FINAL

Total Maximum Daily Loads of Fecal Coliform for the Restricted Shellfish Harvesting/Growing Areas of the Pocomoke River in the Lower Pocomoke River Basin and Pocomoke Sound Basin in Somerset and Worcester Counties, Maryland and Accomack County, Virginia

DEPARTMENT OF THE ENVIRONMENT
1800 Washington Boulevard, Suite 540
Baltimore MD 21230-1718

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY
629 East Main Street
Richmond, VA 23218

Submitted to:

Water Protection Division
U.S. Environmental Protection Agency, Region III
1650 Arch Street
Philadelphia, PA 19103-2029

March 2008

EPA Submittal Date: Feb. 20, 2009
EPA Approval Date: April 15, 2009

Table of Contents

List of Figures

List of Tables

List of Abbreviations

ARA	Antibiotic Resistance Analysis
BMP	Best Management Practice
BST	Bacteria Source Tracking
CAFO	Confined Animal Feeding Operation
cfs	Cubic Feet per Second
cms	Cubic Meters per Second
CFR	Code of Federal Regulations
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
EPA	Environmental Protection Agency
FA	Future Allocation
FDA	U.S. Food and Drug Administration
GIS	Geographic Information System
HEM-3D	VIMS Hydrodynamic Eutrophication Model in 3 Dimensions
km	Kilometer
LA	Load Allocation
M_2	Lunar semi-diurnal tidal constituent
MACS	Maryland Agricultural Cost Share Program
MAR	Multiple-antibiotic-resistance
MDE	Maryland Department of the Environment
MDESCP	MDE Shellfish Certification Program
MDP	Maryland Department of Planning
ml	Milliliter(s)
MOS	Margin of Safety
MPN	Most Probable Number
MSSCC	Maryland State's Soil Conservation Committee
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NSSP	National Shellfish Sanitation Program
TMDL	Total Maximum Daily Load
USDA	U.S. Department of Agriculture
USGS	United States Geological Survey
VA-DEQ	Virginia Department of Environmental Quality
VDH-DSS	Virginia Department of Health - Division of Shellfish Sanitation
VIMS	Virginia Institute of Marine Science
VPDES	Virginia Pollutant Discharge Elimination System
WLA	Wasteload Allocation
WQIA	Water Quality Improvement Act
WQMIRA	Water Quality Monitoring, Information, and Restoration Act
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Plant

EXECUTIVE SUMMARY

The Pocomoke River is an interstate watershed; the boundary between Maryland (MD) and Virginia (VA) follows along the Pocomoke on the eastern shores of these jurisdictions. This fecal coliform TMDL for the Pocomoke watershed was developed through a cooperative agreement between Virginia Department of Environmental Quality (VA-DEQ) and the Maryland Department of the Environment (MDE). This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes Total Maximum Daily Loads (TMDLs) for fecal coliform in MD's portion of the Lower Pocomoke River and Pocomoke Sound ("the Pocomoke") and VA's portion of the Lower Pocomoke River and Pocomoke Sound. Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, States are to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met.

In MD, the restricted shellfish harvesting area in the Pocomoke River is located in portions of two 8-digit basins: Pocomoke Sound (basin number 02130201) and Lower Pocomoke River (basin number 02130202). MDE identified both basins on the MD 303(d) List as impaired by the following (listing years in parentheses): Pocomoke Sound - fecal coliform in tidal portions of the basin (1998), and impacts to biological communities in the tidal portions (2004); Lower Pocomoke River - fecal coliform in tidal portions of the basin (1996), sediments in the tidal and non-tidal portions (1996, 2002), nutrients in the tidal portions (1996), and impacts to biological communities in the non-tidal portions (2004). The MD 2004 303(d) List clarified the fecal coliform listings by the identification of the Pocomoke River restricted shellfish harvesting area as the specific area of impairment for fecal coliform. The assessment unit listing code for this area in Maryland's 2008 303(d) List is MD-POCMH-OH-POCOMOKE_SOUND-RIVER. In VA, Pocomoke Sound and Pocomoke River [VAT-C09E-10] condemnation zone 75 was also identified on the VA 303(d) List submitted to U.S. EPA in 1998. The sediment, nutrient, and biological impairments within the Lower Pocomoke River Basin and Pocomoke Sound Basin listed on MD's 303(d) lists will be addressed at a future date. This document, upon approval by EPA, establishes a TMDL of fecal coliform for the restricted shellfish harvesting area/condemnation zone in the Pocomoke watershed in both MD and VA that will allow for attainment of their respective shellfish harvesting designated uses.

The applicable MD fecal coliform water quality criteria for shellfish harvesting area are that the median concentration does not exceed 14 Most Probable Number (MPN) per 100 milliliters, and the 90^{th} percentile concentration does not exceed 49 MPN per 100 milliliters for a three-tube decimal dilution test. See COMAR 26.08.02.03-3.C.

The applicable VA state standard specifies that the number of fecal coliform bacteria shall not exceed a geometric mean of 14 Most Probable Number per 100 milliliters (ml) and a 90^{th}

percentile value of 49 MPN/100ml (3-tube, 3-dilution) or 43 MPN/100ml (5-tube, 3-dilution) (Virginia Water Quality Standard 9-VAC 25-260-160).

An inverse three-dimensional model was used to estimate current fecal coliform loads and to establish allowable loads for the impaired shellfish harvesting area in the Pocomoke River watershed. The inverse model incorporates influences of freshwater discharge, tidal and density-induced transport, and fecal coliform decay, thereby representing the fate and transport of fecal coliform in the Pocomoke Sound and Lower Pocomoke River and its corresponding restricted shellfish harvesting area. The potential sources (human, livestock, pets, and wildlife) are identified by analysis of the Bacteria Source Tracking (BST) data collected in the Pocomoke Sound and Lower Pocomoke River over a one-year period.

The allowable loads required to meet water quality standards within restricted shellfish harvesting areas were computed using the median and 90th percentile fecal coliform criteria for MD, and geometric mean and 90th percentile fecal coliform criteria for VA. An implicit Margin of Safety (MOS) was incorporated into the analysis to account for uncertainty. The TMDLs developed for the restricted shellfish harvesting areas of the Pocomoke River watershed for fecal coliform are as follows:

Waterbody	**Fecal Coliform TMDL [counts per day]**	
	based on Median/Geo-mean Criterion	**based on 90th Percentile Criterion**
Pocomoke Sound and Pocomoke River (MD)	1.95×10^{13}	6.50×10^{13}
Pocomoke Sound and Pocomoke River (VA)	2.42×10^{12}	1.04×10^{13}
Pocomoke Sound and Pocomoke River (in total)	2.19×10^{13}	7.54×10^{13}

The goal of TMDL allocation is to determine the maximum allowable loads for each known source in the watershed that will ensure the attainment of the water quality standard. The TMDL was developed based on the most stringent criterion (i.e., the 90th percentile criterion), requiring a reduction of about 42.13% for the Pocomoke watershed.

The existing loading adjacent to the restricted area comes from both VA and MD. The TMDL will be shared by both jurisdictions excluding loads discharged from the area upstream of the Pocomoke River, which has less contribution than the area adjacent to the restricted area. A shared TMDL is summarized as follows:

The 90th percentile TMDL (counts per day):

Area	TMDL	=	LA	+	ΣWLA*	+	MOS
Pocomoke River and Pocomoke Sound, MD	6.50×10^{13}	=	6.50×10^{13}	+	4.42×10^{10}	+	Implicit
	Where ΣWLA		*MD0022551*		*$3.62X10^{9}$*		
			MD0051632		*$4.92X10^{8}$*		
			MD0060348		*$2.95X10^{8}$*		
			MD0022764		*$2.95X10^{9}$*		
			Future Growth		*$3.68x10^{10}$*		
Pocomoke River and Pocomoke Sound, VA	1.04×10^{13}	=	1.04×10^{13}	+	1.37×10^{8}	+	Implicit
	Where ΣWLA		*VA0023078*		*$1.51x10^{7}$*		
			VA0090875		*$7.57x10^{6}$*		
			Future Growth		*$1.14x10^{8}$*		

*This allocation is less than 0.1% of the total TMDL.

Once EPA has approved this TMDL, both MDE and VA-DEQ will begin an iterative process of implementation, focusing first on those sources that have the greatest impact on water quality while giving consideration to the relative ease of implementation and cost. The source contributions estimated from the BST results may be used as a tool to target and prioritize initial implementation efforts. Continued monitoring will be undertaken by MDE's Shellfish Certification Division and VA's Department of Health – Division of Shellfish Sanitation. The data will be used to assess the effectiveness of the MDE and VA-DEQ's implementation efforts on an ongoing basis.

During MD's development of the TMDL for Pocomoke Sound and Pocomoke River, interested stakeholders are notified early in the development stage, at interagency review, during the public comment period, at submittal, and at approval. The public draft version and the final version of the report are made available on MDE's website at the respective time periods. Meetings are held at the request of the public and stakeholders, and typically include informational presentations and discussions of the project

During VA's development of the TMDL for Pocomoke Sound and Pocomoke River, public involvement was encouraged through a public participation process that included a draft post-TMDL report published on the web, encouraging public review of the TMDL report, public meetings, and stakeholder meetings. The first and only public meeting was held on July 23, 2008 for the Growing Area 75 in Accomack County. A basic description of the TMDL process and the agencies involved was presented and a discussion was held regarding the source assessment input, bacterial source tracking, and model results. The TMDL and allocation results were presented.

1.0 INTRODUCTION

Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each State to develop a Total Maximum Daily Load (TMDL) for each impaired water quality limited segment (WQLS) on the Section 303(d) list, taking into account seasonal variations and including a protective margin of safety (MOS) to account for scientific uncertainty (CFR 2006C). A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and/or numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

Fecal coliform are found in the intestinal tracts of humans and other warm-blooded animals. Fecal coliform may occur in surface waters from point and nonpoint sources. Few fecal coliform are pathogenic; however, the presence of elevated levels of fecal coliform in shellfish waters may indicate recent sources of pollution. Some common waterborne diseases associated with the consumption of raw clams and oysters harvested from polluted water include viral and bacterial gastroenteritis and hepatitis A.

Fecal coliform is an indicator organism used in water quality monitoring in shellfish waters to indicate fresh sources of pollution from human and other animal wastes. When the water quality standard for fecal coliform in shellfish waters is exceeded, waters are closed to shellfish harvesting to protect human health due to the potential risk from consuming raw molluscan shellfish from contaminated waters. The U.S. Food and Drug Administration (FDA), rather than EPA, is responsible for food safety. Water quality criteria for shellfish waters are established under the National Shellfish Sanitation Program (NSSP), a cooperative program that involves states, industry, academic and federal agencies, with oversight by FDA. The NSSP continues to use fecal coliform as the indicator organism to assess shellfish harvesting waters. The water quality goal of this TMDL is to establish the reduction in fecal coliform needed to meet the designated uses for this restricted shellfish harvesting area.

In Maryland, on both the 1996 and 1998 303(d) Lists of Impaired Waters, many shellfish listings were identified at the broad 8-digit watershed scale. These listings were refined in the 2004 303(d) List to specific, smaller shellfish harvesting areas. Since 2004, these listings are based on the shellfish water quality monitoring data that show areas that do not meet the criteria to be open to shellfish harvesting (MDE 2006).

The restricted shellfish harvesting area in the Pocomoke River is located in portions of two 8-digit basins: Pocomoke Sound (basin number 02130201) and Lower Pocomoke River (basin number 02130202). Both basins were identified on the MD 303(d) List submitted to EPA by the Maryland Department of the Environment (MDE). The designated uses in Pocomoke Sound were listed as impaired by fecal coliform in tidal portions of the basin (1998), and impacts to biological communities in the tidal portions (2004). The designated uses in the Lower Pocomoke River were listed as impaired by fecal coliform in tidal portions of the basin (1996), sediments in the tidal and non-tidal portions (1996, 2002), nutrients in the tidal portions (1996), and impacts to biological communities in the non-tidal portions (2004). The MD 2004 303(d) List was clarified by the identification of the Pocomoke River mainstem as the specific area of impairment for fecal coliform. The assessment unit listing code for this area in MD's 303(d) List is MD-POCMH-OH-POCOMOKE_SOUND-RIVER. The sediment, nutrient, and biological impairments within the Lower Pocomoke River basin and Pocomoke Sound Basin listed on MD's 303(d) lists will be addressed at a future date.

In Virginia (VA), Pocomoke Sound and Pocomoke River [VAT-C09E-10] condemnation zone 75 was identified on the VA 303(d) List submitted to EPA in 1998 and subsequent lists thereafter (VA-DEQ 2004, 2006). This document, upon approval by EPA, establishes a TMDL of fecal coliform for the restricted shellfish harvesting area/condemnation zone in the Pocomoke watershed in both MD and VA that will allow for attainment of their respective shellfish harvesting/growing area designated uses.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

The Pocomoke River and Sound ("the Pocomoke") is an interstate watershed; the boundary between MD and VA follows along the Pocomoke on the eastern shores of these jurisdictions. The impaired portion of the Pocomoke addressed in this report includes the Pocomoke River mainstem and Pocomoke Sound, located on MD's Eastern Shore in Somerset County and Accomack County in VA, as shown in Figure 2.1.1. The portion of the Pocomoke River mainstem restricted to shellfish harvesting is in the Lower Pocomoke River and Pocomoke Sound. The Pocomoke River has a length of approximately 62 km and its width ranges from 100 m to 200 m upstream and is approximately 7.0 km at its mouth, where it flows into Chesapeake Bay. The portion restricted to shellfish harvesting has a length of 8.3 km and a drainage area of 1,344.5 km^2 (332,222.0 acres).

The Pocomoke River watershed is flat, with poorly drained soils underlain by unconsolidated Coastal Plain sediments. The shallow aquifer system is characterized by complex heterogeneous hydrogeology with short, shallow ground-water flow paths (Hamilton et al. 1993). A relatively thin sandy surficial aquifer, which is overlain by poorly drained soils, contains the shallow water table (Hancock et al. 2007). The dominant tide in this region is the lunar semi-diurnal (M_2) tide, with a tidal range of 0.71 m in the restricted portion of the Pocomoke River and a tidal period of 12.42 hours (National Oceanic and Atmospheric Administration (NOAA) 2006). Please refer to Table 2.1.1 for the mean volume and mean water depth of this restricted shellfish harvesting area.

Table 2.1.1: Physical Characteristics of the Restricted Shellfish Harvesting Area in Pocomoke River and Pocomoke Sound

Restricted Shellfish Harvesting Area	Mean Water Volume in m^3	Mean Water Depth in m
Pocomoke Sound and Pocomoke River	24,416,296.3	1.56

The 2000 Maryland Department of Planning (MDP) land use/land cover data and the National Land Cover Data of United States Geological Survey (USGS) show that the watershed can be characterized as primarily rural for the Pocomoke River, with nearly 55% of the area being forest and more than 31% being cropland. The land use information for the restricted shellfish harvesting areas in the Pocomoke River Basin is shown in Table 2.1.2 and Figure 2.1.2. Residential urban land use identified in Table 2.1.2 includes low-density residential, medium-density residential, and high-density residential and accounts for only 2.7% of the total watershed. Non-residential urban land use, 1.0% of the total watershed, includes commercial, industrial, institutional, extractive, and open urban land.

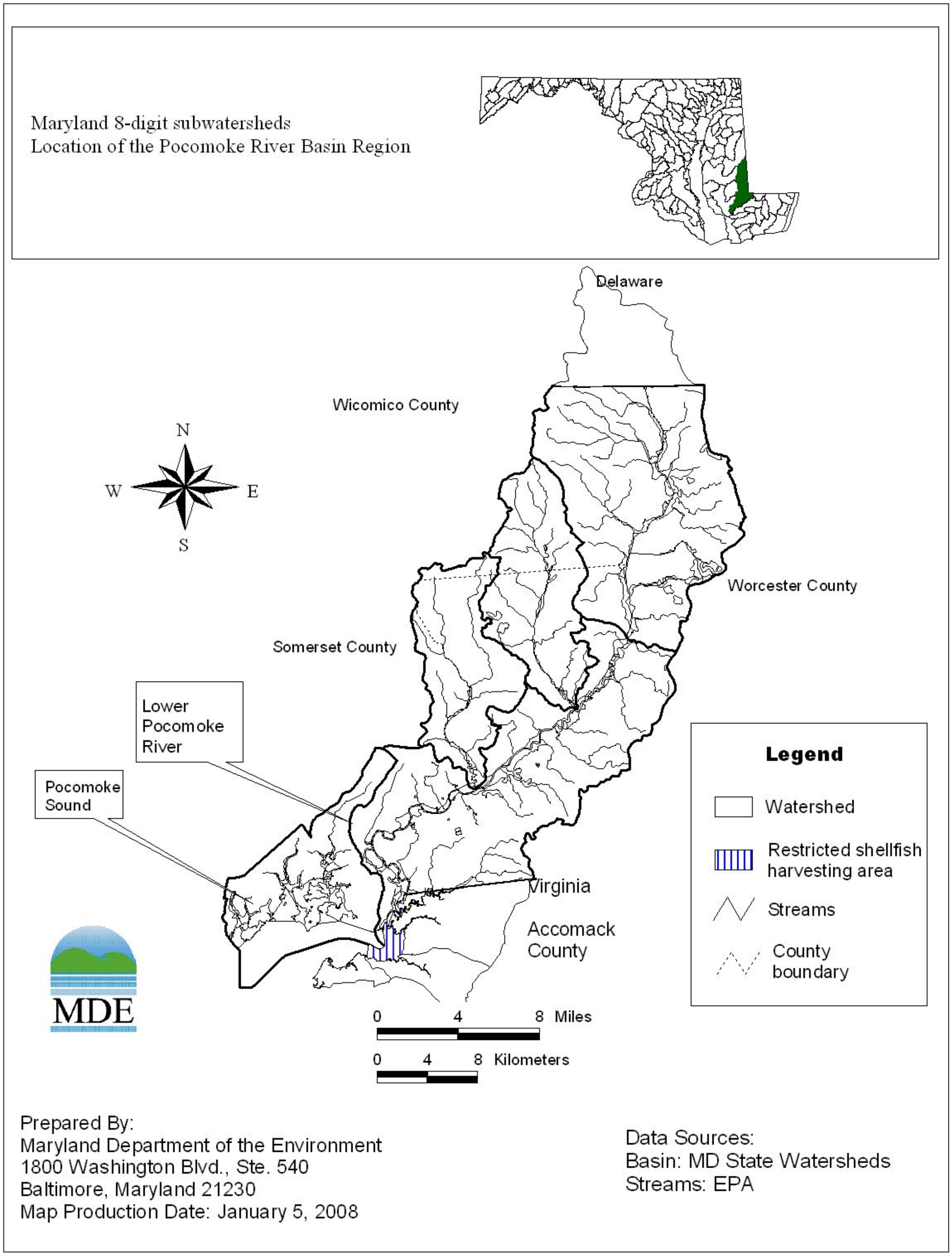

Figure 2.1.1: Location Map of the Pocomoke River Basin

Table 2.1.2: Land Use Percentage Distribution for Pocomoke River Watershed

Land Type	Acreage	Percentage
Residential urban	9,923.0	2.7%
Non-Residential urban	3,615.8	1.0%
Cropland	115,206.4	31.3%
Pasture	4,033.8	1.1%
Feedlot	5,511.0	1.5%
Forest	201,935.0	54.8%
Water	1,658.6	0.5%
Wetlands	25,396.4	6.9%
Barren	616.4	0.2%
Totals	**367,896.4**	**100.0%**

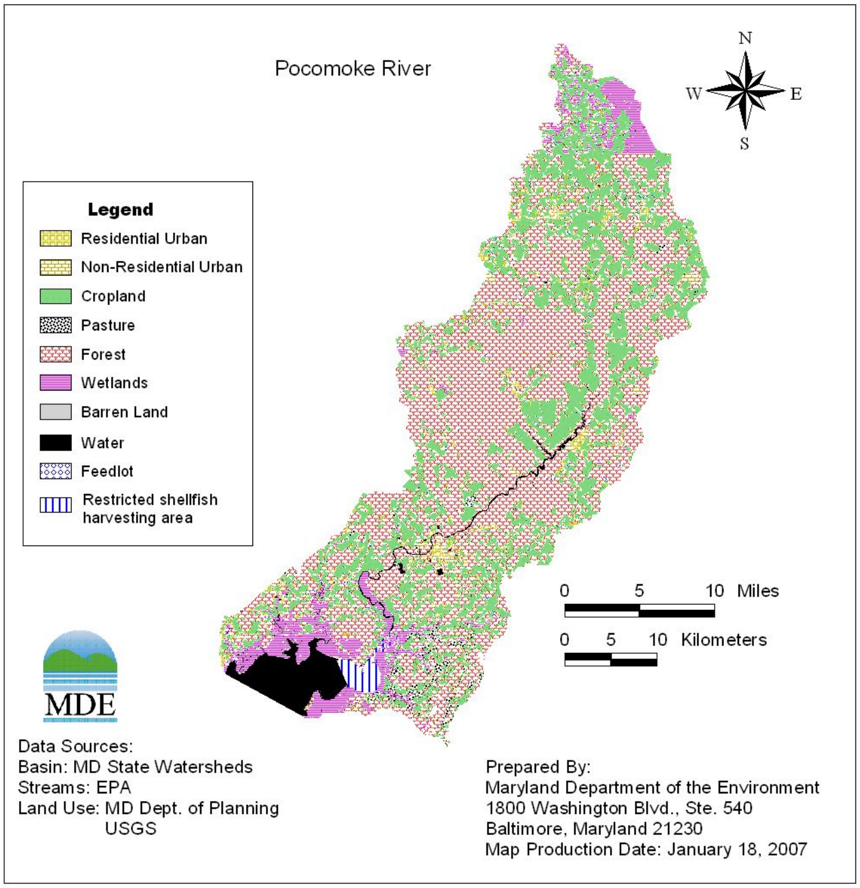

Figure 2.1.2: Land Use in the Pocomoke River Watershed

2.2 Water Quality Characterization

Maryland

MDE's Shellfish Certification Program (MDESCP) is responsible for classifying shellfish harvesting waters to ensure oysters and clams are safe for human consumption. As discussed above, MDE adheres to the requirements of the NSSP, with oversight by FDA. MDE conducts shoreline surveys and collects routine bacteria water quality samples in the shellfish waters of MD to assure that MD's shellfish waters are properly classified.

MDE's Shellfish Certification Program monitors shellfish waters throughout MD. There are six shellfish monitoring stations in the restricted shellfish harvesting area addressed in this report. The station identifications and observations recorded during the period of September 2002 – December 2005 are provided in Table 2.2.1 and Figure 2.2.1. The time series plots of fecal coliform are shown in Figures 2.2.2 through 2.2.7. A tabulation of observed fecal coliform values at the six MD monitoring stations included in this report is provided in Appendix D.

Table 2.2.1: Locations of the MD Shellfish Monitoring Stations in the Restricted Shellfish Harvesting Area of Pocomoke River

Station Location	Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
Pocomoke Sound and Pocomoke River (MDESCP)	18-06-700	2002-2005	30	37 58 00.0	75 40 42.0
	18-07-010	2002-2005	32	37 58 49.2	75 37 48.8
	18-07-012	2002-2005	32	37 58 46.5	75 38 13.6
	18-07-014	2002-2005	33	37 57 47.6	75 39 03.2
	18-07-015	2002-2005	33	37 57 13.3	75 38 55.7
	18-07-111	2002-2005	33	37 57 24.9	75 39 54.0

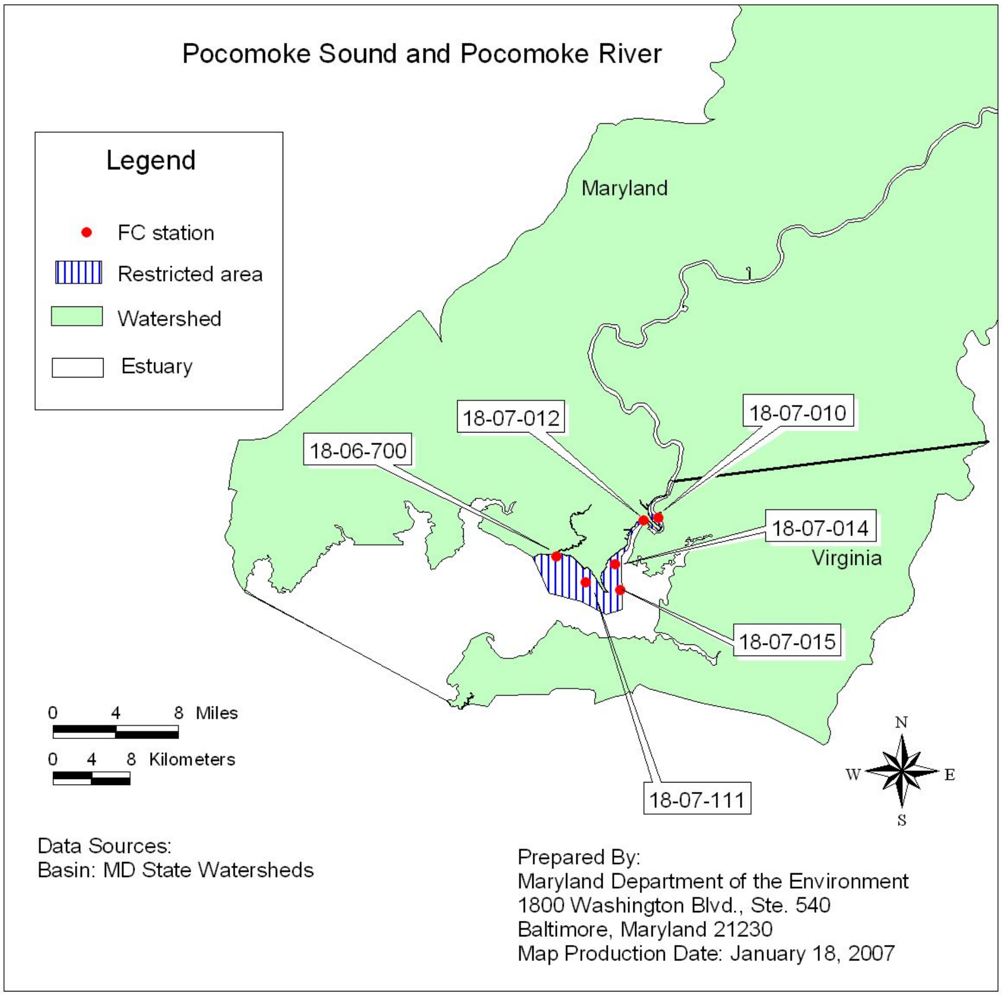

Figure 2.2.1: Maryland Shellfish Monitoring Stations in the Restricted Shellfish Harvesting Area of Pocomoke River

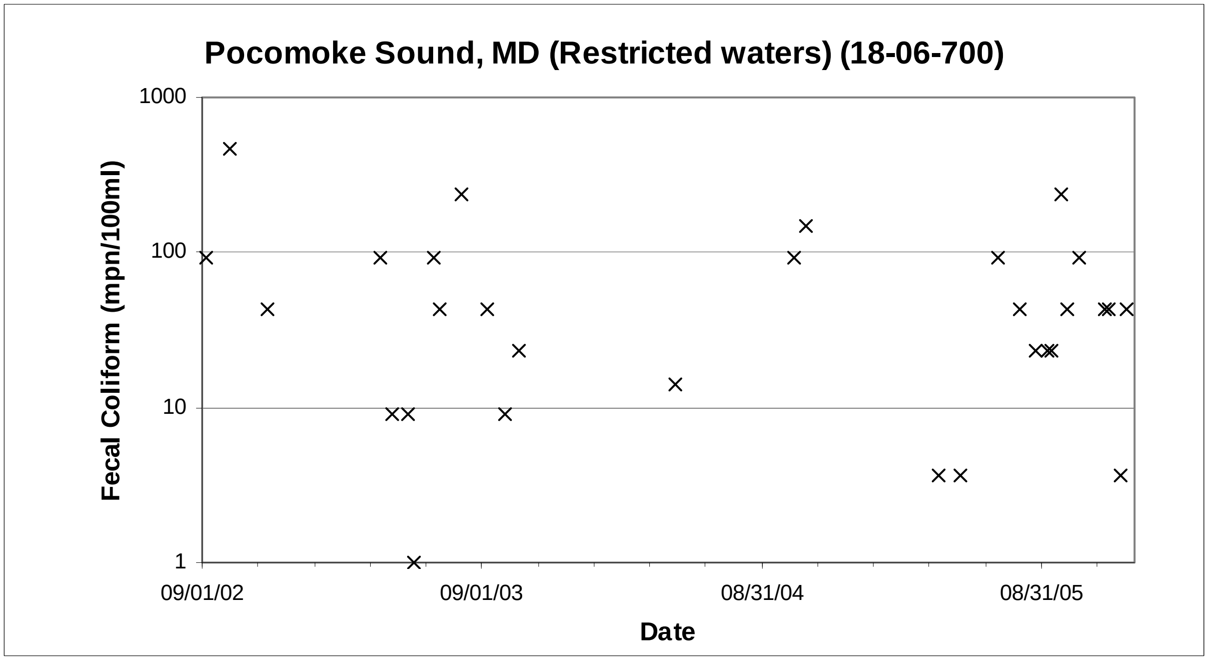

Figure 2.2.2: Observed Fecal Coliform Concentrations at Station 18-06-700

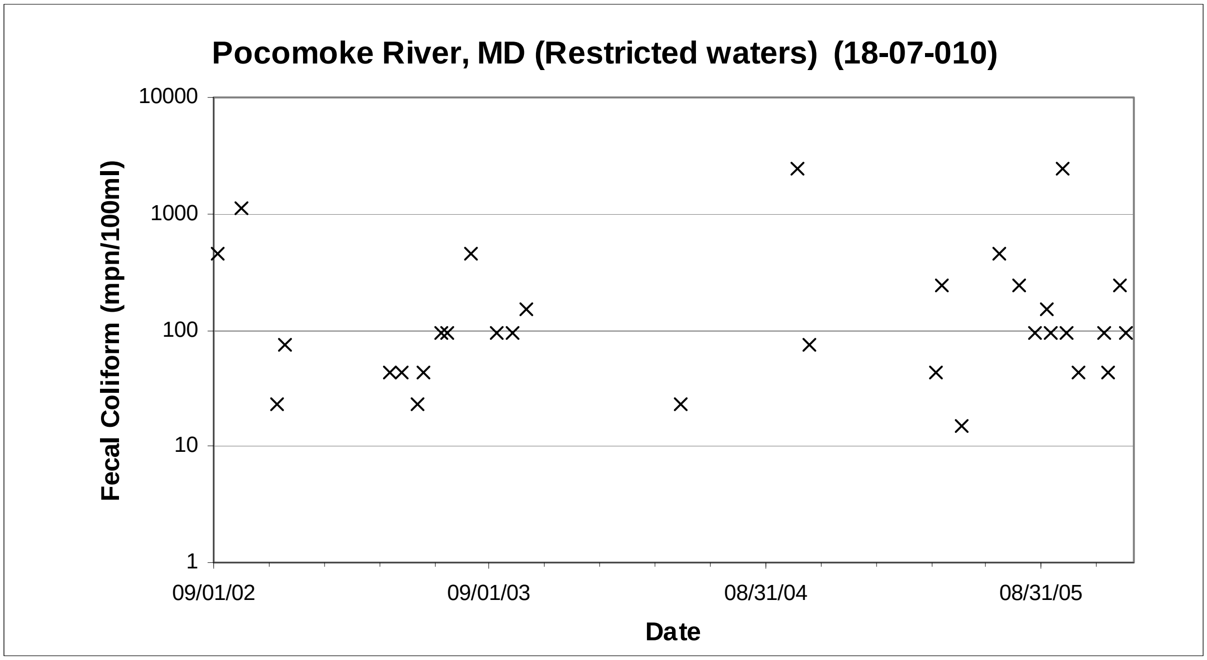

Figure 2.2.3: Observed Fecal Coliform Concentrations at Station 18-07-010

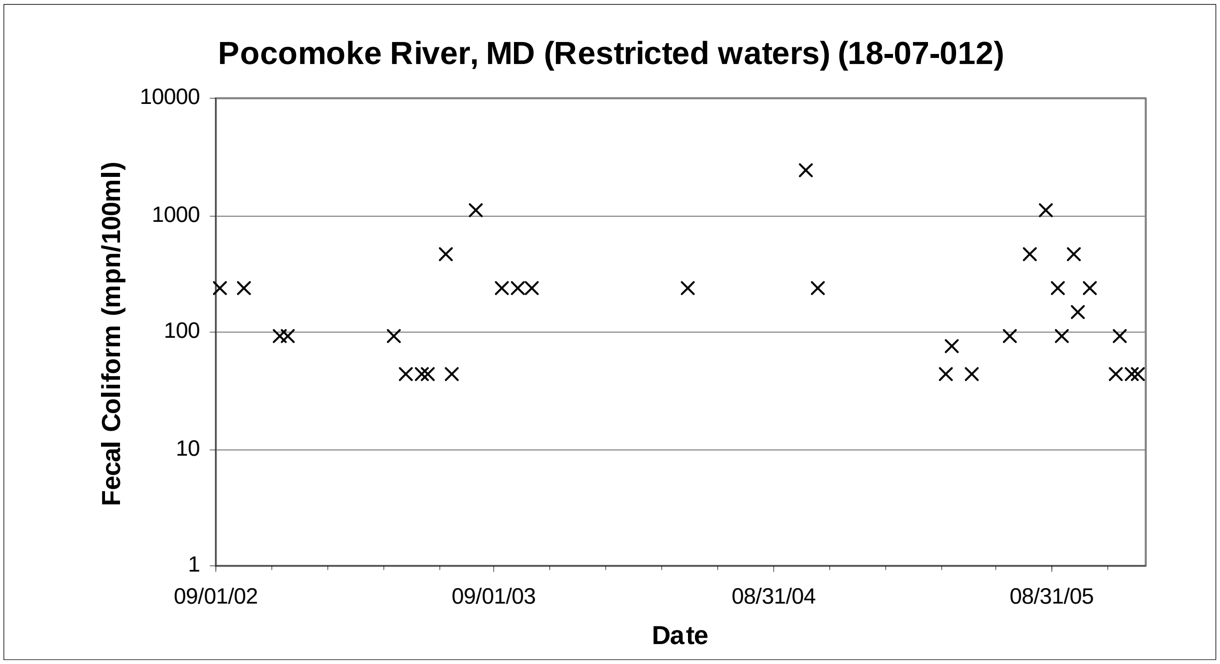

Figure 2.2.4: Observed Fecal Coliform Concentrations at Station 18-07-012

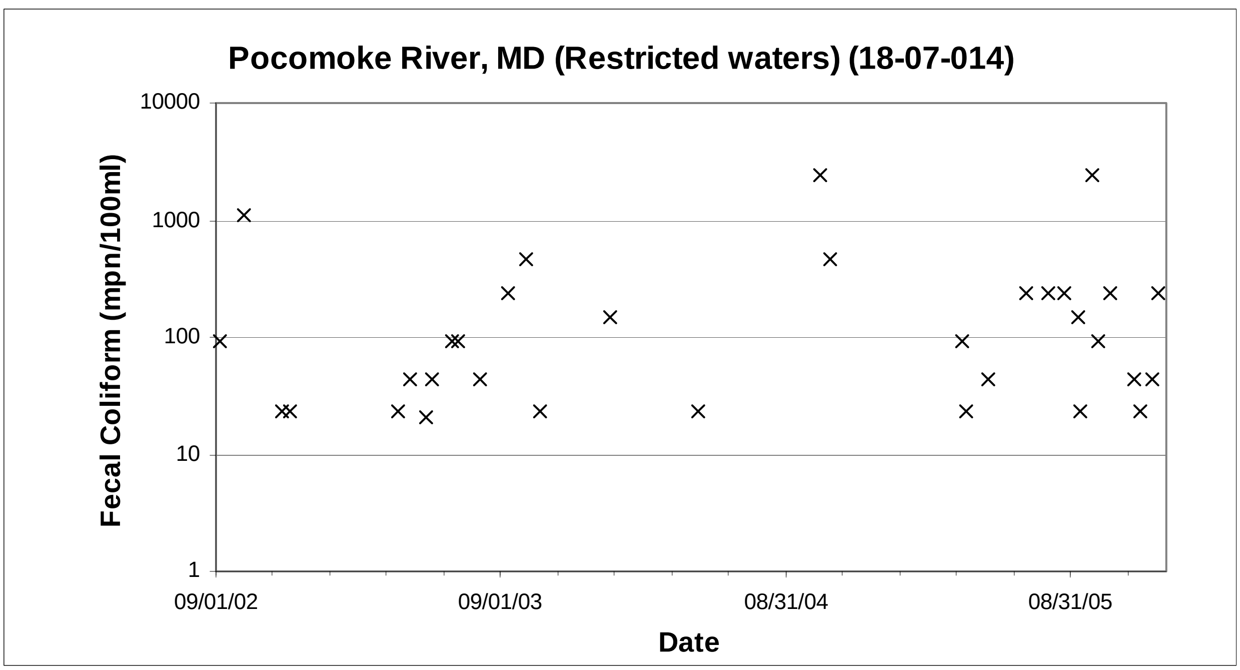

Figure 2.2.5: Observed Fecal Coliform Concentrations at Station 18-07-014

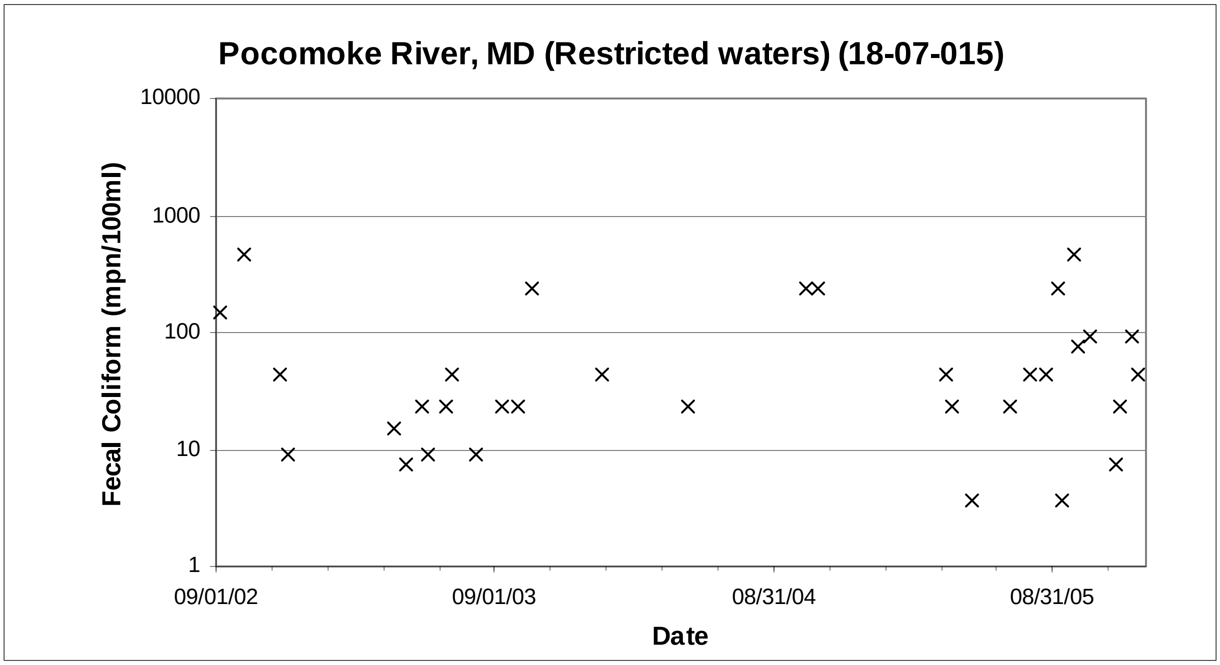

Figure 2.2.6: Observed Fecal Coliform Concentrations at Station 18-07-015

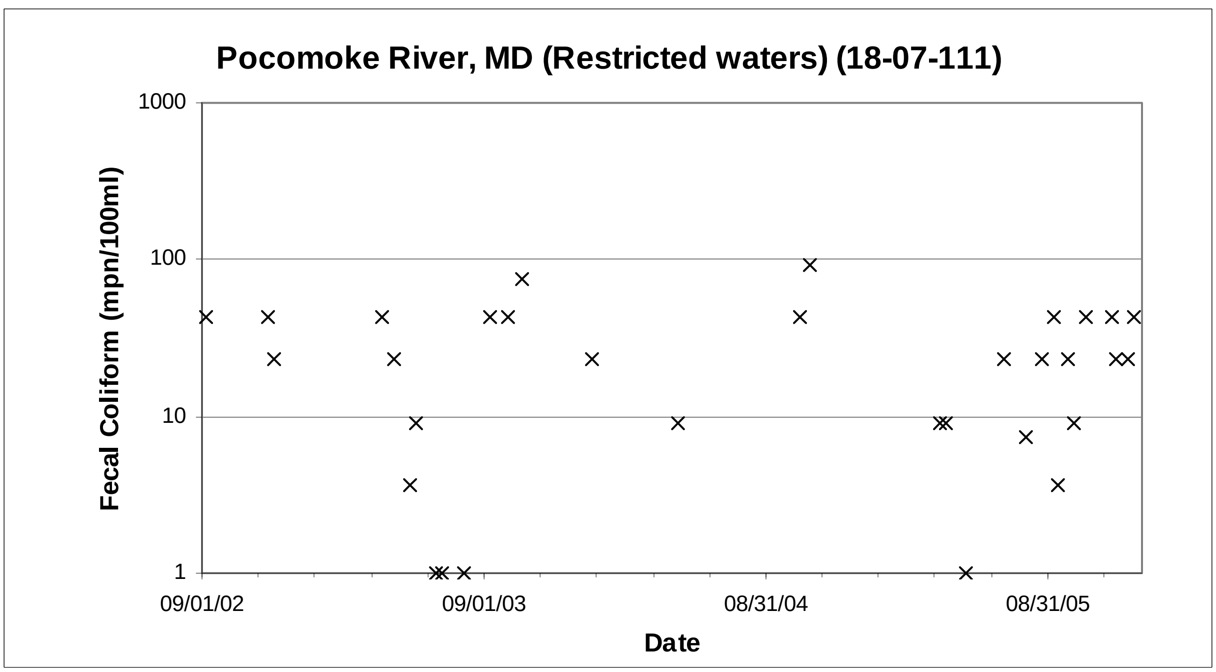

Figure 2.2.7: Observed Fecal Coliform Concentrations at Station 18-07-111

Virginia

Virginia Department of Health - Division of Shellfish Sanitation (VDH-DSS) is responsible for classifying shellfish growth areas of VA and routinely monitors the fecal coliform in the Pocomoke Sound. There are 12 bacteria monitoring stations in the shellfish harvesting area addressed in this report and it downstream. The station identifications and observations recorded during the period of November 2002 – December 2005 are provided in Table 2.2.2 and Figure 2.2.8. The time series plots of fecal coliform are shown in Figures 2.2.9 through 2.2.20. A tabulation of observed fecal coliform values at the 12 VA Virginia monitoring stations included in this report is provided in Appendix D.

Table 2.2.2: Locations of the VA Shellfish Monitoring Stations in the shellfish Growing area of Pocomoke River

Station Location	Shellfish Monitoring St.	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
Pocomoke Sound (VDH-DSS)	75-B1*	2002-2005	30	37 54 52.1	75 45 28.0
	75-C3*	2002-2005	30	37 55 28.0	75 45 49.1
	75-D2*	2002-2005	30	37 55 10.0	75 44 8.2
	75-D4*	2002-2005	30	37 55 38.1	75 44 6.6
	75-E5*	2002-2005	30	37 55 52.3	75 44 27.6
	75-H7*	2002-2005	30	37 56 21.1	75 43 29.4
	75-L7*	2002-2005	30	37 56 20.7	75 42 53.3
	75-O8	2002-2005	30	37 56 29.8	75 41 47.1
	75-P8	2002-2005	30	37 56 27.3	75 40 12.5
	75-Q8	2002-2005	30	37 56 24.7	75 40 29.9
	75-R7	2002-2005	30	37 56 18.6	75 40 43.2
	75-S7	2002-2005	30	37 56 17.3	75 39 12.7

* Stations located downstream of condemnation area

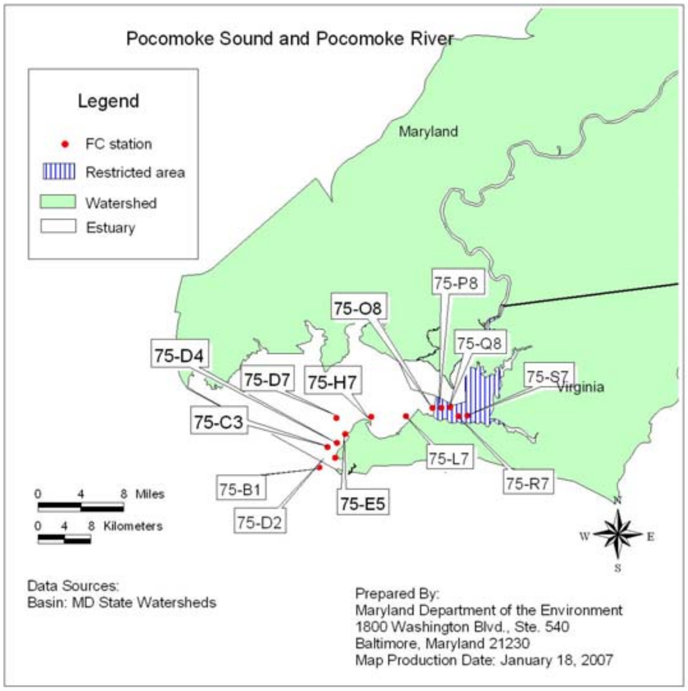

Figure 2.2.8: Virginia Shellfish Monitoring Stations in Pocomoke Sound

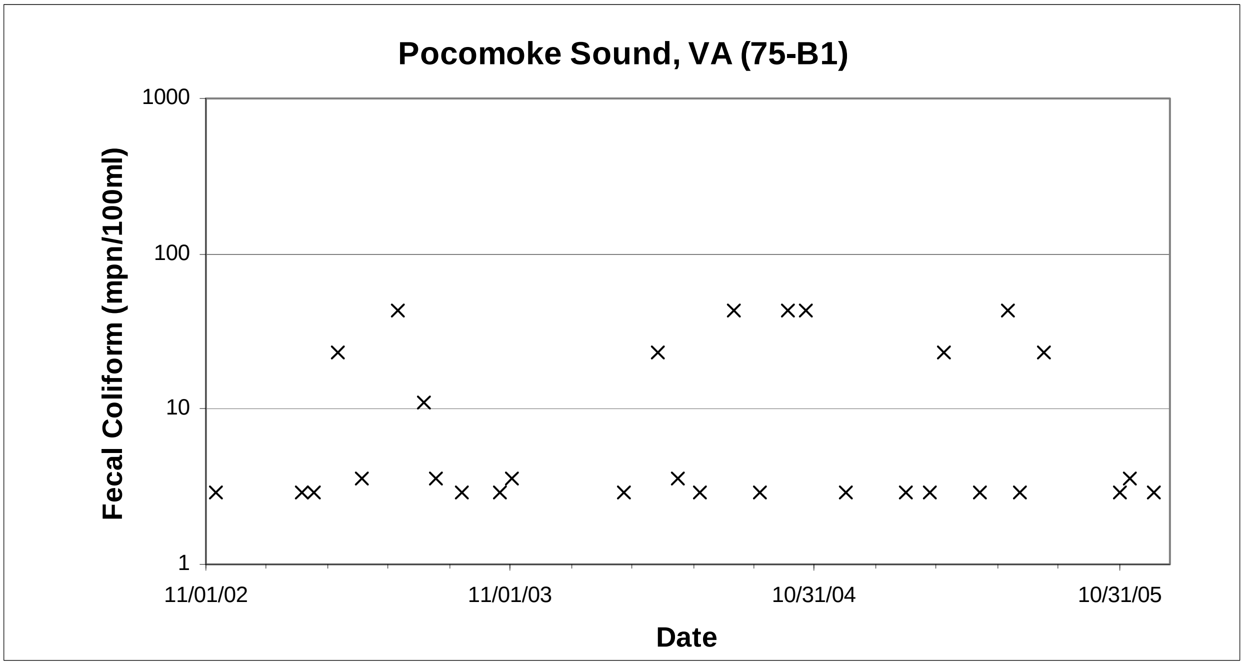

Figure 2.2.9: Observed Fecal Coliform Concentrations at Station 75-B1

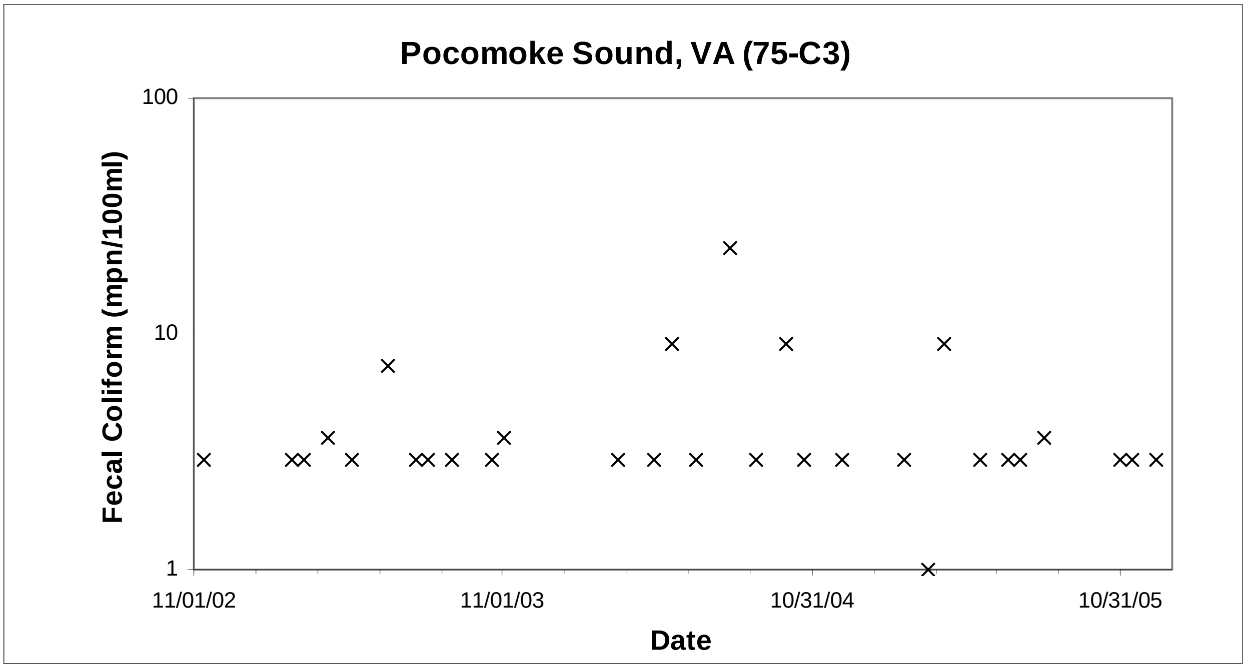

Figure 2.2.10: Observed Fecal Coliform Concentrations at Station 75-C3

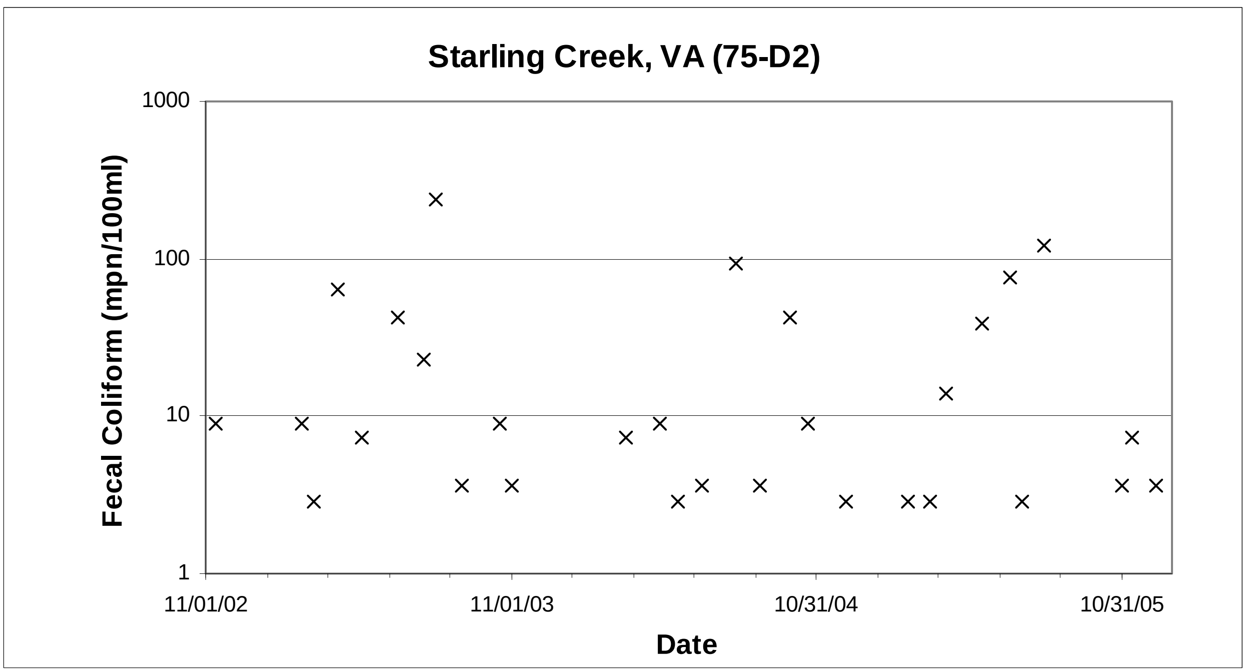

Figure 2.2.11: Observed Fecal Coliform Concentrations at Station 75-D2

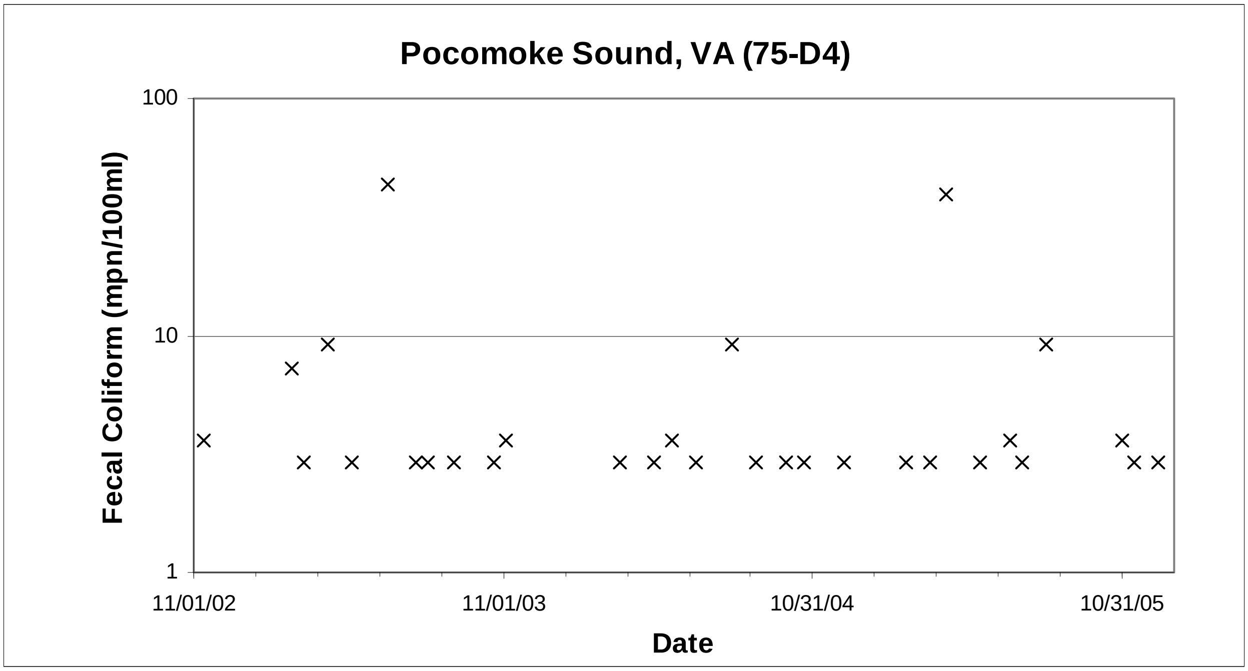

Figure 2.2.12: Observed Fecal Coliform Concentrations at Station 75-D4

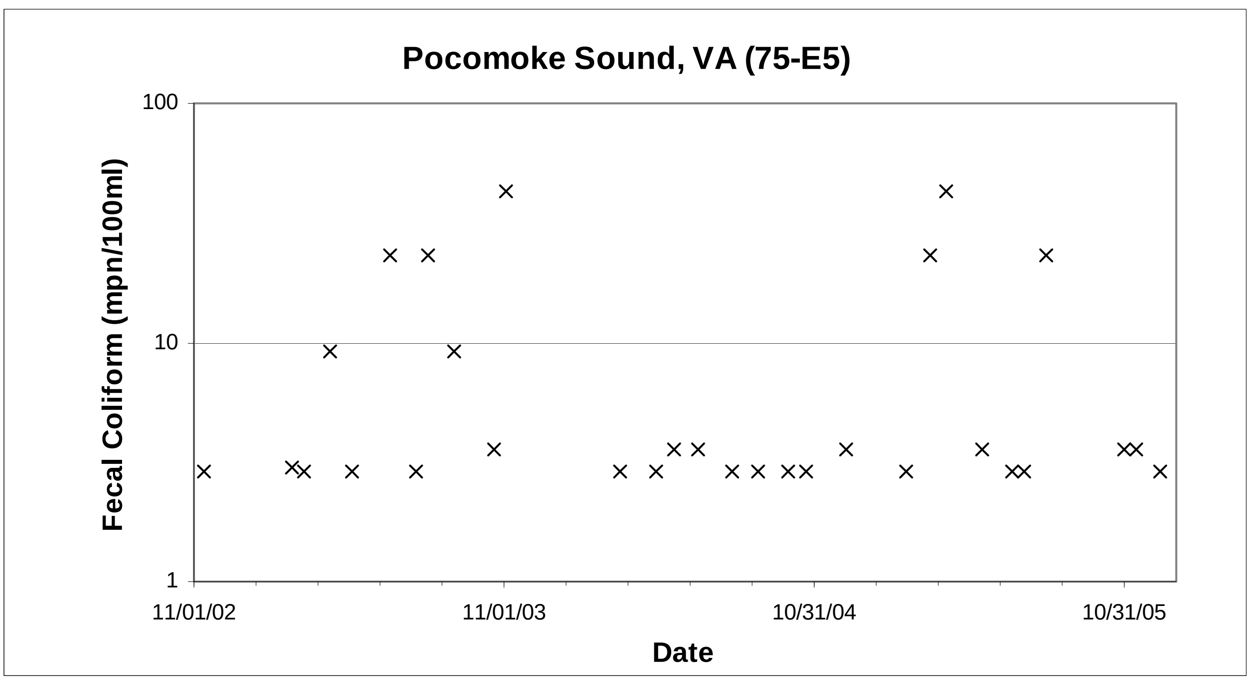

Figure 2.2.13: Observed Fecal Coliform Concentrations at Station 75-E5

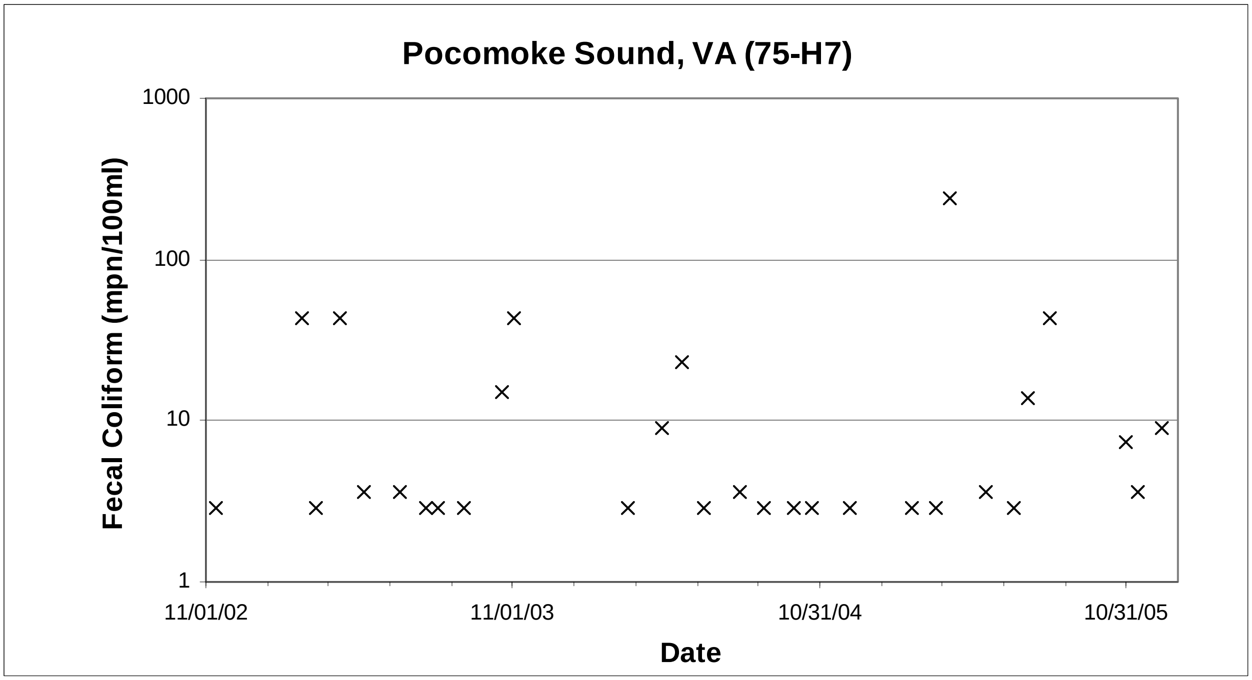

Figure 2.2.14: Observed Fecal Coliform Concentrations at Station 75-H7

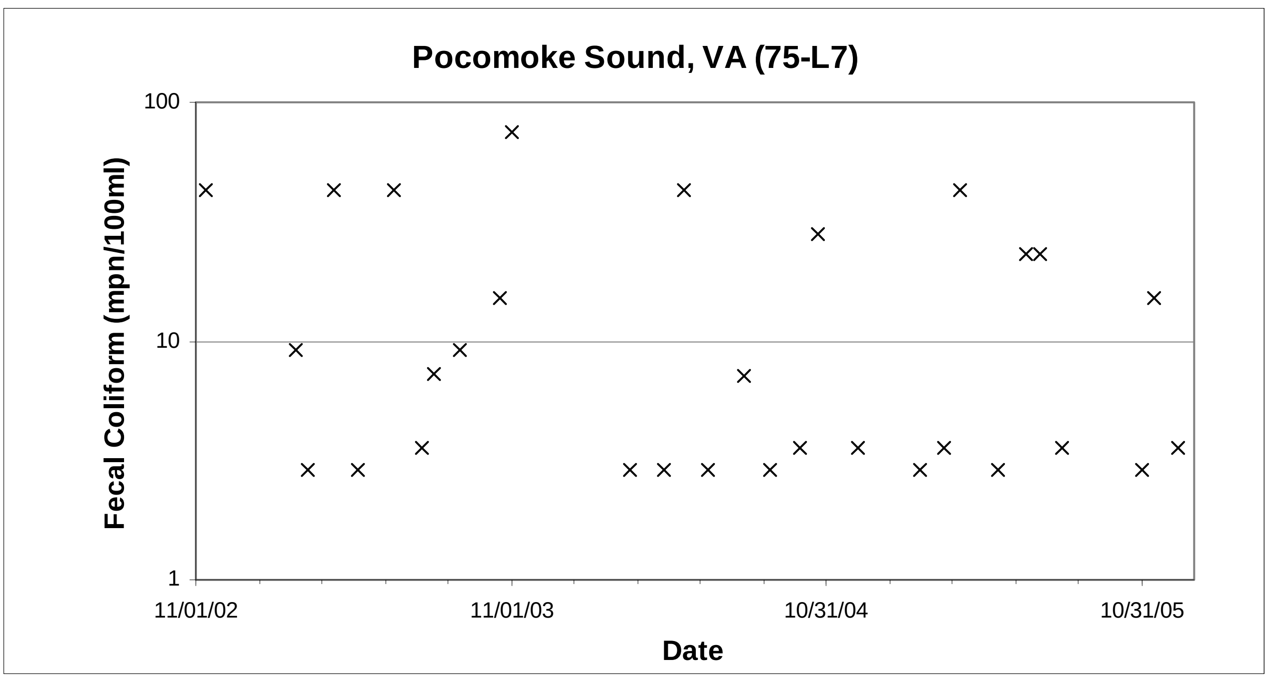

Figure 2.2.15: Observed Fecal Coliform Concentrations at Station 75-L7

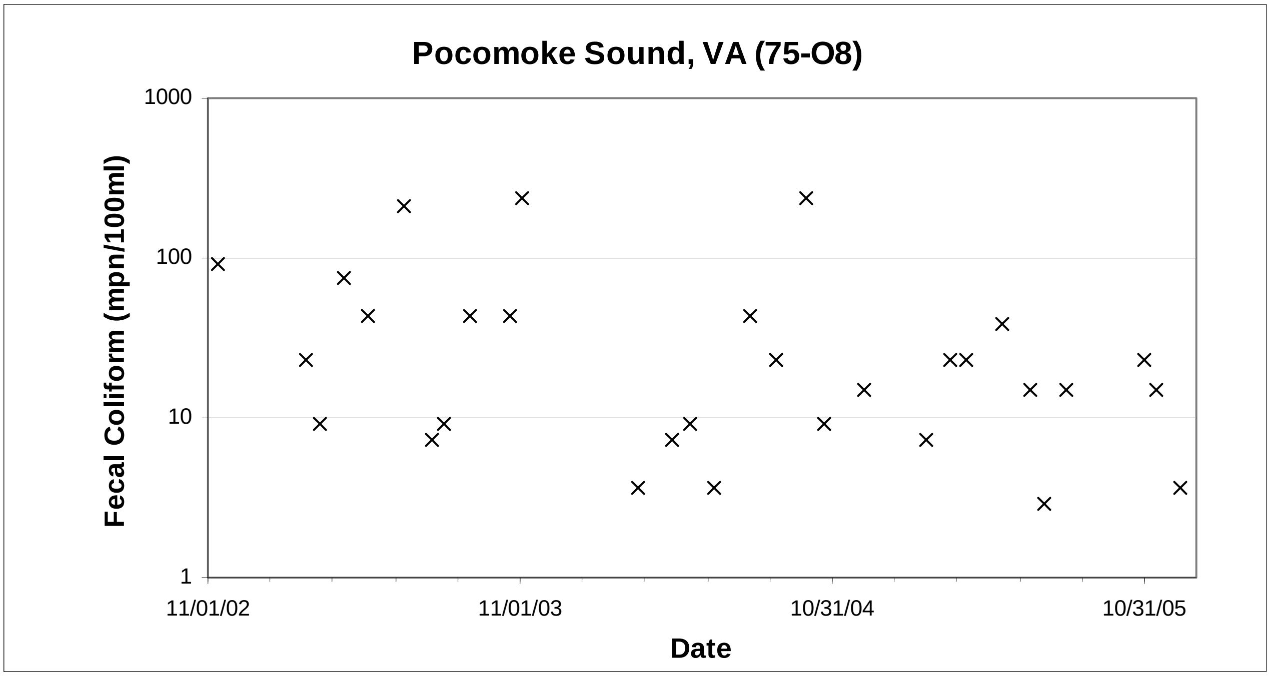

Figure 2.2.16: Observed Fecal Coliform Concentrations at Station 75-O8

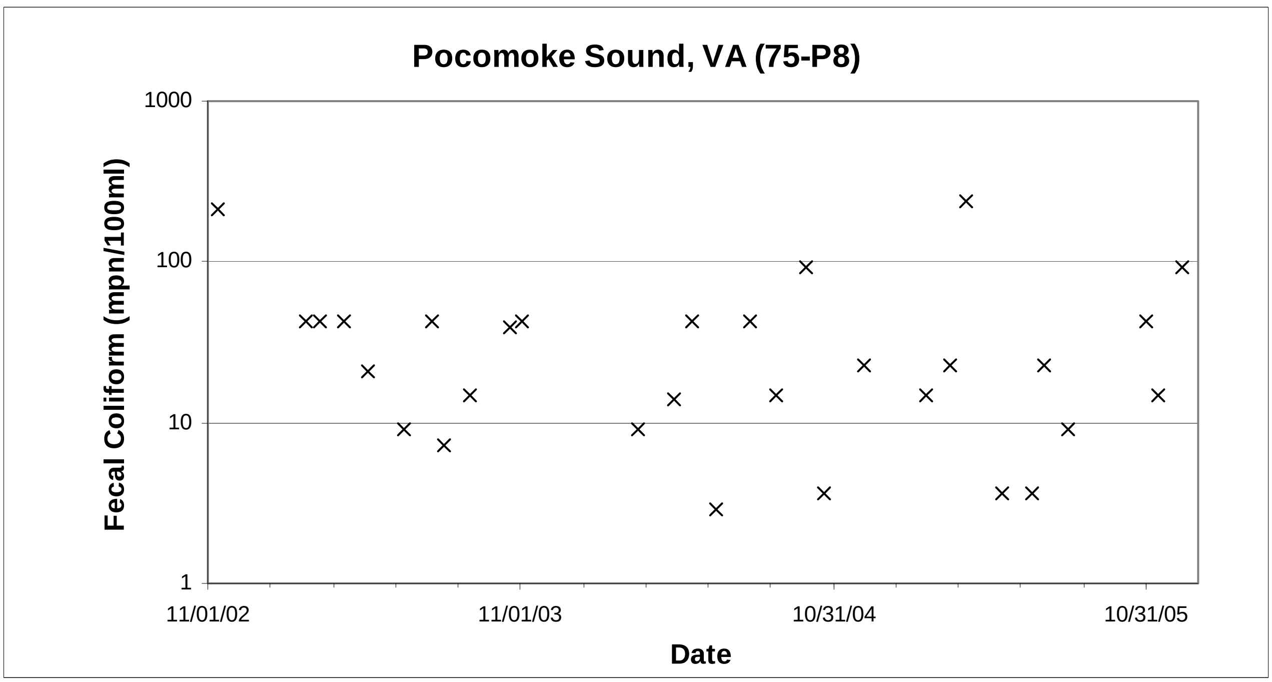

Figure 2.2.17: Observed Fecal Coliform Concentrations at Station 75-P8

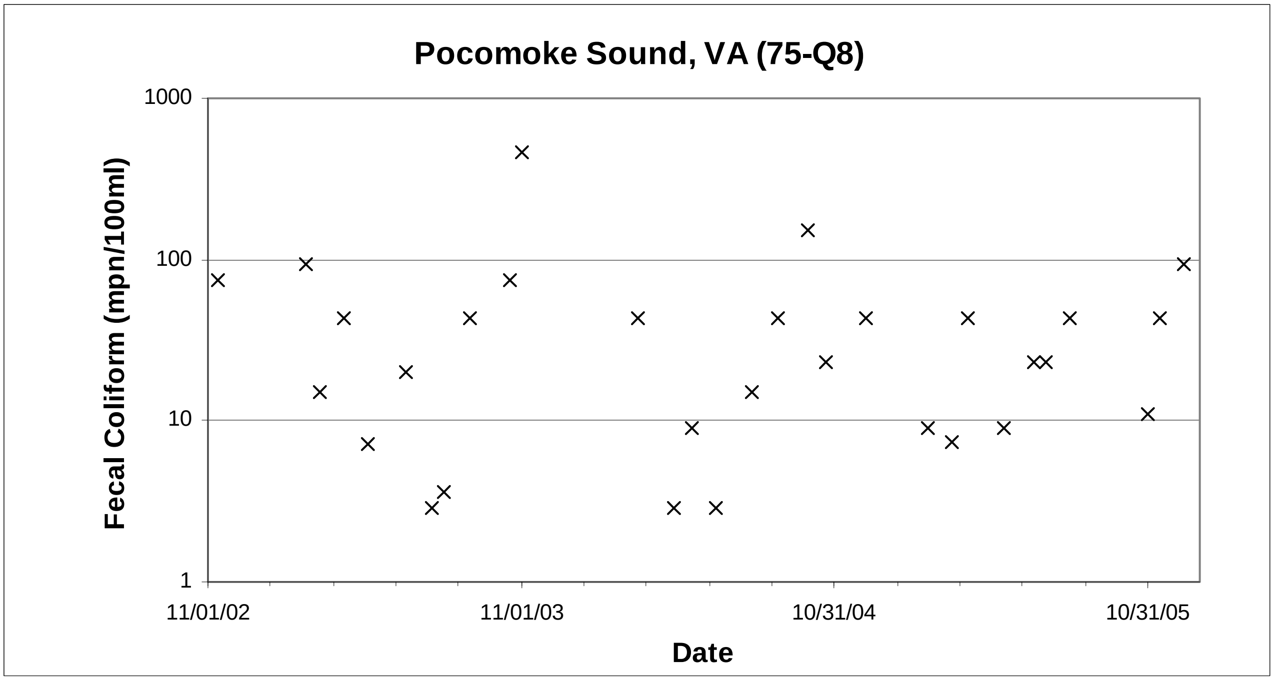

Figure 2.2.18: Observed Fecal Coliform Concentrations at Station 75-Q8

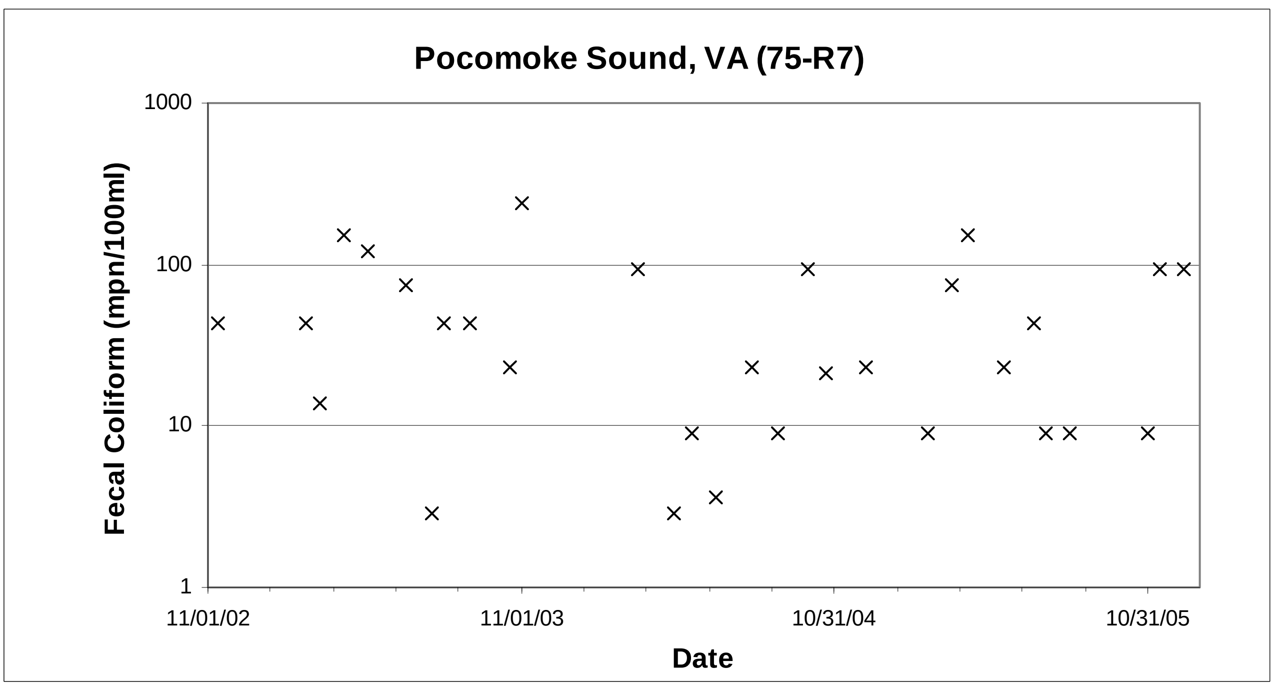

Figure 2.2.19: Observed Fecal Coliform Concentrations at Station 75-R7

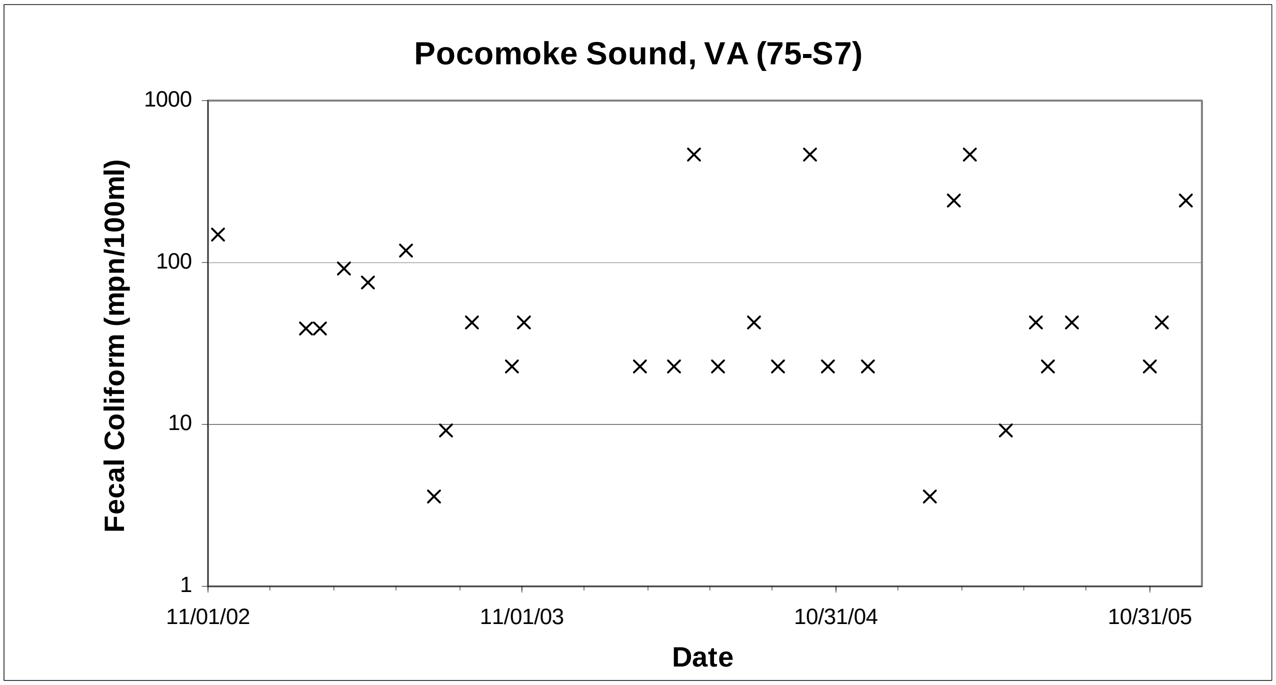

Figure 2.2.20: Observed Fecal Coliform Concentrations at Station 75-S7

2.3 Water Quality Impairment

Maryland

The fecal coliform impairment addressed in this analysis was determined with reference to Maryland's Classification of Use II Waters - Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting in the Code of Maryland Regulations (COMAR), Surface Water Quality Criteria 26.08.02.03-3.C(2), which states:

> 2) Classification of Use II Waters for Harvesting.
>
> (a) Approved classification means that the median fecal coliform MPN of at least 30 water sample results taken over a 3-year period to incorporate inter-annual variability does not exceed 14 per 100 milliliters; and:
>
> (i) In areas affected by point source discharges, not more than 10 percent of the samples exceed an MPN of 43 per 100 milliliters for a five tube decimal dilution test or 49 MPN per 100 milliliters for a three tube decimal dilution test; or
>
> (ii) In other areas, the 90th percentile of water sample results does not exceed an MPN of 43 per 100 milliliters for a five tube decimal dilution test or 49 MPN per 100 milliliters for a three tube decimal dilution test.

MDE updated and promulgated shellfish water quality criteria for shellfish waters in June 2004. Bacteriological criteria for shellfish harvesting waters were unchanged and the intent was to include the NSSP classification requirements that previously were not included in COMAR. In 2005, MDE revised the use designations in COMAR as part of the Chesapeake Bay Program revision to reflect living resources-based habitat needs, and did not change the fecal coliform criteria for shellfish harvesting waters or shellfish harvesting use designations.

MD water quality standards explicitly state the fecal coliform criteria as a median and 90^{th} percentile of at least 30 water sample results taken over a 3-year period. Therefore, a requirement of a daily TMDL value is not appropriate. Rather, the TMDL refers to an average daily value that will ensure that the more stringent of the two criteria is met.

For this analysis, MDE used three years of monitoring data spanning a period from September 2002 and December 2005. Most shellfish harvesting areas have been monitored routinely since before 1950 and, due to an emerging oyster aquaculture industry, there are a few shellfish harvesting areas that have less than five years worth of data. For the purpose of classifying shellfish harvesting areas, a minimum of 30 samples is required. For TMDL development, if fewer than 30 samples are available, all of the most recent data will be used to estimate current loads, and the assimilative capacity will be based on the approved classification requirements of a median of 14 MPN/100 ml and a 90^{th} percentile of less than 49 MPN/100 ml. For this TMDL development, a three years of monitoring data set was used to assess the water quality in conjunction with available VA monitoring data.

<u>Virginia</u>

VA Water Quality Standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.). According to VA water Quality Standards (9 VAC 25-260-5) (VA-DEQ, 2007), the term *"water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."*

Generally, all tidal waters in VA are designated as shellfish waters. The identification of the applicable river reaches can be found in the river basin tables at 9 VAC 25-260-390 et seq. For a shellfish-supporting waterbody to be in compliance with Virginia bacterial standards, VA-DEQ specifies the following criteria (9 VAC 25-260-160): "*In all open ocean or estuarine waters capable of propagating shellfish or in specific areas where public or leased private shellfish beds are present, and including those waters on which condemnation or restriction classifications are established by the State Department of Health the following criteria for fecal coliform bacteria shall apply; The geometric mean fecal coliform value for a sampling station shall not exceed an MPN (most probable number) of 14 per 100 milliliters. The 90th* *percentile shall not exceed an MPN of 43 for a 5 tube, 3 dilution test or 49 for a 3 tube, 3 dilution test."*

Maryland

In MD, the water quality impairment in the Pocomoke was assessed as not meeting either the 90th percentile or median criterion at six monitoring stations based on the 3-year data recorded (at least 30 observations). Descriptive statistics of MD's monitoring data and the requirements for the approved classification are shown in Table 2.3.1.

Table 2.3.1: Pocomoke River and Pocomoke Sound Fecal Coliform Statistics (data from 2002-2005)

Area Name	Station	Median		90th Percentile	
		Monitoring Data	Criterion	Monitoring Data	Criterion
		MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml
Pocomoke Sound and Pocomoke River	18-06-700	43.00	14	200.41	49
	18-07-010	93.00	14	575.01	49
	18-07-012	121.50	14	601.83	49
	18-07-014	93.00	14	558.05	49
	18-07-015	43.00	14	204.27	49
	18-07-111	23.00	14	117.30	49

Virginia

In 1998, the Pocomoke Sound and Pocomoke River (VAT-C09E) condemnation zone 75 was identified on the VA303(d) List as impaired by fecal coliform and submitted to EPA in 1998. The water quality impairment in the Pocomoke Sound and Pocomoke River was assessed using data obtained by VDH-DSS as not meeting the 90th percentile criterion at six monitoring stations, and not meeting the geometric mean criterion at five of the same six monitoring stations. Descriptive statistics of the monitoring data and the requirements for the approved classification are shown in Table 2.3.2.

Table 2.3.2: Pocomoke River Fecal Coliform Statistics (data from VA-DEQ 2002-2005)

Area Name	Station	Median**		Geometric Mean		90th Percentile	
		Monitoring Data	Criterion	Monitoring Data	Criterion	Monitoring Data	Criterion
		MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml
Pocomoke Sound and Pocomoke River	75-B1*	3.25	N/A	6.49	14	27.04	49
	75-C3*	2.90	N/A	3.54	14	7.27	49
	75-D2*	8.20	N/A	11.77	14	59.12	49
	75-D4*	2.90	N/A	4.15	14	10.47	49
	75-E5*	3.30	N/A	5.20	14	16.83	49
	75-H7*	3.60	N/A	6.62	14	30.51	49
	75-L7*	5.40	N/A	8.38	14	35.47	49
	75-O8	19.00	N/A	20.14	14	96.20	49
	75-P8	23.00	N/A	22.26	14	94.81	49
	75-Q8	23.00	N/A	23.11	14	113.43	49
	75-R7	33.00	N/A	28.74	14	138.46	49
	75-S7	41.00	N/A	43.37	14	221.07	49

* Stations located downstream of condemnation area
** While VA does not use median values to assess water quality standard attainment, these data were used for model calibration purposes.

2.4 Source Assessment

Nonpoint Source Assessment

Nonpoint sources of fecal coliform do not have a single discharge point, but rather they occur over the entire length of a stream or waterbody. There are many types of nonpoint sources in watersheds discharging to the restricted shellfish harvesting area. The possible introductions of fecal coliform to the land surface are through the manure spreading process, direct deposition from livestock during the grazing season, and excretions from pets and wildlife. As the runoff occurs during rain events, surface runoff transports water and fecal coliform over the land surface and into surface waters. The deposition of non-human fecal coliform directly to the restricted shellfish harvesting areas may occur when livestock or wildlife have direct access to the waterbody. Nonpoint source contributions from human activities generally arise from failing septic systems and their associated drain fields as well as through pollution from recreational vessel discharges. The potential transport of fecal coliform from land surfaces to restricted shellfish harvesting waters is dictated by the hydrology, soil type, land use, and topography of the watershed.

In order to determine the sources of fecal coliform contribution and reduction needed to achieve water quality criteria and to allocate fecal coliform loads among these sources, it is necessary to identify all existing sources. MDE and VA-DEQ conducted sampling over a one-year period in the Pocomoke Sound and Lower Pocomoke River to evaluate the source characterization through a process called Bacteria Source Tracking (BST) in 2005-2006 and 2002-2003, respectively, by

MDE and VA-DEQ. BST analysis is used to provide evidence regarding contributions from anthropogenic sources (*i.e.*, human or livestock) as well as background sources, such as wildlife. The Antibiotic Resistance Analysis (ARA) BST method was used to determine the potential sources of fecal coliform in the Pocomoke Sound and Pocomoke River. ARA uses enterococci or *Escherichia coli* (*E. coli*) and patterns of antibiotic resistance in these bacteria to identify sources. The premise is that the antibiotic resistance of bacteria isolated from different hosts can be discerned based upon differences in the selective pressure of microbial populations found in the gastrointestinal tract of those hosts (humans, livestock, pets, wildlife) (Wiggins 1996).

In the Pocomoke River basin, wildlife contributions, both mammalian and avian, are considered natural conditions and may represent a background level of bacterial loading. Livestock contributions, such as those from mammalian and avian livestock, mainly result from surface runoff. The watershed is predominantly cropland and forest. According to land use information, wildlife and livestock could be the dominant sources. Pet contributions usually occur through runoff from streets and land. Human sources mainly result from failure of septic systems. Figure 2.1.2 shows the land use categories.

<u>Maryland</u>

Table 2.4.1 lists MD BST data analysis results. Based on the analysis of BST data collected at seven (7) stations, livestock is the dominant source, followed by wildlife. There are 34.3% water isolates from unknown (unclassified) probable sources. BST data analysis includes a statistical comparison of known sources collected in the watershed and water samples collected over the study period. The fecal coliform sources in water samples are unknown until matched with the library of known sources. The 34.3% unknown sources for BST analysis are those where no match was identified in the known library. They do not represent unknown sources in the sense that they cannot be identified; rather, they represent a portion of the statistical analysis where no matches to the known-source BST library were found (see Appendix B for details on BST used for this report).

Table 2.4.1: Bacteria Source Distribution Based on BST Data Analysis (MDE)

Human	Livestock	Wildlife	Pets	Unknown
11.5%	35.6%	13.1%	5.5%	34.3%
*17.6%	*54.2%	*19.9%	*8.4%	

*Percent excludes unknown sources

Virginia

Table 2.4.2 lists the VA BST data analysis results based on the data collected from station 75-S7 in the Pocomoke Sound stations from 2002-2003, in which the dominant source is wildlife. For VA BST data analysis, only four categories were used to classify the bacteria source contribution. Detailed results of BST analysis are presented in Appendix B.

Table 2.4.2: Source Distribution Based on BST Data Analysis (VA-DEQ)

Human	Livestock	Wildlife	Pets	Unknown
17.1%	4.0%	48.4%	30.4%	N/A

The BST data are collected from different locations and from different years by MDE and VA-DEQ. The fecal coliform sources vary from different time periods and at different stations. By combining both MD and VA data, excluding water isolates from unidentified sources, a weighted average source contribution can be estimated which is listed in Table 2.4.3. The predominant bacteria source is from wildlife (34.2%), followed by livestock (29%), pet (19%), and human (17%) sources.

Table 2.4.3: Weighted Average Source Distribution Based on MDE and VA-DEQ BST Data Analysis (excluding unknown category in MDE's BST Data)

Human	Livestock	Wildlife	Pets
17.4%	29.0%	34.2%	19.4%

Point Source Assessment

Maryland

There are no industrial point source facilities with permits regulating the discharge of fecal coliform that affect the restricted shellfish harvesting areas of the Pocomoke in MD. However, there are four municipal point source facilities located in the MD portion of the Pocomoke watershed with National Pollutant Discharge Elimination System (NPDES) permits regulating the discharge of fecal coliform to the tributaries of the Pocomoke. The NPDES permit numbers for these facilities are as follows: MD0022551 (Pocomoke City WWTP), MD0051632 (Willards WWTP), MD0060348 (Pittsville WWTP), and MD0022764 (Snow Hill WWTP). The NPDES permit limits of these facilities for fecal coliform are a monthly log mean of 200 MPN/100 ml, with design flows of 1.47 million gallons per day (MGD), 0.2 MGD, 0.12 MGD and 1.2 MGD, respectively (see Table 2.4.4). The estimated total allowable loads from these facilities are 2.26×10^9 and 7.36×10^9, respectively, corresponding to the median and 90th percentile scenarios. All MD discharges are discharging significantly less than the permitted fecal coliform concentrations. The allocation of the permitted load from these point source facilities will be addressed in Section 4.7.

Table 2.4.4. Summary of Point Source Facilities and Loads (Maryland)

Facility Name	NPDES Permit Number	Design flow (MGD)	Permitted FC Concentration in MPN/100ml (Monthly Log Mean)	Permitted FC Loads in MPN/Day	
				Median	90th Percentile*
Pocomoke City WWTP	MD0022551	1.47	200	1.11E+09	3.62E+09
Willards WWTP	MD0051632	0.20	200	1.51E+08	4.92E+08
Pittsville WWTP	MD0060348	0.12	200	9.08E+07	2.95E+08
Snow Hill WWTP	MD0022764	1.20	200	9.08E+08	2.95E+09
Total				2.26E+09	7.36E+09

*Estimated using a conversion factor of 3.25 to convert a log mean of FC permit value to a 90% confidence level value.

Virginia

There are no point source facilities with permits regulating the discharge of fecal coliform that directly discharge to the restricted shellfish harvesting areas of the Pocomoke in VA. However, there are seven point source facilities located within Accomack County, Virginia discharging into small creeks. These facilities have the following NPDES permit numbers: VAG750050 (Tims Car Wash); VAG250097(KMX Chemical Corporation); VAR050238 (Davis Auto Center Incorporated); VAR050491 (KMX Chemical Corporation); VA0023078 (VDOT- Route 13 Information Center); VA0090875 (Oak Hall Shopping Center); and VA0065196 (Cardinal Village). Two facilities VA0023078 and VA0090875 have permitted flows of 0.02 and 0.01 MGD, respectively, and permitted fecal concentration of 200MPN/100ml (see Table 2.4.5). The estimated total allowable load from these facilities is 2.27×10^7, corresponding to the median scenarios. The allocation of the permitted load from these point source facilities will be addressed in Section 4.7.

Table 2.4.5. Summary of Point Source Facilities (Virginia)

Facility Name	NPDES Permit Number	Design Flow (MGD)	Permitted FC Concentration in MPN/100ml (Monthly Log Mean)	Permitted FC Loads in MPN/Day	
				Median	90th Percentile*
VDOT - Route 13 Information Center	VA0023078	0.02	200	1.51×10^7	N/A
Oak Hall Shopping Center	VA0090875	0.01	200	7.57×10^6	N/A
Total		0.03		2.27×10^7	N/A

* 90^{th} percentile load is not applicable in VA

3.0 TARGETED WATER QUALITY GOAL

The overall objective of the fecal coliform TMDLs in this document is to establish the maximum loading allowed that will ensure attainment of water quality standards in the restricted shellfish harvesting waters in the Pocomoke River and Sound. These standards are described fully in Section 2.3, Water Quality Impairment.

4.0 TOTAL MAXIMUM DAILY LOADS AND LOAD ALLOCATION

4.1 Overview

This section documents detailed fecal coliform TMDLs and load allocation development for the restricted shellfish harvesting waters in the Pocomoke River watershed. The required load reduction was determined based on data collected from September 2002 to December 2005 for Maryland, and November 2002 to December 2005 for Virginia. The TMDLs are presented as counts/day. Section 4.2 describes the analysis framework for simulating fecal coliform concentration in the restricted shellfish harvesting water in the Pocomoke River. Section 4.3 addresses critical conditions and seasonality. The TMDL calculations are presented in Section 4.4. Section 4.5 provides a summary of baseline loads and Section 4.6 discusses TMDL loading caps. Section 4.7 provides the description of the waste load and load allocations. The margin of safety is discussed in Section 4.8. Finally, the TMDL equation is summarized in Section 4.9.

A TMDL is the total amount of a pollutant that a waterbody can receive and still meet water quality criteria, which in the case of this document would be Maryland's water quality criteria for fecal coliform in shellfish harvesting waters. A TMDL may be expressed as a “mass per unit time, toxicity, or other appropriate measure” (CFR 2006b). These loads are based on an averaging period that is defined by the specific water quality criteria for shellfish harvesting waters. The averaging period used for development of these TMDLs requires at least 30 samples and uses a three-year window of data to identify current baseline conditions.

A TMDL is the sum of individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, incorporating natural background levels. The TMDL must, either implicitly or explicitly, include a margin of safety (MOS) that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody, and in the scientific and technical understanding of water quality in natural systems. In addition, when applicable, the TMDL may include a future allocation (FA) when necessary. This definition is denoted by the equation:

$$TMDL = WLAs + LAs + MOS + (FA,\ \text{where applicable})$$

4.2 Analysis Framework

In general, tidal waters are exchanged through their connecting boundaries. The tide and amount of freshwater discharged into the restricted shellfish harvesting area are the dominant forces that influence the transport of fecal coliform in the Pocomoke River and Pocomoke Sound. The restricted area is located in the Lower Pocomoke River and Pocomoke Sound and is influenced by both tide and freshwater input. The current distribution in the system varies as tidal and freshwater discharges change. In order to simulate the transport processes in the Pocomoke River accurately, the 3-dimensional hydrodynamic and eutrophication model (HEM-3D) has been used for this study. The HEM-3D model is a general 3D model for environmental studies. The model simulates density and topographically induced circulation as well as tidal and wind-driven flows, and spatial and temporal distributions of salinity, temperature, and suspended sediment concentration, conservative tracers, eutrophication processes, and fecal coliform. For a detailed model description, the reader is referred to Park et al. (1995).

The Pocomoke River is represented by a horizontal network of model grid cells. There are a total of 91 model grid cells in the modeling domain. To better simulate the stratification effect, three layers are used in the vertical. For this study, the model was calibrated for the tide and long-term mean salinity distribution. In order to address the standards of median/geo-mean and 90^{th} percentile of fecal coliform, an inverse approach has been adopted here to estimate the loads from the watershed. The watershed is divided into 20 subwatersheds. The loads from each subwatershed are discharged into the river from the river's tributaries.

The model was forced by the M_2 constituent of the tide and the mean salinity concentration at the river mouth. The long-term mean freshwater input was estimated based on data from United States Geological Survey (USGS) gage station 01485500. The discharges from subwatersheds are estimated based on the ratio of subwatershed area to the total drainage basin of the USGS station. Because MD's numerical criteria are based on a median and 90^{th} percentile and VA's numerical criteria are based on a geo-mean and 90^{th} percentile, the inverse method is used to estimate the existing load discharged from each subwatershed based on median, geo-mean, and 90^{th} percentile data obtained from observations. The model is also used to establish the allowable loads for the river. Because median values at observation stations are very close to geo-mean values at these stations, the model results show that the loads estimated based on the median value and geo-mean value are equivalent. Therefore, the model results are based on 3-year median and 90^{th} percentile values and were used to estimate the existing loads. Detailed modeling procedures are described in Appendix A.

4.3 Critical Condition and Seasonality

EPA's regulations require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters (40 CFR 130.7 (c)(1)). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The critical condition accounts for the hydrologic variation in the watershed over many sampling years, whereas the critical period is the time during which a waterbody is most likely to violate the water quality standard(s).

The 90th percentile concentration is the concentration that exceeded the water quality criterion only 10% of the time. Since the data used were collected over a three-year period, the critical condition is implicitly included in the value of the 90th percentile. Given the length of the monitoring record used and the limited applicability of best management practices to extreme conditions, the 90th percentile is utilized instead of the absolute maximum.

A comparison of the median values and the 90th percentile values against the water quality criteria determines which represents the more critical condition or higher percent reduction. If the median or geometric mean values dictate the higher reduction, this suggests that, on average, water sample counts are very high with limited variation around the mean. If the 90th percentile criterion requires a higher reduction, this suggests an occurrence of high fecal coliform due to the variation of hydrological conditions.

The seasonal fecal coliform distributions for the MDE six monitoring stations are presented in Appendix C. The results show the seasonal variability of fecal coliform concentrations. High concentrations occur in the months of August through October in the Pocomoke River restricted shellfish harvesting area. The largest standard deviations correspond to the highest variability in concentration for each station. These high concentrations result in a high 90th percentile concentration, which indicates that exceedances may occur only during a few months of the year.

Similar to the critical condition, seasonality is also implicitly included in the analysis due to the averaging required in the water quality standards. The MDE shellfish-monitoring program uses a systematic random sampling design that was developed to cover inter-annual variability. The monitoring design and the statistical analysis used to evaluate water quality attainment therefore implicitly include the effect of seasonality. By examining the seasonal variability of fecal coliform, it's apparent that the highest fecal coliform values often occur during the few months of the year that correspond to the critical condition. If loads under the critical condition can be controlled, water quality attainment can be achieved.

The seasonal fecal coliform distributions for the Virginia's five monitoring stations are presented in Appendix C. The results show the seasonal variability of fecal coliform concentrations. High concentrations occur in the months of April through June, and September through October in the Pocomoke River restricted shellfish harvesting area. The largest standard deviations correspond to the highest variability in concentration for each station. These high concentrations result in a high 90th percentile concentration, which indicates that exceedances may occur in spring and in fall. Similar to the critical condition, seasonality is also implicitly included in the analysis due to the averaging required in the water quality standards.

4.4 TMDL Computation

According to the water quality standard for fecal coliform in shellfish waters, computation of a TMDL requires analyses of both the median and 90th percentile scenarios.

Routine monitoring data were used to estimate the current loads. Both the median and 90th percentile analyses have been performed. The restricted shellfish harvesting area in Pocomoke River has six MDE shellfish monitoring stations and five VA shellfish monitoring stations. To accurately estimate the load with consideration of available monitoring data, the watershed was segmented into 20 subwatersheds. The load for each subwatershed was discharged into its corresponding receiving water model. The inverse method was used to compute the watershed loads discharged into the river based on the best match of observations and model simulation of fecal coliform values for the river. The total loads are reported in Table 4.4.1 and Table 4.4.2. Detailed results by subwatershed are also listed in Appendix A.

The allowable load is calculated using the water quality criteria of a median of 14 MPN/100ml and a 90th percentile of 49 MPN/100ml. The 3-D model was used to compute the allowable load for each subwatershed by reducing the existing loads from the watershed so that the fecal coliform concentration in the receiving water meets the standards. The total loads discharged into the river are the summation of loads discharged from each subwatershed. The load reduction needed for the attainment of the criteria is determined as follows:

$$\textbf{Load Reduction} = \frac{\textbf{Current Load} - \textbf{Allowable Load}}{\textbf{Current Load}} \times 100\,\%$$

The TMDL calculations are presented in Appendix A. The calculated results are listed in Table 4.4.1 and Table 4.4.2.

Table 4.4.1: Median Analysis of Current Load and Estimated Load Reduction

Restricted Area	Mean Volume M^3	Fecal Coliform Median Standard MPN/100mL	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction (%)
Pocomoke River and Pocomoke Sound	24,416,296	14	3.53E+13	2.19E+13	37.88

Table 4.4.2: 90th Percentile Analysis of Current Load and Estimated Load Reduction

Restricted Area	Mean Volume M^3	Fecal Coliform 90th Percentile Standard MPN/100mL	Current Load counts/day	Allowable Load Counts/day	Required Percent Reduction (%)
Pocomoke River and Pocomoke Sound	24,416,296	49	1.30E+14	7.54E+13	42.13

4.5 Summary of Baseline Loads

For the TMDL analysis period, the calculated baseline (current) loads of fecal coliform from all sources in the restricted shellfish harvesting area in the Pocomoke River basin are summarized in Table 4.5.1 (see also Table 4.4.1 and Table 4.4.2 above).

Table 4.5.1: Summary of Baseline Loads

Pocomoke River and Pocomoke Sound	Fecal Coliform Baseline Loads [counts per day]	
	Median Analysis Scenario	**90th Percentile Analysis Scenario**
Maryland	2.95×10^{13}	1.05×10^{14}
Virginia	5.83×10^{12}	2.55×10^{13}
Total	3.53×10^{13}	1.30×10^{14}

4.6 TMDL Loading Caps

This section presents the TMDLs that would meet the median and 90th percentile criteria. Seasonal variability is addressed implicitly through the interpretation of the water quality standards (see Section 4.3). The median and 90th percentile based TMDLs for the restricted shellfish harvesting waters of the Pocomoke River basin are summarized in Table 4.6.1.

Table 4.6.1: Summary of TMDL Loading Caps

Pocomoke River and Pocomoke Sound	Fecal Coliform TMDL [counts per day]	
	based on Median Criterion	based on 90^{th} Percentile Criterion*
Maryland	1.95×10^{13}	6.50×10^{13}
Virginia	2.42×10^{12}	1.04×10^{13}
Pocomoke River and Pocomoke Sound	2.19×10^{13}	7.54×10^{13}

* The comparison of the reductions required based on the median and 90th percentile criteria indicated that the 90th percentile scenario requires the largest percent reductions. Therefore, reductions required to meet the 90th percentile criterion were the bases for the TMDL allocations.

A three-year averaging period was used to develop the fecal coliform TMDLs for the shellfish harvesting areas in the Pocomoke. This specific averaging period was chosen based on the water quality criteria, which requires at least 30 samples (COMAR 2006 and 9 VAC 25-260-160). When allocating loads among sources, the scenario that requires the greatest overall reductions (here the 90^{th} percentile scenario) was applied. Table 4.7.1 below summarizes the necessary load reductions by area.

4.7 Load Allocation and Reduction

Maryland

The purpose of this section is to allocate the TMDLs between point (WLA) and nonpoint (LA) sources. As stated in Section 2.4, there are four active municipal point source facilities located in the MD portion of the Pocomoke watershed that have NPDES permits regulating the discharge of fecal coliform: MD0022551 (Pocomoke City WWTP), MD0051632 (Willards WWTP), MD0060348 (Pittsville WWTP), and MD0022764 (Snow Hill WWTP). The permitted fecal coliform load from these facilities is approximately 7.36×10^{9} counts per day and will be included in the WLA.

Virginia

As stated in Section 2.5, there are two active point source facilities in the VA portion of the watershed that have NPDES permits regulating the discharge of fecal coliform: VA0023078 (VDOT – Route 13 Information Center) and VA0090875 (Oak Hall Shopping Center). The estimated total loads from these facilities is approximately $2.27\text{x}10^{7}$ counts per day and will be included in the WLA.

The load reduction scenario results in a load allocation by which the TMDL can be implemented to achieve water quality standards. MD and VA reserve the right to revise these allocations, provided the allocations are consistent with the achievement of water quality standards. The load reductions calculated in this document were based on the 90th percentile water quality criterion, which is shown in Table 4.7.1, for the restricted shellfish harvesting area of the Pocomoke.

For the Pocomoke River mainstem, the fecal coliform loads from point source facilities constitute less than 0.01% of the total loads. For these facilities, the allowable loads and baseline loads are the same, are estimated from the permit limits, and no reductions are needed. For the upstream portion of the MD watershed, no reduction is required. Therefore, the reduction of 42.13% is applied to nonpoint source loads from the Pocomoke River watershed.

Table 4.7.1: Load Reductions

Restricted Shellfish Harvesting Area	Required Reduction
Pocomoke Sound and Pocomoke River (MD)	37.97%
Pocomoke Sound and Pocomoke River (VA)	59.23%
Pocomoke Sound and Pocomoke River (Total)	42.13 %

Since the load reduction applied to this watershed was based on the 90th percentile water quality standard, it targets only those critical events that occur less frequently. Therefore, the load reduction established is not a literal daily reduction, but rather an indicator that control measures for bacterial loads are needed for these more extreme events. Extreme events are often a result of hydrologic variability, land use practices, water recreation uses, or wildlife activities.

4.8 Margin of Safety

A Margin of Safety (MOS) is required as part of a TMDL in recognition of many uncertainties in the understanding and simulation of water quality in natural systems. For example, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural waterbodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection.

For TMDL development, the MOS needs to be incorporated to account for uncertainty due to model parameter selection. The decay rate is one of the most sensitive parameters in the model.

For a given system, the higher the decay rate, the higher the assimilative capacity. The value of the decay rate varies from 0.7 to 3.0 per day in salt water (Mancini 1978; Thomann and Mueller 1987). A decay rate of 0.7 per day was used as a conservative estimate in the TMDL calculation. Further literature review supports this assumption as a conservative estimate of the decay rate (MDE 2004). Therefore the MOS is implicitly included in the calculation.

4.9 Summary of Total Maximum Daily Loads

There are four active point source facilities located in the MD portion of the Pocomoke watershed that have NPDES permits regulating the discharge of fecal coliform to the Pocomoke River and its tributaries: MD0022551 (Pocomoke City WWTP), MD0051632 (Willards WWTP), MD0060348 (Pittsville WWTP), and MD0022764 (Snow Hill WWTP). The permitted fecal coliform load from these point sources is approximately 7.36×10^{9} counts per day. There are two active point source facilities located in the Virginia portion of the watershed: VA0023078 (VDOT - Route 13 Information Center) and VA0090875 (Oak Hall Shopping Center). The estimated total loads from these facilities is approximately 2.27×10^{7} counts per day. The total permitted fecal coliform load from these point source is approximately 7.38×10^{9} counts per day. In this study, to account for future growth on permitted facilities in these watersheds, the point source flows were increased by an additional factor of 5, while retaining the 90th percentile limit on fecal coliform bacteria. Therefore, a total load of 4.43×10^{10} counts per day will be included in the WLA. The remaining loads assimilative capacity will be allocated to the load allocation. The TMDLs are established based on the 90th percentile load represents the more stringent standard and is summarized as follows:

The 90th percentile TMDL (counts per day):

Area	TMDL	=	LA	+	WLA*	+	FA	+	MOS
Pocomoke River and Pocomoke Sound	**7.54×10^{13}**		**7.54×10^{13}**	+	**4.43×10^{10}**	+	**N/A**	+	**Implicit**

* This allocation is less than 0.1% of the total TMDL.

Where:

TMDL = Total Maximum Daily Load
LA = Load Allocation (Nonpoint Source)
WLA = Waste Load Allocation (Point Source)
FA = Future Allocation
MOS = Margin of Safety

The existing loading adjacent to the restricted area comes from both VA and MD. The TMDL will be shared by both jurisdictions excluding loads discharged from the area upstream of the Pocomoke River, which has less contribution than the area adjacent to the restricted area. The point source facilities are required to discharge at or below the bacteria water quality criteria.

Therefore, a violation of those criteria would result in a violation of their discharge permits. Because the permits for these facilities already protect against violating the criteria, there is no need to modify the existing permits.

A scenario has also been developed to account for future growth for permitted facilities in the Pocomoke River and Pocomoke Sound. This future growth could be the addition of new point sources or expansions of existing facilities in the watershed. This approach will result in a total WLA that can accommodate such growth. The point source flows were increased by an additional factor of 5, while retaining the 90th percentile limit on fecal coliform bacteria. This effectively increased the WLA for Pocomoke River and Pocomoke Sound by a factor of 5. A shared TMDL is summarized as follows:

The 90th percentile TMDL (counts per day):

Area	TMDL	=	LA	+	ΣWLA*	+	MOS
Pocomoke River and Pocomoke Sound, MD	6.50×10^{13}	=	6.50×10^{13}	+	4.42×10^{10}	+	Implicit
	WhereΣWLA		*MD0022551*		*3.62X10^9*		
			MD0051632		*4.92X10^8*		
			MD0060348		*2.95X10^8*		
			MD0022764		*2.95X10^9*		
			Future Growth		*3.68x10^10*		
Pocomoke River and Pocomoke Sound, VA	1.04×10^{13}	=	1.04×10^{13}	+	1.37×10^{8}	+	Implicit
	Where ΣWLA		*VA0023078*		*1.51x10^7*		
			VA0090875		*7.57x10^6*		
			Future Growth		*1.14x10^8*		

*** This allocation is less than 0.1% of the total TMDL.**

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the fecal coliform TMDL will be achieved and maintained. The appropriate measures to reduce pollution levels in the impaired segments include, where appropriate, the use of better treatment technology or installation of best management practices (BMPs). Details of these methods are to be described in the implementation plan.

Maryland

In general, MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the greatest impact on water quality, with consideration given to ease of implementation and cost. The source contributions estimated from the BST data analysis (see Table 2.4.3) may be used as a tool to target and prioritize initial implementation efforts. The iterative implementation of BMPs in the watershed has several benefits: tracking of water quality improvements following BMP implementation through follow-up stream monitoring; providing a mechanism for developing public support through periodic updates on BMP implementation; and helping to ensure that the most cost-effective practices are implemented first.

Potential funding sources for implementation include Maryland's Agricultural Cost Share Program (MACS), which provides grants to farmers to help protect natural resources, and the Environmental Quality and Incentives Program, which focuses on implementing conservation practices and BMPs on land utilized for livestock and agricultural production. Low interest loans are available to property owners with failing septic systems through MDE's Linked Deposit Program. It is also anticipated that the Bay Restoration Fund will provide funding to upgrade onsite sewage disposal systems with priority given to failing systems and holding tanks in the Chesapeake and Atlantic Coastal Bays Critical Areas. Local governments can utilize funding from the State Water Quality Revolving Loan Fund and the Stormwater Pollution Cost Share Program. Details of these programs and additional funding sources can be found at http://www.dnr.state.md.us/bay/services/summaries.html.

Maryland law requires the following types of facilities to have pumpout stations: existing marinas wishing to expand to a total of 11 or more slips that are capable of berthing vessels that are 22 feet or larger; new marinas with more than 10 slips capable of berthing vessels that are 22 feet or larger; and marinas with 50 or more slips and that berth any vessel over 22 feet in length (Maryland 1996). Any public or private marina in Maryland is eligible to apply for up to $15,000 in grant funds to install a pumpout station through the Maryland Department of Natural Resources.

Regulatory enforcement of potential bacteria sources may include MDE's routine sanitary surveys of shellfish growing areas, and through NPDES permitting activities such as Confined Animal Feeding Operations (CAFOs). Though not directly linked, it is assumed that the nutrient management plans from the MD's Water Quality Improvement Act of 1998 (WQIA) will result in some reduction of bacteria from manure application practices.

As part of MD's commitment to the NSSP, MDE continues to monitor shellfish waters and classify harvesting areas. Those waters meeting shellfish water quality standards are reclassified as open to harvesting and may serve to track the effectiveness of TMDL implementation and water quality improvements.

<u>Virginia</u>

In general, VA intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from water bodies. This has been shown to be very effective in lowering fecal coliform concentrations in water bodies, both by reducing the cattle deposits themselves and by providing additional riparian buffers. Additionally, in both urban and rural areas, reducing the human fecal loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems. In urban areas, reducing the loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. The iterative implementation of BMPs in the watershed has several benefits: 1) It enables tracking of water quality improvements following BMP implementation through follow-up monitoring; 2) It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling; 3) It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements; 4) It helps ensure that the most cost effective practices are implemented first; and 5) It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards. Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. Specific goals for BMP implementation will be established as part of the implementation plan development.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the Virginia Pollutant Discharge Elimination System (VPDES) program, which typically includes consideration of the Water Quality Monitoring, Information, and Restoration Act (WQMIRA) requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process, and with the exception of stormwater related permits, permitted sources are not usually addressed during the development of a TMDL implementation plan.

VDH-DSS will continue sampling at the established bacteriological monitoring stations in accordance with its shellfish monitoring program. VA-DEQ will continue to use data from these monitoring stations and related ambient monitoring stations to evaluate improvements in the bacterial community and the effectiveness of TMDL implementation in attainment of the general water quality standard.

Implementation of this TMDL will contribute to ongoing water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. Other TMDLs have been developed for impaired shellfish waters in Accomack County for Onancock Creek, Holden Creek, Pettit Branch, Pungoteague Creek, Messongo Creek, Nandua Creek, Assawoman Creek, and Folly Creek watersheds. Reports for these TMDLs are available at the Department of Environmental Quality website http://www.deq.virginia.gov/tmdl/. A tributary strategy has been developed for the VA tributaries to the Atlantic Ocean. Up-to-date information on tributary strategy development can be found at http://www.snr.virginia.gov/Initiatives/TributaryStrategies.

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for VA’s Non-point Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture’s Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality

Improvement Fund. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

Implementation and Wildlife Sources

It is expected that in some waters for which TMDLs will be developed, the bacteria source analysis will indicate that after controls are in place for all anthropogenic sources, the waterbody will not meet water quality standards. However, neither MD or VA, nor the EPA, is proposing the elimination of wildlife to allow for the attainment of water quality standards. This is considered to be an impracticable and undesirable action. While managing the overpopulation of wildlife remains an option for State and local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

Implementation may begin by first managing controllable sources (human, livestock, and pets) and then determining if the TMDL can be achieved. If the total required reduction is still not met, then a reduction may need to be applied to the wildlife source. Given the nonpoint source characteristics of the wildlife contribution, it may be assumed that best management practices applied to controllable sources may also reduce some wildlife sources contributing to the restricted shellfish harvesting area.

Following this first implementation stage, MDE would re-assess the water quality to determine if the designated use is being achieved. If the water quality standards are not attained, then MDE may consider developing either a risk-based adjusted water quality assessment or a Use Attainability Analysis to reflect the presence of naturally high bacteria levels from uncontrollable (natural) sources.

In Virginia the process to address potentially unattainable reductions based on the above is as follows: First is the development of a Stage 1 Scenario such as those presented previously in this chapter. The pollutant reductions in the Stage 1 Scenario are targeted primarily at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases where excess populations can be determined by appropriate authorities. During the implementation of the Stage 1 Scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach. DEQ will re-assess water quality in the stream during and subsequent to the implementation of the Stage 1 Scenario to determine if the WQS is attained. This effort will also evaluate if the modeling assumptions were correct. If WQSs are not being met, and no additional cost-effective and reasonable best management practices can be identified, a UAA may be initiated with the goal of re-designating the stream for secondary contact recreation.

REFERENCES

ASAE (American Society of Agricultural Engineers). 1998. *ASAE Standards, 45th Edition: Standards, Engineering Practices, Data*. St. Joseph, MI: American Society of Agricultural Engineers.

Bertsekas, D. P. 1995. *Nonlinear Programming*. Belmont, MA: Athena Scientific.

Brodie, H., and L. Lawrence. 1996. *Nutrient Sources on Agricultural Lands in Maryland: Final Report of Project NPS 6*. Annapolis, MD: Chesapeake Bay Research Consortium.

CFR (Code of Federal Regulations). 2006a. *40 CFR 122.26 (b).* http://www.gpoaccess.gov/cfr/index.html (Accessed August, 2006).

__________. 2006b. *40 CFR 130.2 (i)*. http://www.gpoaccess.gov/cfr/index.html (Accessed August, 2006).

__________. 2006c. *40 CFR 130.7(c)(1)*. http://www.gpoaccess.gov/cfr/index.html (Accessed August, 2006).

COMAR (Code of Maryland Regulations). 2006. *26.08.02.03-3C(2)*. http://www.dsd.state.md.us/comar/26/26.08.02.03-3.htm (Accessed August, 2006).

De Walle, F. B. 1981. Failure Analysis of Large Septic Tank Systems. *Journal of Environmental Engineering Division* 107:229-240.

DNR (Maryland Department of Natural Resources). 2003. *2002-2003 Game Program Annual Report*. Annapolis, MD: Maryland Department of Natural Resources, Wildlife and Heritage Services.

__________. 2004. Personal Communication with Douglas Horton.

__________. 2005. Personal Communication with Larry Hindman.

FDA (Food and Drug Administration). 2003. Chapter IV: Shellstock Growing Areas. In *National Shellfish Sanitation Program: Guide for the Control of Molluscan Shellfish*. Rockville, MD: Food and Drug Administration, Department of Health and Human Services. Also Available at http://www.cfsan.fda.gov/~ear/nss2-toc.html.

Frana, M.F. and E. A. Venso. 2005. Bacterial Source Tracking Report: Identifying Sources of Fecal Pollution in the Nanticoke River Shellfish Harvesting Waters, Maryland. Salisbury University, Salisbury, MD 21801.

Hagedorn, C., Robinson, S.L., Filtz, J.R., Grubbs, S.M., Angier, T.A. and Beneau, R.B. 1999. Determining Sources of Fecal Pollution in a Rural Virginia Watershed with Antibiotic Resistance Patterns in Fecal Streptococci. *Appl. Environ. Microbiol.* 65, 5522-5531.

Hamilton, P. A., J. M. Denver, P. J. Phillips, and P. J. Shedlock (1993). Water-quality assessment of the Delmarva Peninsula, Delaware, Maryland, and Virginia--effects of agricultural activities on, and distribution of, nitrate and other inorganic constituents in the surficial aquifer, U.S. Geological Survey, Open-File Report 93-40, 87 p.

Hamrick, J. M. 1992a. Estuarine Environmental Impact Assessment Using a Three-Dimensional Circulation and Transport Model. In *Estuarine and Coastal Modeling, Proceedings of the 2nd International Conference*, edited by M. L. Spaulding, K. Bedford, and A. F. Blumberg. New York: American Society of Civil Engineers.

__________. 1992b. A Three-Dimensional Environmental Fluid Dynamics Code: Theoretical and Computational Aspects. *Special Report in Applied Marine Science and Ocean Engineering* No. 317. 63 pp.

Hancock, T. C., J. M. Denver, G. F. Riedel, and C.V. Miller. (2007). Source, transport, and fate of arsenic in the Pocomoke River Basin, a Poultry dominated Chesapeake Bay watershed. http://wwwbrr.cr.usgs.gov/Arsenic/FinalAbsPDF/hancock.pdf. (last accessed Nov. 19, 2007).

Kator, H., and M. W. Rhodes. 1996. Identification of Pollutant Sources Contributing to Degraded Sanitary Water Quality in Taskinas Creek National Estuarine Research Reserve, Virginia. *Special Report in Applied Marine Science and Ocean Engineering* No. 336. 47 pp.

Mancini, J. L. 1978. Numerical Estimates of Coliform Mortality Rates Under Various Conditions. *Journal - Water Pollution Control Federation* 50 (November):2477-2484.

Maryland. 1996. Environment: 9-333. Marinas. *The Annotated Code of Maryland*. Charlottesville, VA: Reed Elsevier Inc.

MDA (Maryland Department of Agriculture). 2002a. *Agriculture in Maryland 2002 Summary*. Annapolis, MD: Maryland Department of Agriculture, Maryland Agricultural Statistics Services. Also Available at http://www.nass.usda.gov/md/Ag%20in%20Maryland%202002.pdf.

__________. 2002b. *Maryland Equine: Results of the 2002 Maryland Equine Census*. Annapolis, MD: Maryland Department of Agriculture, Maryland Agricultural Statistics Services, and The Maryland Horse Industry Board. Also Available at http://www.marylandhorseindustry.org/census2.htm.

MDE (Maryland Department of the Environment). 2004. *Technical Memorandum: Literature Survey of Bacteria Decay Rates*. Baltimore, MD: Maryland Department of the Environment.

__________. 2005. *Total Maximum Daily Loads of Fecal Coliform for Restricted Shellfish Harvesting Areas in the Potomac River Lower Tidal Basin in St. Mary's County, Maryland*. Baltimore, MD: Maryland Department of the Environment. Also Available at http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/ApprovedFinalTMDL/index.asp.

__________. 2006. *2004 303(d) List Searchable Database*. http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/Maryland 303 dlist/303d_search/ (Accessed August, 2006).

MDP (Maryland Department of Planning). 2000. *2000 Land Use Data*. Baltimore, MD: Maryland Department of Planning.

__________. 2003. *Estimates of Septic Systems*. Baltimore, MD: Maryland Department of Planning, Comprehensive Planning Unit.

__________. 2004. *Maryland Department. of Natural Resources 12 Digit Watershed GIS Coverage*. Baltimore, MD: Maryland Department of Planning.

NOAA (National Oceanic and Atmospheric Administration). 2006. *Tides Online*. http://tidesonline.nos.noaa.gov/ (Accessed August, 2006).

Park, K., A. Y. Kuo, J. Shen, and J. M. Hamrick. 1995. A Three Dimensional Hydrodynamic Eutrophication Model: Description of Water Quality and Sediment Process Submodels. *Special Report in Applied Marine Science and Ocean Engineering* No. 327. 98 pp.

Shen, J. 2006. Optimal Estimation of Parameters for a Estuarine Eutrophication Model. *Ecological Modeling* 191:521-537.

Shen, J., and A. Y. Kuo. 1996. Inverse Estimation of Parameters for an Estuarine Eutrophication Model. *Journal of Environmental Engineering* 122 (11):1031-1040.

Shen, J., H. Wang, M. Sisson, and W. Gong. 2006. Storm Tide Simulation in the Chesapeake Bay Using an Unstructured Grid Model. *Estuarine, Coastal and Shelf Science* 68 (1-2):1-16.

Shen, J., J. Boon, and A. Y. Kuo. 1999. A Numerical Study of a Tidal Intrusion Front and Its Impact on Larval Dispersion in the James River Estuary, Virginia. *Estuary* 22 (3):681-692.

Sun, N.Z., and W. W. G. Yeh. 1990. Coupled Inverse Problems in Groundwater Modeling 1. Sensitivity Analysis and Parameter Identification. *Water Resources Research* 20 (10):2507-2525.

Swann, C. 1999. *A Survey of Residential Nutrient Behaviors in the Chesapeake Bay*. Ellicott City, MD: Widener Burrows Inc, Chesapeake Bay Research Consortium, and the Center for Watershed Protection.

Thomann, R. V., and J. Mueller. 1987. *Principles of Surface Water Quality Modeling and Control*. New York: Harper Collins Publishers.

USDA (U.S. Department of Agriculture). 1997a. Maryland State Level Data. In *1997 Census of Agriculture*. Washington, DC: U.S. Department of Agriculture, National Agricultural Statistics Service. Also Available at http://www.nass.usda.gov/census/census97/volume1/md-20/toc97.htm.

__________. 1997b. Maryland County Level Data. In *1997 Census of Agriculture*. Washington, DC: U.S. Department of Agriculture, National Agricultural Statistics Service. Also Available at http://www.nass.usda.gov/census/census97/volume1/md-20/toc297.htm.

__________. 2006. *State Soil Geographic (STATSGO) Database for Maryland*. http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/index.html (Accessed August, 2006).

USDOC (U.S. Department of Commerce). 2000. *United States 2000 Census Data*. Washington, DC: U.S. Department of Commerce, U.S. Census Bureau. http://www.census.gov/main/www/cen2000.html.

USEPA (U.S. Environmental Protection Agency). 1994. *Chesapeake Bay Program Watershed Model Application to Calculate Bay Nutrient Loadings: Final Findings and Recommendations*. Annapolis, MD: U.S. Environmental Protection Agency, Chesapeake Bay Program. Also Available at http://www.chesapeakebay.net/pubs/subcommittee/mdsc/doc-nutrientloadings-7-16-1994.pdf.

__________. 2000. *Bacteria Indicator Tool User's Guide*. Washington, DC: U.S. Environmental Protection Agency, Office of Water.

__________. 2001. *Protocol for Developing Pathogen TMDLs*. Washington, DC: U.S. Environmental Protection Agency, Office of Water. Also Available at http://nepis.epa.gov/pubtitleOW.htm.

__________. 2002. *Memorandum: Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLA) for Stormwater Sources and NPDES Permit Requirements Based on Those WLAs*. Washington, DC: U.S. Environmental Protection Agency.

__________. 2006. *Stormwater Manager Resource Center*. http://www.stormwatercenter.net/ (Accessed August, 2006).

VA-DEQ (Virginia Department of Environmental Quality). 2002. *Fecal Coliform TMDL for Dodd Creek Watershed, Virginia*. Washington, DC: The Louis Berger Group, Inc. Also Available at http://www.deq.virginia.gov/tmdl/apptmdls/newrvr/dodd.pdf.

__________. 2004. *Virginia 2004 Water Quality Assessment 305(b)/303(d) Integrated Report.* Virginia Department of Environmental Quality. Also available at http://www.deq.virginia.gov/wqa/ir2004.html

__________. 2006. *Final 305(b)/30(d) Water Quality Assessment Integrated Report.*

__________. 2006. *Virginia 2006 Water Quality Assessment 305(b)/303(d) Integrated Report.* Virginia Department of Environmental Quality. Also available at http://www.deq.virginia.gov/wqa/ir2006.html

__________. 2007. *State Water Control Board: 9 VAC 25-260 Virginia Water Quality Standards. Statutory Authority: §62.1-44.15 3a of the Code of Virginia with Amendments Effective August 14, 2007*. Virginia Department of Environmental Quality.

VIMS (Virginia Institute of Marine Sciences). 2002-2004. Personal Communication with Helen Woods.

__________. 2004. *Technical Memorandum for Fecal Coliform TMDL of Shellfish Harvesting Areas*. Gloucester Point, VA: Virginia Institute of Marine Sciences.

Virginia's State Water Control Board. 2007. Virginia Water Quality Standards 9 VAC 25-260-5, 160 and 390.

Wiggins, B.A. 1996. Discriminant Analysis of Antibiotic Resistance Patterns in Fecal Streptococci, a Method to Differentiate Human and Animal Sources of Fecal Pollution in Natural Waters. *Appl. Environ. Microbiol.* 62,3997-4002.

Appendix A. Model Development

The 3-dimensional hydrodynamic and eutrophication model (HEM-3D) has been used for this study. The HEM-3D model is a general 3D model for environmental studies. The model simulates density and topographically induced circulation as well as tidal and wind-driven flows, and spatial and temporal distributions of salinity, temperature, and suspended sediment concentration, conservative tracers, eutrophication processes, and fecal coliform. The model has been applied for varieties of environmental problems in estuaries (Hamrick 1992a; Park et al. 1995; Shen et al. 1999). For a detailed discussion of the model theory, readers are referred to Hamrick (1992b).

Figure A-1 is the model grid superimposed on the 20 subwatersheds of the Pocomoke River. The modeling domain consists of 91 grid cells. Because the Pocomoke River is narrow in its upstream portion, a one-dimensional model grid was used to represent the river in the upstream portion of the river whereas a two-dimensional model grid was used in the downstream portion of the river. The model open boundary is placed approximately 9 km downstream of the restricted area. To better simulate estuarine circulation, a total of three layers are used in the vertical. The fecal coliform is simulated using a conservative tracer with first-order decay. The decay rate varies from 0.7 to 3.0 per day in salt water (Mancini 1978; Thomann and Mueller 1987). A decay rate of 0.7 per day was used as a conservative estimate in this TMDL study.

The Pocomoke River is a tidal river. The dominant tidal constituent is M_2. To simulate tide correctly, a calibration of tide was conducted. The model was forced by M_2 tide with mean tidal range at the model open boundary. The model was calibrated against mean tidal ranges along the river obtained from analysis of data from NOAA tidal tables from the website: http://tidesandcurrents.noaa.gov/tides06/tpred2.html#MD. The locations of these stations are shown in Figure A-2. The model results and observed tidal ranges are listed in Table A-1. The HEM-3D model results compare well against results reported on the tidal table. The model simulation of salinity was calibrated based on the mean salinity obtained from monitoring stations along the river. The locations of these stations are shown in Figure A-2. For the mean salinity calibration, the dominant M_2 tide was used as a forcing at the model open boundary. Mean salinity measured at the station nearest the mouth was used as the salinity boundary condition. The quantity of freshwater discharged from each subwatershed was estimated according to the average long-term flow from the USGS gage of 01485500 (Nassawango Creek near Snow Hill, MD). The flow of each subwatershed was estimated based on the ratio of the subwatershed area to the drainage basin area of the USGS gage. The mean flows used for the model calibration are listed in Table A-2 below for the subwatersheds shown in Figure A-1. A comparison of model results against observations is shown in Figure A-3. It can be seen that the model simulation of salinity distribution is satisfactory in the estuary.

Since the water quality standards for fecal coliform are median (MD), geo-mean (VA) and 90th percentile (MD and VA), the modeling tasks are to estimate fecal coliform mean daily loads from the watershed corresponding to the median, geo-mean, and 90th percentile, respectively. For a relatively small waterbody, the tidal prism model has been used to estimate the loads based on the observations and water quality standards using the inverse method (or back calculation)

(MDE 2005). For this study, an inverse modeling approach method built on the HEM-3D has been used to estimate fecal coliform loading from the watershed. The purpose of the inverse modeling is to estimate the long-term average daily loads corresponding to the median and 90th percentile concentrations in the waterbody. Therefore, the fecal coliform daily loads from each subwatershed can be considered as constant model parameters. The inverse methods have been used for many environmental problems to estimate point source loads and model parameters (Shen and Kuo 1996; Sun and Yeh 1990; Shen 2006).

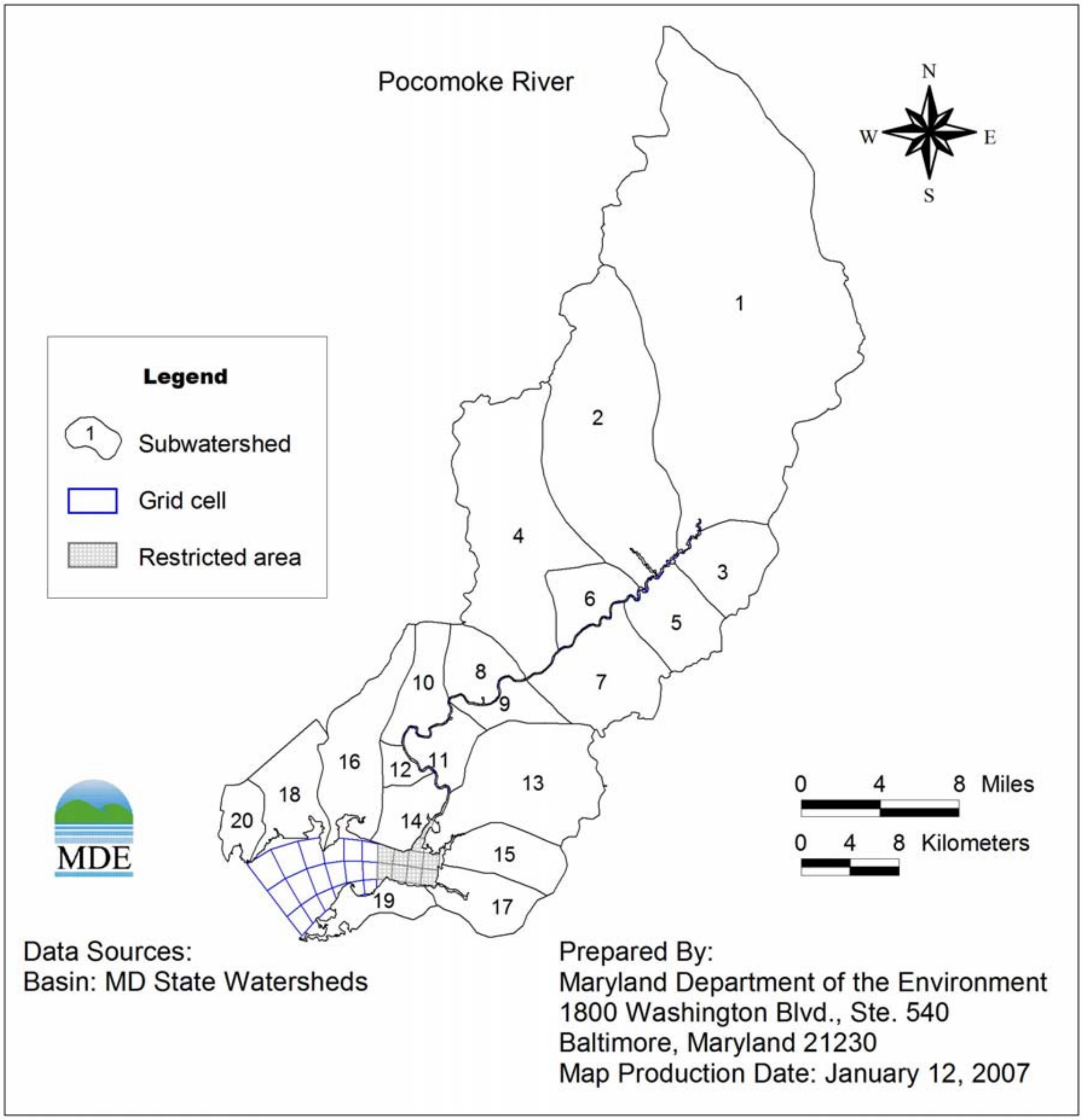

Figure A-1: HEM-3D grid cells and subwatersheds in the Pocomoke River

Table A-1: Comparison of modeled and NOAA predicted mean tidal range

Station	Modeled Range (m)	NOAA Predicted Range (m)
Ape Hole Creek, Pocomoke Sound	0.691	0.701
Shelltown	0.748	0.731
Pocomoke City	0.497	0.487
Snowhill, City Park	0.540	0.579

Table A-2: Estimated mean flows of subwatersheds in the Pocomoke River

Subwatershed	Flow (cms)
1	5.17
2	1.93
3	0.42
4	1.58
5	0.43
6	0.30
7	0.68
8	0.28
9	0.19
10	0.32
11	0.23
12	0.09
13	1.01
14	0.23
15	0.36
16	0.65
17	0.33
18	0.40
19	0.23
20	0.19

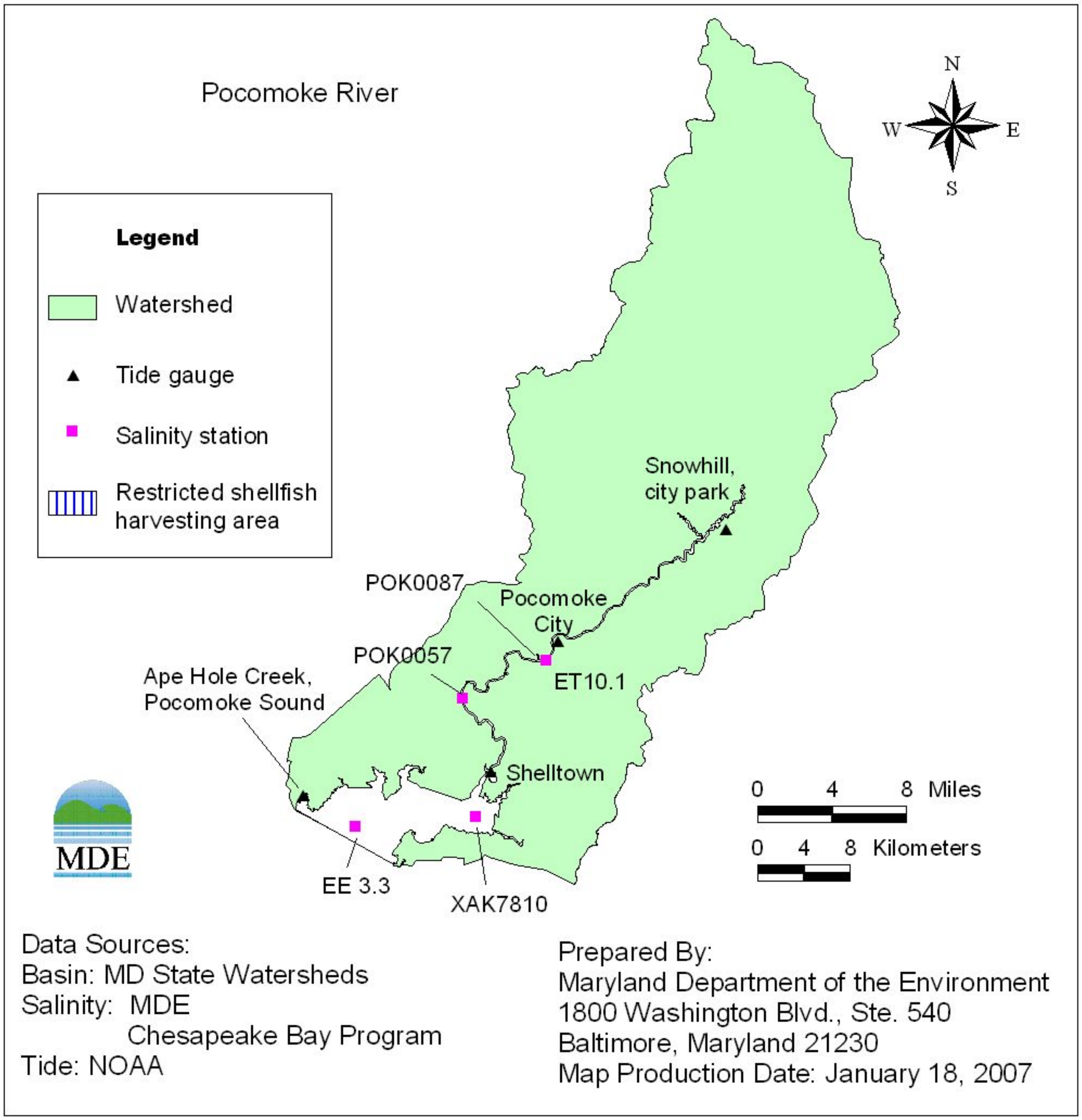

Figure A-2: Tide and salinity stations of the Pocomoke River used in model calibration

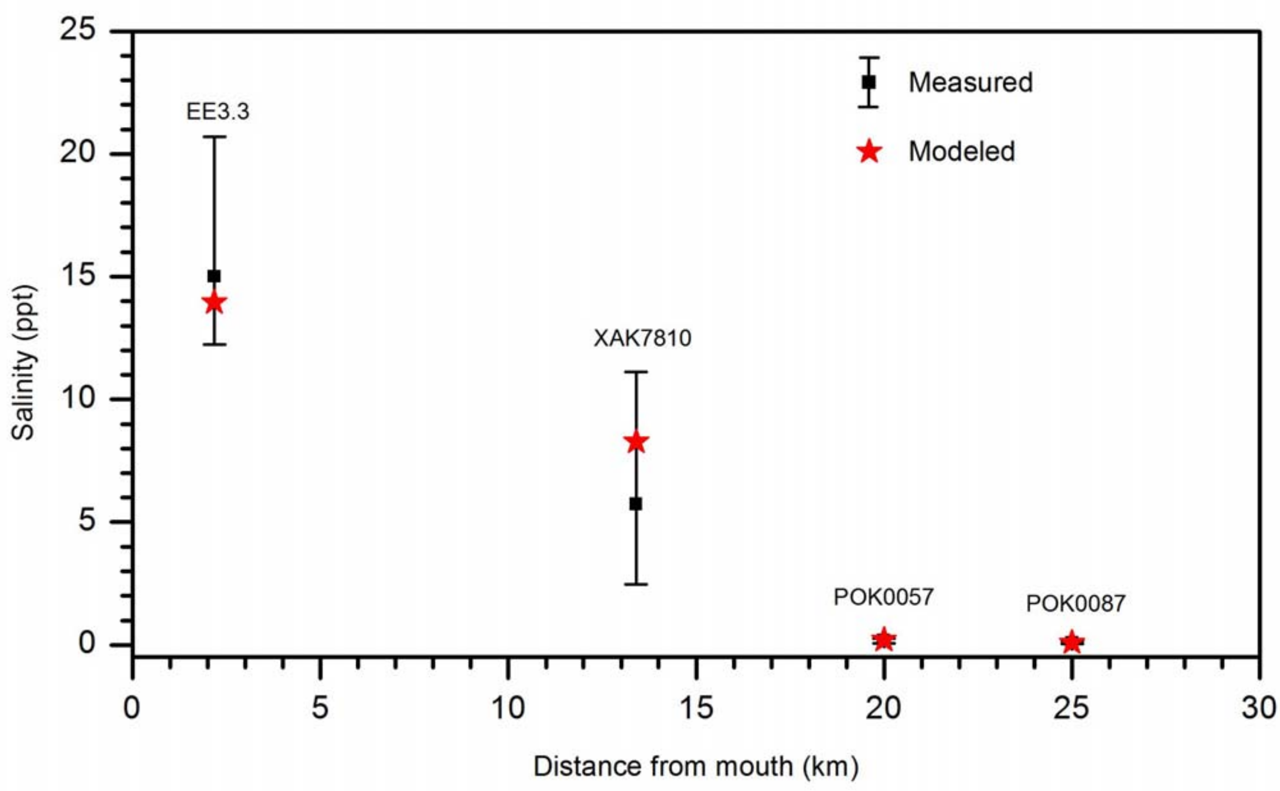

Figure A-3: Comparison of measured and calculated salinities

The problem of loads estimation can be treated as an inverse problem: to find a set of loads such that a defined goal function (or cost function), which measures the data misfit between the model predictions and the observations, becomes minimal. It can be presented as follows:

$$J(\mathbf{C};\boldsymbol{\beta}^*) = \min J(\mathbf{C};\boldsymbol{\beta}) \quad (1)$$

subject to:

$$\boldsymbol{\beta}^* \in \boldsymbol{\beta}_0 \quad (2)$$

$$\mathbf{F} = 0 \quad (3)$$

where $\boldsymbol{J}$ is a goal or cost function; $\boldsymbol{\beta}^* = (\beta_1, \beta_2, \ldots, \beta_m)$ is the optimal parameter (*i.e.*, loads); $\boldsymbol{\beta_0}$ is an acceptable set of loads. **F** is transport function. Different methods can be used to characterize the noninferior solutions. Choosing a weighted least-square criterion to measure the data misfit, the scalar cost function is then defined as follows:

$$J(\mathbf{C};\boldsymbol{\beta}) = \int_{T_N} \iint_{\Omega} \frac{w}{2}(C(x,z,t) - C^0(x,z,t))^2 d\Omega dt \qquad (4)$$

where C and C^0 are modeled and measured fecal coliform in the river, Ω is the spatial domain in the x- and z- directions, T_N is time later than the last date when the prototype observations are available, and w is the weight. In our case, let $C^0_m(x)$ be the median or 90th percentile obtained from the observations at location (x). If we choose:

$$C_m(x) = \max(C(x,z,t)) \qquad for \quad T_0 < t < T_N \qquad (5)$$

Equation (4) can be written as:

$$J(\mathbf{C};\boldsymbol{\beta}) = \int_X \frac{w}{2}(C_m(x,t) - C^0_m(x))^2 dx \qquad (6)$$

The algorithm can be constructed as a sequence of the unconstrained minimization problem. Many authors have studied the solution of the optimization problem extensively. Several different methods can be used to solve the problem including the Gradient method, Conjugate direction method, and the Variational method (Bertsekas 1995). For this study, the modified Newton method was used to solve the optimization problem (Shen 2006).

The fecal coliform loads discharged to the river consist of 20 subwatersheds, as shown in Figure A-1. For estimating existing median loads, the model was forced by an M_2 tide and mean salinity at the mouth. The mean freshwater inflows from the subwatersheds are discharged into the river. A set of initial loads from 20 subwatersheds was estimated and discharged to the river. The initial loads are estimated based on the land use type and drainage sizes. The model was run for 60 days to reach equilibrium and the maximum concentration at the last day was used to calculate the cost function against the observed median, geo-mean, and 90th percentile values along the river. Pocomoke River mainstem fecal coliform monitoring stations are shown in Figure A-4, and the fecal coliform values from these stations are shown in Table A-3. The modified Newton method was used to update the loads until the cost function is minimum. For estimating the existing loads for 90th percentile, the same method was used except the existing 90th percentile concentrations were used to minimize the cost function.

Because the observational data are only available in the downstream portion of the river, it is not feasible to use data collected in this downstream region and in turn use the inverse model to estimate loads from subwatersheds adjacent to the upper portion of the Pocomoke River. An alternative approach using short-term measurements from upstream to establish loads from the upstream watershed was used. A monthly survey was conducted in the upstream region from September to November in 2005. The data analysis shows that the variation of the mean fecal coliform value is not significant along the river, which indicates that sources of fecal coliform are discharged into the river from subwatersheds along the river. The maximum concentration of fecal coliform along the upstream portion of the Pocomoke River is in the same range as the 90th percentile concentration in the restricted area. The short-term data were used to provide the estimated loading from upstream.

A portion of the watershed is located in Delaware. To evaluate the contribution of fecal coliform loading to the downstream restricted area, a model sensitivity run was conducted by discharging fecal coliform with a high concentration of 3000 MPN/100ml at the headwater. The fecal coliform along the river is shown in Figure A-8. It can be seen that the fecal coliform concentration reduces to less than 1 MPN at the upper boundary of the restricted area. This suggests that most of the fecal coliform is lost during the transport due to decay resulting in less contribution to the high fecal coliform concentration that is found in the restricted area. Therefore, no reduction is considered for the TMDL calculation for the subwatersheds well above the restricted area (subwatersehds 1 – 3 , 5 and 6 in Figure A-4).

Figures A-5 to A-7 show the model results of simulated median, geo-mean, and 90th percentile, respectively, along the river. Because the median and geo-mean fecal coliform concentrations are very close, the mean of median and geo-mean is not different statistically using t-test (α=0.05). Therefore, the estimated loads using the median or geo-mean values are equivalent and the median value was used to develop the Pocomoke TMDL. It can be seen that the model results are satisfactory with an R^2 value of 0.92 indicating that about 92 percent of variances can be described by model results. (Note that fecal coliform data at two adjacent stations can be very different at same model grid, while the model gave the same results because of the model grid resolution and watershed delineation). Some discrepancies between model results and observations can be expected. The existing loads for each subwatershed are listed in Table A-4.

For the TMDL calculation, both the existing median and 90th percentile loads were reduced so that the model simulated fecal coliform values along the river to meet both the median and 90th percentile criteria. The resultant loads are the allowable loads for the river. With the use of existing loads and TMDLs, the percentage reduction can be estimated. Comparing the reduction needed for both median and 90th percentile loads, the maximum reductions required for each subwatershed are used to establish the TMDLs. The existing and allowable loads are listed in Table A-4. Note that the current median and 90 percentile loads are used as allowable loads for some subwatersheds with no reduction needed.

The reductions required show that the 90th percentile scenario requires the largest reduction. Therefore, the reductions required to meet the 90th percentile represent the overall reductions required for the subwatersheds. The allowable loads and required reductions for the watershed are listed in Table A-5.

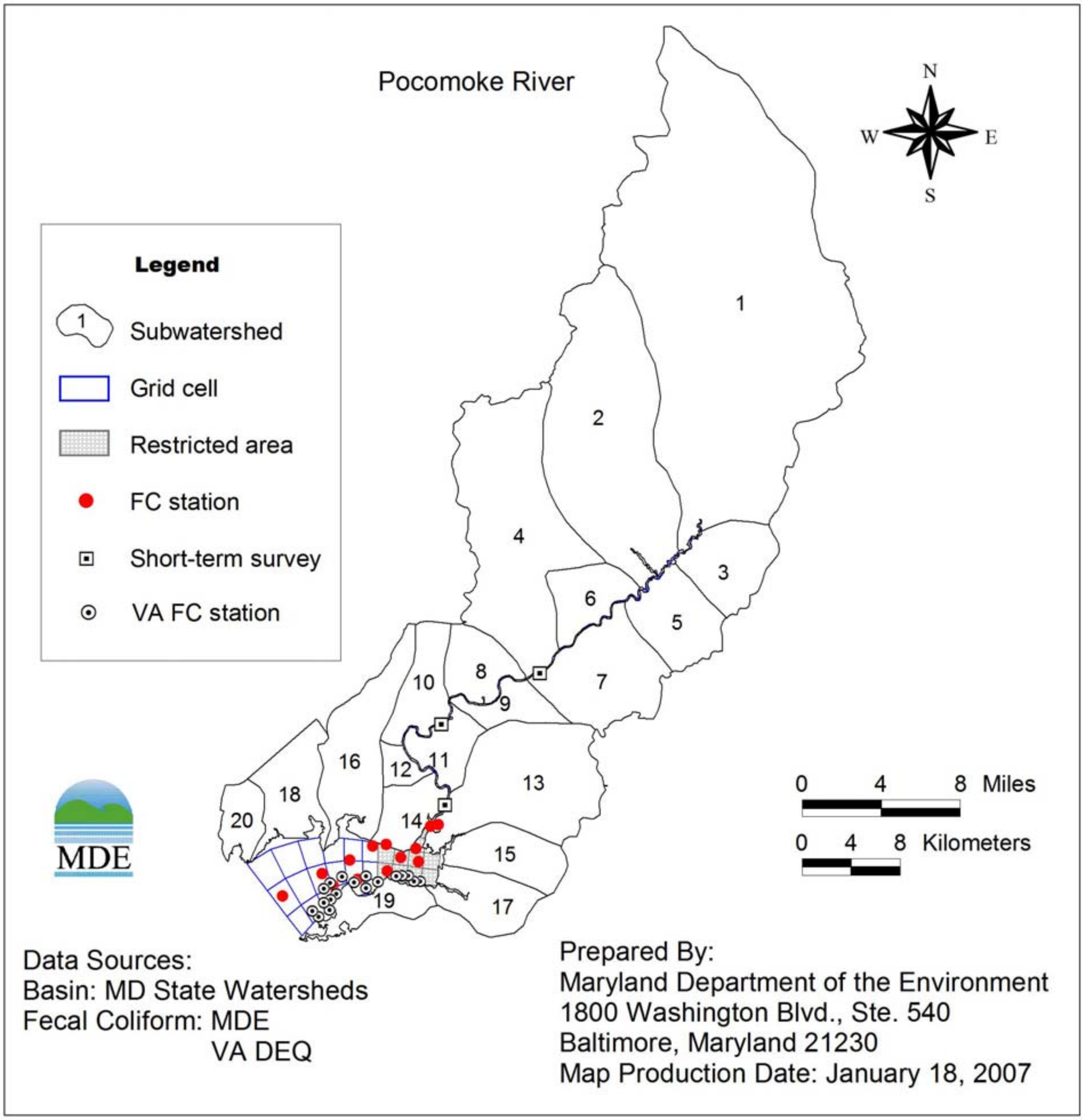

Figure A-4: Locations of Pocomoke River and Pocomoke Sound fecal coliform monitoring stations

Table A-3: Pocomoke River Fecal Coliform Statistics used by model (data from 2002-2005)

Area Name	Station	Median/Geo-mean			90th Percentile	
		Median	Geo-mean	Criterion	Monitoring Data	Criterion
		MPN/100ml		MPN/100ml	MPN/100ml	MPN/100ml
Pocomoke River	18-06-700	43.00	33.16	14	200.41	49
	18-07-010	93.00	113.92	14	575.01	49
	18-07-012	121.5	147.87	14	601.83	49
	18-07-014	93.00	97.38	14	558.05	49
	18-07-015	43.00	37.83	14	204.27	49
	18-07-111	23.00	17.34	14	117.30	49
Pocomoke River (outside of restricted area)	18-06-113	3.60	4.72	14	27.76	49
	18-06-201	19.00	15.10	14	74.01	49
	18-06-707	23.00	14.39	**14**	85.50	49
	18-06-701	1.00	1.98	14	6.27	49
	18-06-704	1.00	2.18	14	7.53	49
	18-06-705	1.00	2.00	14	7.78	49
	18-06-706	6.35	6.30	14	27.69	49
Pocomoke Sound (VA)	75-B1	3.25	6.49	14	27.04	49
	75-C3	2.90	3.54	14	7.27	49
	75-D4	2.90	4.15	14	10.47	49
	75-E5	3.30	5.20	14	16.83	49
	75-H7	3.60	6.62	14	30.51	49
	75-L7	5.40	8.38	14	35.47	49
	75-O8	19.00	20.14	14	96.20	**49**
	75-P8	23.00	22.26	14	94.81	**49**
	75-Q8	23.00	23.11	14	113.43	49
	75-R7	33.00	28.74	14	138.46	**49**
	75-S7	41.00	43.37	14	221.07	49

Table A-4: TMDL calculation results for Pocomoke River Mainstem

Subwatersheds	Median			90th Percentile		
	Allowable Load Counts/day	**Current Load Counts/day**	**Percent Reduction**	**Allowable Load Counts/day**	**Current Load Counts/day**	**Percent Reduction**
1-3,5-6 (MD)	1.101E+13	1.101E+13	0.00%	3.221E+13	3.221E+13	0.00%
4,7-12 (MD)	5.107E+12	8.617E+12	40.73%	1.880E+13	2.943E+13	36.11%
13a,15,17,19 (VA)	2.421E+12	5.831E+12	58.47%	1.040E+13	2.552E+13	59.23%
13b,14,16,18,20 (MD)	3.383E+12	9.832E+12	65.59%	1.395E+13	4.308E+13	67.61%
Total	**2.192E+13**	**3.529E+13**	**37.88%**	**7.536E+13**	**1.302E+14**	**42.13%**

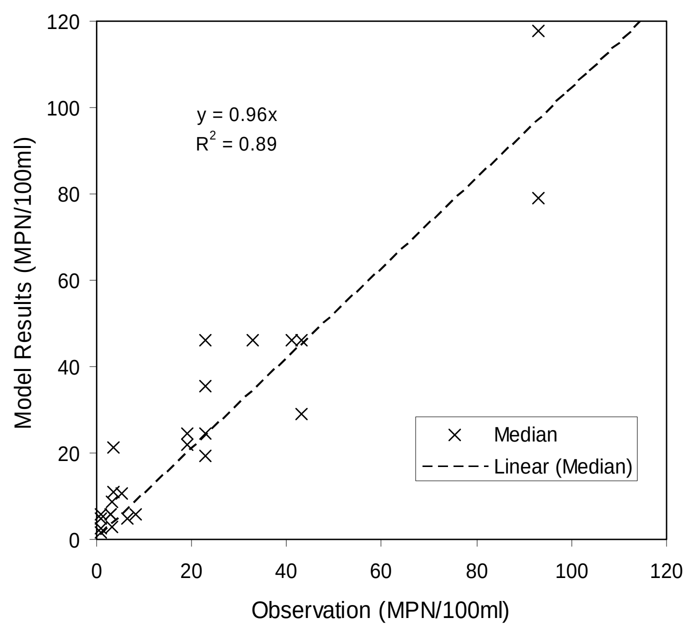

Figure A-5: Model results vs. observations for the median concentration

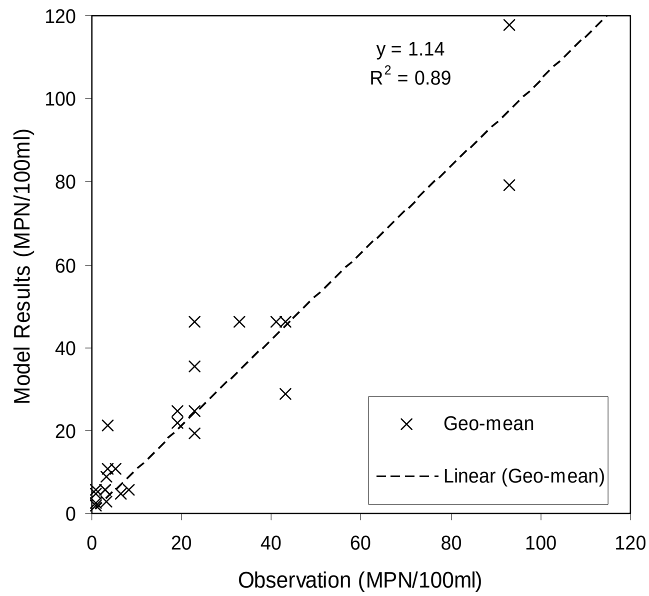

Figure A-6: Model results vs. observations for the geo-mean concentration

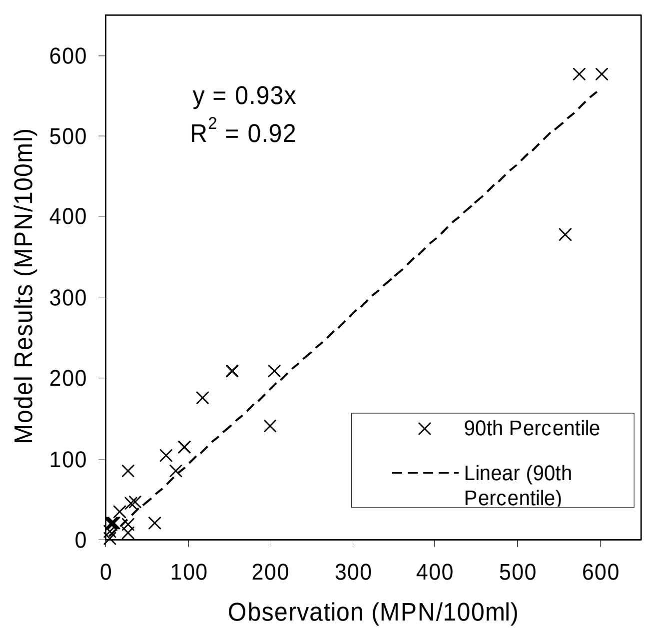

Figure A-7: Model results vs. observations for the 90th percentile concentration

Table A-5: Load allocation and reduction by subwatershed

Subwatershed	Load Allocation	Required Reduction
1-3,5-6	3.221E+13	0.00%
4,7-12	1.880E+13	36.11%
13a,15,17,19	1.040E+13	59.23%
13b,14,16,18,20	1.395E+13	67.61%
TOTALS	**7.536E+13**	**42.13%**

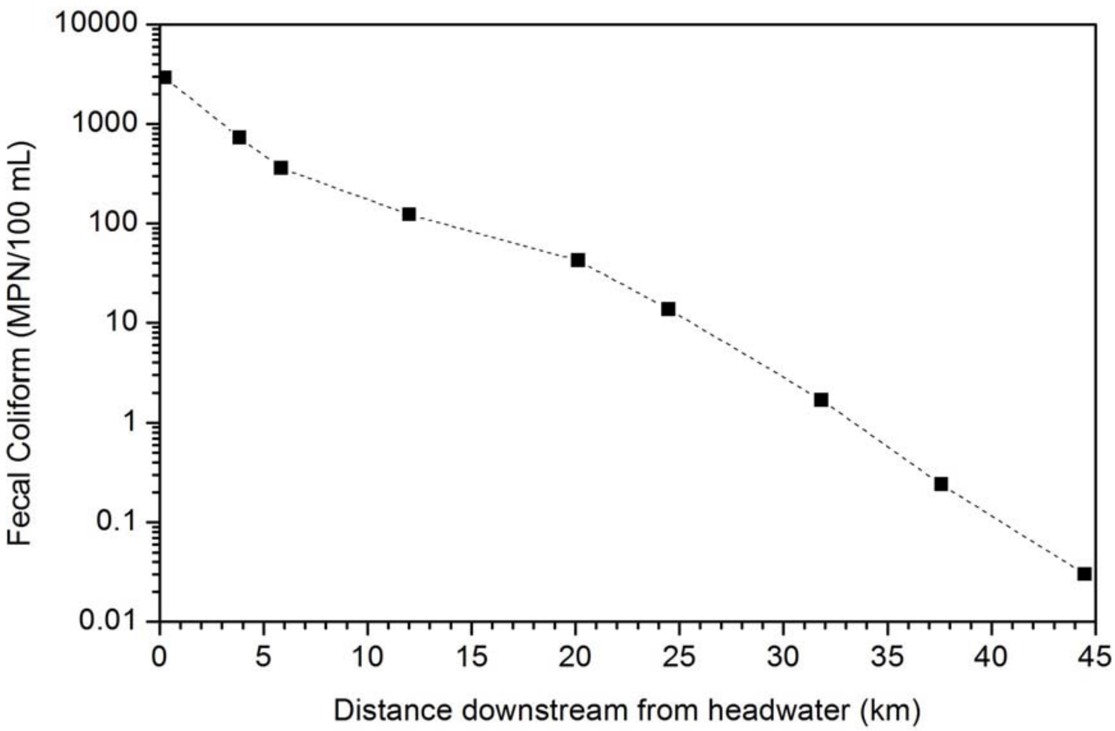

Figure A-8: Fecal coliform concentrations along Pocomoke River

(sensitivity test for SWSs 1-3, 5-6)

Appendix B. Bacteria Source Tracking

Nonpoint sources of fecal coliform do not have one discharge point and may occur over the entire length of a stream or waterbody. The possible introductions of fecal coliform bacteria to the land surface are through the manure spreading process, direct deposition from livestock during the grazing season, and excretions from pets and wildlife. As the runoff occurs during rain events, surface runoff transports water and fecal coliform over the land surface to surface waters. Nonpoint source contributions to the bacteria levels from human activities generally arise from failing septic systems from recreation vessel discharges. The transport of fecal coliform from land surface to shellfish harvesting areas is dictated by the hydrology, soil type, land use, and topography of the watershed.

In order to determine the significant sources of fecal coliform and reduction needed to achieve water quality criteria among these sources, it is necessary to identify all existing sources. The nonpoint source assessment was conducted using the fecal coliform monitoring data (provided by MDE Shellfish Certification Programs) and bacteria source tracking analysis to quantify source loadings from humans, livestock, pets, and wildlife.

Bacteria Source Tracking

In order to assess the potential fecal bacteria sources that contribute to the Pocomoke River, eight stations in the Pocomoke River were selected to evaluate the source characterization through a process called Bacteria Source Tracking (BST), seven in MD and one in VA. BST is used to provide evidence regarding contributions from anthropogenic sources (*i.e.*, human or livestock) as well as background sources, such as wildlife. Maryland sampling was conducted over a twelve-month period from November 2005 through October 2006. Antibiotic Resistance Analysis (ARA) was used to determine the potential sources of fecal coliform in the Pocomoke River. ARA uses enterococci or *Escherichia coli* (*E. coli*) and patterns of antibiotic resistance to identify sources. The premise is that the antibiotic resistance of bacteria isolated from different hosts can be discerned based upon differences in the selective pressure of microbial populations found in the gastrointestinal tract of those hosts (humans, livestock, pets, wildlife) (Wiggins 1996). (Bacteria isolated from the fecal material of wildlife would be expected to have a much lower level of resistance to antibiotics than bacteria isolates collected from the fecal material of humans, livestock, and pets). In addition, depending upon the specific antibiotics used in the analysis, isolates from humans, livestock and pets could be differentiated from each other.

In ARA, isolates from known sources are tested for resistance or sensitivity against a panel of antibiotics and antibiotic concentrations. This information is then used to construct a library of antibiotic resistance patterns from known-source bacterial isolates. Bacterial isolates collected from water samples are then tested and their resistance results are recorded. Based upon a comparison of resistance patterns of water and known library isolates, a statistical analysis can predict the likely host source of the water isolates (Hagedorn 1999; Wiggins 1999).

A tree classification method, [1]CART®, was applied to build a model that classifies isolates into source categories based on ARA data. CART® builds a classification tree by recursively splitting the library of isolates into two nodes. Each split is determined by the antibiotic variables (antibiotic resistance measured for a collection of antibiotics at varying concentrations). The first step in the tree-building process splits the library into two nodes by considering every binary split associated with every variable. The split is chosen in order to maximize a specified index of homogeneity for isolate sources within each of the nodes. In subsequent steps, the same process is applied to each resulting node until a *stopping* criterion is satisfied. Nodes where an additional split would lead to only an insignificant increase in the *homogeneity index* relative to the *stopping* criterion are referred to as *terminal* nodes.[2] The collection of *terminal* nodes defines the classification model. Each *terminal* node is associated with one source, the source that is most populous among the library isolates in the node. Each water sample isolate (*i.e.*, an isolate with an unknown source), based on its antibiotic resistance pattern, is identified with one specific *terminal* node and is assigned the source of the majority of library isolates in that *terminal* node.[3] The full BST report for the Pocomoke River basin is located in Frana and Venso (2005) Appendix B.

Results

Water samples were collected monthly from the seven (7) stations in the Pocomoke River by MDE. If weather conditions prevented sampling at a station, a second collection(s) in a later month was performed. The maximum number of enterococci isolates per water sample was 24, although the number of isolates that actually grew was sometimes fewer than 24. A total of 1325 enterococci isolates were analyzed by statistical analysis. Tables B-1 and B-3 below shows the ARA results by category, the number of isolates and percent isolates classified at the 0.50 (50%) cutoff probability, as well as the percent classified overall. The seasonal distribution of water isolates from samples collected at each sampling station is shown below in Table B-2. According to the ARA, wildlife is the predominant bacteria source followed by livestock. Thirty-four percent (34%) of the water isolates were from unknown (unclassified) probable sources.

---

1 The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Hastie T, Tibshirani R, and Friedman J. Springer 2001.

2 An ideal split, i.e., a split that achieves the theoretical maximum for homogeneity, would produce two nodes each containing library isolates from only one source.

3 The CART® tree-classification method we employed includes various features to ensure the development of an optimal classification model. For brevity in exposition, we have chosen not to present details of those features, but suggest the following sources: Breiman L, et al. *Classification and Regression Trees*. Pacific Grove: Wadsworth, 1984; and Steinberg D and Colla P. *CART—Classification and Regression Trees.* San Diego, CA: Salford Systems, 1997.

Table B-1: Probable Host Sources of Water Isolates by Category, Number of Isolates, Percent Isolates Classified at Cutoff Probabilities of 50%

Category	No.	% Isolates Classified 50% Prob.
Pet	73	5.5%
Human	153	11.5%
Livestock	472	35.6%
Wildlife	173	13.1%
*Unknown	454	34.3%
Missing Data	0	
Total w/ Complete Data	1325	
Total	1325	
% Classified		100.0%

* Unknown means that the library of known sources failed to classify for isolates from water samples collected

Table B-2: Number of Enterococci Isolates from Water Collected and Analyzed by Season

Station	Spring	Summer	Fall	Winter	Total
18-06-201	4	47	31	51	133
18-06-700	3	51	27	45	126
18-07-111	6	50	44	61	161
18-07-014	24	60	72	72	228
18-07-015	5	51	59	72	187
18-07-012	33	62	72	72	239
18-07-010	30	71	70	71	242
18-06-012	6	0	0	0	6
18-06-011	3	0	0	0	3
Total	114	392	375	444	1,325

Virginia BST data analysis results were obtained from one station. The source distribution is listed in Table B-4. The results show that the dominant source is wildlife. Since data collected by Maryland and Virginia are from different locations and from different years, a difference in BST analysis results can be expected given the variation of fecal coliform sources. Figure B-1 shows the monthly BST data analysis results. It can be seen that the fecal coliform sources vary monthly and vary at different stations. By combining both Maryland and Virginia data excluding water isolates from unidentified sources, a weighted average source contribution can be estimated which is listed in Table B-5. The predominant bacteria source is from wildlife (34%) followed by livestock (29%), pet (19%), and human (17%) sources.

Table B-3: Source Distribution Based on BST Data Analysis (MDE)

Human	Livestock	Wildlife	Pets	Unknown
11.5%	35.6%	13.1%	5.5%	34.3%
*17.6%	*54.2%	*19.9%	*8.4%	

*Percent exclude unknown sources

Table B-4: Source Distribution Based on BST Data Analysis (VA-DEQ)

Human	Livestock	Wildlife	Pets	Unknown
17.1%	4.0%	48.4%	30.4%	N/A

Table B-5: Averaged Source Distribution Based on MDE and VA-DEQ BST Data Analysis (Exclude unknown category in MDE's BST Data)

Human	Livestock	Wildlife	Pets	Unknown
17.4%	29.0%	34.2%	19.4%	N/A

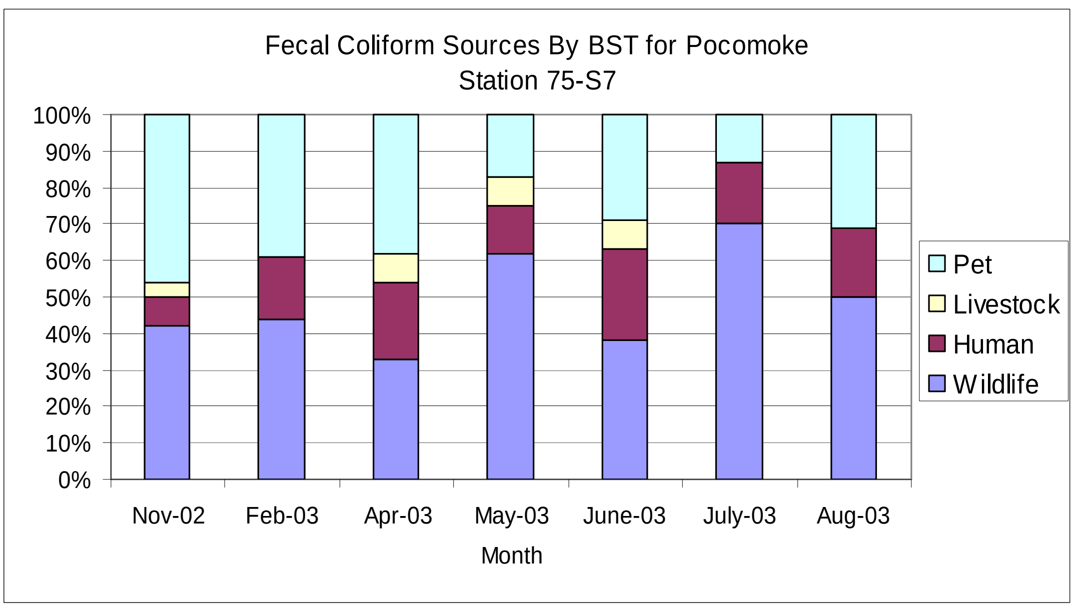

Figure B-1: Monthly Distribution of BST Data Analysis Results at Virginia Stations.

Appendix C. Seasonality Analysis

The Code of Federal Regulations requires that TMDL studies take into account critical conditions for stream flow, loading, and water quality parameters (CFR 2006C). The EPA also requires that these TMDL studies take into account seasonal variations. The consideration of critical condition and seasonal variation is to account for the hydrologic and source variations. The intent of the requirements is to ensure that the water quality of the water body is protected during the most vulnerable times.

In the Chesapeake Bay region, both fecal coliform sources and delivery vary seasonally due to wildlife activity, changes of hydrological conditions, and land use practices. The most probable fecal coliform sources result from runoff from agricultural practices and livestock, wildlife, and developed areas. Precipitation and temperature fluctuate seasonally, producing varied stream flow and surface runoff that serve as a delivery mechanism for fecal coliform, as well as seasonal change in vegetation. Vegetation, particularly in pastureland and agriculture buffer zones, is very important for trapping and preventing fecal coliform from entering waters by decreasing surface runoff. Wildlife are active during summer and fall due to ample food supply, resulting in large sources of fecal coliform, and the probability of their direct contact with receiving waters is comparatively high during warm seasons. The seasonal variation of fecal coliform concentration in water not only results from activities of wildlife on forestland and wetland, but also is related to agricultural activities. Fecal coliform deposition on the field by livestock can be transported into streams and rivers through surface runoff, and thus tends to increase fecal coliform concentrations during wet seasons. In croplands, fecal coliform discharge is often related to the timing of crop planting and fertilization. Improper manure application during crop planting may increase the risk of exceeding fecal coliform standards in the receiving water. Such seasonal changes in both the sources and the delivery mechanisms perhaps lead to obvious seasonal patterns for receiving water fecal coliform concentration in the shellfish growing area.

The three-year monthly mean fecal coliform concentration and its standard deviation were calculated for the six monitoring stations in MD and five stations in VA used in this report. The results are presented in Figures C-1 through C-11. Although seasonal distributions vary from one station to the others, a large standard deviation that corresponds to the high fecal coliform variability at each station suggests that the violation in regards to the criteria may occur in a few months of the year.

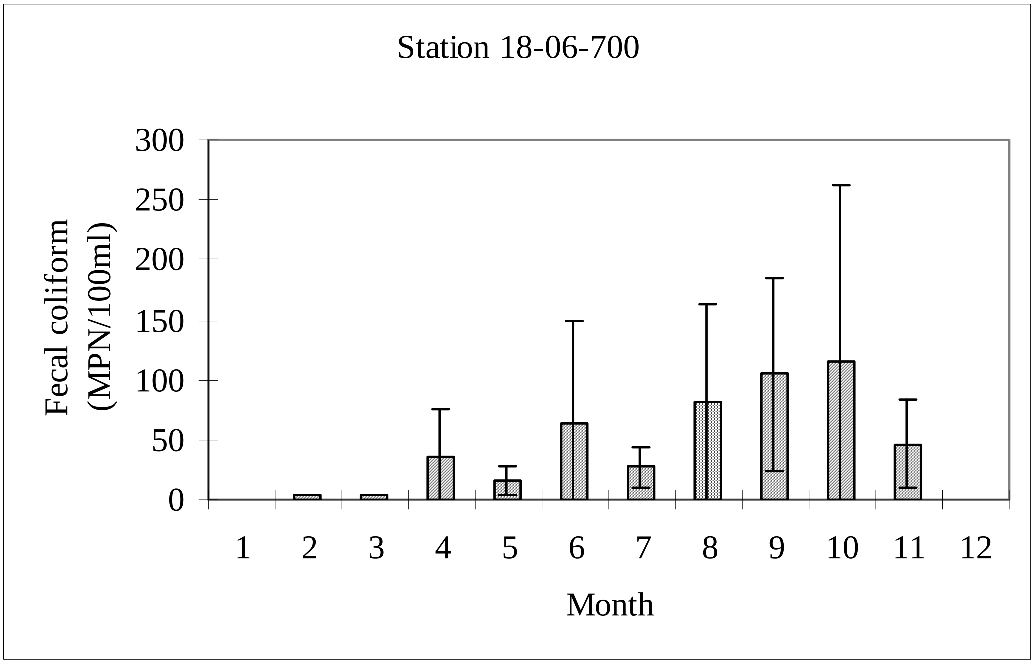

Figure C-1: Seasonality analysis of fecal coliform at Pocomoke Sound Station 18-06-700 (MD)

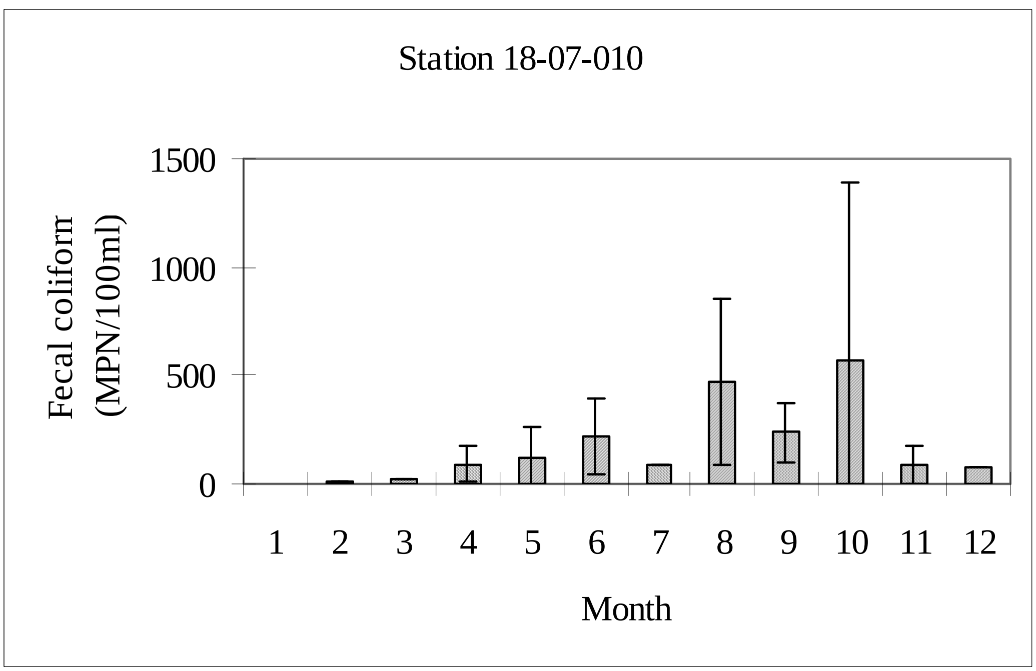

Figure C-2: Seasonality analysis of fecal coliform at Pocomoke Sound Station 18-07-010 (MD)

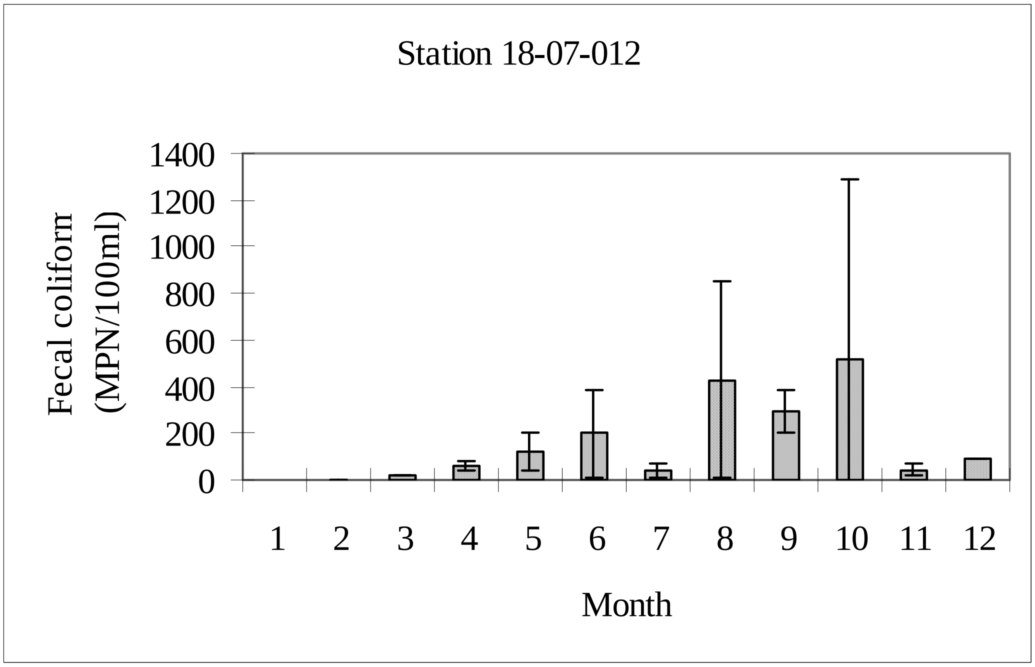

Figure C-3: Seasonality analysis of fecal coliform at Pocomoke River Station 18-07-012 (MD)

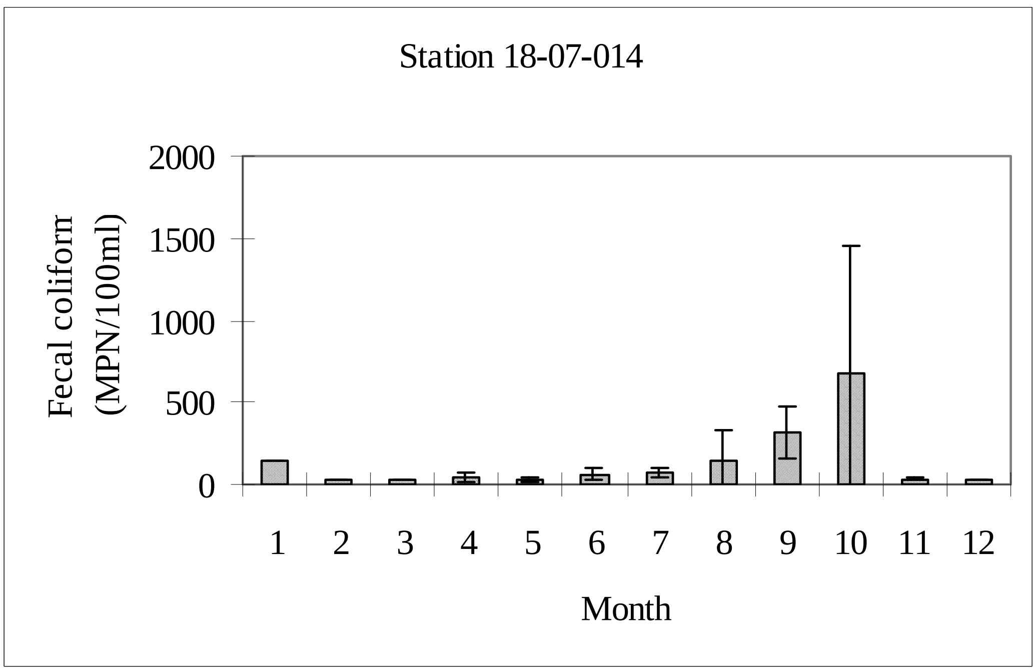

Figure C-4: Seasonality analysis of fecal coliform at Pocomoke River Station 18-07-014 (MD)

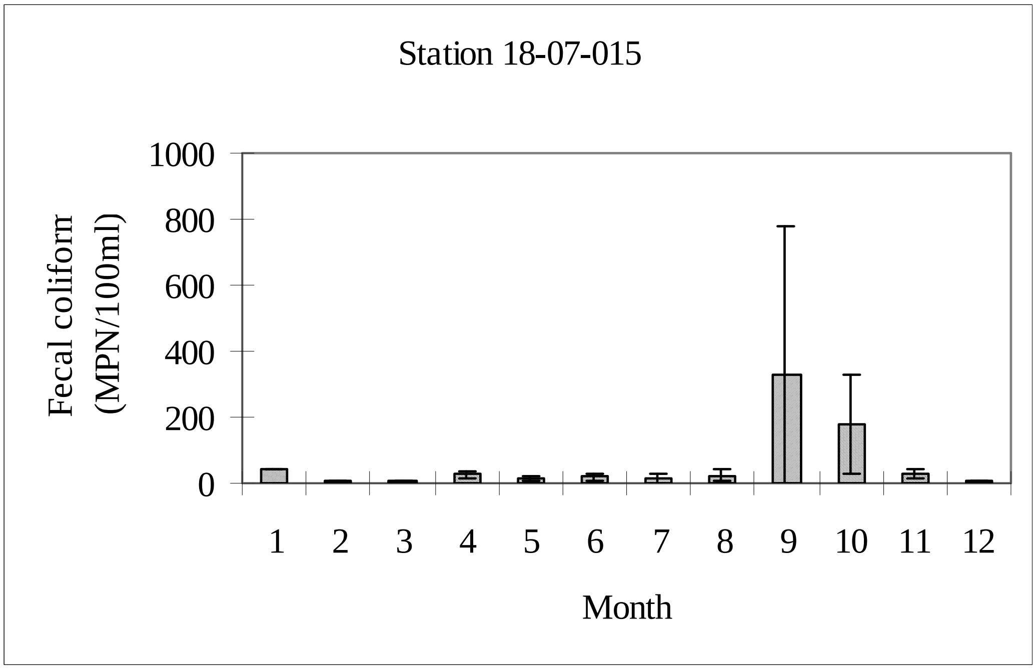

Figure C-5: Seasonality analysis of fecal coliform at Pocomoke River Station 18-07-015 (MD)

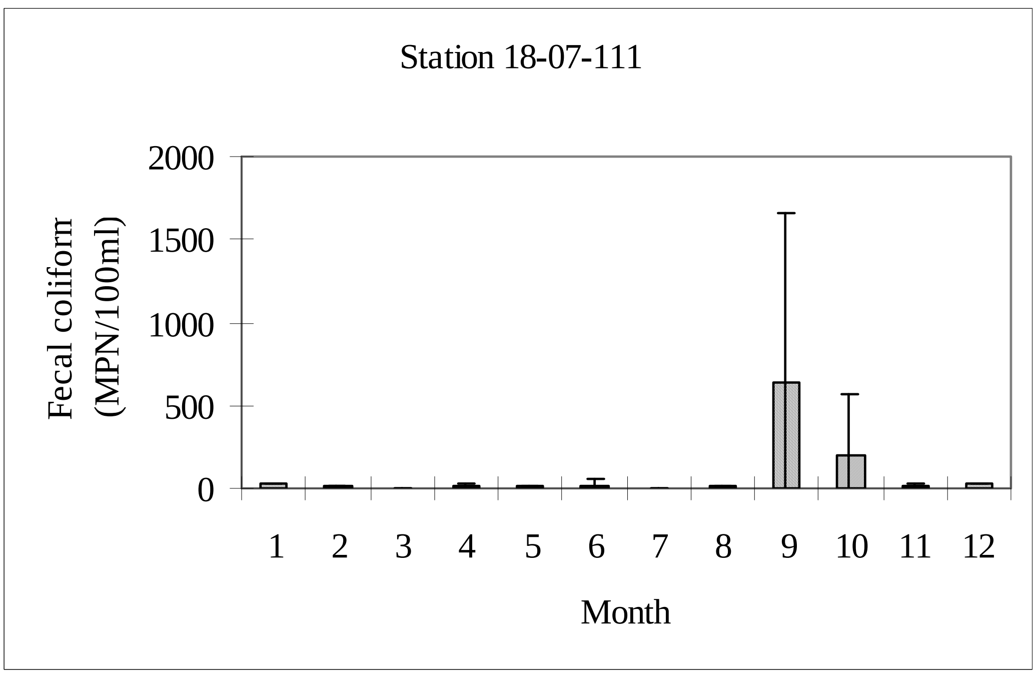

Figure C-6: Seasonality analysis of fecal coliform at Pocomoke River Station 18-07-111 (MD)

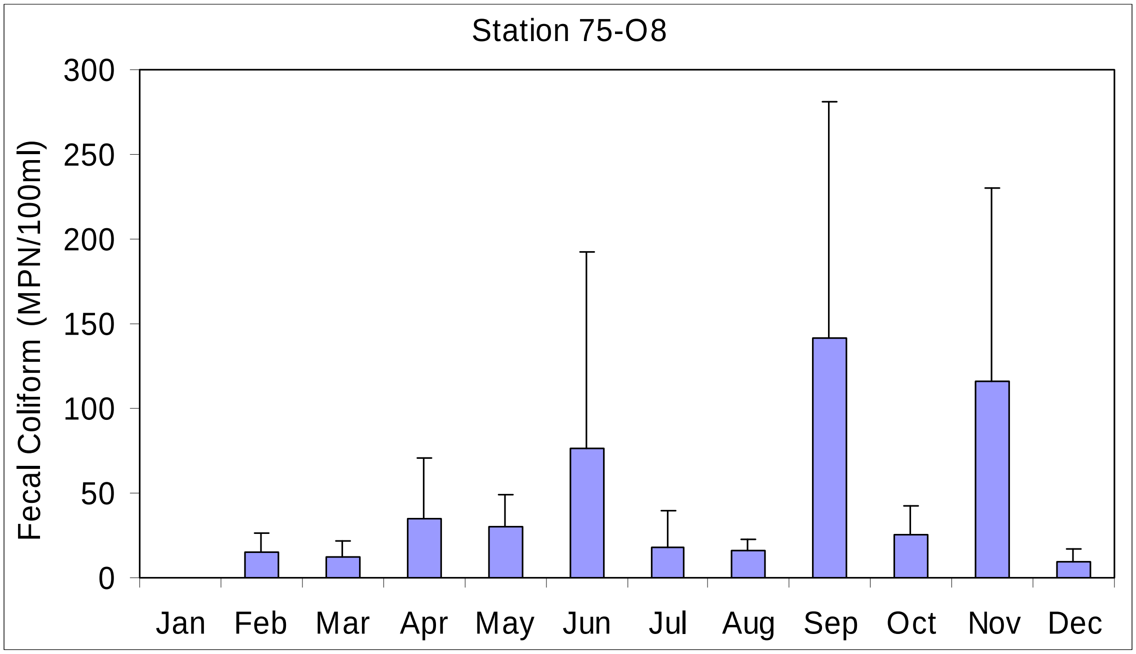

Figure C-7: Seasonality analysis of fecal coliform at Pocomoke River Station 75-08 (VA)

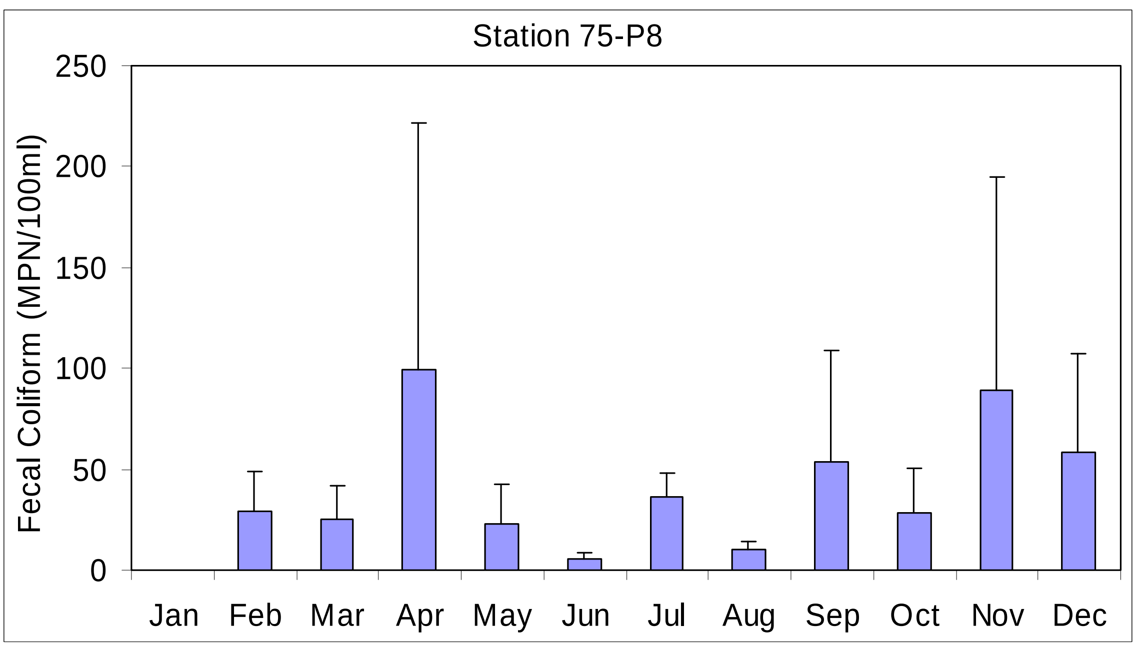

Figure C-8: Seasonality analysis of fecal coliform at Pocomoke River Station 75-P8 (VA)

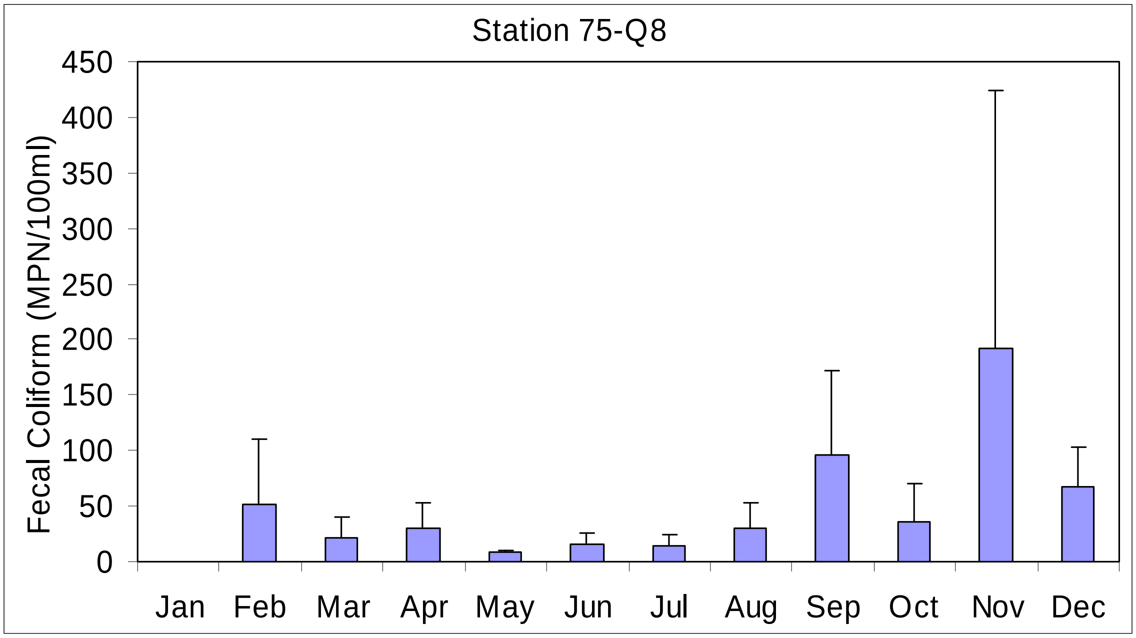

Figure C-9: Seasonality analysis of fecal coliform at Pocomoke River Station 75-Q8 (VA)

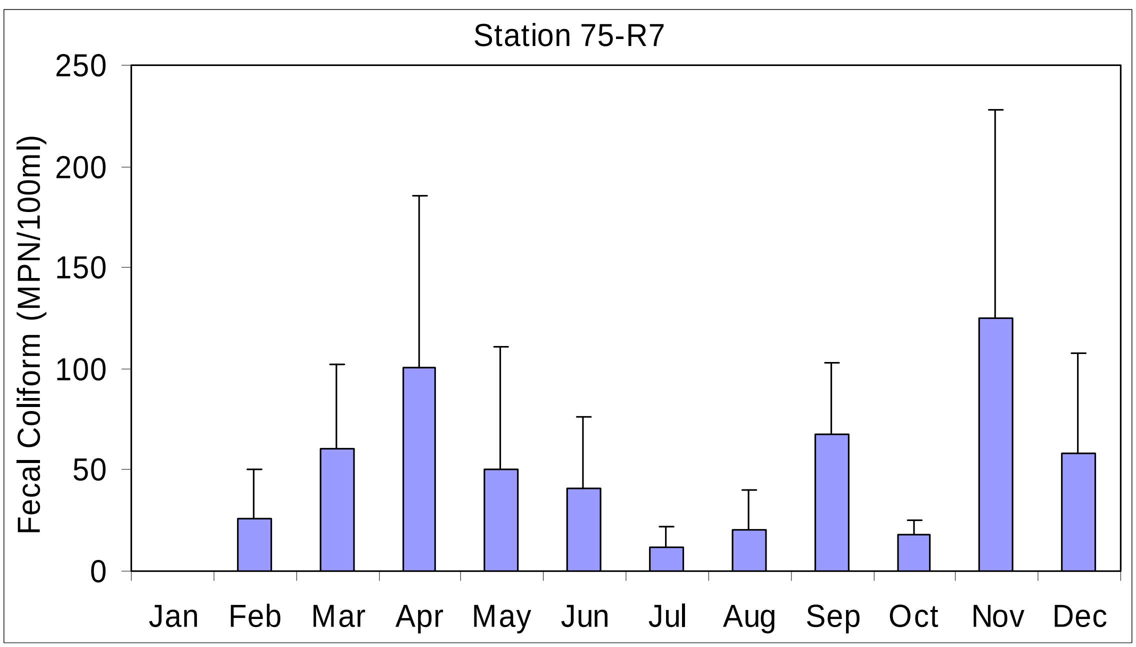

Figure C-10: Seasonality analysis of fecal coliform at Pocomoke River Station 75-R8 (VA)

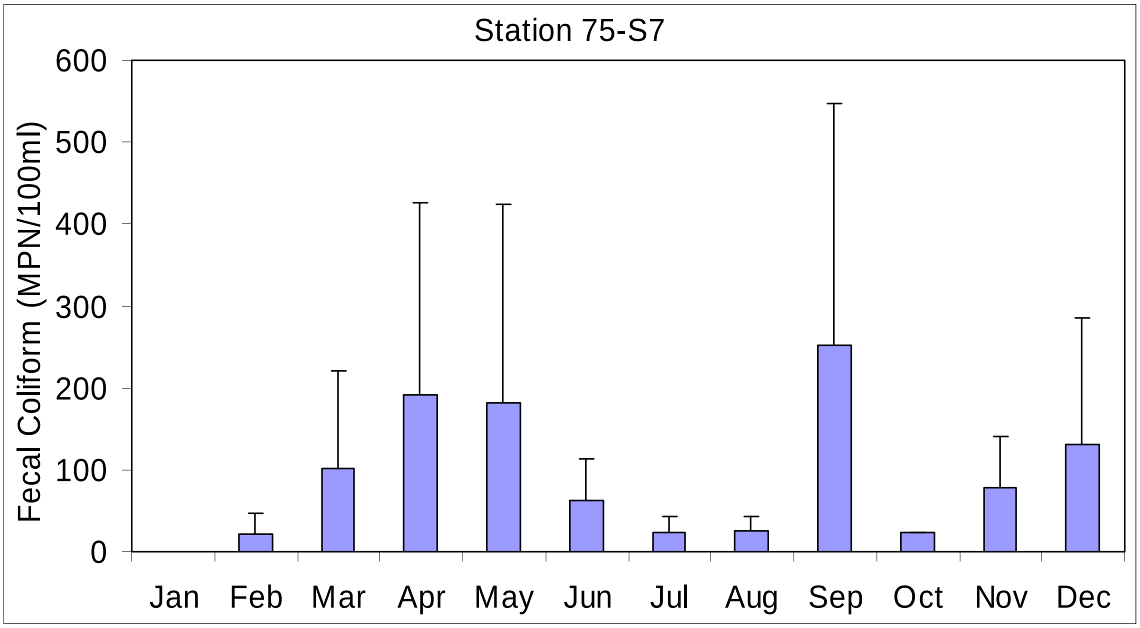

Figure C-11: Seasonality analysis of fecal coliform at Pocomoke River Station 75-S7 (VA)

Appendix D. Tabulation of Fecal Coliform Data

This appendix provides a tabulation of fecal coliform values for the monitoring stations of the Pocomoke River and Pocomoke River Sound in Tables D-1 through D-18. These data are plotted in report Figures 2.2.3 through 2.2.20 of the main report.

Table D-1: Observed Fecal Coliform data at Pocomoke Sound Station 18-06-700

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
05-Sep-02	93	27-Oct-04	150
07-Oct-02	460	20-Apr-05	3.6
25-Nov-02	43	18-May-05	3.6
21-Apr-03	93	05-Jul-05	93
07-May-03	9.1	02-Aug-05	43
29-May-03	9.1	23-Aug-05	23
05-Jun-03	1	08-Sep-05	23
30-Jun-03	93	13-Sep-05	23
08-Jul-03	43	27-Sep-05	240
06-Aug-03	240	04-Oct-05	43
09-Sep-03	43	19-Oct-05	93
02-Oct-03	9.1	21-Nov-05	43
20-Oct-03	23	28-Nov-05	43
10-May-04	14	13-Dec-05	3.6
13-Oct-04	93	20-Dec-05	43

Table D-2: Observed Fecal Coliform data at Pocomoke River Station 18-07-010

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
05-Sep-02	460	27-Oct-04	75
07-Oct-02	1100	13-Apr-05	43
25-Nov-02	23	20-Apr-05	240
04-Dec-02	75	18-May-05	15
21-Apr-03	43	05-Jul-05	460
07-May-03	43	02-Aug-05	240
29-May-03	23	23-Aug-05	93
05-Jun-03	43	08-Sep-05	150
30-Jun-03	93	13-Sep-05	93
08-Jul-03	93	27-Sep-05	2400
06-Aug-03	460	04-Oct-05	93
09-Sep-03	93	19-Oct-05	43
02-Oct-03	93	21-Nov-05	93
20-Oct-03	150	28-Nov-05	43
10-May-04	23	13-Dec-05	240
13-Oct-04	2400	20-Dec-05	93

Table D-3: Observed Fecal Coliform data at Pocomoke River Station 18-07-012

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
05-Sep-02	240	27-Oct-04	240
07-Oct-02	240	13-Apr-05	43
25-Nov-02	93	20-Apr-05	75
04-Dec-02	93	18-May-05	43
21-Apr-03	93	05-Jul-05	93
07-May-03	43	02-Aug-05	460
29-May-03	43	23-Aug-05	1100
05-Jun-03	43	08-Sep-05	240
30-Jun-03	460	13-Sep-05	93
08-Jul-03	43	27-Sep-05	460
06-Aug-03	1100	04-Oct-05	150
09-Sep-03	240	19-Oct-05	240
02-Oct-03	240	21-Nov-05	43
20-Oct-03	240	28-Nov-05	93
10-May-04	240	13-Dec-05	43
13-Oct-04	2400	20-Dec-05	43

Table D-4: Observed Fecal Coliform data at Pocomoke River Station 18-07-014

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
05-Sep-02	93	27-Oct-04	460
07-Oct-02	1100	13-Apr-05	93
25-Nov-02	23	20-Apr-05	23
04-Dec-02	23	18-May-05	43
21-Apr-03	23	05-Jul-05	240
07-May-03	43	02-Aug-05	240
29-May-03	21	23-Aug-05	240
05-Jun-03	43	08-Sep-05	150
30-Jun-03	93	13-Sep-05	23
08-Jul-03	93	27-Sep-05	2400
06-Aug-03	43	04-Oct-05	93
09-Sep-03	240	19-Oct-05	240
02-Oct-03	460	21-Nov-05	43
20-Oct-03	23	28-Nov-05	23
20-Jan-04	150	13-Dec-05	43
10-May-04	23	20-Dec-05	240
13-Oct-04	2400		

Table D-5: Observed Fecal Coliform data at Pocomoke River Station 18-07-015

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
05-Sep-02	150	27-Oct-04	240
07-Oct-02	460	13-Apr-05	43
25-Nov-02	43	20-Apr-05	23
04-Dec-02	9.1	18-May-05	3.6
21-Apr-03	15	05-Jul-05	23
07-May-03	7.3	02-Aug-05	43
29-May-03	23	23-Aug-05	43
05-Jun-03	9.1	08-Sep-05	240
30-Jun-03	23	13-Sep-05	3.6
08-Jul-03	43	27-Sep-05	460
06-Aug-03	9.1	04-Oct-05	75
09-Sep-03	23	19-Oct-05	93
02-Oct-03	23	21-Nov-05	7.5
20-Oct-03	240	28-Nov-05	23
20-Jan-04	43	13-Dec-05	93
10-May-04	23	20-Dec-05	43
13-Oct-04	240		

Table D-6: Observed Fecal Coliform data at Pocomoke River Station 18-07-111

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
05-Sep-02	43	27-Oct-04	93
07-Oct-02	1100	13-Apr-05	9.1
25-Nov-02	43	20-Apr-05	9.1
04-Dec-02	23	18-May-05	1
21-Apr-03	43	05-Jul-05	23
07-May-03	23	02-Aug-05	7.3
29-May-03	3.6	23-Aug-05	23
05-Jun-03	9.1	08-Sep-05	43
30-Jun-03	1	13-Sep-05	3.6
08-Jul-03	1	27-Sep-05	23
06-Aug-03	1	04-Oct-05	9.1
09-Sep-03	43	19-Oct-05	43
02-Oct-03	43	21-Nov-05	43
20-Oct-03	75	28-Nov-05	23
20-Jan-04	23	13-Dec-05	23
10-May-04	9.1	20-Dec-05	43
13-Oct-04	43		

Table D-7: Observed Fecal Coliform data at Pocomoke Sound Station 75-B1

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
11/12/2002	2.9	7/27/2004	43
2/24/2003	2.9	8/26/2004	2.9
3/11/2003	2.9	9/30/2004	43
4/9/2003	23	10/21/2004	43
5/7/2003	3.6	12/7/2004	2.9
6/19/2003	43	2/17/2005	2.9
7/21/2003	11	3/17/2005	2.9
8/4/2003	3.6	4/5/2005	23
9/3/2003	2.9	5/17/2005	2.9
10/20/2003	2.9	6/20/2005	43
11/3/2003	3.6	7/5/2005	2.9
3/17/2004	2.9	8/1/2005	23
4/27/2004	23	10/31/2005	2.9
5/19/2004	3.6	11/14/2005	3.6
6/16/2004	2.9	12/12/2005	2.9

Table D-8: Observed Fecal Coliform data at Pocomoke Sound Station 75-C3

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
11/12/2002	2.9	7/27/2004	23
2/24/2003	2.9	8/26/2004	2.9
3/11/2003	2.9	9/30/2004	9.1
4/9/2003	3.6	10/21/2004	2.9
5/7/2003	2.9	12/7/2004	2.9
6/19/2003	7.3	2/17/2005	2.9
7/21/2003	2.9	3/17/2005	1
8/4/2003	2.9	4/5/2005	9.1
9/3/2003	2.9	5/17/2005	2.9
10/20/2003	2.9	6/20/2005	2.9
11/3/2003	3.6	7/5/2005	2.9
3/17/2004	2.9	8/1/2005	3.6
4/27/2004	2.9	10/31/2005	2.9
5/19/2004	9.1	11/14/2005	2.9
6/16/2004	2.9	12/12/2005	2.9

Table D-9: Observed Fecal Coliform data at Starling Creek Station 75-D2

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
11/12/2002	9.1	7/27/2004	93
2/24/2003	9.1	8/26/2004	3.6
3/11/2003	2.9	9/30/2004	43
4/9/2003	64	10/21/2004	9.1
5/7/2003	7.3	12/7/2004	2.9
6/19/2003	43	2/17/2005	2.9
7/21/2003	23	3/17/2005	2.9
8/4/2003	240	4/5/2005	14
9/3/2003	3.6	5/17/2005	39
10/20/2003	9.1	6/20/2005	75
11/3/2003	3.6	7/5/2005	2.9
3/17/2004	7.3	8/1/2005	120
4/27/2004	9.1	10/31/2005	3.6
5/19/2004	2.9	11/14/2005	7.3
6/16/2004	3.6	12/12/2005	3.6

Table D-10: Observed Fecal Coliform data at Pocomoke Sound Station 75-D4

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
11/12/2002	3.6	7/27/2004	9.1
2/24/2003	7.3	8/26/2004	2.9
3/11/2003	2.9	9/30/2004	2.9
4/9/2003	9.1	10/21/2004	2.9
5/7/2003	2.9	12/7/2004	2.9
6/19/2003	43	2/17/2005	2.9
7/21/2003	2.9	3/17/2005	2.9
8/4/2003	2.9	4/5/2005	39
9/3/2003	2.9	5/17/2005	2.9
10/20/2003	2.9	6/20/2005	3.6
11/3/2003	3.6	7/5/2005	2.9
3/17/2004	2.9	8/1/2005	9.1
4/27/2004	2.9	10/31/2005	3.6
5/19/2004	3.6	11/14/2005	2.9
6/16/2004	2.9	12/12/2005	2.9

Table D-11: Observed Fecal Coliform data at Pocomoke Sound Station 75-E5

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
11/12/2002	2.9	7/27/2004	2.9
2/24/2003	3	8/26/2004	2.9
3/11/2003	2.9	9/30/2004	2.9
4/9/2003	9.1	10/21/2004	2.9
5/7/2003	2.9	12/7/2004	3.6
6/19/2003	23	2/17/2005	2.9
7/21/2003	2.9	3/17/2005	23
8/4/2003	23	4/5/2005	43
9/3/2003	9.1	5/17/2005	3.6
10/20/2003	3.6	6/20/2005	2.9
11/3/2003	43	7/5/2005	2.9
3/17/2004	2.9	8/1/2005	23
4/27/2004	2.9	10/31/2005	3.6
5/19/2004	3.6	11/14/2005	3.6
6/16/2004	3.6	12/12/2005	2.9

Table D-12: Observed Fecal Coliform data at Pocomoke Sound Station 75-H7

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
11/12/2002	2.9	7/27/2004	3.6
2/24/2003	43	8/26/2004	2.9
3/11/2003	2.9	9/30/2004	2.9
4/9/2003	43	10/21/2004	2.9
5/7/2003	3.6	12/7/2004	2.9
6/19/2003	3.6	2/17/2005	2.9
7/21/2003	2.9	3/17/2005	2.9
8/4/2003	2.9	4/5/2005	240
9/3/2003	2.9	5/17/2005	3.6
10/20/2003	15	6/20/2005	2.9
11/3/2003	43	7/5/2005	14
3/17/2004	2.9	8/1/2005	43
4/27/2004	9.1	10/31/2005	7.3
5/19/2004	23	11/14/2005	3.6
6/16/2004	2.9	12/12/2005	9.1

Table D-13: Observed Fecal Coliform data at Pocomoke Sound Station 75-L7

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
11/12/2002	43	7/27/2004	7.2
2/24/2003	9.1	8/26/2004	2.9
3/11/2003	2.9	9/30/2004	3.6
4/9/2003	43	10/21/2004	28
5/7/2003	2.9	12/7/2004	3.6
6/19/2003	43	2/17/2005	2.9
7/21/2003	3.6	3/17/2005	3.6
8/4/2003	7.3	4/5/2005	43
9/3/2003	9.1	5/17/2005	2.9
10/20/2003	15	6/20/2005	23
11/3/2003	75	7/5/2005	23
3/17/2004	2.9	8/1/2005	3.6
4/27/2004	2.9	10/31/2005	2.9
5/19/2004	43	11/14/2005	15
6/16/2004	2.9	12/12/2005	3.6

Table D-14: Observed Fecal Coliform data at Pocomoke Sound Station 75-O8

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
11/12/2002	93	7/27/2004	43
2/24/2003	23	8/26/2004	23
3/11/2003	9.1	9/30/2004	240
4/9/2003	75	10/21/2004	9.1
5/7/2003	43	12/7/2004	15
6/19/2003	210	2/17/2005	7.3
7/21/2003	7.3	3/17/2005	23
8/4/2003	9.1	4/5/2005	23
9/3/2003	43	5/17/2005	39
10/20/2003	43	6/20/2005	15
11/3/2003	240	7/5/2005	2.9
3/17/2004	3.6	8/1/2005	15
4/27/2004	7.3	10/31/2005	23
5/19/2004	9.1	11/14/2005	15
6/16/2004	3.6	12/12/2005	3.6

Table D-15: Observed Fecal Coliform data at Pocomoke Sound Station 75-P8

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
11/12/2002	210	7/27/2004	43
2/24/2003	43	8/26/2004	15
3/11/2003	43	9/30/2004	93
4/9/2003	43	10/21/2004	3.6
5/7/2003	21	12/7/2004	23
6/19/2003	9.1	2/17/2005	15
7/21/2003	43	3/17/2005	23
8/4/2003	7.3	4/5/2005	240
9/3/2003	15	5/17/2005	3.6
10/20/2003	39	6/20/2005	3.6
11/3/2003	43	7/5/2005	23
3/17/2004	9.1	8/1/2005	9.1
4/27/2004	14	10/31/2005	43
5/19/2004	43	11/14/2005	15
6/16/2004	2.9	12/12/2005	93

Table D-16: Observed Fecal Coliform data at Pocomoke Sound Station 75-Q8

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
11/12/2002	75	7/27/2004	15
2/24/2003	93	8/26/2004	43
3/11/2003	15	9/30/2004	150
4/9/2003	43	10/21/2004	23
5/7/2003	7.2	12/7/2004	43
6/19/2003	20	2/17/2005	9.1
7/21/2003	2.9	3/17/2005	7.3
8/4/2003	3.6	4/5/2005	43
9/3/2003	43	5/17/2005	9.1
10/20/2003	75	6/20/2005	23
11/3/2003	460	7/5/2005	23
3/17/2004	43	8/1/2005	43
4/27/2004	2.9	10/31/2005	11
5/19/2004	9.1	11/14/2005	43
6/16/2004	2.9	12/12/2005	93

Table D-17: Observed Fecal Coliform data at Pocomoke Sound Station 75-R7

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
11/12/2002	43	7/27/2004	23
2/24/2003	43	8/26/2004	9.1
3/11/2003	14	9/30/2004	93
4/9/2003	150	10/21/2004	21
5/7/2003	120	12/7/2004	23
6/19/2003	75	2/17/2005	9.1
7/21/2003	2.9	3/17/2005	75
8/4/2003	43	4/5/2005	150
9/3/2003	43	5/17/2005	23
10/20/2003	23	6/20/2005	43
11/3/2003	240	7/5/2005	9.1
3/17/2004	93	8/1/2005	9.1
4/27/2004	2.9	10/31/2005	9.1
5/19/2004	9.1	11/14/2005	93
6/16/2004	3.6	12/12/2005	93

Table D-18: Observed Fecal Coliform data at Pocomoke Sound Station 75-S7

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
11/12/2002	150	7/27/2004	43
2/24/2003	39	8/26/2004	23
3/11/2003	39	9/30/2004	460
4/9/2003	93	10/21/2004	23
5/7/2003	75	12/7/2004	23
6/19/2003	120	2/17/2005	3.6
7/21/2003	3.6	3/17/2005	240
8/4/2003	9.1	4/5/2005	460
9/3/2003	43	5/17/2005	9.1
10/20/2003	23	6/20/2005	43
11/3/2003	43	7/5/2005	23
3/17/2004	23	8/1/2005	43
4/27/2004	23	10/31/2005	23
5/19/2004	460	11/14/2005	43
6/16/2004	23	12/12/2005	240