Total Maximum Daily Loads of Fecal Coliform for the Restricted Shellfish Harvesting Area in Wells Cove of the Kent Narrows - Prospect Bay Basin in Queen Anne's County, Maryland

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FINAL

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List of Abbreviations

BMP	Best Management Practice
BST	Bacteria Source Tracking
CAFO	Concentrated 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
EQIP	Environmental Quality and Incentives Program
FA	Future Allocation
FDA	U.S. Food and Drug Administration
GIS	Geographic Information System
km	Kilometer
LA	Load Allocation
LMM	Long-term Moving Median
M_2	Lunar semi-diurnal tidal constituent
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
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

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.

Kent Narrows - Prospect Bay (basin number 02-13-05-04) 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). The designated uses in Kent Narrows - Prospect Bay were impaired by sediments, nutrients, and fecal coliform in tidal portions. On the 2004 303(d) List, the fecal coliform listing was clarified by the identification of Wells Cove as the specific area of impairment. This document, upon EPA approval, establishes a TMDL of fecal coliform for Wells Cove. The nutrient and suspended sediment impairments within the Kent Narrows - Prospect Bay basin will be addressed at a future date.

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 Kent Narrows - Prospect Bay 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 area of the Kent Narrows - Prospect Bay Basin for fecal coliform median load and 90th percentile load are as follows:

Wells Cove:
The median load of fecal coliform TMDL = 1.353×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 4.734×10^{10} counts per day

The goal of load allocation is to determine the estimated loads for sources in the watershed while ensuring that the water quality standard can be attained. For the Wells Cove area in the Kent Narrows - Prospect Bay Basin, the 90th percentile criterion requires the greatest reduction – about 32% within the watershed. Therefore, the load reduction scenario is developed based on the 90th percentile load TMDL, and will result in the load reductions that allow attainment of the water

quality standard. Reductions from current baseline conditions are estimated and presented in this report.

Once EPA has approved this TMDL, MDE will begin an iterative process of implementation, focusing first on those sources that have the greatest impact on water quality while giving consideration to the relative ease of implementation and cost. The source contributions estimated from the 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 the 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 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.

Kent Narrows - Prospect Bay (basin number 02-13-05-04) was first identified on the 1996 303(d) List submitted to EPA by the Maryland Department of the Environment (MDE). The designated uses in Kent Narrows - Prospect Bay were impaired by sediments, nutrients, and fecal coliform in tidal portions. On the 2004 303(d) List, the fecal coliform listing was clarified by the identification of Wells Cove as the specific area of impairment. This document, upon EPA approval, establishes a TMDL for fecal coliform for Wells Cove. 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. Shellfish waters are closed or restricted to harvesting when the fecal coliform criteria for shellfish harvesting waters are exceeded. The criteria include both a median and a 90th percentile. The suspended sediment and nutrient impairments within the Kent Narrows - Prospect Bay 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 in the Kent Narrows - Prospect Bay basin is addressed in this report: Wells Cove. Wells Cove is located on Maryland's Eastern Shore in Queen Anne's County, MD, as shown in Figure 2.1.1. Wells Cove has a length of 0.4 km and a width of 0.3 km at its mouth, where it flows to the southwest into Prospect Bay. The Wells Cove restricted shellfish harvesting area has a drainage area of 67.1 acres (0.27 km^2).

The soils in the Wells Cove watershed are moderately well drained silty soils that have a firm silty clay loam to plastic clay subsoil (U.S. Department of the Agriculture (USDA), 1966). The dominant tide in this region is the lunar semi-diurnal (M_2) tide, with a tidal range of 0.37 m in the restricted portion of Wells Cove 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 this restricted shellfish harvesting area.

Table 2.1.1: Physical Characteristics of the Kent Narrows - Prospect Bay Restricted Shellfish Harvesting Area

Restricted Shellfish Harvesting Area	Mean Water Volume in m^3	Mean Water Depth in m
Wells Cove	138,536	0.96

The 2000 Maryland Department of Planning (MDP) land use/land cover data show that the watershed can be characterized as partially urban (53%) and partially rural for Wells Cove, with nearly 44% of the area being wetlands. The land use information for this restricted shellfish harvesting area in the Kent Narrows - Prospect Bay 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.

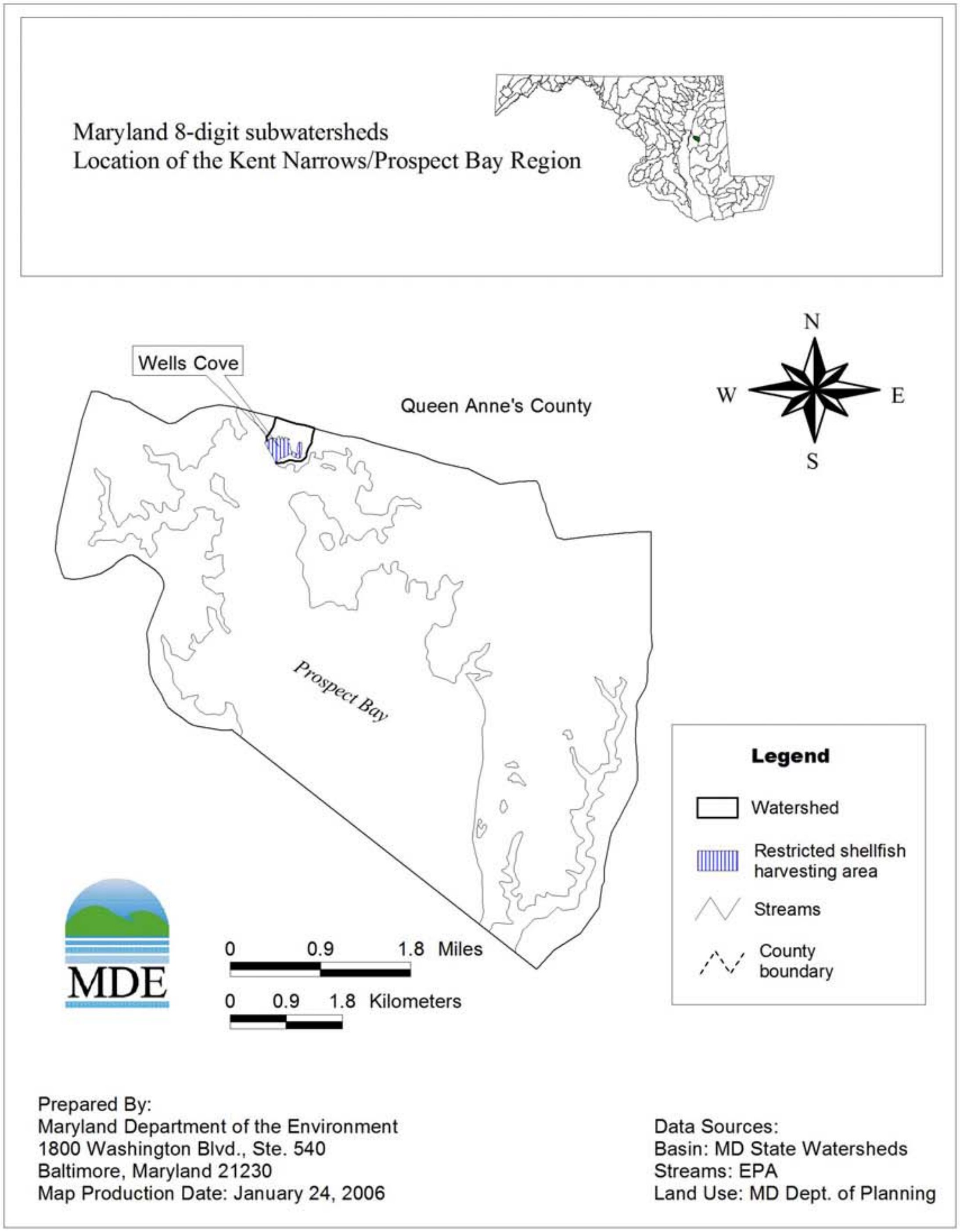

Figure 2.1.1: Location Map of the Kent Narrows - Prospect Bay Basin

Table 2.1.2: Land Use Percentage Distribution for Wells Cove

Land Type	Acreage	Percentage
Residential urban	21.3	31.8
Non-Residential urban	14.1	21.0
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	29.8	44.4
Barren	0.0	0.0
Transportation	1.9	2.8
Totals	**67.1**	**100.0**

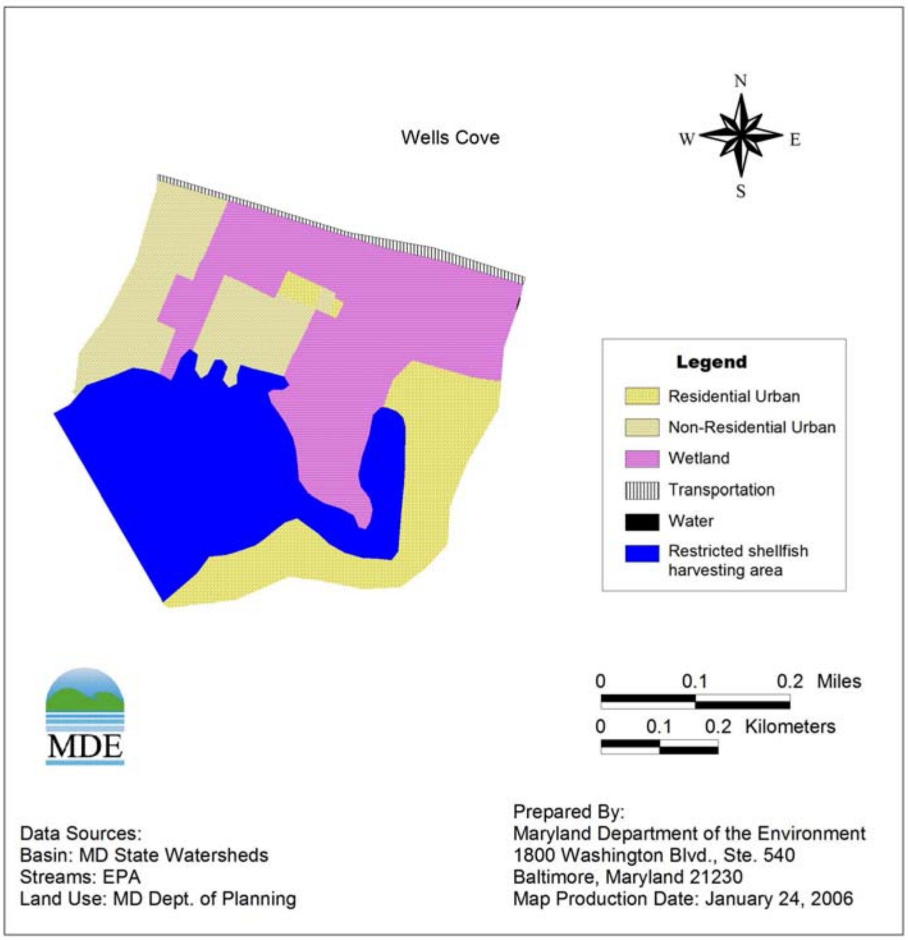

Figure 2.1.2: Land Use in the Wells Cove Basin

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 NSSP, with oversight by the FDA. 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 waters throughout Maryland for the past several decades. There is one shellfish monitoring station in close proximity to the restricted shellfish harvesting area addressed in this report. The station identification and observations recorded during the period of June 2000 – June 2005 are provided in Table 2.2.1 and Figure 2.2.1 through Figure 2.2.2. A tabulation of observed fecal coliform values at the single monitoring station included in this report is provided in Appendix D.

Table 2.2.1: Location of the Shellfish Monitoring Station in Wells Cove

Station Location	Shellfish Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
Wells Cove	08-03-202	2000-2005	81	38 57 54.6	76 14 35.9

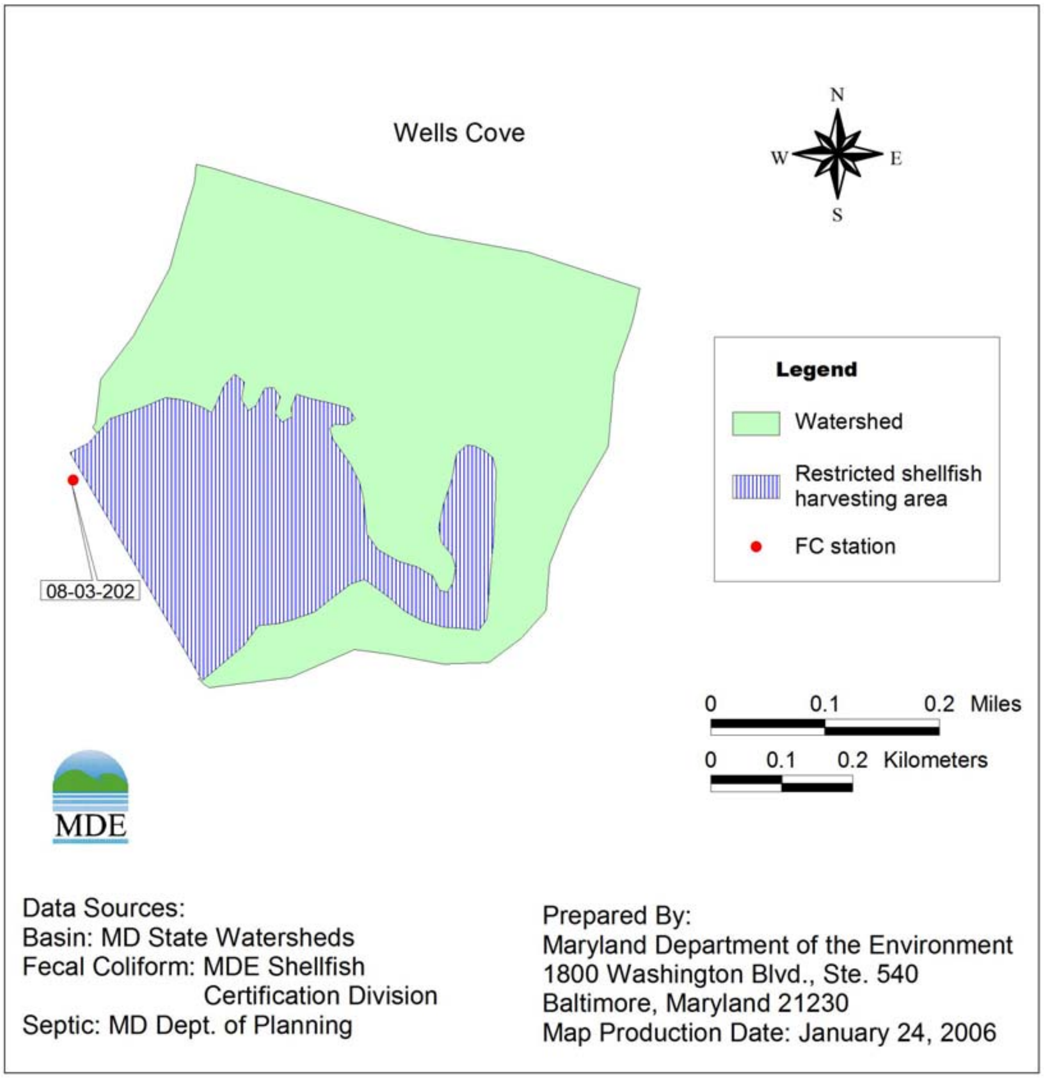

Figure 2.2.1: Shellfish Monitoring Station in Wells Cove

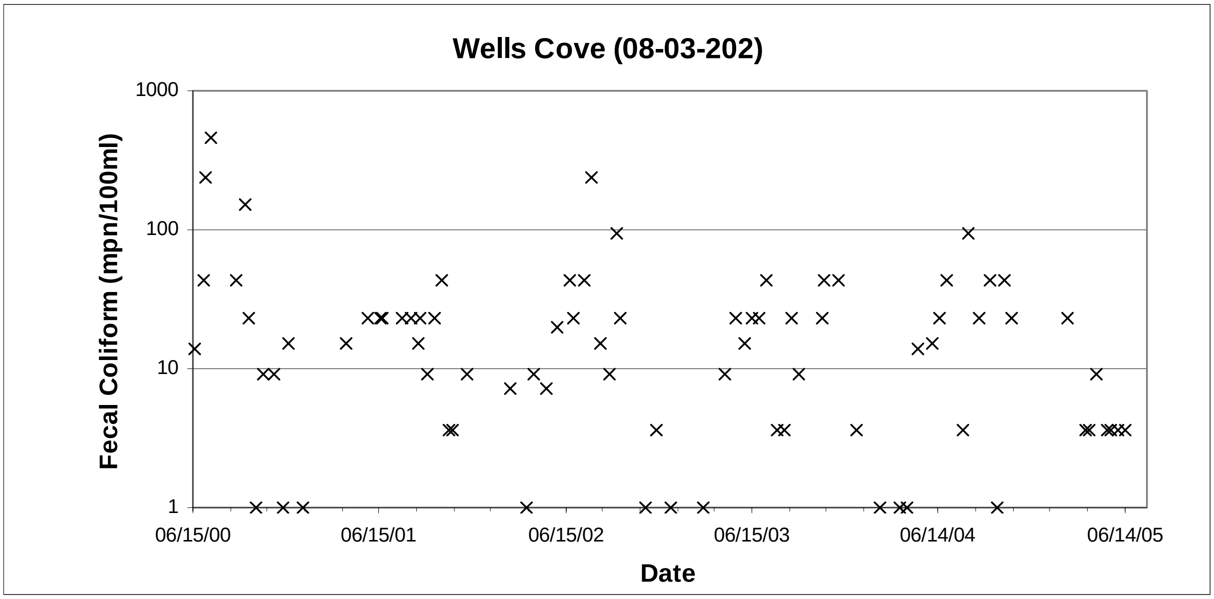

Figure 2.2.2: Observed Fecal Coliform Concentrations at Station 08-03-202

2.3 Water Quality Impairment

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

2) Classification of Use II Waters for Harvesting.

(a) Approved classification means that the median fecal coliform MPN of at least 30 water sample results taken over a 3-year period to incorporate inter-annual variability does not exceed 14 per 100 milliliters; and:

(i) In areas affected by point source discharges, not more than 10 percent of the samples exceed an MPN of 43 per 100 milliliters for a five tube decimal dilution test or 49 MPN per 100 milliliters for a three tube decimal dilution test; or

(ii) In other areas, the 90th percentile of water sample results does not exceed an MPN of 43 per 100 milliliters for a five tube decimal dilution test or 49 MPN per 100 milliliters for a three tube decimal dilution test.

MDE updated and promulgated shellfish water quality criteria for shellfish waters in June 2004. Bacteriological criteria for shellfish harvesting waters were unchanged and the intent was to include the 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 assimilative 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.

Kent Narrows - Prospect Bay, specifically Wells Cove, has been included in the 2004 Integrated 303(d) List as impaired by fecal coliform. The water quality impairment in Wells Cove was assessed as not meeting either the median or the 90th percentile at one monitoring station (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: Wells Cove 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
Wells Cove	08-03-202	15.00	14	71.71	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 area. The possible introductions of fecal coliform to the land surface are through the manure spreading process, direct deposition from livestock during the grazing season, and excretions from pets and wildlife. As the runoff occurs during rain events, surface runoff transports water and fecal coliform over the land surface and 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 distribution of source loads is 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 Wells Cove Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	0.00E+00	0.0%
Pets	2.59E+10	78.8%
Human	8.11E+08	2.5%
Wildlife	6.15E+09	18.7%
Total	3.29E+10	100.0%

Point Source Assessment

There are no point source facilities with permits regulating the release of fecal coliform directly into the restricted shellfish harvesting area, based on MDE point source permitting information.

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 Wells Cove. These standards are described fully in Section 2.3, Water Quality Impairment.

4.0 TOTAL MAXIMUM DAILY LOADS AND LOAD ALLOCATION

4.1 Overview

This section documents detailed fecal coliform TMDLs and load allocation development for the restricted shellfish harvesting waters in the Kent Narrows - Prospect Bay Basin. The required load reduction was determined based on the most recent 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 restricted shellfish harvesting waters in the Kent Narrows - Prospect Bay Basin. 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 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)). 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, 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 the U.S. Geological Survey (USGS) gage # 01492500, located in Sallie Harris Creek near Carmichael, MD. For the restricted shellfish harvesting area, 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
Wells Cove	67.1	0.10

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 were 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 distribution for the single applicable monitoring station is presented in Appendix C. The results show the seasonal variability of fecal coliform concentration. High concentrations occur between July and September in the Wells Cove restricted shellfish harvesting area. The largest standard deviations correspond to the highest variability in concentration for this 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. Wells Cove has a single monitoring station (08-03-202). For Wells Cove, Station 08-03-202 was used to represent the restricted shellfish harvesting area concentration and to provide the boundary condition. The total load is reported in Table 4.4.1 and Table 4.4.2.

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 Mean Volume M^3	Fecal Coliform Concentration Median MPN/100mL	Estimated Water Residence Time day	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction (%)
Wells Cove	138,536	15.0	3.2	1.449E+10	1.353E+10	6.63%

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	Estimated Water Residence Time day	Current Load counts/day	Allowable Load counts/day	Required Percent Reduction (%)
Wells Cove	138,536	71.7	3.2	6.928E+10	4.734E+10	31.67%

4.5 TMDL Loading Caps

This section presents the TMDLs 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 waters of Wells Cove in the Kent Narrows - Prospect Bay Basin are as follows:

Wells Cove:
The median load of fecal coliform TMDL = 1.353×10^{10} counts per day
The 90th percentile of fecal coliform TMDL = 4.734×10^{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 source allocation. In this case, the 90th percentile requires the greater reduction for the area. 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 TMDLs between point (WLA) and nonpoint (LA) sources. There are no point source facilities with permits regulating the release of fecal coliform directly into the single restricted shellfish harvesting area, based on MDE point source permitting information. Therefore, the TMDLs will be allocated entirely to the LA.

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 31.7% for the restricted shellfish harvesting area of the Wells Cove watershed.

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

4.7 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

Since there are no permitted point sources in this watershed, all allocations are to nonpoint sources (LA). The TMDLs are summarized as follows:

The median TMDL (counts per day):

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Wells Cove	**1.35×10^{10}**	=	**1.35×10^{10}**	+	**N/A**	+	**N/A**	+	**Implicit**

The 90th percentile TMDL (counts per day):

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Wells Cove	**4.73×10^{10}**	=	**4.73×10^{10}**	+	**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.

The major source of fecal coliform within the watershed was identified to be from pets. Education of pet owners regarding pet waste is an important aspect of controlling this source. Queen Anne's county has "pooper scooper" laws that governs pet waste cleanup.

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 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.

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. 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:

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

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:

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

$$Q_bC + kVC = Q_0C_0 + L_f + L_l \qquad (4)$$

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

$$C = \frac{Q_0C_0 + L_f + L_l}{Q_b + kV} \qquad (5)$$

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:

$$Load_T = C_c(Q_b + kV) - Q_0 C_0 \tag{6}$$

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).

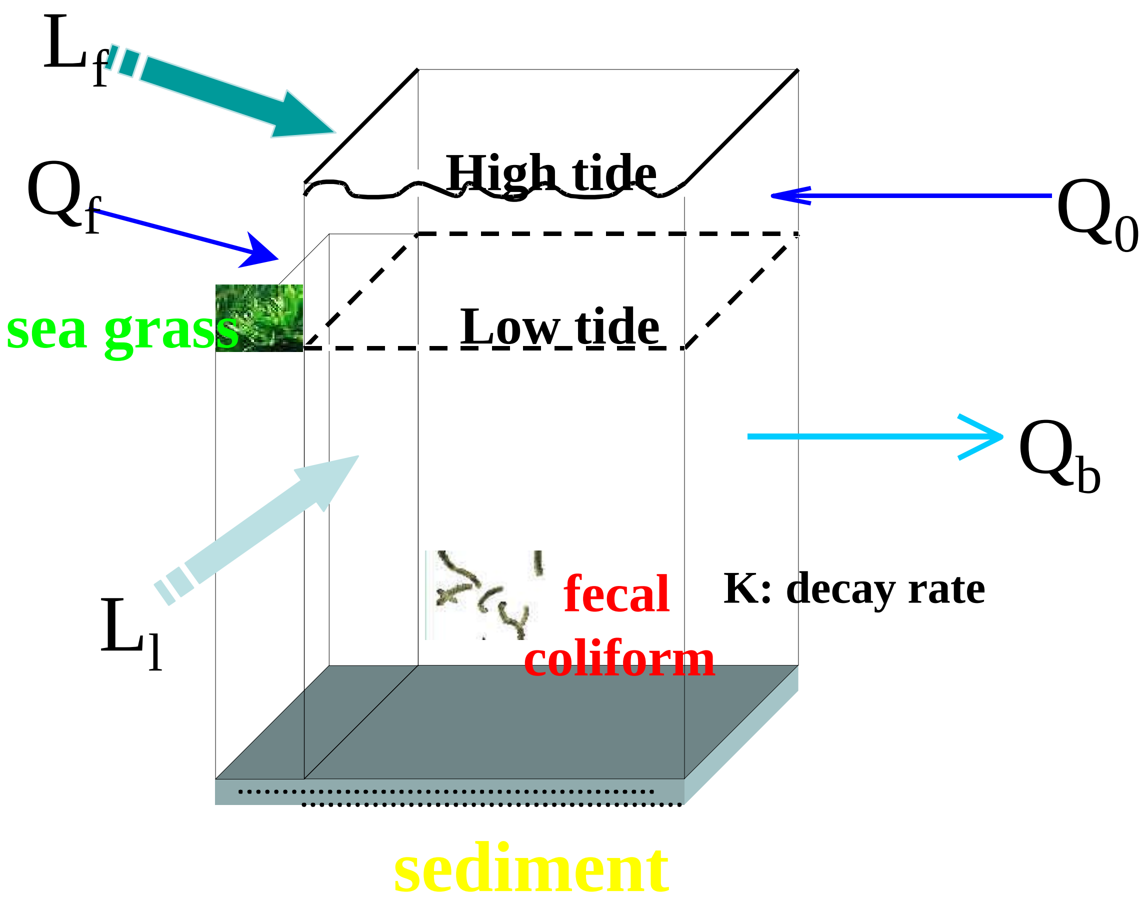

Figure A-1: The schematic diagram for the tidal prism model

A Tidal Prism Model Calculation for Wells Cove

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 = 138535.6 (m^3)
k = Fecal coliform removal rate =0.36 (T^{-1})
Q_f = Freshwater discharge
= 0.100 cfs = 0.100 × 0.0283 × 86400 × 12.42 ÷ 24 = 126.5 (m^3T^{-1})
Q_0 = 22149.7 (m^3T^{-1})
Q_b = 22276.3 ($m^3\ T^{-1}$)
C_c = water quality criterion = 14 MPN/100ml
C = current fecal coliform 5-year median concentration = 15.00 (MPN/100ml)
C_0 = fecal coliform 5-year median outside of the embayment = 15.00 (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
$= [C_c(Q_b + kV) - Q_0 C_c] \times Cf$
$= [14\times (22276.3 + 0.36\times138535.6) - 22149.7 \times14] \times24\div12.42\times10000$
$= 1.353\times10^{10}$

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
$= [(C)(Q_b + kV) - Q_0(C_0)] \times Cf$
$= [(15.00) \times (22276.3 + 0.36\times138535.6) - 22149.7 \times (15.00)] \times24\div12.42\times10000$
$= 1.449\times10^{10}$

The load reduction is estimated as follows:

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

$$\text{Load Reduction} = \frac{1.449\times10^{10} - 1.353\times10^{10}}{1.449\times10^{10}} = 6.63\%$$

A Tidal Prism Model Calculation for Wells Cove

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 = 138535.6 (m^3)
k = Fecal coliform removal rate =0.36 (T^{-1})
Q_f = Freshwater discharge
= 0.100 cfs = 0.100 × 0.0283 × 86400 × 12.42 ÷ 24 = 126.5 (m^3T^{-1})
Q_0 = 22149.7 (m^3T^{-1})
Q_b = 22276.3 (m^3 T^{-1})
C_c = water quality criterion = 49 MPN/100ml
C = current fecal coliform 5-year 90th percentile concentration = 71.71 (MPN/100ml)
C_0 = fecal coliform 5-year 90th percentile at the outside of the embayment
= 71.71 (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× (22276.3 + 0.36×138535.6) – 22149.7 × 49] ×24÷12.42×10000
= 4.734×10^{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
$= [(C)(Q_b + kV) - Q_0(C_0)] \times Cf$
= [(71.71) × (22276.3 + 0.36×138535.6) – 22149.7 × (71.71)] ×24÷12.42×10000
= 6.928×10^{10}

The load reduction is estimated as follows:

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

$$\text{Load Reduction} = \frac{6.928\times10^{10} - 4.734\times10^{10}}{6.928\times10^{10}} = 31.67\%$$

Sample calculations of load reductions for both the median and 90th percentiles have been presented for the only embayment in this report (*i.e.*, Wells Cove). 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		90th Percentile	
						C	C_0	C	C_0
Wells Cove	138535.6	0.36	126.5	22149.7	22276.3	15.00	15.00	71.71	71.71

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	
Wells Cove	1.353E+10	1.449E+10	6.63	4.734E+10	6.928E+10	31.67

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 Kent Narrows - Prospect Bay 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. Since there are no direct point source discharges to the embayment and there is a lack of information available for the discharge from boats, it is assumed that human loading results from failures in septic systems. The major nonpoint source contributions assessed for the restricted shellfish area in the Kent Narrows - Prospect Bay 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 Kent Narrows - Prospect Bay Basin. Since the subwatershed of Kent Narrows - Prospect 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 in proportion to the population within the area of the subwatershed. The results are shown in Table B-4.

Table B-4: Estimated Population, Households, and Septic Systems in Kent Narrows - Prospect Bay

Area Name	Estimated Population	Estimated Septic Systems	Estimated Households	Public Sewer
Wells Cove	102	90	55	All

The distribution of septic systems for the Wells Cove watershed 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 as estimated using GIS is shown in Table B-4. The Wells Cove restricted shellfish harvesting area is served by a public sewer system.

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 area 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 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 from septic system failure is less than 1%.

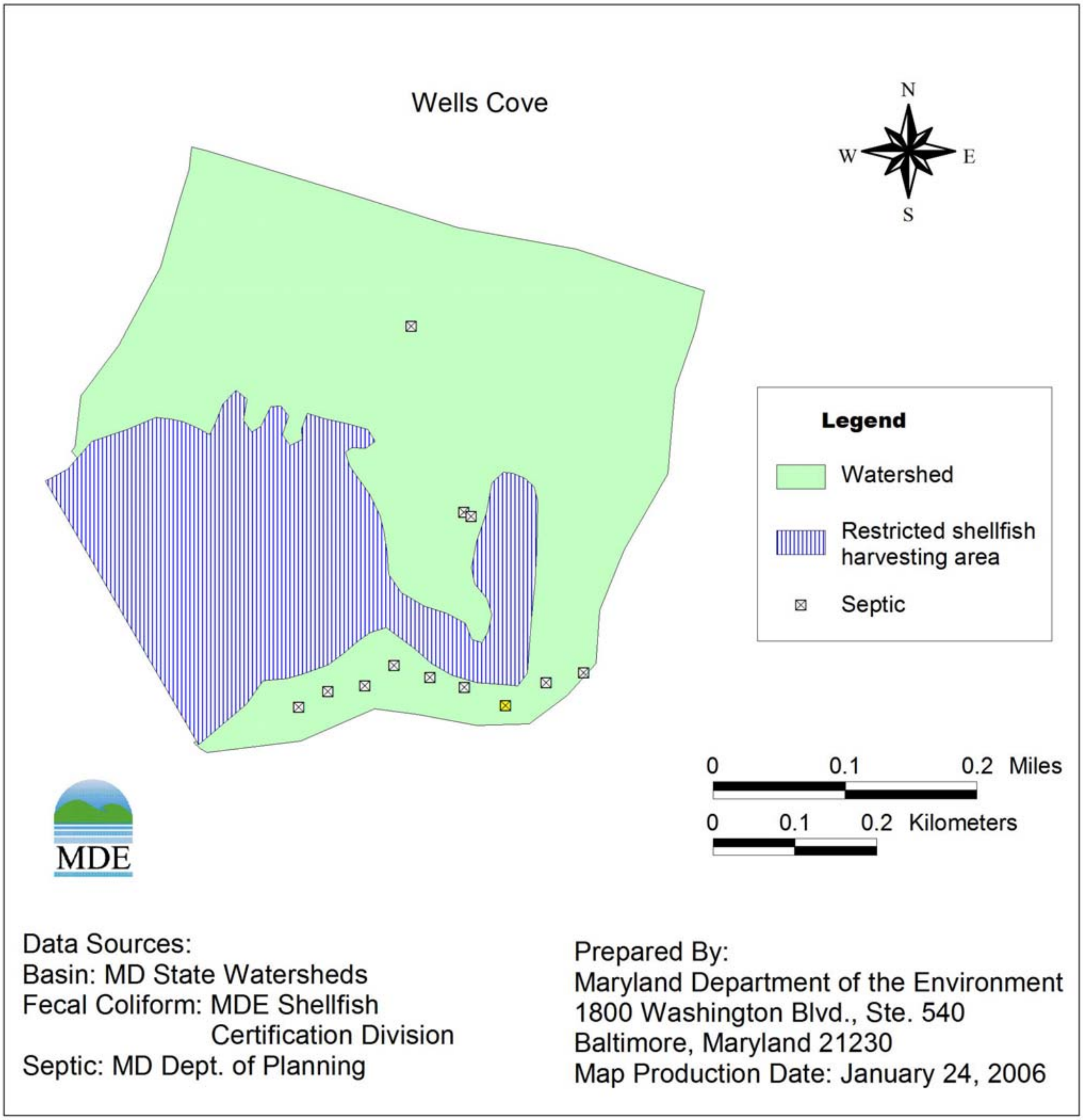

Figure B-1: Distribution of Septic Systems in the Wells Cove Watershed

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 Kent Narrows - Prospect Bay 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 may be through 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-2. The fecal coliform load was estimated based on the total number of livestock and their fecal coliform production rates. It should be noted that, because there is no agricultural land use in the Wells Cove basin, there is no livestock contribution.

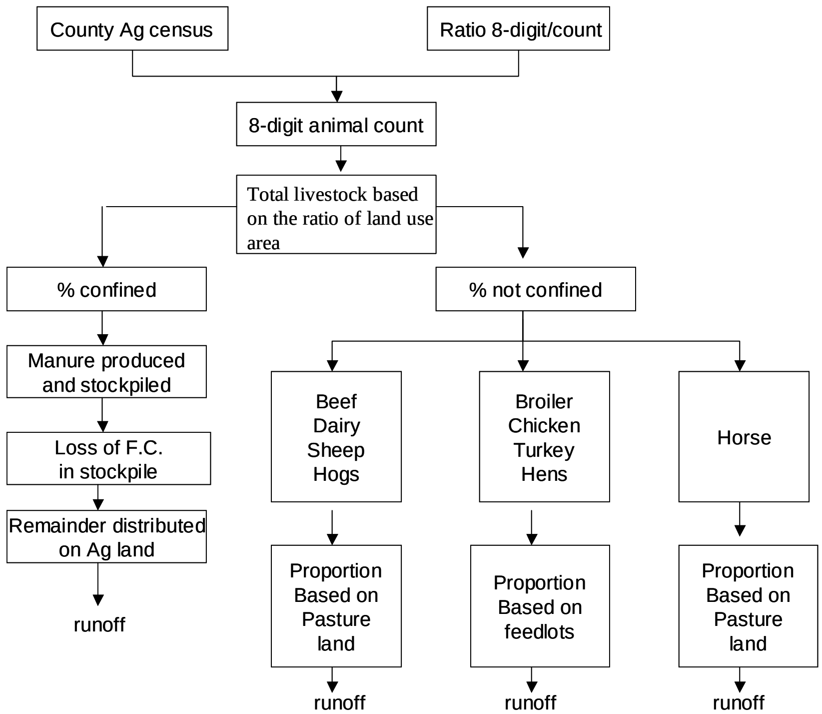

Figure B-2: Diagram to Illustrate Procedure Used to Estimate Fecal Coliform Production from Estimated Livestock Population

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 Wells Cove Basin

Fecal Coliform Source	Loading Counts/day	Loading Percent
Livestock	0.00E+00	0.0%
Pets	2.59E+10	78.8%
Human	8.11E+08	2.5%
Wildlife	6.15E+09	18.7%
Total	3.29E+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, 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 runoff from agricultural practices and livestock, wildlife, and developed areas. Precipitation and temperature fluctuate seasonally, producing varied stream flow and surface runoff that serve as a delivery mechanism for fecal coliform, as well as seasonal change in vegetation. Vegetation, particularly in pastureland and agriculture buffer zones, is very important for trapping and 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. 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 stations used in this report. The results are presented in Figure C-1. It is shown that high fecal coliform concentrations occur in the months between July and September in Wells Cove. 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.

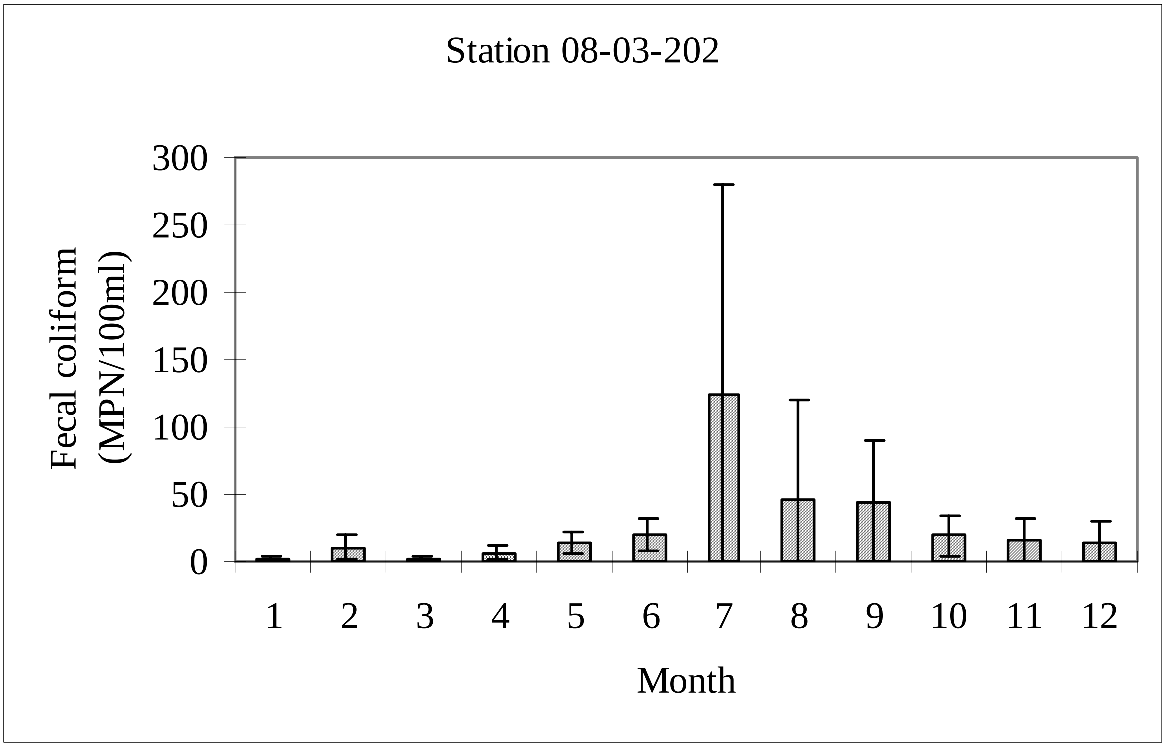

Figure C-1: Seasonality analysis of fecal coliform at Wells Cove Station 08-03-202

Appendix D. Tabulation of Fecal Coliform Data

This appendix provides a tabulation of fecal coliform values for the one monitoring station of Wells Cove of the Kent Narrows - Prospect Bay Basin in Table D-1. These data are plotted in report Figure 2.2.2.

Table D-1: Observed Fecal Coliform data at Kent Narrows - Prospect Bay Station 08-03-202

DATE	Fecal Coliform MPN/100 ml	DATE	Fecal Coliform MPN/100 ml
6/7/2000	7.3	11/20/2002	1
6/19/2000	14	12/9/2002	3.6
7/5/2000	43	1/7/2003	1
7/10/2000	240	3/11/2003	1
7/19/2000	460	4/22/2003	9.1
9/6/2000	43	5/15/2003	23
9/27/2000	150	6/2/2003	15
10/2/2000	23	6/16/2003	23
10/16/2000	1	6/30/2003	23
10/30/2000	9.1	7/12/2003	43
11/20/2000	9.1	8/4/2003	3.6
12/7/2000	1	8/18/2003	3.6
12/18/2000	15	9/2/2003	23
1/16/2001	1	9/16/2003	9.1
4/12/2001	15	10/30/2003	23
5/24/2001	23	11/3/2003	43
6/18/2001	23	12/1/2003	43
6/21/2001	23	1/5/2004	3.6
7/30/2001	23	2/19/2004	1
8/15/2001	23	3/29/2004	1
8/29/2001	15	4/15/2004	1
9/4/2001	23	5/5/2004	14
9/18/2001	9.1	6/3/2004	15
10/1/2001	23	6/17/2004	23
10/17/2001	43	6/29/2004	43
10/31/2001	3.6	8/2/2004	3.6
11/5/2001	3.6	8/10/2004	93
12/3/2001	9.1	8/31/2004	23
2/27/2002	7.3	9/23/2004	43
4/1/2002	1	10/7/2004	1

4/15/2002	9.1	10/20/2004	43
5/9/2002	7.3	11/4/2004	23
5/28/2002	20	2/22/2005	23
6/24/2002	43	3/29/2005	3.6
7/1/2002	23	4/4/2005	3.6
7/22/2002	43	4/20/2005	9.1
8/5/2002	240	5/12/2005	3.6
8/21/2002	15	5/18/2005	3.6
9/10/2002	9.1	6/1/2005	3.6
9/24/2002	93	6/15/2005	3.6
10/1/2002	23		