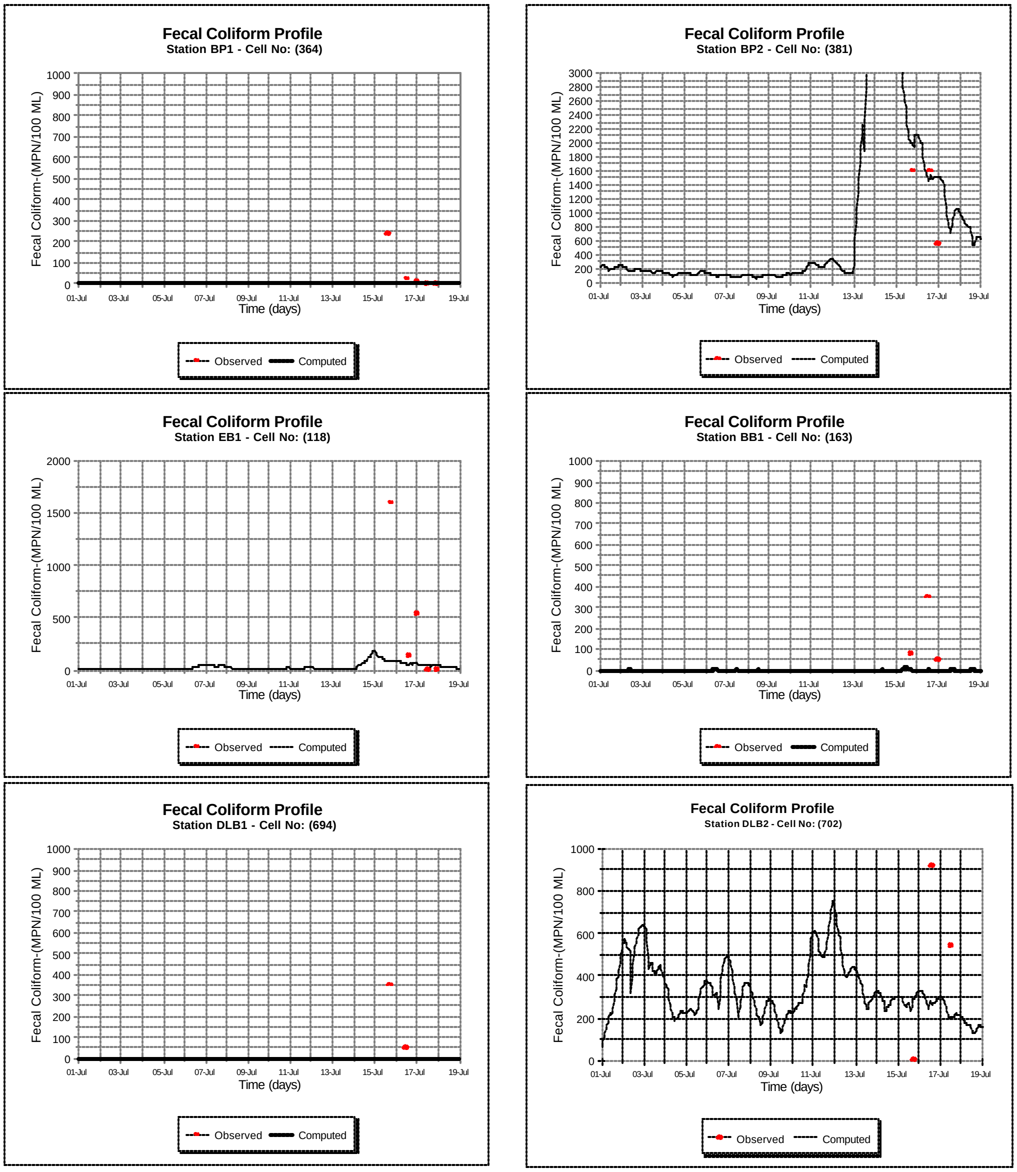

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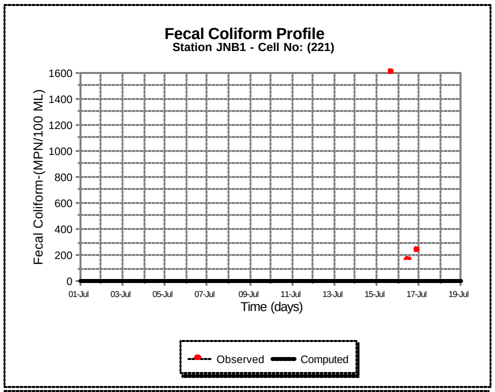
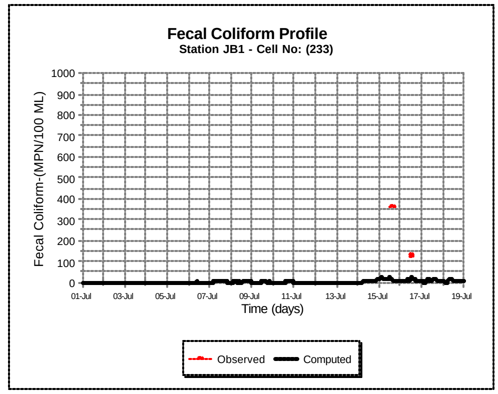




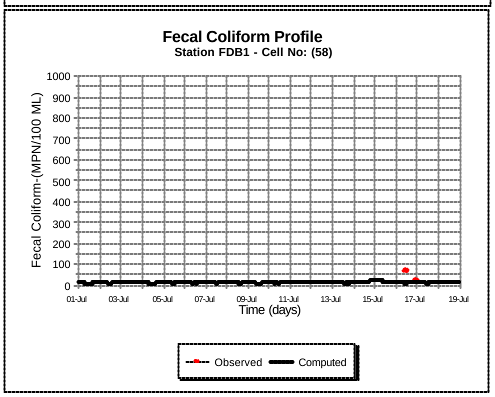
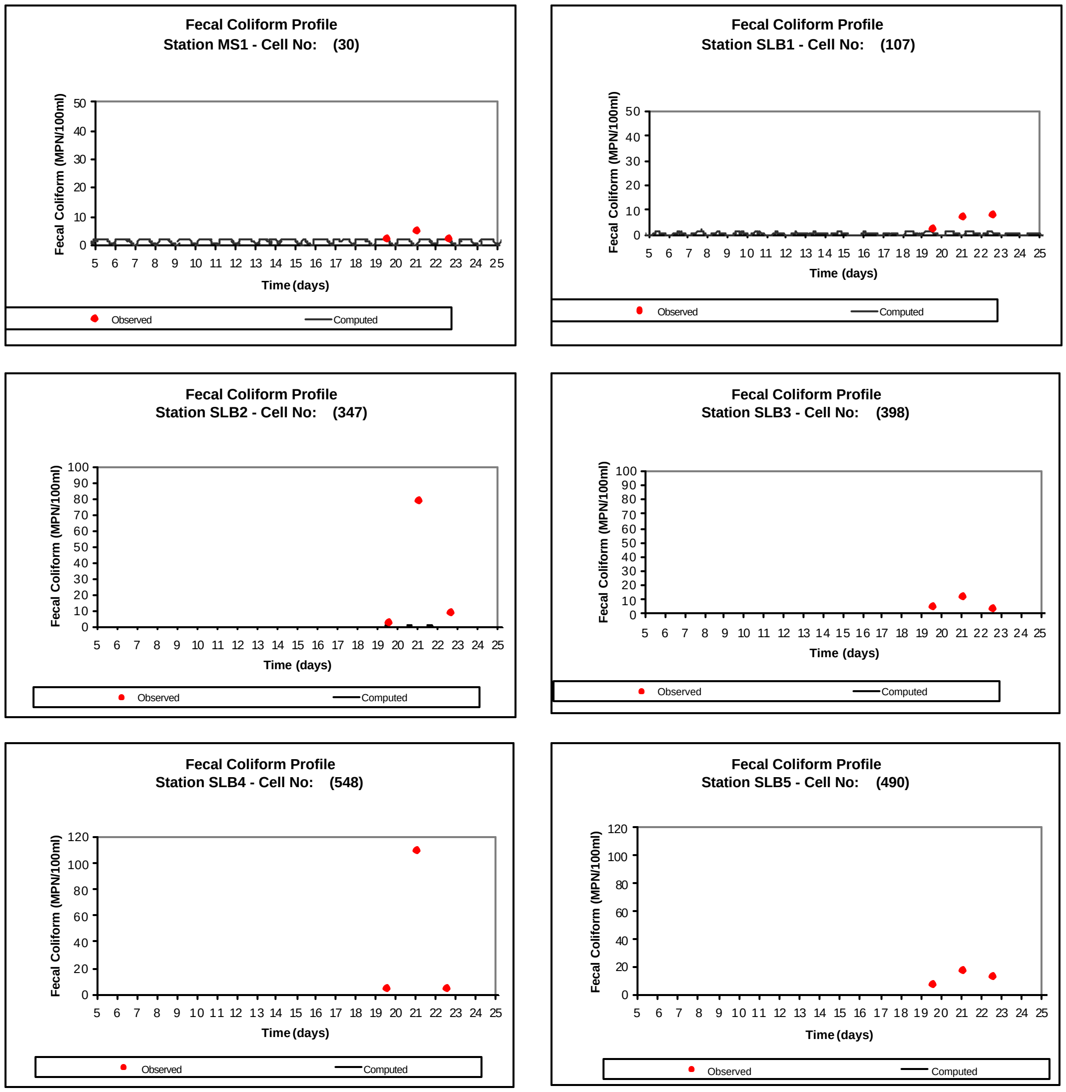


Figure B.2 Verification Temporal Fecal Coliform Profiles at St. Louis Bay, April 5-25, 1999



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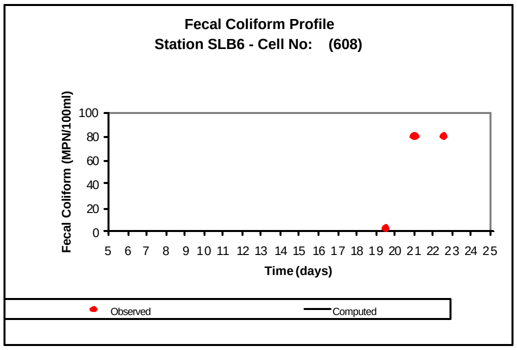

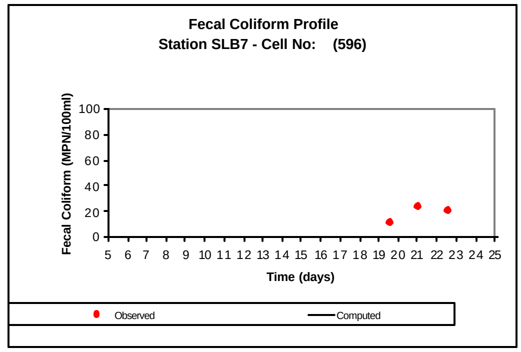

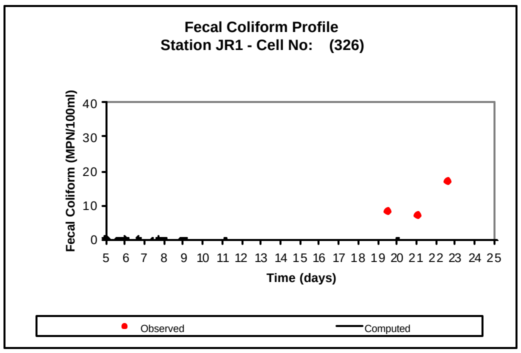

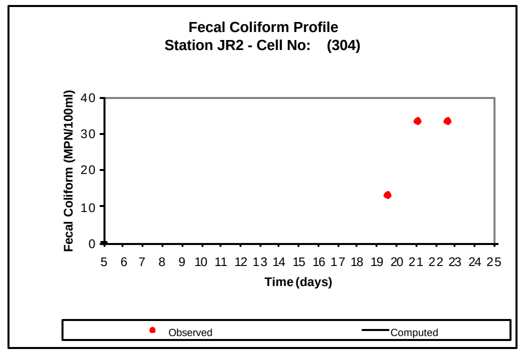

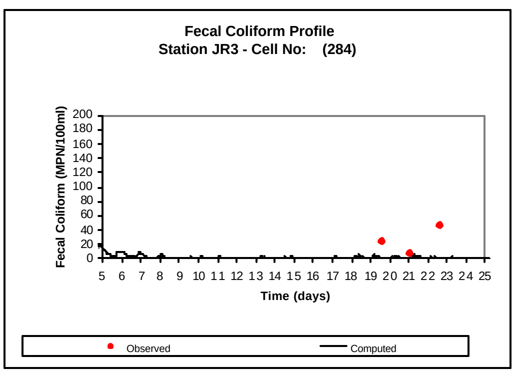

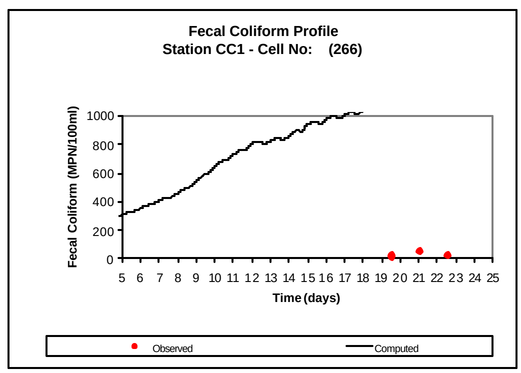

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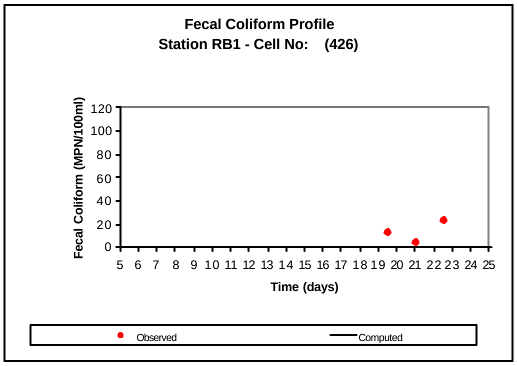

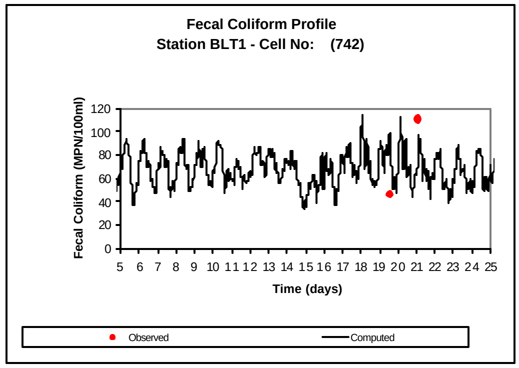

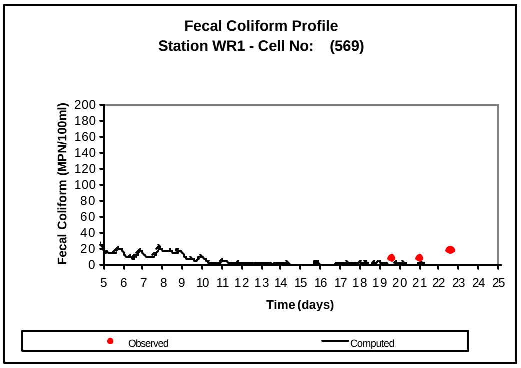

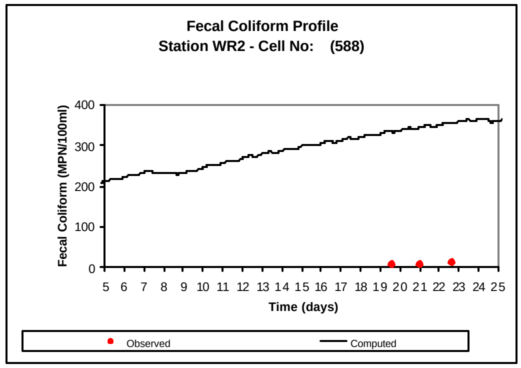

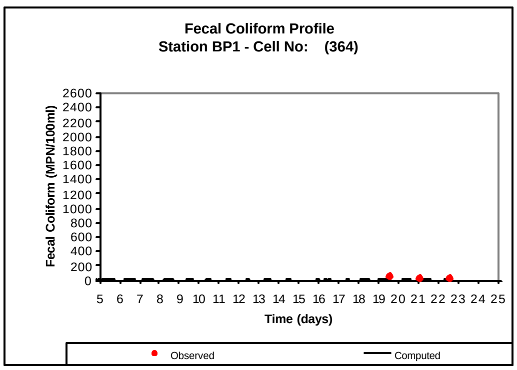

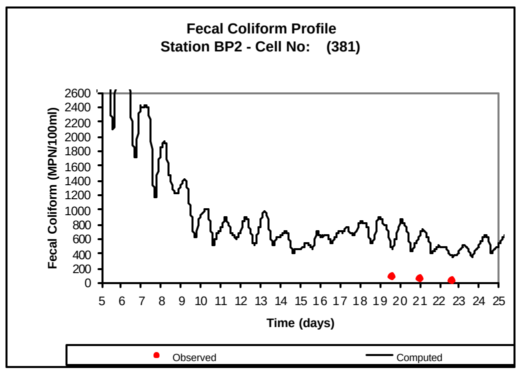

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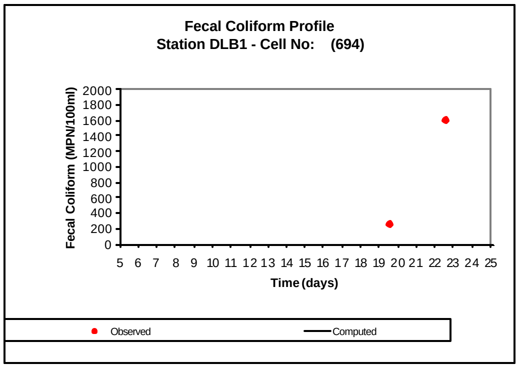

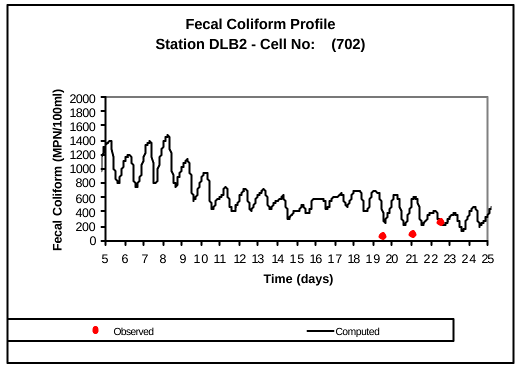

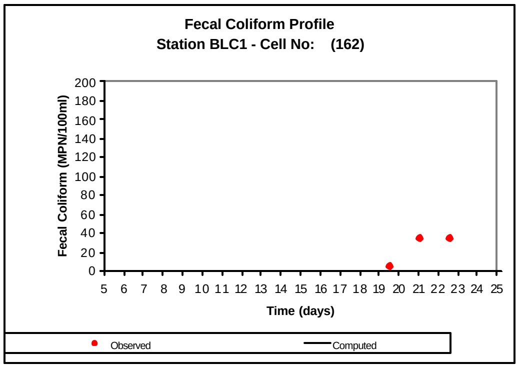

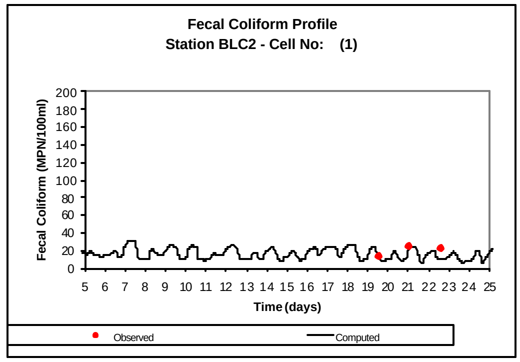

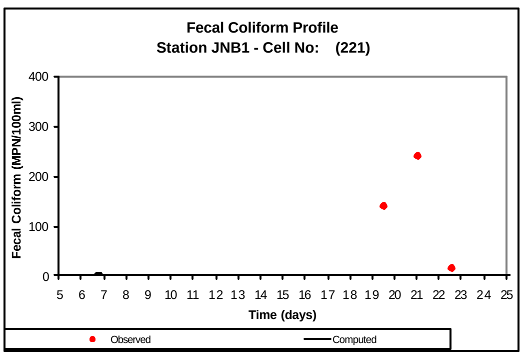

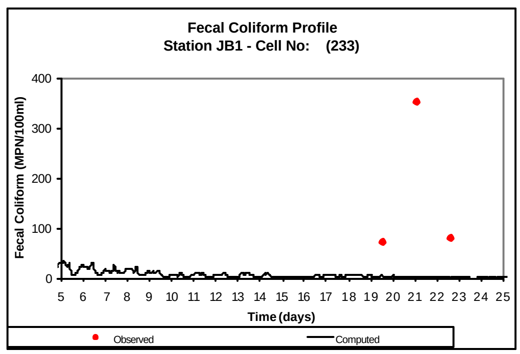

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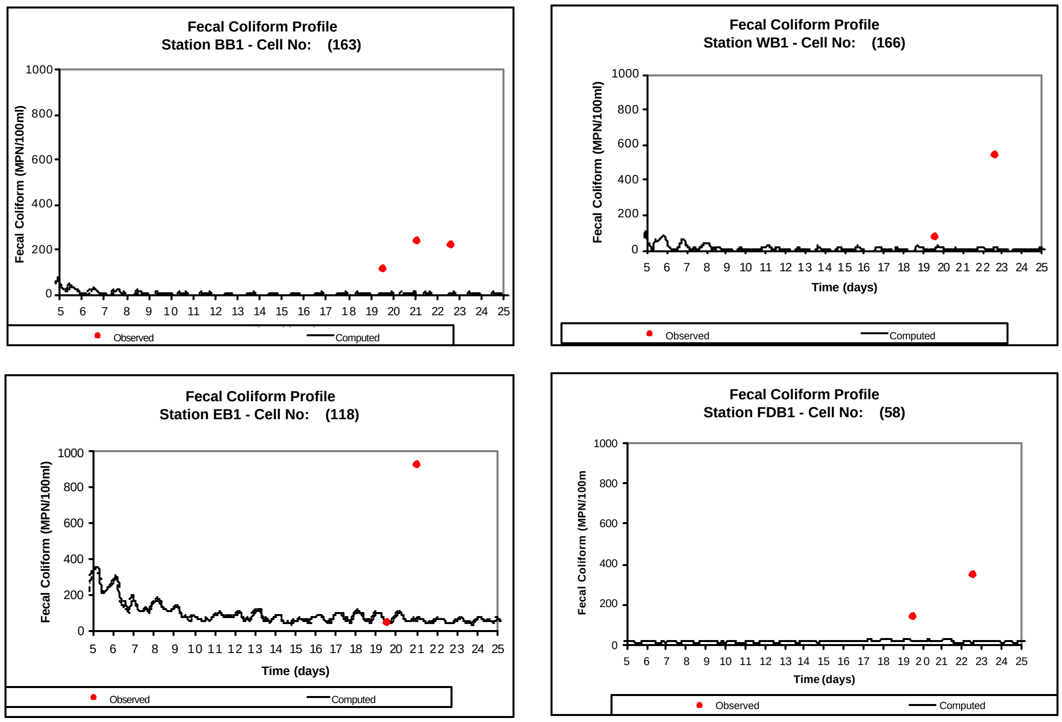


APPENDIX C

Baseline and Allocation Modeling Results

Figure C.1 Baseline Model Results

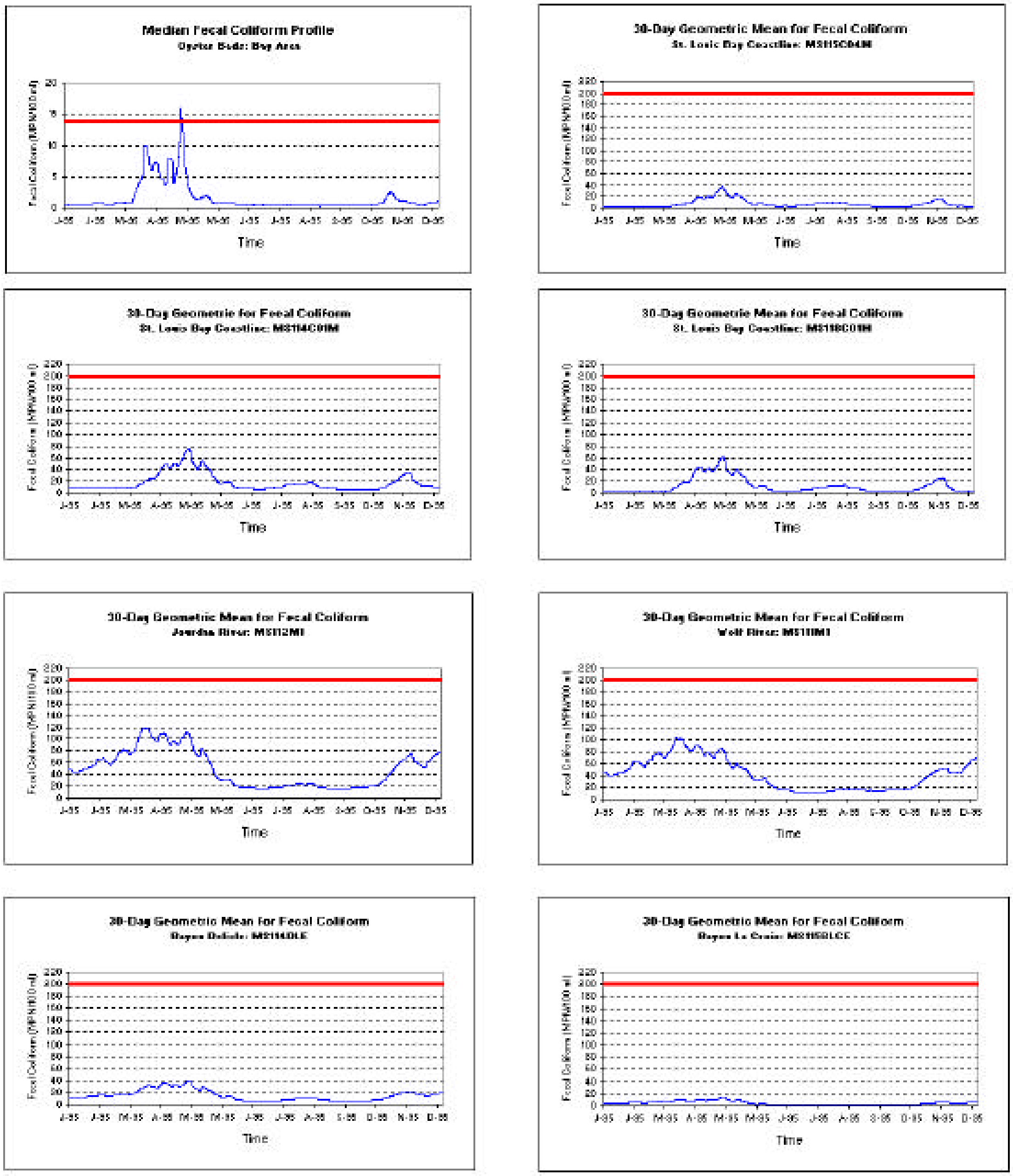


Figure C.1 Continued

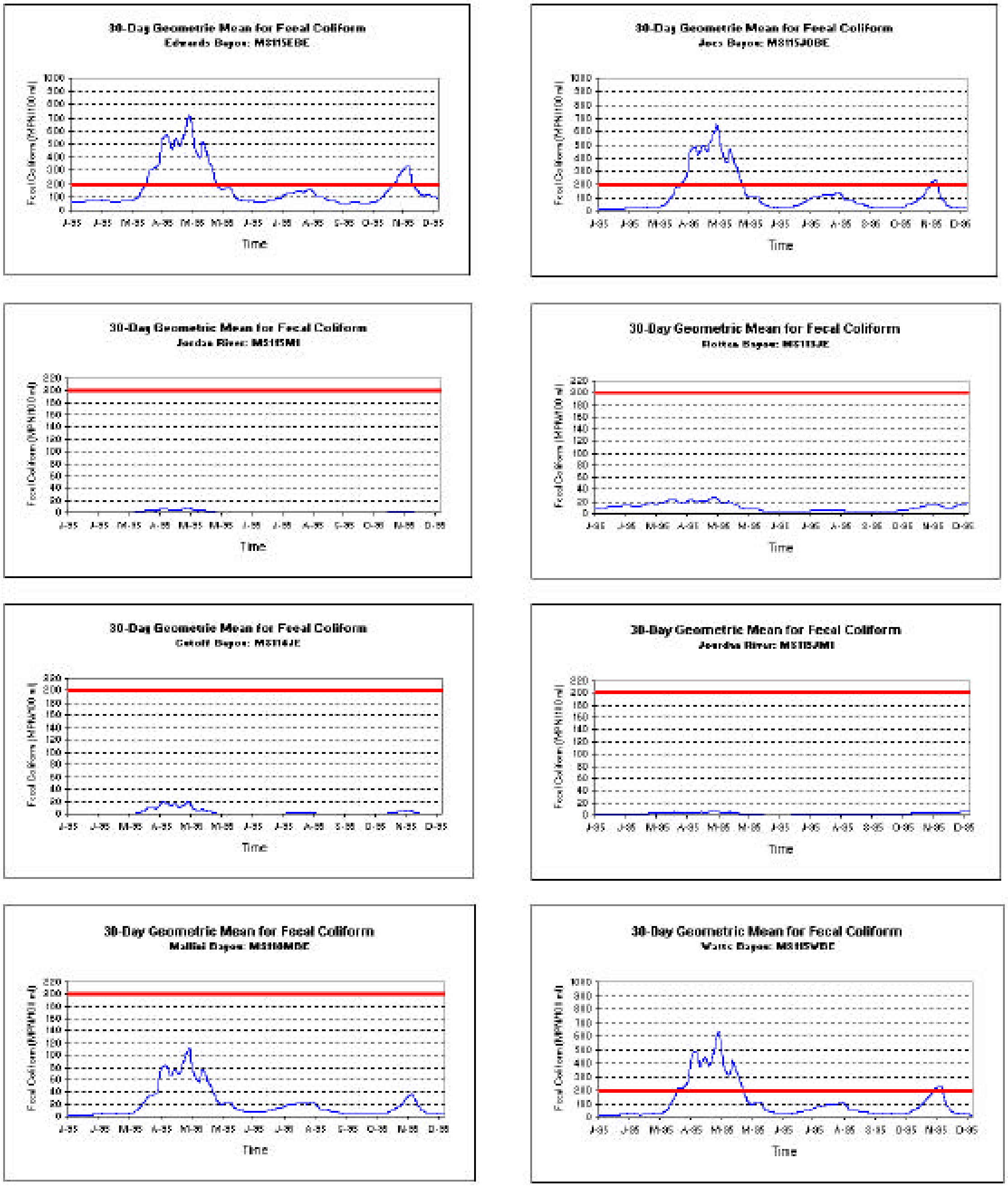
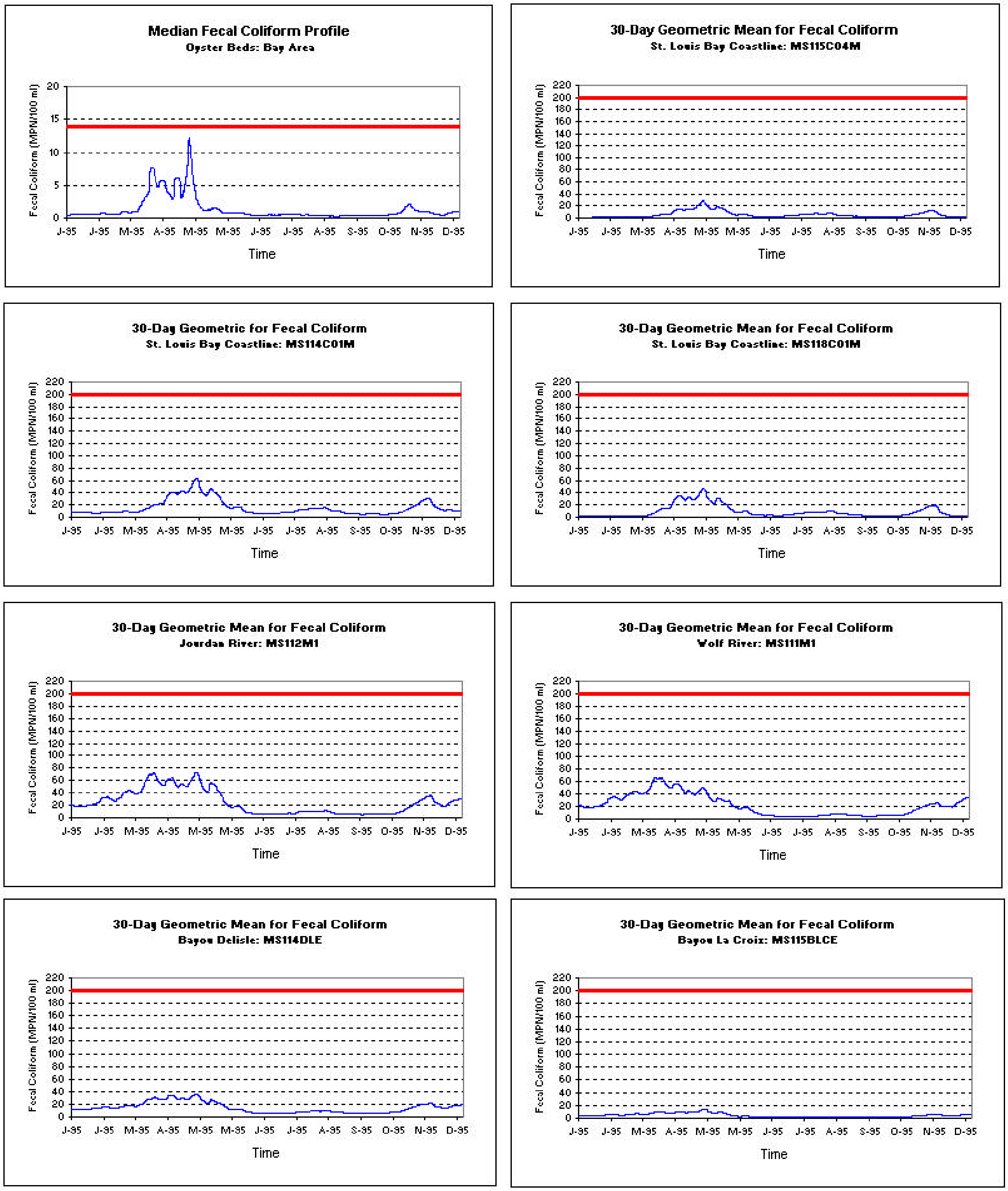
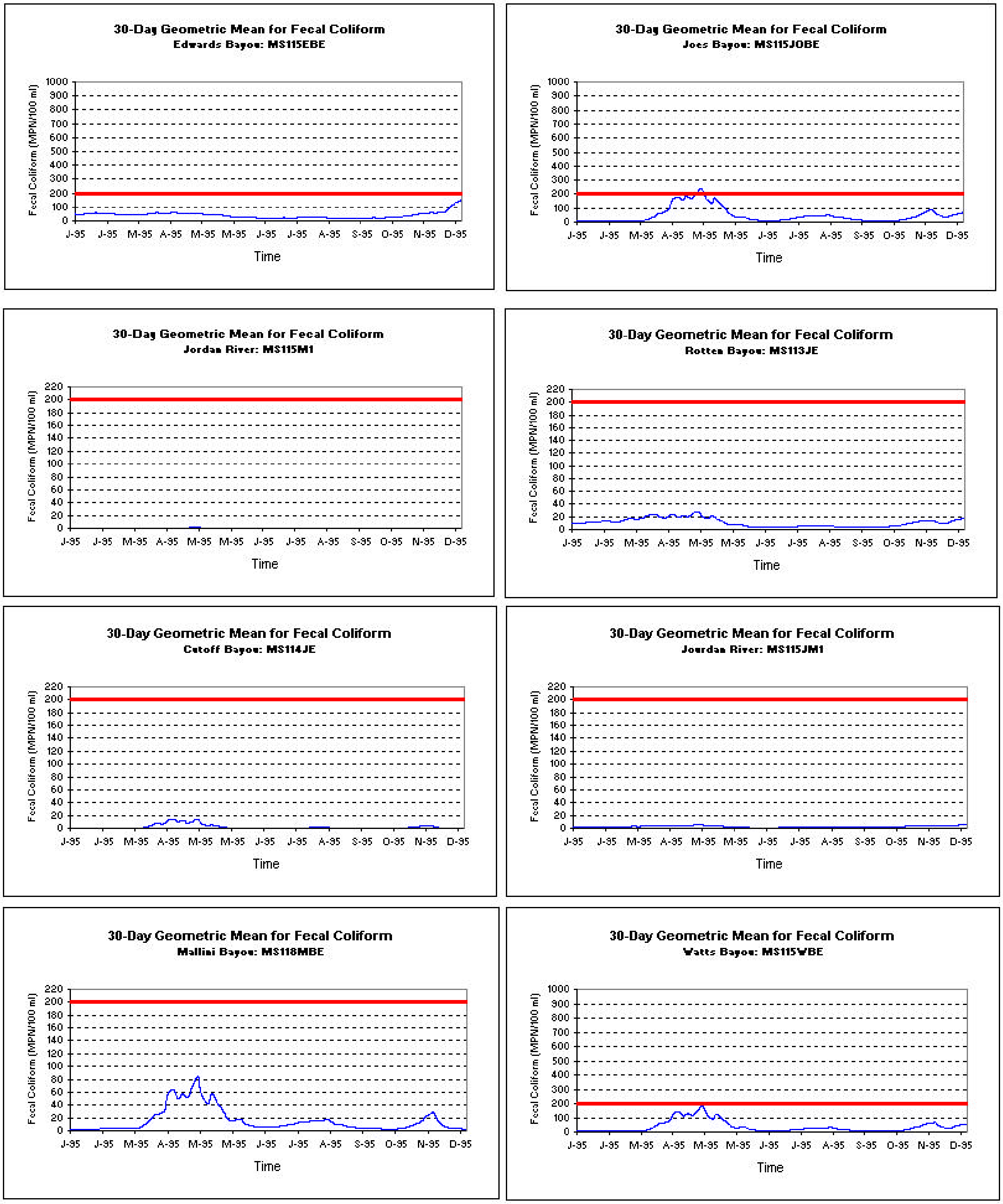


Figure C.2 Allocated Model Results



Blue line - Reduced watershed loads with 75% urban load reduction on Edwards, Joes, and Watts Bayous
- 25% Urban load reduction on other small bayous

Figure C.2 Continued



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- 25% Urban load reduction on other small bayous