Total Maximum Daily Loads of Fecal Coliform for Restricted Shellfish Harvesting Areas in Whitehall Creek, Indian Creek, Goose Creek, Warwick River, and San Domingo Creek for the Lower Choptank River Basin in Dorchester and Talbot Counties, Maryland

FINAL

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List of Abbreviations

BMP	Best Management Practice
BST	Bacteria Source Tracking
CAFO	Confined Animal Feeding Operations
cfs	Cubic Feet per Second
CFR	Code of Federal Regulations
COMAR	Code of Maryland Regulations
CSO	Combined Sewer Overflow
CWA	Clean Water Act
CWP	Center for Watershed Protection
EPA	Environmental Protection Agency
FA	Future Allocation
FDA	U.S. Food and Drug Administration
GIS	Geographic Information System
km	Kilometer
LA	Load Allocation
LMM	Long-term Moving Median
MACS	Maryland Agricultural Cost Share Program
MASS	Maryland Agricultural Statistics Service
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
ml	Milliliter(s)
MOS	Margin of Safety
MPN	Most Probable Number
MRLC	Multi-Resolution Land Cover
MSSCC	Maryland State's Soil Conservation Committee
MS4	Municipal Separate Storm Sewer System
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NSSP	National Shellfish Sanitation Program
SSO	Sanitary Sewer Overflows
T^{-1}	Per Tidal Cycle
TMDL	Total Maximum Daily Load
USDA	US Department of Agriculture
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 current 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.

Lower Choptank River (basin number 02-13-04-03) was first identified on the 1996 303(d) List submitted to U.S. Environmental Protection Agency (EPA) by the Maryland Department of the Environment (MDE) as impaired by nutrients, sediments, and fecal coliform in the tidal portions, with listings of biological impacts in the non-tidal portions added in 2002. On the 2004 303(d) List, the fecal coliform impairment was clarified with the identification of five specific restricted shellfish harvesting areas within the basin. This document addresses the fecal coliform impairment listings of the areas identified: Whitehall Creek, Indian Creek, Goose Creek, Warwick River, and San Domingo Creek. The nutrient, sediment, bacteria, and biological impairments within other parts of the Lower Choptank River basin will be addressed at a future date.

It should be noted that a TMDL analysis of the northwest branch of the San Domingo Creek was completed by MDE and approved by EPA in June 2005, the report for which is on the following website: http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/Pub_Notice/index.asp. However, that site was reported separately due to its inclusion in another watershed. Additionally, TMDL reports for the main stem portion of the lower Choptank will be submitted subsequent to the current report due to the need to utilize a three-dimensional modeling approach at sites in this portion of the Lower Choptank.

A steady state tidal prism model was used to estimate current fecal coliform loads based on volume of water and concentration of fecal coliform, and to establish allowable loads for the restricted shellfish harvesting area in the Lower Choptank River Basin. The tidal prism model incorporates influences of both freshwater discharge and tidal flushing for the area, thereby representing the hydrodynamics of the selected restricted shellfish harvesting area. The potential sources (human, livestock, pets and wildlife) are identified by determining the proportional contribution of each source based on animal/source density per land use acre multiplied by the fecal coliform production.

The allowable loads for the restricted shellfish harvesting area were then 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. 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 Lower Choptank Basin for fecal coliform median loads and 90th percentile loads are as follows:

Whitehall Creek:
The median load of fecal coliform TMDL = 2.96×10^{10} counts per day
The 90^{th} percentile of fecal coliform TMDL = 1.04×10^{11} counts per day

Indian Creek:
The median load of fecal coliform TMDL = 1.71×10^{10} counts per day
The 90^{th} percentile of fecal coliform TMDL = 5.99×10^{10} counts per day

Goose Creek:
The median load of fecal coliform TMDL = 9.57×10^{09} counts per day
The 90^{th} percentile of fecal coliform TMDL = 3.35×10^{10} counts per day

Warwick River:
The median load of fecal coliform TMDL = 7.15×10^{10} counts per day
The 90^{th} percentile of fecal coliform TMDL = 2.50×10^{11} counts per day

San Domingo Creek:
The median load of fecal coliform TMDL = 4.18×10^{10} counts per day
The 90^{th} percentile of fecal coliform TMDL = 1.46×10^{11} counts per day

The goal of load allocation is to determine the estimated loads for the watershed of each restricted shellfish harvesting area while ensuring that the water quality standard can be attained. For restricted shellfish harvesting areas in the Lower Choptank River Basin, the 90^{th} percentile criterion requires the greatest reductions – approximately 67%, 84%, 70%, 85%, and 65%, respectively, for the restricted shellfish harvesting areas of Whitehall Creek, Indian Creek, Goose Creek, Warwick River, and San Domingo Creek. Therefore, the load reduction scenario is developed based on the 90^{th} percentile load TMDL, and will result in the load allocation meeting water quality standards.

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 and giving consideration to the relative ease of implementation and cost. The source contributions estimated from the watershed analysis may be used as a tool to target and prioritize initial implementation efforts. To confirm the bacteria source allocations, MDE is conducting a one-year bacteria source tracking (BST) study for each restricted shellfish harvesting area identified in this report. Continued monitoring will be undertaken MDE's Shellfish Certification Division and 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. 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 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 sewage 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 whereby the designated uses for this restricted shellfish harvesting area will be met.

In both the 1996 and 1998 Maryland 303(d) Lists of Impaired Waterbodies, many 8-digit watersheds were identified as being impaired, since these waterbodies are closed to shellfish harvesting. Shellfish waters are continuously monitored, and openings and closings occur routinely. The 2004 303(d) List indicates currently restricted shellfish harvesting areas within an 8-digit watershed that require TMDLs.

Lower Choptank River (basin number 02-13-04-03) was first identified on the 1996 303(d) list submitted to U.S. Environmental Protection Agency (EPA) by the Maryland Department of the Environment (MDE) as impaired by nutrients, sediments, and fecal coliform in the tidal portions, with listings of biological impacts in the non-tidal portions added in 2002. On the 2004 303(d) List, the fecal coliform impairment was clarified by the identification of five specific restricted shellfish harvesting areas within the basin. This document addresses the fecal coliform impairment listings of the areas identified: Whitehall Creek, Indian Creek, Goose Creek, Warwick River, and San Domingo Creek. Sites impaired for fecal coliform in the main stem portion of the Choptank River will be addressed in a subsequent report, since the analysis of these sites involves using a three-dimensional modeling capability. The basis of the shellfish closure is fecal coliform data from the shellfish water quality monitoring indicating that either the median or 90th percentile standard had been exceeded, thereby resulting in the areas being classified as "restricted" or closed to direct harvest. The nutrient, sediment and biological impairments within the Lower Choptank River basin will be addressed at a future date.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Five restricted shellfish harvesting areas are addressed in this report. All five areas are located on Maryland's Eastern Shore; four of these areas (Whitehall Creek, Indian Creek, Goose Creek, and Warwick River) are in Dorchester County, MD and the fifth area (San Domingo Creek) is in Talbot County, MD. The first two restricted shellfish harvesting areas, Whitehall Creek and Indian Creek, enter the Lower Choptank River from the southeast, as shown in Figure 2.1.1. Both these creeks have lengths of approximately 1.5 km and average widths of 0.2 km. To the northeast, the third and fourth areas, Goose Creek and Warwick River, enter the Lower Choptank River from the east. Goose Creek has both a length and width of about 300 to 400 meters, whereas the Warwick River has a length of 2.8 km and an average width of approximately 0.2 km, widening to approximately 1 km at its mouth. The fifth and last area, San Domingo Creek, is located approximately 20 km to the northwest. It enters the Lower Choptank River from the north downstream of the other shellfish harvesting areas. San Domingo Creek is approximately 900 m in length and 200 to 300 m wide. The drainage areas of Whitehall Creek, Indian Creek, Goose Creek, Warwick River, and San Domingo Creek are, respectively, 909.1 acres (3.7 km^2), 1702.4 acres (6.9 km^2), 588.5 (2.4 km^2), 4,055.7 acres (16.4 km^2), and 606.9 acres (2.5 km^2).

The Lower Choptank River basin consists of mixed soil beds and runoff characteristics. The area is characterized as having moderate to high runoff. Whitehall Creek and Warwick River basins are characterized as having moderate runoff, Goose Creek and San Domingo Creek have high runoff, and Indian Creek has moderate to high runoff. The dominant tide in this region is the lunar semi-diurnal (M_2) tide with tidal ranges of 0.62 m, 0.62 m, 0.62 m, 0.55 and 0.49 m, respectively, in the restricted shellfish harvesting area portions of Whitehall Creek, Indian Creek, Goose Creek, Warwick River, and San Domingo Creek with a tidal period of 12.42 hours (National Oceanic and Atmospheric Administration (NOAA), 2004). Please refer to Table 2.1.1 for the mean volume and mean water depth of each restricted shellfish harvesting area.

Table 2.1.1: Physical Characteristics of the Lower Choptank River Restricted Shellfish Harvesting Areas

Restricted Shellfish Area	Mean Water Volume in m^3	Mean Water Depth in m
Whitehall Creek	297,457	0.73
Indian Creek	163,760	0.76
Goose Creek	94,050	0.78
Warwick River	705,270	0.85
San Domingo Creek	425,862	0.92

The 2000 Maryland Department of Planning (MDP) land use/land cover data show that the watershed can be characterized as rural for Whitehall Creek, Indian Creek, Goose Creek, Warwick River, and San Domingo Creek with over 60% cropland and forest land use for each. The land use information for these restricted shellfish harvesting areas in the Lower Choptank River Basin are shown in Table 2.1.2 through Table 2.1.6 and Figure 2.1.2 through Figure 2.1.6. Residential urban land use identified in these tables includes low-density residential, medium-density residential, and high-density residential. Non-residential urban land use in these tables includes commercial, industrial, institutional, extractive, and open urban land.

There are two restricted areas known as San Domingo Creek, which are its two branches, shown in Figure 2.1.7. It should be noted a TMDL analysis of the branch towards the northwest was approved by the EPA in June 2005. The final report can be seen at the following website: http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/Pub_Notice/index.asp
The branch towards the southeast comprises the site that this TMDL report assesses.

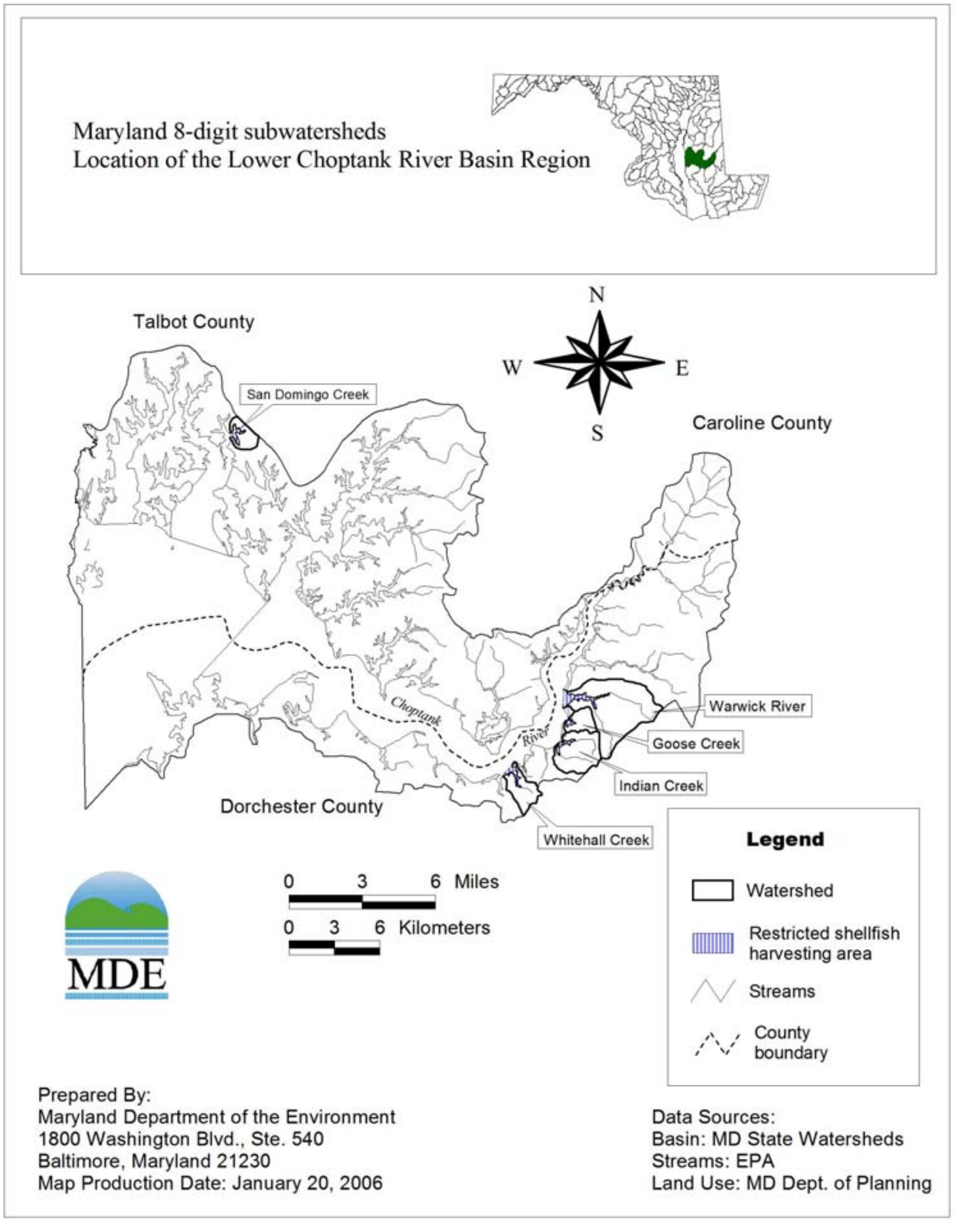


Figure 2.1.1: Location Map of the Lower Choptank River Basin

Table 2.1.2: Land Use Percentage Distribution for Whitehall Creek

Land Type	Acreage	Percentage
Residential urban	117.9	13.0
Non-Residential urban	47.9	5.3
Cropland	490.2	53.9
Pasture	0.0	0.0
Feedlot	0.0	0.0
Forest	145.3	16.0
Water	13.8	1.5
Wetlands	94.0	10.3
Barren	0. 0	0.0
Totals	**909.1**	**100.0**

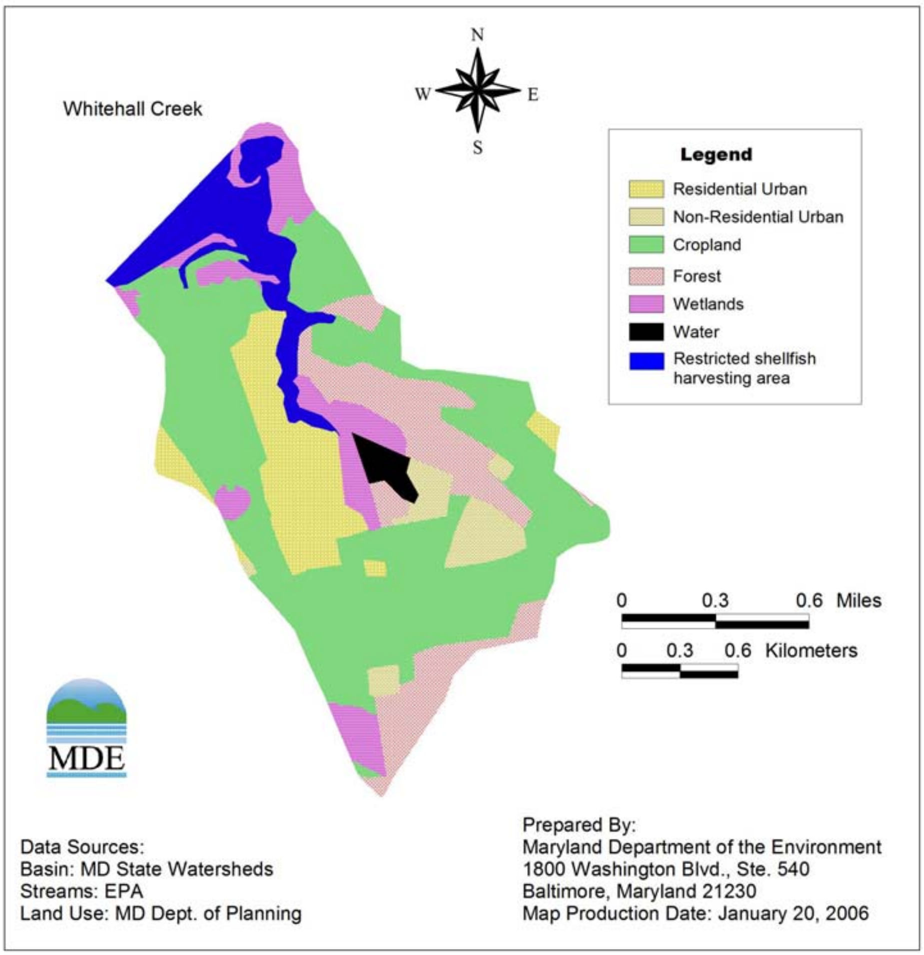


Figure 2.1.2: Land Use in the Whitehall Creek Basin

Table 2.1.3: Land Use Percentage Distribution for Indian Creek

Land Type	Acreage	Percentage
Residential urban	223.7	13.1
Non-Residential urban	13.7	0.8
Cropland	715.1	42.0
Pasture	0.0	0.0
Feedlot	0.0	0.0
Forest	697.9	41.0
Water	0.0	0.0
Wetlands	52.0	3.1
Barren	0.0	0.0
Totals	**1702.4**	**100.0**

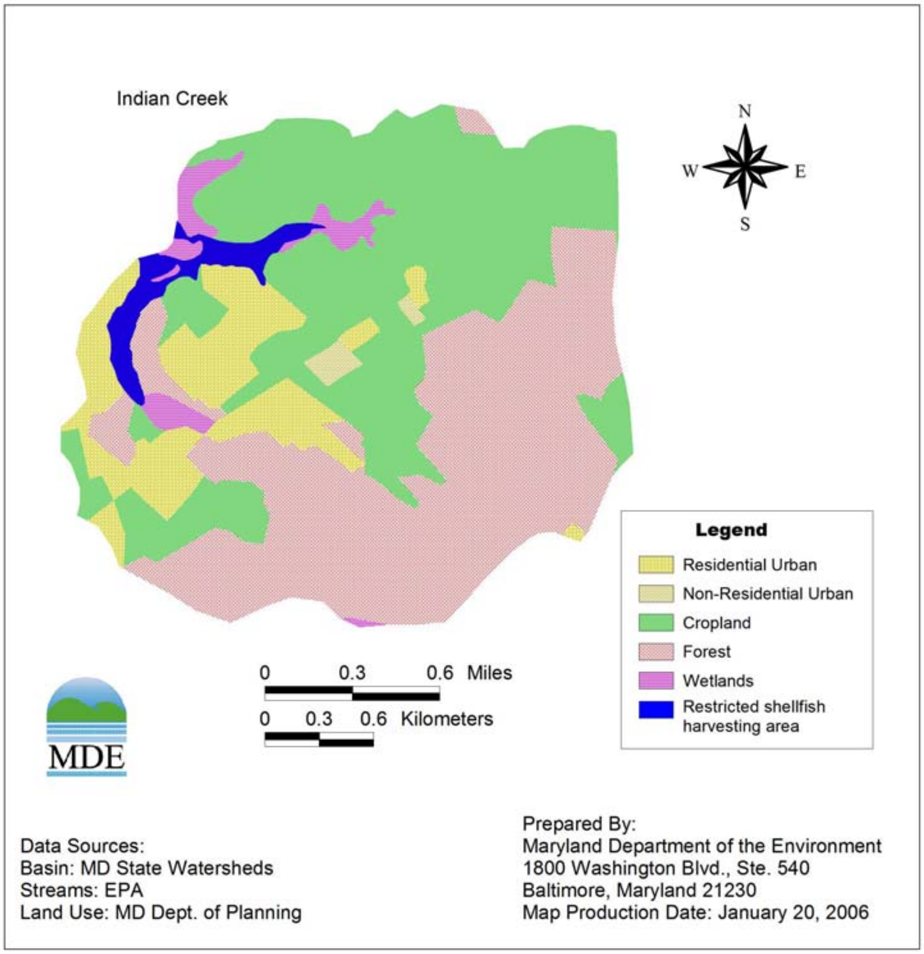


Figure 2.1.3: Land Use in the Indian Creek Basin

Table 2.1.4: Land Use Percentage Distribution for Goose Creek

Land Type	Acreage	Percentage
Residential urban	47.0	8.0
Non-Residential urban	8.3	1.4
Cropland	363.3	61.7
Pasture	0.0	0.0
Feedlot	0.0	0.0
Forest	149.9	25.5
Water	0.0	0.0
Wetlands	20.0	3.4
Barren	0.0	0.0
Totals	**588.5**	**100.0**

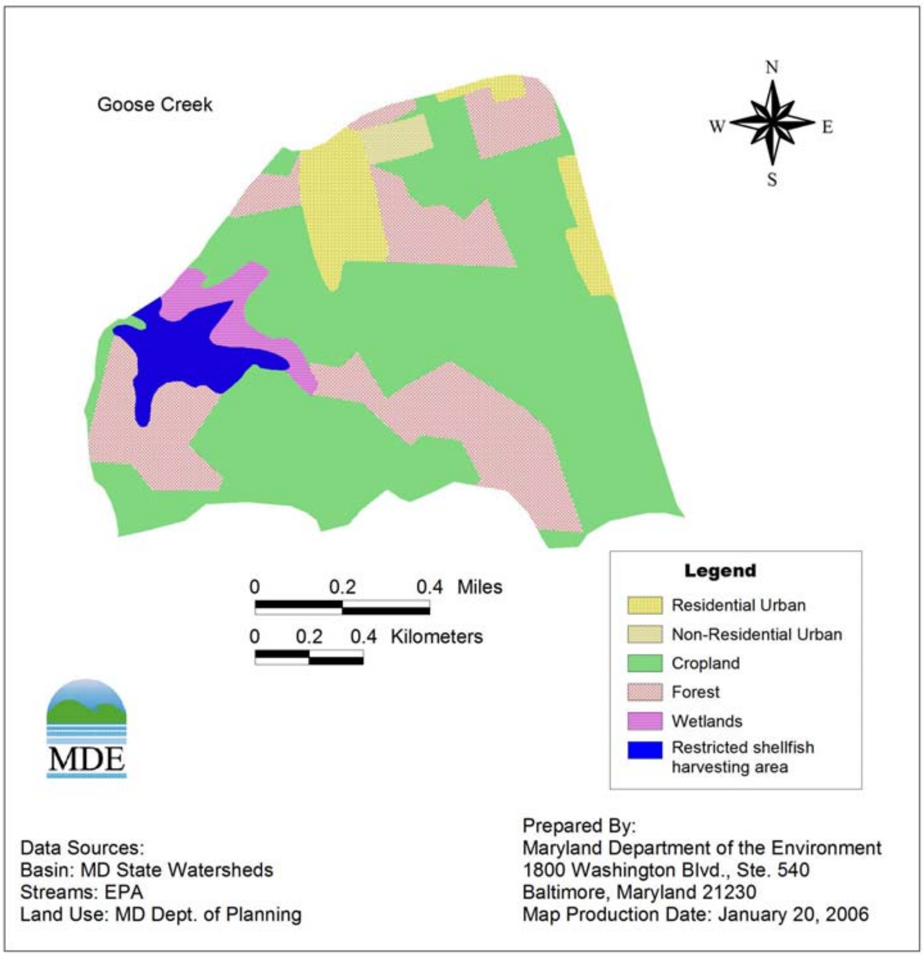


Figure 2.1.4: Land Use in the Goose Creek Basin

Table 2.1.5: Land Use Percentage Distribution for Warwick River

Land Type	Acreage	Percentage
Residential urban	392.2	9.7
Non-Residential urban	153.7	3.8
Cropland	2693.3	66.4
Pasture	11.6	0.3
Feedlot	0.0	0.0
Forest	737.7	18.2
Water	0.0	0.0
Wetlands	67.3	1.7
Barren	0.0	0.0
Totals	**4055.7**	**100.0**

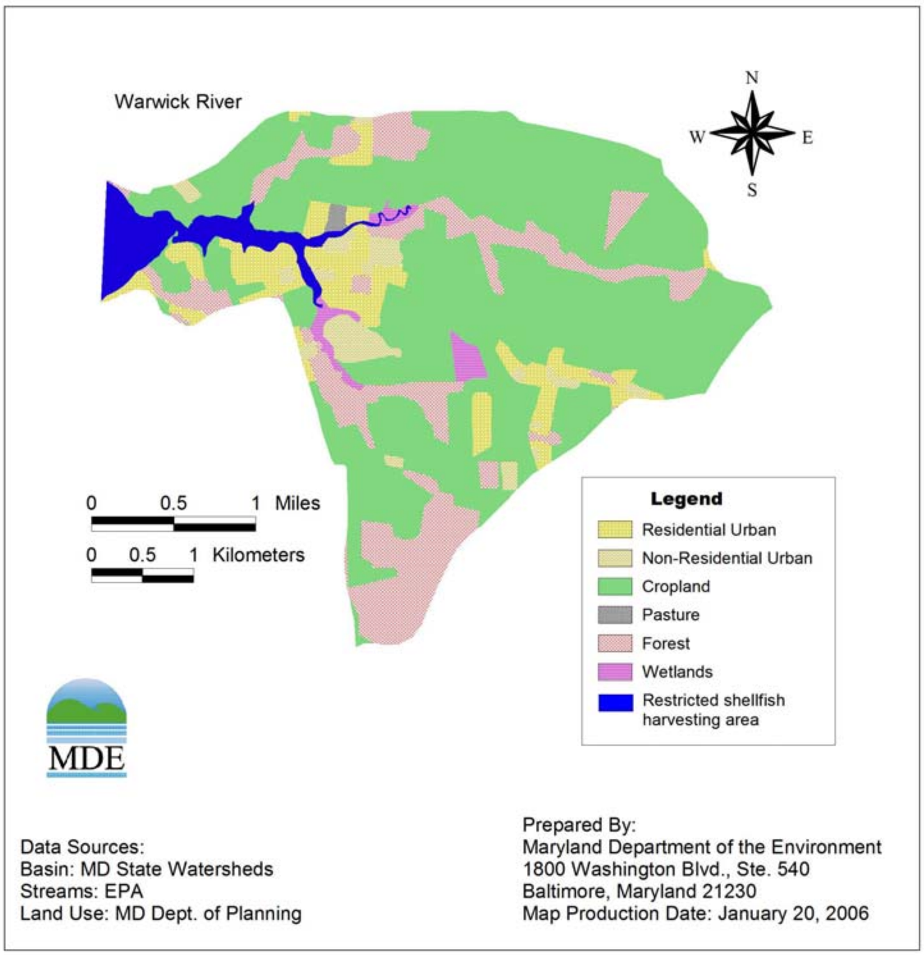


Figure 2.1.5: Land Use in the Warwick River Basin

Table 2.1.6: Land Use Percentage Distribution for San Domingo Creek

Land Type	Acreage	Percentage
Residential urban	116.4	19.2
Non-Residential urban	54.5	9.0
Cropland	261.8	43.1
Pasture	0.0	0.0
Feedlot	0.0	0.0
Forest	174.2	28.7
Water	0.0	0.0
Wetlands	0.0	0.0
Barren	0.0	0.0
Totals	**606.9**	**100.0**

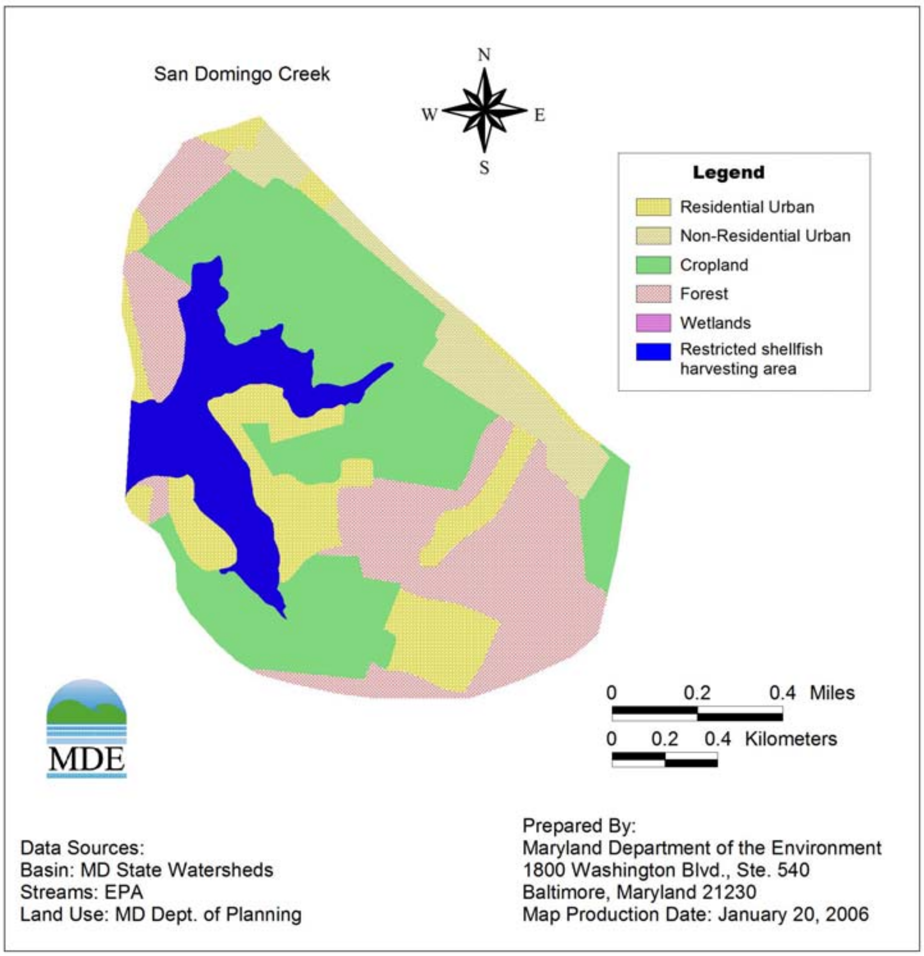


Figure 2.1.6: Land Use in the San Domingo Creek Basin

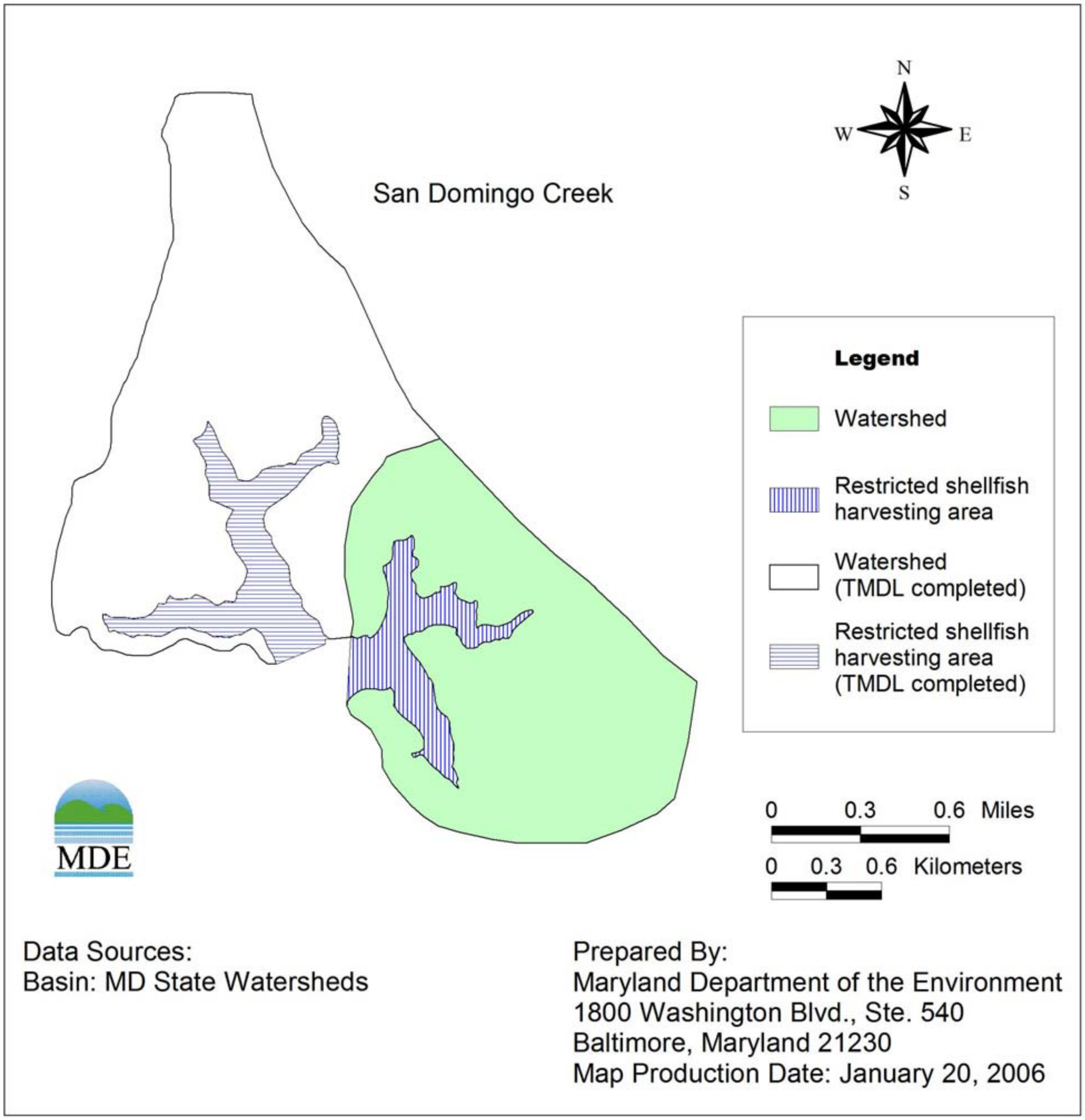


Figure 2.1.7: Map showing completed and current TMDL sites for San Domingo Creek

2.2 Water Quality Characterization

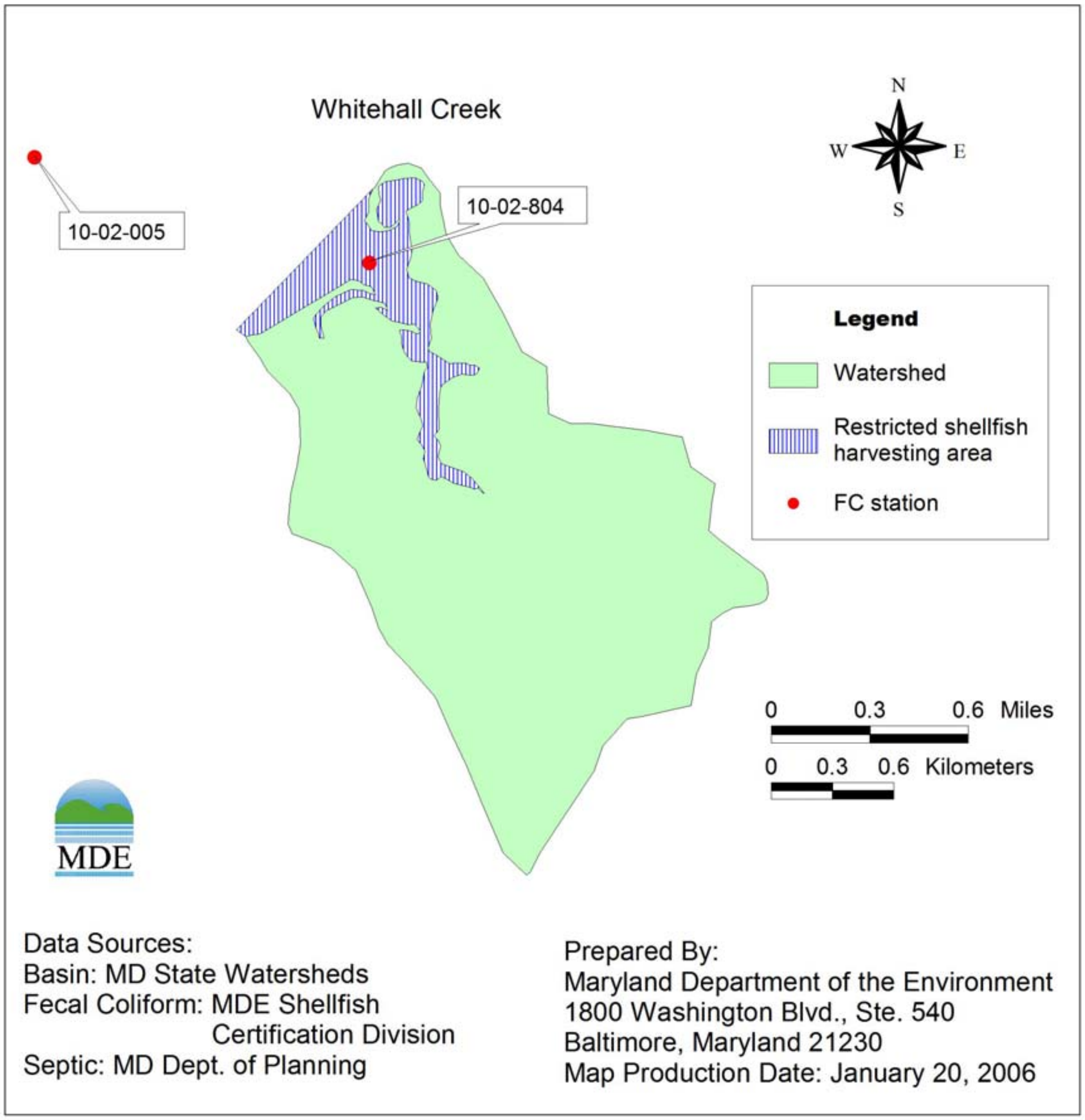
MDE's Shellfish Certification Program is responsible for classifying shellfish harvesting waters to ensure oysters and clams are safe for human consumption. MDE adheres to the requirements of the National Shellfish Sanitation Program (NSSP), with oversight by the U.S. Food and Drug Administration. MDE conducts shoreline surveys and collects routine bacteria water quality samples in the shellfish waters of Maryland. These data are used to determine if the shellfish water classification is being met.

MDE's Shellfish Certification Program has monitored shellfish throughout Maryland for the past several decades. There are five shellfish monitoring stations in the restricted shellfish harvesting areas addressed in this report. Additionally, there are three shellfish monitoring stations (Stations 10-02-005, 10-01-010, and 08-07-005) that are used as model boundary conditions. It should be noted that these three boundary condition stations are not used in the impairment analysis, but are only used for determining boundary conditions. The monitoring stations and observations recorded during the period of June 2000 – June 2005 are provided in Table 2.2.1 through Table 2.2.5 and Figure 2.2.1 through Figure 2.2.10. Tabulations of observed fecal coliform values in most probable number at each monitoring station of this report are provided in Appendix D.

Table 2.2.1: Locations of Shellfish Monitoring Stations in Whitehall Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
10-02-005 *	2000-2005	70	38 34 27.0	76 02 01.0
10-02-804	2000-2005	70	38 34 09.7	76 00 53.5

* boundary condition station, data not included in analysis



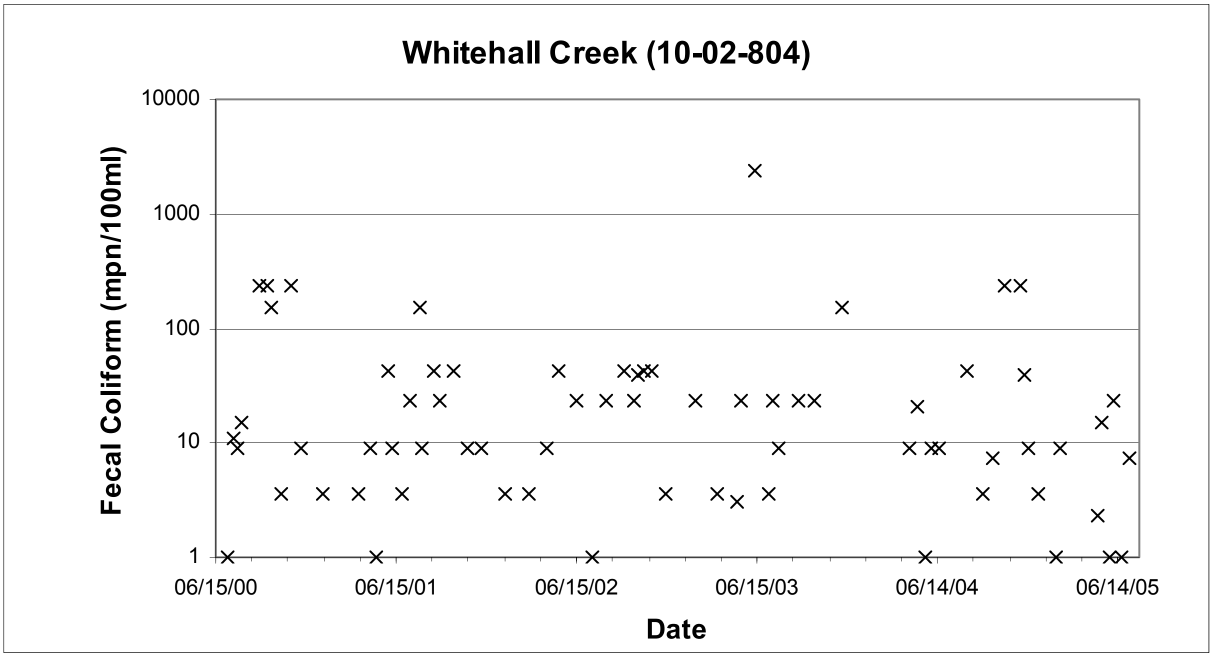


Figure 2.2.2: Observed Fecal Coliform Concentrations at Station 10-02-804

Table 2.2.2: Locations of Shellfish Monitoring Station in Indian Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
10-01-803	2000-2005	59	38 35 10.9	75 58 37.2

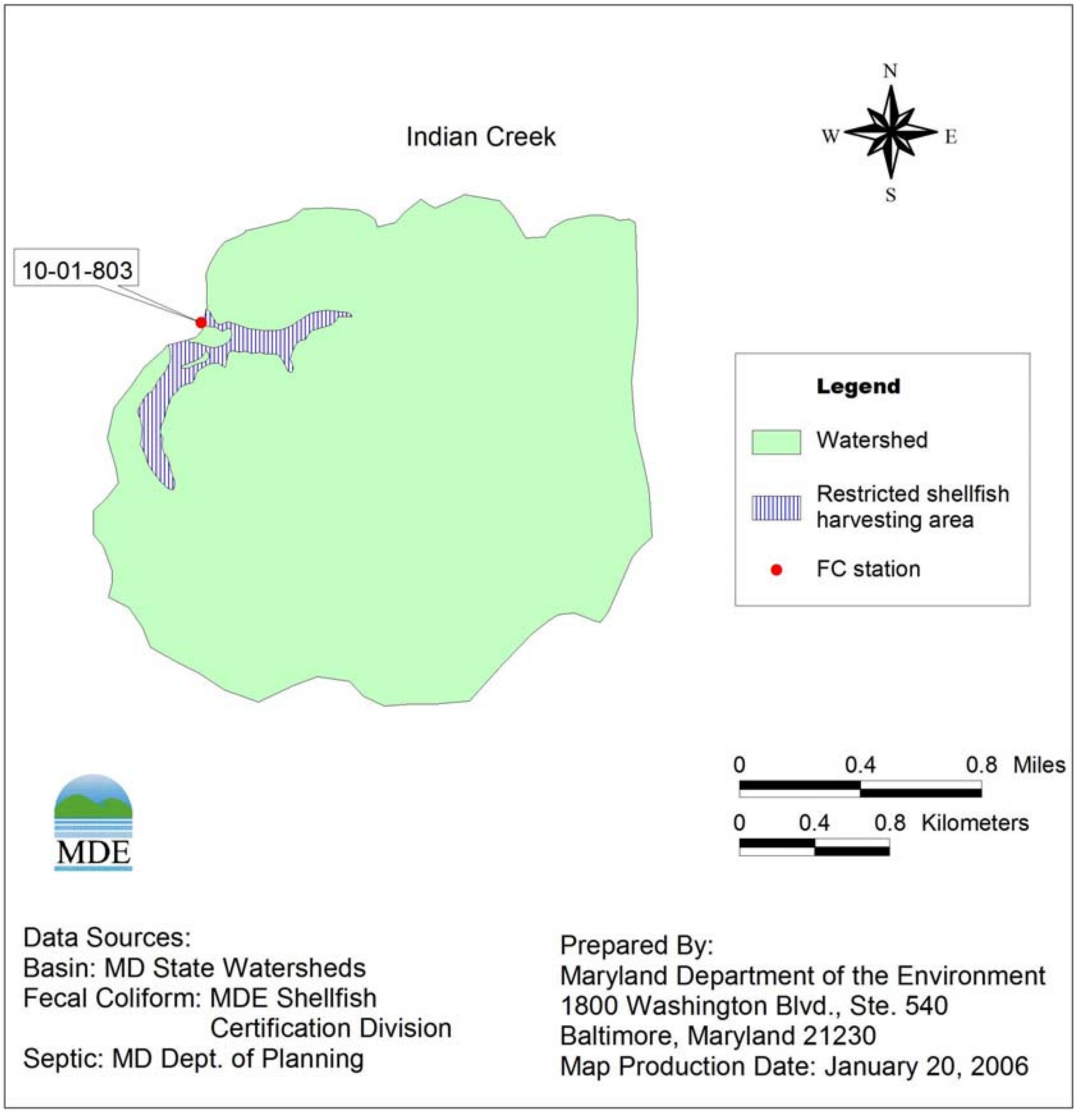


Figure 2.2.3: Shellfish Monitoring Stations in Indian Creek

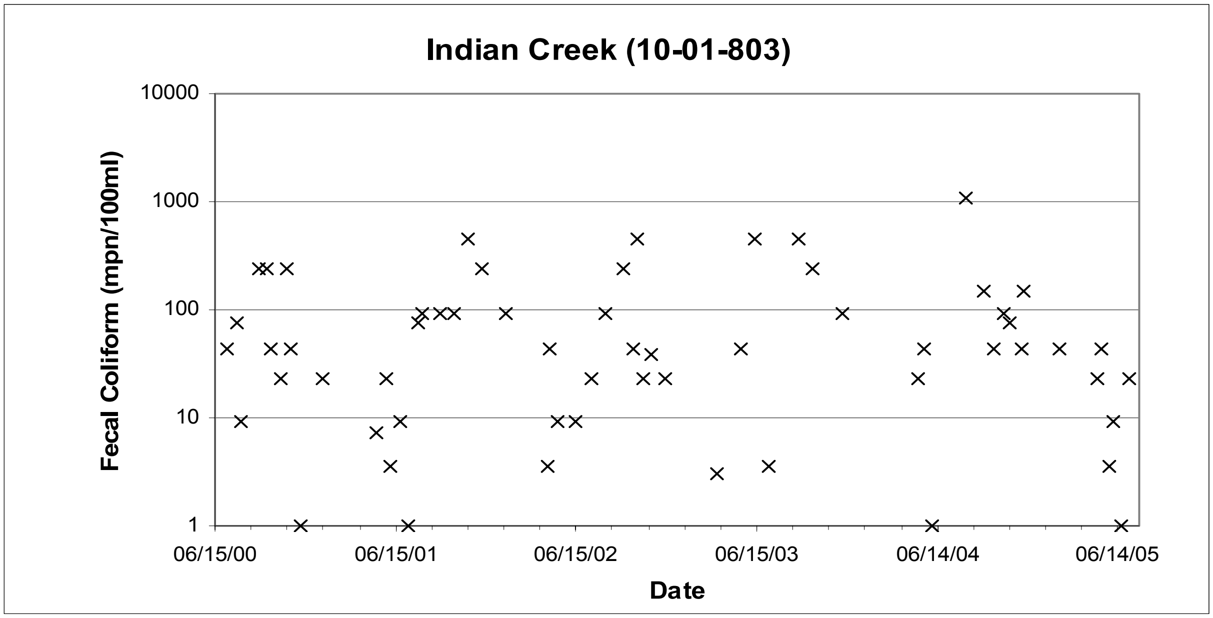


Figure 2.2.4: Observed Fecal Coliform Concentrations at Station 10-01-803

Table 2.2.3: Location of Shellfish Monitoring Station in Goose Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
10-01-802	2000-2005	60	38 35 51.4	75 58 16.6

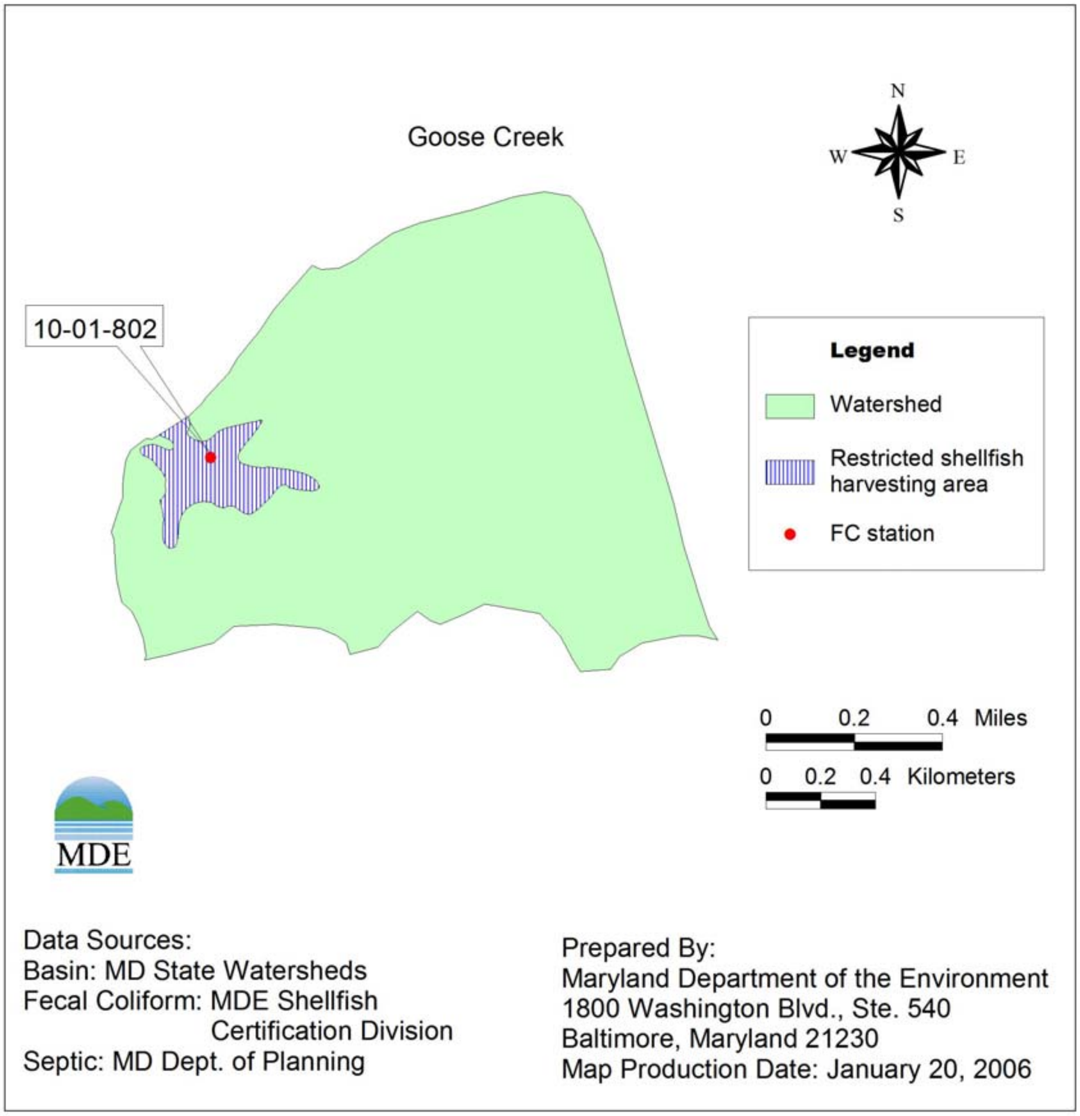


Figure 2.2.5: Shellfish Monitoring Stations in Goose Creek

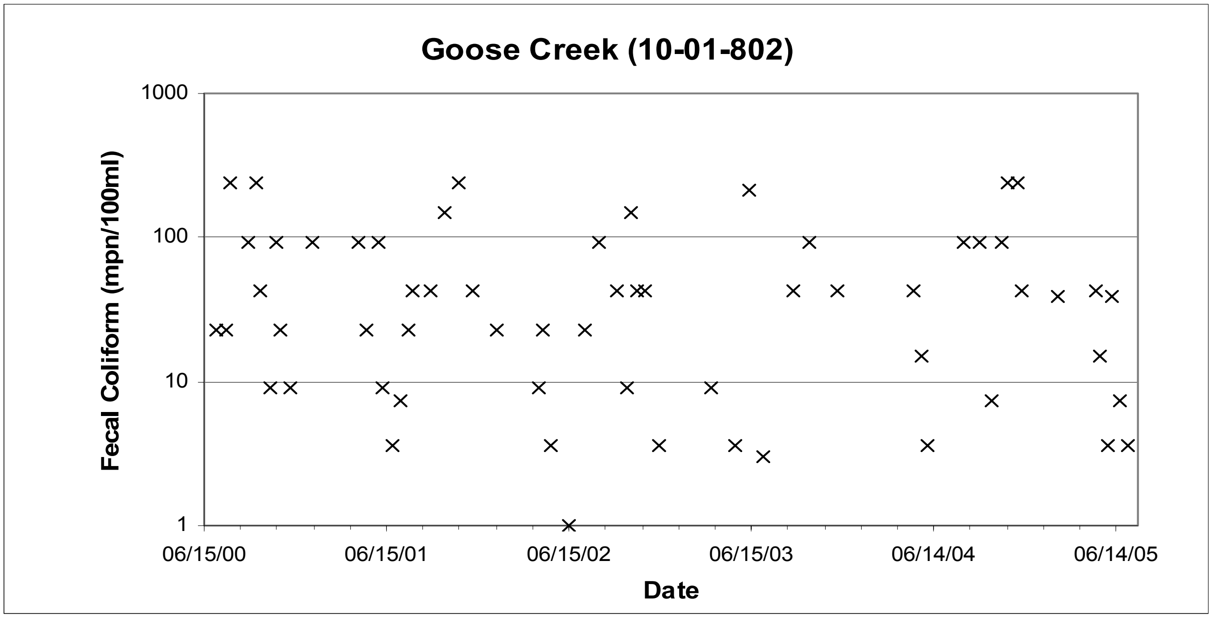


Figure 2.2.6: Observed Fecal Coliform Concentrations at Station 10-01-802

Table 2.2.4: Location of Shellfish Monitoring Stations in Warwick River

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
10-01-010 *	2000-2005	60	38 36 59.5	75 58 55.8
10-01-801	2000-2005	60	38 36 42.7	75 58 13.1

* boundary condition station, data not included in analysis

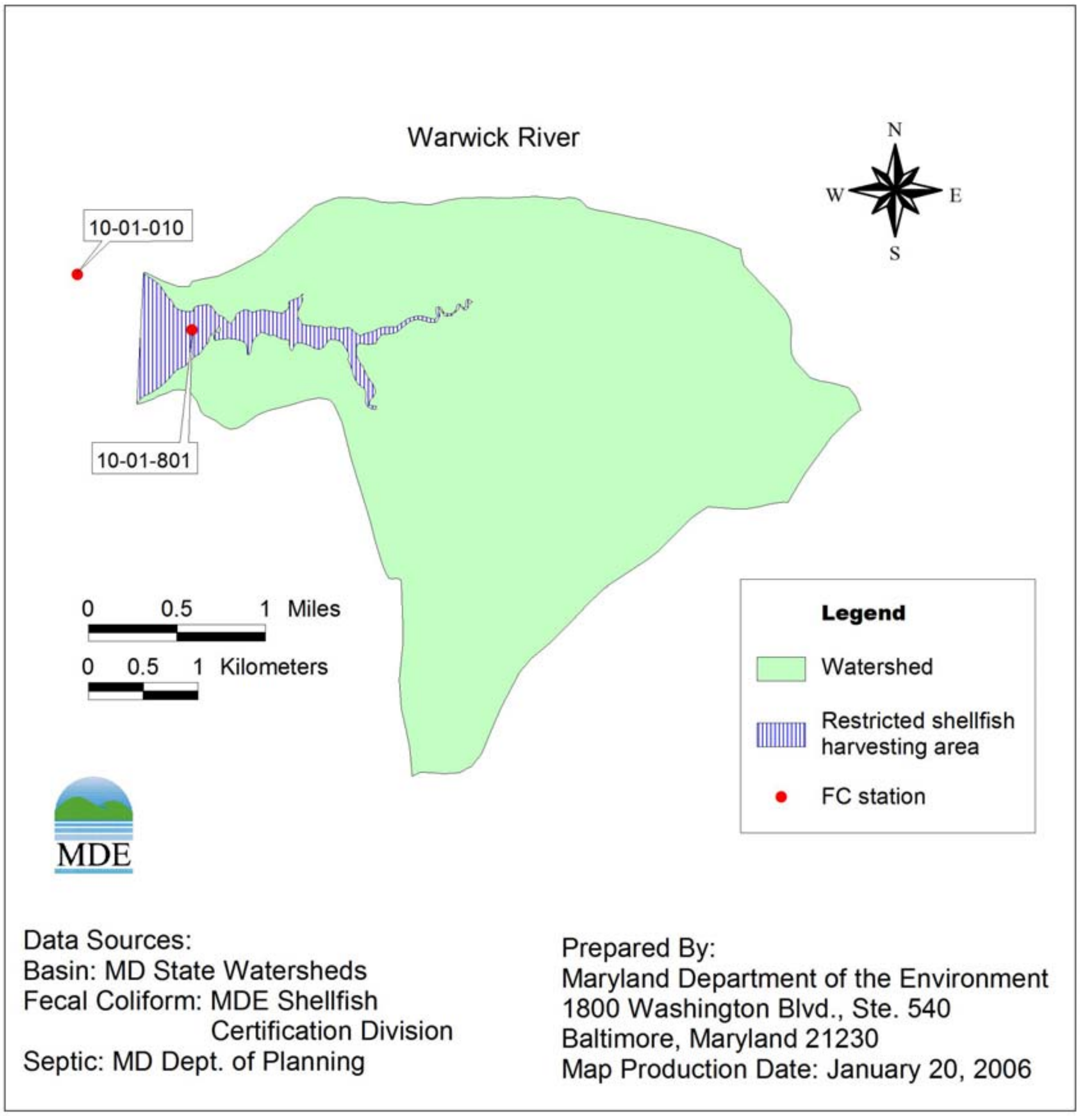


Figure 2.2.7: Shellfish Monitoring Stations in Warwick River

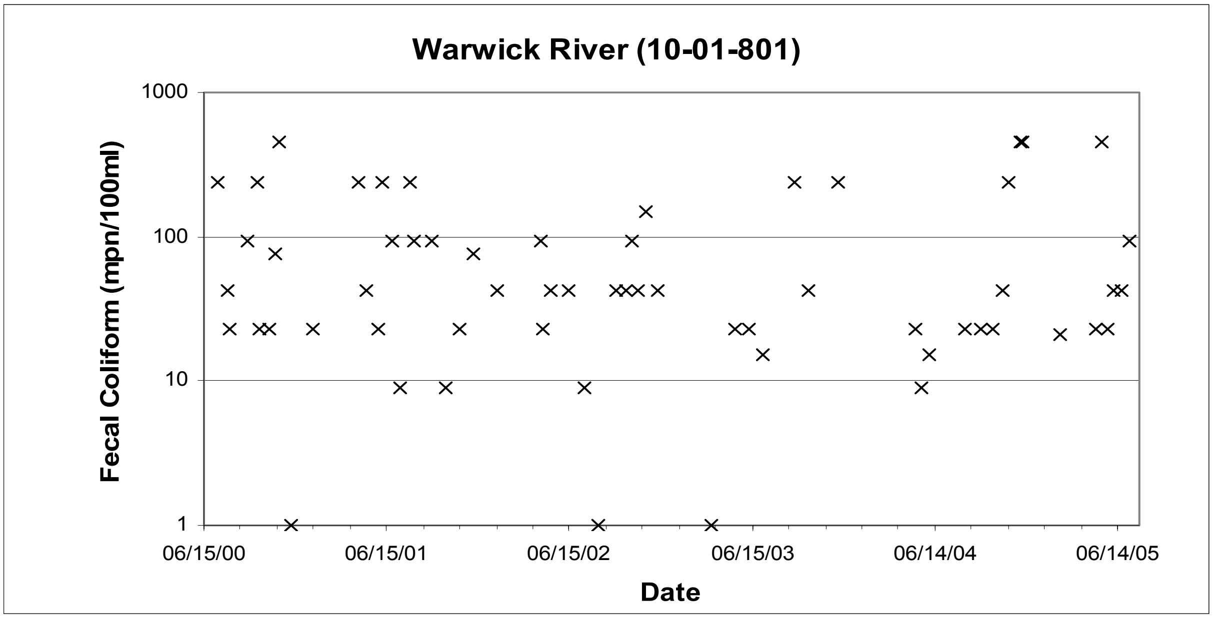


Figure 2.2.8: Observed Fecal Coliform Concentrations at Station 10-01-801

Table 2.2.5: Location of Shellfish Monitoring Stations in San Domingo Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
08-07-005 *	2000-2005	50	38 46 01.0	76 13 40.1
08-07-103	2000-2005	50	38 46 17.0	76 13 16.0

* boundary condition station, data not included in analysis

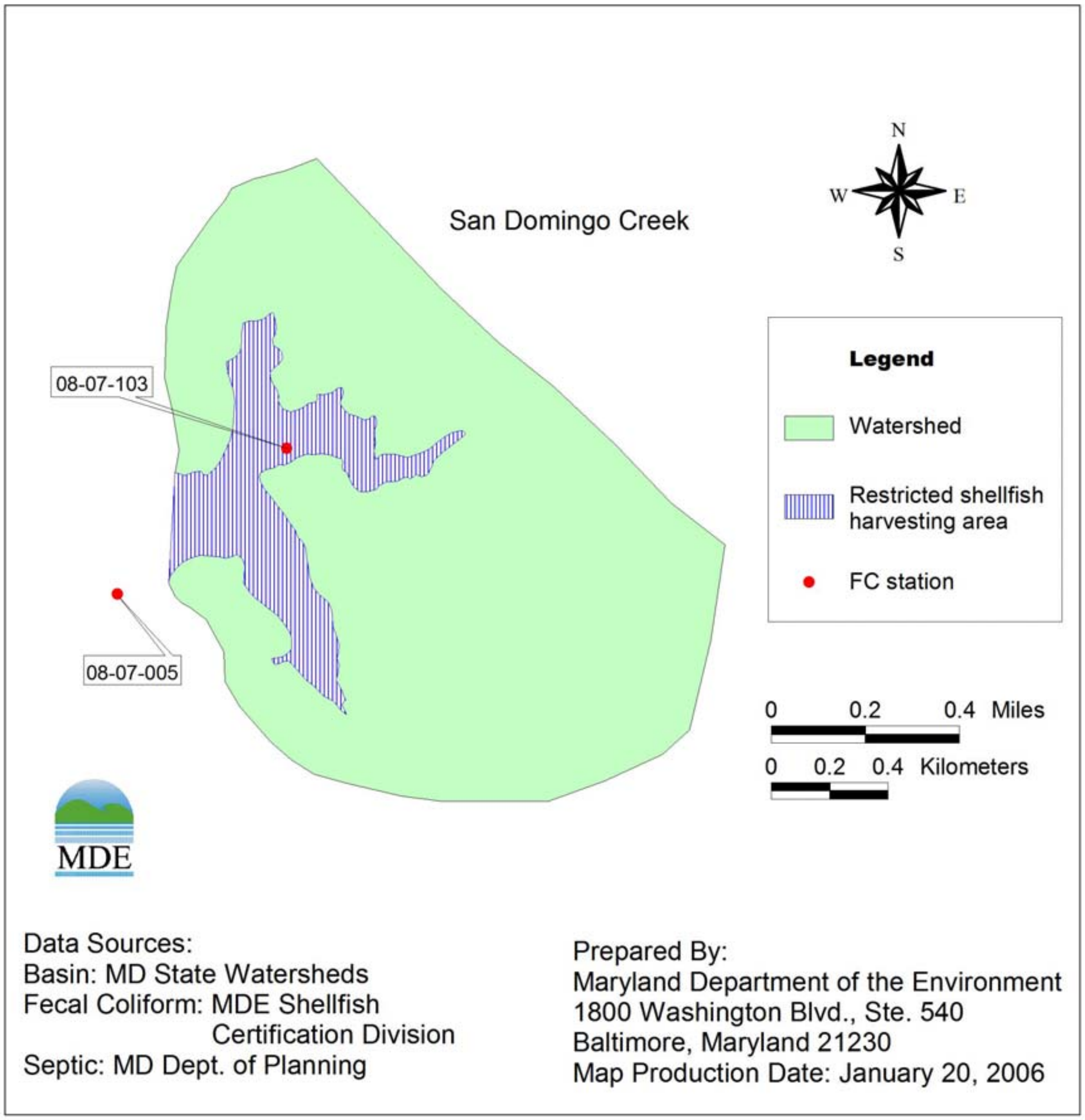


Figure 2.2.9: Shellfish Monitoring Stations in San Domingo Creek

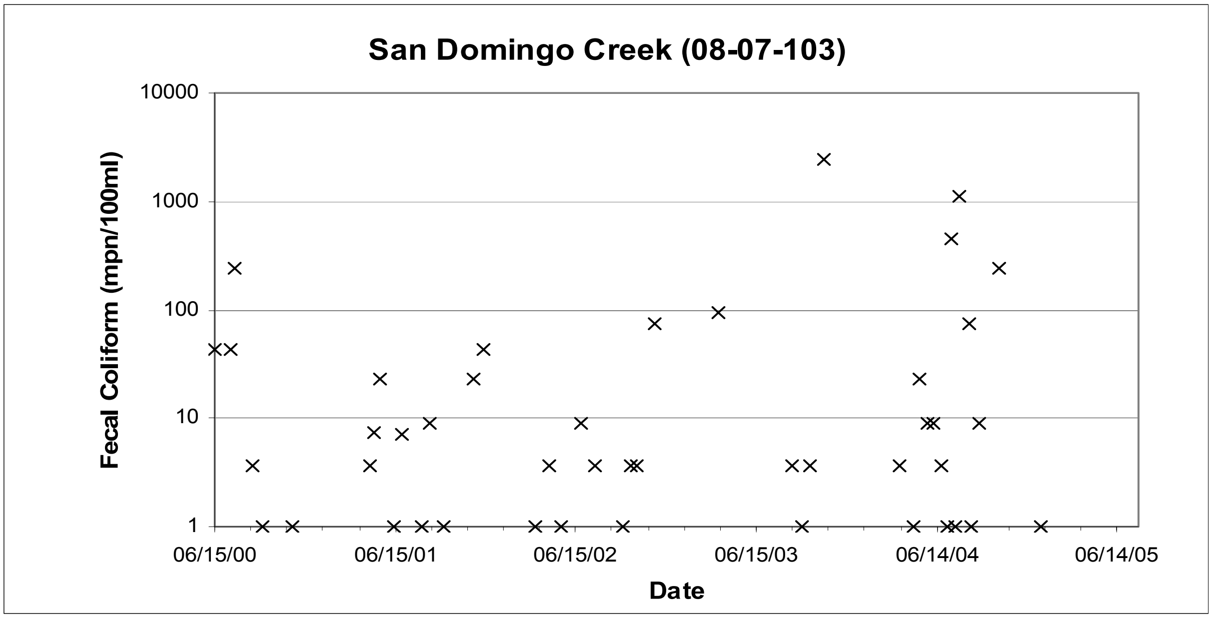


Figure 2.2.10: Observed Fecal Coliform Concentrations at Station 08-07-103

2.3 Water Quality Impairment

The fecal coliform impairment(s) addressed in this analysis were determined with reference to Maryland's Classification of Use II Waters- Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting in COMAR, Surface Water Quality Criteria 26.08.02.033(c), 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 was unchanged and the intent was to include the classification criteria as required under the NSSP, which 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 and did not change the fecal coliform criteria for shellfish harvesting waters or shellfish harvesting use designations.

For this analysis MDE is using routine monitoring data collected over a five-year period between June 2000 and June 2005. Most shellfish harvesting areas have been monitored routinely since before 1950. However, due to an emerging oyster aquaculture industry, there are a few shellfish harvesting areas that have less than five years worth of data. A minimum of 30 samples is required to classify shellfish harvesting areas. 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 assimilated capacity will be based on the approved classification requirements of a median of 14 MPN/100 ml and a 90th percentile of less than 49 MPN/100ml.

The Lower Choptank River, specifically Whitehall Creek, Indian Creek, Goose Creek, Warwick River, and San Domingo Creek, has been included in the 2004 Integrated 303(d) List as impaired for fecal coliform. The water quality impairment was assessed as not meeting the 90th percentile at five monitoring stations, and not meeting either the median or the 90th percentile at three monitoring stations (note that Maryland uses the 3-tube decimal dilution test for fecal coliform bacteria). Descriptive statistics of the monitoring data and the requirements for the approved classification are shown in Table 2.3.1.

Table 2.3.1: Lower Choptank 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
Whitehall Creek	10-02-804	9.10	14	107.43	49
Indian Creek	10-01-803	43.00	14	311.13	49
Goose Creek	10-01-802	41.00	14	160.89	49
Warwick River	10-01-801	43.00	14	258.58	49
San Domingo Creek	08-07-103	3.60	14	104.68	49

2.4 Source Assessment

Nonpoint Source Assessment

Nonpoint sources of fecal coliform do not have one discharge point but 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 areas. 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 and discharges to the restricted shellfish harvesting area. The deposition of non-human fecal coliform directly to the restricted shellfish area occurs 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 transport of fecal coliform from land surface to the restricted shellfish harvesting area is dictated by the hydrology, soil type, land use, and topography of the watershed.

The complete distributions of these source loads are listed in Table 2.4.1 through Table 2.4.5, along with counts/day for each source. Details of the source estimate procedure can be found in Appendix B. The Bacteria Source Tracking (BST) data, when they become available, will be used to further confirm the source distribution.

Table 2.4.1: Distribution of Fecal Coliform Source Loads in the Whitehall Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	7.29E+11	80.7%
Pets	5.23E+10	5.8%
Human	2.30E+09	0.3%
Wildlife	1.20E+11	13.2%
Total	9.03E+11	100.0%

Table 2.4.2: Distribution of Fecal Coliform Source Loads in the Indian Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	1.15E+12	22.5%
Pets	6.32E+10	1.2%
Human	2.67E+09	0.1%
Wildlife	3.88E+12	76.2%
Total	5.09E+12	100.0%

Table 2.4.3: Distribution of Fecal Coliform Source Loads in the Goose Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	6.25E+11	51.0%
Pets	1.70E+10	1.4%
Human	7.31E+08	0.1%
Wildlife	5.81E+11	47.5%
Total	1.22E+12	100.0%

Table 2.4.4: Distribution of Fecal Coliform Source Loads in the Warwick River Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	4.35E+12	66.5%
Pets	2.29E+11	3.5%
Human	9.31E+09	0.1%
Wildlife	1.95E+12	29.8%
Total	6.54E+12	100.0%

Table 2.4.5: Distribution of Fecal Coliform Source Loads in the San Domingo Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	4.16E+11	34.5%
Pets	3.39E+10	2.8%
Human	1.27E+09	0.1%
Wildlife	7.56E+11	62.6%
Total	1.21E+12	100.0%

Point Source Assessment

There is point source facility with a permit regulating the discharge of fecal coliform, Twin Cities Municipal (National Pollutant Discharge Elimination System (NPDES) permit number MD0055352), which discharges fecal coliform directly into the Warwick River. Its permit specifies limitations of 14 MPN/100ml monthly median fecal coliform concentration with a flow of 0.281 million gallons per day (mgd). The total fecal coliform discharged from this point source is 1.489×10^8 counts per day. The allocation of the permitted load from this point source facility will be addressed in Section 4.8.

3.0 TARGETED WATER QUALITY GOAL

The overall objective of the fecal coliform TMDLs in this document is to establish the maximum loading needed to assure attainment of water quality standards in the restricted shellfish harvesting waters in the Lower Choptank 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 detailed fecal coliform TMDLs and load allocation development for the identified restricted shellfish harvesting waters in the Lower Choptank River Basin. The required load reductions were determined based on the most recent five years of data spanning June 2000 to June 2005. The TMDLs are presented as counts/day. The second section describes the analysis framework for simulating fecal coliform concentration in the Lower Choptank River Basin. The third section addresses the critical condition and seasonality. The fourth section presents the TMDL calculation. The fifth section discusses TMDL loading caps. The sixth section presents the load allocation. The margin of safety is discussed in Section 4.7. Finally, the variables of the equation are combined in a summary accounting of the TMDL.

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality criteria, in this case 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" (40 Code of Federal Regulations (CFR) 130.2(i)) (U. S. Government Manual, 2004). It is also important to note that the TMDLs presented herein are not literal daily limits. These loads are based on an averaging period that is defined by the specific water quality criteria for shellfish harvesting waters (*i.e.*, at least 30 samples). The averaging period used for development of these TMDLs requires at least 30 samples and uses the most recent five-year window of data to identify current baseline conditions.

A TMDL is comprised of the sum of individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, incorporating natural background levels. The TMDL must include a margin of safety (MOS), either implicitly or explicitly, 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, the TMDL may include a future allocation (FA) when necessary. Conceptually, 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 discharge into the restricted shellfish harvesting area are the dominant influences on the transport of fecal coliform. The methodology used assumes that freshwater input, tidal range, and the first-order decay of fecal coliform are all constant. The TMDL is calculated based on the steady-state tidal prism model. Compared to the volumetric method (EPA Shellfish Workshop, 2002), the steady-state tidal prism model provides improvements incorporating the influences of tidal-induced transport, freshwater, and decay of fecal coliform in the embayment. A detailed description of the model is presented in Appendix A.

The most recent five-year median and 90th percentile concentrations were used to estimate the current loads. Using the steady state tidal prism model, the loads can be estimated according to the equation as follows (see also Appendix A):

$$L = \left[C\left(Q_b + kV\right) - Q_0 C_0\right] \times Cf \qquad (1)$$

where:
L = fecal coliform load (counts per day)
C = fecal coliform concentration (MPN /100ml) of embayment
Q_b = the quantity of mixed water that leaves the embayment on the ebb tide that did not enter the embayment on the previous flood tide (m^3 per tidal cycle)
k = the fecal coliform decay rate (per tidal cycle)
V = the mean volume of the embayment (m^3)
Q_0 = the quantity of water that enters the embayment on the flood tide through the ocean boundary that did not flow out of the embayment on the previous ebb tide (m^3 per tidal cycle)
C_0 = the fecal coliform concentration (MPN/100ml) at the oceanside boundary
Cf = the unit conversion factor.

Q_b and Q_0 are estimated based on the steady-state condition as follows:

$$Q_b = Q_0 + Q_f$$

where Q_f is the mean freshwater discharge during the tidal cycle

$$Q_0 = \beta Q_T$$

where β is an exchange ratio and Q_T is the total ocean water entering the embayment on the flood tide, which is calculated based on tidal range. The dominant tide in this region is the lunar semi-diurnal (M_2) tide with a tidal period of 12.42 hours; therefore, the M_2 tide is used for the representative tidal cycle. In general, the exchange ratio varies from 0.3 to 0.7 (Kuo *et al.*, 1998; Shen *et al.*, 2002). Therefore, a value of 0.5 is used for the exchange ratio. The stream flow used for the estimation of Q_f was based on the flows of two U.S. Geological Survey (USGS) gages. USGS gage # 01487000, located in the Nanticoke River near Bridgeville, Delaware, was used to estimate average long-term flows for Whitehall Creek, Indian Creek, Goose Creek, and Warwick River. For these restricted shellfish harvesting areas, the average long-term flow for this USGS gage (*i.e.*, 95.25 cfs) was adjusted by the ratio of each drainage basin area to that of the gage's basin (*i.e.*, 48,256 acres) to derive estimates of long-term flows. USGS gage # 01492500, located in Sallie Harris Creek near Carmichael, MD, was used to estimate average long-term flow for San Domingo Creek. For this restricted shellfish harvesting areas, the average long-term flow for this USGS gage (*i.e.*, 7.70 cfs) was adjusted by the ratio of the drainage basin area to that of the gage's basin (*i.e.*, 5,177.6 acres) to derive estimates of long-term flows. See Table 4.2.1 below.

Table 4.2.1: Restricted Shellfish Harvesting Area Drainage Acreage and Average Long-Term Flow

Restricted Shellfish Harvesting Area	Drainage Area in Acres	Average Long-Term Flow in cfs
Whitehall Creek	909.1	1.83
Indian Creek	1702.4	3.43
Goose Creek	588.5	1.19
Warwick River	4055.7	8.17
San Domingo Creek	606.9	0.90

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 exceeded only 10% of the time. Since data collected during the most recent five-year period was used to calculate the 90th percentile, 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 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 five applicable monitoring stations are presented in Appendix C. The results show the seasonal variability of fecal coliform concentration. Overall, higher concentrations occur between July and November in the Lower Choptank River restricted shellfish harvesting areas and lower concentrations occur between January and March. The largest standard deviations correspond to the highest variability in concentration for each station. These high concentrations result in a high 90th percentile concentration. The results indicate that violations may occur in only 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 which 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

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. These analyses are described below.

The most recent five-year window of fecal coliform monitoring data (at least 30 samples) was used to estimate the current loads. This was conducted for the median and for the 90th percentile conditions. Whitehall Creek has two monitoring stations (10-02-005 and 10-02-804). For Whitehall Creek, Station 10-02-804 was used to represent the restricted shellfish harvesting area concentration and Station 10-02-005 was used to provide the boundary condition. The total load is reported in Table 4.4.1 and Table 4.4.2. Indian Creek has one monitoring station (10-01-803) that was used both to represent the restricted shellfish harvesting area concentration and to provide the boundary condition. Goose Creek has one monitoring station (10-01-802), also used both to represent the restricted shellfish harvesting area concentration and to provide the boundary condition. Warwick River has two monitoring stations (10-01-010 and 10-01-801). For Warwick River, Station 10-01-801 was used to represent the restricted shellfish harvesting area concentration and Station 10-01-010 was used to provide the boundary condition. San Domingo Creek has two monitoring stations (08-07-005 and 08-07-103). For San Domingo Creek, Station 08-07-103 was used to represent the restricted shellfish harvesting area concentration and Station 08-07-005 was used to provide the boundary condition.

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 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

Area	Mean Volume m^3	Fecal Coliform Concentration Median MPN/100mL	Decay Rate per tidal cycle	Estimated Water Residence Time day	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction (%)
Whitehall Creek	297,457	9.1	0.36	1.2	1.924E+10	2.960E+10	0.00
Indian Creek	163,760	43.0	0.36	1.2	5.259E+10	1.712E+10	67.45
Goose Creek	94,050	41.0	0.36	1.2	2.802E+10	9.567E+09	65.85
Warwick River	705,270	43.0	0.36	1.5	3.075E+11	7.148E+10	76.76
San Domingo Creek	425,862	3.6	0.36	2.4	1.074E+10	4.178E+10	0.00

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

Area	Mean Volume m^3	Fecal Coliform Concentration 90th percentile MPN/100mL	Decay Rate per tidal cycle	Estimated Water Residence Time Day	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction (%)
Whitehall Creek	297,457	107.4	0.36	1.2	3.178E+11	1.036E+11	67.40
Indian Creek	163,760	311.1	0.36	1.2	3.805E+11	5.993E+10	84.25
Goose Creek	94,050	160.9	0.36	1.2	1.099E+11	3.348E+10	69.54
Warwick River	705,270	258.6	0.36	1.5	1.679E+12	2.502E+11	85.10
San Domingo Creek	425,862	104.7	0.36	2.4	4.178E+11	1.462E+11	64.99

4.5 TMDL Loading Caps

This section presents the TMDL for the median and 90th percentile conditions. Seasonal variability is addressed implicitly through the interpretation of the water quality standards. The TMDLs for the identified restricted shellfish harvesting waters of the Lower Choptank River Basin are as follows:

Whitehall Creek:
The median load of fecal coliform TMDL = 2.96×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 1.04×10^{11} counts per day

Indian Creek:
The median load of fecal coliform TMDL = 1.71×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 5.99×10^{10} counts per day

Goose Creek:
The median load of fecal coliform TMDL = 9.57×10^{09} counts per day
The 90th percentile of fecal coliform TMDL = 3.35×10^{10} counts per day

Warwick River:
The median load of fecal coliform TMDL = 7.15×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 2.50×10^{11} counts per day

San Domingo Creek:
The median load of fecal coliform TMDL = 4.18×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 1.46×10^{11} counts per day

The greater reduction required when comparing the median and the 90th percentile results (see Table 4.4.1 and Table 4.4.2) was used for the source allocation. In this case, the 90th percentile requires the greater reduction. It is also important to note that the TMDLs presented herein are not literal daily limits. These loads are based on an averaging period that is defined by the water quality criteria (*i.e.*, at least 30 samples). The averaging period used for development of these TMDLs is five years.

4.6 Load Allocation

The purpose of this section is to allocate the TMDL between point (WLA) and nonpoint (LA) sources. There is a Twin Cities municipal point source facility (NPDES MD0055352) located in the Warwick River watershed. The permitted fecal coliform load from this point source is approximately 1.49×10^{8} counts per day and will be included as the WLA. The remaining 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. This load allocation results in load reductions of approximately 67.4%, 84.3%, 69.5%, 85.1%, and 65.0%, respectively, in the Whitehall Creek, Indian Creek, Goose Creek, Warwick River, and San Domingo Creek watersheds.

Since the load reductions applied to these watersheds are based on the 90^{th} percentile water quality standard, they target only those critical events that occur less frequently. Therefore, the load reductions established are not literal daily reductions, but rather an indicator that the control measures for bacterial loads are needed for these more extreme events. The extreme events are often a result of hydrologic variability, land use practices, water recreation uses, or wildlife activities.

4.7 Margin of Safety

A 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. Based on previous analysis (Virginia Institute of Marine Science (VIMS), 2004), it was determined that the most sensitive parameter is the decay rate. 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.

4.8 Summary of Total Maximum Daily Loads

There is a point source facility (Twin Cities Municipal, NPDES permit number MD0055352) that has permit limits for discharging fecal coliform directly into the Warwick River. The permitted fecal coliform load from this point source is approximately 1.49×10^8 counts per day and will be included as the WLA. The remaining loads assimilative capacity will be allocated to the load allocation. The TMDLs are summarized as follows:

The median TMDL (counts per day):

TMDL = LA + WLA + FA + MOS

Area										
Whitehall Creek	2.96×10^{10}	=	2.96×10^{10}	+	N/A	+	N/A	+	Implicit
Indian Creek	1.71×10^{10}	=	1.71×10^{10}	+	N/A	+	N/A	+	Implicit
Goose Creek	9.57×10^{09}	=	9.57×10^{09}	+	N/A	+	N/A	+	Implicit
Warwick River	7.15×10^{10}	=	7.14×10^{10}	+	1.49×10^{08}	+	N/A	+	Implicit
San Domingo Creek	4.18×10^{10}	=	4.18×10^{10}	+	N/A	+	N/A	+	Implicit

The 90th percentile TMDL (counts per day):

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Whitehall Creek	1.04×10^{11}	=	1.04×10^{11}	+	N/A	+	N/A	+	Implicit
Indian Creek	5.99×10^{10}	=	5.99×10^{10}	+	N/A	+	N/A	+	Implicit
Goose Creek	3.35×10^{10}	=	3.35×10^{10}	+	N/A	+	N/A	+	Implicit
Warwick River	2.50×10^{11}	=	2.50×10^{11}	+	1.49×10^{08}	+	N/A	+	Implicit
San Domingo Creek	1.46×10^{11}	=	1.46×10^{11}	+	N/A	+	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 (BMPs). 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 the watershed analyses (see Table 2.4.1 through Table 2.4.5) 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 involved with livestock and production. Additional funding available for local governments includes 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. Low interest loans are available to property owners with failing septic systems through MDE's Linked Deposit Program. In addition, it is anticipated that in 2006 there may be funding available through the Bay Restoration Fund to upgrade onsite sewage disposal systems to the best available technology for removing nitrogen. Priority for Bay Restoration Funds is to be given to upgrading failing systems and holding tanks in the Chesapeake and Atlantic Coastal Bays Critical Areas. Maryland law, Environmental Article § 9-333, requires the flowing 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. 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 National Pollutant Discharge Elimination System (NPDES) permitting activities such as confined animal feeding operations (CAFOs). Though 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 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. Additional monitoring will also include bacteria source tracking, which will be used to confirm the source estimates presented in this document. Results of bacteria source tracking may be used as an additional tool to further guide implementation efforts. Bacteria source tracking will be completed according to the schedule posted on MDE's website, http://www.mde.state.md.us:8001/assets/document/BST_schedule.pdf.

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 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 changing a natural background condition is not the intended goal of a TMDL.

Implementation may begin by first managing controllable resources (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.

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Appendix A. Tidal Prism Model

A detailed description of the tidal flushing model is presented in this section. It is assumed that a single volume can represent a waterbody, and that the pollutant is well mixed in the waterbody system, as shown in Figure A-1.

The mass balance of water can be written as follows (Guo and Lordi, 2000):

$$\frac{dV}{dT} = (Q_0 - Q_b + Q_f) \qquad (1)$$

where Q_0 is the quantity of water that enters the embayment on the flood tide through the ocean boundary (m^3T^{-1}); Q_b is the quantity of mixed water that leaves the bay on the ebb tide that did not enter the bay on the previous flood tide (m^3 per tidal cycle); Q_f is total freshwater input over the tidal cycle (m^3); V is the volume of the bay (m^3); T is the dominant tidal period (hours).

It is further assumed that Q_0 is the pure ocean water that did not flow out of the embayment on the previous ebb tide, and that Q_b is the embayment water that did not enter into the system on the previous flood tide. The mass balance for the fecal coliform can then be written as follows:

$$\frac{dVC}{dT} = Q_0 C_0 - Q_b C + L_f + L_l - kVC \qquad (2)$$

where L_f is the loading from upstream; L_l is the additional loading from the local area within the tidal cycle; k is the fecal coliform decay rate (or a damped parameter for the net loss of fecal coliform); C is fecal coliform concentration in the embayment; and C_0 is the fecal coliform concentration from outside the embayment.

In a steady-state condition, the mass balance equations for the water and the fecal coliform concentration can be written as follows:

$$Q_b = Q_0 + Q_f \qquad (3)$$

$$Q_b C + kVC = Q_0 C_0 + L_f + L_l \qquad (4)$$

The fecal coliform concentration in the embayment can be calculated as follows:

$$C = \frac{Q_0 C_0 + L_f + L_l}{Q_b + kV} \qquad (5)$$

From Equation (4), assuming $L_f + L_l = Load_t$ and letting C_c be the criterion of fecal coliform in the embayment, the loading capacity can be estimated as:

$$Load_T = C_c(Q_b + kV) - Q_0C_0 \tag{6}$$

The daily load can be estimated based on the dominant tidal period in the area. For the upper Chesapeake Bay the dominant tide is lunar semi-diurnal (M_2) tide with a tidal period of 12.42 hours. If fecal coliform concentration is in MPN/100ml, the daily load (counts day^{-1}) can be estimated as:

$$Load = Load_T \times \frac{24}{12.42} \times 10000 \tag{7}$$

In practice, one may not know *Q_0 a priori*. Instead, one is given the tidal range of the tidal embayment. From that, Q_T, the total ocean water entering the bay on the flood tide, can be calculated. From this, Q_0, the volume of new ocean water entering the embayment on the flood tide can be determined by the use of the ocean tidal exchange ratio β as:

$$Q_0 = \beta Q_T \tag{8}$$

where β is the exchange ratio and Q_T is the total ocean water entering the bay on the flood tide. The exchange ratio can be estimated from salinity data (Fischer *et al.*, 1979):

$$\beta = \frac{S_f - S_e}{S_0 - S_e} \tag{9}$$

where S_f is the average salinity of ocean water entering the bay on the flood tide, S_e is the average salinity of the bay water leaving the bay, and S_0 is the salinity at the ocean side. The numerical value of β is usually smaller than 1, and it represents the fraction of new ocean water entering the embayment. Once Q_0 is known, then Q_b can be calculated from equation (3).

The residence time, T_L, is an estimate of time required to replace the existing pollutant concentration in a system; it can be calculated as follows:

$$T_L = \frac{V_b}{Q_b} \tag{10}$$

where V_b is mean volume of the embayment. From the definition, the denominator can either be Q_T or Q_b. However, using Q_T assumes that the ocean water entering into the embayment during the flood tide is 100% new, whereas using Q_b takes into consideration that a portion of water is not entirely new. It can be shown that the latter is more realistic. If Q_b is used in the residence time calculation, it will result in a longer time scale than if Q_T is used (Ketchum, 1951; Guo and Lordi, 2000).

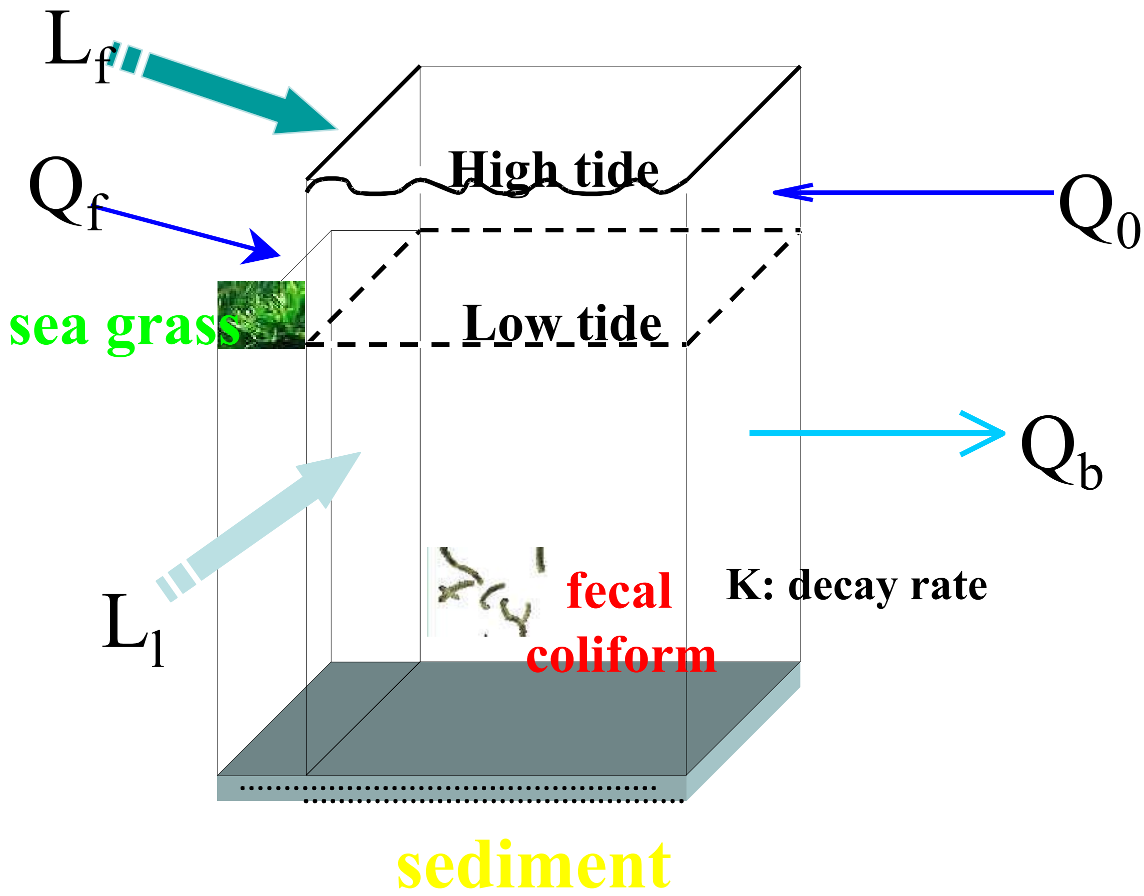

Figure A-1: The schematic diagram for the tidal prism model

A Tidal Prism Model Calculation for Whitehall Creek

Case I: The most recent five-year fecal coliform median concentration is used.

The median load calculation is illustrated as follows:

V = Mean volume of the embayment = 297457 (m^3)
k = Fecal coliform removal rate =0.36 (T^{-1})
Q_f = Freshwater discharge
= 1.83 cfs = 1.83 × 0.0283×86400×12.42÷24 = 2315.6 (m^3T^{-1})
Q_0 = 125820.6 (m^3T^{-1})
Q_b = 128136.2 (m^3 T^{-1})
C_c = water quality criterion = 14 MPN/100ml
C = current fecal coliform 5-year median concentration = 9.10 (MPN/100ml)
C_0 = fecal coliform 5-year median outside of the embayment = 9.10 (MPN/100ml)
T = tidal cycle =12.42 hours
Cf = the unit conversion factor

For allowable calculation, C_c is used as fecal coliform concentration (*i.e.*, 14 MPN/100ml). The fecal coliform concentration at the outside of the embayment also uses 14 MPN/100ml. The allowable load is calculated as follows:

Allowable Load
$= [C_c(Q_b + kV) - Q_0C_c] \times Cf$
= [14× (128136.2 +0.36×297457) – 125820.6 ×14] ×24÷12.42×10000
= 2.960×10^{10}

For the current load estimation, the most recent five-year median fecal coliform concentration is used for the calculation. The current load is calculated as follows:

Current Load
$= [(C)(Q_b + kV) - Q_0(C_0)] \times Cf$
= [(9.10) × (128136.2 +0.36×297457) – 125820.6 × (9.10)] ×24÷12.42×10000
= 1.924×10^{10}

The load reduction is estimated as follows:

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

$$\text{Load Reduction} = \frac{1.924\times10^{10} - 2.960\times10^{10}}{1.924\times10^{10}} \times 100\% = 0.00\%$$

A Tidal Prism Model Calculation for Whitehall Creek

Case II: The most recent five-year fecal coliform 90th percentile concentration is used.

The 90th percentile load calculation is illustrated as follows:

V = Mean volume of the embayment = 297457 (m^3)
k = Fecal coliform removal rate =0.36 (T^{-1})
Q_f = Freshwater discharge
= 1.83 cfs = 1.83 × 0.0283×86400×12.42÷24 = 2315.6 (m^3T^{-1})
Q_0 = 125820.6 (m^3T^{-1})
Q_b = 128136.2 (m^3 T^{-1})
C_c = water quality criterion = 49 MPN/100ml
C = current fecal coliform 5-year 90th percentile concentration = 107.43 (MPN/100ml)
C_0 = fecal coliform 5-year 90th percentile at the outside of the embayment
= 70.14 (MPN/100ml)
T = tidal cycle =12.42 hours
Cf = the unit conversion factor

For allowable calculation, C_c is used as fecal coliform concentration (*i.e.*, 49 MPN/100ml). The fecal coliform concentration at the outside of the embayment also uses 49 MPN/100ml. The allowable load is calculated as follows:

Allowable Load

$$= [C_c(Q_b + kV) - Q_0C_c] \times Cf$$

$$= [49\times (128136.2 + 0.36\times297457) - 125820.6\times 49] \times24\div12.42\times10000$$

$$= 1.036\times10^{11}$$

For the current load estimation, the most recent five-year 90th percentile fecal coliform concentration is used for the calculation. The current load is calculated as follows:

Current Load

$$= [(C)(Q_b + kV) - Q_0(C_0)] \times Cf$$

$$= [(107.43) \times (128136.2 + 0.36\times297457) - 125820.6 \times (70.14)] \times24\div12.42\times10000$$

$$= 3.178\times10^{11}$$

The load reduction is estimated as follows:

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

$$\text{Load Reduction} = \frac{3.178\times10^{11} - 1.036\times10^{11}}{3.178\times10^{11}} \times 100\% = 67.40\%$$

Sample calculations load reductions for both the median and 90th percentiles have been presented for the first embayment in this report (*i.e.*, Whitehall Creek). The following table lists the parameter values needed for these calculations at all other embayments in this report. Please refer to the sample calculations for a full description of each parameter, as well as constants required.

Table A-1: Parameter values required for TMDL calculations for each embayment

Area Name						Median		90th Percentile	
	V	k	Q_f	Q_0	Q_b	C	C_0	C	C_0
Whitehall Creek	297,457	0.36	2315.6	125820.6	128136.2	9.10	9.10	107.43	70.14
Indian Creek	163,760	0.36	4341.1	66989.8	71330.9	43.00	43.00	311.13	311.13
Goose Creek	94,050	0.36	1505.8	37486.7	38992.5	41.00	41.00	160.89	160.89
Warwick River	705,270	0.36	10337.9	227615.5	237953.4	43.00	23.00	258.58	177.05
San Domingo Creek	425,862	0.36	1138.8	89244.7	90383.5	3.60	3.60	104.68	43.60

The values attained using the sample calculation are listed below:

Table A-2: TMDL calculation results for each embayment

Area Name	Median			90th Percentile		
	Allowable Load	Current Load	Percent Reduction	Allowable Load	Current Load	Percent Reduction
	Counts/day	Counts/day		Counts/day	Counts/day	
Whitehall Creek	2.960E+10	1.924E+10	0.00	1.036E+11	3.178E+11	67.40
Indian Creek	1.712E+10	5.259E+10	67.45	5.993E+10	3.805E+11	84.25
Goose Creek	9.567E+09	2.802E+10	65.85	3.348E+10	1.099E+11	69.54
Warwick River	7.148E+10	3.075E+11	76.76	2.502E+11	1.679E+12	85.10
San Domingo Creek	4.178E+10	1.074E+10	0.00	1.462E+11	4.178E+11	64.99

Appendix B. Nonpoint Source Assessment

Nonpoint sources of fecal coliform bacteria do not have one discharge point but 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 areas. 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 runoff occurs during rain events, surface runoff transports water and fecal coliform over the land surface and discharges to the restricted shellfish harvesting area. The deposition of non-human fecal coliform directly to the restricted shellfish area occurs when livestock or wildlife have direct access to the waterbody. Nonpoint source contributions to the bacterial levels from human activities generally arise from failing septic systems and their associated drain fields as well as through pollution from recreation vessel discharges. The transport of fecal coliform from land surface to the restricted shellfish harvesting area 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 load among these sources, it is necessary to identify all existing sources. The nonpoint source assessment was conducted using available data collected in the watershed. Multiple data sources were used to determine the potential sources of the fecal coliform load from the watershed. The data used for source assessment are:

1. Land use data of 2000 Maryland Department of Planning (MDP) land use/land cover data
2. Livestock inventory by 8-digit Hydrologic Unit Code (Maryland States Soil Conservation Committee (MSSCC); USDA, 1997; MASS, 2002a; MASS, 2002b; Brodie and Lawrence, 1996)
3. GIS 2000 Census of Human population (MDP)
4. Pet survey results from The Center for Watershed Protection (Swann, 1999)
5. Fecal coliform monitoring data (MDE Shellfish Certification Division)
6. The shoreline sanitary survey data (MDE Shellfish Certification Division)
7. Stream GIS coverage (EPA, 1994)
8. Septic GIS Coverage (MDP, 2003)
9. Wildlife population (Maryland DNR, 2003)

In the Lower Choptank River Basin, wildlife contributions, both mammalian and avian, are 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. Pet contributions usually occur through runoff from streets and land. There is a lack of information available for the discharge from boats and it is assumed that human loading results from failures in septic systems. The major nonpoint source contributions assessed for restricted shellfish areas in the Lower Choptank River are summarized in Table B-1. The potential nonpoint sources were grouped into four categories: wildlife; human; pets; and livestock. Due to insufficient data sources, the source assessment method does not account for boat discharge, resuspension from bottom sediment, and the potential for regrowth of fecal coliform in the embayment.

Table B-1: Summary of Nonpoint Sources

Category	Source
Wildlife	Beaver, deer, goose, duck, swan, muskrat, raccoon and wild turkey
Human	Septic
Pets	Dog
Livestock	Cattle, sheep, chicken, and horse

A. Wildlife Contributions

In general it is assumed that the wildlife species existent in the watershed include beaver, deer, goose, duck, swan, muskrat, raccoon and wild turkey. Fecal coliform from wildlife can be from excretion on land that is subject to runoff or direct deposition into the stream. Wildlife populations within the watershed were estimated based on a combination of information from the Maryland DNR Wildlife and Heritage Service and from habitat information listed in Virginia bacteria TMDL report (VA DEQ, 2002). Habitat density results were reviewed by the Maryland Department of Natural Resources, and are listed in Table B-2.

Table B-2: Wildlife Habitat and Densities

Wildlife Type	Population Density	Habitat Requirements
Beaver[1]	4.8 animals/ mile of stream	Tidal and non-tidal regions
Deer[2]	0.047 animals/acre	Entire watershed
Goose[2]	0.087 animals/acre	Entire watershed
Duck[2]	0.039 animals/acre	Entire watershed
Muskrat[1]	2.75 animals/acre	Within 66 feet of streams and ponds
Raccoon[1]	0.07 animals/acre	Within 600 feet of streams and ponds
Wild Turkey[1]	0.01 animals/acre	Entire watershed excluding farmsteads and urban

[1] VA DEQ (2002); [2]MD DNR (2003)

The habitat areas for each species were determined using ArcView GIS with the 2000 MDP land use data and EPA reach coverage in the watershed. The GIS tool was applied to the land use coverage to create a habitat area according to Table B-2. For the deer population, the total number was estimated based on the deer density in each land use category (Horton, 2004). For goose, duck, and swan populations, the totals estimated were obtained from GIS data provide by the Maryland DNR (Hindman, 2005). Wildlife populations were obtained by applying assumed wildlife densities to these extracted areas. The populations of the wildlife were obtained by applying density factors to estimated habitat areas. The fecal coliform contributions were estimated based on the estimated number of wildlife and fecal coliform production rates, which are listed in Table B-3. To obtain the total wildlife contribution, population density is multiplied by the applicable acreage or stream mile and that product is multiplied by fecal coliform production rates for each animal.

Table B-3: Wildlife Fecal Coliform Production Rates

Source	Fecal Coliform Production (counts/animal/day)
Beaver[1]	2.50E+08
Deer[1]	5.00E+08
Goose[2]	2.43E+09
Duck[1]	2.43E+09
Swan[5]	2.43E+09
Muskrat[3]	3.40E+07
Raccoon[3]	1.00E+09
Wild turkey[4]	9.30E+07

[1]USEPA (2000);); [2]Use duck rate (USEPA, 2000);
[3]Kator and Rhodes (1996); [4]ASAE (1998); [5]use duck rate

B. Human Contributions

Human loading can result from failures in septic systems or through pollution from recreational vessel discharges in the identified restricted shellfish harvesting area. It is assumed that a failing septic system is a direct load contribution from humans. The estimation of human contribution is based on human population, number of properties, the estimated number of septic systems in the watershed, and an estimated septic system failure rate.

The human population and the number of households were estimated from the GIS 2000 Census Block that includes the Lower Choptank River Basin. Since the subwatersheds throughout the Lower Choptank River Basin are sub-areas of the Census Block, the GIS tool was used to extract these areas from the 2000 Census Block. The percentage of the subwatershed area relative to the total area of the 2000 Census Block was calculated. This percentage was applied to partition the total census block population and total census block number of households in proportion to the population within the area of the subwatersheds. The results are shown in Table B-4.

Table B-4: Estimated Population, Households, and Septic Systems in Lower Choptank River

Area Name	Estimated Population	Estimated Septic Systems	Estimated Households	Public Sewer
Whitehall Creek	289	109	111	None
Indian Creek	336	184	134	None
Goose Creek	92	26	36	Partial
Warwick River	1171	162	485	Partial
San Domingo Creek	160	51	72	None

(Note: Residential septic systems only, public sewer excluded)

The distributions of septic systems for Whitehall Creek, Indian Creek, Goose Creek, Warwick River, and San Domingo Creek are shown, respectively, in Figure B-1 to Figure B-5. Based on GIS property coverage, a point is assumed to represent a septic system. The total number of septic systems, as estimated using GIS, is shown in Table B-4. Portions of the Goose Creek and Warwick River restricted shellfish harvesting areas are served by public sewer systems.

It is assumed that any human contribution is attributed to septic systems (although recreational vessels might be a source, we have not found a means to quantify that source). The human contribution to the restricted shellfish harvesting areas was estimated using the number of septic systems, the average number of people per septic system, and an estimated failure rate for septic systems. The estimated fecal coliform loading from humans is calculated as follows:

$Load = P\ S\ F_r\ C\ Q\ C_V$

Where
P = number of people per septic system
S = number of septic systems in the restricted area
F_r = failure rate of septic systems
C = fecal coliform concentration of wastewater
Q = daily discharge of wastewater per person
C_V = unit conversion factor (37.854)

The number of people using each septic system is estimated by the ratio of the population to the number of septic systems. In the absence of shoreline sanitary survey data, the estimated septic system failure rate of 3% for coastal restricted shellfish harvesting areas was used. This rate was used for the total number of failing septic systems for the watersheds. This rate is in the same range as that in the upper Chesapeake Bay (De Walle, 1981; EPA Stormwater Management Center). It was assumed that wastewater for each person was 70 gallons per day with a fecal coliform concentration of 1×10^5 most probable number (MPN)/100ml. The estimated from septic system failure is less than 1%.

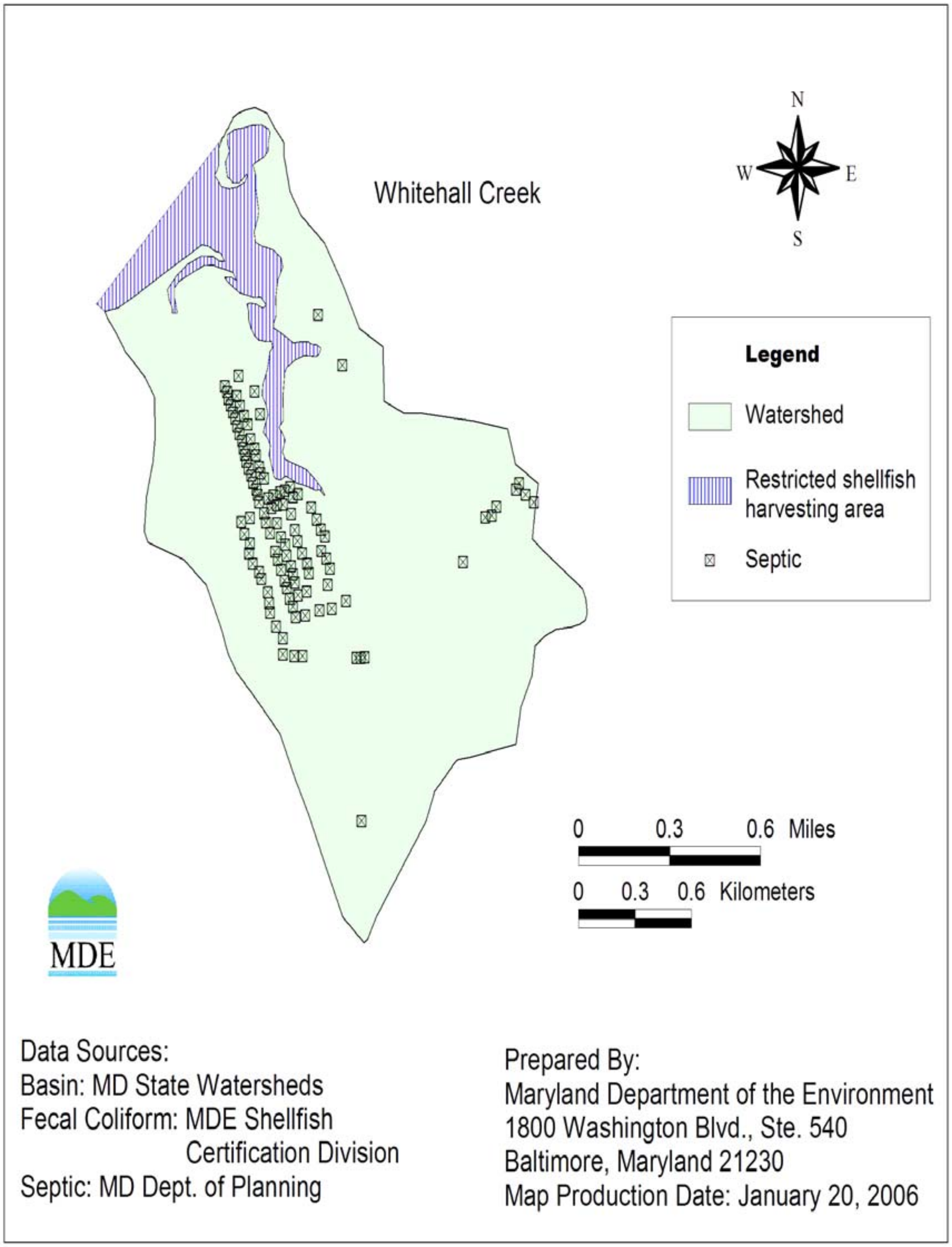

Figure B-1: Distribution of Septic Systems in the Whitehall Creek Watershed

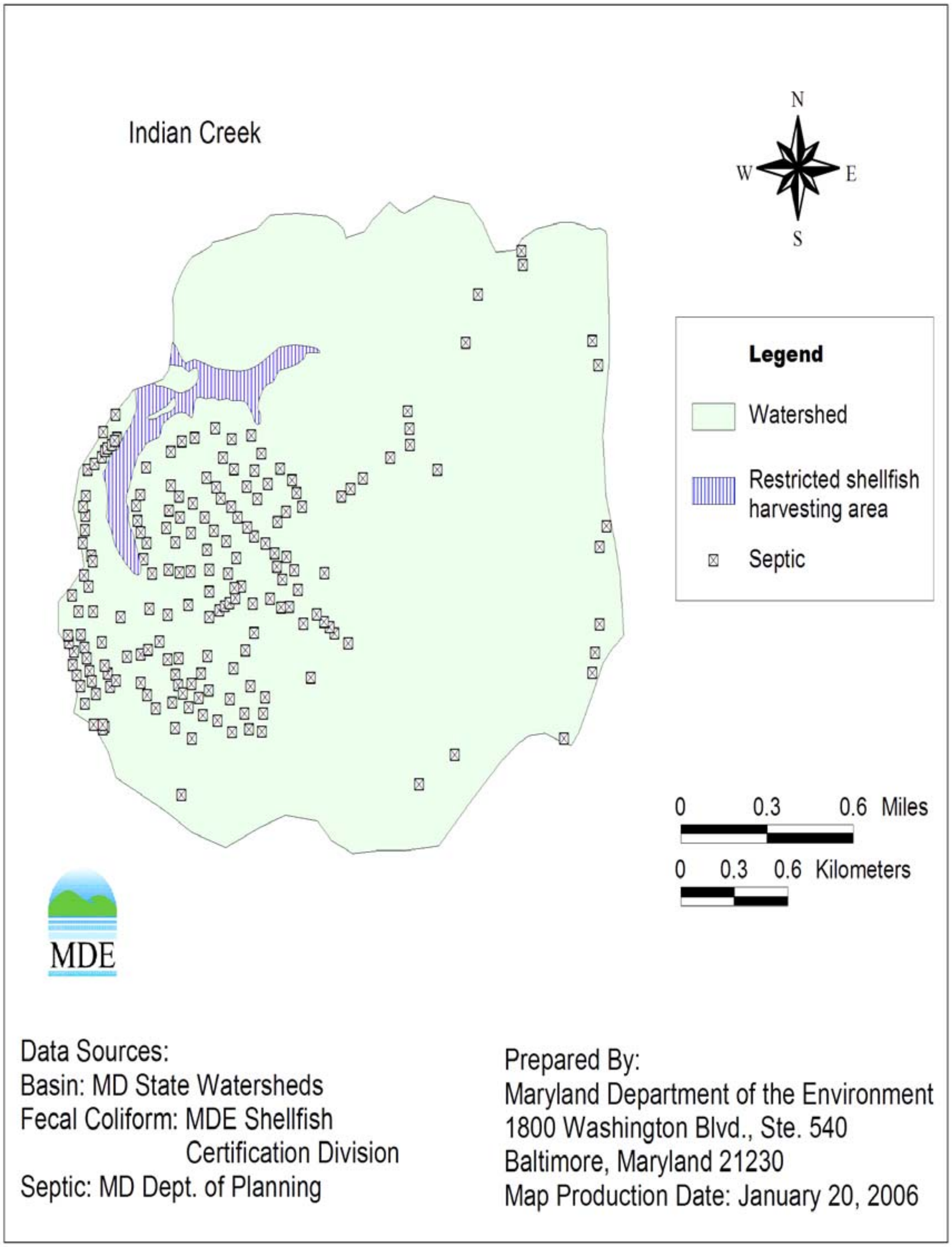

Figure B-2: Distribution of Septic Systems in the Indian Creek Watershed

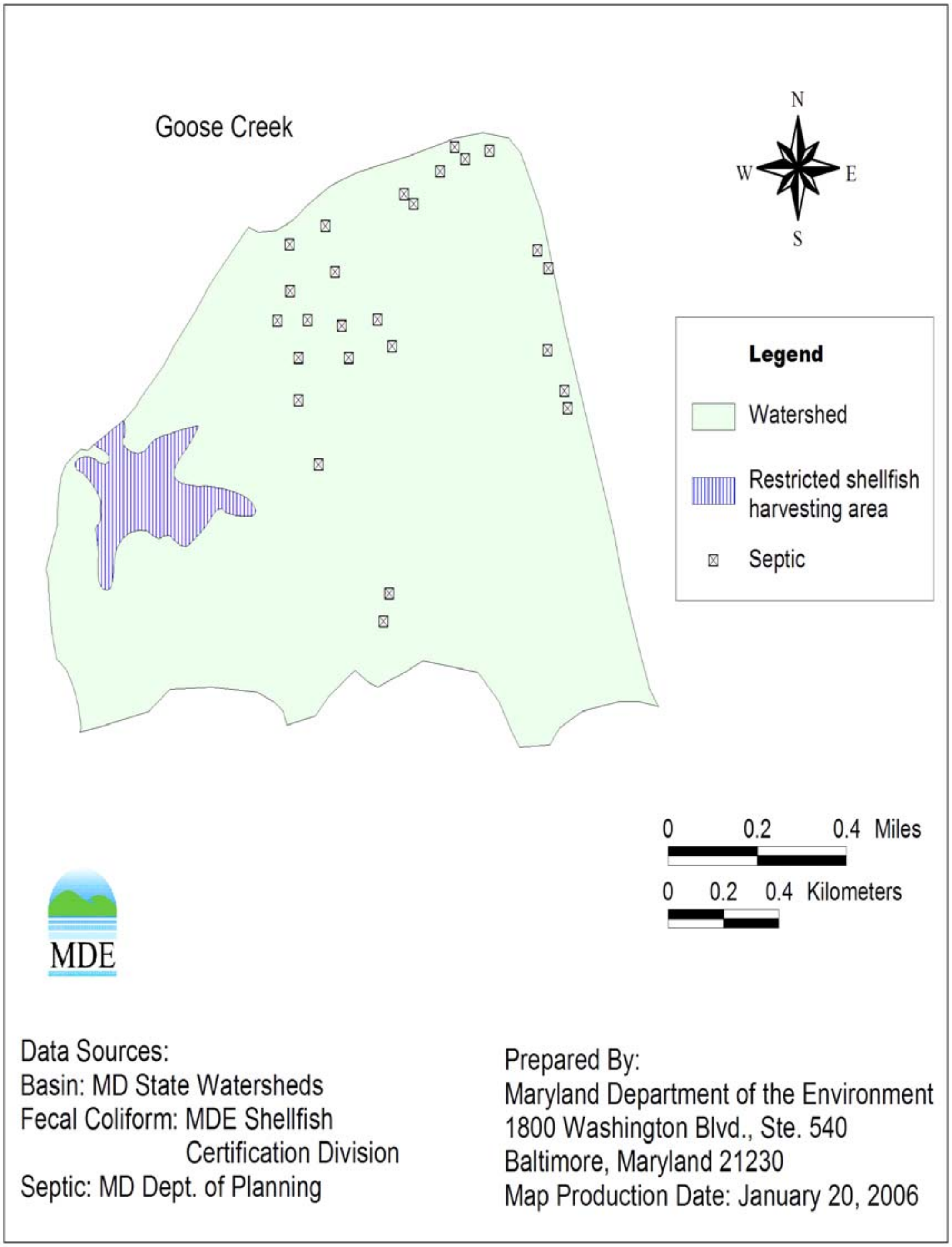

Figure B-3: Distribution of Septic Systems in the Goose Creek Watershed

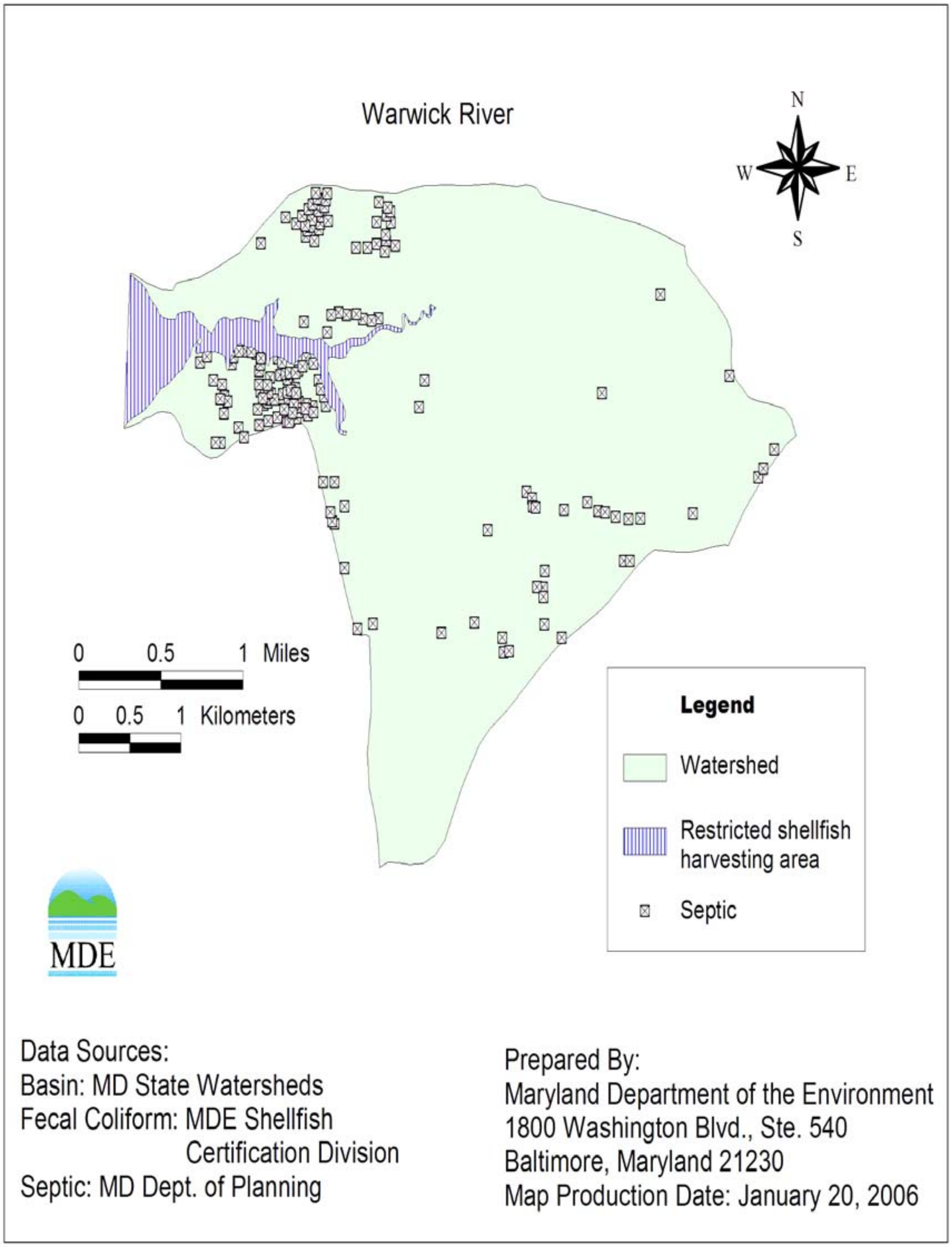

Figure B-4: Distribution of Septic Systems in the Warwick River Watershed

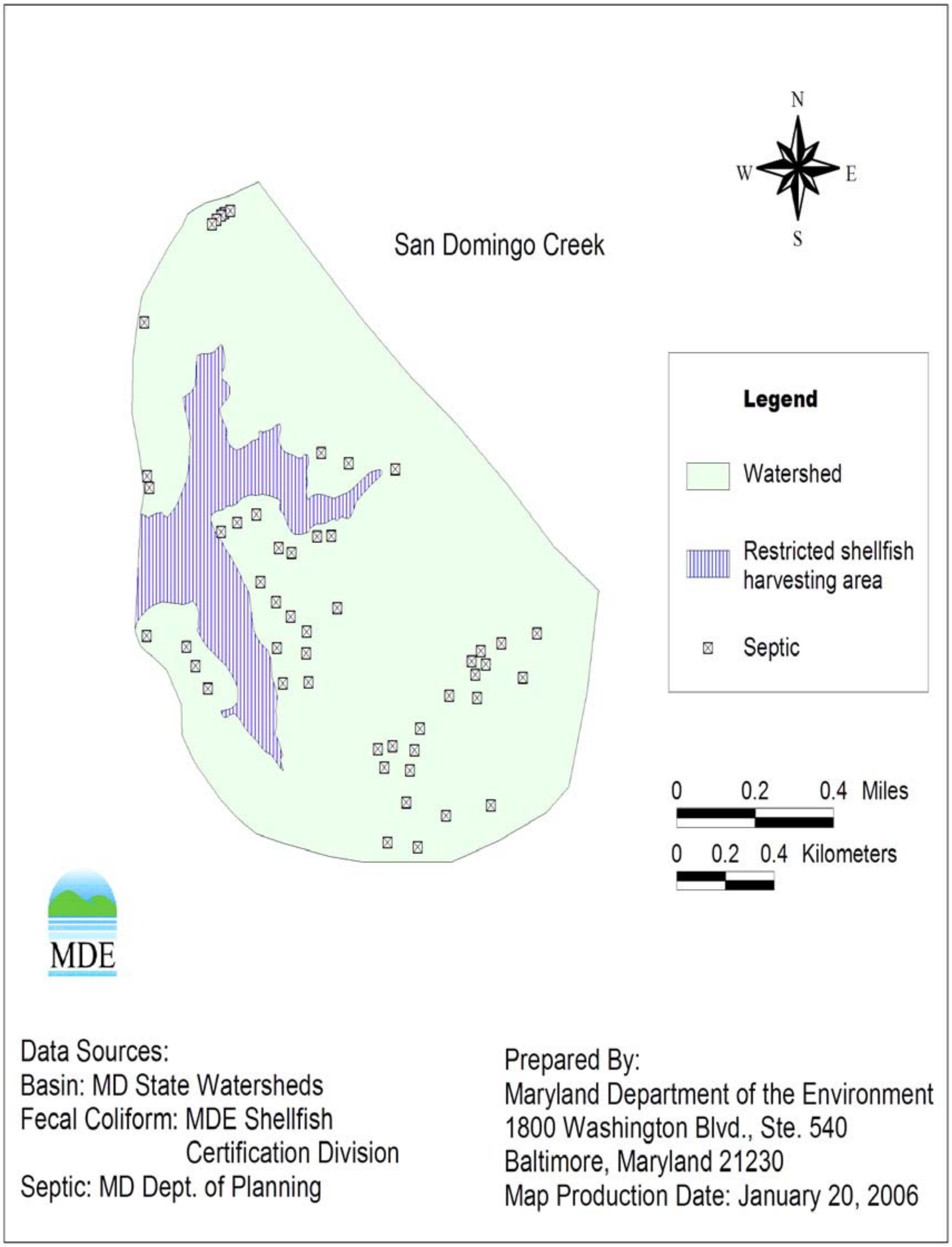

Figure B-5: Distribution of Septic Systems in the San Domingo Creek Watershed

C. Pet Contributions

Pet contributions usually occur through runoff from either an urban or a low-density residential area. Dogs are the only domestic pets assumed to contribute fecal coliform. Dog license information can be obtained from the county; however, these data will not include feral or unlicensed pets. This is likely to cause an underestimation of the total population. Therefore, the dog populations for restricted shellfish harvesting areas in the Lower Choptank River watershed were estimated based on the number of households (see Table B-4). According to a survey conducted by the Center for Watershed Protection of Chesapeake Bay residents, about 41% of the households own a dog. Of these dog owners, only about 56% walk their dogs, and of that group only 59% clean up most of the time (*i.e.*, 41% do not) (Swann, 1999). The estimated total load available for wash off is 23% (*i.e.*, 56% x 41%). The fecal coliform contribution from the dog population was estimated using a production rate of 5×10^9 counts/dog/day (EPA, 2000). Using information from Table B-4, estimated fecal coliform loading from dogs is calculated as follows:

$$LOADING_{dog} = P\ R_1\ R_2\ R_3\ PR_{dog}$$

where:
P = number of households in specified restricted area
R_1 = ratio of dogs per household in this region
R_2 = percentage of owners that walk their dogs
R_3 = percentage of walked dogs contributing fecal matter
PR_{dog} = average fecal coliform production rate for dogs

D. Livestock Contributions

The fecal coliform contribution from livestock may be through the manure spreading and direct deposition during grazing. This contribution was estimated based on land use data and the Maryland livestock census data (Brodie and Lawrence, 1996; USDA, 1997; MASS, 2002). Animal ratio estimators for the 8-digit watersheds were developed based on the finest resolution of animal counts available – statewide, region or county. These Maryland 8-digit watershed livestock animal counts were then proportioned to the sub-watersheds using the procedure outlined in Figure B-5. The fecal coliform load was estimated based on the total number of livestock and their fecal coliform production rates.

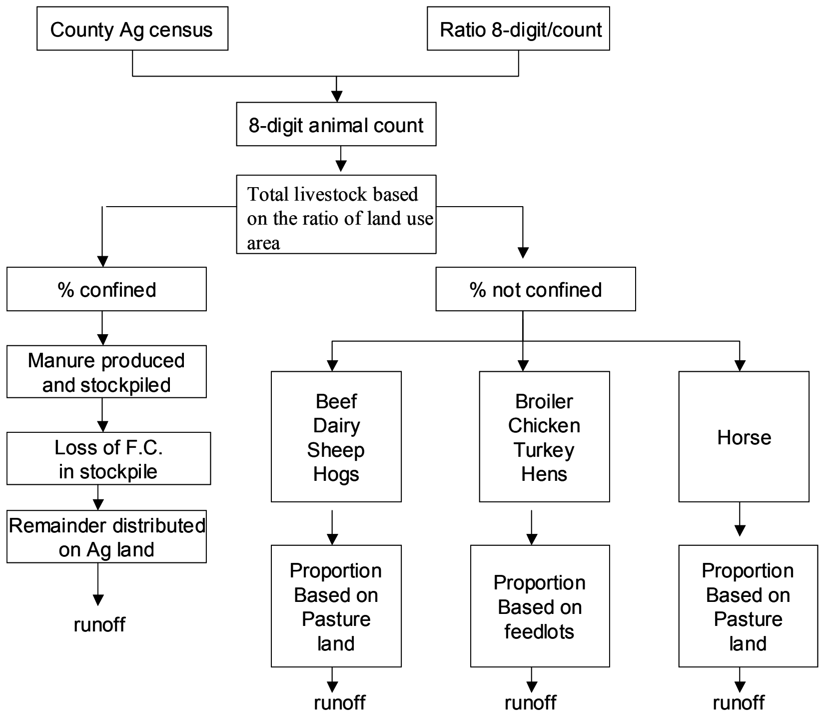

Figure B-6: Diagram to Illustrate Procedure Used to Estimate Fecal Coliform Production from Estimated Livestock Population

Fecal coliform production rates used to estimate loading are listed in Table B-5. The estimated fecal coliform produced by animals was divided into manure spreading and direct deposition, depending on the percent of time they were confined. The percent of time livestock was confined is listed in Table B-6. The estimated percentage of manure available for wash off is about 40% (VIMS, 2004). For chickens, however, only about 10% is available for wash off (Woods, 2004). Therefore, fecal coliform decay is also considered in the estimation of fecal coliform production. The percent of fecal coliform available for wash off from manure spreading in the field is also listed in Table B-6.

Table B-5: Livestock Fecal Coliform Production Rates

Source	Fecal Coliform Production (counts/animal/day)
Dairy	1.01E+11
Beef	1.20E+10
Horses	4.20E+08
Sheep	1.20E+10
Broilers	1.36E+08
Turkeys	9.30E+07
Chickens	1.36E+08
Layers	1.36E+08
Hogs	1.08E+10

Table B-6: Percent of Time Livestock is Confined

Livestock	Percent of time confined	Percent Manure Available For Wash off
Dairy	80.0%	40.0%
Beef	20.0%	40.0%
Horses	50.0%	40.0%
Sheep	50.0%	40.0%
Broilers	85.0%	10.0%
Turkeys	85.0%	10.0%
Chickens	85.0%	10.0%
Layers	85.0%	10.0%
Hogs	100.0%	40.0%

E. Nonpoint Source Summary

The complete distributions of these source loads are also listed in Tables B-7 to B-11, along with counts/day for each loading. The Bacteria Source Tracking (BST) data will be used to further confirm the source distribution when it becomes available.

Table B-7: Distribution of Fecal Coliform Source Loads in the Whitehall Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	7.29E+11	80.7%
Pets	5.23E+10	5.8%
Human	2.30E+09	0.3%
Wildlife	1.20E+11	13.2%
Total	9.03E+11	100.0%

Table B-8: Distribution of Fecal Coliform Source Loads in the Indian Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	1.15E+12	22.5%
Pets	6.32E+10	1.2%
Human	2.67E+09	0.1%
Wildlife	3.88E+12	76.2%
Total	5.09E+12	100.0%

Table B-9: Distribution of Fecal Coliform Source Loads in the Goose Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	6.25E+11	51.0%
Pets	1.70E+10	1.4%
Human	7.31E+08	0.1%
Wildlife	5.81E+11	47.5%
Total	1.22E+12	100.0%

Table B-10: Distribution of Fecal Coliform Source Loads in the Warwick River Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	4.35E+12	66.5%
Pets	2.29E+11	3.5%
Human	9.31E+09	0.1%
Wildlife	1.95E+12	29.8%
Total	6.54E+12	100.0%

Table B-11: Distribution of Fecal Coliform Source Loads in the San Domingo Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	4.16E+11	34.5%
Pets	3.39E+10	2.8%
Human	1.27E+09	0.1%
Wildlife	7.56E+11	62.6%
Total	1.21E+12	100.0%

Appendix C. Seasonality Analysis

The EPA Code of Federal Regulations (40 CFR 130.7 (c)(1)) requires that TMDL studies take into account critical conditions for stream flow, loading, and water quality parameters. 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, in fact, both fecal coliform sources and delivery vary seasonally due to changes of hydrology conditions and land use practices. The most probable fecal coliform sources result from agricultural practices and livestock, wildlife, and urban runoff. Precipitation and temperature fluctuate seasonally, producing seasonally 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 deterring fecal coliform from entering waters by both decreasing surface runoff and absorbing fecal coliform. Warm-blooded animals, the sources of fecal coliform, are directly or indirectly connected with vegetation productivity via food chain relationships. In temperate forests, for example, 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. Manure application during crop planting often increases 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 areas.

The 5-year monthly mean fecal coliform concentration and its standard deviation were calculated for the five monitoring stations used in this report. The results are presented in Figure C-1 through Figure C-5. Overall, it is shown that higher fecal coliform concentrations occur in the months between July and November in the restricted shellfish harvesting areas of the Lower Choptank River, whereas lower concentrations occur between January and March. Although seasonal distributions vary from one month to the next, a large standard deviation that corresponds to the high fecal coliform concentration variability at each station suggests that the violation frequently may occur in a few months of the year.

The high fecal coliform concentration, even for an isolated event, often results in a higher 90th percentile concentration. The 90th percentile concentration is the concentration exceeded only 10% of the time. This value represents the critical condition for the year. Since data collected during the most recent five-year period was used to calculate the 90th percentile, both the seasonal and the critical condition are implicitly included in the value of the 90th percentile.

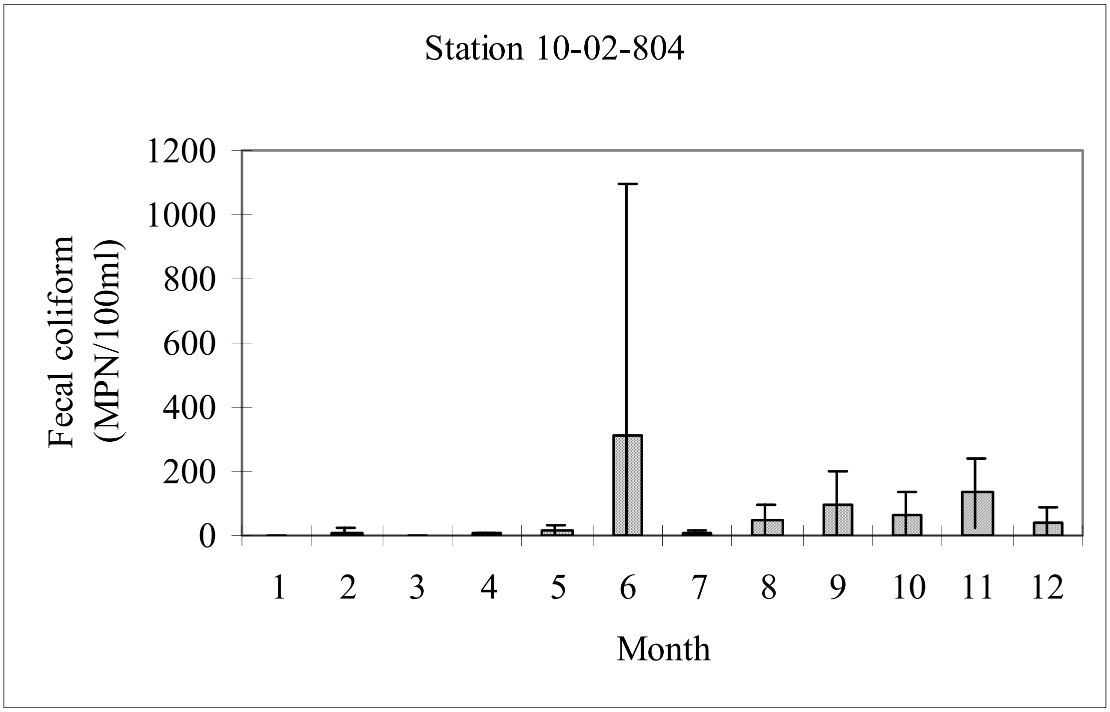

Figure C-1: Seasonality analysis of fecal coliform at Whitehall Creek Station 10-02-804

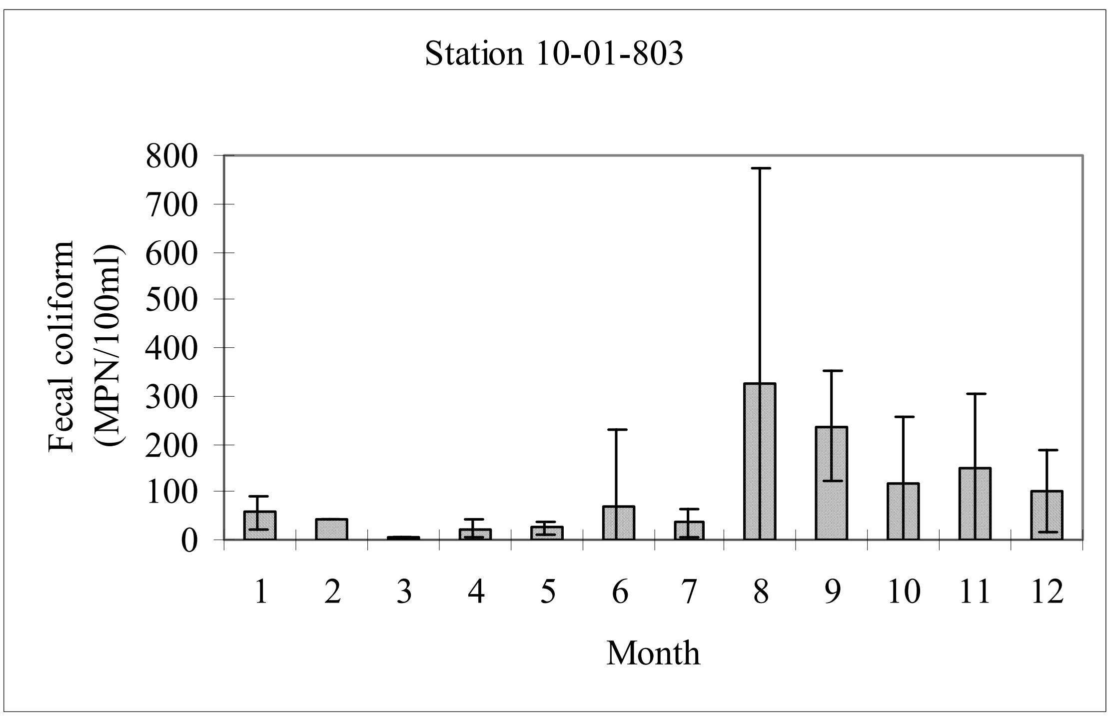

Figure C-2: Seasonality analysis of fecal coliform at Indian Creek Station 10-01-803

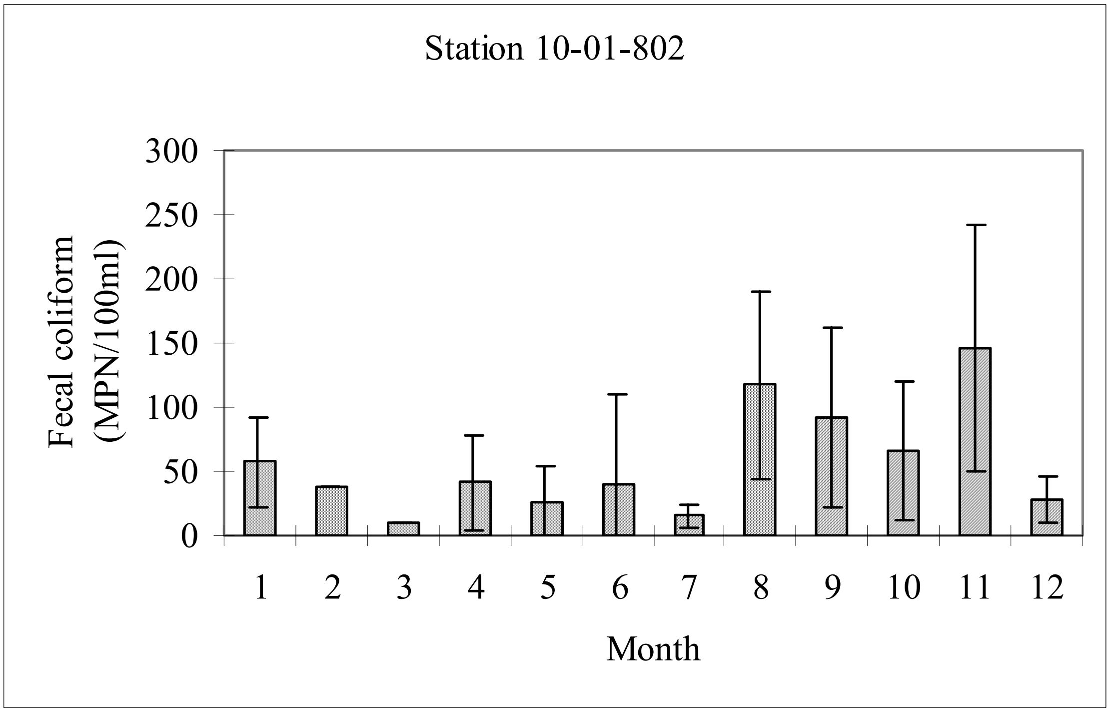

Figure C-3: Seasonality analysis of fecal coliform at Goose Creek Station 10-01-802

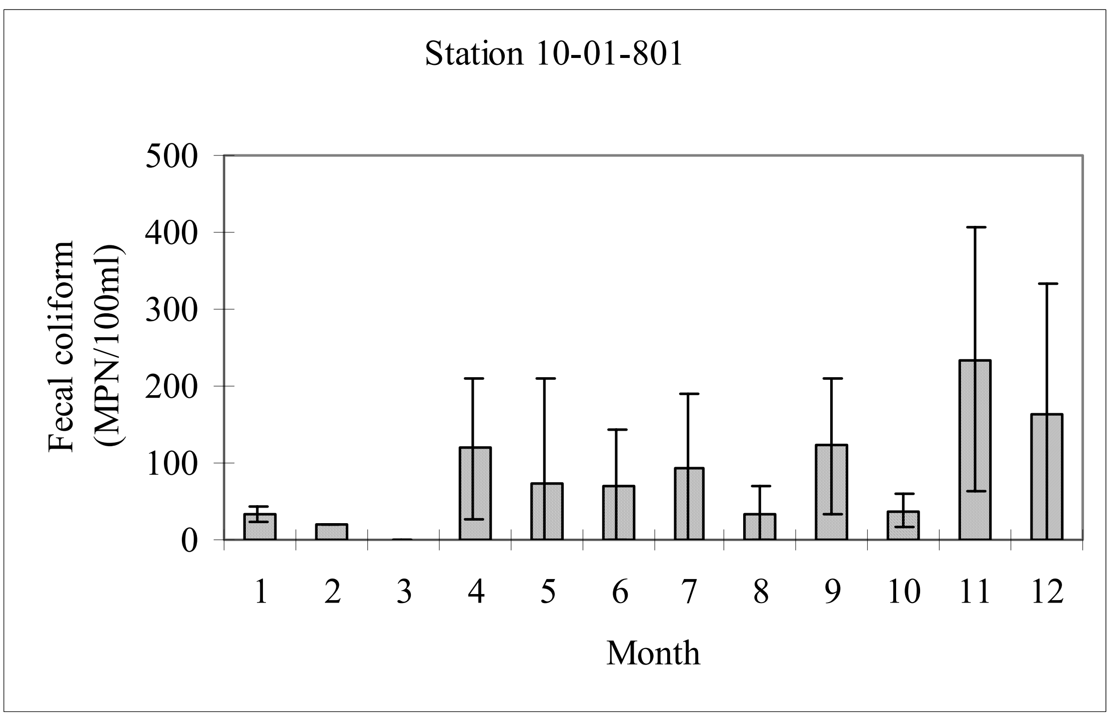

Figure C-4: Seasonality analysis of fecal coliform at Warwick River Station 10-01-801

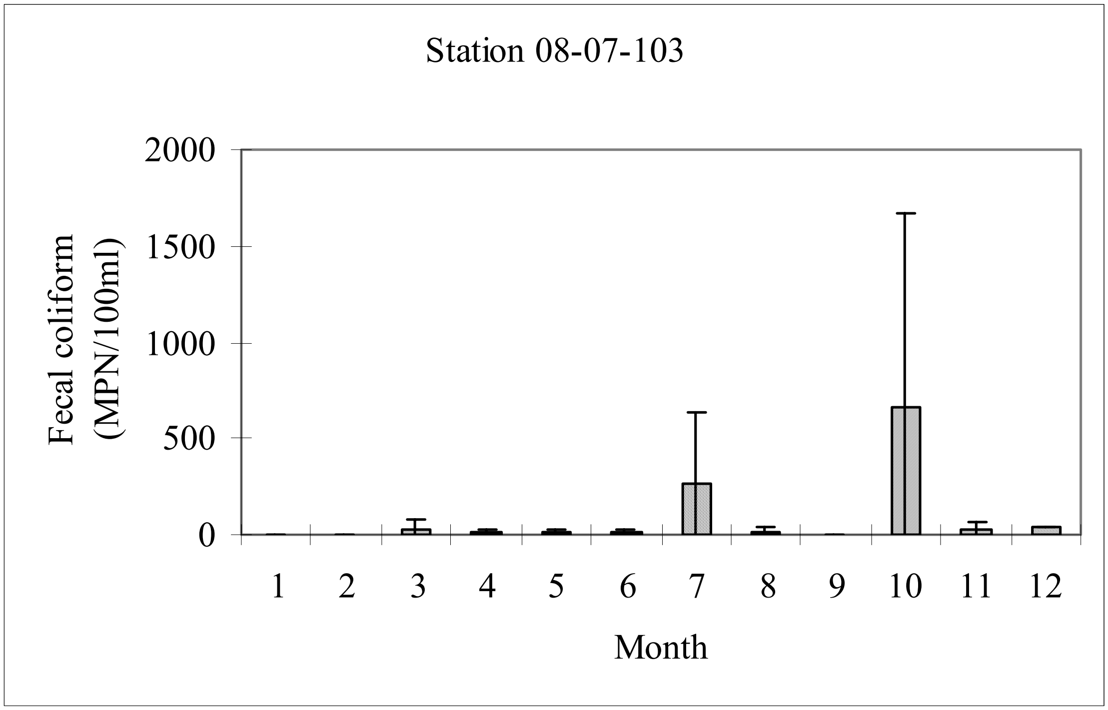

Figure C-5: Seasonality analysis of fecal coliform at San Domingo Creek Station 08-07-103

Appendix D. Tabulation of Observed Fecal Coliform Data

This appendix provides a tabulation of fecal coliform values for each monitoring station in the restricted shellfish harvesting area of the Lower Choptank River Basin in Tables D-2, D-3, D-4, D-6, and D-8. These data are plotted in report Figures 2.2.2, 2.2.4, 2.2.6, 2.2.8, and 2.2.10, respectively. Additionally, a tabulation of fecal coliform values for each station used as model boundary conditions is provided in Tables D-1, D-5, and D-7.

Table D-1: Observed Fecal Coliform data at Whitehall Creek Station 10-02-005

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/11/2000	1	10/28/2002	75
7/20/2000	3.6	11/14/2002	23
7/31/2000	3.6	12/10/2002	3
8/7/2000	9.1	2/10/2003	43
9/11/2000	240	3/25/2003	3.6
9/28/2000	39	5/6/2003	3.6
10/5/2000	43	5/12/2003	9.1
10/25/2000	9.1	6/9/2003	240
11/13/2000	240	7/8/2003	1
12/4/2000	9.1	7/15/2003	3.6
1/17/2001	1	7/29/2003	1
3/29/2001	9.1	9/8/2003	23
4/25/2001	150	10/7/2003	43
5/7/2001	1	12/4/2003	93
5/29/2001	43	4/20/2004	23
6/6/2001	3.6	5/5/2004	43
6/26/2001	3.6	5/19/2004	3.6
7/11/2001	1	6/3/2004	1
8/2/2001	150	6/17/2004	3.6
8/7/2001	23	8/12/2004	23
8/30/2001	23	9/15/2004	1
9/12/2001	43	10/5/2004	43
10/10/2001	43	10/27/2004	23
11/7/2001	7.3	11/29/2004	43
12/5/2001	9.1	12/6/2004	23
1/22/2002	1	12/16/2004	23
3/11/2002	1	1/5/2005	7.3
4/17/2002	3.6	2/8/2005	7.3
5/9/2002	3.6	2/17/2005	9.1
6/13/2002	1	5/2/2005	9.1

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/15/2002	3.6	5/12/2005	9.1
8/12/2002	7.2	5/26/2005	1
9/18/2002	23	6/6/2005	21
10/7/2002	3.6	6/20/2005	1
10/17/2002	23	7/7/2005	7.3

Table D-2: Observed Fecal Coliform data at Whitehall Creek Station 10-02-804

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/11/2000	1	10/28/2002	43
7/20/2000	11	11/14/2002	43
7/31/2000	9.1	12/10/2002	3.6
8/7/2000	15	2/10/2003	23
9/11/2000	240	3/25/2003	3.6
9/28/2000	240	5/6/2003	3
10/5/2000	150	5/12/2003	23
10/25/2000	3.6	6/9/2003	2400
11/13/2000	240	7/8/2003	3.6
12/4/2000	9.1	7/15/2003	23
1/17/2001	3.6	7/29/2003	9.1
3/29/2001	3.6	9/8/2003	23
4/25/2001	9.1	10/7/2003	23
5/7/2001	1	12/4/2003	150
5/29/2001	43	4/20/2004	9.1
6/6/2001	9.1	5/5/2004	21
6/26/2001	3.6	5/19/2004	1
7/11/2001	23	6/3/2004	9.1
8/2/2001	150	6/17/2004	9.1
8/7/2001	9.1	8/12/2004	43
8/30/2001	43	9/15/2004	3.6
9/12/2001	23	10/5/2004	7.3
10/10/2001	43	10/27/2004	240
11/7/2001	9.1	11/29/2004	240
12/5/2001	9.1	12/6/2004	39
1/22/2002	3.6	12/16/2004	9.1
3/11/2002	3.6	1/5/2005	3.6
4/17/2002	9.1	2/8/2005	1
5/9/2002	43	2/17/2005	9.1
6/13/2002	23	5/2/2005	2.3
7/15/2002	1	5/12/2005	15
8/12/2002	23	5/26/2005	1
9/18/2002	43	6/6/2005	23
10/7/2002	23	6/20/2005	1
10/17/2002	39	7/7/2005	7.3

Table D-3: Observed Fecal Coliform data at Indian Creek Station 10-01-803

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/11/2000	43	10/7/2002	43
7/31/2000	75	10/17/2002	460
8/7/2000	9.1	10/28/2002	23
9/11/2000	240	11/13/2002	39
9/28/2000	240	12/10/2002	23
10/5/2000	43	3/25/2003	3
10/25/2000	23	5/12/2003	43
11/6/2000	240	6/9/2003	460
11/13/2000	43	7/8/2003	3.6
12/6/2000	1	9/8/2003	460
1/17/2001	23	10/7/2003	240
5/7/2001	7.3	12/4/2003	93
5/29/2001	23	5/5/2004	23
6/6/2001	3.6	5/19/2004	43
6/26/2001	9.1	6/3/2004	1
7/11/2001	1	8/12/2004	1100
7/30/2001	75	9/14/2004	150
8/7/2001	93	10/7/2004	43
9/12/2001	93	10/27/2004	93
10/10/2001	93	11/8/2004	75
11/7/2001	460	11/30/2004	43
12/5/2001	240	12/6/2004	150
1/22/2002	93	2/17/2005	43
4/17/2002	3.6	5/2/2005	23
4/22/2002	43	5/12/2005	43
5/9/2002	9.1	5/26/2005	3.6
6/13/2002	9.1	6/6/2005	9.1
7/15/2002	23	6/20/2005	1
8/12/2002	93	7/7/2005	23
9/18/2002	240		

Table D-4: Observed Fecal Coliform data at Goose Creek Station 10-01-802

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/11/2000	23	9/18/2002	43
7/31/2000	23	10/7/2002	9.1
8/7/2000	240	10/17/2002	150
9/11/2000	93	10/28/2002	43
9/28/2000	240	11/13/2002	43
10/5/2000	43	12/10/2002	3.6
10/25/2000	9.1	3/25/2003	9.1
11/6/2000	93	5/12/2003	3.6
11/13/2000	23	6/9/2003	210
12/6/2000	9.1	7/8/2003	3
1/17/2001	93	9/8/2003	43
4/18/2001	93	10/7/2003	93
5/7/2001	23	12/4/2003	43
5/29/2001	93	5/5/2004	43
6/6/2001	9.1	5/19/2004	15
6/26/2001	3.6	6/3/2004	3.6
7/11/2001	7.3	8/12/2004	93
7/30/2001	23	9/14/2004	93
8/7/2001	43	10/7/2004	7.3
9/12/2001	43	10/27/2004	93
10/10/2001	150	11/8/2004	240
11/7/2001	240	11/30/2004	240
12/5/2001	43	12/6/2004	43
1/22/2002	23	2/17/2005	39
4/17/2002	9.1	5/2/2005	43
4/22/2002	23	5/12/2005	15
5/9/2002	3.6	5/26/2005	3.6
6/13/2002	1	6/6/2005	39
7/15/2002	23	6/20/2005	7.3
8/12/2002	93	7/7/2005	3.6

Table D-5: Observed Fecal Coliform data at Warwick River Station 10-01-010

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/11/2000	43	9/18/2002	43
7/31/2000	23	10/7/2002	23
8/7/2000	23	10/17/2002	23
9/11/2000	93	10/28/2002	43
9/28/2000	93	11/13/2002	240
10/5/2000	23	12/10/2002	23
10/25/2000	23	3/25/2003	3.6
11/6/2000	240	5/12/2003	15
11/13/2000	43	6/9/2003	93
12/6/2000	1	7/8/2003	75
1/17/2001	43	9/8/2003	43
4/18/2001	23	10/7/2003	240
5/7/2001	1	12/4/2003	240
5/29/2001	43	5/5/2004	23
6/6/2001	9.1	5/19/2004	23
6/26/2001	21	6/3/2004	23
7/11/2001	1	8/12/2004	23
7/30/2001	23	9/14/2004	23
8/7/2001	93	10/7/2004	9.1
9/12/2001	23	10/27/2004	460
10/10/2001	43	11/8/2004	460
11/7/2001	23	11/30/2004	93
12/5/2001	43	12/6/2004	240
1/22/2002	75	2/17/2005	39
4/17/2002	3.6	5/2/2005	3.6
4/22/2002	240	5/12/2005	9.1
5/9/2002	15	5/26/2005	43
6/13/2002	3.6	6/6/2005	9.1
7/15/2002	1	6/20/2005	3.6
8/12/2002	9.1	7/7/2005	43

Table D-6: Observed Fecal Coliform data at Warwick River Station 10-01-801

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
7/11/2000	240	9/18/2002	43
7/31/2000	43	10/7/2002	43
8/7/2000	23	10/17/2002	93
9/11/2000	93	10/28/2002	43
9/28/2000	240	11/13/2002	150
10/5/2000	23	12/10/2002	43
10/25/2000	23	3/25/2003	1
11/6/2000	75	5/12/2003	23
11/13/2000	460	6/9/2003	23
12/6/2000	1	7/8/2003	15
1/17/2001	23	9/8/2003	240
4/18/2001	240	10/7/2003	43
5/7/2001	43	12/4/2003	240
5/29/2001	23	5/5/2004	23
6/6/2001	240	5/19/2004	9.1
6/26/2001	93	6/3/2004	15
7/11/2001	9.1	8/12/2004	23
7/30/2001	240	9/14/2004	23
8/7/2001	93	10/7/2004	23
9/12/2001	93	10/27/2004	43
10/10/2001	9.1	11/8/2004	240
11/7/2001	23	11/30/2004	460
12/5/2001	75	12/6/2004	460
1/22/2002	43	2/17/2005	21
4/17/2002	93	5/2/2005	23
4/22/2002	23	5/12/2005	460
5/9/2002	43	5/26/2005	23
6/13/2002	43	6/6/2005	43
7/15/2002	9.1	6/20/2005	43
8/12/2002	1	7/7/2005	93

Table D-7: Observed Fecal Coliform data at San Domingo Creek Station 08-07-005

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
2/24/2000	1	7/22/2002	7.3
4/19/2000	39	9/19/2002	23
4/26/2000	3.6	10/3/2002	1
5/10/2000	23	10/15/2002	9.1
5/31/2000	7.3	11/20/2002	93
6/14/2000	9.1	3/31/2003	43
7/18/2000	23	8/26/2003	9.1
7/27/2000	93	9/15/2003	9.1
8/30/2000	1	9/30/2003	3.6
9/18/2000	23	10/28/2003	93
11/20/2000	1	3/30/2004	1
4/26/2001	3.6	4/27/2004	3.6
5/3/2001	1	5/11/2004	1
5/15/2001	23	5/25/2004	9.1
6/13/2001	3.6	6/9/2004	1
6/28/2001	1	6/23/2004	14
8/9/2001	1	7/7/2004	1
8/22/2001	23	7/13/2004	150
9/19/2001	3.6	7/22/2004	1
11/19/2001	3	7/28/2004	3.6
12/12/2001	3.6	8/17/2004	240
3/25/2002	1	8/24/2004	1
4/24/2002	1	9/7/2004	3.6
5/16/2002	1	10/18/2004	43
6/24/2002	1	1/11/2005	1

Table D-8: Observed Fecal Coliform data at San Domingo Creek Station 08-07-103

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
2/24/2000	1	7/22/2002	3.6
4/19/2000	43	9/19/2002	1
4/26/2000	3.6	10/3/2002	3.6
5/10/2000	23	10/15/2002	3.6
5/31/2000	3.6	11/20/2002	75
6/14/2000	43	3/31/2003	93
7/18/2000	43	8/26/2003	3.6
7/27/2000	240	9/15/2003	1
8/30/2000	3.6	9/30/2003	3.6
9/18/2000	1	10/28/2003	2400
11/20/2000	1	3/30/2004	3.6
4/26/2001	3.6	4/27/2004	1
5/3/2001	7.3	5/11/2004	23
5/15/2001	23	5/25/2004	9.1
6/13/2001	1	6/9/2004	9.1
6/28/2001	7.2	6/23/2004	3.6
8/9/2001	1	7/7/2004	1
8/22/2001	9.1	7/13/2004	460
9/19/2001	1	7/22/2004	1
11/19/2001	23	7/28/2004	1100
12/12/2001	43	8/17/2004	75
3/25/2002	1	8/24/2004	1
4/24/2002	3.6	9/7/2004	9.1
5/16/2002	1	10/18/2004	240
6/24/2002	9.1	1/11/2005	1