FINAL

Total Maximum Daily Loads of Bacteria for Duck Neck Beach of Chester River in the Upper Chester River Basin in Kent and Queen Anne's Counties, Maryland

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Submitted to:

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July 2009

EPA Submittal Date: Sept. 23, 2009
EPA Approval Date: March 18, 2011

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List of Abbreviations

BMP	Best Management Practice
BST	Bacteria Source Tracking
CFR	Code of Federal Regulations
cfu	Colony Forming Units
cms	Cubic Meters per Second
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
EFDC	Environmental Fluid Dynamic Code
EPA	Environmental Protection Agency
FA	Future Allocation
FDA	U.S. Food and Drug Administration
GIS	Geographic Information System
HEM-3D	Hydrodynamic and Eutrophication Model in 3 Dimensions
km	Kilometer
LA	Load Allocation
L_D	Load From Diffuse Sources
m	Meter
M_2	Lunar semi-diurnal tidal constituent
MACS	Maryland Agricultural Cost Share Program
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
mgd	Million Gallons per Day
ml	Milliliter(s)
MOS	Margin of Safety
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer Systems
MSSCC	Maryland State's Soil Conservation Committee
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NSSP	National Shellfish Sanitation Program
PSSS	Pollution Source Shoreline Survey
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
VIMS	Virginia Institute of Marine Science
WLA	Wasteload Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTPs	Wastewater Treatment Plants

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for bacteria in the Duck Neck public beach, Upper Chester River watershed (MD basin number 02130510). Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, states are required to either establish a TMDL of the specified substance that the waterbody can receive without violating water quality standards or demonstrate that water quality standards are being met.

Duck Neck Beach, a public beach, is located near the border between Kent and Queen Anne's Counties on the southern bank of the Maryland 8-digit basin Upper Chester River (basin number 02130510). Duck Neck Beach is designated as a Use I water: Water Contact Recreation and Protection of Nontidal Warmwater Aquatic Life (COMAR 26.08.02.02). The tidal portion of the basin was first identified in 1996 as impaired for fecal coliform (bacteria). In the 2008 *Integrated Report of Surface Water Quality* (Integrated Report), the bacteria impairment (enterococci) was clarified and identifies only Duck Neck Beach (assessment unit ID: MD-CHSTF-Duck_Neck_Beach). The designated uses in Upper Chester River were listed as impaired by sediments (1996), nutrients (1996), bacteria in tidal portions of the basin (1996, 2008), impacts to biological communities (2006), and methylmercury in fish tissue in one of the basin's impoundments (Millington Wildlife Management Ponds) in 2004. A nutrient TMDL was completed in 2006 for this basin. This document, upon EPA approval, establishes a TMDL of enterococci bacteria for the waters of Duck Neck Beach that will allow for the attainment of its designated use. The listings for sediments, impacts to biological communities and methylmercury in fish tissue within the Upper Chester River Basin will be addressed at a future date.

An inverse modeling approach using a three-dimensional model, Environmental Fluid Dynamics Code (EFDC) model, was used to estimate current bacteria loads and to establish allowable loads for the waters of Duck Neck Beach in the Upper Chester River watershed. The inverse model incorporates influences of freshwater discharge, tidal and density-induced transport, and bacteria decay, thereby representing the fate and transport of bacteria in the Upper Chester River Basin. The loadings from potential sources (human, livestock, pets, and wildlife) were assessed based on the pollution source shoreline survey (PSSS).

The allowable bacteria load for the area was computed using geometric mean concentration of water quality criterion for enterococci (35 cfu/100ml) for steady-state, dry weather conditions during the beach season. An implicit Margin of Safety (MOS) was incorporated into the analysis to account for uncertainty. The TMDL developed for the waters of Duck Neck Beach in the Upper Chester River Basin is as follows:

Waterbody	**Enterococci Baseline Load [counts per day]**	**Enterococci TMDL [counts per day]**
Duck Neck Beach	9.554×10^{12}	4.750×10^{12}

The goal of TMDL allocation is to determine the maximum allowable loads based on known sources in the watershed that will ensure the attainment of the water quality standard. The TMDL allocations proposed in this document were developed based on the scenario requiring the biggest percent reduction. For Duck Neck Beach, the available steady-state data were collected during beach seasons from 2005 to 2008. For a conservative purpose, the maximum two-year-rolling geometric mean concentration of Enterococci from 2005 to 2008 was chosen to estimate the baseline load. The TMDL requires a reduction of bacteria about 50.28% for Duck Neck Beach in the Upper Chester River watershed.

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 identified during a pollution source shoreline survey may be used as a tool to target and prioritize initial implementation efforts. Continued monitoring is included in the routine monitoring conducted by Queen Anne’s County, and the data will be used to assess the effectiveness of the Department's implementation efforts on an ongoing basis.

1.0 INTRODUCTION

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

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

Duck Neck Beach, a public beach located in Queen Anne's County on the southern bank of the Maryland 8-digit basin Upper Chester River (basin number 02130510). Duck Neck Beach is designated as a Use I water: Water Contact Recreation and Protection of Nontidal Warmwater Aquatic Life (COMAR 26.08.02.02). The tidal portion of the basin was first identified in 1996 as impaired for fecal coliform (bacteria). In the 2008 *Integrated Report of Surface Water Quality* (Integrated Report), the bacteria impairment (enterococci) was clarified and identifies only Duck Neck Beach (assessment unit ID: MD-CHSTF-Duck_Neck_Beach). The designated uses in Upper Chester River were listed as impaired by sediments (1996), nutrients (1996), bacteria in tidal portions of the basin (1996, 2008), impacts to biological communities (2006), and methylmercury in fish tissue in one of the basin's impoundments (Millington Wildlife Management Ponds) in 2004. A nutrient TMDL was completed in 2006 for this basin. This document, upon EPA approval, establishes a TMDL of enterococci bacteria for the waters of Duck Neck Beach that will allow for the attainment of its designated use. The listings for sediments, impacts to biological communities and methylmercury in fish tissue within the Upper Chester River Basin will be addressed at a future date.

Fecal bacteria are microscopic single-celled organisms (primarily fecal coliform and fecal Streptococci) found in the intestinal tract of humans and other warm-blooded animals. Their presence in water is used to assess the sanitary quality of water for body-contact recreation, for consumption of molluscan bivalves (shellfish), and for drinking waters. Excessive amounts of fecal bacteria in surface water used for recreation are known to indicate an increased risk of pathogen-induced illness to human. Infections due to pathogen-contaminated recreation waters include gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases (US EPA 1986).

In 1986, EPA published "Ambient Water Quality Criteria for Bacteria", in which three indicator organisms were assessed to determine their correlation with swimming-associated illnesses: fecal coliform, *E. coli* and enterococci. Fecal coliform bacteria are a subgroup of total coliform bacteria and *E. coli* bacteria are a subgroup of fecal coliform. Most *E. coli* are harmless and are found in great quantities in the intestines of people and warm-blooded animals. Enterococci are a subgroup of bacteria in the fecal streptococcus group. Fecal coliform, *E. coli*, and enterococci can all be classified as fecal bacteria. The results of the epidemiological studies conducted by EPA demonstrated that *E. coli* and enterococci had the best quantifiable relationship between the density of an indicator in the water and the potential human health risks associated with swimming in sewage contaminated waters.

Maryland promulgated EPA's 1986 bacteria criteria in 2004 for all Use I waters-enterococci (marine or freshwater) and *E. coli* (freshwater only) standards. Maryland's bacteria indicator criterion is a conservative measure, which protects the public from the potential risks associated with swimming and other primary contact recreation activities. A few high values of the indicators may or may not be indicative of impairment. Therefore, it is necessary to evaluate the results from indicator organisms from multiple sampling events over time to adequately quantify water quality conditions (MDE 2008a).

The bacteria impairment for Duck Neck Beach in the Upper Chester River was based on the data collected by Queen Anne's County Health department. In Maryland, county health departments have been delegated the authority to monitor beach water quality and notify the public of beach advisories and closures. MDE works closely with county health departments who also submit monitoring data and beach notification data to MDE. In this study, the criterion for public beaches adopted by MDE is that steady-state geometric mean density of enterococci shall not exceed 35 cfu/100 ml (MDE 2008a).

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

This report addresses the bacteria impairment at Duck Neck Beach in the southern bank of the Upper Chester River Basin (basin number 02130510) located on Maryland's Eastern Shore in Queen Anne's County, as shown in Figure 2.1.1. The Chester River is approximately 44.5 km in length and its width ranges from 30 to 500 m upstream and approximately 5.4 km at its mouth (where it flows into Chesapeake Bay). Duck Neck Beach has a length of 22 meters. The drainage area, affecting the water quality of the public beach, is 15,901 acres (64.4 km^2).

The 2000 Maryland Department of Planning (MDP) land use/land cover data show that the Chester River watershed can be primarily characterized as rural, with 63% of the area being cropland and more than 24% being forest. The land use information in the Chester River Basin is shown in Table 2.1.1 and Figure 2.1.2. Residential urban land use identified in Table 2.1.1 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. The land use of the drainage basin of the Duck Neck public beach is similar to the entire Chester River Basin with about 70% of the area being cropland and about 24% being forest (Table 2.1.2 and Figure 2.1.3).

The dominant tide in this region is the lunar semi-diurnal (M_2) tide, with a tidal range of 0.64 m in the restricted portion of the Chester River and a tidal period of 12.42 hours (NOAA 2006). Because of tidal excursion, loading discharged from the subwatersheds located upstream and downstream of the beach have an effect on the beach. The drainage basin of the impaired area is determined based on the characteristics of tidal induced bacteria transport in the Upper Chester River.

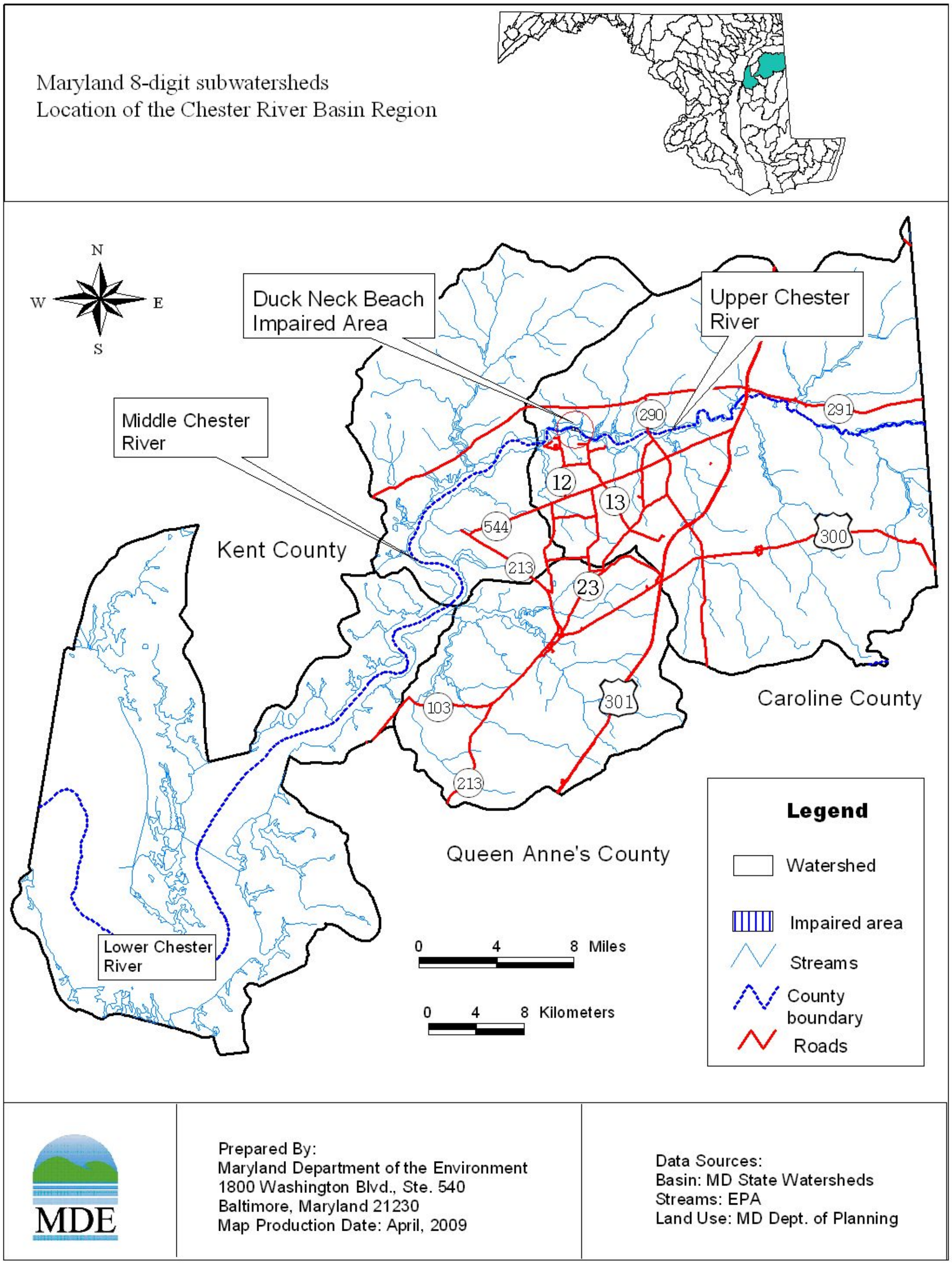


Figure 2.1.1: Location Map of the Chester River Basin

Table 2.1.1: Land Use Percentage Distribution for Chester River Watershed

Land Type	Acreage	Percentage
Residential Urban[1]	7,676.6	3.93
Non-Residential Urban[2]	2,003.1	1.02
Cropland	123,200.7	63.00
Pasture	1,277.3	0.65
Feedlot	1,272.4	0.65
Forest	47,788.9	24.44
Water	1,367.5	0.70
Wetlands	10,927.3	5.59
Barren	34.4	0.02
Totals	**195,548.2**	**100.00**

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

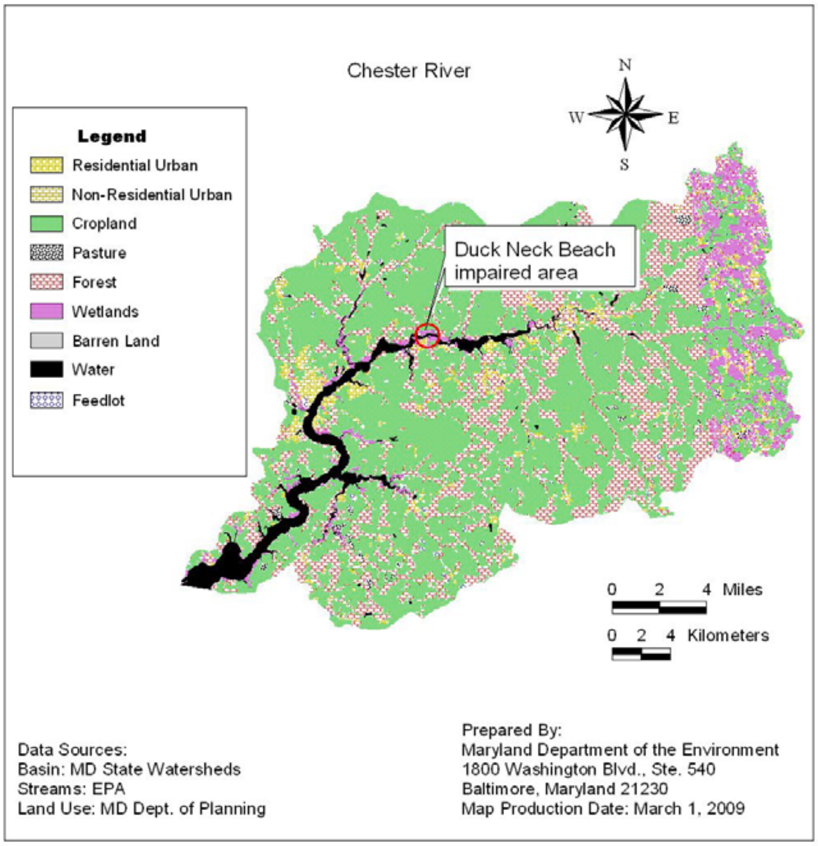
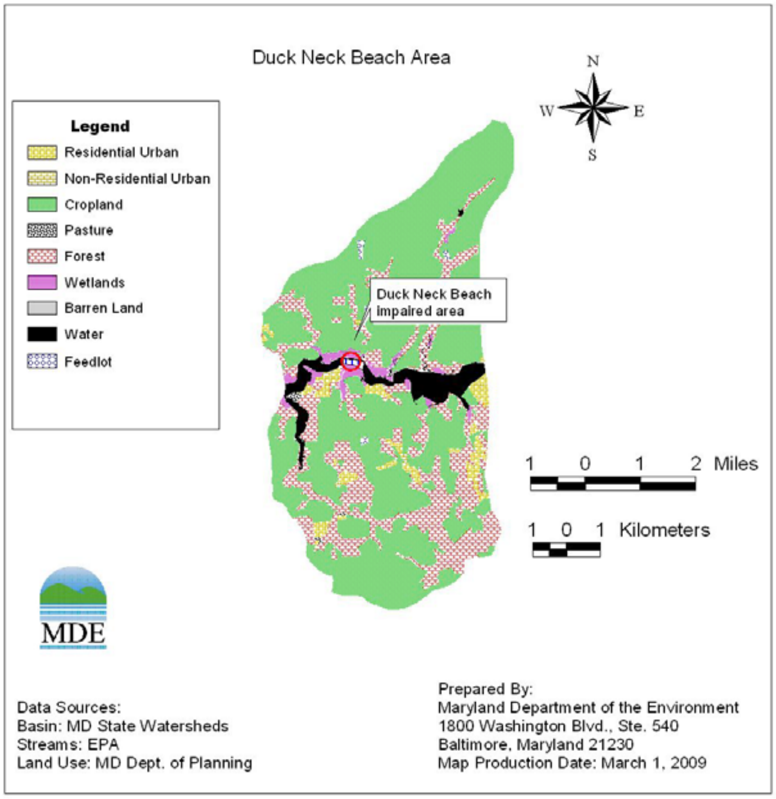


Figure 2.1.2: Land Use in the Chester River Basin

Table 2.1.2: Land Use Percentage Distribution for Duck Neck Watershed

Land Type	Acreage	Percentage
Residential Urban[1]	595.9	3.7
Non-Residential Urban[2]	22.2	0.1
Cropland	11049.2	69.5
Pasture	34.9	0.2
Feedlot	50.7	0.3
Forest	3749.6	23.6
Water	85.6	0.5
Wetlands	313.8	2.0
Barren	0.0	0.0
Totals	**15,901.9**	**100.00**

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



Data Sources:
Basin: MD State Watersheds
Streams: EPA
Land Use: MD Dept. of Planning

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Figure 2.1.3: Land Use in the Area Surrounding Duck Neck Public Beach

2.2 Water Quality Characterization

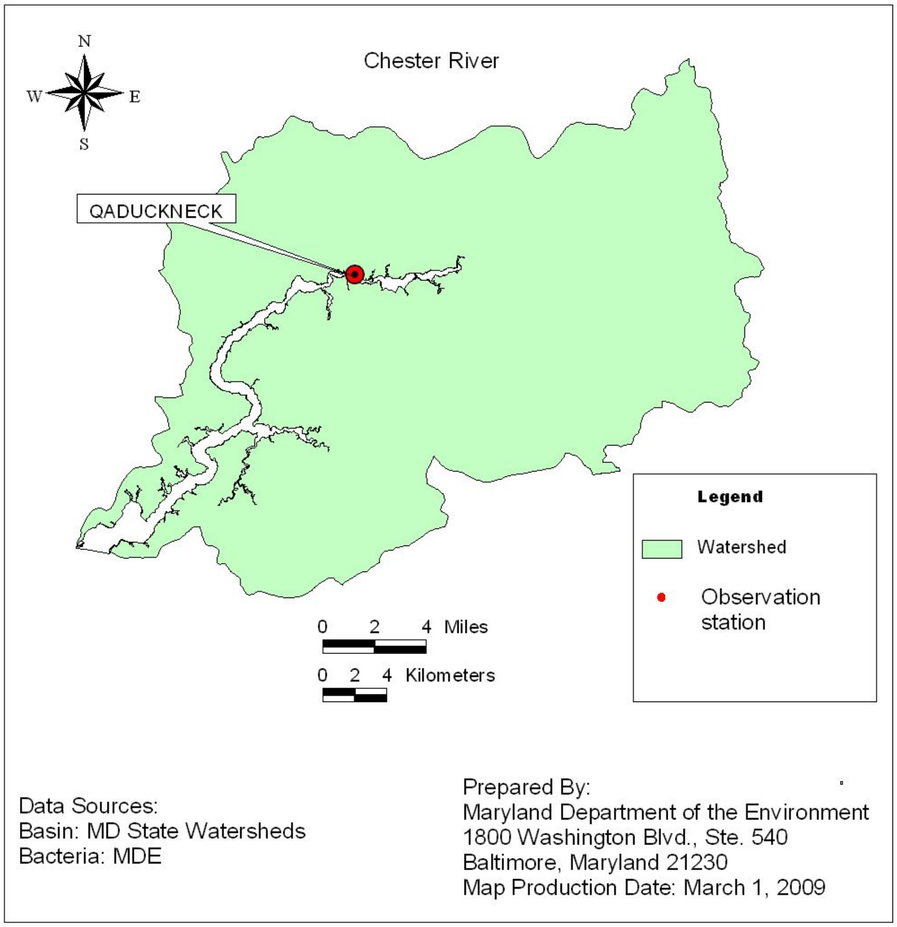
EPA's guidance document, "Ambient Water Quality Criteria for Bacteria" (USEPA, 1986), recommended that states use *E. coli* (for fresh water) or enterococci (for fresh or salt water) as pathogen indicators. Fecal bacteria, *E. coli*, and enterococci, were assessed as indicator organisms for predicting human health impacts. A statistical analysis found that the highest correlation to gastrointestinal illness was linked to elevated levels of *E. coli* and enterococci in fresh water (enterococci in salt water).

In Maryland, beaches are monitored from at least two weeks before Memorial Day through Labor Day. During this period, beaches are monitored based on a tiered approach of high, medium, and low priority which are monitored weekly, biweekly, and monthly, respectively. The factors used to determine if a beach is high, medium or low priority include: rainfall, known or potential pollution sources, and density of bathers. Based on these factors, Duck Neck Beach is ranked as a low to medium priority beach. However, Queen Anne's County has chosen to monitor weekly at this beach.

There is one routine bacterial monitoring station at Duck Neck Beach addressed in this report. The station identification and observations recorded during beach seasons from June 2005 to August 2008 are provided in Table 2.2.1, Figure 2.2.1, and Figure 2.2.2. The presented observations are conducted each beach season during dry weather conditions, which represent a steady-state condition during the beach season. A tabulation of observed enterococci values at the station is provided in Appendix C.

Table 2.2.1: Location of the Bacteria Monitoring Station in Duck Neck Public Beach in the Upper Chester River

Station Location	Monitoring Station	Obs. Period	Total Obs.	LATITUDE Deg-min-sec	LONGITUDE Deg-min-sec
Duck Neck Beach	QADUCKNECK	2005-2008	141	39-12-17	76-3-6.1



Data Sources:
Basin: MD State Watersheds
Bacteria: MDE

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Figure 2.2.1: Bacteria Monitoring Station in Duck Neck Public Beach

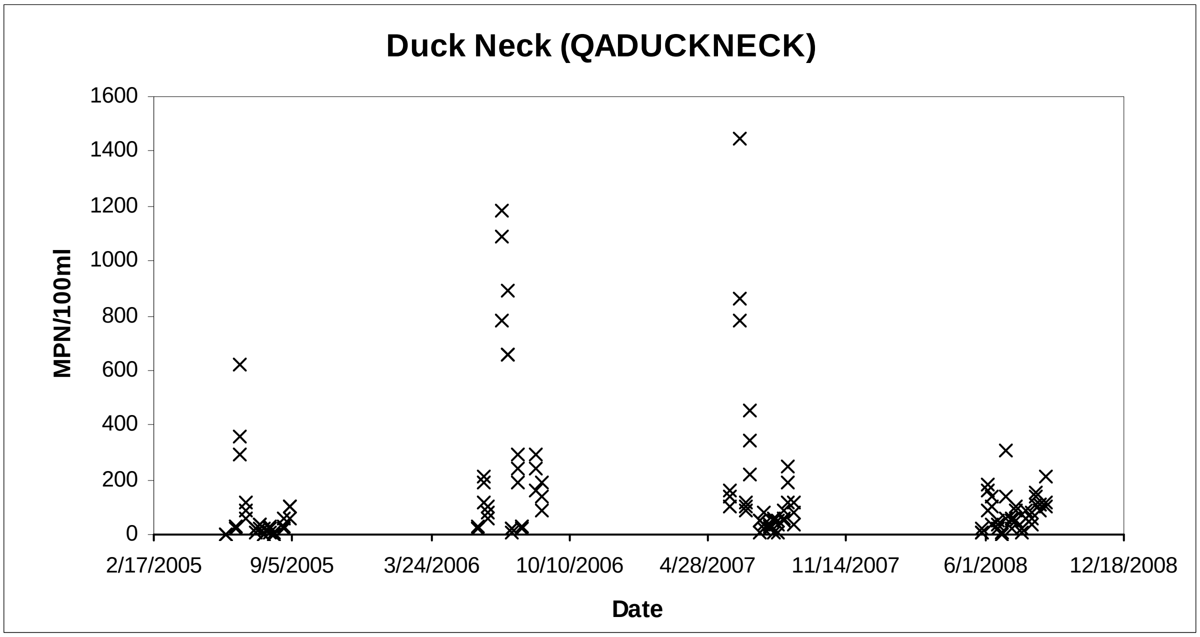

Figure 2.2.2: Observed Enterococci Concentrations at Station QADUCKNECK

2.3 Designated Uses and Water Quality Standard

The Surface Water Use Designation for the waters of Duck Neck Beach is Use I: Water Contact Recreation and Protection of Nontidal Warmwater Aquatic Life (COMAR 26.08.02.02). Upper Chester River was listed as impaired by fecal coliform (bacteria) in 1996. In 2008, the listing was refined and Duck Neck Beach was identified (MDE, 2008a), due to elevated bacteria concentrations detected at the monitoring station QADUCKNECK.

Water Quality Criteria

As per EPA's guidance, Maryland adopted *E. coli* and enterococci as indicators for beach water quality monitoring and to protect public health in Use I waters. The Maryland water quality standard for bacteria (enterococci) used in this study is as follows:

Table 2.3.1: Water Quality Criterion for Duck Neck Beach

Indicator (Salt Water)	Steady-state Geometric Mean Indicator Density
Enterococci	35 cfu/100ml

When presenting the water quality standards, laboratory results and model results it is important to understand the definition of the reported units. In the laboratory analysis of fecal indicator bacteria, using membrane filtration analysis, plate counts are direct counts of living organisms (e.g. E. coli or enterococci) to estimate bacteria counts and are expressed in Colony Forming Units (cfu), the bacteria units presented in COMAR. The laboratory technique used for all the observations in this report is the IDEXX Enterolert ™ method to estimate bacteria counts. The results are the number of positives referenced to a most probable number table. The data collected for this report are reported in MPN/100 ml and are directly compared to the water quality standard presented in cfu/100 ml. Because both cfu and MPN are estimating bacteria counts, the TMDL is reported in counts/day.

Pursuant to the listing methodology (MDE 2008 Integrated Report), the listing of impaired beaches requires analysis of data collected from the previous two to five years. The data for the calculation of the geometric mean should be from samples collected during steady-state, dry weather conditions and during the beach season (Memorial Day through Labor Day) to be representative of the critical condition (highest use).

Water Quality Assessment

The bacteria impairment addressed in this analysis was determined with reference to Maryland's Classification of Use I Waters and water quality criteria in tidal Use I waters. For this analysis, MDE used steady-state monitoring data collected during beach seasons from 2005 to 2008. The maximum two-year-rolling geometric mean of enteroccoci concentration from 2005 to 2008 was chosen to estimate the baseline load (current load) for conservative purposes. Descriptive statistics of the monitoring data are shown in Table 2.3.2.

Table 2.3.2: Duck Neck Beach Statistics (Summer Data from 2005-2008)

Area Name	Period	Geometric Mean (MPN/100ml)
Duck Neck Beach	**2008-2007**	**64.5**
	2007-2006	**98.2**
	2006-2005	**46.1**

2.4 Source Assessment

Nonpoint Source Assessment

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

In order to better identify potential sources of bacterial contamination that may be impacting the water quality of Duck Neck Beach, MDE conducted a pollution source shoreline survey (PSSS) of the area surrounding Duck Neck Beach (Appendix B). A PSSS is a tool historically used by MDE's – Shellfish Program to identify potential sources of bacterial contamination affecting shellfish harvesting areas. The Shellfish Program PSSS mainly focuses on inspecting residential shoreline homes for septic systems violations. As the Beach Program evolved, the PSSS became an obvious tool for identifying sources of bacterial contamination at beach areas. With funding provided by the US EPA, the Shellfish Program PSSS tool was adapted to the Beaches Program by incorporating a technology-based data collection system, which facilitates the collection of detailed geo-referenced information, as well as improved data management and analysis. In addition, the system also improves data sharing between agencies responsible for the water quality of beaches.

In April and May 2009, MDE personnel surveyed properties within the watershed thought to have an impact on the water quality of Duck Neck Beach. Information collected included but was not limited to: latitude/longitude, wastewater system type and problems, and type and number of animals on site. Duck Neck Beach is approximately 22 meters in length and is surrounded by the Duck Neck Campground. The capacity at Duck Neck Camp ground is 355 camp sites, however, the largest number of visitors is only 100 on holiday weekends. The campground sewer system consists of a holding tank and group septic systems that are routinely pumped. According to the survey, no evidence of leaking sewage was observed at any of the campsites, including the five that were occupied at the time. Only five agriculture operations/livestock farms were observed in the vicinity of Duck Neck Beach, however, based on the inspection at the time, these livestock and manure contributions are not considered to have a direct impact on the water quality at Duck Neck Beach.-Based on observations during the PSSS of Duck Neck Beach, the only significant sources of bacteria to the waters at Duck Neck Beach are the adjacent marsh area, which is home to various types of wildlife and waterfowl and could be a source of and reservoir for re-growth of indicator bacteria contributing to the elevated levels of bacteria found, and that this may be affecting water quality at Duck Neck Beach. Therefore, the survey indicates that wildlife might be the major bacteria source for Duck Neck Beach. The complete survey is included as Appendix B of this report.

Point Source Assessment

There are two municipal wastewater treatment plants (WWTPs) which have permit regulating the discharge of fecal bacteria in the watershed of Duck Neck Beach: Millington WWTP (NPDES permit number MD0020435) and Sudlersville WWTP (NPDES number MD0020559). Their permitted flows are 0.140 and 0.075 MGD, respectively. The locations of point source are shown in Figure 2.4.1. The monthly log mean fecal coliform permits for both of them are 200 MPN/100 ml. The following equation is used to convert the permit values from fecal coliform to enterococci (VADEQ, 2003):

$$\log_2(C_{ent}) = 1.2375 + 0.59984 * \log_2(C_{fc}) = 1.2375 + 0.59984 * \log_2(200) = 5.8226$$
$$C_{ent} = 57 \text{ MPN/100 ml}$$

where C_{fc} and C_{ent} are concentrations for fecal coliform and enterococci, respectively. The total bacteria loading is 4.64×10^8 per day for enterococci. The detailed point source information is summarized in Table 2.4.1. The allocation of the regulated loads from these point source facilities are addressed in Section 4.7.

Table 2.4.1: Summary of Point Source Facilities

Facility Name	NPDES Permit Number	Design flow (MGD)	Permitted Enteroccoci Concentration in MPN/100ml (Monthly Log Mean)	Permitted Enteroccoci Loads in MPN/Day
Millington WWTP	MD0020435	0.14	57	3.02E+08
Sudlersville WWTP	MD0020559	0.075	57	1.62E+08
Total				4.64E+08

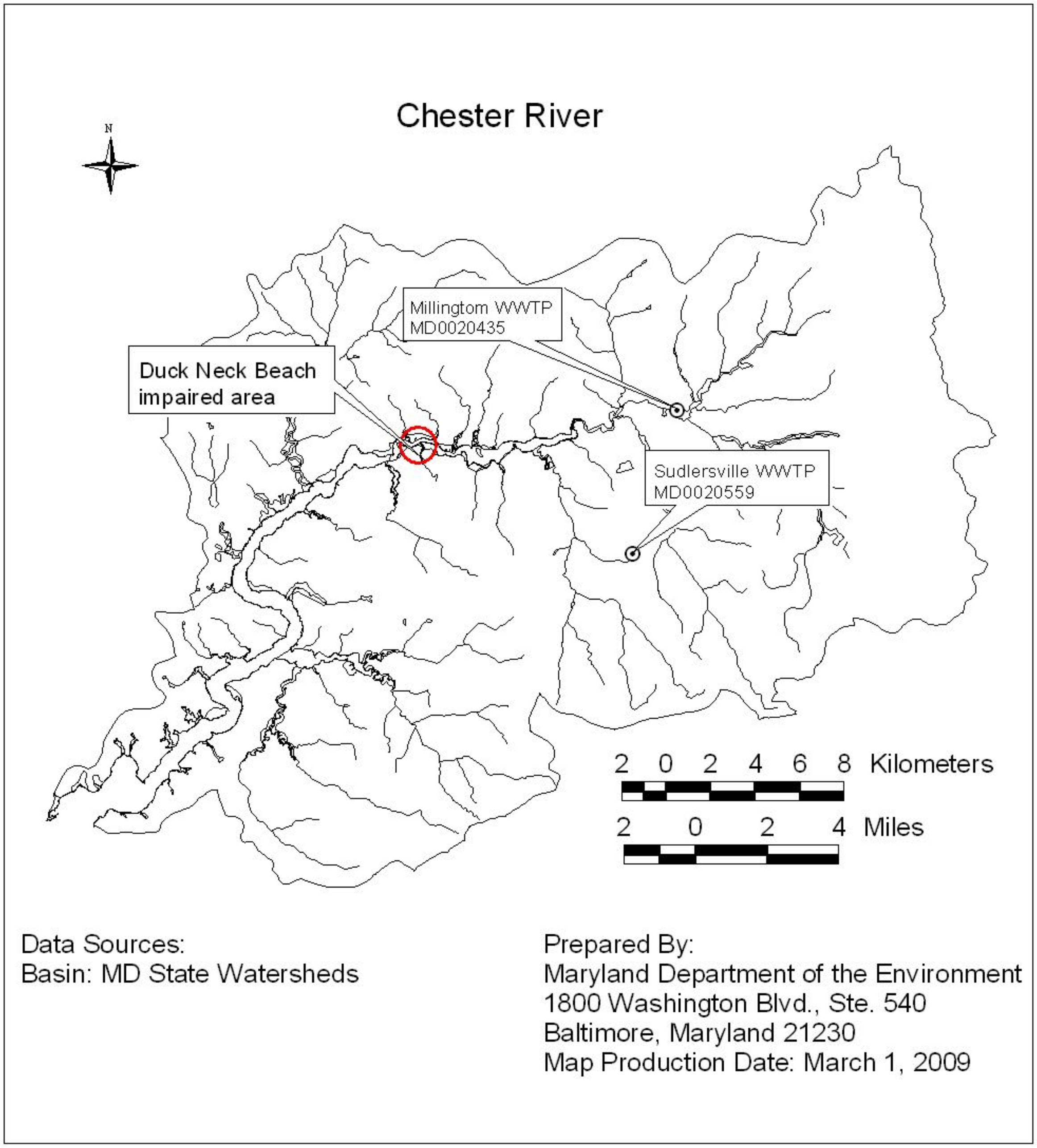

Figure 2.4.1: Locations of the Point Sources of Municipal Wastewater Treatment Plants.

3.0 TARGETED WATER QUALITY GOAL

The overall objective of the bacteria TMDLs summarized in this document is to establish the maximum loading needed to ensure attainment of water quality standard for the waters of Duck Neck Beach. The standard is described fully in Section 2.3, Designated Uses and Water Quality Standard.

4.0 TOTAL MAXIMUM DAILY LOADS AND LOAD ALLOCATION

4.1 Overview

This section documents the detailed bacteria TMDLs and load allocation development for the waters of Duck Neck Beach in the Upper Chester River watershed. Section 4.2 describes the analysis framework for simulating enterococci concentration in the impaired area at Duck Neck Beach. Section 4.3 addresses critical conditions and seasonality. The TMDL calculations are presented in Section 4.4. The TMDL is presented as counts per day. Section 4.5 provides a summary of baseline loads and Section 4.6 discusses TMDL loading caps. Section 4.7 provides the description of the waste load and load allocations. The Margin of Safety (MOS) is discussed in Section 4.8. Finally, the TMDL equation is summarized in Section 4.9.

A TMDL is the total amount of a pollutant that a waterbody can receive and still meet water quality standards. In the case of this document, Maryland's water quality criteria for Use I waters must be met. A TMDL may be expressed as a “mass per unit time, toxicity, or other appropriate measure” (CFR 2006b). These loads are based on an averaging period that is defined by the specific water quality criteria for Use I waters. The averaging period used for development of the TMDL requires data collected from the previous two (2) to five (5) years, for computing a steady-state geometric mean to establish current condition.

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

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

4.2 Analysis Framework

In general, tidal waters are exchanged through their connecting boundaries. The tide and amount of freshwater discharged into the impaired area are the dominant forces that influence the transport of bacteria. The impaired area is located in the Upper Chester River and it is influenced by both tide and freshwater input. The current distribution in the system varies as tidal and freshwater discharges change. In order to simulate the transport and fate of bacteria in the Upper Chester River accurately, the 3-dimensional hydrodynamic model, Environmental Fluid

Dynamics Code (EFDC) model, has been used for this study. The EFDC model is a general 3-Dimensional (3-D) model for environmental studies. The model simulates density and topographically induced circulation as well as tidal and wind-driven flows, and spatial and temporal distributions of salinity, temperature, and suspended sediment concentration, conservative tracers, eutrophication processes, and fecal bacteria. For a detailed model description, the reader is referred to Hamrick (1992a,1992b) and Park et al. (1995).

In order to account for bacteria transport from both the upstream and downstream, the entire Chester River is simulated. The Chester River is represented by a horizontal network of model grid cells. The model grid was used in the Chester River fecal coliform TMDL (MDE, 2008b). The model grid was refined in the area of Duck Neck Beach and a small tributary located upstream of the beach was added to the grid. There are a total of 217 model grid cells in the modeling domain. To better simulate the stratification effect, three layers are used in the vertical direction. For this study, the model was calibrated for the tide and long-term mean salinity distribution. In order to address the geometric mean of bacteria concentrations, an inverse approach was adopted to estimate the loads from the watershed. The watershed is divided into 27 subwatersheds. The loads from each subwatershed are discharged into the river from the river's tributaries.

The model was forced by 6 major tidal constituents, namely M_2, S_2, K_1, O_1, K_2, and N_2, and the mean salinity concentration at the river's mouth. The long-term mean freshwater input estimated based on data from United States Geological Survey (USGS) gage station 01493500 was used. The discharges from subwatersheds are estimated based on the ratio of subwatershed area to the total drainage basin of the USGS station. The inverse method is used to estimate the existing load discharged from each subwatershed based on geometric mean concentration of bacteria obtained from the observations. The model is also used to establish the allowable loads for the river. Detailed modeling procedures are described in Appendix A.

4.3 Critical Condition and Seasonality

EPA's regulations require TMDLs to be "established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with *seasonal variations* and a *margin of safety* . . . Determinations of TMDLs shall take into account *critical conditions* for stream flow, loading, and water quality parameters" (CFR 2006c). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The critical condition accounts for the hydrologic variation in the watershed over many sampling years, whereas the critical period is the time during which a waterbody is most likely to violate the water quality standard.

The data used in the development of this TMDL were collected during beach season (Memorial Day through Labor Day) and during steady-state, dry whether conditions to be representative of the critical condition, when maximum water contact is expected. Therefore, the seasonality and critical condition are included in the requirement for the monitoring data for beaches. Steady-state data collected over the previous 4 beach seasons from 2005 to 2008 were used to develop the TMDL for the waters of Duck Neck Beach. The TMDL allocation is developed based on the scenario in which the greatest reduction is needed to meet the water quality standard, in this case, the scenario using the maximum two-year-rolling geometric mean concentration of enteroccoci (2006-2007 geometric mean, see Table 2.3.2). Therefore, critical conditions requirement is met for the TMDL development in this document.

4.4 TMDL Computation

Routine monitoring data were used to estimate the current loads. There is one routine monitoring station located near Duck Neck Beach. In order to estimate the existing condition of fecal coliform for the beach, additional data were collected in the 2008 summer season by Queen Anne's County Health Department. Three months of data (June to August) were collected both upstream and downstream of the beach, and on the tributary draining the area near the beach in the Upper Chester River (Appendix A and Table A-4 shows the additional data stations). These data were used to calibrate the model. The watershed is segmented into 27 subwatersheds and the load from each subwatershed was discharged into its corresponding segment of the river. The inverse method was used to compute the watershed loads discharged into the river based on the least-square criterion between the observations and model simulation of bacteria concentrations in the river. Detailed computation is presented in Appendix A. The total loads are reported in Table 4.4.1. Detailed results by subwatershed are also listed in Appendix A.

According to the water quality standards for bacteria in Use I waters computation of a TMDL and load reduction requires analyses of steady-state geometric mean from the previous two to five years' data. For Duck Neck Beach, the available steady-state beach season data are from 2005 to 2008. For conservative purposes, the load estimation scenario using the maximum two-year- rolling geometric mean concentration of enteroccoci was chosen for the baseline load, since this scenario will require the greatest reduction to meet water quality criteria. According to Table 2.3.2, the maximum steady-state geometric mean values of enterococci from two-year-rolling data is 98.2 MPN/100ml for the period from 2006 to 2007. Therefore, the baseline load (current load) from the Duck Neck Beach watershed is estimated based on the maximum concentration of 98.2 MPN100ml.

The allowable load is calculated using the water quality criterion of a geometric mean bacteria density, i.e., enterococci of 35 cfu/100ml. The 3-D model was used to compute the allowable load for each subwatershed by reducing the existing loads from the watershed so that the bacteria concentrations in the receiving water meet the appropriate water quality standards. The total loads discharged into the river are the summation of loads discharged from each subwatershed. 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.

Table 4.4.1: Geometric Mean Analysis of Loads and Estimated Load Reduction

Location	Drainage area (acres)	Geometric Mean Criterion (cfu/100mL)	Allowable Load (counts/day)	Current Load (counts/day)	Required Percent Reduction (%)
Duck Neck Beach	15,901.9	35	4.750×10^{12}	9.554×10^{12}	50.28

4.5 Summary of Baseline Loads

For the TMDL analysis period, the 2005-2008 beach seasons, the calculated baseline (current) loads of enterococci from all sources in the Duck Neck Beach watershed in the Upper Chester River Basin are summarized in Table 4.5.1 (see also Table 4.4.1).

Table 4.5.1: Summary of Baseline Loads

Waterbody	Enterococci Baseline Loads [counts per day]
	Geometric Mean Analysis Scenario
Duck Neck Beach	9.554×10^{12}

4.6 TMDL Loading Caps

This section presents the TMDLs that would meet the geometric mean criterion. Seasonal variability is addressed implicitly through the interpretation of the water quality standards (see Section 4.3). The TMDL for the waters of Duck Neck Beach in the Upper Chester River Basin is summarized in Table 4.6.1.

Table 4.6.1: Summary of TMDL Loading Caps

Waterbody	Enterococci TMDL [counts per day]
	based on steady-state Geometric Mean
Duck Neck Beach	4.750×10^{12}

A two-year rolling period was used to develop the bacteria TMDLs for the Duck Neck Beach in the Upper Chester River. When allocating loads among sources, the scenario that requires the greatest overall reductions based on data analysis of the two-year rolling period from 2005 to 2008. For Duck Neck Beach, the TMDL allocation is based on reductions from a scenario using the 2006 to 2007 data. Table 4.7.1 below summarizes the necessary load reductions by area.

4.7 TMDL Allocations and Percent Reductions

The purpose of this section is to allocate the TMDLs between point (WLA) and nonpoint (LA) sources. As stated in Section 2.4, there are two point source facilities in the watershed which have the potential to impact waters of the beach. These facilities have permits regulating the discharge of fecal bacteria to the Chester River (or its tributaries) and the permitted enterococci load from these point sources is approximately 4.64×10^8 counts per day and will be included in the WLA. The remaining assimilative capacity will be allocated to the load allocation (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. The load reduction is shown in Table 4.7.1.

Table 4.7.1: Load Reductions

Waterbody	Required Reduction
Duck Neck Beach	**50.28 %**

The load reduction applied to this watershed was based on the geometric mean of data collected during steady-state, dry weather conditions and during the beach season. It targets only those critical conditions when the recreational water is in highest use. 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 critical conditions.

4.8 Margin of Safety

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

For TMDL development, the MOS needs to be incorporated to account for uncertainty due to model parameter selection. The decay rate is one of the most sensitive parameters in the model. For a given system, the higher the decay rate, the higher the assimilative capacity. The value of the decay rate varies from 0.7 to 3.0 per day in salt water (Mancini, 1978; Thomann and Mueller, 1987). A decay rate of 0.7 per day was used as a conservative estimate in the TMDL calculation. Further literature review supports this assumption as a conservative estimate of the decay rate (MDE 2004). Therefore the MOS is implicitly included in the calculation.

4.9 Summary of Total Maximum Daily Loads

There are two municipal WWTPs that have permits regulating the discharge of fecal bacteria in the watershed of Duck Neck Beach: Millington WWTP (National Pollution Discharge Elimination System (NPDES) permit number MD0020435) and Sudlersville WWTP (NPDES number MD0020559). Their permitted flows are 0.140 and 0.075 MGD, respectively. The monthly log mean fecal coliform limits for both WWTPs are 200 MPN/100 ml. The corresponding enterococci concentration estimated based on the regression equation is 57 MPN/100ml. The total bacteria loading from the point sources is 4.64×10^8 count per day and will be included in the WLA. The remaining loads will be allocated to the LA. The TMDL is summarized as follows:

Table 4.9.1: Summary of Enterococci TMDL (Counts per Day) Based on the Geometric Mean Criterion

Area	TMDL	=	LA	+	WLA	+	FA	+	MOS
Duck Neck Beach	**4.75×10^{12}**	=	**4.75×10^{12}**	+	**4.64×10^8**	+	**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 assurance that the bacteria TMDLs will be achieved and maintained. The appropriate measures to reduce pollution levels at the beach include, where appropriate, the use of better treatment technology or installation of best management practices. Details of these methods are to be described in the implementation plan.

In general, MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the greatest impact on water quality, with consideration given to ease of implementation and cost. The potential source contributions from the PSSS (Appendix B) may be used as a tool to target and prioritize initial implementation efforts. The iterative approach towards best management practice (BMP) implementation throughout the watershed will help to ensure that the most cost-effective practices are implemented first. The success of BMP implementation will be evaluated and tracked through follow-up stream monitoring.

Existing Funding and Regulatory Framework

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

Maryland law requires the following types of facilities to have pumpout stations: existing marinas wishing to expand to a total of 11 or more slips that are capable of berthing vessels that are 22 feet or larger; new marinas with more than 10 slips capable of berthing vessels that are 22 feet or larger; and marinas with 50 or more slips and that berth any vessel over 22 feet in length (Maryland 1996). Any public or private marina in Maryland is eligible to apply for up to $15,000 in grant funds to install a pumpout station through the Maryland Department of Natural Resources. Also, although not directly linked, it is assumed that the nutrient management plans from the Water Quality Improvement Act of 1998 (WQIA) will result in some reduction of bacteria from manure application practices.

Implementation and Wildlife Sources

It is expected that, due to significant wildlife bacteria contribution, some waterbodies will not be able to meet water quality standards even after all anthropogenic sources are controlled. Neither the State of Maryland nor EPA is proposing the elimination of wildlife to allow for the attainment of water quality standards. This is considered to be an impracticable and undesirable action. While managing the overpopulation of wildlife remains an option for State and local stakeholders, the reduction of wildlife or the changing of a natural background condition is not the intended goal of a TMDL.

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

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Appendix A. Model Development

The 3-dimensional Environmental Fluid Dynamic Code model EFDC (which is also referred to as "HEM3D" in VIMS 2004) has been used for this study. The EFDC model is a general 3D model for environmental studies. The model simulates density and topographically induced circulation as well as tidal and wind-driven flows, spatial and temporal distributions of salinity, temperature, and suspended sediment concentrations, conservative tracers, eutrophication processes, and bacteria. The model has been applied for varieties of environmental problems in estuaries (Hamrick 1992a; Shen et al., 1999). For a detailed discussion of the model theory, readers are referred to Hamrick (1992b) and Park et al. (1996).

The Chester River is a tidal river. The dominant tidal constituent is M_2 (lunar semi-diurnal tide). To simulate tidal flux correctly, a calibration of mean tide was conducted. The model was forced by 6 tidal constituents, namely M_2, S_2, K_1, O_1, K_2, and N_2, at the model open boundary based on the National Oceanic and Atmospheric Administration (NOAA) data and Chesapeake Bay model (Shen et al., 2006). The model results of mean range are compared with NOAA predicted tides at four stations inside the Chester River (NOAA 2006). The locations of these stations are shown in Figure A-2. The model results and observed tidal ranges are listed in Table A-1. The EFDC model results compare well with results reported from the tidal table. The model simulation of salinity was calibrated based on the mean salinity obtained from monitoring stations along the river. The locations of these stations are shown in Figure A-2. For the mean salinity calibration, the dominant M_2 tide was used as a tidal forcing with mean tidal range of 0.55 m at the model open boundary. Mean salinity measured at the station nearest the mouth was used as the salinity boundary condition. The quantity of freshwater discharged from each subwatershed was estimated according to the average long-term flow from the USGS gage of 01493500 (Morgan Creek near Kennedyville, MD). The flow of each subwatershed was estimated based on the ratio of the subwatershed area to the drainage basin area of the USGS gage. The mean flows used for the model calibration are listed in Table A-2 below for the subwatersheds shown in Figure A-1. A comparison of model results against observations is shown in Figure A-3. It can be seen that the model simulation of salinity distribution is satisfactory in the estuary.

Since the water quality criterion for bacteria applicable in this watershed is expressed in terms of the geometric mean concentration, the modeling task is to estimate daily bacteria loading corresponding to the geometric mean concentration. For a relatively small waterbody, the tidal prism model has been used to estimate the loads based on the observations and water quality standards using the inverse method (or back calculation) (MDE 2005). For this study, an inverse modeling approach method built on the EFDC has been used to estimate bacteria loading from the watershed. The purpose of the inverse modeling is to estimate the long-term average daily loads corresponding to the geometric mean concentrations in the waterbody. Therefore, the bacteria daily loads from each subwatershed can be considered as constant model parameters. The inverse methods have been used for many environmental problems to estimate point source loads and model parameters (Sun and Yeh 1990; Shen 2006; Sisson et al, 2008).

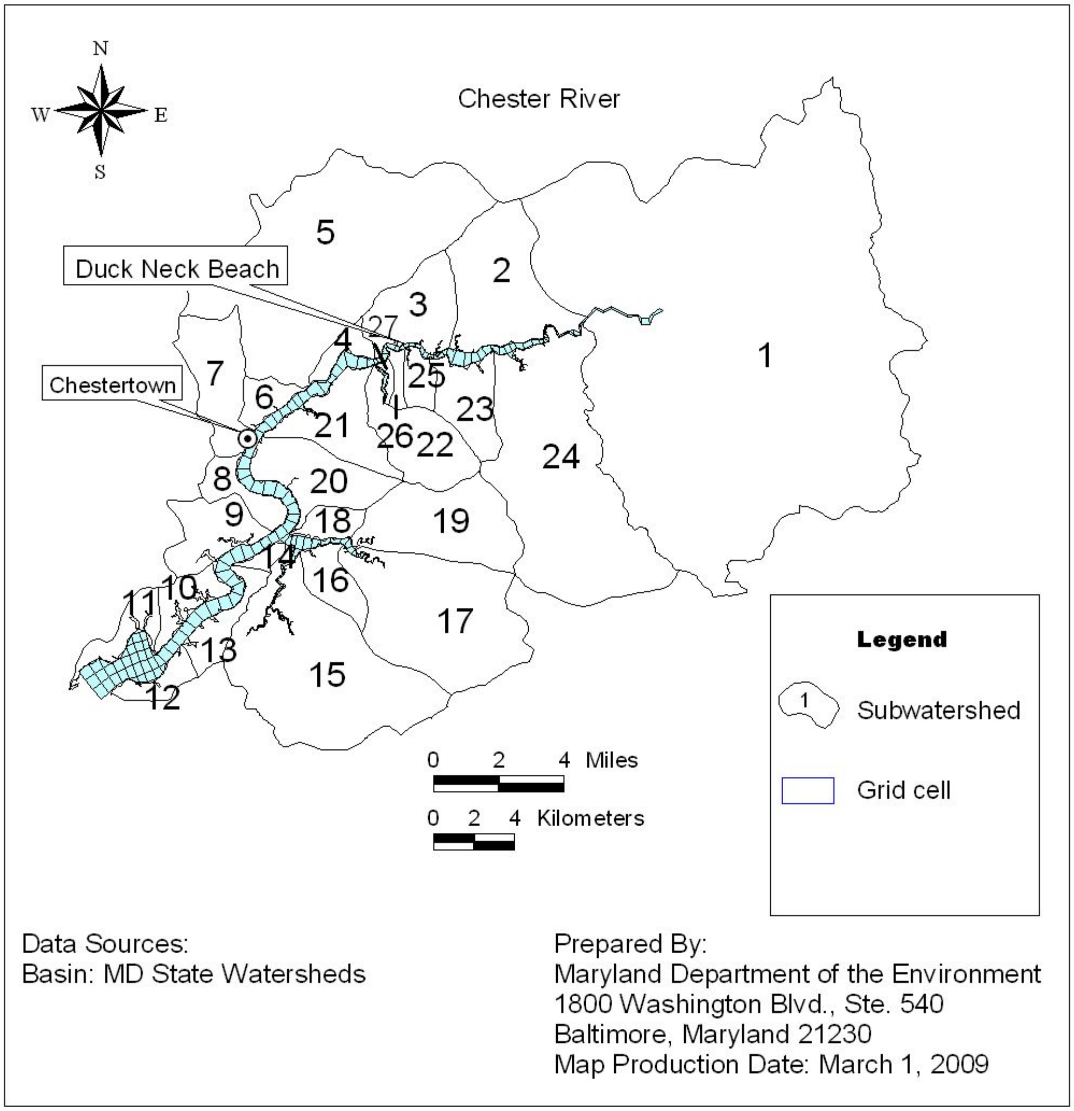


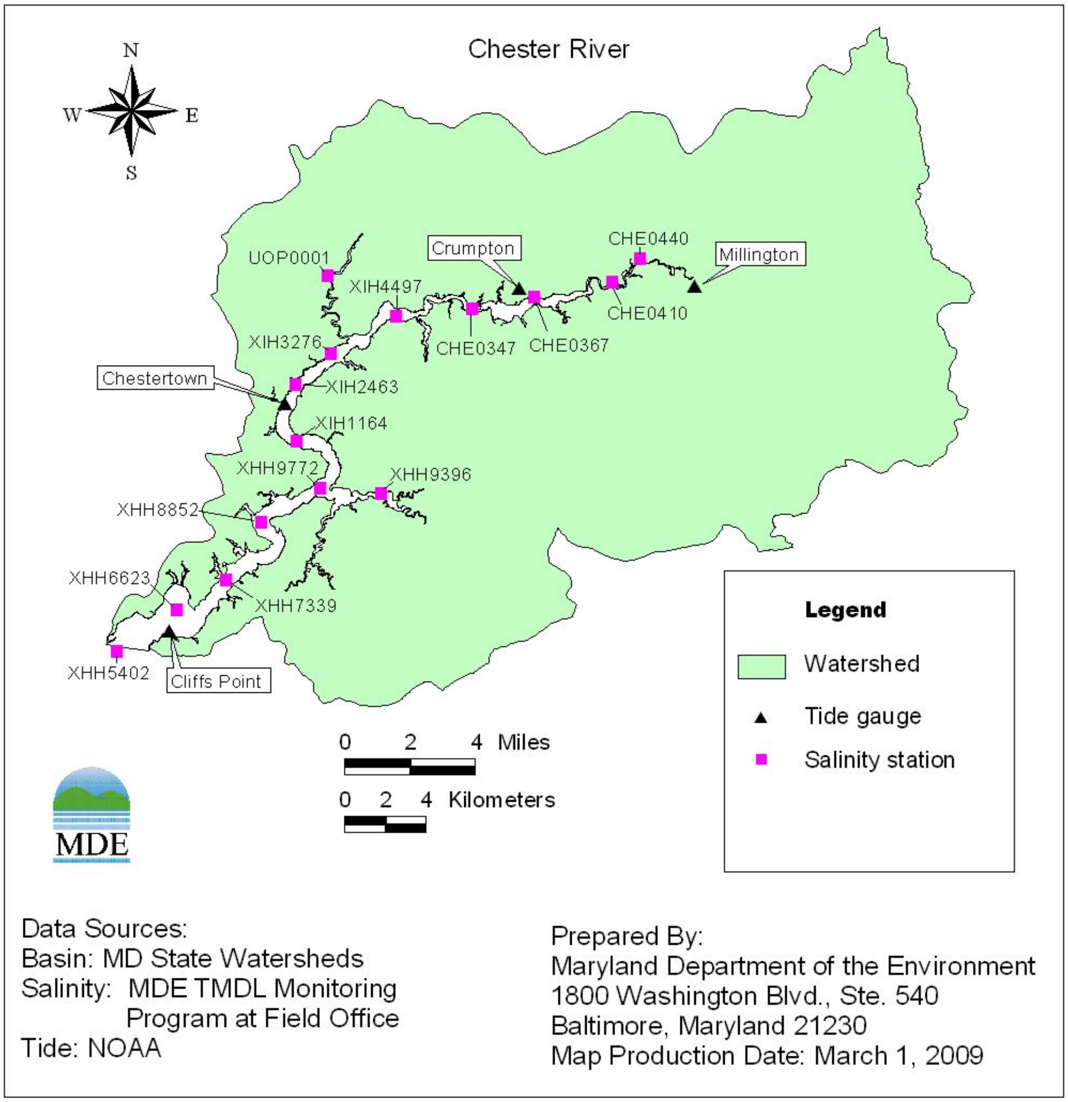
Figure A-1: Model Grid Cells and Subwatersheds in the Chester River

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

Station	Modeled Range (m)	NOAA Predicted Range (m)
Cliffs Point	0.466	0.457
Chestertown	0.567	0.548
Crumpton	0.661	0.732
Millington	0.617	0.610

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

Subwatershed	Mean Flow (cms)
1	2.887
2	0.285
3	0.150
4	0.035
5	0.855
6	0.044
7	0.161
8	0.062
9	0.115
10	0.059
11	0.061
12	0.044
13	0.065
14	0.015
15	0.547
16	0.071
17	0.431
18	0.041
19	0.253
20	0.158
21	0.146
22	0.159
23, 25-27	0.178
24	0.685



Data Sources:
Basin: MD State Watersheds
Salinity: MDE TMDL Monitoring Program at Field Office
Tide: NOAA

Prepared By:
Maryland Department of the Environment
1800 Washington Blvd., Ste. 540
Baltimore, Maryland 21230
Map Production Date: March 1, 2009

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

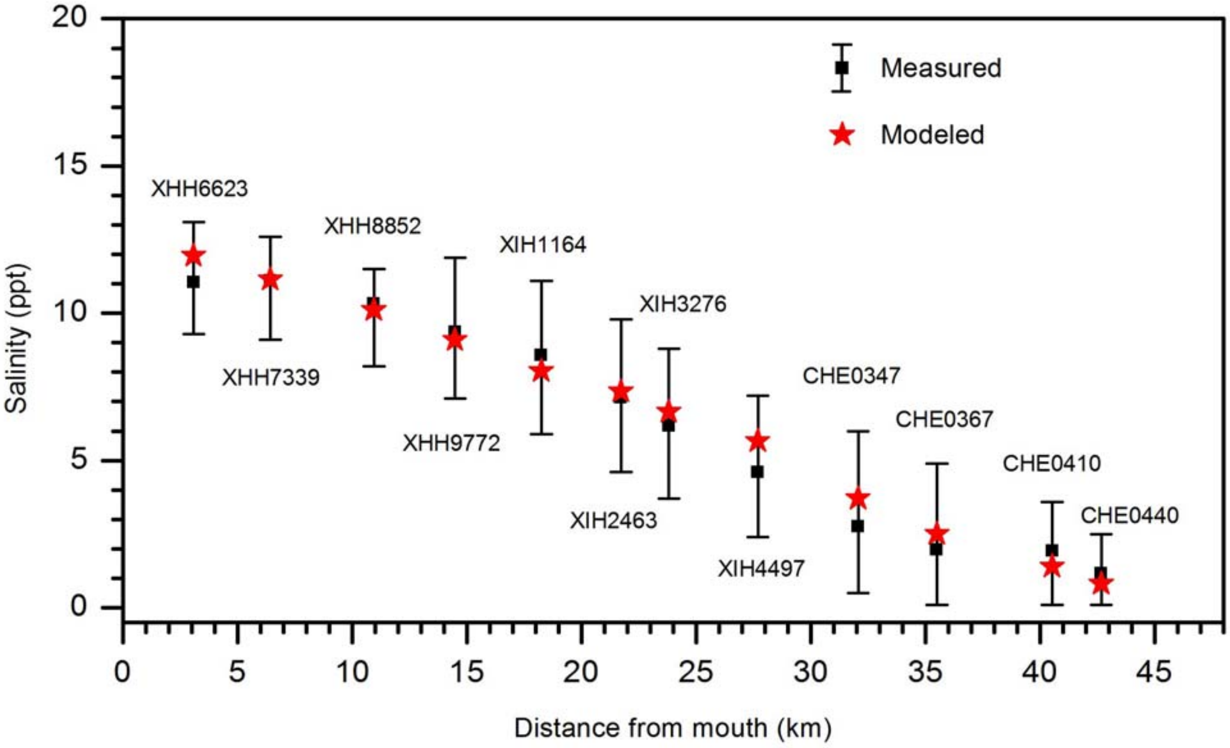


Figure A-3: Comparison of Measured and Calculated Salinities

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

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

subject to:

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

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

where $\boldsymbol{J}$ is a goal or cost function; $\boldsymbol{\beta}^* = (\beta_1, \beta_2, ..., \beta_m)$ is the optimal parameter (*i.e.*, loads); $\boldsymbol{\beta}_0$ is an acceptable set of loads. **F** is transport function. Different methods can be used to characterize the noninferior solutions. Choosing a weighted least-square criterion to measure the data misfit, the scalar cost function is then defined as follows:

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

where C and C^0 are modeled and measured bacteria concentration in the river, Ω is the spatial domain in the x- and z- directions, T_N is time later than the last date when the prototype observations are available, and w is the weight. In our case, let $C_m(x)$ be the geometric mean obtained from the observations at location (x). If we choose:

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

where $\overline{C}(x,t)$ is the vertical mean bacteria concentration. Equation (4) can be written as:

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

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

The bacteria loads discharged to the river originate from 27 subwatersheds, as shown in Figure A-1. There is only one routine station located near Duck Neck Beach, which is not sufficient for the modeling. In order to conduct model calibration, Queen Anne's County Health Department conducted an additional survey in Summer 2008 (June to August) at stations located upstream, downstream, and on the tributary draining the area near the beach. The observation stations are shown in Figure A-4 and the statistics are listed in Table A-3. The geometric mean concentration indicates that the highest bacteria concentration is observed at Station QAChesterDuckI, which is located in a small tributary next to Duck Neck Beach. The concentrations at both upstream and downstream are lower than the concentration at Duck Neck Beach. It suggests that the bacteria sources discharged from the tributary near the beach have a significant impact on the elevated bacteria concentration of the beach. Because both bacteria discharged into the river from upstream and downstream watersheds can affect this region due to tidal induced transport, an appropriate way to estimate background loading from the upstream and downstream is needed for model simulation. During September to December 2005, a short-term bi-weekly monitoring of fecal coliform was conducted and steady-state geometric mean concentration can be estimated at stations listed as short-time survey stations along Chester River in Figure A-4. Using a correlation established between fecal coliform and enterococci concentration (see section: Point Source Assessment), a corresponding geometric mean concentration of enterococci can be estimated at these stations. Incorporating these short-term measures, a completed bacteria distribution along the river can be obtained. Although this approach may deviate from the true values, the estimated results can be expected to be within the same range since the geometric mean represents a steady-state condition, which are suitable for the model calibration. Because two bacteria measurement stations were located at the upstream and downstream boundaries of the beach, the fluxes into and out of the waters at the beach are more accurately estimated with the inclusion of these two stations. Therefore, the loading in the drainage area of the beach can be estimated correctly. The data obtained from 2008 were used as the model calibration to estimate the corresponding loadings. The model was forced by six tidal constituents and mean salinity at the mouth. The mean freshwater inflows from the subwatersheds are discharged into the river. A set of initial loads from 27 subwatersheds was estimated and discharged to the river. The initial loads are estimated based on the land use types and drainage area sizes. The model was run for 90 days to reach dynamic equilibrium and the maximum concentration for the last 15 days, which covers spring-neap tidal cycle, was used to calculate the cost function against the observed geometric mean along the river. The modified Newton method was used to update the loads until the cost function is minimal. Figure A-5 shows the model calibration results. The correlation between observed and modeled (R^2) is 0.98. It can be seen that the model results are satisfactory.

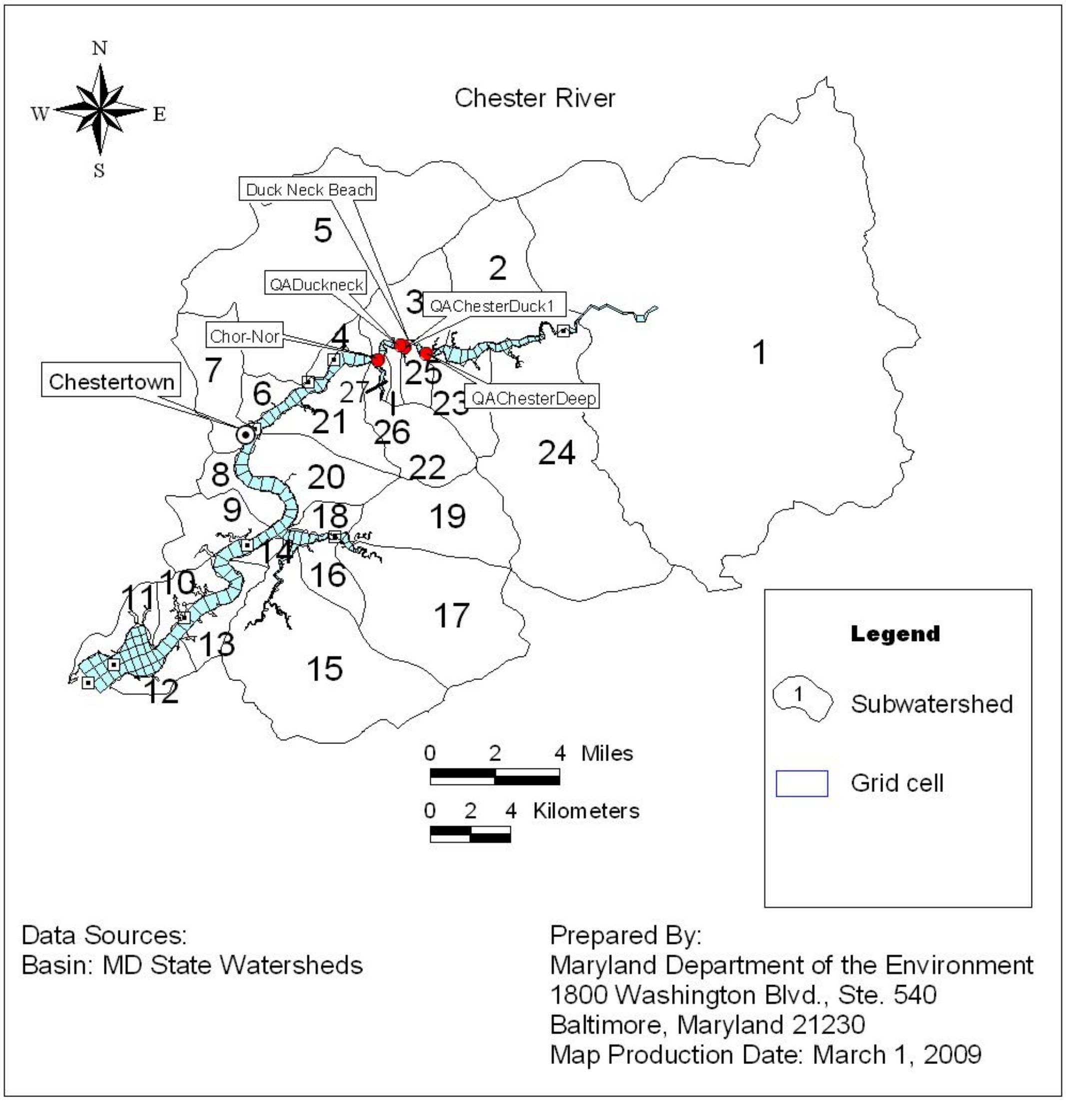


Figure A-4: Locations of the Bacteria Monitoring Stations in Duck Neck Area

The water quality assessment requires analysis of the steady-state geometric mean of previous two to five year period. For Duck Neck Beach, the available steady-state beach season data is from 2005 to 2008. For conservative purposes, the load estimation scenario using the maximum two-year-rolling geometric mean concentration of enteroccoci was chosen for the baseline load, since this scenario will require the greatest reduction to meet water quality criteria. According to Table 2.3.2, the maximum steady-state geometric mean value of enterococci from two-year rolling data is 98.2 MPN/100ml, for the period from 2006 to 2007. Therefore, the baseline load (current load) for Duck Neck Beach was estimated based on the maximum concentration of 98.2 MPN/100ml. In order to estimate the baseline load corresponding to this 2-year high bacteria concentration, the loading obtained from the model calibration from the watersheds adjacent to the beach was increased in proportionally and the model rerun until the concentration at the

QADuckneck station matched the concentration of 98.2 MPN/100 ml. The estimated loading is listed in Table A-4. As the downstream watersheds have very limited impact on the beach, only subwatersheds adjacent to the beach and areas upstream are listed in Table A-4.

The headwaters of the Chester River are located in Delaware. To evaluate the contribution of bacteria loading to the downstream watershed, a model sensitivity analysis was conducted by discharging bacteria with a high concentration of 3000 MPN/100ml at the headwaters (sub-watershed 1). The normalized bacteria concentration along the river is shown in Figure A-7. The bacteria concentration reduces by more than three orders of magnitude and the concentration is less than 1 MPN/100ml at the beach. This suggests that most of the bacteria are lost during the transport due to decay resulting in less contribution to the waters of the beach. Therefore, no bacteria loads from the headwater portion of Chester River are considered for the TMDL calculation.

Similar model sensitivity analyses were conducted to identify the downstream watersheds which have potential impacts to the beach's waters. The subwatersheds whose loads have no influence to the waters of the beach are not considered in the TMDL calculation.

For the TMDL calculation, the baseline loads from the watershed adjacent to the beach and the watershed upstream were reduced so that the model simulated bacteria concentrations at the beach meet the geometric mean concentration of water quality standard. The resultant loads are the allowable loads for the river. With the use of baseline loads and TMDLs, the percentage reduction can be estimated for each subwatershed. The baseline and allowable loads are listed in Table A-5. Because upstream subwatersheds 1, 2, and 24 have no direct impact on the waters of Duck Neck Beach, the final TMDL calculation excluded loads from these watersheds.

Table A-3: Duck Neck Monitoring Station Statistics (2008 Summer Data)

Station Name	**Geometric Mean**	
	Monitoring Data (MPN/100ml)	**Criterion (cfu/100ml)**
QAChesterChor	29.0	35
QADuckneck	52.1	35
QAChesterDuckI	157.3	35
QAChesterDeep	30.2	35

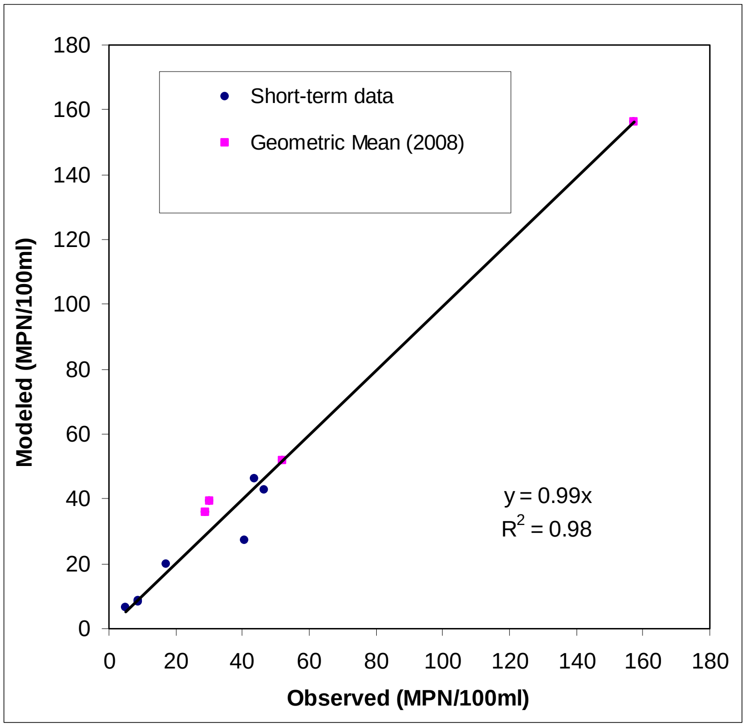


Figure A-5: Comparison of Measured and Modeled Bacteria Concentrations (Note: measurement data shown includes both long-term and short-term)

Table A-4: TMDL Calculation Results for Each Subwatershed

Subwatershed	**Geometric Mean**		
	Allowable Load*	**Current Load**	**Percent Reduction**
	Counts/day	**Counts/day**	
25,26,27	7.533E+11	2.95498E+12	74.51%
3,23	4.254E+11	4.25404E+11	0.00%
22,21,4,5	3.570E+12	6.17336E+12	42.15%
1,2,24	2.704E+12	2.70166E+12	0.00%
Total	7.452E+12	1.226E+13	39.20%

Table A-5: Load Allocation and Reduction by Subwatershed

Subwatershed	Geometric Mean		
	Allowable Load*	Current Load	Percent Reduction
	Counts/day	Counts/day	
25,26,27	7.533E+11	2.95498E+12	74.51%
3,23	4.254E+11	4.25404E+11	0.00%
22,21,4,5	3.570E+12	6.17336E+12	42.15%
Total	4.750E+12	9.554E+12	50.28%

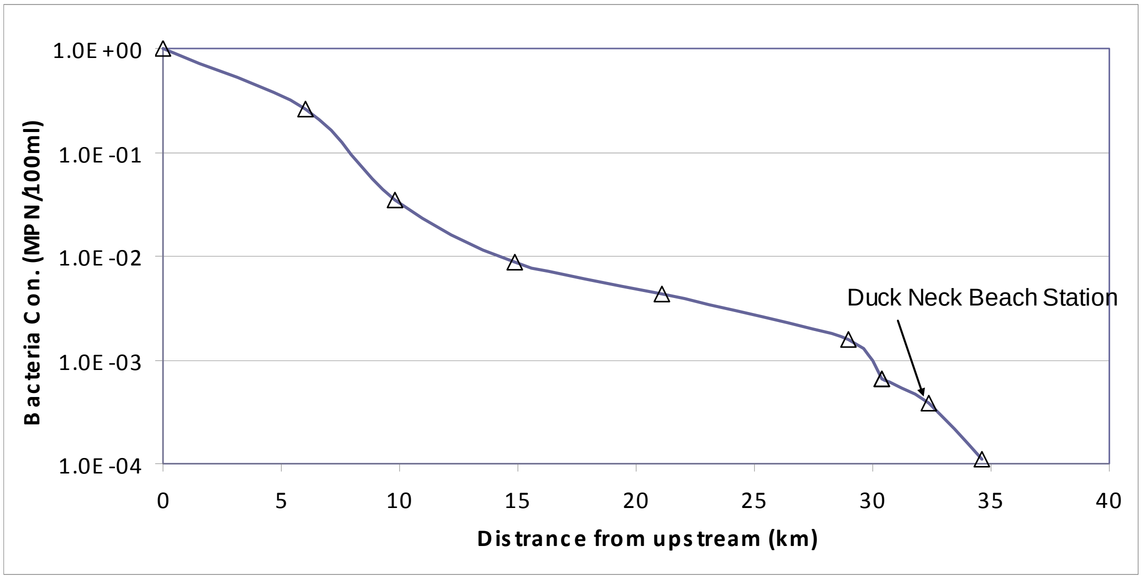


Figure A-6: Fecal Coliform Concentrations along Chester River

Appendix B. Pollution Source Shoreline Survey: Duck Neck Beach, Queen Anne's County

Pollution Source Shoreline Survey

Duck Neck Beach

Queen Anne's County, Maryland

June 2009

Maryland Department of the Environment
Science Services Administration
Beaches Program

INTRODUCTION

Duck Neck Beach is currently listed as impaired on Maryland's Integrated Report of Surface Water Quality due to elevated bacteria levels in the waters of the beach. The Maryland Department of the Environment (MDE) conducted a pollution source survey of the Duck Neck Beach area in order to better identify potential sources of bacterial contamination that may be impacting the water quality of the Duck Neck Beach area.

Figure B-1 – Duck Neck Beach Area

Figure B-2- Duck Neck Beach (aerial)

SITE DESCRIPTION

Duck Neck Beach (**Figure B-1**) is a small beach in Queen Anne's County located along the Kent/Queen Anne's Counties border on the southern bank of the Chester River. This portion of the Chester River is considered tidal and brackish, and is located approximately 8 kilometers northeast and upstream of Chestertown, MD (**Figure B-2**). Soils in this area are sandy.

Duck Neck Beach is approximately 22 meters in length and is surrounded by Duck Neck Campground, a location for summer visitors who dwell in trailers. The campground sewer system consists of a holding tank and group septic systems that are routinely pumped.

The surrounding watershed consists of marsh, forest, agriculture and some residential areas.

Water quality samples are collected at Duck Neck Beach because Queen Anne's County Health Department has designated this area as a beach. Below are the yearly geometric mean averages of the most probably number (MPN) representing Enterococci bacteria concentrations for water samples collected from this beach from 2005 through 2008. Only steady-state data was included in the analysis. Steady-state is defined as the absence of more than 1 inch of precipitation in a 24 hour period for 48 hours.

Table B-1: Yearly Geometric Mean Averages of the Most Probably Number (MPN) of Enterococci

Year	Geometric mean (MPN)
2005	19
2006	121
2007	83
2008	52

POLLUTION SOURCE SHORELINE SURVEY

A pollution source shoreline survey is a tool historically used by MDE's Beaches and Shellfish Program to identify potential sources of bacterial contamination affecting beach water and shellfish harvesting areas with a focus on inspecting residential shoreline homes for septic systems violations. The technology-based data collection system utilizes Global Positioning System (GPS) and Geographic Information System (GIS) technologies.

Field Survey

Queen Anne's County Environmental Health Department personnel were contacted in an effort to obtain local "hands-on" knowledge of the potential sources of bacteria contamination. Queen Anne's County Environmental Health Department provided field personnel and local knowledge of the surrounding area.

The Pollution Source Survey is an obvious tool for identifying sources of contamination associated with impaired beaches. This technology-based data collection system facilitates the collection of detailed geo-referenced information, as well as, improved data management and analysis. In addition, the system also improves data sharing between the agencies responsible for the water quality of beaches.

The technology-based data collection system utilizes Global Positioning System (GPS) and Geographic Information System (GIS) technologies. The prototype system developed for the Beaches Program enables field personnel to document and geo-reference any observed potential pollution source that may impact beaches. The hardware component of the system consists of a tablet laptop computer and hand held GPS. The prototype database and data entry form was developed using MS ACCESS. The database was pre-populated with MD PropertyView 2004.

In April and May 2009, MDE personnel surveyed properties within the watershed thought to have an impact on the water quality of the Duck Neck Beach area. Information collected included but was not limited to: latitude/longitude, wastewater system type and problems, and type and number of animals on site.

Potential Bacteria Sources

Duck Neck Campground

The capacity of Duck Neck Campground is 355 sites. However, on holiday weekends during the summer, there are usually up to approximately 100 visitors. During the time of the survey, only five campground sites lining the shore were occupied. Field staff inspected all campground sites along the shoreline for evidence of leaking sewage. No evidence was found, although a discharge pipe was identified at the southeast part of the campground over the creek east of the campground (**Figures B-3 and B-4**). Field personnel will notify Queen Anne’s County Health Department to alert them of this pipe. Because of the distance between this discharge pipe and the beach, water quality at Duck Neck Beach would likely not be impacted by a discharge from the pipe.

Because of the transient nature of this community and the frequency of their sewage hook up activities (at least yearly), the chance of a mistake occurring with sewage capture seems more likely than with permanent systems. MDE will recommend that Queen Anne’s County Health Department work closely with the Duck Neck Campground management to monitor the sewage containment at the campground.

Figure B-3 - Discharge pipe along creek

Figure B-4 - Location of discharge pipe

Residential Homes

A search for leaking septic systems (located in the front yards in the community southwest of Duck Neck) was conducted along the Chester River. No leaking septic systems were identified in this community. Also, MDE field personnel tried to conduct a sanitary survey of homes located on Hickory Lane east of the Duck Neck Campground. All of these properties were marked with "No Trespassing" signs except one, which also served as a sheep farm and will be discussed in the Agriculture section below.

Agriculture

There were several agricultural operations around Duck Neck Beach.

A sheep farm and residence was located approximately 1 kilometer southeast of Duck Neck Beach. The farm had 24 sheep and considering the amount of surrounding vegetation and distance from the Chester River, it is not considered to have a direct impact on the water quality at Duck Neck Beach.

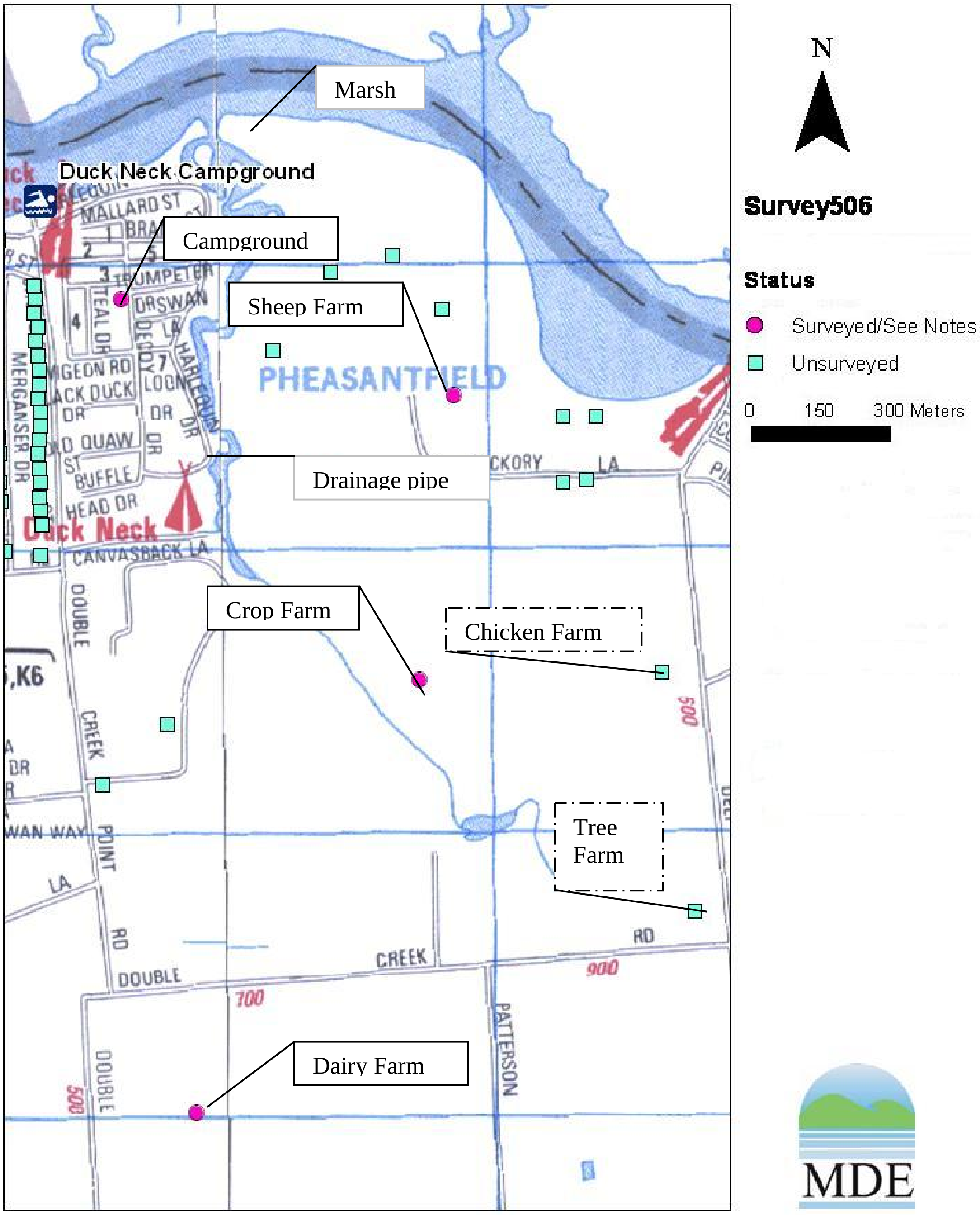
South of the sheep farm was a crop farm approximately 1.5 kilometers south of Duck Neck Beach. This farm surrounded a tributary leading to Duck Neck Beach. The owner of this farm did not allow staff to come onto the farm but based on aerial maps it appears that the vegetative buffer zone surrounding the tributary ranges from 13 meters to 33 meters. After contacting the MDE Solid Waste and Sewage Sludge Permits Section, Beaches Program staff learned that this farm does not have a permit to apply sludge at this farm. The closest farm that applies sludge is approximately 5 to 6 miles southeast of Duck Neck Campground.

Further south, approximately 2 kilometers south of Duck Neck Beach, was a dairy and crop farm. On site were 440 head of cattle including calves. Cattle were kept 600 meters from the closest portion (head) of the tributary leading to the Chester River. Manure was recycled by using a separating system and a lagoon. Manure was flushed down the center of the milking barn and separated. Solids were then trucked to other farms or mixed with sand and recycled as bedding for the dairy cows. Liquids were pumped to a lagoon and then pumped back to the milking barn to flush manure out (twice per day). Because of this closed system, manure is not allowed to reach surface water so it is not believed that operations at this farm have affected water quality at Duck Neck.

To the east of the crop farm was a chicken farm that looked like it was not being actively used. There were several "No Trespassing" signs posted on this property so it was not surveyed. However it is not believed that this farm would be a source of pollution since it is not in use.

To the southeast of the crop farm was a tree farm. It is not likely that this farm would be a source of fecal pollution although it may contribute to sediment in the tributary.

Duck Neck Campground Sanitary Survey - June 2009



Wildlife

During a site visit on July 22, 2008, approximately 40 Canada Geese were sighted at the beach area (**Figure B-5**). If these birds are residents, their fecal waste may contribute to elevated bacteria concentrations especially during heavy storm events.

Duck Neck Beach is immediately downstream of a marsh which is home to various types of wildlife and waterfowl. It is likely that this marsh is a source of and reservoir for re-growth of indicator bacteria.

Figure B-5 - Canada geese at Duck Neck Beach

DISCUSSION

Using the Pollution Source Survey, MDE personnel identified potential sources of bacteria that may impact the water quality of the beach area. These sources included a marsh area that is home to various species of wildlife. Although staff did not find any issues with the sewage systems on the individual trailers at the campground, MDE will recommend that Queen Anne's County Health Department address the drainage pipe at the tributary leading to the Chester River, and that they work closely with Duck Neck Campground staff to ensure that sewage systems are connected properly. It is believed that the adjacent marsh area is a source of and reservoir for re-growth of indicator bacteria, and that this may be affecting water quality at Duck Neck Beach.

Appendix C. Tabulation of Enterococci Data

This appendix provides a tabulation of Enterococci bacteria values (included all duplicates) for the monitoring station near Duck Neck Beach in the Upper Chester River in Table C-1. These data are plotted in Figure 2.2.2 of the main report.

Table C-1: Observed Bacteria Data at Duck Neck Station QADUCKNECK (MPN/100ml)

Date	Bacteria	Date	Bacteria	Date	Bacteria	Date	Bacteria
5/28/2008	20	5/30/2007	100	5/31/2006	20	6/1/2005	1
5/28/2008	10	5/30/2007	160	5/31/2006	20	6/1/2005	1
5/28/2008	10	5/30/2007	140	5/31/2006	30	6/1/2005	1
6/4/2008	160	6/13/2007	1450	6/7/2006	120	6/15/2005	30
6/4/2008	90	6/13/2007	780	6/7/2006	190	6/15/2005	30
6/4/2008	180	6/13/2007	860	6/7/2006	210	6/15/2005	20
6/11/2008	100	6/20/2007	120	6/14/2006	60	6/22/2005	620
6/11/2008	40	6/20/2007	90	6/14/2006	80	6/22/2005	290
6/11/2008	140	6/20/2007	100	6/14/2006	100	6/22/2005	360
6/18/2008	20	6/27/2007	450	7/5/2006	780	6/29/2005	120
6/18/2008	40	6/27/2007	340	7/5/2006	1090	6/29/2005	90
6/18/2008	50	6/27/2007	220	7/5/2006	1180	6/29/2005	60
6/25/2008	1	7/11/2007	50	7/12/2006	660	7/13/2005	20
6/25/2008	10	7/11/2007	10	7/12/2006	660	7/13/2005	20
6/25/2008	10	7/11/2007	50	7/12/2006	890	7/13/2005	10
7/2/2008	310	7/18/2007	80	7/19/2006	10	7/20/2005	40
7/2/2008	140	7/18/2007	20	7/19/2006	20	7/20/2005	20
7/2/2008	60	7/18/2007	40	7/19/2006	20	7/20/2005	40
7/9/2008	50	7/25/2007	30	7/26/2006	190	7/27/2005	20
7/9/2008	60	7/25/2007	20	7/26/2006	240	7/27/2005	1
7/9/2008	20	7/25/2007	40	7/26/2006	290	7/27/2005	1
7/16/2008	100	8/1/2007	50	8/2/2006	20	8/3/2005	20
7/16/2008	90	8/1/2007	10	8/2/2006	30	8/3/2005	10
7/16/2008	50	8/1/2007	60	8/2/2006	30	8/3/2005	30
7/23/2008	20	8/8/2007	50	8/23/2006	160	8/10/2005	10
7/23/2008	20	8/8/2007	40	8/23/2006	240	8/10/2005	1
7/23/2008	10	8/8/2007	10	8/23/2006	290	8/10/2005	1
7/30/2008	90	8/15/2007	90	8/30/2006	90	8/24/2005	60
7/30/2008	60	8/15/2007	50	8/30/2006	140	8/24/2005	20

7/30/2008	60	8/15/2007	60	8/30/2006	190	8/24/2005	30
8/6/2008	80	8/22/2007	250			8/31/2005	60
8/6/2008	60	8/22/2007	120			8/31/2005	100
8/6/2008	40	8/22/2007	190			8/31/2005	100
8/13/2008	150	8/29/2007	120				
8/13/2008	140	8/29/2007	40				
8/13/2008	110	8/29/2007	80				
8/20/2008	110						
8/20/2008	90						
8/20/2008	110						
8/27/2008	120						
8/27/2008	100						
8/27/2008	210						