Total Maximum Daily Loads of Fecal Coliform for the Restricted Shellfish Harvesting Area in Back Creek of the Honga River Basin in Dorchester County, Maryland

FINAL

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Table of Contents

List of Figures

List of Tables

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
GIS	Geographic Information System
km	Kilometer
LA	Load Allocation
LMM	Long-term Moving Median
MACS	Maryland Agricultural Cost Share Program
MASS	Maryland Agricultural Statistic 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
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	U. S. 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
FDA	U.S. Food and Drug Administration

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.

Honga River (basin number 02-13-04-01) 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. On the 2004 303(d) List, the fecal coliform impairment was clarified with the identification of Back Creek as the specific area of impairment. This document, upon EPA approval, establishes a TMDL of fecal coliform for Back Creek. The nutrient and sediment impairments within the Honga River basin will be addressed at a future date.

A steady state tidal prism model was used to estimate current fecal coliform load based on volume and concentration and establish allowable loads for the restricted shellfish harvesting area in the Honga River Basin. The tidal prism model incorporates both influences of freshwater discharge and tidal flushing for each area, which thereby represents 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 each restricted shellfish harvesting area were then computed using both the median water quality criterion for shellfish harvesting of 14 Most Probable Number (MPN)/100ml and the 90th percentile criterion 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 area of the Honga River Basin for fecal coliform median load and 90th percentile load are as follows:

Back Creek:
The median load of fecal coliform TMDL = 1.236×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 4.325×10^{10} counts per day

The goal of load allocation is to determine the estimated loads for the watershed while ensuring that the water quality standard can be attained.

For the restricted shellfish harvesting area in the Honga River Basin, the 90th percentile criterion requires the greatest reduction – approximately 30% within the watershed. Therefore, the load reduction scenario is developed based on the 90th 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 with the largest 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 by 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 a protective margin of safety (MOS) to account for 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 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. Few fecal coliform are pathogenic; however, the presence of elevated levels of fecal coliform in shellfish waters indicates 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 may occur in surface waters from point and nonpoint sources.

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 safety of food consumed by people and therefore, FDA issues the standards protecting shellfish harvesting and has retained the fecal coliform standards. 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 due to elevated fecal coliform concentrations as required under the National Shellfish Sanitation Program. Monitoring is ongoing in shellfish areas, 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.

Honga River (basin number 02-13-04-01) 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. On the 2004 303(d) List, the fecal coliform impairment was clarified with the identification of Back Creek as the specific area of impairment.

This document, upon EPA approval, establishes a TMDL of fecal coliform for Back Creek. The basis of the harvesting area closure was current fecal coliform data from the shellfish monitoring program indicating that either the median or 90th percentile FDA standards had been exceeded, and therefore resulted in the areas being classified as "restricted" or closed to direct harvest. The nutrient and sediment impairments within the Honga River basin will be addressed at a future date.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

A single restricted shellfish harvesting area is addressed in this report. Honga River is located on Maryland's Eastern Shore in Dorchester County, MD, and its restricted area, Back Creek, is located along its western shore, as shown in Figure 2.1.1. Back Creek is approximately four km in length, and it enters the Honga River about 25 km northwest of the River's mouth. The Back Creek restricted area has a drainage area of 113.0 acres (0.46 km^2) and a width of approximately 300 m.

The Honga River Basin is characterized as hydrology classes C and D and as having moderate to high runoff. The top soil layer mainly consists of silt (48%), sand (32%), and clay (20%) (U. S. Department of Agriculture (USDA), 1995). The dominant tide in this region is the lunar semi-diurnal (M_2) tide with a tidal range of 0.43 m in the restricted area portion of the Honga River 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 Back Creek.

Table 2.1.1: Physical Characteristics of the Back Creek Restricted Shellfish Harvesting Area

Restricted Shellfish Harvesting Area	Mean Water Volume in m^3	Mean Water Depth in m
Back Creek	126,299.9	0.23

The 2000 Maryland Department of Planning (MDP) land use/land cover data shows that the watershed can be characterized as urban for the Back Creek with over 80% residential and non-residential. The land use information for this restricted shellfish harvesting area in the Honga River Basin is shown in Table 2.1.2 and Figure 2.1.2. Residential urban land use identified in Table 2.1.2 includes low-density residential, medium-density residential, and high-density residential. Non-residential urban land use in this table includes commercial, industrial, institutional, extractive, and open urban land.

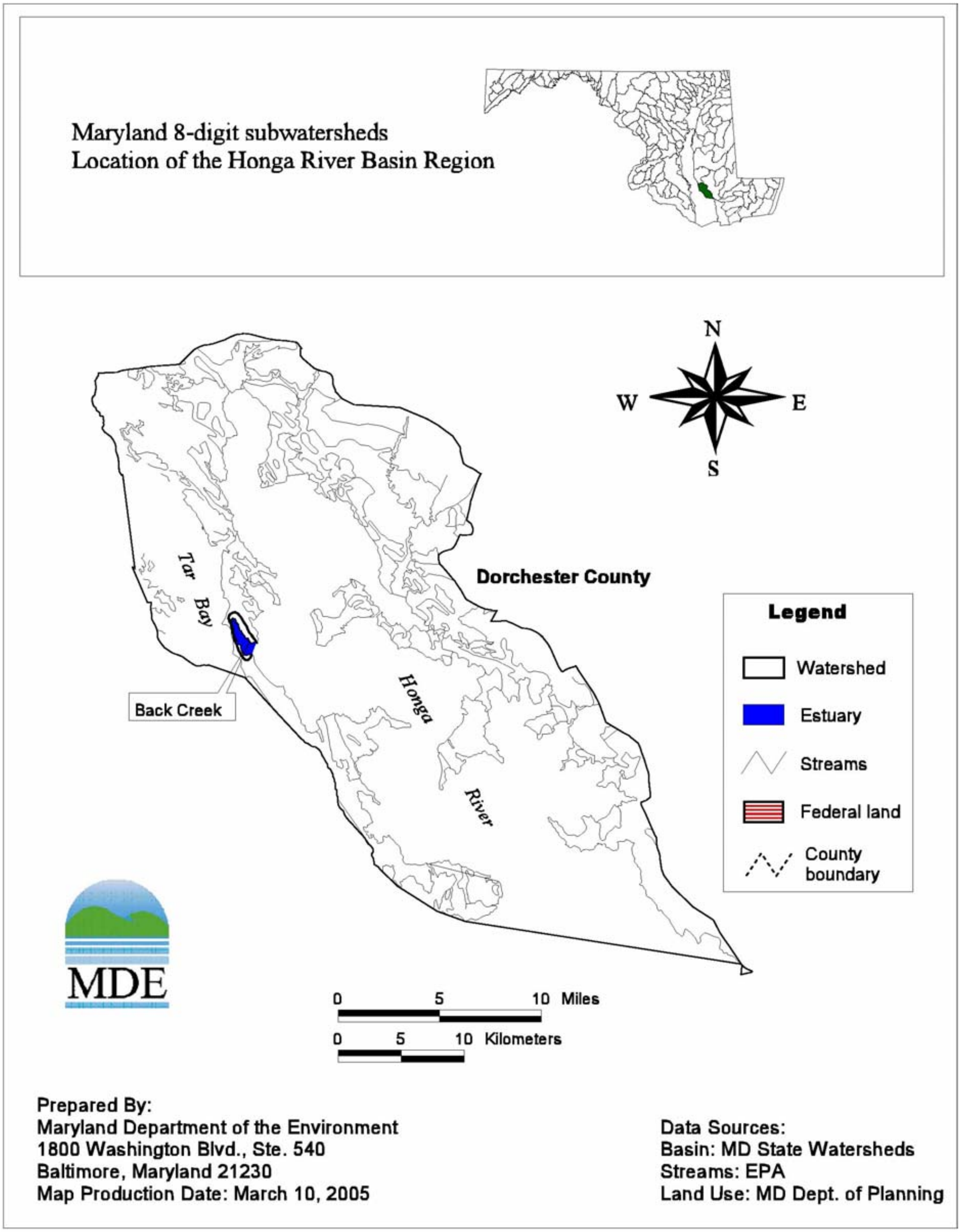

Figure 2.1.1: Location Map of the Honga River Basin

Table 2.1.2: Land Use Percentage Distribution for Back Creek

Land Type	Acreage	Percentage
Residential urban	80.7	71.4
Non-Residential urban	11.3	10.0
Cropland	0.0	0.0
Pasture	0.0	0.0
Feedlot	0.0	0.0
Forest	0.0	0.0
Water	0.0	0.0
Wetlands	21.0	18.6
Barren	0.0	0.0
Totals	**113.0**	**100.0**

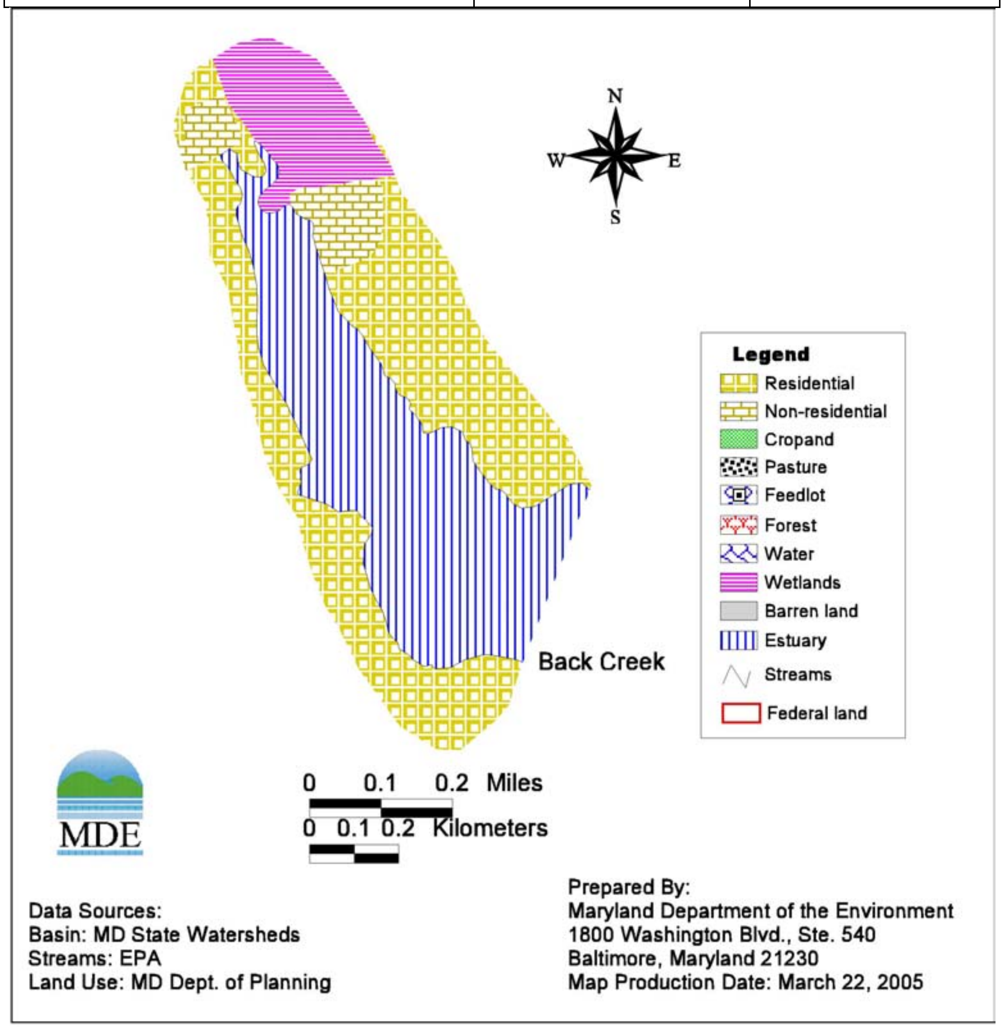

Figure 2.1.2: Land Use in the Back Creek Basin

2.2 Water Quality Characterization

MDE's Shellfish Certification Program is responsible for classifying shellfish harvesting waters to ensure oysters and clams are safe for human consumption. 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-growing areas of Maryland. The data are used to determine if the water quality criteria are being met. If the water quality criteria are exceeded, the shellfish area is closed to harvest and the designated use is not being achieved.

MDE's Shellfish Certification Program has monitored shellfish growing regions throughout Maryland for the past several decades. There is only one shellfish monitoring station in the restricted shellfish harvesting area addressed in this report. The monitoring station and observations recorded during the period of May 1999 – May 2004 are provided in Table 2.2.1 and Figure 2.2.1 through Figure 2.2.2. A tabulation of observed fecal coliform values at the monitoring station for this report are provided in Appendix D.

Table 2.2.1: Location of the Shellfish Monitoring Station in Back Creek

Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
14-01-006	1999-2004	36	38 18 54.	76 13 28.

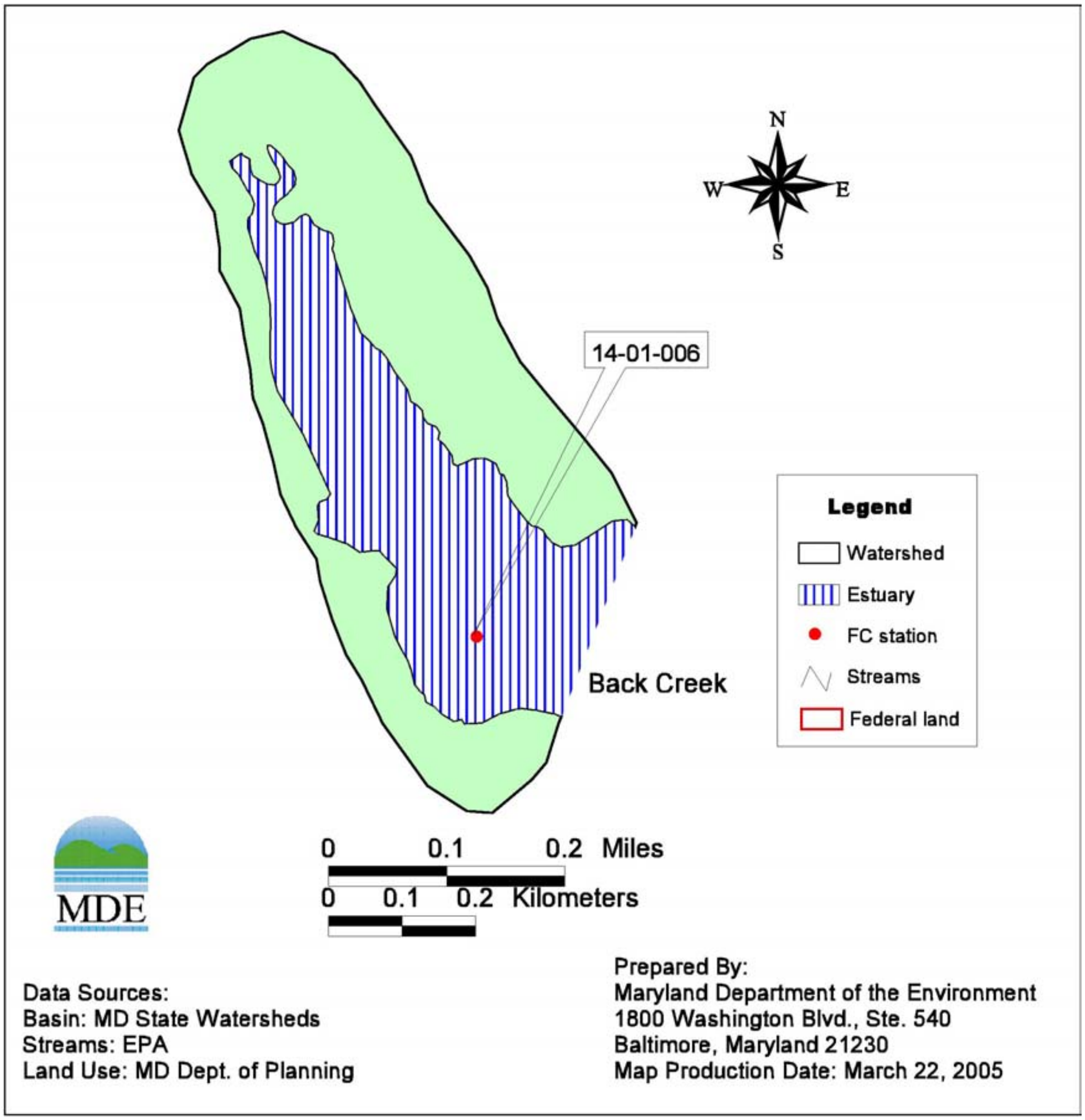

Figure 2.2.1: Shellfish Monitoring Stations in Back Creek

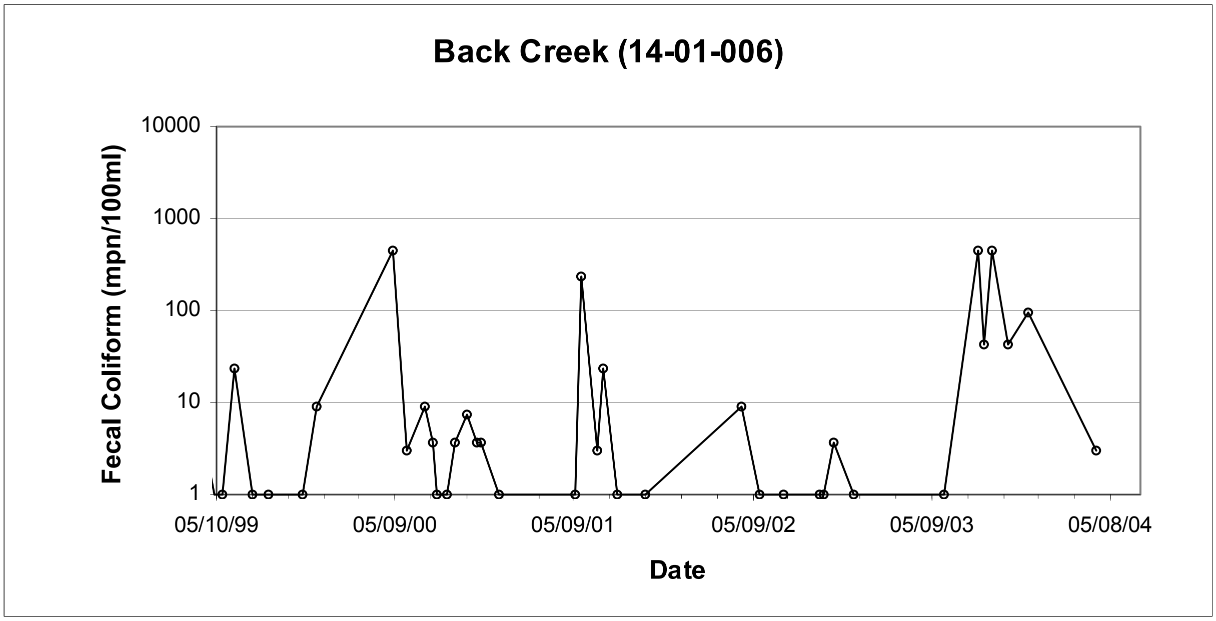

Figure 2.2.2: Observed Fecal Coliform Concentrations at Station 14-01-006

2.3 Water Quality Impairment

The fecal coliform impairment(s) addressed in this analysis were determined with reference to Maryland's water quality standards for shellfish harvesting waters, which are designated "Use II" pursuant to the Department's regulations (Code of Maryland Regulations (COMAR) 26.08.02.08L). In order to satisfy the requirements for this use designation, "the median fecal coliform MPN of at least 30 water sample results taken over a three-year period to incorporate inter-annual variability shall not exceed 14 per 100 ml, and

(i) In areas affected by point source discharges, not more than 10 percent of the samples shall exceed an MPN of 43 per 100 ml for a five tube decimal dilution test or 49 MPN per 100 ml for a three tube decimal dilution test;
(ii) In other areas, the 90th percentile of water sample results shall not exceed an MPN of 43 per 100 ml for a five tube decimal dilution test or 40 MPN per 100 ml for a three tube decimal dilution test."

[COMAR 26.08.02.03-3C]

In determining water quality in the subject waterbody, the Department also imposed minimum sampling requirements based upon the fecal coliform criterion listed above and the systematic random sampling standard established by the National Shellfish Sanitation Program ("NSSP"). The NSSP standard, which is followed by MDE's Shellfish Program in its routine monitoring, is as follows:

- Sample station locations are adequate to produce the data to effectively evaluate all nonpoint sources of pollution.
- Sample collection supports random collection with respect to environmental conditions.
- A minimum of 6 random samples is collected annually from each sample station.
- The results from a minimum of the 30 most recent randomly collected samples from each sample station are used to calculate the median or geometric mean and 90th percentile to determine compliance with the standard.

[NSSP Model Ordinance, Chapter IV, Section F (DHHS, 1999)]

When water quality standards were updated and promulgated in April 2004, the intent was to mirror NSSP guidelines for assessing shellfish growing areas. Accordingly, the bacteria standards for Use II waters were updated to reflect the NSSP Model Ordinance. The minimum temporal extent of three months for sampling was intended to apply only to shellfish waters not previously monitored and was not meant to apply to shellfish harvesting areas with previous monitoring data. As of Spring of 2005, Maryland's water quality standards are being re-promulgated and MDE is using this opportunity to clarify the Department's intent with regard to sampling sufficiency.

For the analysis presented herein, MDE has adopted the NSSP systematic random sampling criteria for shellfish waters with at least five years of existing monitoring data. Therefore, using a combination of 1) minimum of six random samples collected annually and 2) a minimum of the 30 most recent randomly collected samples, MDE is using at least 30 samples collected over five years for assessment.

Most shellfish harvesting areas have been monitored routinely since before 1950. In the few shellfish harvesting areas that have less than five years of monitoring data, a minimum of 30 samples is required to make an assessment for delisting. For TMDL development, if less than 30 samples are available, the most recent data will be used to estimate current loads and the assimilated capacity will be based on the water quality criteria. If 30 samples are available, the MDE shellfish program reviews the temporal span of the data to determine if it is adequate for assessment. This maintains the intent of the statement cited in COMAR 26.08.02.03-3C and coordination with Maryland's governing authority of shellfish harvesting areas.

Honga River has been included on the 2004 Integrated 303(d) List as impaired for fecal coliform. This restricted shellfish harvesting area located in the Honga River is identified as an area in this basin that does not meet shellfish water quality standards. The water quality impairment was assessed using the median and 90th percentile concentrations. Descriptive statistics of the monitoring data and the water quality criteria are shown in Table 2.3.1.

Table 2.3.1: Honga River Shellfish Monitoring Stations (1999-2004) - Median and 90th Percentile

Area Name	Station	Median		90th Percentile	
		Monitoring Data	Criterion	Monitoring Data	Criterion
		MPN/100ml	MPN/100ml	MPN/100ml	MPN/100ml
Back Creek	14-01-006	3.30	14	69.47	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 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, along with counts/day for each source. Details of the source estimate procedure can be found in Appendix B. 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 Back Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	0.00E+00	0.0%
Pets	4.24E+09	16.5%
Human	7.24E+08	2.8%
Wildlife	2.08E+10	80.7%
Total	2.57E+10	100.0%

<u>Point Source Assessment</u>

There are five point source facilities in the identified restricted shellfish harvesting area that have NPDES permit numbers: MDG520179 (A. E. Phillips & Sons, Inc.), MDG520178 (C. H. Parks & Co.), MDG520204 (W. T. Ruark & Co.), MDG522065 (Russell Hall Seafood), and MD0060798 (P. L. Jones Seafood). Four of these point sources facilities have discharge permits limiting fecal coliform (all except P. L. Jones Seafood). The estimated averaged flow for A. E. Phillips is from 700 to 800 gallons per day (gpd). C. H. Parks and Co. has two outfalls with estimated average flow less than 500 gpd for each outfall. W.T. Ruark & Co. discharges about 900 gpd. Russell Hall Seafood has two outfalls with estimated discharge flows of 300 gpd and 20 gpd, respectively. The permitted fecal coliform concentration is 70 MPN/100ml for these four seafood point sources facilities. The total fecal coliform load discharged from these point source facilities is 8×10^6 counts per day. The allocation of permitted loads from these four point sources facilities will be addressed in Section 4.8

3.0 TARGETED WATER QUALITY GOAL

The overall objective of the fecal coliform TMDLs established in this document is to establish the loading caps needed to assure attainment of water quality standards in the restricted shellfish harvesting area. 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 Honga River. The required load reduction was determined based on the most recent five years of data spanning May 1999 to May 2004. The TMDLs are presented as counts/day. The second section describes the analysis framework for simulating fecal coliform concentration in the Honga River. The third section addresses the critical condition and seasonality. The fourth section presents the TMDL calculations. The fifth section discusses TMDL loading caps. The sixth section presents the load allocations. The margin of safety is discussed in Section 4.7. Finally, the TMDL equation is summarized in Section 4.8.

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 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)). 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 requires at least 30 samples and uses the most recent five-year window of data.

A TMDL is comprised of the sum of individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and 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 90^{th} percentile data 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 the U.S. Geological Survey (USGS) gage # 01485500, located in Nassawango Creek near Snow Hill, MD. For each restricted shellfish harvesting area, the average long-term flow for this USGS gage (*i.e.*, 41.45 cfs) was adjusted by the ratio of the drainage basin area to that of the gage's basin (*i.e.*, 28,800.0 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
Back Creek	113.0	0.16

4.3 Critical Condition and Seasonality

EPA 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 condition under which a waterbody is the 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 the high fecal coliform due to the variation of hydrological conditions.

The seasonal fecal coliform distribution for the only reported station is presented in Appendix C. The results show the seasonal variability of fecal coliform concentration. High concentrations occur in May, August, and September in the Honga River. The largest standard deviation corresponds to the highest variability for each station. These high concentrations typically result in a high 90th percentile concentration. The results indicate that violations only occur in 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 includes the effect of seasonality. It is possible that during colder season the bacteria levels will be less, however, this is not always true when reviewing monitoring data. 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. Back Creek has a single monitoring station (14-01-006) located near the mouth of this waterbody. The total load is reported in Table 4.4.1 and Table 4.4.2. Since this site has only a single monitoring station, this station was used both to represent the restricted shellfish harvesting area concentration and 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 (%)
Back Creek	126,300	3.3	0.36	0.9	2.91E+09	1.24E+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 (%)
Back Creek	126,300	69.5	0.36	0.9	6.13E+10	4.33E+10	29.47

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 single restricted shellfish harvesting area of Honga River Basin are as follows:

Back Creek:
The median load of fecal coliform TMDL = 1.236×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 4.325×10^{10} 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 load allocation. In this case, the 90th percentile requires the greater reduction. It is 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 are four permitted point source facilities discharging fecal coliform directly into the single restricted shellfish harvesting area addressed in this report, based on MDE point source permitting information. The loads will be allocated as WLA. The nonpoint sources 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 a load reduction of approximately 29.5% in the Back Creek watershed.

The load reduction applied to this watershed was based on the 90th percentile water quality standard. The 90th percentile concentration is that concentration exceeded only 10% of the time. The load reduction established based on the 90th percentile criterion targets only those critical events that occur less frequently. Therefore, the load reduction established is not a literal daily reduction, but rather, an indicator that the control of fecal loads is 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 water bodies. 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 are four point source facilities (MDG520179, MDG520178, MDG520204, and MDG522065) that have permits limiting their fecal coliform discharge into the water. The total load is 8.00×10^6 counts per day. The load is allocated as WLA. The TMDLs are summarized as follows:

The median TMDL (counts per day):

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Back Creek	**1.24×10^{10}**	=	**1.24×10^{10}**	+	**8.00×10^6**	+	**N/A**	+	**Implicit**

The 90th percentile TMDL (counts per day):

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Back Creek	**4.33×10^{10}**	=	**4.33×10^{10}**	+	**8.00×10^6**	+	**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 TMDL will be achieved and maintained. The appropriate measures to reduce pollution levels in the impaired segments include, where appropriate, the use of better treatment technology or installation of best management practices (BMPs). Details of these methods are to be described in the implementation plan.

In general, MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality, with consideration given to ease of implementation and cost. The source contributions estimated from the watershed analysis (see Table 2.4.1) 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 include 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. Property owners can apply for a low interest loan, through MDE, that can be used to improve a failing septic system. It is anticipated that in 2006, there may be funding available to provide improvement to a portion of septic systems in Maryland's designated Critical Areas. Maryland law, Environment Article § 9-333, requires the following types of facilities to have pumpout stations: Existing marinas wishing to expand to a total of 11 or more slips that are capable of berthing vessels that are 22 feet or larger; new marinas with more than 10 slips capable of berthing vessels that are 22 feet or larger; and marinas with 50 or more slips and that berth any vessel over 22 feet in length. 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 have some reduction of bacteria from manure application practices.

As part of Maryland's commitment to the NSSP, MDE will continue to monitor shellfish waters and classify harvesting areas. Those waters meeting shellfish water quality standards may be reclassified as open to harvesting and can 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 MDE's 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 does 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 non-point 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 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):

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

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:

$$\frac{dVC}{dT} = Q_0C_0 - Q_bC + L_f + L_l - kVC \tag{2}$$

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:

$$Q_b = Q_0 + Q_f \tag{3}$$

$$Q_bC + kVC = Q_0C_0 + L_f + L_l \tag{4}$$

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

$$C = \frac{Q_0C_0 + L_f + L_l}{Q_b + kV} \tag{5}$$

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:

$$Load_T = C_c(Q_b + kV) - Q_0 C_0 \quad (6)$$

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:

$$Load = Load_T \times \frac{24}{12.42} \times 10000 \quad (7)$$

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:

$$Q_0 = \beta Q_T \quad (8)$$

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):

$$\beta = \frac{S_f - S_e}{S_0 - S_e} \quad (9)$$

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:

$$T_L = \frac{V_b}{Q_b} \quad (10)$$

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).

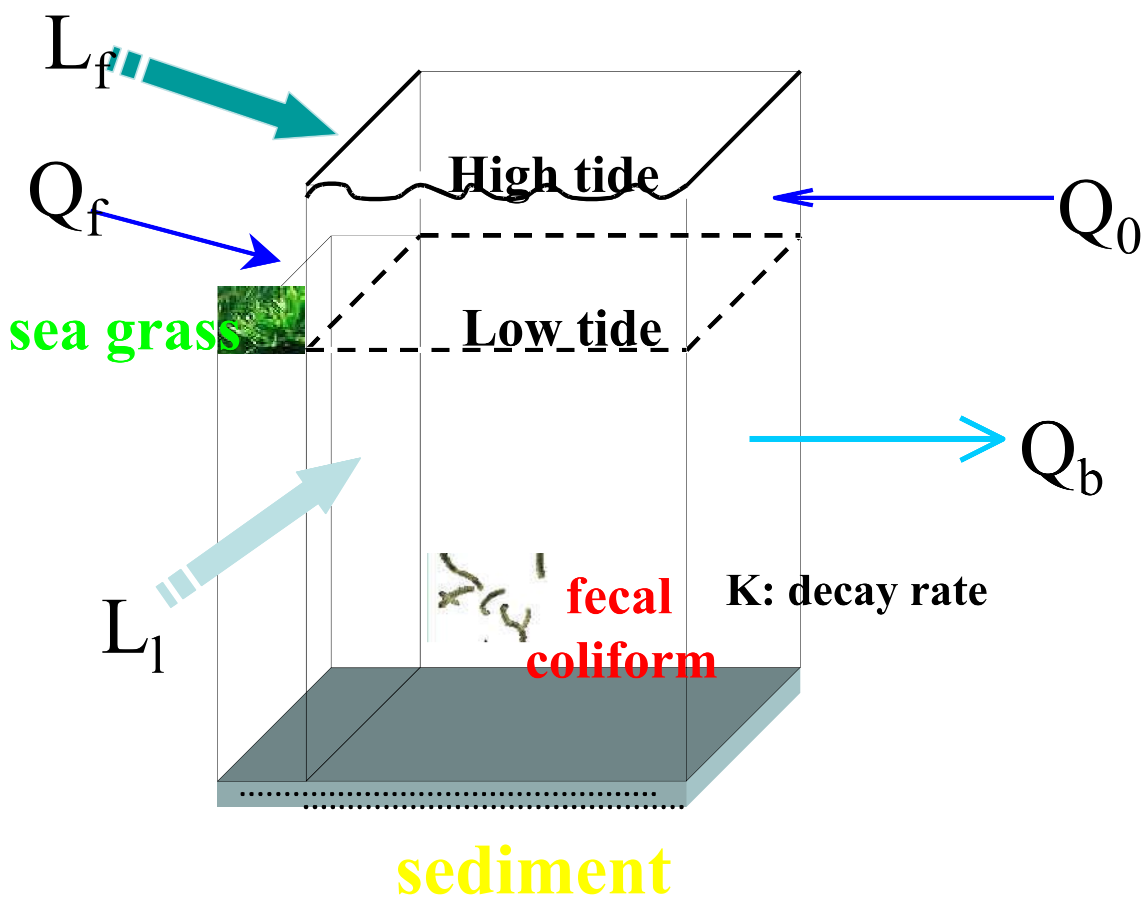

Figure A-1: The schematic diagram for the tidal prism model

A Tidal Prism Model Calculation for Back 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 = 126299.9 (m^3)
k = Fecal coliform removal rate =0.36 (T^{-1})
Q_f = Freshwater discharge
= 0.16294 cfs = 0.16294 × 0.0283×86400×12.42÷24 = 206.2 (m^3T^{-1})
Q_0 = 70096.5 (m^3T^{-1})
Q_b = 70302.7 ($m^3\ T^{-1}$)
C_c = water quality criterion = 14 MPN/100ml
C = current fecal coliform 5-year median concentration = 3.3 (MPN/100ml)
C_0 = fecal coliform 5-year median outside of the embayment = 3.3 (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
$= [C_c(Q_b + kV) - Q_0C_0] \times Cf$
= [14× (70302.7 + 0.36×126299.9) – 70096.5 ×14] ×24÷12.42×10000
= 1.236×10^{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 condition
$= [(C)(Q_b + kV) - Q_0(C_0)] \times Cf$
= [(3.3) × (70302.7 + 0.36×126299.9) – 70096.5 × (3.3)] ×24÷12.42×10000
= 2.913×10^9

The load reduction is estimated as follows:

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

$$\text{Load Reduction} = \frac{2.913\times10^9 - 1.236\times10^{10}}{2.913\times10^9} = 0.00\%$$

A Tidal Prism Model Calculation for Back 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 = 126299.9 (m^3)
k = Fecal coliform removal rate =0.36 (T^{-1})
Q_f = Freshwater discharge
= 0.16294 cfs = 0.16294 × 0.0283×86400×12.42÷24 = 206.2 (m^3T^{-1})
Q_0 = 70096.5 (m^3T^{-1})
Q_b = 70302.7 ($m^3\ T^{-1}$)
C_c = water quality criterion = 49 MPN/100ml
C = current fecal coliform 5-year 90th percentile concentration = 69.47 (MPN/100ml)
C_0 = fecal coliform 5-year 90th percentile at the outside of the embayment
= 69.47 (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

$$= [C_c(Q_b + kV) - Q_0C_0] \times Cf$$

$$= [49\times (70302.7 + 0.36\times126299.9) - 70096.5 \times 49] \times24\div12.42\times10000$$

$$= 4.325\times10^{10}$$

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 condition

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

$$= [(69.47) \times (70302.7 + 0.36\times126299.9) - 70096.5 \times (69.47)] \times24\div12.42\times10000$$

$$= 6.131\times10^{10}$$

The load reduction is estimated as follows:

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

$$\text{Load Reduction} = \frac{6.131\times10^{10} - 4.325\times10^{10}}{6.131\times10^{10}} = 29.47\%$$

Sample calculations load reductions for both the median and 90th percentiles have been presented for the only embayment in this report (*i.e.*, Back Creek). The following table lists the parameter values needed for this calculation. 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	V	k	Q_f	Q_0	Q_b	Median C	Median C_0	90th Percentile C	90th Percentile C_0
Back Creek	126299.9	0.36	206.2	70096.5	70302.7	3.30	3.30	69.47	69.47

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 Counts/day	Current Load Counts/day	Percent Reduction	Allowable Load Counts/day	Current Load Counts/day	Percent Reduction
Back Creek	1.236E+10	2.913E+09	0.00	4.325E+10	6.131E+10	29.47

Appendix B. 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 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 Honga 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 are four permitted point source facilities in the watershed that discharge to the embayment. The contribution of fecal coliform from these point sources is moderate. There is a lack of information available for the discharge from boats; it is assumed that human loading results from failures in septic waste treatment systems. The major nonpoint source contributions assessed for the restricted shellfish area in the Honga 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, 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, 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, goose and duck estimates the entire watershed was used because the density estimates were developed using watershed area as the ratio estimator. 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
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)

B. Human Contributions

Human loading can result from failures in septic waste treatment systems or through pollution from recreational vessel discharges in the identified restricted shellfish harvesting area. It is assumed that the failing of a septic system is a direct load contribution from humans. The estimation of human contribution is based on human population, properties, the 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 Honga River Basin. Since the subwatershed of the Honga River Basin is a sub-area of the Census Block, the GIS tool was used to extract this area 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 to proportion the population within the area of the subwatershed. The results are shown in Table B-4.

Table B-4: Proportional Population, Households, and Septic Systems in Back Creek

Area Name	Proportional Population	Proportional Septic Systems	Proportional Households	Public Sewer
Back Creek	31	47	16	No

The distribution of septic systems for Back Creek is shown in Figure B-1. Based on GIS property coverage, a point is assumed to represent a septic system. The total number of septic systems in each restricted shellfish harvesting area is shown in Table B-4. According to GIS coverage, the Back Creek restricted shellfish harvesting area watershed does not have a public sewer system.

It is assumed that the human contribution is attributed to septic systems (although recreational vessels might be a source, we have not attempted to quantify that source). The human contribution to the restricted shellfish harvesting area was calculated using the number of septic systems, the average number of people per septic system, and the failure rate of the 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. According to shoreline sanitary survey data in the Honga River watershed, an estimated failing rate of 3% was used for the total number of failing septic systems. 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 load due to failures of septic systems is less than 1%.

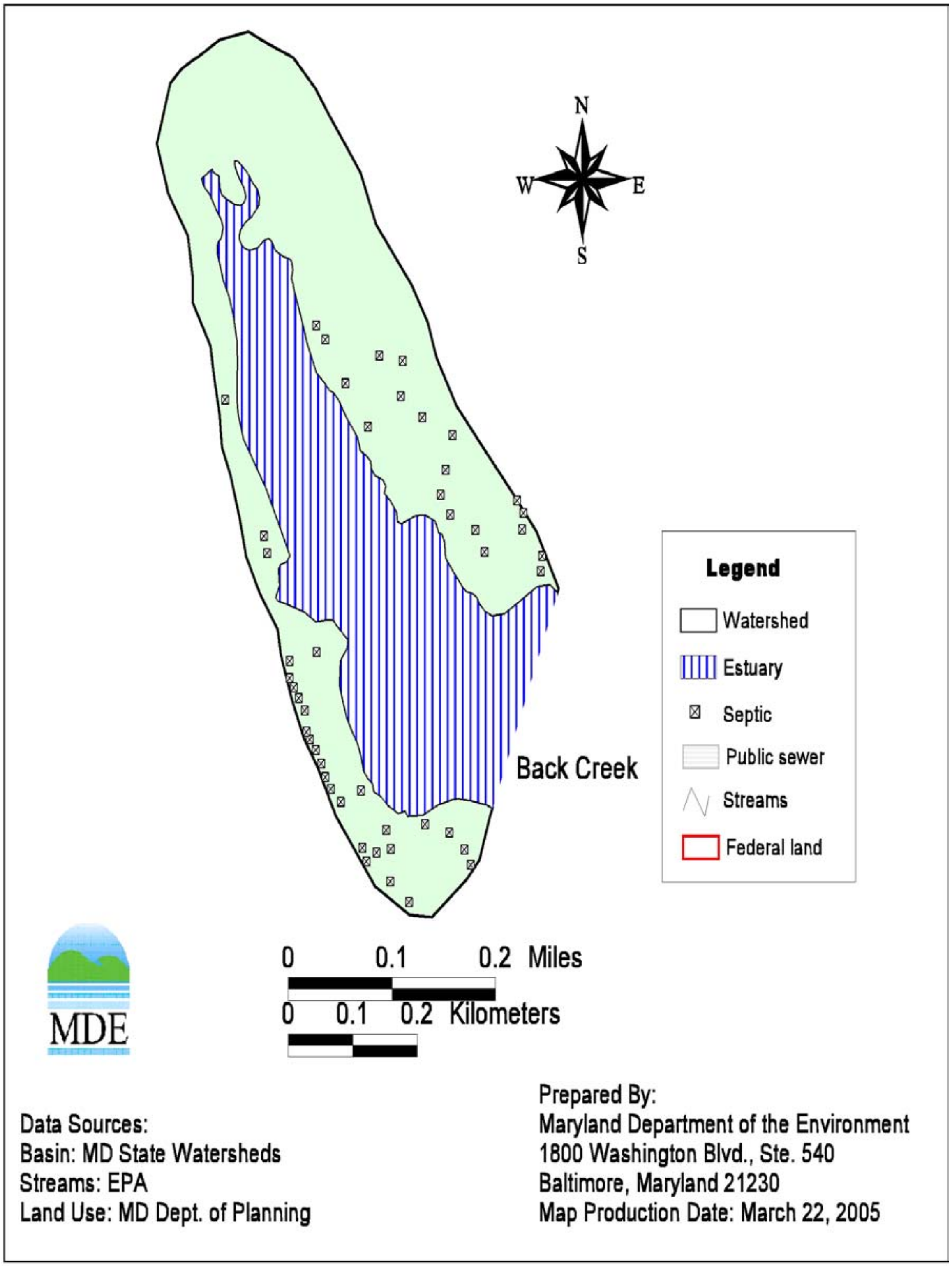

Figure B-1: Distribution of Septic Systems in the Back Creek Watershed

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 population for restricted shellfish harvesting area in the Honga River watershed was estimated based on the number of households (see Table B-4). According to a survey of Chesapeake Bay area residents conducted by the Center for Watershed Protection, 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 is through the manure spreading processes 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-2. The fecal coliform load was estimated based on the total number of livestock and the fecal coliform production rates.

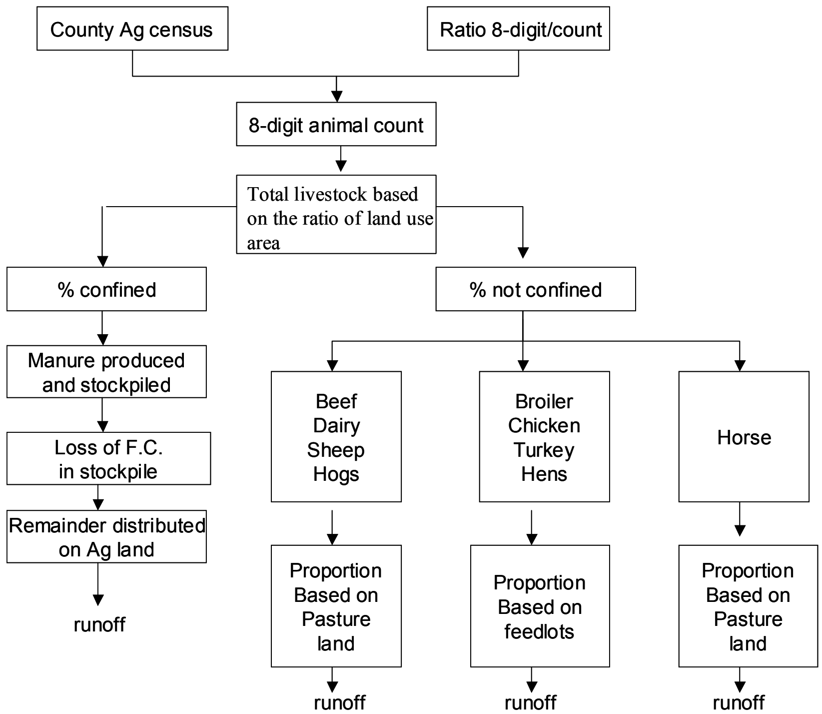

Figure B-2: Diagram to Illustrate Procedure Used to Estimate Fecal Coliform Production from Estimated Livestock Population

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 Table B-7, 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 Back Creek Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	0.00E+00	0.0%
Pets	4.24E+09	16.5%
Human	7.24E+08	2.8%
Wildlife	2.08E+10	80.7%
Total	2.57E+10	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 area.

The 5-year monthly mean fecal coliform concentration and its standard deviation were calculated for the single monitoring station for this report. The results are presented in Figure C-1. It is shown that high fecal coliform concentrations occur in May, August, and September in the Back Creek. 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 indicates that the violation frequently may occur in only a few months of the year.

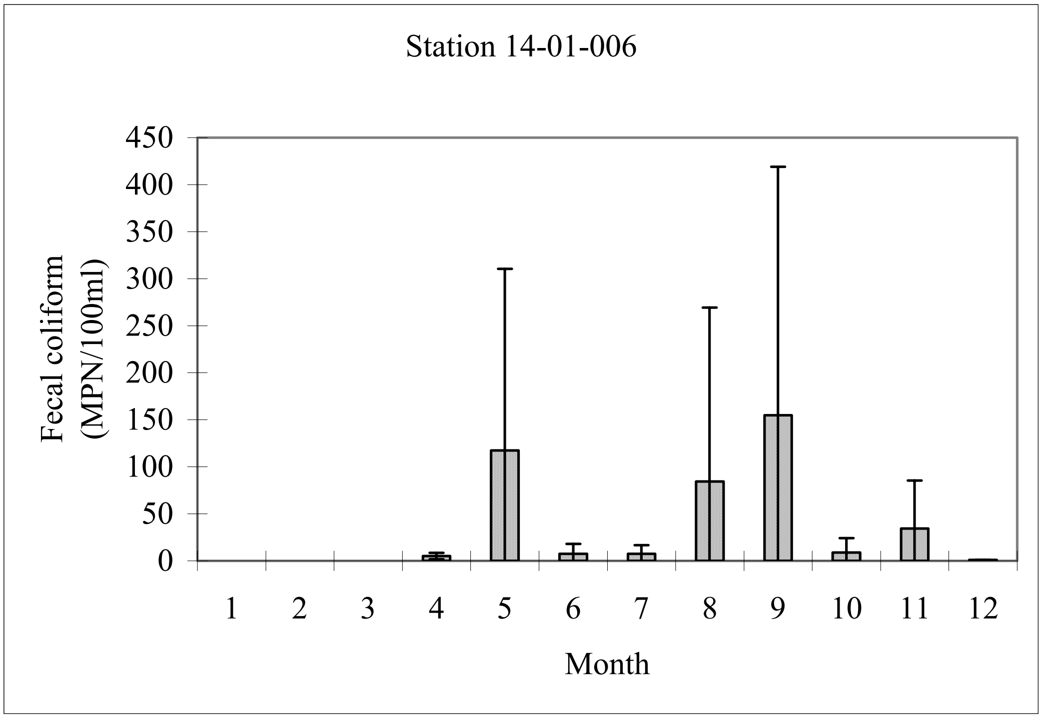

Figure C-1: Seasonality analysis of fecal coliform at Back Creek Station 14-01-006

Appendix D. Tabulation of Observed Fecal Coliform Values

This appendix provides a tabulation of fecal coliform values for the monitoring station in Back Creek of the Honga River Basin in Table D-1. These data are plotted in report Figure 2.2.2.

Table D-1: Observed Fecal Coliform data at Back Creek station 14-01-006

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
5/24/1999	1	6/25/2001	3
6/14/1999	23	7/9/2001	23
7/21/1999	1	8/6/2001	1
8/23/1999	1	10/1/2001	1
11/1/1999	1	4/16/2002	9.1
11/30/1999	9.1	5/22/2002	1
5/2/2000	460	7/11/2002	1
6/1/2000	3	9/24/2002	1
7/10/2000	9.1	10/2/2002	1
7/26/2000	3.6	10/23/2002	3.6
8/2/2000	1	12/2/2002	1
8/22/2000	1	6/3/2003	1
9/6/2000	3.6	8/11/2003	460
10/3/2000	7.3	8/25/2003	43
10/24/2000	3.6	9/10/2003	460
10/30/2000	3.6	10/14/2003	43
12/5/2000	1	11/20/2003	93
5/10/2001	1	4/7/2004	3
5/23/2001	240		