Total Maximum Daily Loads of Fecal Coliform for the Restricted Shellfish Harvesting Area in the Nanticoke River Mainstem in Dorchester and Wicomico Counties, Maryland

FINAL

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

Submitted to:

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

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List of Abbreviations

ARA	Antibiotic Resistance Analysis
BMP	Best Management Practice
BST	Bacteria Source Tracking
CFR	Code of Federal Regulations
cms	Cubic Meters per Second
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	Hydrodynamic and Eutrophication Model in 3 Dimensions
km	Kilometer
LA	Load Allocation
L_D	Load From Diffuse Sources
m	Meter
M_2	Lunar semi-diurnal tidal constituent
MACS	Maryland Agricultural Cost Share Program
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
mgd	Million Gallons per Day
ml	Milliliter(s)
MOS	Margin of Safety
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer Systems
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
USGS	United States Geological Survey
VIMS	Virginia Institute of Marine Science
WLA	Wasteload Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Plant

EXECUTIVE SUMMARY

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 currently required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is 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 (CFR 2006c).

Nanticoke River (basin number 02130305) was first identified on the 1998 303(d) List submitted to U.S. Environmental Protection Agency (EPA) by the Maryland Department of the Environment (MDE). The designated uses in Nanticoke River were listed as impaired by fecal coliform in tidal portions of the basin (1998), bacteria at two public beaches (1998, 2006), and impacts to biological communities in the tidal and non-tidal portions (2004). In 2004, the fecal coliform listing was refined by identifying one restricted shellfish harvesting area within the basin (MDE 2006). The assessment unit listing code for this area in Maryland's 303(d) List is MD-NANMH-NANTICOKE_RIVER. This document, upon EPA approval, establishes TMDLs of fecal coliform for the one restricted shellfish harvesting area in the Nanticoke River basin: the Nanticoke River mainstem. The listings for impacts to biological communities and bacteria at two public beaches within the Nanticoke River basin will be addressed at a future date.

An inverse three-dimensional model was used to estimate current fecal coliform loads and to establish allowable loads for the one restricted shellfish harvesting area in the Nanticoke River Mainstem 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 Nanticoke River and its corresponding restricted shellfish harvesting area. The loadings from potential sources (human, livestock, pets, and wildlife) were quantified by analysis of the bacteria source tracking (BST) collected in the Nanticoke River over a one-year period.

The allowable loads for the restricted shellfish harvesting area were computed using both the median concentration water quality criterion for shellfish harvesting use of 14 Most Probable Number (MPN)/100ml, and the 90th percentile criterion concentration of 49 MPN/100ml for a three-tube decimal dilution. An implicit Margin of Safety (MOS) was incorporated into the analysis to account for uncertainty. The TMDLs developed for the restricted shellfish harvesting area of the Nanticoke River watershed for fecal coliform are as follows:

Waterbody	**Fecal Coliform TMDL [counts per day]**	
	based on Median Criterion	**based on 90th Percentile Criterion**
Nanticoke River mainstem	8.51×10^{13}	1.36×10^{14}

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 allocations proposed in this document were developed based on the criterion requiring the largest percent reductions - here the 90th percentile criterion. The TMDL requires a reduction of approximately 19.9% for the Nanticoke River mainstem.

Once EPA has approved this TMDL, MDE 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 the data will be used to assess the effectiveness of the Department's implementation efforts on an ongoing basis.

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 tract 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 are indicator organisms 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 reduce high fecal coliform concentrations to levels that meet the criteria associated with the shellfish harvesting designated use.

In both the 1996 and 1998 Maryland 303(d) Lists of Impaired Waterbodies, many shellfish listings were identified on a broad 8-digit watershed scale. These listings were further refined in the 2004 303(d) List. Since 2004, the listings that are based on the shellfish water quality monitoring data are limited to the specific currently restricted shellfish harvesting areas within an 8-digit watershed (MDE 2006).

Nanticoke River (basin number 02130305) was first identified on the 1998 303(d) List submitted to EPA by the Maryland Department of the Environment (MDE). The designated uses in the Nanticoke River were listed as impaired by fecal coliform in tidal portions(1998), bacteria at two public beaches (1998, 2006), and impacts to biological communities in the tidal and non-tidal portions (2004). In 2004, the fecal coliform listing was refined by identifying one restricted shellfish harvesting area within the basin: the Nanticoke River mainstem. The assessment unit listing code for this area in Maryland's 303(d) List is MD-NANMH-NANTICOKE_RIVER. This document, upon EPA approval, establishes a TMDL for fecal coliform for the Nanticoke River mainstem. The listings for impacts to biological communities and bacteria at two public beaches within the Nanticoke River basin will be addressed at a future date.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

One restricted shellfish harvesting area in the Nanticoke River basin is addressed in this report: the Nanticoke River mainstem. The Nanticoke River is located on Maryland's Eastern Shore in Dorchester and Wicomico Counties, as shown in Figure 2.1.1. The Nanticoke River mainstem is in the lower Nanticoke River. The Nanticoke River has a length of approximately 64 km and its width ranges from 140 to 300 m upstream and approximately 3 km at its mouth (where it flows into Chesapeake Bay just north of the Chester River. The shellfish harvesting waters in the Nanticoke River extend from Runaway Point (near Station 14-05-025) on the Wicomico County Shore and Long Point on the Dorchester County Shore approximately 10 miles to the mouth of the river where it confluences with Tangier Sound. Approximately 75% of the river basin adjacent to shellfish harvesting waters is tidal marsh. The Nanticoke River restricted shellfish harvesting area has length of 6.3 km and a drainage area of 503,853 acres (2039.0 km^2).

The light and sandy soil conditions found throughout the watershed permit high permeability. The soils in the Nanticoke River watershed range from moderately well-drained to well-drained (USDA 2006). The dominant tide in this region is the lunar semi-diurnal (M_2) tide, with a tidal range of 0.70 m in the restricted portion of the Nanticoke River with a tidal period of 12.42 hours (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 Nanticoke River Mainstem Restricted Shellfish Harvesting Area

Restricted Shellfish Harvesting Area	Mean Water Volume [m^3]	Mean Water Depth [m]
Nanticoke River Mainstem	34,080,462	2.21

The 2000 Maryland Department of Planning (MDP) land use/land cover data show that the watershed can be characterized as primarily rural for the Nanticoke River, with 46% of the area being cropland and more than 28% forested. The land use information for the restricted shellfish harvesting areas in the Nanticoke River Mainstem Basin is shown in Table 2.1.2 and Figures 2.1.2. Residential urban land use identified in Table 2.1.2 includes low-density residential, medium-density residential, and high-density residential. Non-residential urban land use in this table includes commercial, industrial, institutional, extractive, and open urban land.

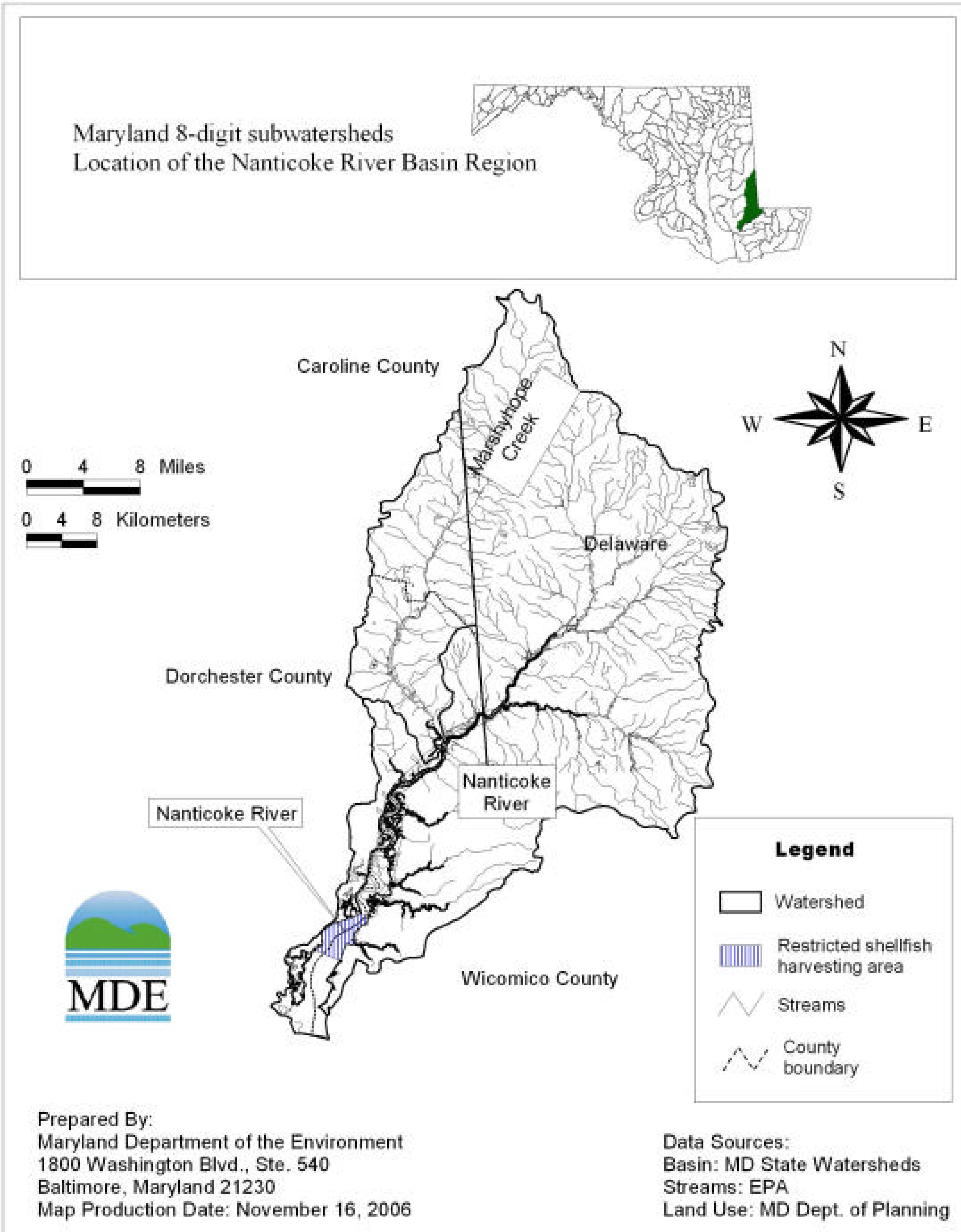

Figure 2.1.1: Location Map of the Nanticoke River Basin

Table 2.1.2: Land Use Percentage Distribution for Nanticoke River Watershed

Land Type	Acreage	Percentage
Residential urban[1]	27,851.2	5.5%
Non-Residential urban[2]	8,111.6	1.6%
Cropland	230,961.0	46.0%
Pasture	1,623.6	0.3%
Feedlot	10,084.3	2.0%
Forest	142,936.5	28.5%
Water	3,627.9	0.7%
Wetlands	76,458.5	15.2%
Barren	852.7	0.2%
Totals	**502,507.2**	**100.0**

Notes: [1] Includes low-density residential, medium-density residential, and high-density residential.
[2] Includes commercial, industrial, institutional, extractive, and open urban land.

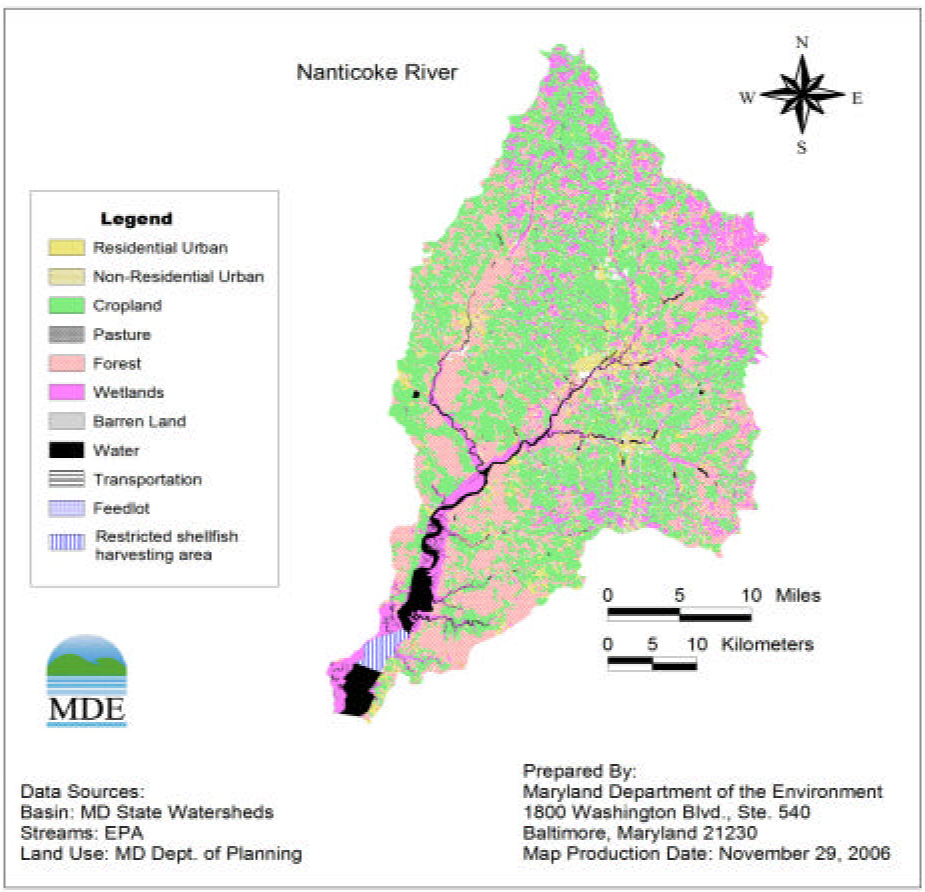

Figure 2.1.2: Land Use in the Nanticoke River Basin

2.2 Water Quality Characterization

MDE's Shellfish Certification Program 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 National Shellfish Sanitation Program, with oversight by FDA. MDE conducts shoreline surveys and collects routine bacteria water quality samples in the shellfish waters of Maryland to assure that Maryland's shellfish waters are properly classified.

MDE's Shellfish Certification Program monitors shellfish waters throughout Maryland. There are seven shellfish monitoring stations in the restricted shellfish harvesting area addressed in this report. The station identification and observations recorded during the period of June 2000 – June 2005 are provided in Table 2.2.1 and Figure 2.2.1 through Figure 2.2.8. A tabulation of observed fecal coliform values at the seven monitoring stations included in this report is provided in Appendix D.

Table 2.2.1: Locations of the Shellfish Monitoring Stations in Nanticoke River Mainstem

Station Location	Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
Nanticoke River mainstem	14-05-022	2000-2005	70	38 19 44.9	75 52 41.5
	14-05-024	2000-2005	70	38 21 10.0	75 52 51.0
	14-05-025	2000-2005	69	38 21 24.0	75 51 21.0
	14-05-144	2000-2005	70	38 19 17.0	75 53 22.0
	14-05-144A	2000-2005	70	38 19 17.0	75 54 12.0
	14-05-144B	2000-2005	69	38 19 25.0	75 54 40.0
	14-05-701	2000-2005	70	38 20 30.0	75 53 25.0

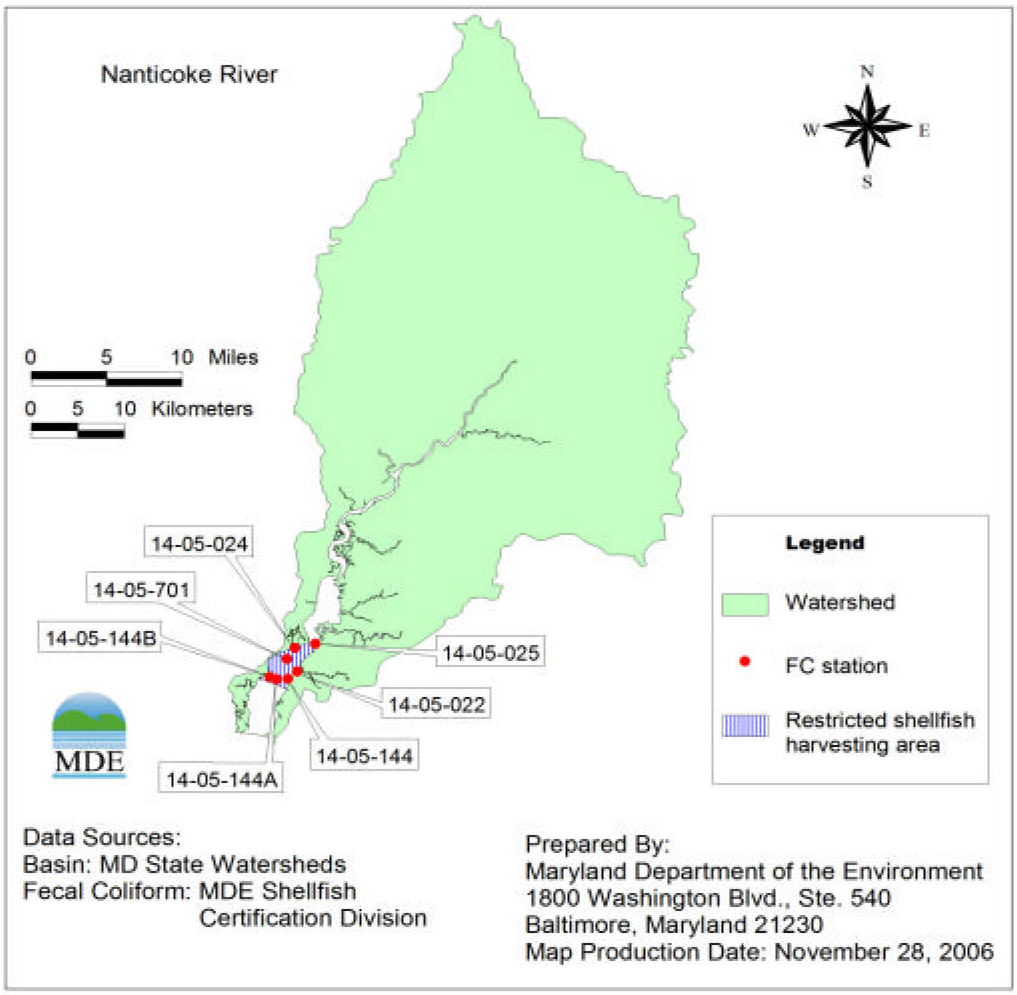

Figure 2.2.1: Shellfish Monitoring Stations in Nanticoke River

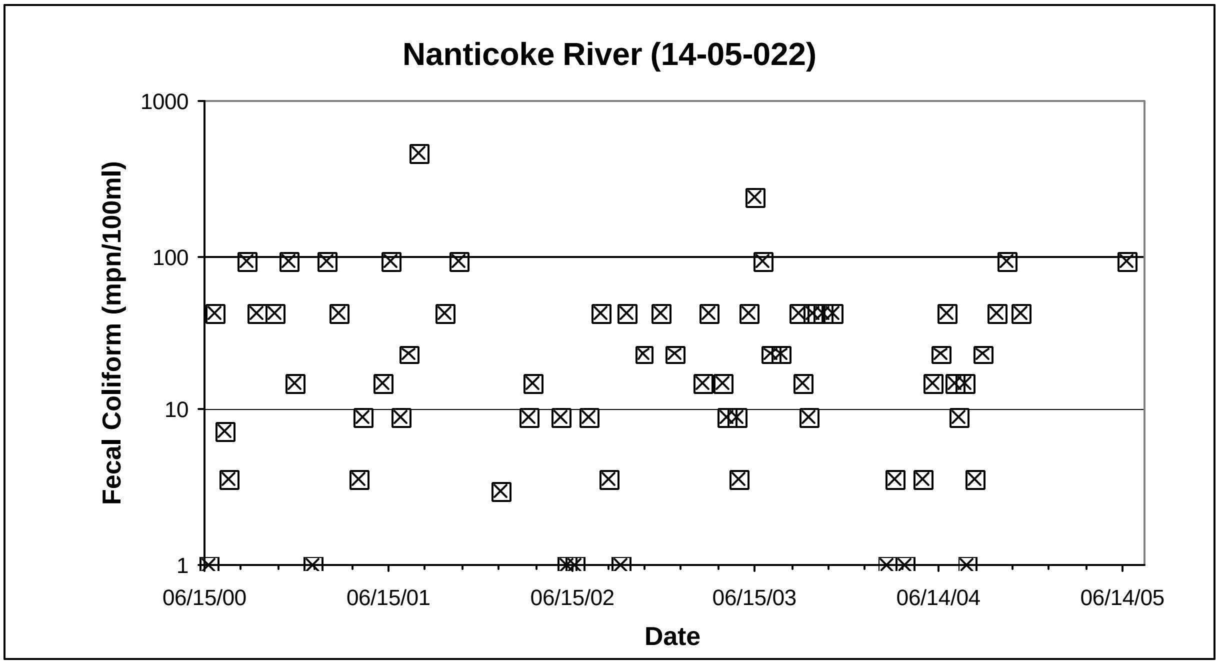

Figure 2.2.2: Observed Fecal Coliform Concentrations at Station 14-05-022

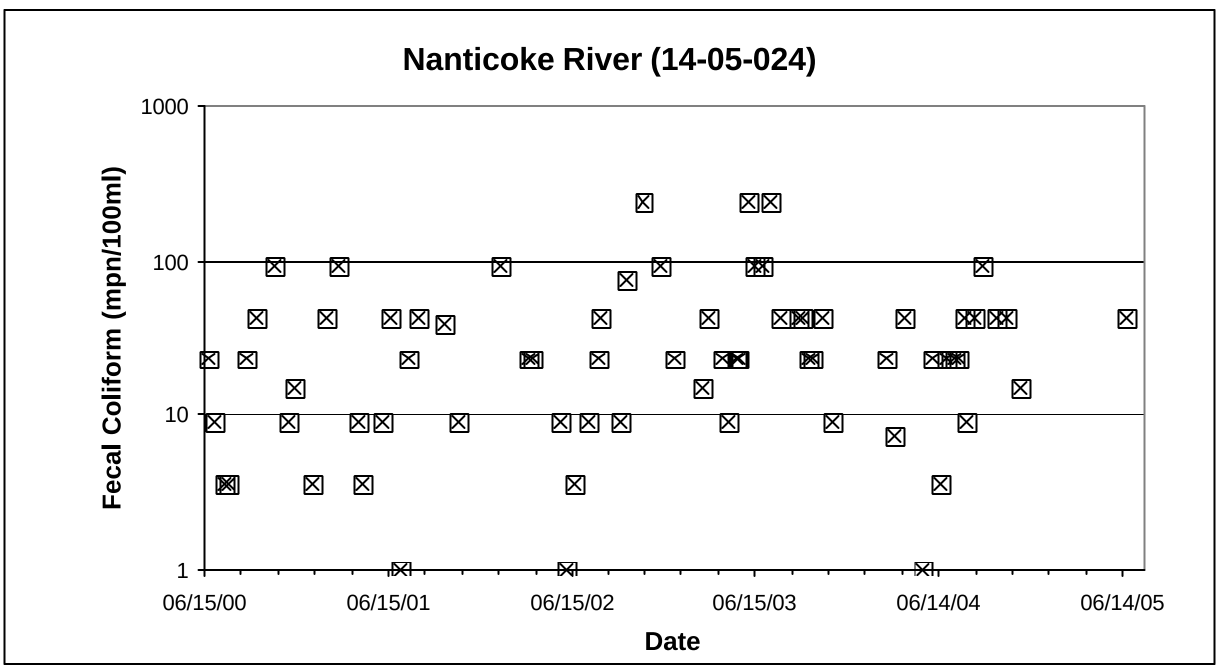

Figure 2.2.3: Observed Fecal Coliform Concentrations at Station 14-05-024

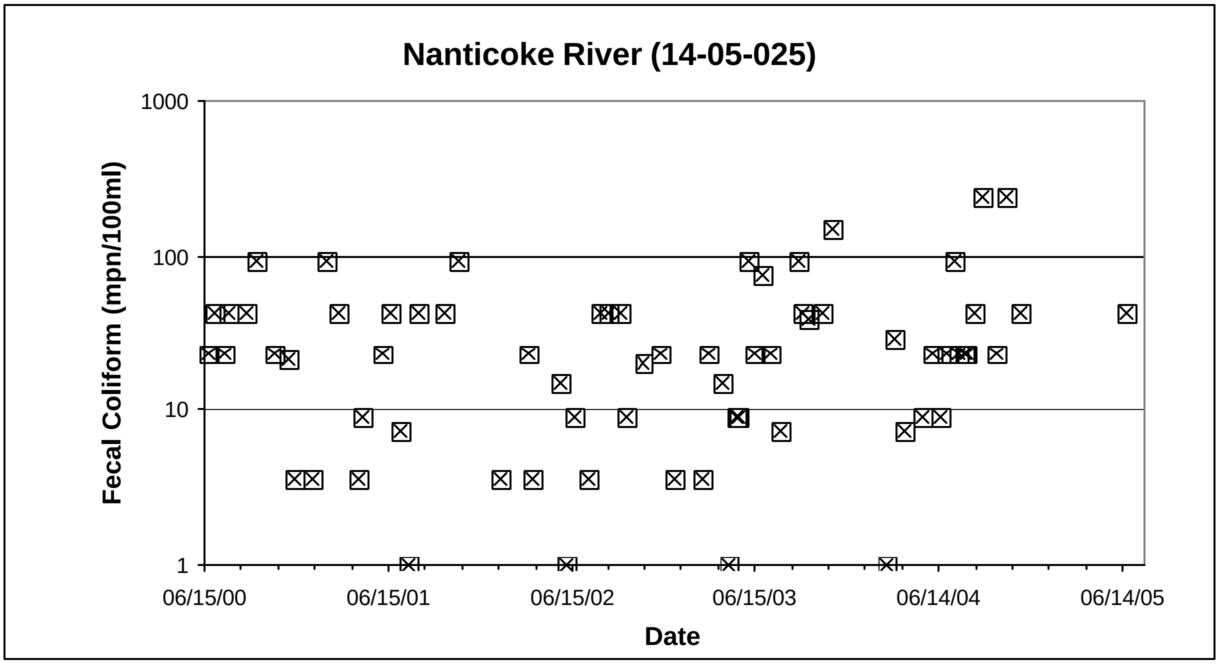

Figure 2.2.4: Observed Fecal Coliform Concentrations at Station 14-05-025

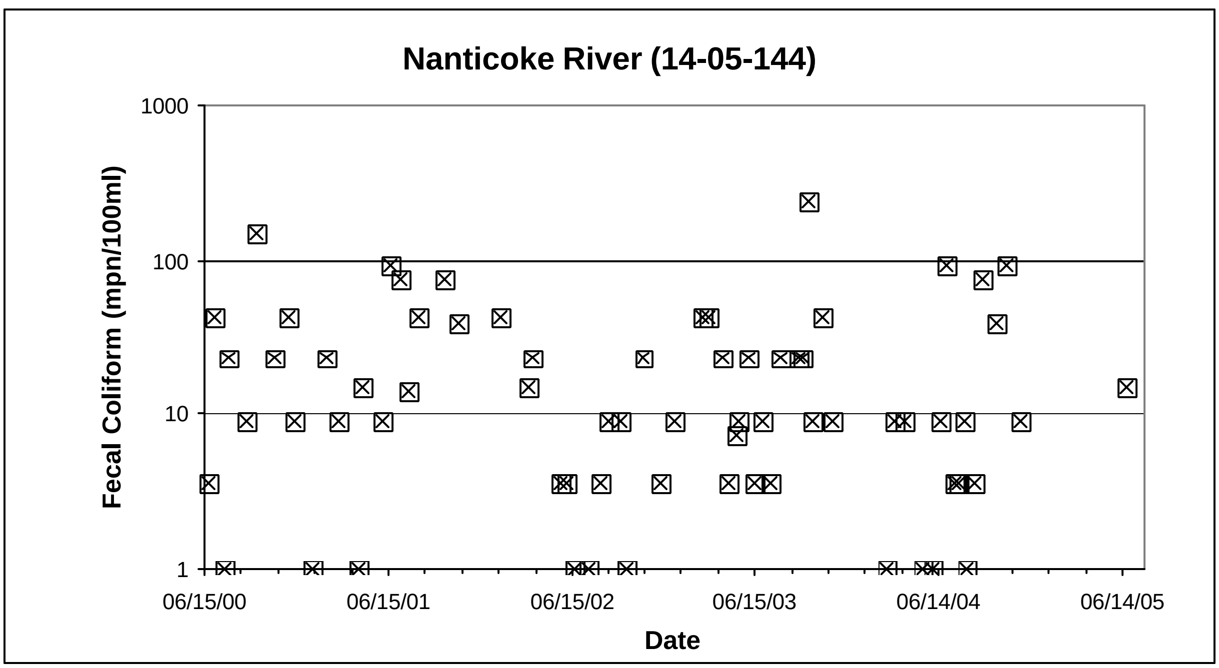

Figure 2.2.5: Observed Fecal Coliform Concentrations at Station 14-05-144

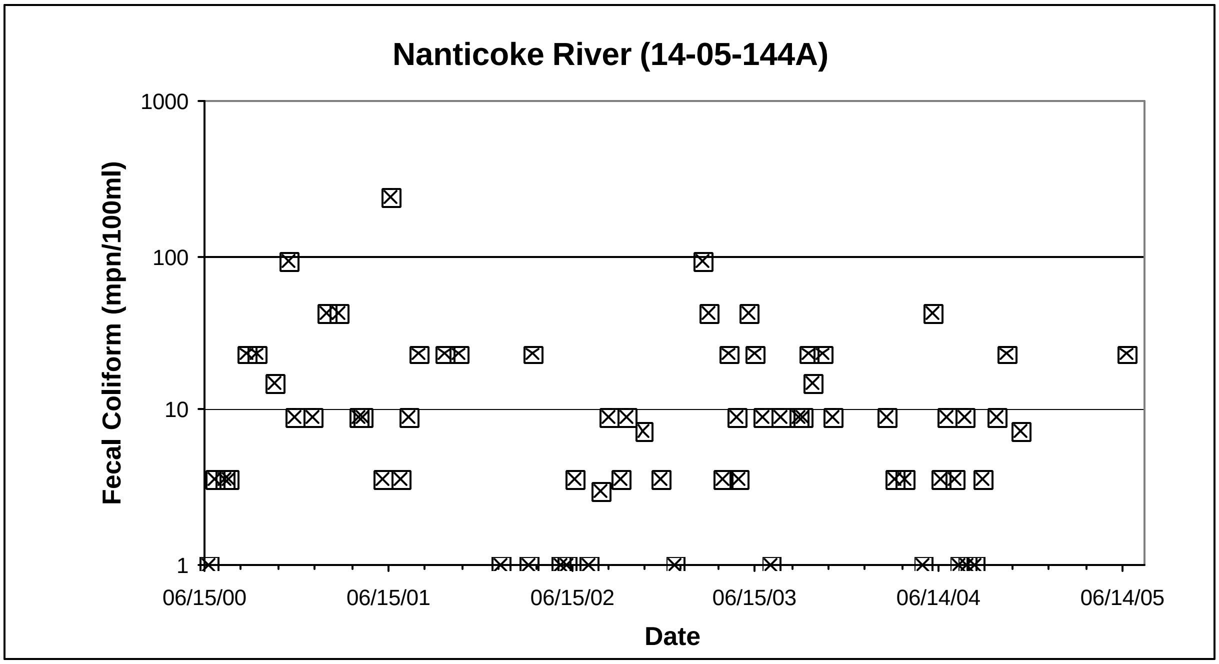

Figure 2.2.6: Observed Fecal Coliform Concentrations at Station 14-05-144A

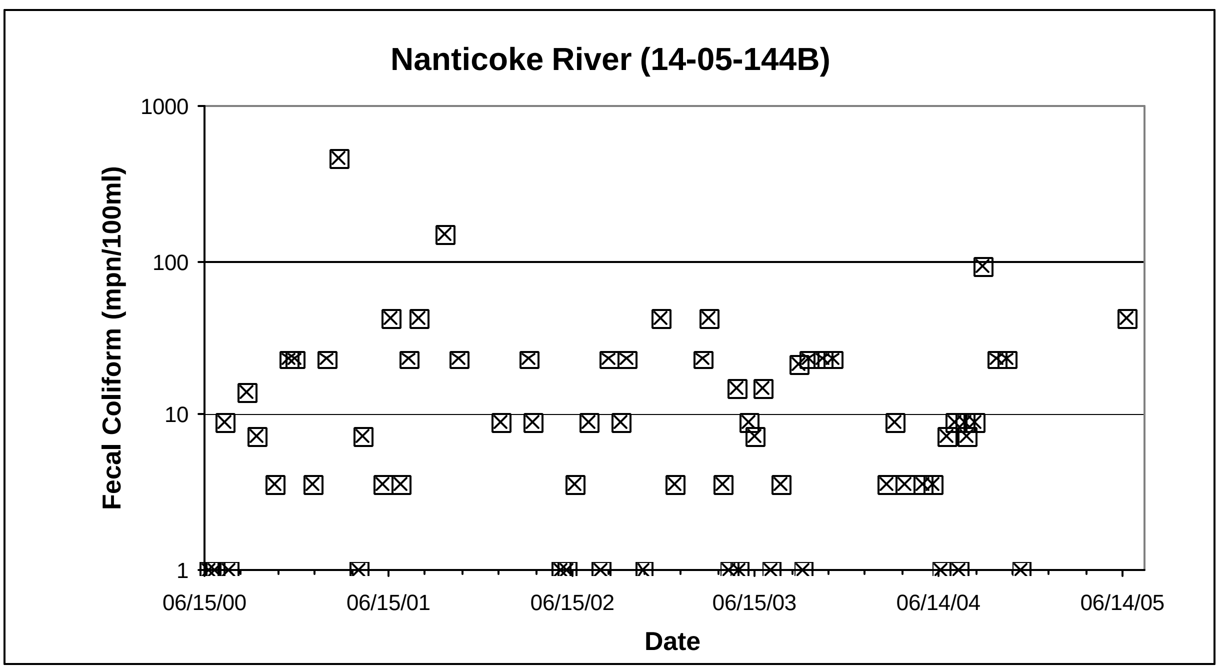

Figure 2.2.7: Observed Fecal Coliform Concentrations at Station 14-05-144B

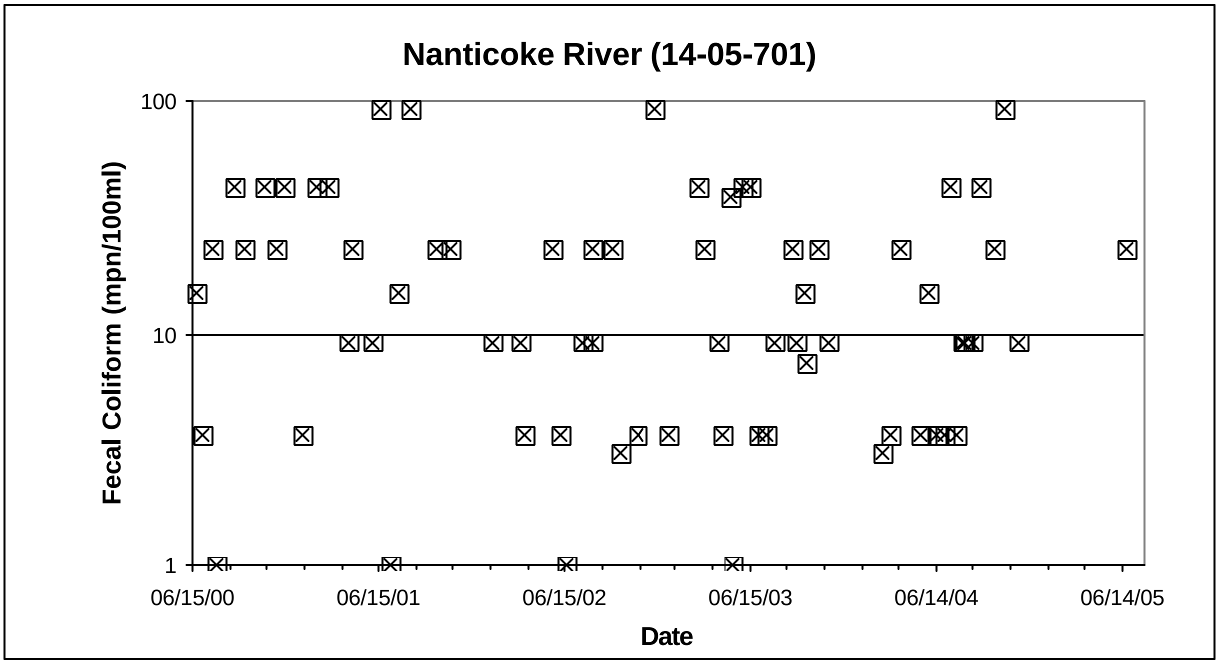

Figure 2.2.8: Observed Fecal Coliform Concentrations at Station 14-05-701

2.3 Water Quality Impairment

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 (COMAR 2006).[1]

MDE updated and promulgated water quality criteria for shellfish waters in June 2004. Although bacteriological criteria for shellfish harvesting waters were unchanged, the update included the classification criteria required under the NSSP that previously was 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, but did not change the fecal coliform criteria for shellfish harvesting waters or shellfish harvesting use designations.

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

For this analysis, MDE is using routine monitoring data collected over a five-year period between July 2000 and July 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, current loads are estimated based on all of the most recent data. The assimilative capacity will be based on the approved classification requirements of a median concentration of 14 MPN/100 ml and a 90th percentile concentration of less than 49 MPN/100 ml.

Nanticoke River was first listed on the 1998 Integrated 303(d) List as impaired by fecal coliform. This listing was further refined in 2004 and specified the following shellfish harvesting waters as impaired by fecal coliform: Nanticoke River mainstem. The water quality impairment in the

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[1] Note that Maryland uses the three-tube decimal dilution test for fecal coliform bacteria monitoring purposes.

Nanticoke River mainstem was assessed as not meeting the median criterion at three of its seven monitoring stations and not meeting the 90th percentile criterion at five of these stations. Descriptive statistics of the monitoring data and the requirements for the approved classification are shown in Table 2.3.1.

Table 2.3.1: Nanticoke River Fecal Coliform Statistics (data from 2000-2005)

Area Name	Station	Median		90th Percentile	
		Monitoring Data	Criterion	Monitoring Data	Criterion
		MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml
Nanticoke River	14-05-022	15	14	100	49
	14-05-024	23	14	99	49
	14-05-025	23	14	97	49
	14-05-144	9	14	65	49
	14-05-144A	9	14	40	49
	14-05-144B	9	14	45	49
	14-05-701	9	14	51	49

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 is introduced 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 conducted sampling over a one-year period in the Nanticoke River watershed using bacteria source tracking (BST) to identify sources of fecal coliform. The nonpoint source assessment was conducted by analyzing BST results to quantify source loadings from humans, livestock, pets, and wildlife.

In the Nanticoke 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 predominately cropland and forest. According to land use information, the 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. Based on the analysis of BST data, wildlife is the predominant bacteria source followed by livestock, human, and pet sources. Twelve percent (12%) of the water isolates were from unknown (unclassified) probable sources. Table 2.4.1 summarizes the source distribution based on BST data analysis. Detailed results of BST analysis are presented in Appendix B.

Table 2.4.1: Source Distribution Based on BST Data Analysis

Human	Livestock	Wildlife	Pets	Unknown
11.6%	22.5%	50.8 %	2.9%	12.1%

BST data analysis includes a statistical comparison of known sources collected in the watershed and compared with unknown source samples collected over the study period. The fecal coliform sources in water samples are unknown until matched with the library of known sources. The 12.1% 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 BST library were found (see Appendix B for details on BST used for this report).

Point Source Assessment

Point sources in the Nanticoke River watershed include municipal and industrial point source facilities. There are four municipal point source facilities that have permits regulating the discharge of fecal coliform to the Nanticoke River (or its tributaries). They are Vienna Waste Water Treatment Plant (WWTP) with National Pollution Discharge Elimination System (NPDES) permit number MD0020664, Mardela High School WWTP (NPDES number MD0024279), Sharptown WWTP (NPDES number MD0052175), and Hebron WWTP (NPDES number MD0059617). The permitted discharges for the above four facilities are 0.1375, 0.014, 0.15, and 0.101 MGD, respectively, with permitted monthly log mean concentrations of fecal coliform of 200 MPN/100ml, E. coli of 126 MPN/100 ml, fecal coliform of 200 MPN/100ml, and E. coli of 126 MPN/100ml, respectively. There are four industrial point sources that have NPDES permit numbers: MD0061115 (Dececco, Inc.), MD0066532 (J.V. Wells, Inc.), MD0000094 (Delmarva Power & Light Co.), and MD0051284 (Howard Sand & Gravel, Inc). These four point source facilities have no permits to discharge fecal coliform. It should be noted that none of the permitted facilities discharge directly to shellfish waters, since the nearest is located approximately 9 miles from shellfish harvesting waters. Detailed information about the fecal coliform permits and loads for these point sources are summarized in Appendix E. The allocation of the load from these point source facilities will be addressed in Section 4.7.

3.0 TARGETED WATER QUALITY GOAL

The overall objective of the fecal coliform TMDLs summarized in this document is to establish the maximum loading allowed to ensure attainment of water quality standards in the restricted shellfish harvesting waters in the Nanticoke River. 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 the detailed fecal coliform TMDLs and load allocation development for the restricted shellfish harvesting waters in the Nanticoke River watershed. The required load reduction was determined based on data collected from June 2000 to June 2005. 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 Nanticoke River basin. 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 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 five-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 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 following equation:

TMDL = WLAs + LAs + MOS + (FA, 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. The Nanticoke River has a length of approximately 64 km and its width ranges from 140 to 300 m upstream to approximately 3 km at its mouth. The river branches at about 20 km from the mouth. The current distribution in the system varies as tidal and freshwater discharges change. In order to simulate the transport processes in the Nanticoke 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 concentrations, conservative tracers, eutrophication processes, and fecal coliform. For a detailed model description, the reader is referred to Park et al. (1995).

The Nanticoke River is represented by a horizontal network of model grid cells. There are a total of 160 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 the median and 90th percentile fecal coliform concentrations, an inverse approach has been adopted here to estimate the loads from the watershed. The watershed is divided into 26 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 01487000. The discharges from subwatersheds are estimated based on the ratio of subwatershed area to the total drainage basin of the USGS station. The inverse method is used to estimate the existing load discharged from each subwatershed based on median and 90th percentile fecal coliform data obtained from observations. The model is also used to establish the allowable loads for the river. Detailed modeling procedures are described in Appendix A.

4.3 Critical Condition and Seasonality

EPA's regulations require TMDLs to be "established at levels necessary to attain and maintain the applicable narrative and numerical WQS [water quality standards] with *seasonal variations* and a *margin of safety* . . . Determinations of TMDLs shall take into account *critical conditions* for stream flow, loading, and water quality parameters" (CFR 2006c). 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.

The 90th percentile concentration is the concentration that exceeded water quality criterion only 10% of the time. Since the data used were collected over a five-year period, the critical condition requirement is implicitly included in the 90th percentile value. Given the length of the monitoring record used and the limited applicability of best management practices (BMPs) to extreme conditions, the 90th percentile concentration 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 values dictate the higher reduction, this suggests that, on average, water sample counts are 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 seven applicable monitoring stations are presented in Appendix C. The results show the seasonal variability of fecal coliform concentrations. Fecal coliform concentrations show strong variation at different stations. High concentrations occur in the months of September, October, and February at some stations, whereas high concentrations occur in March and November at other stations in the Nanticoke River restricted shellfish harvesting area. The large standard deviations occur in June and July, and September and November. These high concentrations result in high 90th percentile concentrations, which indicate 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, the highest fecal coliform concentration often occurs 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.

4.4 TMDL Computation

Because the water quality standards for fecal coliform in shellfish waters include both the median and 90th percentile criteria, TMDLs are calculated against both criteria and the criterion requiring the greatest percent reduction is selected for the TMDL.

Routine monitoring data were used to estimate the current loads. Both the median and the 90th percentile analyses have been performed. There are seven shellfish monitoring stations in the restricted shellfish harvesting area of the Nanticoke River. To accurately estimate the load with consideration of available monitoring data, the 8-digit watershed was segmented into 26 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 concentrations in 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 concentrations in the receiving water meet the appropriate water quality standards. The total loads discharged into the river are the summation of loads discharged from each subwatershed. For the Nanticoke River mainstem, neither the median nor the 90th percentile standard is met at three of the seven stations. 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 Loads and Estimated Load Reduction

Area	Mean Volume M^3	Fecal Coliform Median Criterion MPN/100mL	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction (%)
Nanticoke River Mainstem	34,080,462	14	9.623E+13	8.508E+13	11.6

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

Area	Mean Volume M^3	Fecal Coliform 90th Percentile Criterion MPN/100mL	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction (%)
Nanticoke River mainstem	34,080,462	49	1.696E+14	1.359E+14	19.9

4.5 Summary of Baseline Loads

For the TMDL analysis period, from June 2000 to June 2005, the calculated baseline (current) loads of fecal coliform from all sources in the one restricted shellfish harvesting area in the Nanticoke 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

Waterbody	Fecal Coliform Baseline Loads [counts per day]	
	Median Analysis Scenario	90th Percentile Analysis Scenario
Nanticoke River mainstem	9.623×10^{13}	1.696×10^{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 Nanticoke River basin are summarized in Table 4.6.1.

Table 4.6.1: Summary of TMDL Loading Caps

Waterbody	Fecal Coliform TMDL [counts per day]	
	based on Median Criterion	based on 90th Percentile Criterion*
Nanticoke River mainstem	8.508×10^{13}	1.359×10^{14}

* 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 five-year averaging period was used to develop the fecal coliform TMDLs for the shellfish harvesting areas in the Nanticoke River basin. This specific averaging period was chosen based on the water quality criteria, which requires at least 30 samples (COMAR 2006). When allocating loads among sources, the scenario that requires the greatest overall reductions (here the 90th percentile scenario) was applied. Table 4.7.1 below summarizes the necessary load reductions by area.

4.7 Load Allocation and Percent Reductions

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 point source facilities in the Nanticoke River that have permits regulating the discharge of fecal coliform(or E. coli) to the Nanticoke River (or its tributaries) and the fecal coliform load from these point sources is approximately 9.84×10^{9} counts per day and will be included in the WLA. The remaining loads assimilative capacity will be allocated to the load allocation.

The load reduction scenario results in a load allocation by which the TMDL can be implemented to achieve water quality standards. The State reserves the right to revise these allocations, provided the allocations are consistent with the achievement of water quality standards. The load reduction calculated in this document was based on the 90th percentile water quality criterion, which is shown in Table 4.7.1 for the restricted shellfish harvesting area of the Nanticoke River watershed.

Table 4.7.1: Load Reductions

Restricted Shellfish Harvesting Area	Required Reduction
Nanticoke River mainstem	**19.9 %**

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 the control of measures for bacterial loads is 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 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 the 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 point source facilities (MD0020664 (Vienna WWTP), MD0024279 (Mardela High School WWTP), MD0052175 (Sharptown WWTP), and MD0059617 (Hebron WWTP) that have permit limits regulating the discharge of fecal coliform into the river. The fecal coliform load from these point sources is approximately 9.84×10^9 counts per day and will be included in the WLA. The remaining loads assimilative capacity will be allocated to the load allocation. The TMDL is summarized as follows:

Fecal Coliform TMDL (counts per day) Based on 90th percentile Criterion:

Area	**TMDL**	**=**	**LA**	**+**	**WLA**	**+**	**FA**	**+**	**MOS**
Nanticoke River mainstem	$\mathbf{1.36 \times 10^{14}}$	**=**	$\mathbf{1.36 \times 10^{14}}$	**+**	$\mathbf{9.84 \times 10^{9}}$	**+**	**N/A**	**+**	**Implicit**

Where:

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

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the fecal coliform TMDLs 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. Details of these methods are to be described in the implementation plan.

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 BST analysis (see Table 2.4.1) may be used as a tool to target and prioritize initial implementation efforts. The iterative approach towards best management practice (BMP) implementation throughout the watershed will help to ensure that the most cost-effective practices are implemented first. The success of BMP implementation will be evaluated and tracked through follow-up stream monitoring.

Existing Funding and Regulatory Framework

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 would be covered by MDE's routine sanitary surveys of shellfish growing areas and NPDES permitting activities. Also, although not directly linked, it is assumed that the nutrient management plans from the Water Quality Improvement Act of 1998 (WQIA) will result in some reduction of bacteria from manure application practices.

As part of Maryland's commitment to the NSSP, MDE's Shellfish Certification Program continues to monitor shellfish waters and classify shellfish harvesting areas as restricted, approved, or conditionally approved. A major component of MDE's responsibilities under the Shellfish Certification Program is to identify potential pollution sources and correct or eliminate them. Waters meeting shellfish water quality standards are reclassified as approved or conditionally approved harvesting areas. The removal of shellfish harvesting restrictions may serve as a tracking tool measuring water quality improvements. However, when performing such analyses, it is important to understand that, per FDA/NSSP requirements, areas located near point sources are expected to remain restricted. Existence of such restrictions does not necessarily mean that the area is not meeting water quality standards.

Implementation and Wildlife Sources

It is expected that, due to significant wildlife bacteria contribution, some waterbodies will not be able to meet water quality standards even after all anthropogenic sources are controlled. Neither the State of Maryland nor 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 the changing of a natural background condition is not the intended goal of a TMDL.

MDE envisions an iterative approach to TMDL implementation, which first addresses the controllable sources (i.e., human, livestock, and pets), especially those that have the largest impacts on water quality and create the greatest risks to human health, with consideration given to ease the cost of implementation. It is expected that the best management practices applied to controllable sources may also result in reduction of some wildlife sources. Following the initial implementation stage, MDE expects to re-assess the water quality to determine if the designated use is being attained. If the water quality standards are not attained, other sources may need to be controlled. However, if the required controls go beyond maximum practical reductions, MDE might 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.

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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, 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; Shen, Boon, and Kuo 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 26 subwatersheds of the Nanticoke River. The modeling domain consists of 160 grid cells. Because the Nanticoke River is narrow, a horizontal network approach is used to represent the river. To better simulate estuarine circulation, a total of 3 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 Nanticoke 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 seven tidal harmonic constituents at the river mouth. The tidal harmonic constituents at the mouth were obtained from the 3-dimensional Chesapeake Bay UnTRIM model developed at the Virginia Institute of Marine Science (VIMS) (Shen et al. 2006). The NOAA predicted tidal ranges inside the Nanticoke River were used as the tidal benchmark for calibrating the HEM-3D model. The HEM-3D model results compare well against NOAA predicted tidal ranges (within 5 cm), as shown in Table A-1. Because of limitations of real-time observation data of stream flow, tide, and wind in the Nanticoke River, comparison of real-time salinity simulation against the observed salinity cannot be performed. Therefore, the model calibration for the mean condition of salinity distribution was performed to reproduce the averaged salinity distribution at 6 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 01487000 (Nanticoke River near Bridgefield, DE). 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 simulates salinity distribution well in the estuary.

Since the water quality criteria for fecal coliform are expressed in terms of the median and the 90^{th} percentile concentrations, the modeling tasks are to estimate fecal coliform mean daily loads from the watershed corresponding to the median and 90^{th} 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).

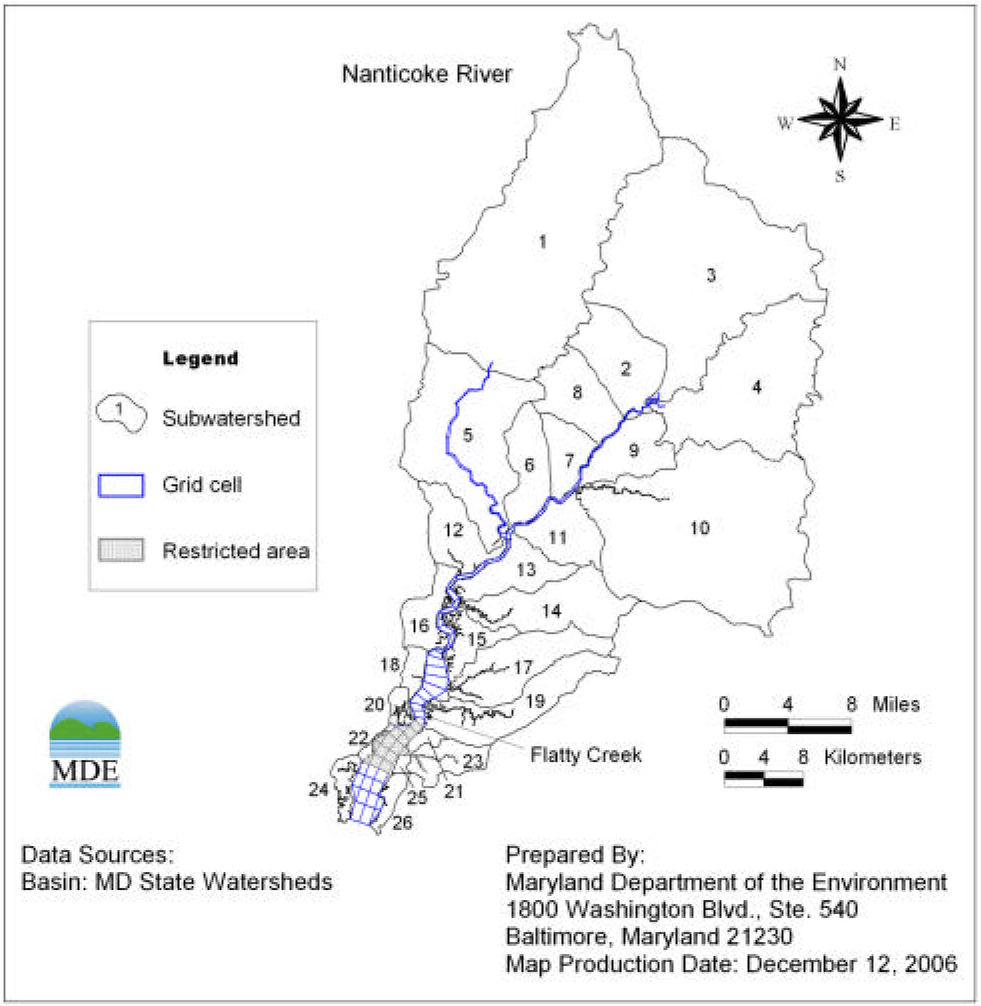

Figure A-1: HEM-3D Grid Cells and Subwatersheds in the Nanticoke River

Table A-1: Comparison of Modeled and NOAA Predicted Mean Tidal Range

Station	Modeled Range (m)	NOAA Predicted Range (m)
Roaring Point	0.709	0.701
Vienna	0.722	0.670
Sharptown	0.748	0.762

Table A-2: Estimated Mean Flows of Subwatersheds in the Nanticoke River

Subwatershed	Mean Flow (cms)
1	5.75
2	0.92
3	4.48
4	2.30
5	2.22
6	0.59
7	0.39
8	0.68
9	0.60
10	4.43
11	0.57
12	0.55
13	0.54
14	1.01
15	0.32
16	0.37
17	0.89
18	0.14
19	0.92
20	0.10
21	0.07
22	0.04
23	0.34
24	0.15
25	0.04
26	0.13

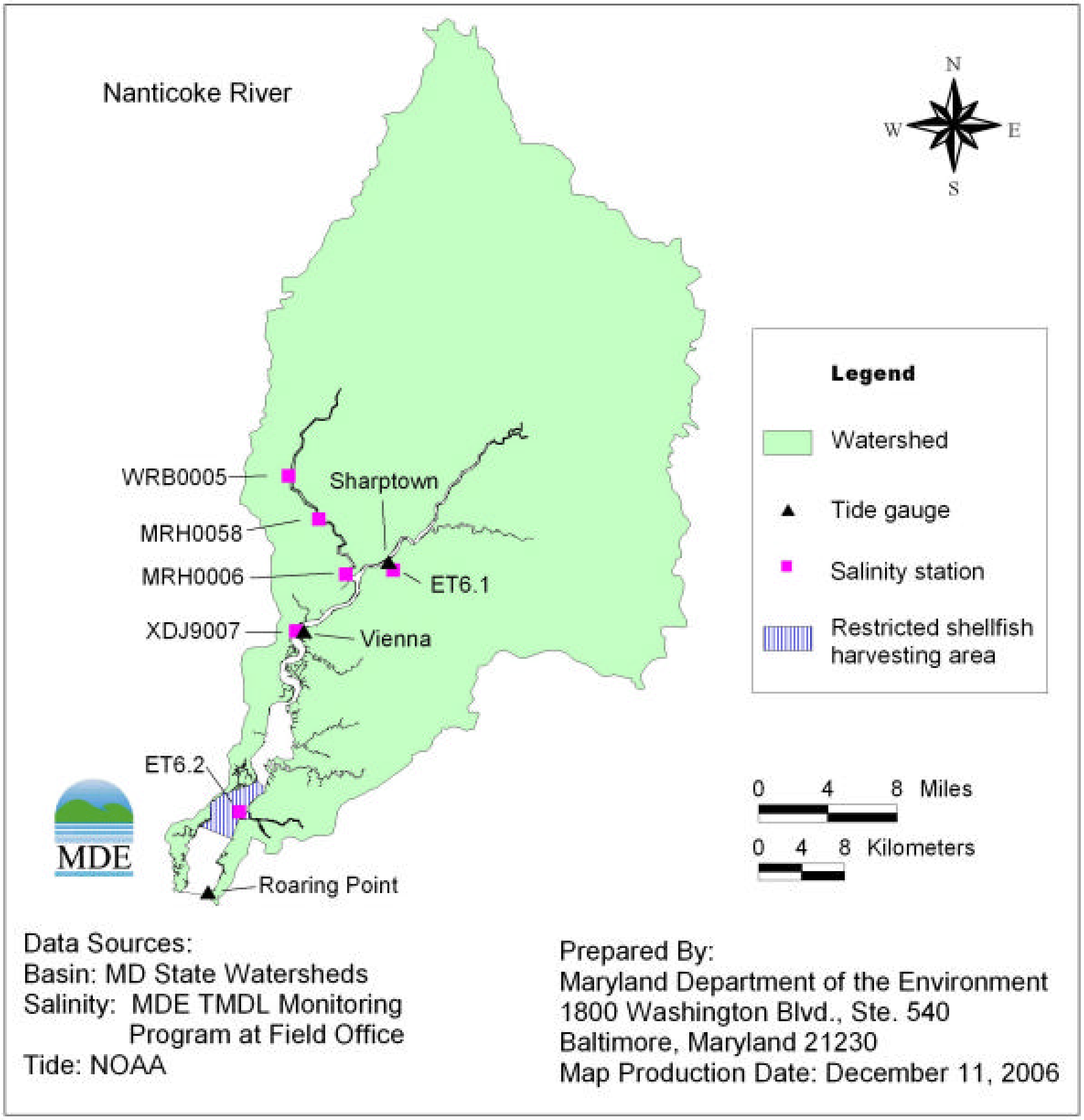

Figure A-2: Tide and Salinity Stations of the Nanticoke River Used in Model Calibration

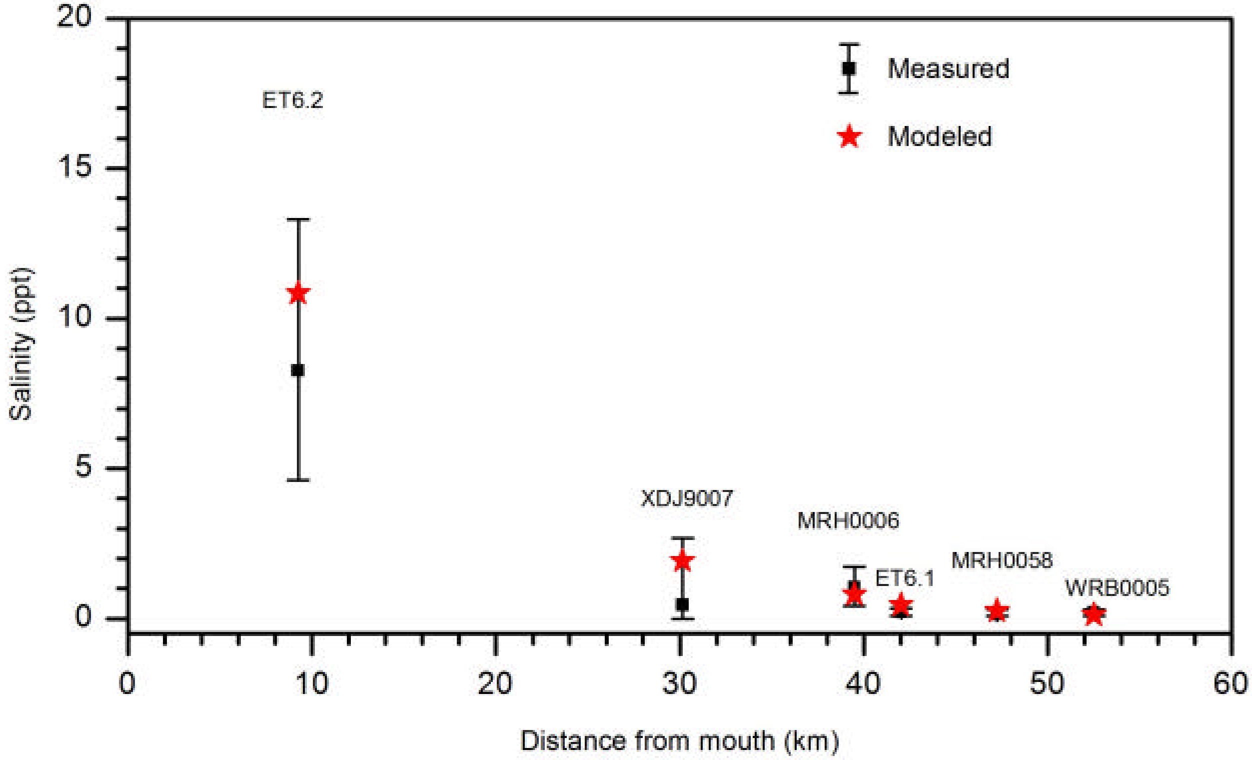

Figure A-3: Comparison of Measured and Calculated Salinities

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:

$$J(\mathbf{C};\mathbf{ß}^*) = \min\ J(\mathbf{C};\mathbf{ß}) \tag{1}$$

subject to:

$$\mathbf{ß}^* \in \mathbf{ß}_0 \tag{2}$$

$$\mathbf{F} = 0 \tag{3}$$

where ***J*** is a goal or cost function; $b^* = (\beta_1, \beta_2, ..., \beta_m)$ is the optimal parameter (*i.e.*, loads); $b_{\mathbf{0}}$ 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:

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

where C and C^0 are modeled and measured fecal coliform in the river, w is weights, 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 $C_m^0(x)$ be the median or 90th percentile obtained from the observations at location (x). If we choose:

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

Equation (4) can be written as:

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

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 originate from 26 subwatersheds, as shown in Figure A-1. For the estimation of existing median and 90th percentile 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 26 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 along the river.

Because the observation 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 26 subwatersheds. A monthly survey was conducted in the upstream region from September to November in 2005. The data analysis shows that the variation of the fecal coliform concentrations is not significant along the river, which indicates that sources of fecal coliform are discharged into the river from subwatersheds along the river. Therefore, the mean and maximum concentrations from the short-term measurements were also used for the model calibration. The short-team concentrations along the upstream of the river were adjusted based on the ratios between short-team mean and maximum concentrations and the median and 90th percentile concentrations downstream. A model sensitivity test suggests that the influence of fecal coliform loads from two upstream tributaries on the downstream fecal coliform concentration is not significant and reduction of fecal coliform loads from the upstream is not needed. The errors associated with upstream loading estimation based on short-term data will not affect loading estimation from the downstream watershed.

Nanticoke River mainstem fecal coliform monitoring stations are shown in Figure A-4, and the fecal coliform concentrations from long-term stations are shown in Table A-2. 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.

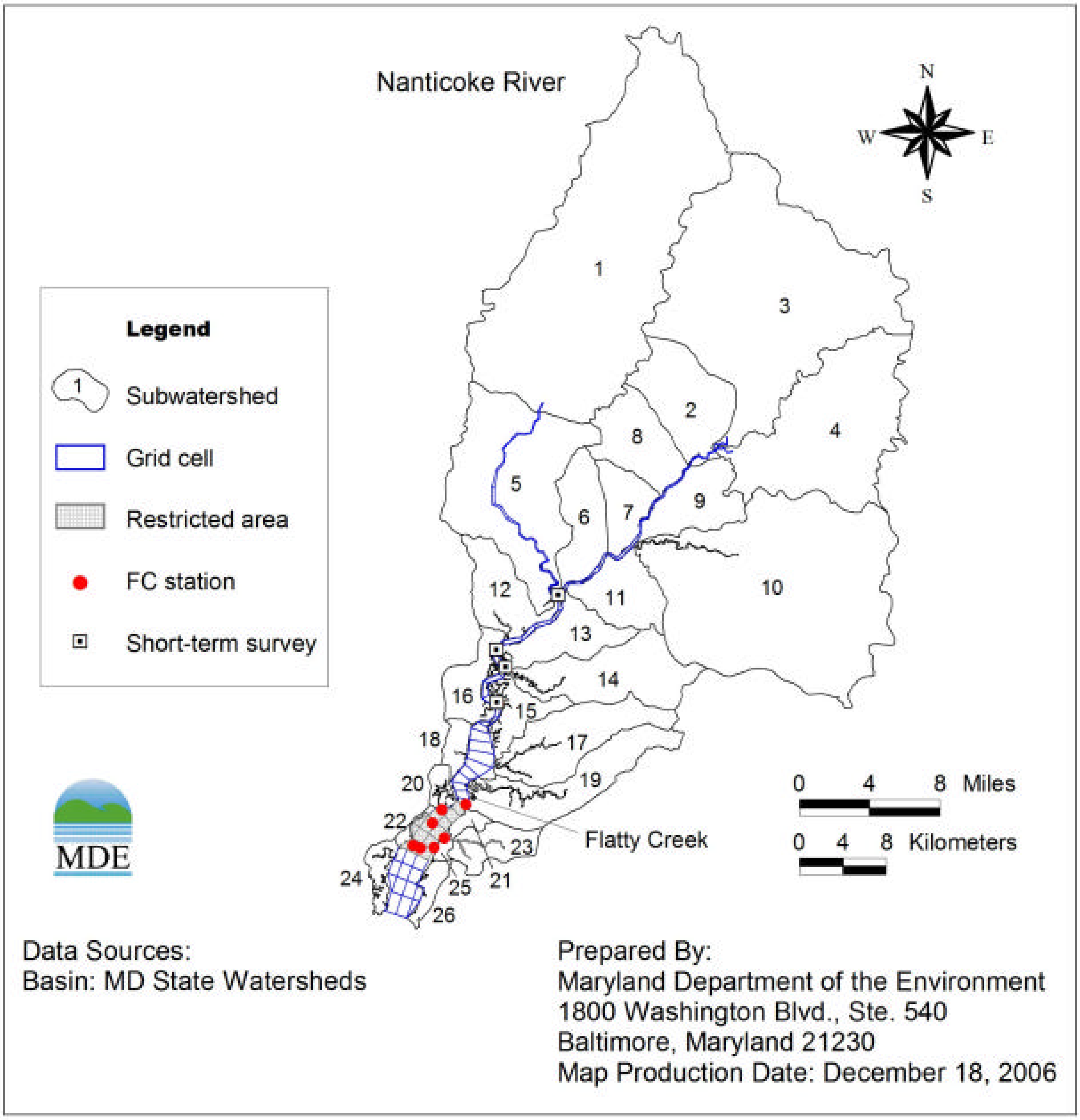

Figure A-4: Locations of Nanticoke River Fecal Coliform Monitoring Stations

Figures A-5 and A-6 show the comparisons of model results of the simulated median and 90th percentile and those from measurements located inside the restricted area, respectively, along the river. It can be seen that the model results are satisfactory. The existing loads for each subwatershed are listed in Table A-3.

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 watershed are used to establish the TMDLs, so that the model simulated fecal coliform concentrations along the river meet the median and 90th percentile standards, respectively. The resultant loads are the allowable loads for the river. The existing and allowable loads are listed in Table A-3.

Table A-2: Nanticoke River Fecal Coliform Statistics (data from 2000-2005)

Area Name	Station	Median		90th Percentile	
		Monitoring Data	Criterion	Monitoring Data	Criterion
		MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml
Nanticoke River	14-05-022	15.00	14	99.98	49
	14-05-024	23.00	14	99.19	49
	14-05-025	23.00	14	97.48	49
	14-05-144	9.10	14	64.60	49
	14-05-144A	9.10	14	40.32	49
	14-05-144B	9.10	14	45.49	49
	14-05-701	9.10	14	51.12	49

Table A-3: TMDL Calculation Results for Nanticoke 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
1-4, 6-11	5.465E+13	5.465E+13	0.0%	7.507E+13	7.507E+13	0.0%
5, 12-18	2.196E+13	3.041E+13	27.8%	3.273E+13	5.283E+13	38.0%
19-26	8.474E+12	1.117E+13	24.1%	2.806E+13	4.172E+13	32.7%
TOTALS	8.508E+13	9.623E+13	11.6%	1.359E+14	1.696E+14	19.9%

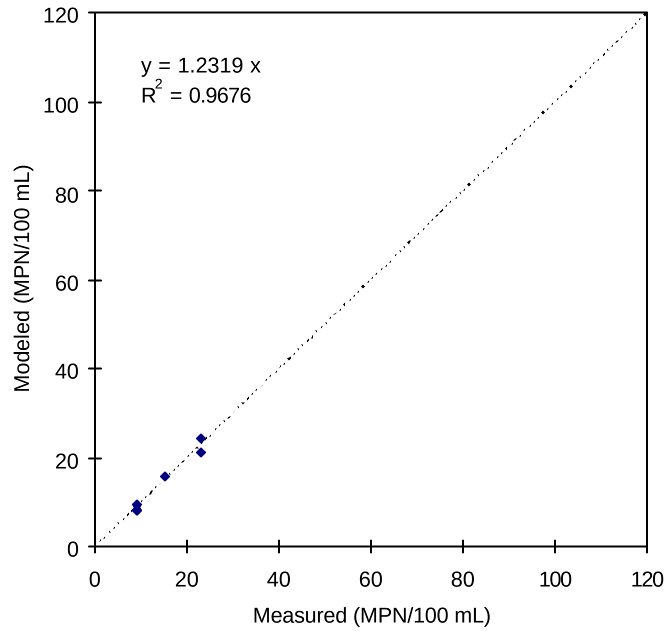

Figure A-5: Model Results vs. Observations for the Median Concentration

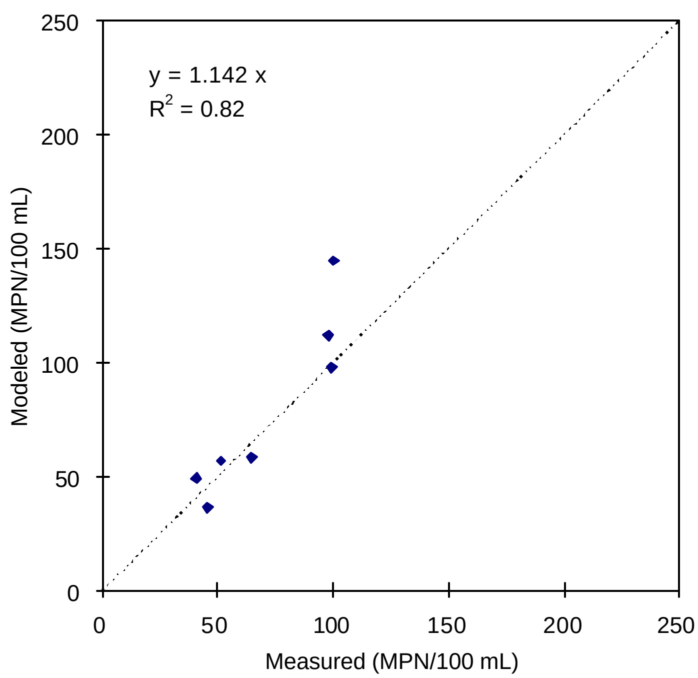

Figure A-6: Model Results vs. Observations for the 90th Percentile Concentration

By comparing the reductions required for median and 90th percentile scenarios, one can see that the 90th percentile requires the largest reduction. Therefore, the reductions required to meet the 90th percentile at each subwatershed are the overall reductions required for the subwatersheds. The allowable loads and required reductions for the watershed are listed in Table A-4.

Table A-4: Load Allocation and Reduction by Subwatershed

Subwatershed	Load Allocation	Required Reduction
1-4, 6-11	7.507E+13	0.0%
5, 12-18	3.273E+13	38.0%
19-26	2.806E+13	32.7%
TOTALS	**1.359E+14**	**19.9%**

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.

<u>Bacteria Source Tracking</u>

In order to assess the potential fecal bacteria sources that contribute to the Nanticoke River, eight stations in the Nanticoke River were selected to evaluate the source characterization through a process called Bacteria Source Tracking (BST). BST is used to provide evidence regarding contributions from anthropogenic sources (*i.e.*, human or livestock) as well as background sources, such as wildlife. Sampling was conducted over a twelve-month period from November 2002 through October 2003. Antibiotic Resistance Analysis (ARA) was the chosen BST method used to determine the potential sources of fecal coliform in the Nanticoke 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. Enterococci isolates were obtained from known source present in the watershed. For the Nanticoke River, these sources included human, dog, chicken, horse, deer, rabbit, fox, raccoon, muskrat, turkey, duck and goose. 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 Nanticoke River basin is located in Frana and Venso (2005) Appendix B.

Results

Water samples were collected monthly from the eight stations in the Nanticoke River. 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 1902 enterococci isolates were analyzed by statistical analysis. Table B-1 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. Twelve percent (12%) of the water isolates were from unknown (unclassified) probable sources.

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[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	56	2.9%
Human	221	11.6%
Livestock	428	22.5%
Wildlife	967	50.8%
*Unknown	230	12.1%
Missing Data	0	
Total w/ Complete Data	1902	
Total	1902	
% Classified		87.9%

* 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	Fall	Winter	Spring	Summer	Total
14-05-022	71	66	55	72	264
14-05-024	71	60	71	48	263
14-05-025	68	45	71	48	232
14-05-144	65	66	66	70	267
14-05-144A	54	64	48	44	210
14-05-144B	69	53	37	72	231
14-05-701	69	42	38	67	216
14-05-702T	61	39	51	68	219

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 Environmental Protection Agency (EPA) also requires that these Total Maximum Daily Load (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 in hydrological conditions, and land use practices. The most probable fecal coliform sources are runoff from wildlife, agricultural practices and livestock, 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 agricultural 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 increased fecal coliform production, 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 it is also related to agricultural activities. Fecal coliform deposition on a field by livestock can be transported into streams and rivers through surface runoff, and thus there tends to be an increase in 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 of fecal coliform may lead to obvious seasonal patterns in fecal coliform concentration in the shellfish growing areas.

A 5-year monthly mean fecal coliform concentration and its standard deviation were calculated for the seven monitoring stations used in this report. The results are presented in Figures C-1 through C-7. It shows that high concentrations occur in the months of September, October, and February at some stations, but high concentrations occur in March and November at other stations in the Nanticoke River restricted shellfish harvesting area. Although seasonal distributions vary from one station to the others, the large standard deviations occur in June and July, and September and November, which often 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.

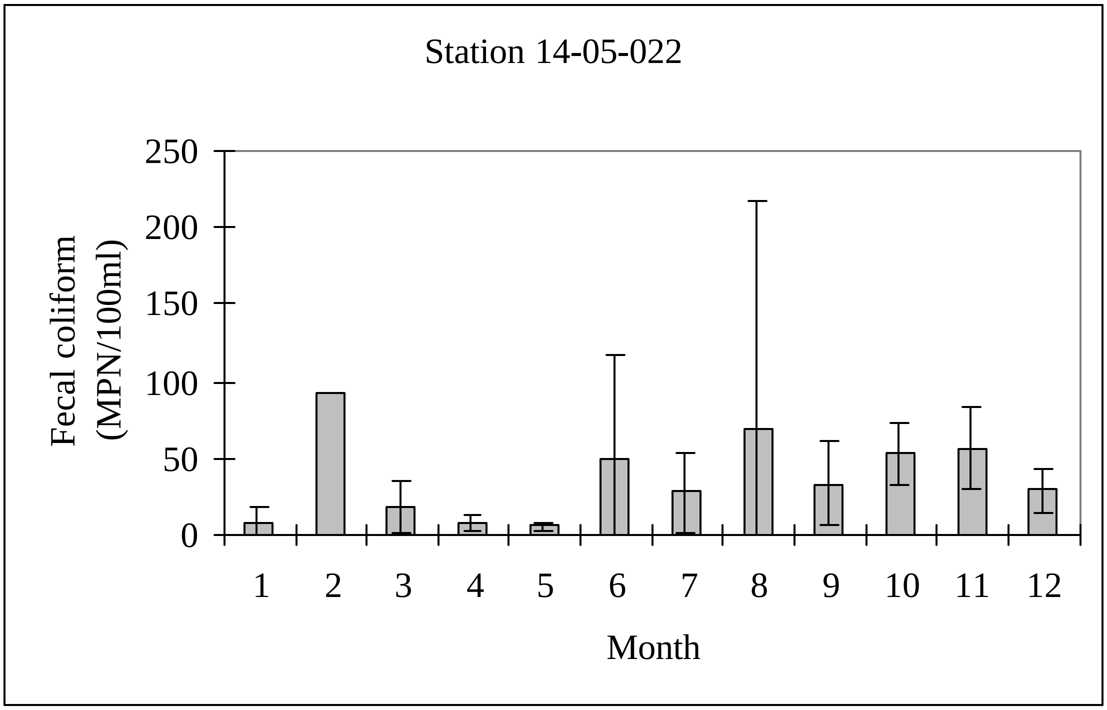

Figure C-1: Seasonality Analysis of Fecal Coliform at Nanticoke River Station 14-05-022

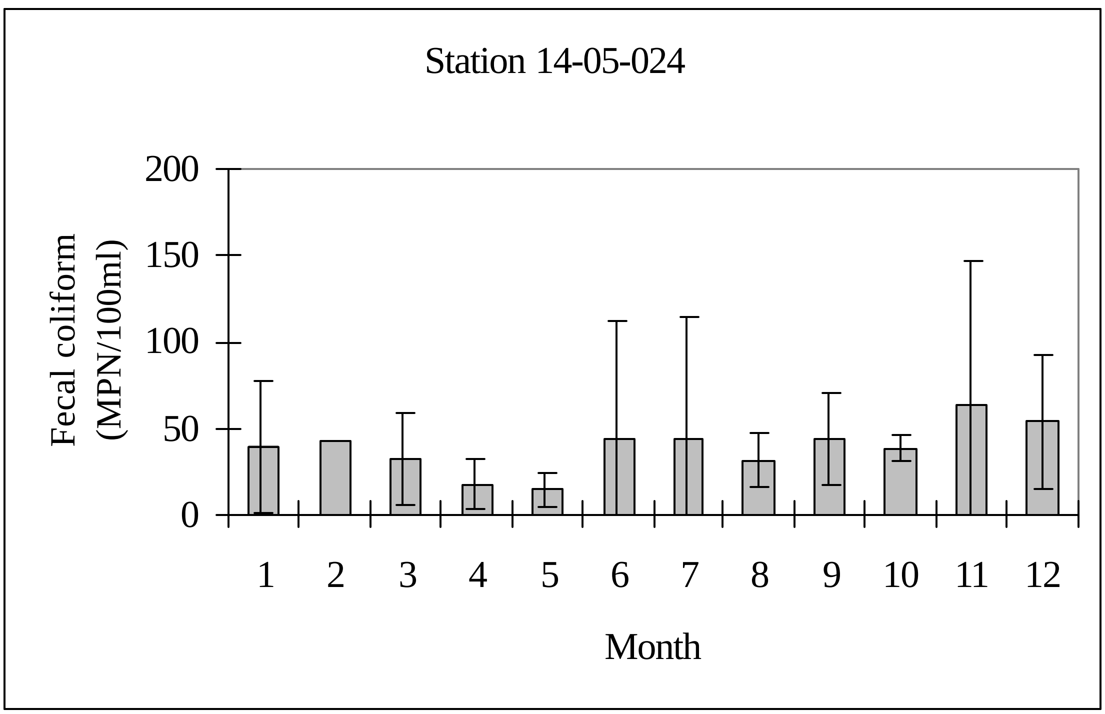

Figure C-2: Seasonality Analysis of Fecal Coliform at Nanticoke River Station 14-05-024

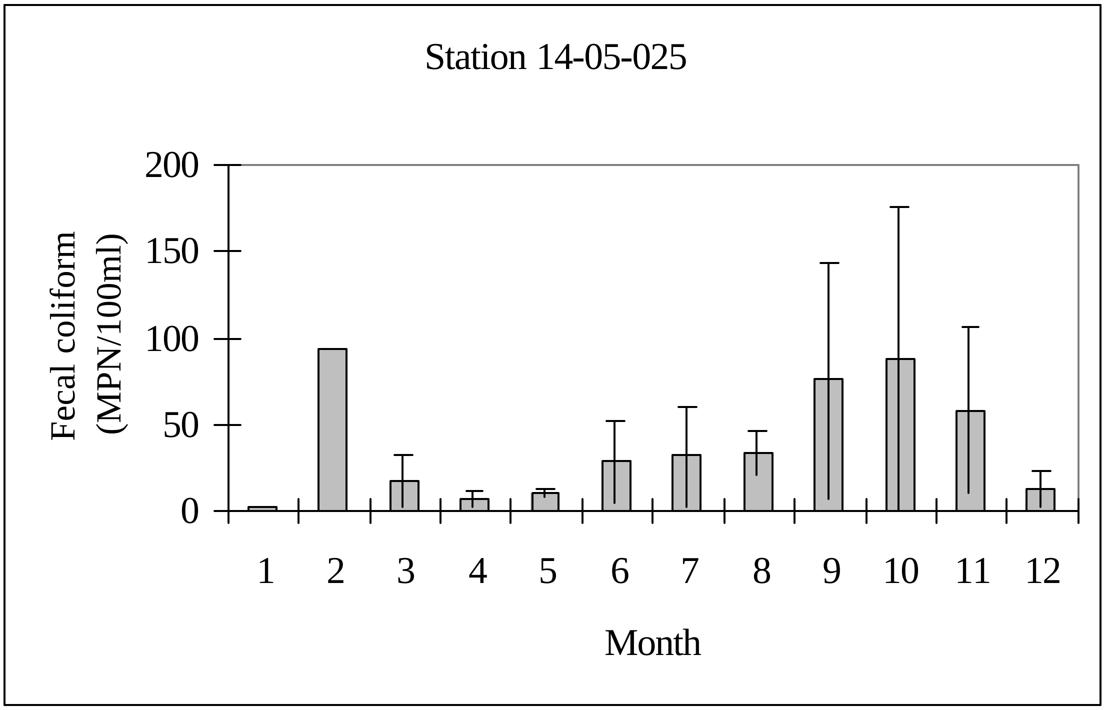

Figure C-3: Seasonality Analysis of Fecal Coliform at Nanticoke River Station 14-05-025

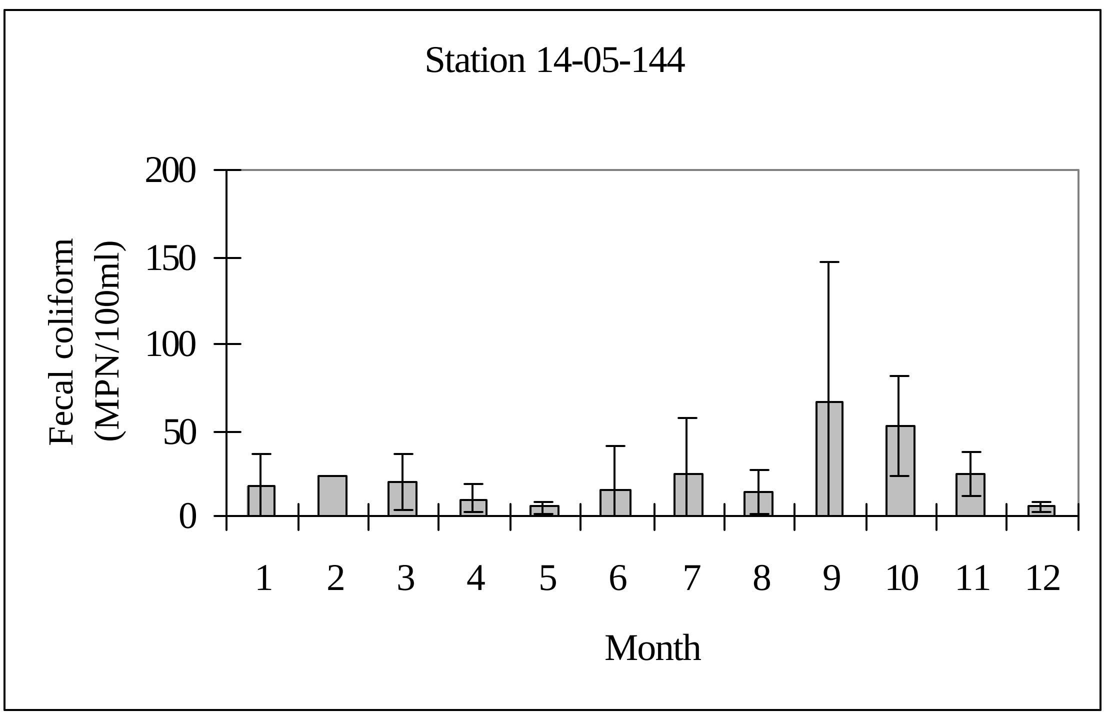

Figure C-4: Seasonality Analysis of Fecal Coliform at Nanticoke River Station 14-05-144

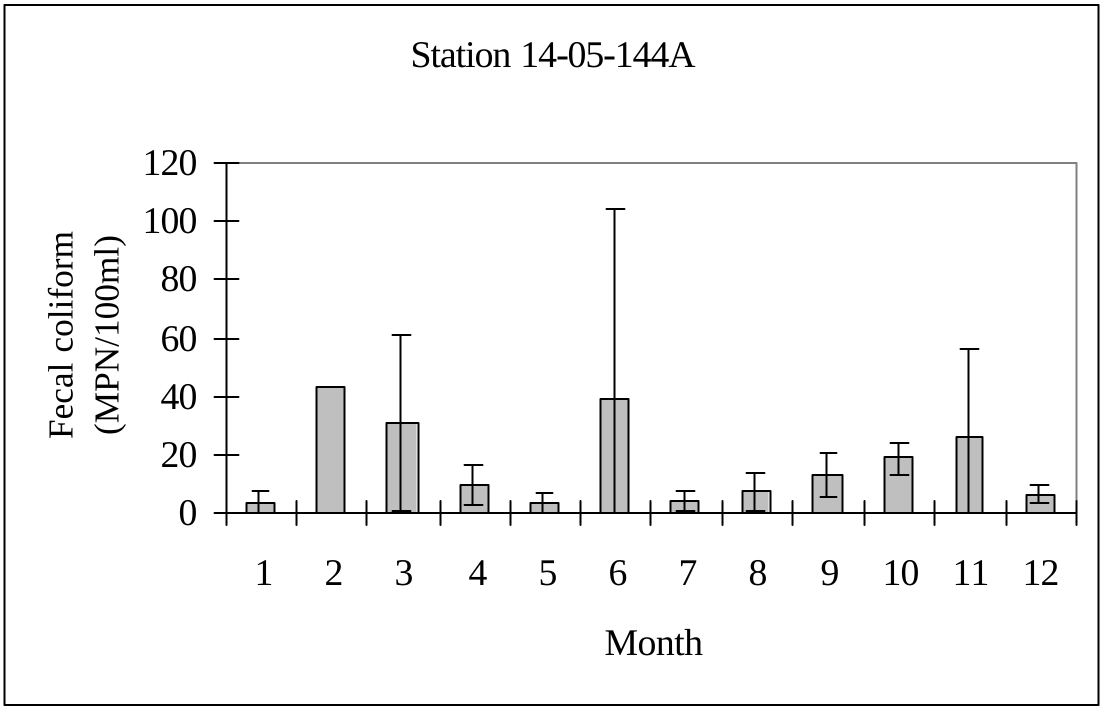

Figure C-5: Seasonality Analysis of Fecal Coliform at Nanticoke River Station 14-05-144A

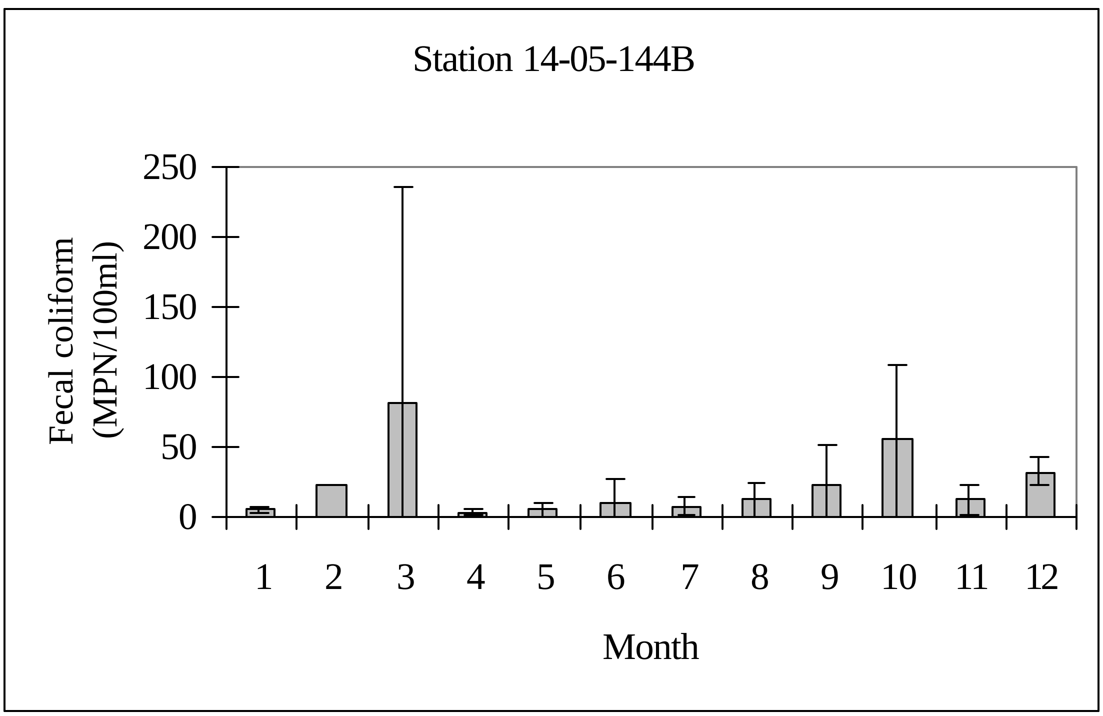

Figure C-6: Seasonality Analysis of Fecal Coliform at Nanticoke River Station 14-05-144B

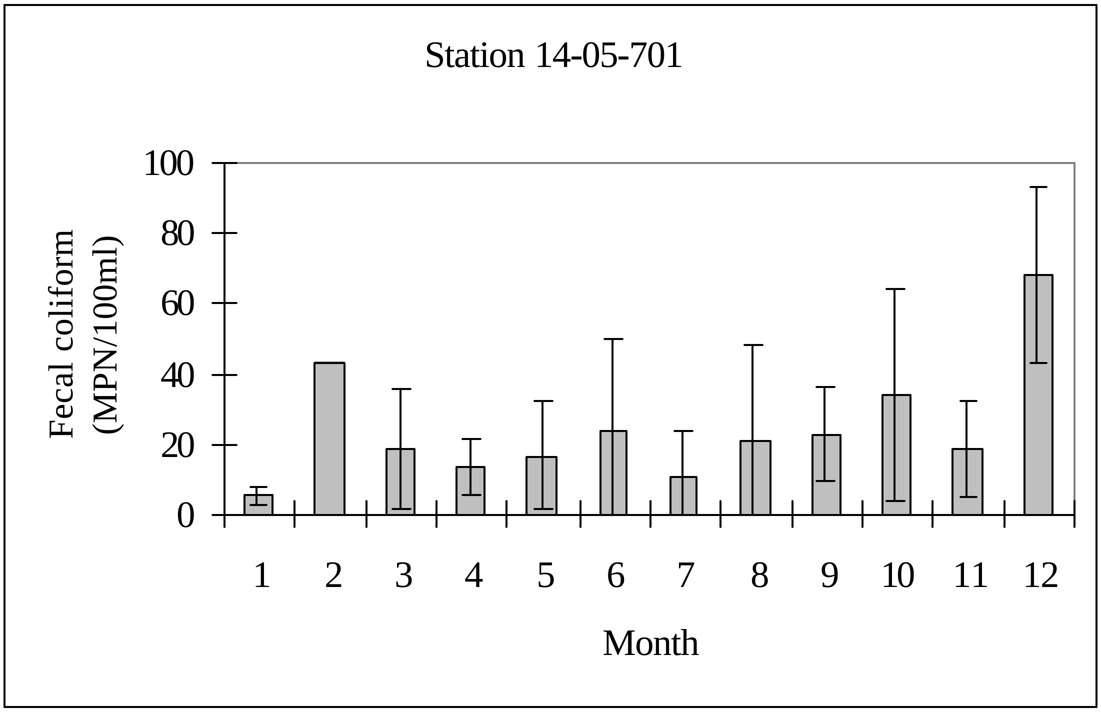

Figure C-7: Seasonality Analysis of Fecal Coliform at Nanticoke River Station 14-05-701

Appendix D. Tabulation of Fecal Coliform Data

This appendix provides a tabulation of fecal coliform values for the monitoring stations of the restricted shellfish harvesting area in the Nanticoke River mainstem of the Nanticoke River basin in Tables D-1 through D-7. These data are plotted in Figures 2.2.2 through 2.2.8 of the main report.

Table D-1: Observed Fecal Coliform Data at Nanticoke River Station 14-05-022

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
6/7/2000	15	1/6/2003	23
6/22/2000	1	3/5/2003	15
7/5/2000	43	3/17/2003	43
7/25/2000	7.3	4/14/2003	15
8/1/2000	3.6	4/22/2003	9.1
9/7/2000	93	5/8/2003	9.1
9/25/2000	43	5/12/2003	3.6
11/2/2000	43	6/2/2003	43
11/27/2000	93	6/16/2003	240
12/12/2000	15	7/1/2003	93
1/17/2001	1	7/16/2003	23
2/13/2001	93	8/4/2003	23
3/8/2001	43	9/8/2003	43
4/16/2001	3.6	9/16/2003	15
4/25/2001	9.1	9/30/2003	9.1
6/4/2001	15	10/6/2003	43
6/18/2001	93	10/27/2003	43
7/9/2001	9.1	11/18/2003	43
7/23/2001	23	3/1/2004	1
8/14/2001	460	3/17/2004	3.6
10/4/2001	43	4/7/2004	1
11/1/2001	93	5/13/2004	3.6
1/22/2002	3	6/1/2004	15
3/18/2002	9.1	6/16/2004	23
3/28/2002	15	7/1/2004	43
5/21/2002	9.1	7/14/2004	15
6/4/2002	1	7/22/2004	9.1
6/19/2002	1	8/5/2004	15
7/17/2002	9.1	8/10/2004	1
8/8/2002	43	8/24/2004	3.6
8/26/2002	3.6	9/7/2004	23
9/16/2002	1	10/6/2004	43

9/30/2002	43	10/26/2004	93
11/6/2002	23	11/22/2004	43
12/10/2002	43	6/21/2005	93

Table D-2: Observed Fecal Coliform Data at Nanticoke River Station 14-05-024

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
6/7/2000	7.2	1/6/2003	23
6/22/2000	23	3/5/2003	15
7/5/2000	9.1	3/17/2003	43
7/25/2000	3.6	4/14/2003	23
8/1/2000	3.6	4/24/2003	9.1
9/7/2000	23	5/8/2003	23
9/25/2000	43	5/12/2003	23
11/2/2000	93	6/2/2003	240
11/27/2000	9.1	6/16/2003	93
12/12/2000	15	7/1/2003	93
1/17/2001	3.6	7/16/2003	240
2/13/2001	43	8/4/2003	43
3/8/2001	93	9/8/2003	43
4/16/2001	9.1	9/16/2003	43
4/25/2001	3.6	9/30/2003	23
6/4/2001	9.1	10/6/2003	23
6/18/2001	43	10/27/2003	43
7/9/2001	1	11/18/2003	9.1
7/23/2001	23	3/1/2004	23
8/14/2001	43	3/17/2004	7.3
10/4/2001	39	4/7/2004	43
11/1/2001	9.1	5/13/2004	1
1/22/2002	93	6/1/2004	23
3/18/2002	23	6/16/2004	3.6
3/28/2002	23	7/1/2004	23
5/21/2002	9.1	7/14/2004	23
6/4/2002	1	7/22/2004	23
6/19/2002	3.6	8/5/2004	43
7/17/2002	9.1	8/10/2004	9.1
8/6/2002	23	8/24/2004	43
8/8/2002	43	9/7/2004	93
9/16/2002	9.1	10/6/2004	43
9/30/2002	75	10/26/2004	43
11/6/2002	240	11/22/2004	15
12/10/2002	93	6/21/2005	43

Table D-3: Observed Fecal Coliform Data at Nanticoke River Station 14-05-025

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
6/7/2000	23	1/6/2003	3.6
6/22/2000	23	3/5/2003	3.6
7/5/2000	43	3/17/2003	23
7/25/2000	23	4/14/2003	15
8/1/2000	43	4/24/2003	1
9/7/2000	43	5/8/2003	9.1
9/25/2000	93	5/12/2003	9.1
11/2/2000	23	6/2/2003	93
11/27/2000	21	6/16/2003	23
12/12/2000	3.6	7/1/2003	75
1/17/2001	3.6	7/16/2003	23
2/13/2001	93	8/4/2003	7.3
3/8/2001	43	9/8/2003	93
4/16/2001	3.6	9/16/2003	43
4/25/2001	9.1	9/30/2003	39
6/4/2001	23	10/27/2003	43
6/18/2001	43	11/18/2003	150
7/9/2001	7.3	3/1/2004	1
7/23/2001	1	3/17/2004	29
8/14/2001	43	4/7/2004	7.3
10/4/2001	43	5/13/2004	9.1
11/1/2001	93	6/1/2004	23
1/22/2002	3.6	6/16/2004	9.1
3/18/2002	23	7/1/2004	23
3/28/2002	3.6	7/14/2004	93
5/21/2002	15	7/22/2004	23
6/4/2002	1	8/5/2004	23
6/19/2002	9.1	8/10/2004	23
7/17/2002	3.6	8/24/2004	43
8/8/2002	43	9/7/2004	240
8/26/2002	43	10/6/2004	23
9/16/2002	43	10/26/2004	240
9/30/2002	9.1	11/22/2004	43
11/6/2002	20	6/21/2005	43
12/10/2002	23		

Table D-4: Observed Fecal Coliform Data at Nanticoke River Station 14-05-144

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
6/7/2000	9.1	1/6/2003	9.1
6/22/2000	3.6	3/5/2003	43
7/5/2000	43	3/17/2003	43
7/25/2000	1	4/14/2003	23
8/1/2000	23	4/24/2003	3.6
9/7/2000	9.1	5/8/2003	7.3
9/25/2000	150	5/12/2003	9.1
11/2/2000	23	6/2/2003	23
11/27/2000	43	6/16/2003	3.6
12/12/2000	9.1	7/1/2003	9.1
1/17/2001	1	7/16/2003	3.6
2/13/2001	23	8/4/2003	23
3/8/2001	9.1	9/8/2003	23
4/16/2001	1	9/16/2003	23
4/25/2001	15	9/30/2003	240
6/4/2001	9.1	10/6/2003	9.1
6/18/2001	93	10/27/2003	43
7/9/2001	75	11/18/2003	9.1
7/23/2001	14	3/1/2004	1
8/14/2001	43	3/17/2004	9.1
10/4/2001	75	4/7/2004	9.1
11/1/2001	39	5/13/2004	1
1/22/2002	43	6/1/2004	1
3/18/2002	15	6/16/2004	9.1
3/28/2002	23	7/1/2004	93
5/21/2002	3.6	7/14/2004	3.6
6/4/2002	3.6	7/22/2004	3.6
6/19/2002	1	8/5/2004	9.1
7/17/2002	1	8/10/2004	1
8/8/2002	3.6	8/24/2004	3.6
8/26/2002	9.1	9/7/2004	75
9/16/2002	9.1	10/6/2004	39
9/30/2002	1	10/26/2004	93
11/6/2002	23	11/22/2004	9.1
12/10/2002	3.6	6/21/2005	15

Table D-5: Observed Fecal Coliform Data at Nanticoke River Station 14-05-144A

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
6/7/2000	43	1/6/2003	1
6/22/2000	1	3/5/2003	93
7/5/2000	3.6	3/17/2003	43
7/25/2000	3.6	4/14/2003	3.6
8/1/2000	3.6	4/24/2003	23
9/7/2000	23	5/8/2003	9.1
9/25/2000	23	5/12/2003	3.6
11/2/2000	15	6/2/2003	43
11/27/2000	93	6/16/2003	23
12/12/2000	9.1	7/1/2003	9.1
1/17/2001	9.1	7/16/2003	1
2/13/2001	43	8/4/2003	9.1
3/8/2001	43	9/8/2003	9.1
4/16/2001	9.1	9/16/2003	9.1
4/25/2001	9.1	9/30/2003	23
6/4/2001	3.6	10/6/2003	15
6/18/2001	240	10/27/2003	23
7/9/2001	3.6	11/18/2003	9.1
7/23/2001	9.1	3/1/2004	9.1
8/14/2001	23	3/17/2004	3.6
10/4/2001	23	4/7/2004	3.6
11/1/2001	23	5/13/2004	1
1/22/2002	1	6/1/2004	43
3/18/2002	1	6/16/2004	3.6
3/28/2002	23	7/1/2004	9.1
5/21/2002	1	7/14/2004	3.6
6/4/2002	1	7/22/2004	1
6/19/2002	3.6	8/5/2004	9.1
7/17/2002	1	8/10/2004	1
8/8/2002	3	8/24/2004	1
8/26/2002	9.1	9/7/2004	3.6
9/16/2002	3.6	10/6/2004	9.1
9/30/2002	9.1	10/26/2004	23
11/6/2002	7.2	11/22/2004	7.3
12/10/2002	3.6	6/21/2005	23

Table D-6: Observed Fecal Coliform Data at Nanticoke River Station 14-05-144B

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
6/7/2000	7.3	1/6/2003	3.6
6/22/2000	1	3/5/2003	23
7/5/2000	1	3/17/2003	43
7/25/2000	9.1	4/14/2003	3.6
8/1/2000	1	4/24/2003	1
9/7/2000	14	5/8/2003	15
9/25/2000	7.3	5/12/2003	1
11/2/2000	3.6	6/2/2003	9.1
11/27/2000	23	6/16/2003	7.3
12/12/2000	23	7/1/2003	15
1/17/2001	3.6	7/16/2003	1
2/13/2001	23	8/4/2003	3.6
3/8/2001	460	9/8/2003	21
4/16/2001	1	9/16/2003	1
4/25/2001	7.3	9/30/2003	23
6/4/2001	3.6	10/27/2003	23
6/18/2001	43	11/18/2003	23
7/9/2001	3.6	3/1/2004	3.6
7/23/2001	23	3/17/2004	9.1
8/14/2001	43	4/7/2004	3.6
10/4/2001	150	5/13/2004	3.6
11/1/2001	23	6/1/2004	3.6
1/22/2002	9.1	6/16/2004	1
3/18/2002	23	7/1/2004	7.3
3/28/2002	9.1	7/14/2004	9.1
5/21/2002	1	7/22/2004	1
6/4/2002	1	8/5/2004	9.1
6/19/2002	3.6	8/10/2004	7.3
7/17/2002	9.1	8/24/2004	9.1
8/8/2002	1	9/7/2004	93
8/26/2002	23	10/6/2004	23
9/16/2002	9.1	10/26/2004	23
9/30/2002	23	11/22/2004	1
11/6/2002	1	6/21/2005	43
12/10/2002	43		

Table D-7: Observed Fecal Coliform Data at Nanticoke River Station 14-05-701

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
6/7/2000	7.3	1/6/2003	3.6
6/22/2000	15	3/5/2003	43
7/5/2000	3.6	3/17/2003	23
7/25/2000	23	4/14/2003	9.1
8/1/2000	1	4/22/2003	3.6
9/7/2000	43	5/8/2003	39
9/25/2000	23	5/12/2003	1
11/2/2000	43	6/2/2003	43
11/27/2000	23	6/16/2003	43
12/12/2000	43	7/1/2003	3.6
1/17/2001	3.6	7/16/2003	3.6
2/13/2001	43	8/4/2003	9.1
3/8/2001	43	9/8/2003	23
4/16/2001	9.1	9/16/2003	9.1
4/25/2001	23	9/30/2003	15
6/4/2001	9.1	10/6/2003	7.3
6/18/2001	93	10/27/2003	23
7/9/2001	1	11/18/2003	9.1
7/23/2001	15	3/1/2004	3
8/14/2001	93	3/17/2004	3.6
10/4/2001	23	4/7/2004	23
11/1/2001	23	5/13/2004	3.6
1/22/2002	9.1	6/1/2004	15
3/18/2002	9.1	6/16/2004	3.6
3/28/2002	3.6	7/1/2004	3.6
5/21/2002	23	7/14/2004	43
6/4/2002	3.6	7/22/2004	3.6
6/19/2002	1	8/5/2004	9.1
7/17/2002	9.1	8/10/2004	9.1
8/6/2002	23	8/24/2004	9.1
8/8/2002	9.1	9/7/2004	43
9/16/2002	23	10/6/2004	23
9/30/2002	3	10/26/2004	93
11/6/2002	3.6	11/22/2004	9.1
12/10/2002	93	6/21/2005	23

Appendix E. Point Source Permits and Loads

Point sources in the Nanticoke River watershed include municipal and industrial point source facilities. There are four municipal point source facilities that have permits regulating the discharge of fecal coliform to the Nanticoke River (or its tributaries). They are Vienna Waste Water Treatment Plant (WWTP) with National Pollution Discharge Elimination System (NPDES) permit number MD0020664, Mardela High School WWTP (NPDES number MD0024279), Sharptown WWTP (NPDES number MD0052175), and Hebron WWTP (NPDES number MD0059617). There are four industrial point sources that have NPDES permit numbers: MD0061115 (Dececco, Inc.), MD0066532 (J.V. Wells, Inc.), MD0000094 (Delmarva Power & Light Co.), and MD0051284 (Howard Sand & Gravel, Inc). These four point source facilities have no permits to discharge fecal coliform. It should be noted that none of the permitted facilities discharge directly to shellfish waters, since the nearest is located approximately 9 miles from shellfish harvesting waters.

This appendix provides a tabulation of fecal coliform permits and loads information for the four municipal point sources listed above which have permits regulating the discharge of fecal coliform to the Nanticoke River (Table E-1).

Table E-1: A Summary of Point Source Facility Discharge

Facility Name	NPDES Permit Number	Design Flow (MGD)	Permitted FC Concentration in MPN/100ml	Permitted FC Loads in MPN/Day	
				Median	90th Percentile
Vienna WWTP	MD0020664	0.1375	200 (monthly log mean)	1.04E+09	3.38E+09
Mardela High School WWTP	MD0024279	0.014	126 (monthly log mean for E. Coli)	1.04E+08	3.37E+08
Sharptown WWTP	MD0052175	0.15	200 (monthly log mean)	1.14E+09	3.69E+09
Hebron WWTP	MD0059617	0.101	126 (monthly log mean for E. Coli)	7.47E+08	2.43E+09
Total				3.03E+09	9.84E+09