Total Maximum Daily Load for Fecal Coliform for Oyster Creek in North Carolina

[Waterbody ID 29-49-3a]

Final TMDL Report
(EPA Approved, May 2011)

Tar-Pamlico River Basin

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List of Abbreviations

AFM	Average Frequency of Misclassification
ARA	Antibiotic Resistance Analysis
ARCC	Average Rate of Correct Classification
ARP	Antibiotic Resistance Patterns
BMP	Best Management Practice
CC	Correct Classification
CFR	Code of Federal Regulations
CWA	Clean Water Act
DWQ	Division of Water Quality
EPA	Environmental Protection Agency
FA	Future Allocation
GIS	Geographic Information System
HQW	High Quality Waters
HS-HF183	Human Specific *Bacteroides*- HF183 Marker
km	Kilometer
LA	Load Allocation
m	Meter
M_2	Lunar semi-diurnal tidal constituent
ml	Milliliter(s)
MDP	Minimum Detectable Percentage
MOS	Margin of Safety
MPN	Most Probable Number
MST	Microbial Source Tracking
MRLC	Multi-Resolution Land Cover
NCDEH	North Carolina Division of Environmental Health
NOAA	National Oceanic and Atmospheric Administration
NCAC	North Carolina Administration Code
NCDENR	North Carolina Department of Environment and Natural Resources
NCSU	North Carolina State University
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NSSP	National Shellfish Sanitation Program
OBs	Optical Brighteners
Rep-PCR	Repetitive element Polymerase Chain Reaction
ROW	Right of way
SSO	Sanitary Sewer Overflows
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
WQLS	Water Quality Limited Segment

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Summary Sheet

Total Maximum Daily Load (TMDL)

1. 303(d) Listed Waterbody Information

State: North Carolina
County: Hyde
Major River Basin: Tar-Pamlico River Basin
Watershed: Oyster Creek
Impaired Waterbody (2006 303(d) List):

Waterbody Name-(ID)	Description	Water Quality Classification	Acres
Oyster Creek-(29-49-3a)	From source to a line 990 meters east of Swanquarter Bay	SA ORW	35.3

Constituent(s) of Concern: Fecal Coliform Bacteria
Designated Uses: Shellfish Harvesting
Applicable Tidal Salt Water Quality Standards for Class SA Waters:

> *"Organisms of coliform group: fecal coliform group not to exceed a median MF of 14/100 ml and not more than 10 percent of the samples shall exceed an MF count of 43/100 ml in those areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions."*

2. TMDL Development

Development Tools (Analysis/Modeling):
The finite difference transport model and Bayesian approach were combined to develop the fecal coliform TMDL for the restricted shellfish harvesting area of Oyster Creek. The one-dimensional finite difference transport model was used to simulate the bacteria in the embayment. The nonpoint source loads (both existing and maximum allowable loads), together with their uncertainties, were estimated by the Bayesian statistical method. As the sampling strategy of fecal coliform covered rainfall events and normal condition over a 5-year period, and both median and 90th percentile of the 5-year observations are used to compute the loadings by the model, the model results account for the seasonal variability and critical conditions, which thereby represents the hydrology, hydrodynamics, and water quality condition of the restricted shellfish harvesting area.

Critical Conditions:
The 90th percentile concentration is the concentration exceeded only 10% of the time, which represents the occurrence of high fecal coliform in the waterbody, partially during rainfall events. Since current loading to the waterbody was determined using the 90th percentile concentration

together with a long-term record of flow, the critical condition is implicitly included in the computations of loading corresponding to the 90th percentile of fecal coliform concentration and loading reduction scenario.

Seasonal Variations:
Seasonal variations in hydrology, climatic conditions, and watershed activities are represented through the use of long-term statistics of median and 90th percentile of concentrations to compute the loadings. Given the intensive sampling strategy and the length of the observational period, the seasonal variability is directly included in the model simulation.

3. TMDL Allocation Summary
Model results show that 90th percentile load requires highest reduction. The allocation is established based on 90th percentile load.

Waterbody	Pollutant	Existing	WLA	LA	MOS	Reduction Required	TMDL
Oyster Creek (29-49-3a)	Fecal coliform (counts/day)	3.1×10^{12}	1.6×10^{9}	2.1×10^{11}	2.3×10^{10}	92.6%	2.3×10^{11}

Notes: WLA = wasteload allocation, LA = load allocation, MOS = margin of safety, WLA = TMDL-LA-MOS

4. Contributing Municipalities TMDL Allocation Summary: N/A

5. Contributing NPDES Facilities TMDL Allocation Summary:

Pollutant	NCDOT Existing Permitted Load (cfu/day)	WLA	Reduction
Fecal Coliform (Counts per Day)	N/A	1.6×10^{9}	0.0%

6. Public Notice Information

Summary:	The TMDL was announced on the Modeling and TMDL Unit website and the NC TMDL list-serve on March 14, 2011. The TMDL was also public noticed on April 15, 2011 through the NCWRRI email list-serve. The TMDL was available on DWQ's website during the comment period. The public comment period lasted until April 14, 2011. DWQ received no comments on the TMDL.
Did notification contain specific mention of TMDL Proposal?	***Yes***
Were comments received from the public?	***No***
Was a responsiveness summary prepared?	***N/A***

7. Public Notice Date: March 14, 2011

8. Submittal Date: April 20, 2011

9. EPA Approval Date: May 11, 2011

10. DOT a Significant Contribution (Yes or Blank):

11. Endangered Species (yes or blank):

12. MS4s Contributions to Impairment (Yes or Blank): Yes, NCDOT

14. TMDL Considers Point Source, Nonpoint Source, or both: Both

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.

Oyster Creek is located in the Tar-Pamlico River Basin (NC Subbasin 30308 – HUC 03020105030020) in Hyde County. The Creek is located within the shellfish area designated G3 by the North Carolina Division of Environmental Health (NCDEH). Part of Oyster Creek is considered impaired by fecal coliform on the 2006 North Carolina Integrated Report (NCDENR, 2007). This document addresses the fecal coliform impairment of the restricted shellfish harvesting area of Oyster Creek as listed in the following table.

305(b) ID	Name	Description
29-49-3a	Oyster Creek	From source to a line 990 meters east of Swanquarter Bay

The restricted shellfish harvesting area is impaired by levels of bacteria exceeding North Carolina's water quality standards for fecal coliform, which has resulted in closure of the waterbodies to shellfish harvesting.

Fecal coliform is an indicator organism used in water quality monitoring in shellfish waters to indicate the potential presence of pathogens associated with warm blooded animals. When the water quality standard for fecal coliform in shellfish waters is exceeded, waters are restricted for shellfish harvesting to protect human health risks associated with the consumption of molluscan shellfish from contaminated waters. The water quality goal of this TMDL is to reduce high fecal coliform concentrations to levels whereby the designated uses for the Creek will be met.

A variety of data at the watershed scale, including shoreline sanitary survey data and Geographic Information Systems (GIS) data coverage, were used to identify potential fecal coliform contributions. There are no permitted point source facilities in the restricted shellfish area addressed in this report. Microbial source tracking (MST) was used to identify nonpoint sources. The major contributions of fecal coliform load are nonpoint sources, including wildlife, pets, livestock, etc. The load is allocated to sources (human, livestock, pets, and wildlife).

The combined Bayesian statistical method and finite difference transport modeling approaches was used to estimate fecal coliform load from watersheds and to develop TMDLs. As both median and 90th percentile of the 5-year observations are used for model simulation and the sampling strategy of fecal coliform covered rainfall events, the model results account for the seasonal variability and critical conditions, which thereby represent the hydrology, hydrodynamics, and water quality condition of the restricted shellfish harvesting area. The current loads were estimated using long-term water quality monitoring data, and the allowable loads were computed using both the median water quality standard for shellfish harvesting of 14 Most Probable Number (MPN)/100ml and the 90th percentile standard of 43 MPN/100ml. An explicit Margin of Safety (MOS) of 10% was incorporated into the analysis to account for uncertainty. The TMDLs developed for the restricted shellfish harvesting area of Oyster Creek for fecal coliform load are as follows:

The fecal coliform TMDL = 2.3×10^{11} counts per day

The goal of load allocation is to determine the estimated loads for the drainage area while ensuring that the water quality standard can be attained. For the restricted shellfish harvesting area in Oyster Creek, the 90th percentile criterion requires the greatest reduction. Therefore, the load reduction scenario is developed based on the 90th percentile water quality standard. The load reductions needed to meet the shellfish criteria and the load allocations required to meet the TMDL is 92.6%.

Once the EPA has approved a TMDL, and it is known what measures must be taken to reduce pollution levels, implementation of best management practices (BMPs) is expected to take place. The North Carolina Department of Environment and Natural Resources (NCDENR) intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality, with consideration given to ease of implementation and cost.

1.0 Introduction

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

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

Oyster Creek is located in the Tar-Pamlico River Basin (NC Subbasin 30308 – HUC 03020105030020) in Hyde County. The designated water use is SA water- Shellfish Harvesting. The Creek is located within the shellfish area designated G3 by the North Carolina Division of Environmental Health (NCDEH). Oyster Creek is considered impaired for fecal coliform on the 2006 North Carolina Integrated Report. This report provides an analysis of the monitoring data and proposes to establish TMDLs of fecal coliform for the restricted shellfish harvesting area of Oyster Creek.

Fecal coliform bacteria are found in the intestinal tract of humans and other warm-blooded animals. Few fecal coliform bacteria are pathogenic. However, the presence of elevated levels of fecal coliform in shellfish waters indicates recent sources of pollution. Some common waterborne diseases associated with the consumption of raw clams and oysters harvested from polluted water include viral and bacterial gastroenteritis and hepatitis A. Fecal coliform may occur in surface waters from point and nonpoint sources.

1.1 TMDL Components

The 303(d) process requires that a TMDL be developed for each of the waters appearing in Category 5 of the Surface Water Integrated list. The objective of a TMDL is to estimate allowable pollutant loads and allocate to known sources so that actions may be taken to restore the water to its intended uses (USEPA, 1991). 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 North Carolina's water quality criteria for shellfish waters. Currently, TMDLs are expressed as a "mass per unit time, toxicity, or other appropriate measure" (40 CFR 130.2(i)). It is also important to note that the TMDLs presented herein are not literal daily limits. These loads are based on an averaging period that is defined by the water quality criteria (i.e., 30 samples per station). The averaging period used for development of these TMDLs requires at least 30 samples and uses the most recent 5-year window of data. Generally, the primary components of a

TMDL, as identified by EPA (1991) and the Federal Advisory Committee (USEPA, 1998) are as follows:

Target Identification or selection of pollutant(s) and endpoint(s) for consideration. The pollutant and endpoint are generally associated with measurable water quality related characteristics that indicate compliance with water quality standards. North Carolina indicates known pollutants on the 303(d) list.

Source Assessment. All sources that contribute to the impairment should be identified and loads quantified, where sufficient data exist.

Reduction Target. Estimation or level of pollutant reduction needed to achieve water quality goal. The level of pollution should be characterized for the waterbody, highlighting how current conditions deviate from the target endpoint. Generally, this component is identified through water quality modeling.

Allocation of Pollutant Loads. Allocating pollutant control responsibility to the sources of impairment. The wasteload allocation portion of the TMDL accounts for the loads associated with existing and future point sources. Similarly, the load allocation portion of the TMDL accounts for the loads associated with existing and future nonpoint sources, stormwater, and natural background.

Margin of Safety. The margin of safety addresses uncertainties associated with pollutant loads, modeling techniques, and data collection. Per EPA (2000), the margin of safety may be expressed explicitly as unallocated assimilative capacity or implicitly due to conservative assumptions.

Seasonal Variation. The TMDL should consider seasonal variation in the pollutant loads and endpoint. Variability can arise due to stream flows, temperatures, and exceptional events (e.g., droughts, hurricanes).

Critical Conditions. Critical conditions indicate the combination of environmental factors that result in just meeting the water quality criterion and have an acceptably low frequency of occurrence.

Section 303(d) of the CWA and the Water Quality Planning and Management regulation (USEPA, 2000) require EPA to review all TMDLs for approval or disapproval. Once EPA approves a TMDL, then the waterbody may be moved to Category 4t of the Integrated Report. Waterbodies remain in Category 4t until compliance with water quality standards is achieved. Where conditions are not appropriate for the development of a TMDL, management strategies may still result in the restoration of water quality.

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

TMDL = WLAs + LAs + MOS + (FA, where applicable)

1.2 Documentation of Impairment

The North Carolina Division of Water Quality (DWQ) Surface Water and Wetlands classification for the restricted shellfish harvesting area of Oyster Creek is Class SA Waters – Shellfish Harvesting Waters (15A NCAC 02B.0221 Tidal Salt Water Quality Standards for Class SA Waters). All SA waters are also classified as High Quality Waters (HQW). A Class SA water is a waterbody that is suitable for commercial shellfishing and all other tidal saltwater use (NCAC, 2003).

Oyster Creek was first identified on the 2006 North Carolina Integrated Report, as not meeting its designated use. Waters within the SA classification, according to 15A NCAC 02B.0021 (Tidal Salt Water Quality Standards for Class SA Waters), must meet the following water quality standard in order to meet their designated use: **“Organisms of coliform group: fecal coliform group not to exceed a median MF of 14/100 ml and not more than 10 percent of the samples shall exceed an MF count of 43/100 ml in those areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions.”**

For this report, the monitoring data averaging period was based on monitoring procedures for classifying SA water, i.e. fecal coliform concentration cannot exceed a median value of 14 MPN per 100 ml and a 90^{th} percentile of 43 MPN per 100 ml, for six samples per year and 30 samples per station. The averaging period for the monitoring data required at least 30 samples and used all data within the most recent five-year period. The water quality impairment was assessed using the median and 90^{th} percentile concentrations.

1.3 Watershed Description

Oyster Creek is located in Hyde County. Figure 1.3.1 shows the location of Oyster Creek (NC Subbasin 30308 – HUC 03020105030020) and the restricted shellfish harvesting area. The Creek empties into the Swanquarter Bay. The length of the Creek is approximately 1.8 km and the width of the Creek is about 0.7 km near the mouth. The mean depth of the Creek is about 1 m (mean low water). The restricted shellfish harvesting area extends from the source to a line about 990 m east of Swanquarter Bay. The drainage area of the restricted area is 4,767 acres (19.3 km^2). The United States Geological Survey (USGS) soil survey shows that the watershed is dominated by a 0-2 percent slope, rarely flooded Hydeland silt loam, Ponzer muck, Roper muck, and Scuppernong muck. (U. S. Department of Agriculture (USDA), 2006). The dominant tide in this region is the lunar semidiurnal (M2) tide with a mean tidal range of 0.15 m (Lin et al., 2008) with a tidal period of 12.42 hours (National Oceanic and Atmospheric Administration (NOAA), 2010).

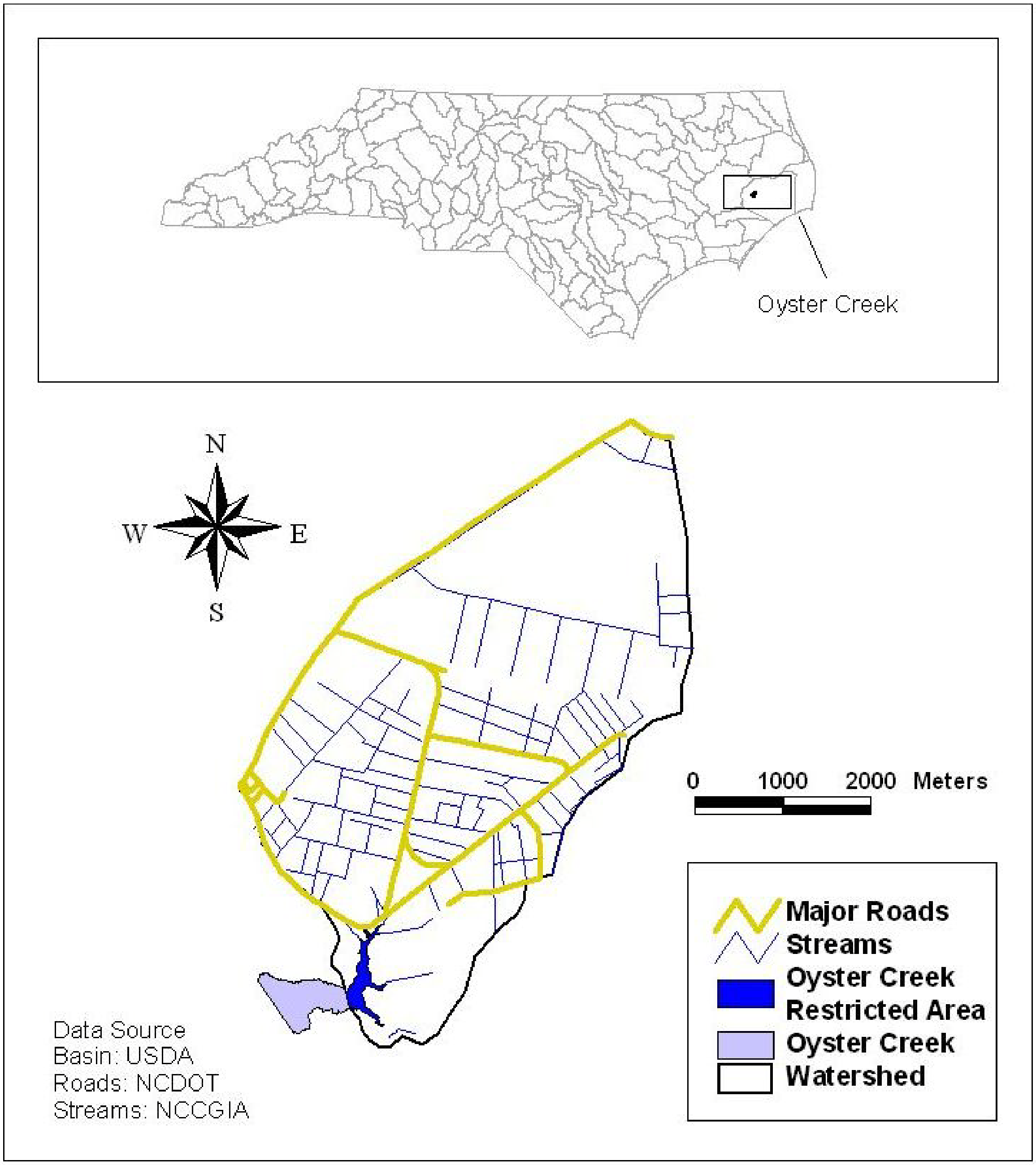

Figure 1.3.1: Location Map of the Oyster Creek Restricted Shellfish Harvesting Area

1.3.1 Land Cover Data

The USGS Multi-Resolution Land Characterization (MRLC) land use/land cover data show that the watershed can be characterized as rural. The land use distribution is shown in Figure 1.3.2 based on National Land Cover Database 2001 (NLCD 2001). Land use statistics are listed in Table 1.3.1, in which the land uses are grouped into five categories: Open Water, Wetland, Forest, Cropland, and Urban. Wetland and Cropland are the dominant land uses in the watershed, which are approximately 44.0% and 40.9%, respectively.

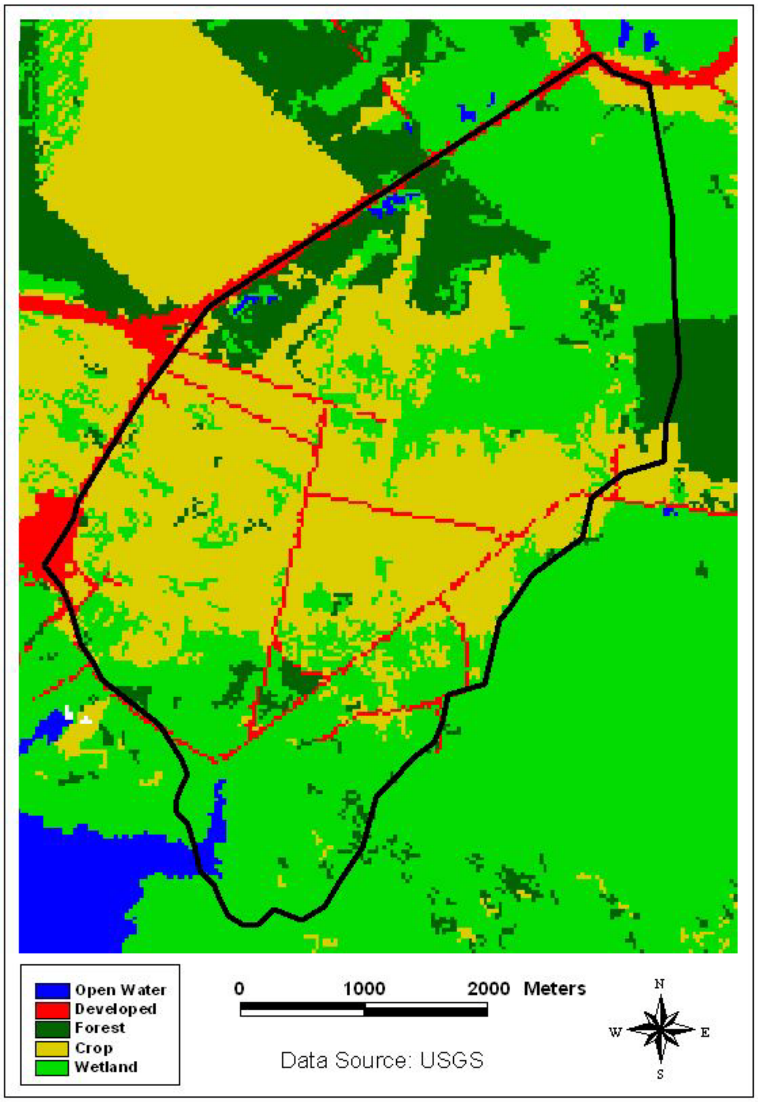

Figure 1.3.2: Land Cover Distributions

Table 1.3.1: A Summary of Landuse Statistics

Category	Area (km^2)	Percentage
Open Water	0.1332	0.7%
Developed	0.8046*	4.1%
Forest	1.9827	10.2%
Cropland	7.9560	40.9%
Wetland	8.5563	44.0%
TOTAL	**19.4328**	**100%**

* Includes 0.153587 km^2 of NCDOT area (0.79% of total).

1.4 Water Quality Characterization

The Shellfish Sanitation and Recreational Water Quality Section of NCDEH is responsible for classifying shellfish harvesting waters to ensure that oysters and clams are safe for human consumption. NCDEH adheres to the requirements of the National Shellfish Sanitation Program (NSSP), with oversight by the U.S. Food and Drug Administration (USDA). NCDEH conducts shoreline surveys and collects routine bacteria water quality samples in the shellfish growing areas of North Carolina. The data are used to determine if the water quality criteria are being met. If the water quality criteria are exceeded, the shellfish areas are restricted to harvest and the designated use is not being achieved.

NCDEH has monitored shellfish growing regions throughout North Carolina for the past few decades. Oyster Creek is sampled using the systematic random sampling strategy as outlined in the NSSP's Model Ordinance and guidance document. Most data were collected at least six times a year. There are 3 fecal coliform monitoring stations inside Oyster Creek. The locations of these stations are shown in Figure 1.4.1. The data collected from these observation stations are used for the water quality assessment for the TMDL study. The time series plots of the observations from 2000 to 2010 are shown in Appendix A. Based on field measurements of the last 30 samples, the fecal coliform concentrations exceed the 90th percentile water quality standard of 43 MPN/100ml at Station 10B (Table 1.4.1).

From November 2008 to January 2010, North Carolina State University (NCSU) took monthly measurements in Oyster Creek for Microbial Source Tracking (MST) analysis. Three of the stations overlap with the NCDEH monitoring stations (10, 10A, and 10B). The stations used in the TMDL loading estimation are shown in Figure 1.4.1. The statistics of these observations are listed in Table 1.4.2. The statistics combining both NCDEH and NCSU observations at Stations 10, 10A, and 10B are listed in Table 1.4.3. The results show that the 90th percentile water quality criterion was exceeded at Stations 10A and 10B.

Table 1.4.1: Summary Statistics of the NCDEH Last 30 Fecal Coliform Observation Data

Station	Median (MPN/100ml)	90th Percentile (MPN/100ml)
10	1.7	6.7
10A	1.9	10.3
10B	7.8	**49.3**

Table 1.4.2: Summary Statistics of the NCSU Fecal Coliform Observation Data

Station	Number of Samples	Median (MPN/100ml)	90th Percentile (MPN/100ml)
10	12	27.8	274.9
10A	12	54.6	588.8
10B	12	77.0	753.5
OC-1A	10	77.9	1536.4
OC-1B	10	86.7	850.1
OC-2	11	100.6	884.1
OC-3	10	116.7	1076.5
OC-4	11	142.4	1346.3
OC-5	10	125.1	899.7
OC-6	10	381.6	3220.8
OC-7	10	126.7	1900.1
OC-8	11	83.2	1289.7
OC-9	10	138.9	881.2
OC-10	10	188.0	2188.7
OC-11	10	128.8	1327.7
OC-12	10	135.6	865.2
OC-13	10	102.5	1086.9
OC-14	6	67.2	540.8
OC-15	8	41.5	544.0
OC-16	8	44.3	325.0
OC-17	9	60.0	1176.2
OC-18	6	52.1	767.2

Table 1.4.3: Summary Statistics of the Combined NCDEH and NCSU Fecal Coliform Observation Data for the Most Recent 5 Years

Station	Number of Samples	Median (MPN/100ml)	90th Percentile (MPN/100ml)
10	43	1.7	34.4
10A	43	2.0	**74.3**
10B	43	13.0	**186.6**

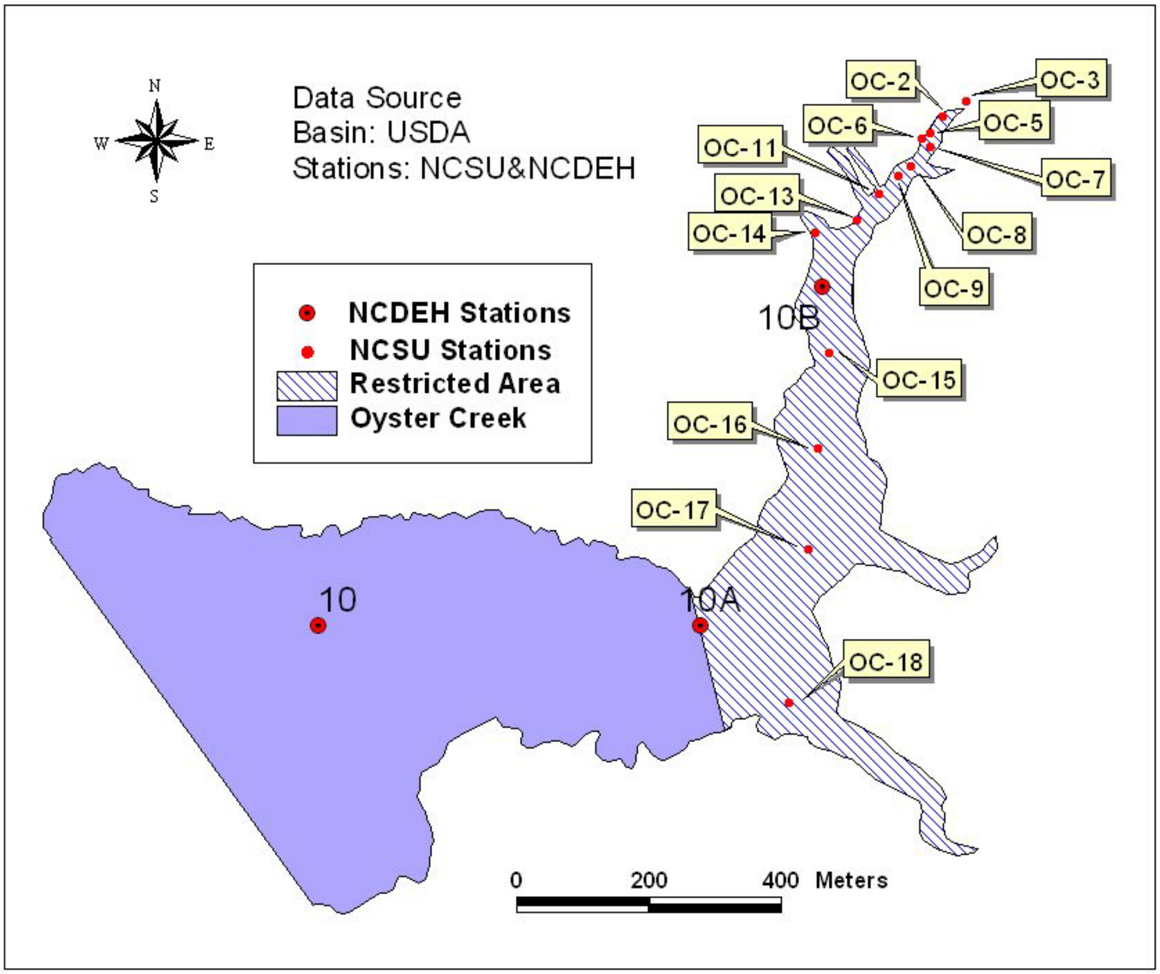

Figure 1.4.1: Locations of Fecal Coliform Monitoring Stations in Oyster Creek

2.0 Source Assessment

2.1 Nonpoint Source Assessment

Nonpoint sources of fecal coliform bacteria do not have one discharge point but occur over the entire length of a stream or waterbody. There are many types of nonpoint sources in watersheds discharging to the restricted shellfish harvesting areas. The possible introductions of fecal coliform bacteria to the nonhuman sources are through the manure spreading process, direct deposition from livestock during the grazing season, and excretions from pets and wildlife. 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 nonhuman fecal coliform directly to the restricted shellfish area occurs when runoff occurs and when livestock or wildlife has 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.

From August 2003 to December 2008, a sanitary survey of the G3 and G4 areas including Oyster Creek was conducted by NCDENR (2009) and five pollution sites were found in the watershed of the restricted shellfish harvesting area of Oyster Creek. Among the five pollution sites, three are animal pollutions and two of them are no longer in operation. The influence of these pollutions sites on the fecal coliform impairment in Oyster Creek is minimal. The details of the survey can be found in Appendix B.

Microbial Source Tracking (MST) technology was used to distinguish the origins of bacteria found in Oyster Creek. The bacteria isolated from different hosts can be discriminated based on differences in the selective pressure of microbial populations found in the gastrointestinal tract of the hosts, i.e., humans, livestock, pets, and wildlife (Wiggins, 1996). Based on the research results of NCSU, the complete distributions of these source loads for the restricted area of Oyster Creek are listed in Table 2.1.1. It can be seen that wildlife is the dominant source of the area. Details of the source estimation can be found in Appendix B.

In brief, a mixture of sources contributing to the observed fecal indicator levels was identified by MST. The wildlife category comprised the dominant source of fecal coliforms at all stations. Wildlife was the source of approximately 67% of the isolates when the data from all stations were combined. Livestock accounted for approximately 9% of bacteria. Human and pets accounted for approximately 12% of the counts. An evaluation of source contributions at stations 10, 10A and 10B revealed a significantly greater human (17.3%), livestock (6.8%) and pet (16.8%) contribution at station 10B than stations 10 and 10A (Tukey-Kramer HSD, $p \leq 0.05$). The wildlife (95.4%) contribution at station 10 was significantly greater than stations 10A (89.6%) and 10B (59.3%). A human contribution was not detected at station 10. When the data were observed collectively, no significant patterns of seasonal variation in host source contributions from livestock and pets were detected (Tukey-Kramer HSD, $p \leq 0.05$). However, the human contribution (14.0%) in August 2009 was significantly greater than the human contribution (3%) in December 2008. There were no statistical differences in the human contributions for the remaining collection times. The wildlife (89.4%) contribution in December 2008, was not statistically different from the wildlife contributions in November 2008, October 2009, and January 2010 (66.8-69%), but was statistically greater than the contributions during the other sampling times (Tukey-Kramer HSD, $p \leq 0.05$).

Table 2.1.1: Distribution of Fecal Coliform Source Loads

Fecal Coliform Source	**Load Counts/Day Median**	**Load Counts/Day 90th Percentile**	**Loading Percentage**
Human	1.80E+10	3.72E+11	12
Livestock	1.30E+10	2.79E+11	9
Pets	1.80E+10	4.03E+11	12
Wildlife	1.01E+11	2.08E+12	67
TOTAL	**1.50E+11**	**3.10E+12**	**100**

2.2 Point Source Assessment

There are no permitted point source facilities discharging fecal coliform directly into the restricted shellfish harvesting area of Oyster Creek. Stormwater has previously been considered a nonpoint source; however, current EPA guidance and policy requires that NPDES-permitted stormwater sources be included in the wasteload allocation (WLA) of the TMDL as opposed to the load allocation (LA). Many of the roadways in the watershed are maintained by the North Carolina Department of Transportation (NCDOT). These NCDOT roads fall under the NCDOT statewide NPDES stormwater permit (NCS000250). NCDOT's contribution to fecal coliform loading in the watershed was tracked separately from other land use types in order to calculate their WLA and load reduction requirements.

3.0 Total Maximum Daily Loads and Load Allocation

This section documents detailed fecal coliform TMDL development and allocations for the restricted shellfish harvesting area of Oyster Creek. In order to simulate the instream transport of fecal coliform and to estimate existing and allowable loads, the method of Shen and Zhao (2009) and VADEQ (2008) was adopted. The restricted area was divided into 11 segments. The watershed of the restricted area was divided into 11 sub-watersheds correspondingly. A one-dimensional finite difference transport model was used to simulate fecal coliform transport in the Creek. The nonpoint source loads were treated as unknown parameters and estimated by the Bayesian approach. The TMDL is presented as counts/day. The following sections present the detailed TMDL development and load allocations for the Oyster Creek restricted area. The first section describes the modeling approach. The second and third sections address the critical conditions and seasonality. The fourth section discusses TMDL loading caps. The fifth section presents the load allocation and the sixth section presents the margin of safety. Finally, the variables of the equation are combined in a summary accounting of the TMDL.

3.1 Modeling Approach

3.1.1 Instream Transport Model

For a coastal basin, the tidal prism model has been applied to develop fecal coliform TMDLs in shellfish growing areas (e.g., NCDENR 2007, 2009). For Oyster Creek, however, as the tidal range is very small (about 0.15 m) and the Creek is narrow, a tidal prism model is not applicable. Therefore, a one-dimensional, tidally-averaged finite difference transport model (Thomann and Mueller, 1987) was applied to simulate the transport of bacteria, and compute the existing loads and TMDLs. Since the long-term median and 90th percentile criteria are used to determine the loads, a steady state modeling approach was used. The restricted shellfish harvesting area of Oyster Creek was divided into 11 segments according to the water quality monitoring station availability and the geometry of the Creek, and the corresponding watershed was divided into 11 subwatersheds as well (Figure 3.1.1). Three branches were delineated as segments based on branch area and data availability. The mass balance equation for fecal coliform can be written as

$$\frac{\partial c}{\partial t} + \frac{1}{A}\frac{\partial (Q\ c)}{\partial x} = \frac{1}{A}\frac{\partial}{\partial x}\left(AE\frac{\partial c}{\partial x} \right) + c_0$$

where x is the distance (m), $\overline{A}$ is the tidally averaged cross-section area (m^2), Q is the tidally averaged net transport due to freshwater discharge and tide (m^3·s^{-1}), c is the tidally averaged concentration of dissolved substance (mass·m^{-3}), E is the dispersion coefficient (m^2·s^{-1}), and c_0 is a source/sink or loading term (mass·s^{-1}). For a segment i in the main stream, the mass balance equation can be written as:

$$V_i \frac{dc_i}{dt} = Q_{i-1}c_{i-1} - Q_i c_i + Q_{ib}C_{ib} + E'_{i-1}(c_{i-1} - c_i) - E'_i(c_i - c_{i+1}) + E'_{ib}(c_{ib} - c_i) - kV_i c_i + L_i = 0$$

and that at Branch *ib* can be written as:

$$V_{ib}\frac{dc_{ib}}{dt} = -Q_{ib}c_{ib} - E'_{ib}(c_{ib} - c_i) - kV_{ib}c_{ib} + L_{ib} = 0$$

where V is the volume, t is the time, Q is the flow, C is the bacteria concentration, k is the bacteria decay coefficient, L is the loading, and E' is the bulk dispersion coefficient across the segment boundary, which is related to the dispersion coefficient E as:

$$E_i^{'} = \frac{E_i A_i}{\Delta x_i}$$

where A_i is the cross-sectional area on the upstream side of segment i and Δx_i is the distance between segments i-1 and i. Detail model description and solution procedures are presented in Appendix F.

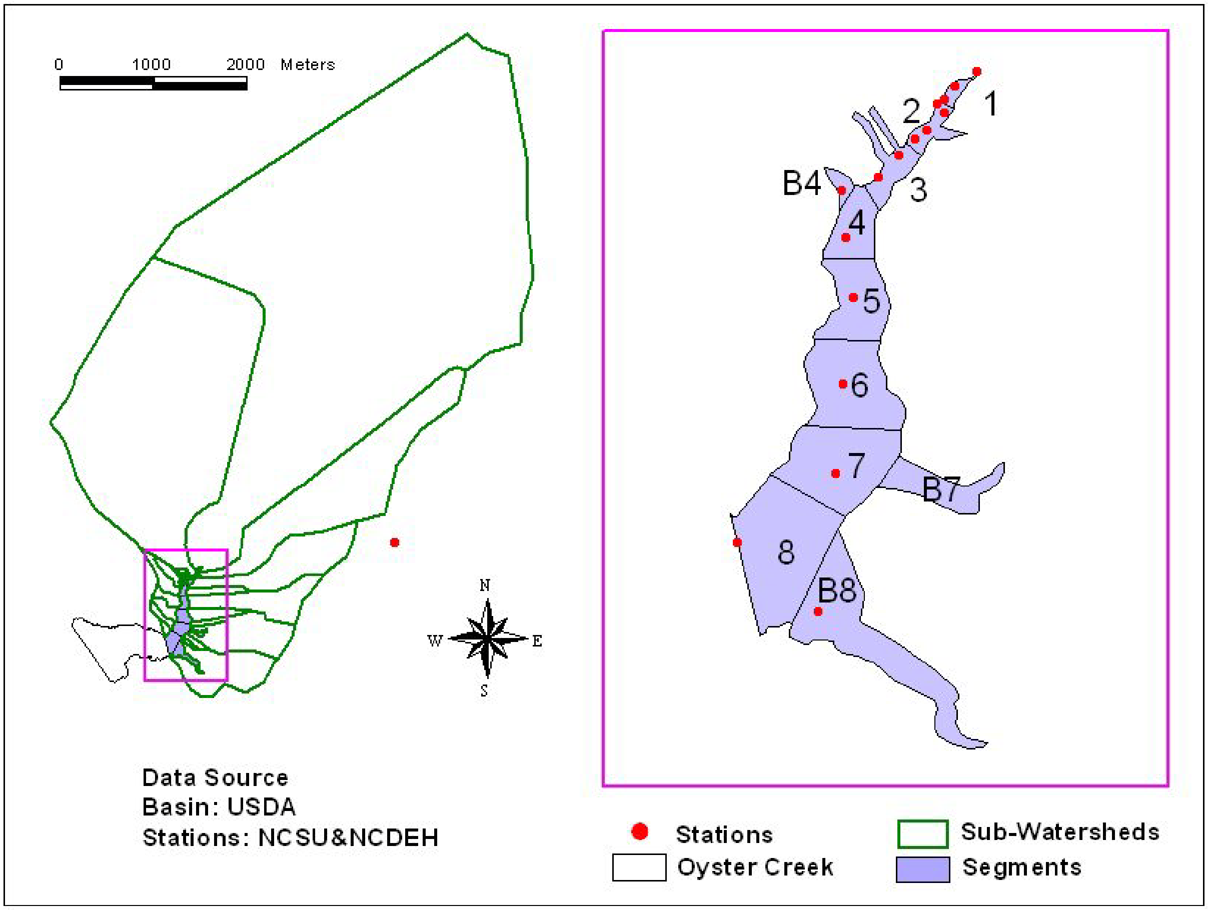

Figure 3.1.1: Segmentation of the Restricted Area and Watershed of Oyster Creek

The magnitude of the dispersion coefficient is a function of tide, geometry, and hydrodynamic conditions. It was estimated using the long term salinity data (from 2000 to 2010) while incorporating a steady state approach (*dc/dt=0*). It was assumed that the dispersion coefficient remained constant throughout the Creek, as the salinity data were only available at Stations 10, 10A, and 10B. A 20 year monthly flow at the adjacent USGS gage station 02084540 (Durham Creek at Edward) were used to estimate the flow by dividing by its drainage area, and then multiplying by the drainage area of each subwatershed of Oyster Creek. The mean and 90th percentile flows were used to compute the loadings corresponding to median and 90th percentile fecal coliform concentrations, respectively. The average concentration of a sampling day for all the stations within each segment was used as the concentration of the segment at that day. Then the median and 90th percentile concentrations were calculated for each segment. According to the monitoring procedures for classifying SA water, the most recent five-year instream fecal coliform concentration data set is ideal to be used in the model simulation. However, these data are only available at Stations 10, 10A, and 10B, while intensive short-term data (from late 2008 to present) are available at all the stations shown in Figure 1.4.1. Therefore, two conversion factors were calculated first by dividing the long-term data statistics (median and 90th percentile, respectively, Table 1.4.3) by the short-term data statistics for Stations 10A and 10B (Table 1.4.2). Then, the long-term statistics for Segments 7 and B8 were calculated by multiplying their short-term statistics by the conversion factor of Station 10A, and those for other segments were calculated by multiplying their short-term statistics by the conversion factor of Station 10B. The original short-term and adjusted long-term fecal coliform concentrations in the 11 segments are shown in Table 3.1.1. 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. Other geometric parameters, such as cross-sectional area, water volume, and distance between adjacent segments, were obtained by GIS data and some are shown in Appendix C.

Table 3.1.1: Original Short-Term and Adjusted Long-Term Fecal Coliform Concentrations in Each Segment of Oyster Creek (Units in MPN/100ml)

Segment	Median		90^{th} Percentile	
	Original	Adjusted	Original	Adjusted
1	91.7	15.5	795.2	196.9
2	127.8	21.6	1416.9	350.8
3	86.0	14.5	937.5	232.1
4	77.0	13.0	753.5	186.6
5	44.2	7.5	614.5	152.1
6	44.3	7.5	621.0	153.7
7	49.8	1.8	741.6	93.6
8	54.6	2.0	588.8	74.3
B4	52.6	8.9	641.4	158.8
B7	49.8	8.4	741.6	183.6
B8	51.5	1.9	782.5	98.7

3.1.2 Loading Estimation

The inverse modeling approach was used to estimate the loadings (Shen *et al.*, 2006). Because of the large uncertainty involved in computing the existing loads and the errors associated with the observations, the Bayesian statistical method was used to estimate the loads. The Bayesian method uses statistics in conjunction with prior information and observations to establish a probability distribution (posterior) to describe the unknown parameters (i.e., in this study, loadings) (Huang and McBean, 2007). The advantage of the method is that it not only provides a sound estimation of loadings, but also the uncertainties associated with the model simulation. The Bayes' theorem can be written as follows:

$$p(\theta | C) = \frac{p(C | \theta) \times p(\theta)}{P(C)}$$

where $p(\theta | C)$ is the posterior distribution and expresses the probability of the model parameter values (loadings) given the observed data. $p(C)$ is the expected value of the likelihood function over the parameter distributions and is used as a normalizing constant. $p(C | \theta)$ is the likelihood of possible fecal coliform concentrations given a fixed value of the loading, and $p(\theta)$ is the prior belief of unknown parameters (loadings) density distribution function.

The statistics software WinBUGs (Spiegelhalter *et al.*, 2003) was used to estimate the loadings with the use of instream fecal coliform concentrations. The combined long-term statistics (median and 90th percentile, Table 3.1.1) were used to estimate the existing loads. The fecal coliform criteria of 14 MPN/100ml (for median) and 43 MPN/100ml (for 90th percentile) were used to estimate the TMDLs. The comparison plots of the observations and model simulations are shown in Figures 3.1.2 and 3.1.3 for median and 90th percentile concentrations, respectively. The results show that model simulates the instream concentration correctly with R^2 values larger than 0.68. The model results of mean concentrations, together with the median and 2.5% and 97.5% confidence intervals, are listed in Appendix C. The estimated existing loads and TMDLs are listed in Table 3.1.2. The estimated loading for each segment is listed in Appendix C.

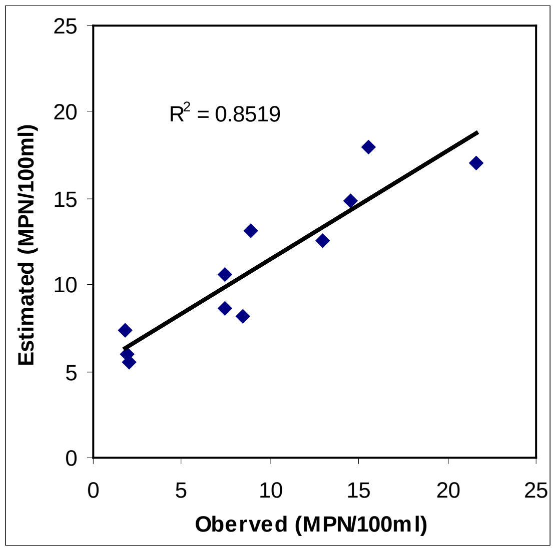

Figure 3.1.2: Scatter Plot of Estimated and Adjusted Median Concentrations

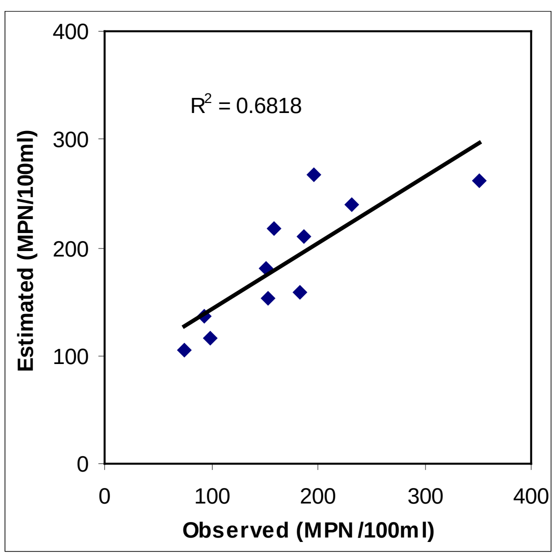

Figure 3.1.3: Scatter Plot of Estimated and Adjusted 90th Percentile Concentrations

Table 3.1.2: Existing Loads and TMDLs

Endpoint	Existing Load (counts/day)	Allowable Load (counts/day)	Reduction
Median	1.5×10^{11}	4.1×10^{10}	72.6%
90th Percentile	3.1×10^{12}	2.3×10^{11}	92.6%

3.2 Critical Conditions

The EPA Code of Federal Regulations (40 CFR 130.7 (c)(1)) requires TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The critical condition accounts for the hydrologic variation in the watershed over many sampling years whereas the critical period is the condition under which a waterbody is the most likely to violate the water quality standard(s).

The 90th percentile concentration is the concentration exceeded only 10% of the time. Since the data observational period spans about 5 years, which includes both favorable and unfavorable weather conditions, and the flow used is 90th percentile high flow, the critical condition is implicitly included in the value of the 90th percentile of model results.

3.3 Seasonality

Fecal coliform distributions often show high seasonal variability, which is required to be considered in calculating TMDLs. The seasonal fecal coliform distributions for Stations 10, 10A, and 10B are presented in Figure 3.3.1. The seasonal distributions for other stations were not generated as most of the stations have only one data per month. The results show that high fecal coliform concentrations occurred from June to October. In general, the concentrations in Station 10B are higher than the other two, and Station 10 has the lowest concentrations among the three stations. The largest standard deviation corresponds to the highest concentration. These high concentrations result in a high 90th percentile concentration. Because the model simulates the statistics that were computed using data from a full 5-year period, the seasonal variability is directly included in the model simulation.

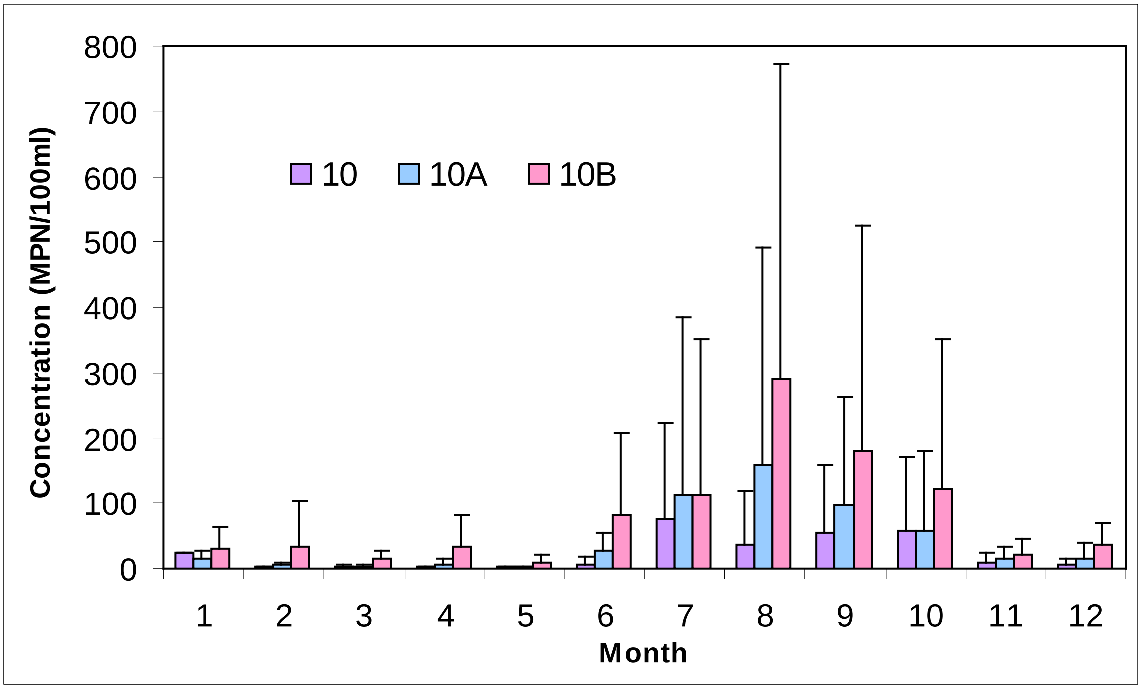

Figure 3.3.1: Seasonal Distribution of Fecal Coliform at Stations 10, 10A, and 10B. Error Bars Denote Standard Deviations.

3.4 TMDL Loading Cap

This section presents the TMDL for the median and 90th percentile conditions for Oyster Creek. The TMDLs for the restricted shellfish harvesting area are:

For median criterion:
The fecal coliform TMDL = 4.1×10^{10} Counts/Day

For 90th percentile criterion:
The fecal coliform TMDL = 2.3×10^{11} Counts/Day

The greater reduction required when comparing the median and the 90th percentile results was used for the load allocation. These loads are based on an averaging period that is defined by the water quality criteria (i.e., at least 30 samples).

3.5 Wasteload Allocation

As described in Section 2.2, NCDOT is the only NPDES-permitted discharge in the watershed included in the WLA. The WLA for NCDOT land was isolated from other sources by multiplying the total load and the ratio of NCDOT road right of way (ROW) area to total watershed area. The NCDOT ROW area was calculated by multiplying the road length and width of US highways, NC roads, and state route roads within the watershed. If the road is shared by the Oyster Creek watershed and other watersheds, only the area within the Oyster Creek watershed was used. The total NCDOT ROW is 0.154 km^2, which is 0.796% of the total watershed area. Model sensitivity test shows that there is no significant difference in predicted bacterial concentration by eliminating the loading from NCDOT showing that NCDOT is not a significant contributor to the impairment in this watershed. The resulting WLA for NC DOT is 1.6×10^9 counts per day. The WLA of each subwatershed was calculated as well with the same method and can be found in Appendix E.

Table 3.5.1: WLA Summary

Pollutant	NCDOT Existing Permitted Load	WLA	Reduction
Fecal Coliform (Counts per Day)	N/A	1.6×10^9	0.0%

NC DOT will continue to implement measures required by the permit, including illicit discharge detection and elimination, post-construction controls, management of hydraulic encroachments, sediment and erosion control, BMP retrofits, stormwater pollution prevention for industrial facilities, research, and education programs.

3.6 Load Allocation

Based on the model results, the 90th percentile criterion requires the greatest reduction for the restricted shellfish harvesting areas in Oyster Creek. The load reduction needed to meet the shellfish criterion is 92.6%. The reduction established based on the 90th percentile criterion ensures that the water body will meet water quality standards 90% of the time. Management strategies to meet the proposed reduction will be implemented on a daily basis, to achieve the control of fecal loads for all but the most extreme 10% of events (i.e. ensure that 90% of the concentrations are at or below the 90th percentile criterion). These extreme events are often caused due to hydrologic variability, storm water management, change of land use practices, and change of wildlife activities during the previous ten year period. Source reductions can be assigned by first managing controllable sources (human, livestock, and pets, which contribute 33% of the total existing loads according to Table 2.1.1) and then determining if the TMDL could be achieved. Although wildlife is the main source of fecal colifrom according to BST analysis (Table 2.1.1), the reduction of wildlife as a feasible strategy for fecal coliform reduction is not recommended, as it is hard to justify or implement.

3.7 Margin of Safety

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

For TMDL development, the MOS needs to be incorporated to account for uncertainty due to model parameter selection. In the TMDL calculation of this study, an explicit MOS of 10% is used. Though Bayesian estimation also provides uncertainty for the point estimation of loading (e.g., 95% credible intervals), it is the uncertainty of loading alone. The uncertainties associated with other factors, such as bacteria decay, flow, measurement of geometry parameters, can all be reflected qualitatively by this 10% MOS as a more conservative estimation.

3.8 Summary of Total Maximum Daily Loads

As described in Section 2.1.2, NCDOT is the only NPDES-permitted discharge in the watershed included in the WLA. The TMDLs calculated based on 10 years of data are summarized as follows:

Table 3.7.1 The Fecal Coliform TMDL (counts per day)

Area	TMDL=	LA+	WLA+	FA+	MOS
Oyster Creek restricted shellfish harvesting area	2.3×10^{11}	2.1×10^{11}	1.6×10^{9}	NA	2.3×10^{10}

Where:

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

4.0 TMDL Implementation Plan

The TMDL analysis was performed using the best data available to specify the fecal coliform reductions necessary to achieve water quality criteria. The intent of meeting the criteria is to support the designated use classifications in the watershed. An implementation plan is not included in this TMDL. The involvement of local governments and agencies will be needed in order to develop an implementation plan. Potential funding sources for implementation include Section 319 funds, and 205(j) funds.

The appropriate measures to reduce pollution levels in the impaired area include, where appropriate, the use of better treatment technology or installation of best management practices (BMPs). In general, NCDENR recommends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality, with consideration given to ease of implementation and cost. The 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.

The preliminary source assessment suggests wildlife may be the major source of fecal coliform loading to Oyster Creek. Therefore, reductions for fecal coliforms should first be sought through installation and maintenance of BMPs to tackle loads from the primary sources. It is expected that in some waters for which TMDLs will be developed, the bacteria source analysis will indicate that after controls are in place for all anthropogenic sources, the waterbody does not meet water quality standards. However, neither the State of North Carolina 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.

5.0 Stream monitoring

The Shellfish Sanitation Section of DEH will continue to monitor shellfish waters and classify harvesting areas and close them if levels of fecal coliform indicate that harvesting shellfish from those waters could cause a public health risk. Those waters meeting shellfish water quality standards may be reclassified as open to harvesting and can serve to track the effectiveness of TMDL implementation and water quality improvements. Additional monitoring will also include microbial source tracking that will be used to confirm the source estimates presented in this document. In the future, data needed for TMDL development should include samples collected immediately after a rainfall event causing closure of waterbodies.

6.0 Future Efforts

Potential mechanisms for reduction of fecal coliform include implementation of appropriate BMPs, local regulations or ordinances related to zoning, land use, or storm water runoff controls. Local governments can provide funding assistance through general revenues, bond issuance, special taxes, utility fees, and impact fees. Additional mechanisms may employ concurrent education and outreach, training, technology transfer, and technical assistance with incentive-based pollutant management measures. The state and local governments will take the primary lead in the TMDL implementation. Microbial source tracking can be used to confirm the source estimates presented in this document and target major fecal coliform sources for reduction. DWQ will work with NCDEH Shellfish Sanitation section to prioritize shellfish areas and to collect additional data immediately after a rainfall event causing closure of waterbodies.

7.0 Public Participation

A draft of the TMDL was publicly noticed through various means. The TMDL was public noticed on the NC Modeling and TMDL website and the North Carolina Division of Water Quality TMDL list-serve on March 14, 2011. The TMDL was also public noticed on April 15, 2011 through the North Carolina Water Resources Research Institute email list-serve. Copies of the public notices are included in Appendix C. Finally, the TMDL was available on DWQ's website (http://portal.ncdenr.org/web/wq/ps/mtu) during the comment period. The public comment period lasted until April 14, 2011. DWQ received no public comment on the Oyster Creek Fecal Colifom TMDL.

8.0 Further Information

Further information concerning North Carolina's TMDL program can be found on the Internet at the Division of Water Quality website**:** http://portal.ncdenr.org/web/wq/ps/mtu/tmdl.

Technical questions regarding this TMDL should be directed to the following members of the DWQ Modeling/TMDL Unit:

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Appendix A. Observation Time Series Plots and Water Quality Data

For the fecal coliform observation data of NCDEH from 2000 to 2010 (if available), the time series plots together with the median and 90th percentile standards are shown in Figures A1-A3. The data from both NCDEH and NCSU are listed in Table A1.

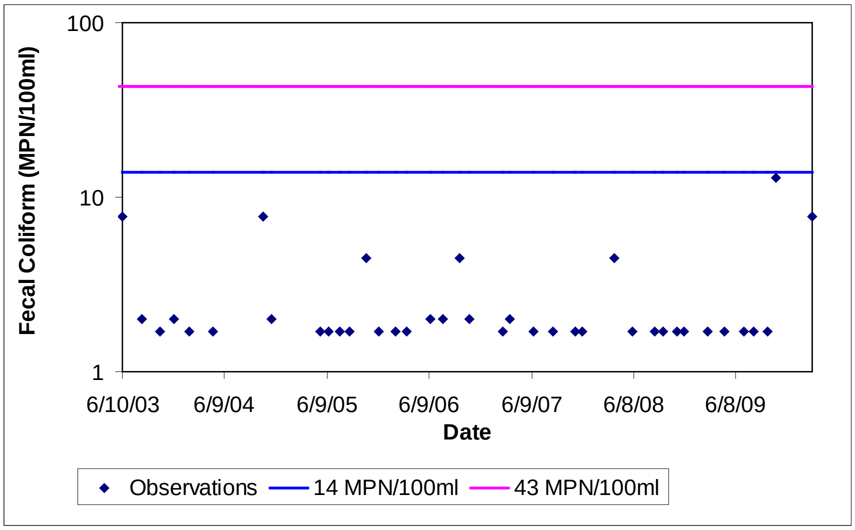

Figure A1: Time Series Plots and Water Quality Standards of Fecal Coliform Observations at Station 10

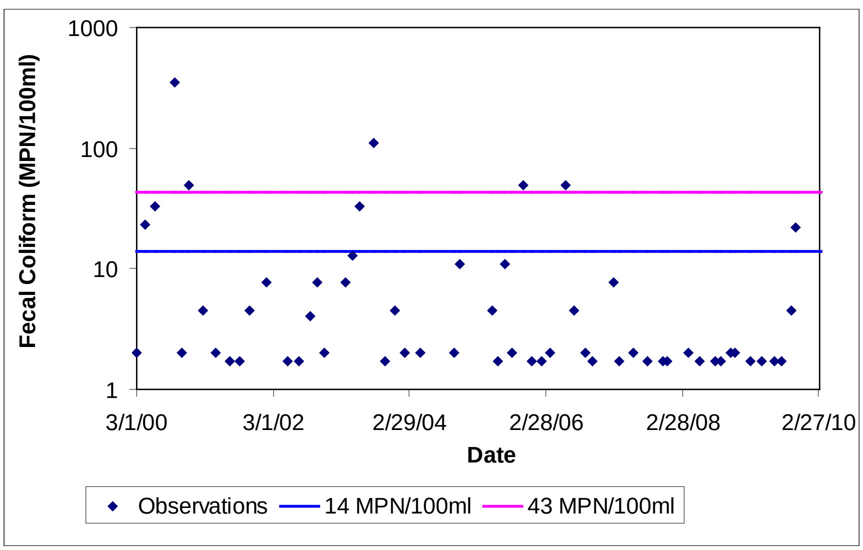

Figure A2: Time Series Plots and Water Quality Standards of Fecal Coliform Observations at Station 10A

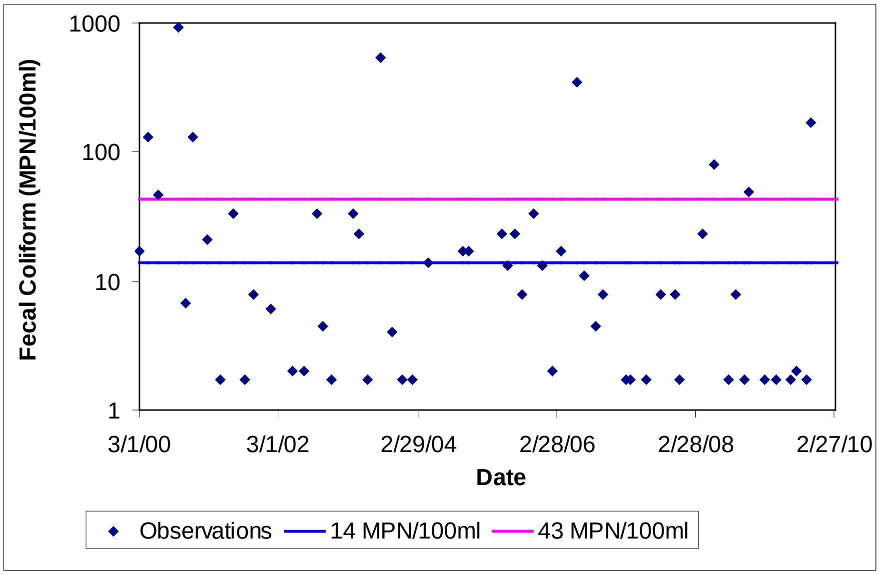

Figure A3: Time Series Plots and Water Quality Standards of Fecal Coliform Observations at Station 10B

Table A1: List of Fecal Coliform Observations at Stations 10, 10A, and 10B (Bold and italic fonts denote observations from NCSU, all others from NCDEH)

Date	10	10A	10B		Date	10	10A	10B
3/1/00		2.0	17.0		6/13/06	2	49	350
4/17/00		23.0	130.0		7/26/06	2	4.5	11
6/5/00		33.0	46.0		9/25/06	4.5	2	4.5
9/20/00		350.0	920.0		11/1/06	2	1.7	7.8
11/1/00		2.0	6.8		2/27/07	1.7	7.8	1.7
12/5/00		49.0	130.0		3/26/07	2	1.7	1.7
2/21/01		4.5	21.0		6/14/07	1.7	2	1.7
4/30/01		2.0	1.7		8/27/07	1.7	1.7	7.8
7/9/01		1.7	33.0		11/14/07	1.7	1.7	7.8
9/4/01		1.7	1.7		12/8/07	1.7	1.7	1.7
10/24/01		4.5	7.8		4/2/08	4.5	2	23
1/23/02		7.8	6.1		6/2/08	1.7	1.7	79
5/16/02		1.7	2.0		8/21/08	1.7	1.7	1.7
7/16/02		1.7	2.0		9/23/08	1.7	1.7	7.8
9/18/02		4.0	33.0		11/12/08	1.7	2	1.7
10/23/02		7.8	4.5		***11/22/08***	***12.4***	***23.0***	***59.0***
12/2/02		2.0	1.7		12/3/08	1.7	2	49
3/27/03		7.8	33.0		***12/20/08***	***4.8***	***14.7***	***34.8***
4/30/03		13.0	23.0		2/25/09	1.7	1.7	1.7
6/10/03	7.8	33.0	1.7		***2/27/09***	***5.5***	***14.3***	***174.2***

8/18/03	2.0	110.0	540.0		4/28/09	1.7	1.7	1.7
10/21/03	1.7	1.7	4.0		***5/8/09***	***3.1***	***3.1***	***6.3***
12/9/03	2.0	4.5	1.7		***6/20/09***	***29.2***	***71.6***	***94.9***
2/2/04	1.7	2.0	1.7		7/8/09	1.7	1.7	1.7
4/27/04	1.7	2.0	14.0		***7/10/09***	***295.5***	***663.5***	***600.4***
10/25/04	7.8	2.0	17.0		8/10/09	1.7	1.7	2.0
11/22/04	2.0	11.0	17.0		***8/18/09***	***203.8***	***835.5***	***1176.5***
5/18/05	1.7	4.5	23		***9/24/09***	***209.5***	***329.9***	***302.6***
6/15/05	1.7	1.7	13		9/30/09	1.7	4.5	1.7
7/26/05	1.7	11	23		***10/16/09***	***258.2***	***329.6***	***624.6***
8/30/05	1.7	2	7.8		10/27/09	13.0	22.0	170.0
10/27/05	4.5	49	33		***11/23/09***	***36.2***	***55.7***	***50.6***
12/13/05	1.7	1.7	13		***12/22/09***	***26.4***	***53.4***	***50.0***
2/8/06	1.7	1.7	2		***1/11/10***	***25.3***	***25.2***	***54.5***
3/22/06	1.7	2	17		3/8/10	7.8	2.0	2.0

Appendix B. Nonpoint Source Information

From August 2003 to December 2008, a sanitary survey was conducted in the G-3 and G-4 oyster growing area of North Carolina, including the restricted shellfish harvesting area of Oyster Creek. The pollution points found in Oyster Creek drainage area are listed in Table B1. Figures B1-B3 shows the locations of these pollutions points.

Table B1: Pollution Points in the Drainage Area of Oyster Creek Restricted Shellfish Harvesting Area

Type	Name	Note
Animals	Swan Acre Hog Farm	Design capacity: 300 hogs; no longer in operation (closed in 2005)
	Duck Impoundment	--
	Tiny Oak Hog Farm (became Spencer Heritage Farms in 1993)	Design capacity: 350 hogs; no longer in operation (closed in 2003)
Area of Concern	Waste Collection Center	Dumpsters, recycling bins, and a large pile of used appliances and organic waste
Dockage	Oyster Creek Marina	--

Figure B1: The Location of the Animal Pollution Points in Oyster Creek Watershed. Numbers: 15-Swan Acre Hog Farm; 20-Duck Impoundment; 21-Tiny Oak Hog Farm. (NCDENR, 2009)

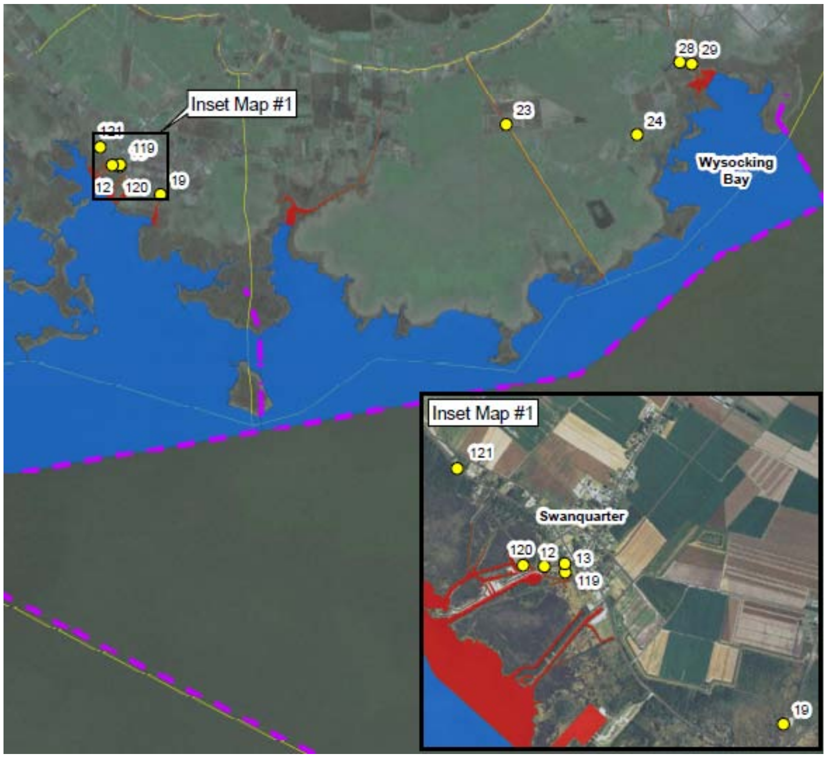

Figure B2: The Location of the Areas of Concern Pollution Point in Oyster Creek Watershed. Number: 19-Waste Collection Center (NCDENR, 2009)

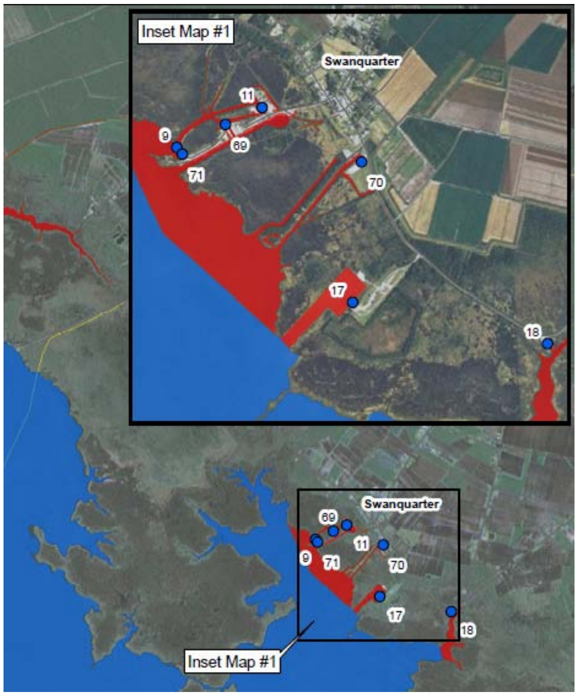

Figure B3: The Location of the Dockage Pollution Points in Oyster Creek Watershed. Number: 18-Oyster Creek Marina (NCDENR, 2009)

Antibiotic Resistance Analysis (ARA)

Antibiotic resistance analysis (ARA) was performed on 5,088 host-origin *E. coli* isolates and 10,368 *E. coli* isolates from 216 surface water samples. The host origin isolates were collected from the watershed and grouped into four categories, human (sewage pump out trucks, septic tanks), livestock (cattle, swine, horse), pets (cats, dogs) and wildlife (deer, various waterfowl). Ten to twenty isolates were collected from each fecal sample. Twenty-eight concentrations of seven antibiotics were used to determine antibiotic resistance patterns (ARPs) of the isolates. The antibiotic and concentrations were selected based on previous ARA studies and their common use in human and veterinary medicine (Mathew et al., 1998). An isolate was considered to be resistant to a given concentration of antibiotic if growth comparable to the control plate (no antibiotic) was observed. Observations were converted to binary data; with growth on a given antibiotic concentration represented “1” and “0” represented no growth. Any isolates which failed to grow on the control plates were excluded from the analysis. The details of the ARA procedure have been described and are the same as that used in the method comparison studies Graves et al., 2002; Harwood et al., 2003; Stoeckel et al., 2004).

Host-origin Library

Data were analyzed with SAS-JMP statistical software (v. 5.0.1, SAS Inst., Cary, NC). ARA patterns were evaluated by discriminant analysis (DA, with covariance pooled and not pooled) and cluster analysis (to produce a dendrogram for visualizing the degree of overlap). Clustering analysis is the technique of grouping data together that share similar values across a number of variables. The distance graph feature associated with cluster analysis clustered the isolates as points and demonstrated whether source patterns were clustered about a central location or if there were multiple clusters around different locations. The host-origin library was developed and clonal isolates (duplicate ARPs) were identified and removed. Classification ties were assigned a source depending on where the isolate was observed in dendrograms (Ritter et al., 2003). Additional efforts to develop a stringent host origin library and to obtain reliable source identification of unknown source isolates involved the application of an 80% threshold criterion for correct classification to the library. All isolates below the 80% correct classification certainty (based on posterior probabilities from discriminant analysis) were excluded from the library. The second approach was to calculate the average frequency of misclassification (AFM) for each source category, and use this average to develop a minimum detectable percentage (MDP) to make decisions about the significance of hosts contributing minor sources *E. coli* in water samples

Calculation of ARCC, AFM and MDP

The average rate of correct classification (ARCC) was calculated by adding the percentage of isolates correctly classified from each source category and dividing by the total number of source categories. The average frequency of misclassification (AFM) was calculated by adding the percentage of isolates incorrectly classified from each source category and dividing by the total number of source categories (Harwood et al., 2000; Ritter et al., 2003).

The AFM can be used to estimate the likelihood that an isolate that is not from category X will in fact be classified into category X, and therefore can provide the basis for a significance cut-off (minimum detectable percentage, MDP) when predicting the source of isolates from water samples or unknown sources (Whitlock et al., 2002; Wiggins et al., 2003).

For example, if the AFM of the isolates in an ARA library with nine sources were misclassified by 0.68 ± 0.92 SD. Given that the library had nine source categories, nine multiplied by the standard deviation (0.92) added to the AFM of 0.68% produces a 9% MDP. With nine source categories, the probability of an isolate being assigned to any category by chance alone was 11%. However, 9% should be taken as a more stringent lower limit for considering any one source category to be a significant contributor of fecal pollution (Harwood et al., 2003). Therefore, for example, wildlife would be considered a significant contributor to the indicator bacteria in a water sample only if 9% or more of the isolates were classified into the 'bird' source category. Ultimately, when classifying isolates of unknown origin (water samples), source categories identified at percentages below the MDP were considered a negligible contributing source.

Cross-validation analysis via the hold-out method was used to determine the representativeness of the library. An individual isolate was removed from the library one at a time. Then, the removed isolate was classified based on the library comprised of the remaining isolates, and the ARCC for these removed isolates was calculated (Wiggins et al., 2003).

The removal of clonal isolates, those isolates with duplicate ARPs resulted in a loss of 45-85% of isolates from the individual source categories, reducing the total number of *E. coli* 5,088 (5,088) to 2,130 isolates. The 2,130 isolates with unique ARPs were subjected to discriminant analysis, producing an average rate of correct classification (ARCC) of 82%, with individual source correct classification (CC) rates ranging from 70 -100%. The application of an 80% correct classification certainty threshold resulted in a loss of up to 45% of isolates from the individual source categories. The refined library of 1,065 isolates had an ARCC of 90%, with individual source CC rates ranging from 78-96%. With four source categories, the probability of an isolate being assigned to any category by chance alone was 25%. The AFM (3.0 ± 2.8) for the library was used to calculate the MDP of 14.2% for the study site and represented a stringent lower limit for considering any one source category to be a significant contributor of fecal pollution (Harwood et al., 2000) (Table B2).

The library composed of 1,065 unique ARPs to which an 80% correct classification threshold criterion was applied, was subjected to cross-validation analysis by the hold-out method. The cross -validation ARCCs for human (92%), livestock (86%), pets (72) and wildlife (87%) were only 4-9% lower than the CC rates for these categories listed in table B2.

A representative known source library composed of unique antibiotic resistance patterns (ARP) among the host source categories with reliable correct classification (CC) rates is important for unknown source identification. The high rate of correct classification obtained with our database (90%) may be attributed to the removal of clonal isolates, those isolates with identical antibiotic resistance patterns (ARPs) and the application of an 80% correct classification threshold criterion to the non-clonal isolates. Furthermore, the cross validation testing indicated the library was representative with a 9% or less difference in the ARCC of the validation analysis and the CC rates of the individual sources in the library.

Table B2: Discriminant analysis of unique antibiotic resistance patterns (ARPs) used to classify *E. coli* from four groups of known host sources into source categories

	Categories into which isolates from the ARA library were classified								
Source of Isolates	**Human**		**Livestock**		**Pets**		**Wildlife**		**Total**
	CC*	**MC†**	**CC**	**MC**	**CC**	**MC**	**CC**	**MC**	**(n_i)**
Human	220			0		26		4	**230**
Livestock		0	249			10		5	**270**
Pets		10		3	195			2	**250**
Wildlife		0		18		19	239		**250**
Total	220	10	249	27	195	55	239	11	
Total isolates(n)									**1,065**
% n CC=(100CC)/(n_i)		96	92		78		96		**90** ‡
%n MC= (100)MC/(n-n_i)		**1**	**3**		**7**		**1**		

* Number of isolates correctly classified (CC) by discriminant analysis; † Number of isolates misclassified (MC) by discriminant analysis; ‡ Average rate of correct classification (ARCC); n= Total isolates ; n_i= Total isolates in an individual source category

Water samples were most often collected during ebb tide, the period between high tide and low tide during which water flows away from the shore. Collection during this time provided an opportunity to more accurately identify the sources of fecal pollution entering Oyster Creek and may have also contributed to the overall higher fecal indicator counts than those observed by NCDEH. According to the ARA method, wildlife (54-96%) represented the predominant host source of *E. coli* isolates in Oyster Creek at all sampling locations (Table B3). Several sampling locations were impacted by human and pet hosts as indicated by source identifications above the 14.2% MDP (Table B3). Isolates identified as livestock at levels above the 14.2% ARA MDP were detected at four locations representing an average of 14-17% of isolates.

Table B3: Summary of the Antibiotic Resistance Analysis Results

Station	Number of Water Samples	*E. coli* isolates evaluated by ARA (48 isolates/water sample)	Mean Percentage of *E. coli* isolates from Oyster Creek classified as:			
			Human	**Livestock**	**Pets**	**Wildlife**
10	12	576	0	2	3	95
10A	12	576	6	2	2	90
10B	12	576	17	7	17	59
OC-1A	10	480	12	9	25	54
OC-1B	10	480	12	11	22	55
OC-2	11	528	14	12	20	54
OC-3	10	480	15	11	14	60
OC-4	11	528	17	10	13	60
OC-5	10	480	12	12	21	55
OC-6	10	480	15	14	13	58
OC-7	10	480	17	13	16	54
OC-8	11	528	10	14	17	59
OC-9	10	480	10	10	12	68
OC-10	10	480	17	8	11	64
OC-11	10	480	20	5	18	57
OC-12	10	480	17	5	10	68
OC-13	10	480	18	6	9	67
OC-14	6	288	8	11	7	74
OC-15	8	384	12	17	14	57
OC-16	8	384	4	15	12	69
OC-17	9	432	4	4	0	92
OC-18	6	288	2	2	0	96
Total	**216**	**10,368**				
		Average	**12 ± 6**	**9 ± 4**	**13 ± 7**	**67 ± 14**

Repetitive Element Polymerase Chain Reaction (Rep-PCR)

The 1,065 isolates used in the ARA library were subjected to rep-PCR as a means for cross validation of the ARA results. The rep-PCR procedure (Lupski and Weinstock, 1992; Veralovic et al., 1991) was performed using a modified method of Rademaker and DeBruijn (1997) for *E. coli*. Observations were converted to binary data; with the presence of a molecular band fragment at given size represented by "1" and "0" represented the absence of the bands. The rep-PCR data were analyzed in the same manner as described under ARA.

The removal of clonal isolates, those isolates with duplicate molecular band fragment patterns resulted in a loss of 25-57% of isolates from the individual source categories, reducing the total number of *E. coli* (1,065) to 639 isolates. The 639 isolates with unique molecular banding patterns were subjected to discriminant analysis, producing an average rate of correct classification (ARCC) of 79%. The application of an 80% correct classification certainty threshold resulted in a loss of up to 37% of isolates from the individual source categories. The refined library of 565 isolates had an ARCC of 87%, with individual source CC rates ranging from 82-92%. With four source categories, the probability of an isolate being assigned to any category by chance alone was 25%. The AFM (4.5± 2.0) for the library was used to calculate the MDP of 12.5% for the study site and represented a stringent lower limit for considering any one source category to be a significant contributor of fecal pollution (Harwood et al., 2000). (Table B4).

The library composed of 565 unique molecular banding patterns to which an 80% correct classification threshold criterion was applied, was subjected to cross-validation analysis by the hold-out method. The cross -validation ARCCs for human (83%), livestock (79%), pets (86) and wildlife (81%) were 2-8% lower than the CC rates for these categories listed in table B4.

Similar to the ARA library, the high rate of CC obtained with our database (87%) may be attributed to the removal of clonal isolates, those isolates with identical antibiotic resistance patterns (ARPs) and the application of an 80% correct classification threshold criterion to the non-clonal isolates. Furthermore, the cross validation testing indicated the library was representative with a 8% or less difference in the ARCC of the validation analysis and the CC rates of the individual sources in the library.

Table B4: Discriminant analysis of unique molecular rep-PCR banding patterns used to classify *E. coli* from four groups of known host sources into source categories

	Categories into which isolates from the rep-PCR library were classified								
Source of Isolates	**Human**		**Livestock**		**Pets**		**Wildlife**		**Total**
	CC[*]	**MC**[†]	**CC**	**MC**	**CC**	**MC**	**CC**	**MC**	**(n_i)**
Human	100			0		6		2	**110**
Livestock		2	108			5		7	**132**
Pets		5		4	116			5	**140**
Wildlife		3		20		13	169		**183**
Total	100	10	108	24	116	24	169	14	
Total isolates(n)									**565**
% n CC=(100CC)/(n_i)		91	82		83		92		**87** [‡]
%n MC= (100)MC/(n-n_i)		**3**	**6**		**6**		**4**		

[*] Number of isolates correctly classified (CC) by discriminant analysis; [†] Number of isolates misclassified (MC) by discriminant analysis; [‡] Average rate of correct classification (ARCC); n= Total isolates ; n_i= Total isolates in an individual source category

A subset of *E. coli* isolates (1,728) from the surface waters of Oyster Creek were evaluated by rep-PCR. Similar to the ARA method, rep-PCR implicated wildlife (57-100%) as the predominant host source contributor of *E. coli* isolates in Oyster Creek at all sampling locations (Table B5.) More than eight sampling stations were impacted by human and pet sources as indicated by source identifications above the rep-PCR 12.5% MDP (Table B5). The livestock contribution was below the rep-PCR 12.5% MDP at all sampling stations.

Table B5: Summary of Rep-PCR Validation of Antibiotic Resistance Analysis Results

Station	Number of Water Samples	*E. coli* isolates evaluated by ARA (8 isolates/water sample)	Mean Percentage of *E. coli* isolates from Oyster Creek classified as:			
			Human	**Livestock**	**Pets**	**Wildlife**
10	12	96	0	0	0	100
10A	12	96	5	0	0	95
10B	12	96	10	5	10	75
OC-1A	10	80	10	5	25	60
OC-1B	10	80	10	8	22	60
OC-2	11	88	16	8	14	62
OC-3	10	80	10	11	19	60
OC-4	11	88	12	10	18	60
OC-5	10	80	9	8	18	65
OC-6	10	80	15	11	11	63
OC-7	10	80	16	9	15	60
OC-8	11	88	8	11	22	59
OC-9	10	80	13	10	20	57
OC-10	10	80	20	4	8	68
OC-11	10	80	19	5	16	60
OC-12	10	80	15	2	12	71
OC-13	10	80	19	4	18	59
OC-14	6	48	10	3	7	80
OC-15	8	64	8	6	11	75
OC-16	8	64	0	0	30	70
OC-17	9	72	0	0	0	100
OC-18	6	48	0	0	0	100
Total	**216**	**1,728**				
		Average	**10 ± 6**	**5 ± 4**	**13 ± 9**	**71 ± 15**

Optical Brighteners (OBs)

Optical brighteners (OBs) were detected with a field fluorometer (Model 10-AU-005, Turner Designs, Sunnyvale, California) set to detect long wavelength OBs (excitation wavelength, 360 nm; emission wavelength, 410-600 nm) as described by the manufacturer. Water samples were refrigerated in the dark at 4°C until processed. The fluorometer was zeroed with distilled water (negative control) and 100 mg L^{-1} of commercially available optical brightener Tinopl CBS-X (Ciba Specialty Chemicals) provided a 100 fluorometric units (positive control) (Hagedorn *et al.* 2003; Hagedorn *et al.* 2005). Each water sample was analyzed in the discrete mode at room temperature (20-25°C) and was read within 30 s to avoid heating effects by the UV lamp in the fluorometer. Any site with a fluorometric value $\geq$100 suggested samples were positive for optical brighteners. Samples were exposed to UV light for 4 hours and a percentage decrease in fluorometric value $\geq$ 30% confirmed the presence of optical brighteners (Hartel *et al.* 2007a, 2007b).

The approach to evaluating OBs can be described as four possible contamination scenarios: 1) high concentrations of OBs and high enterococci counts, which suggests a malfunctioning septic drainfield or leaking sewer pipe, 2) high concentrations of OBs and low enterococci counts, which suggests gray water in the storm water system, 3) low concentrations of OBs and high enterococci counts, which suggests other warm-blooded animals or a human source from something like an outhouse, and 4) low concentrations of OBs and low enterococci counts, which suggests no source of fecal contamination (Hartel *et al.* 2007a, 2007b).

The OB results from this study suggest a human or animal source of pollution throughout the study area (Table B6). Fifteen sampling stations had an average OB decline$\geq$ 30%. Eight of the fifteen sampling stations positive for optical brighteners also had library dependent results implicating a human source above the 14.2% ARA MDP and 12.5% Rep-PCR MDP (Table B6).

Human specific *Bacteroides* HF183 marker

Water samples collected during the last three sampling dates were evaluated for the presence of the human specific *Bacteroides* HF183 marker. PCR was carried out using primers designed to amplify the human-specific marker (HF183F forward: 5’-ATC ATG AGT TCA CAT GTC CG-3’, BAC 708R general reverse: 5’-CAA TCG GAG TTC TTC GTG-3’) and the general marker (BAC32F AAC GCT AGC TAC AGG CTT; BAC 708R general reverse: 5’-CAA TCG GAG TTC TTC GTG-3’) (Bernhard *et al.* 2003). PCR reactions were performed in a 50 µL reaction mixture containing 1 × PCR buffer, 1.5 mM MgCl2, 200µM of each of the four deoxyribonucleotides, 0.3 µM of each primer, 2.5 U of HotStarTaq DNA polymerase, and 5 µL of template DNA. Amplification was performed with an initial step at 95^{o}C for 15 minutes (to activate Taq polymerase), followed by 30 cycles of 94^{o}C for 1 min, 63^{o}C for 1 min, and 72^{o}C for 5 min. PCR reactions (including a positive and negative control) were electrophoresed on 1% agarose gels stained with ethidium bromide and visualized under UV light to assess production of PCR products of the correct size.

Fifteen of the 22 sampling locations were positive for the HS-HF183 marker. Eight of the fifteen positive for HS-HF183 marker also had library dependent results implicating a human source above the 14.2% ARA MDP and 12.5% Rep-PCR MDP (Table B6).

Summary of MST Data from Stations used to develop the TMDL.

An evaluation of source contributions at stations 10, 10A and 10B revealed a significantly greater human (17.3%), livestock (6.8%) and pet (16.8%) contribution at station 10B than stations 10 and 10A (Tukey-Kramer HSD, $p \leq 0.05$). Station 10B was also positive for OBs and the HS-HF183 molecular marker. The wildlife (95.4%) contribution at station 10 was significantly greater than stations 10A (89.6) and 10B (59.3%). A human contribution was not detected at station 10. When the data were observed collectively, no significant patterns of seasonal variation in host source contributions from livestock and pets were observed. However, the human contribution (14.0%) in August 2009 was significantly greater than the human contribution (3%) in December 2008. There were no statistical differences in the human contributions for the remaining collection times. The wildlife (89.4%) contribution in December 2008, was not statistically different from the wildlife contributions in November 2008, October 2009, and January 2010 (66.8-69%), but was statistically greater than the contributions during the other sampling times (Tukey-Kramer HSD, $p \leq 0.05$).

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Table B6: Summary of Multiple Microbial Source Tracking Results

Station	Average Enterococci densities mpn/100mL	Average OB (µg/L) value before UV exposure	Average OB (µg/L) value after UV exposure	Average OB Decline (%)	OB Host Source Suggestion	(%) human by ARA	(%) human by rep-PCR	HF183 marker (+)
10	268.1	65.6	58.0	12	Animal	0	0	No
10A	500.7	65.7	59.2	10	Animal	6	5	No
10B	672.4	106.0	71.0	33	Human	17	10	Yes
OC1A	798.3	149.0	111.0	25	Animal	12	10	Yes
OC1B	765.2	153.0	107.0	30	Human	12	10	Yes
OC2	842.2	147.0	98.6	33	Human	14	16	Yes
OC3	607.2	143.0	96.8	32	Human	15	10	Yes
OC4	530.4	150.0	98.1	34	Human	17	12	Yes
OC5	635.2	147.0	95.2	35	Human	12	9	Yes
OC6	597.5	147.0	96.6	34	Human	15	15	Yes
OC7	522.3	142.0	86.7	39	Human	17	16	Yes
OC8	870.7	136.0	87.7	35	Human	10	8	Yes
OC9	540.8	140.0	89.3	36	Human	10	13	Yes
OC10	1472.3	106.0	73.3	30	Human	17	20	Yes
OC11	1480.0	117.0	76.5	34	Human	20	19	Yes
OC12	605.2	142.0	92.7	34	Human	17	15	Yes
OC13	256.9	116.0	73.7	36	Human	18	19	Yes
OC14	92.3	126.0	78.0	38	Animal	8	10	No
OC15	736.6	87.0	64.5	26	Animal	12	8	No
OC16	191.7	132.0	102.0	23	Animal	4	0	No
OC17	574.6	161.0	130.0	19	Animal	4	0	No
OC18	118.2	49.6	37.5	23	Animal	2	0	No

Table B7: Percent Source contributions of *E. coli* based on Antibiotic Resistance Analysis Results for all samples.

Antibiotic Resistance Analysis: Raw Data						
Sampling Month	**Station**	**Human**	**Livestock**	**Wildlife**	**Pets**	**Sum**
November 2008	10	0	3	96	1	100
December 2008	10	0	3	96	1	100
February 2009	10	0	1	95	4	100
May 2009	10	0	0	100	0	100
June 2009	10	0	1	93	6	100
July 2009	10	0	1	96	3	100
August 2009	10	0	5	90	5	100
September 2009	10	0	1	94	5	100
October 2009	10	0	2	97	1	100
November 2009	10	0	5	93	2	100
December 2009	10	0	4	96	0	100
January 2010	10	0	1	99	0	100
November 2008	10A	4	4	88	4	100
December 2008	10A	1	3	95	1	100
February 2009	10A	5	5	86	4	100
May 2009	10A	5	0	93	2	100
June 2009	10A	13	0	84	4	100
July 2009	10A	2	0	97	1	100
August 2009	10A	7	6	86	2	100
September 2009	10A	3	6	87	4	100
October 2009	10A	11	0	85	4	100
November 2009	10A	12	0	87	1	100
December 2009	10A	5	3	91	0	100
January 2010	10A	1	0	96	3	100
November 2008	10B	17	10	63	10	100
December 2008	10B	9	8	66	18	100
February 2009	10B	22	2	52	24	100
May 2009	10B	13	1	71	15	100
June 2009	10B	20	9	55	17	100
July 2009	10B	21	6	62	11	100
August 2009	10B	19	7	52	21	100
September 2009	10B	16	7	62	15	100
October 2009	10B	23	9	53	15	100
November 2009	10B	15	7	57	21	100

Antibiotic Resistance Analysis: Raw Data						
Sampling Month	**Station**	**Human**	**Livestock**	**Wildlife**	**Pets**	**Sum**
December 2009	10B	20	8	55	16	100
January 2010	10B	12	7	63	18	100
February 2009	OC1A	9	12	44	34	100
May 2009	OC1A	9	5	55	31	100
June 2009	OC1A	16	8	47	29	100
July 2009	OC1A	19	6	53	22	100
August 2009	OC1A	17	12	59	12	100
September 2009	OC1A	18	13	54	15	100
October 2009	OC1A	12	5	57	26	100
November 2009	OC1A	5	6	42	47	100
December 2009	OC1A	7	16	58	19	100
January 2010	OC1A	6	13	67	14	100
February 2009	OC1B	10	12	56	21	100
May 2009	OC1B	15	15	54	16	100
June 2009	OC1B	12	16	53	19	100
July 2009	OC1B	18	10	51	21	100
August 2009	OC1B	16	9	54	21	100
September 2009	OC1B	10	11	57	22	100
October 2009	OC1B	12	12	55	22	100
November 2009	OC1B	6	12	57	25	100
December 2009	OC1B	14	4	50	31	100
January 2010	OC1B	10	12	57	21	100
November 2008	OC2	15	11	50	24	100
February 2009	OC2	13	12	49	26	100
May 2009	OC2	16	15	56	13	100
June 2009	OC2	18	7	57	18	100
July 2009	OC2	17	11	60	22	110
August 2009	OC2	11	13	56	20	100
September 2009	OC2	15	15	52	8	90
October 2009	OC2	11	12	54	23	100
November 2009	OC2	18	13	53	16	100
December 2009	OC2	13	10	51	26	100
January 2010	OC2	12	10	59	19	100
February 2009	OC3	15	12	62	11	100
May 2009	OC3	16	8	67	9	100
June 2009	OC3	13	10	64	13	100
July 2009	OC3	11	23	60	6	100
August 2009	OC3	19	11	50	20	100

Antibiotic Resistance Analysis: Raw Data						
Sampling Month	**Station**	**Human**	**Livestock**	**Wildlife**	**Pets**	**Sum**
September 2009	OC3	12	12	61	15	100
October 2009	OC3	15	14	56	15	100
November 2009	OC3	18	10	67	5	100
December 2009	OC3	17	5	49	29	100
January 2010	OC3	16	6	66	12	100
November 2008	OC4	13	12	65	11	100
February 2009	OC4	21	8	61	10	100
May 2009	OC4	16	15	52	17	100
June 2009	OC4	18	11	55	16	100
July 2009	OC4	17	11	57	14	100
August 2009	OC4	22	9	59	10	100
September 2009	OC4	17	2	62	18	100
October 2009	OC4	18	13	55	14	100
November 2009	OC4	23	6	63	8	100
December 2009	OC4	12	8	64	16	100
January 2010	OC4	12	16	62	10	100
February 2009	OC5	14	10	55	21	100
May 2009	OC5	11	3	55	31	100
June 2009	OC5	13	15	45	27	100
July 2009	OC5	6	9	64	21	100
August 2009	OC5	9	12	62	17	100
September 2009	OC5	18	16	43	23	100
October 2009	OC5	16	15	53	16	100
November 2009	OC5	15	14	52	19	100
December 2009	OC5	6	10	60	24	100
January 2010	OC5	16	11	59	14	100
February 2009	OC6	11	9	66	15	100
May 2009	OC6	15	12	63	10	101
June 2009	OC6	16	18	51	15	100
July 2009	OC6	17	17	49	17	100
August 2009	OC6	17	19	59	4	100
September 2009	OC6	16	16	64	4	100
October 2009	OC6	15	15	47	23	100
November 2009	OC6	17	11	58	13	99
December 2009	OC6	12	13	60	15	100
January 2010	OC6	18	9	64	9	100
February 2009	OC7	16	14	58	12	100
May 2009	OC7	17	12	59	12	100

Antibiotic Resistance Analysis: Raw Data						
Sampling Month	**Station**	**Human**	**Livestock**	**Wildlife**	**Pets**	**Sum**
June 2009	OC7	25	14	48	13	100
July 2009	OC7	16	14	49	21	100
August 2009	OC7	22	7	59	11	99
September 2009	OC7	12	14	54	20	100
October 2009	OC7	12	14	51	23	100
November 2009	OC7	17	12	52	19	100
December 2009	OC7	16	17	55	12	100
January 2010	OC7	13	9	57	21	100
November 2008	OC8	7	14	54	25	100
February 2009	OC8	11	17	51	21	100
May 2009	OC8	8	12	56	24	100
June 2009	OC8	10	15	63	12	100
July 2009	OC8	17	13	60	10	100
August 2009	OC8	9	12	62	18	100
September 2009	OC8	14	10	60	16	100
October 2009	OC8	10	12	64	14	100
November 2009	OC8	11	15	60	14	100
December 2009	OC8	4	14	60	21	100
January 2010	OC8	11	16	57	16	100
February 2009	OC9	10	9	68	13	100
May 2009	OC9	10	9	67	14	100
June 2009	OC9	11	6	71	12	100
July 2009	OC9	9	10	60	21	100
August 2009	OC9	9	12	67	12	100
September 2009	OC9	13	10	69	8	100
October 2009	OC9	9	9	75	7	100
November 2009	OC9	12	11	69	8	100
December 2009	OC9	11	11	66	12	100
January 2010	OC9	9	9	72	10	100
February 2009	OC10	24	8	60	8	100
May 2009	OC10	4	12	63	21	100
June 2009	OC10	12	8	64	16	100
July 2009	OC10	11	4	66	19	100
August 2009	OC10	22	5	54	19	100
September 2009	OC10	28	9	61	2	100
October 2009	OC10	9	8	72	11	100
November 2009	OC10	24	10	65	1	100
December 2009	OC10	19	7	69	5	100

Antibiotic Resistance Analysis: Raw Data						
Sampling Month	**Station**	**Human**	**Livestock**	**Wildlife**	**Pets**	**Sum**
January 2010	OC10	17	8	64	11	100
November 2008	OC11	27	7	59	7	100
May 2009	OC11	22	3	60	15	100
June 2009	OC11	12	5	56	27	100
July 2009	OC11	19	3	51	27	100
August 2009	OC11	16	0	64	19	100
September 2009	OC11	25	4	50	20	100
October 2009	OC11	23	2	56	19	100
November 2009	OC11	27	10	57	6	100
December 2009	OC11	18	3	53	26	100
January 2010	OC11	15	16	59	10	100
February 2009	OC12	19	1	79	1	100
May 2009	OC12	18	3	70	9	100
June 2009	OC12	10	9	63	18	100
July 2009	OC12	19	1	70	10	100
August 2009	OC12	18	5	66	11	100
September 2009	OC12	17	12	51	19	100
October 2009	OC12	19	8	68	6	100
November 2009	OC12	14	8	75	2	100
December 2009	OC12	20	0	69	11	100
January 2010	OC12	14	6	66	14	100
February 2009	OC13	19	10	64	7	100
May 2009	OC13	23	2	62	13	100
June 2009	OC13	16	12	69	3	100
July 2009	OC13	13	5	64	18	100
August 2009	OC13	18	9	68	5	100
September 2009	OC13	17	5	64	14	100
October 2009	OC13	15	4	76	4	100
November 2009	OC13	18	4	66	12	100
December 2009	OC13	20	11	68	1	100
January 2010	OC13	22	1	60	17	100
November 2008	OC14	4	6	79	11	100
February 2009	OC14	8	13	74	5	100
May 2009	OC14	10	13	75	3	100
June 2009	OC14	9	13	72	5	100
September 2009	OC14	8	11	77	4	100
October 2009	OC14	6	10	73	11	100
November 2008	OC15	13	17	57	13	100

Antibiotic Resistance Analysis: Raw Data						
Sampling Month	**Station**	**Human**	**Livestock**	**Wildlife**	**Pets**	**Sum**
February 2009	OC15	12	17	58	13	100
May 2009	OC15	15	17	58	10	100
July 2009	OC15	9	18	56	16	100
August 2009	OC15	11	18	56	16	100
November 2009	OC15	16	16	55	12	100
December 2009	OC15	8	14	57	20	99
January 2010	OC15	12	15	60	13	100
November 2008	OC16	1	14	71	14	100
December 2009	OC16	10	12	63	15	100
June 2009	OC16	3	15	70	12	100
September 2009	OC16	3	15	71	11	100
October 2009	OC16	7	17	68	8	100
November 2009	OC16	4	14	69	13	100
December 2009	OC16	1	17	70	13	100
January 2010	OC16	5	18	67	10	100
December 2008	OC17	3	5	92	0	100
June 2009	OC17	8	9	83	0	100
July 2009	OC17	7	9	85	0	100
August 2009	OC17	4	6	90	0	100
September 2009	OC17	2	3	95	0	100
October 2009	OC17	9	1	91	0	100
November 2009	OC17	3	4	93	0	100
December 2009	OC17	3	0	97	0	100
January 2010	OC17	1	2	97	0	100
December 2008	OC18	2	0	98	0	100
September 2009	OC18	0	2	98	0	100
October 2009	OC18	3	1	96	0	100
November 2009	OC18	1	5	94	0	100
December 2009	OC18	5	4	91	0	100
January 2010	OC18	1	3	96	0	100

Table B8: Percent Source Contributions based on rep-PCR Results for all samples.

Rep-PCR: Raw Data						
Sampling Month	**Station**	**Human**	**Livestock**	**Pets**	**Wildlife**	**Sum**
November 2008	10	0	0	0	100	100
December 2008	10	0	0	0	100	100
February 2009	10	0	0	0	100	100
May 2009	10	0	0	0	100	100
June 2009	10	0	0	0	100	100
July 2009	10	0	0	0	100	100
August 2009	10	0	0	0	100	100
September 2009	10	0	0	0	100	100
October 2009	10	0	0	0	100	100
November 2009	10	0	0	0	100	100
December 2009	10	0	0	0	100	100
January 2010	10	0	0	0	100	100
November 2008	10A	4	0	0	96	100
December 2008	10A	2	0	0	98	100
February 2009	10A	11	0	0	89	100
May 2009	10A	4	0	0	96	100
June 2009	10A	9	0	0	91	100
July 2009	10A	3	0	0	97	100
August 2009	10A	5	0	0	95	100
September 2009	10A	9	0	0	91	100
October 2009	10A	5	0	0	95	100
November 2009	10A	6	0	0	94	100
December 2009	10A	7	0	0	93	100
January 2010	10A	1	0	0	99	100
November 2008	10B	8	1	16	75	100
December 2008	10B	4	11	8	77	100
February 2009	10B	8	5	7	80	100
May 2009	10B	14	5	10	72	100
June 2009	10B	17	8	0	75	100
July 2009	10B	9	7	8	76	100
August 2009	10B	11	4	8	77	100
September 2009	10B	16	1	7	76	100
October 2009	10B	6	7	19	68	100
November 2009	10B	10	7	12	71	100
December 2009	10B	11	3	8	78	100
January 2010	10B	7	3	21	70	100

Rep-PCR: Raw Data						
Sampling Month	**Station**	**Human**	**Livestock**	**Pets**	**Wildlife**	**Sum**
February 2009	OC1A	10	3	25	62	100
May 2009	OC1A	5	4	26	65	100
June 2009	OC1A	16	6	17	60	100
July 2009	OC1A	13	3	28	56	100
August 2009	OC1A	12	6	22	61	100
September 2009	OC1A	7	6	30	57	100
October 2009	OC1A	8	5	25	62	100
November 2009	OC1A	7	7	28	58	100
December 2009	OC1A	11	7	27	55	100
January 2010	OC1A	11	5	24	60	100
February 2009	OC1B	10	9	22	59	100
May 2009	OC1B	13	10	16	61	100
June 2009	OC1B	7	13	22	58	100
July 2009	OC1B	16	3	24	57	100
August 2009	OC1B	7	7	22	64	100
September 2009	OC1B	12	10	14	64	100
October 2009	OC1B	8	8	24	60	100
November 2009	OC1B	13	7	18	62	100
December 2009	OC1B	7	4	29	60	100
January 2010	OC1B	7	9	29	55	100
November 2008	OC2	14	10	7	69	100
February 2009	OC2	16	4	21	59	100
May 2009	OC2	19	15	5	61	100
June 2009	OC2	8	8	28	56	100
July 2009	OC2	11	12	15	62	100
August 2009	OC2	20	10	2	69	100
September 2009	OC2	19	4	16	61	100
October 2009	OC2	23	6	11	61	100
November 2009	OC2	11	8	17	64	100
December 2009	OC2	15	12	14	59	100
January 2010	OC2	17	5	18	61	100
February 2009	OC3	13	13	12	62	100
May 2009	OC3	9	11	24	57	100
June 2009	OC3	11	9	24	56	100
July 2009	OC3	12	13	11	64	100
August 2009	OC3	11	9	24	56	100
September 2009	OC3	8	11	22	59	100
October 2009	OC3	12	16	10	62	100

Rep-PCR: Raw Data						
Sampling Month	**Station**	**Human**	**Livestock**	**Pets**	**Wildlife**	**Sum**
November 2009	OC3	12	13	14	60	100
December 2009	OC3	3	5	31	61	100
January 2010	OC3	9	11	17	63	100
November 2008	OC4	16	14	8	62	100
February 2009	OC4	13	3	26	58	100
May 2009	OC4	15	12	10	63	100
June 2009	OC4	9	14	13	63	100
July 2009	OC4	11	10	14	65	100
August 2009	OC4	12	13	11	64	100
September 2009	OC4	16	13	10	60	100
October 2009	OC4	15	10	17	57	100
November 2009	OC4	12	3	29	56	100
December 2009	OC4	9	9	30	52	100
January 2010	OC4	6	8	26	60	100
February 2009	OC5	15	11	8	66	100
May 2009	OC5	9	10	14	68	100
June 2009	OC5	6	5	25	64	100
July 2009	OC5	10	12	19	60	100
August 2009	OC5	8	5	23	65	100
September 2009	OC5	11	7	12	71	100
October 2009	OC5	8	11	19	62	100
November 2009	OC5	5	3	27	65	100
December 2009	OC5	12	8	14	66	100
January 2010	OC5	7	9	20	64	100
February 2009	OC6	13	14	14	59	100
May 2009	OC6	14	12	12	62	100
June 2009	OC6	18	13	7	62	100
July 2009	OC6	15	5	20	60	100
August 2009	OC6	13	9	17	61	100
September 2009	OC6	13	13	11	63	100
October 2009	OC6	20	11	0	69	100
November 2009	OC6	15	12	8	65	100
December 2009	OC6	18	14	2	66	100
January 2010	OC6	10	7	19	63	100
February 2009	OC7	16	7	20	57	100
May 2009	OC7	18	13	6	63	100
June 2009	OC7	15	7	12	65	100
July 2009	OC7	19	11	9	61	100

Rep-PCR: Raw Data						
Sampling Month	**Station**	**Human**	**Livestock**	**Pets**	**Wildlife**	**Sum**
August 2009	OC7	14	12	15	59	100
September 2009	OC7	22	10	6	62	100
October 2009	OC7	16	7	20	58	100
November 2009	OC7	14	12	13	61	100
December 2009	OC7	16	7	19	58	100
January 2010	OC7	11	4	30	55	100
November 2008	OC8	4	13	23	60	100
February 2009	OC8	10	9	23	57	100
May 2009	OC8	8	4	31	57	100
June 2009	OC8	5	13	24	57	100
July 2009	OC8	15	10	12	63	100
August 2009	OC8	6	7	27	59	100
September 2009	OC8	8	13	18	61	100
October 2009	OC8	7	11	25	57	100
November 2009	OC8	9	13	23	55	100
December 2009	OC8	10	13	14	63	100
January 2010	OC8	9	14	18	58	100
February 2009	OC9	11	10	20	59	100
May 2009	OC9	14	7	20	59	100
June 2009	OC9	18	9	17	55	100
July 2009	OC9	9	10	28	53	100
August 2009	OC9	10	6	23	61	100
September 2009	OC9	12	11	22	56	100
October 2009	OC9	10	17	17	56	100
November 2009	OC9	17	7	24	52	100
December 2009	OC9	14	12	14	60	100
January 2010	OC9	15	9	16	59	100
February 2009	OC10	21	7	0	73	100
May 2009	OC10	20	10	0	70	100
June 2009	OC10	19	2	11	68	100
July 2009	OC10	16	5	9	70	100
August 2009	OC10	24	1	9	65	100
September 2009	OC10	20	6	7	66	100
October 2009	OC10	15	1	16	69	100
November 2009	OC10	24	2	8	65	100
December 2009	OC10	19	4	14	63	100
January 2010	OC10	22	2	8	69	100
November 2008	OC11	13	6	19	62	100

Rep-PCR: Raw Data						
Sampling Month	**Station**	**Human**	**Livestock**	**Pets**	**Wildlife**	**Sum**
May 2009	OC11	19	3	21	57	100
June 2009	OC11	25	4	7	65	100
July 2009	OC11	17	2	20	61	100
August 2009	OC11	17	10	18	55	100
September 2009	OC11	18	4	17	61	100
October 2009	OC11	20	6	10	64	100
November 2009	OC11	19	1	22	58	100
December 2009	OC11	20	5	16	59	100
January 2010	OC11	21	9	11	59	100
February 2009	OC12	12	2	16	71	100
May 2009	OC12	19	6	5	70	100
June 2009	OC12	15	2	9	74	100
July 2009	OC12	17	2	6	76	100
August 2009	OC12	11	4	16	69	100
September 2009	OC12	20	0	12	68	100
October 2009	OC12	14	3	14	68	100
November 2009	OC12	17	7	8	68	100
December 2009	OC12	12	0	19	69	100
January 2010	OC12	15	2	11	72	100
February 2009	OC13	20	4	20	55	100
May 2009	OC13	16	8	15	61	100
June 2009	OC13	21	6	13	59	100
July 2009	OC13	19	2	20	59	100
August 2009	OC13	18	4	16	63	100
September 2009	OC13	16	1	21	62	100
October 2009	OC13	17	1	27	55	100
November 2009	OC13	16	7	19	58	100
December 2009	OC13	22	2	13	62	100
January 2010	OC13	25	7	13	55	100
November 2008	OC14	10	2	1	88	100
February 2009	OC14	10	5	12	73	100
May 2009	OC14	10	5	10	76	100
June 2009	OC14	10	4	5	81	100
September 2009	OC14	10	0	14	76	100
October 2009	OC14	9	1	2	88	100
November 2008	OC15	11	7	7	75	100
February 2009	OC15	10	9	7	74	100
May 2009	OC15	10	4	8	78	100

Rep-PCR: Raw Data						
Sampling Month	**Station**	**Human**	**Livestock**	**Pets**	**Wildlife**	**Sum**
July 2009	OC15	2	5	13	80	100
August 2009	OC15	9	9	12	70	100
November 2009	OC15	10	5	10	75	100
December 2009	OC15	9	3	12	76	100
January 2010	OC15	6	6	13	75	100
November 2008	OC16	0	0	28	72	100
December 2009	OC16	0	0	30	70	100
June 2009	OC16	0	0	32	68	100
September 2009	OC16	0	0	28	72	100
October 2009	OC16	0	0	28	72	100
November 2009	OC16	0	0	32	68	100
December 2009	OC16	0	0	31	69	100
January 2010	OC16	0	0	33	67	100
December 2008	OC17	0	0	0	100	100
June 2009	OC17	0	0	0	100	100
July 2009	OC17	0	0	0	100	100
August 2009	OC17	0	0	0	100	100
September 2009	OC17	0	0	0	100	100
October 2009	OC17	0	0	0	100	100
November 2009	OC17	0	0	0	100	100
December 2009	OC17	0	0	0	100	100
January 2010	OC17	0	0	0	100	100
December 2008	OC18	0	0	0	100	100
September 2009	OC18	0	0	0	100	100
October 2009	OC18	0	0	0	100	100
November 2009	OC18	0	0	0	100	100
December 2009	OC18	0	0	0	100	100
January 2010	OC18	0	0	0	100	100

Table B9: Raw Data for Optical Brighteners and HS-HF183

Station	Average OB (µg/L) value Before UV exposure	Average OB (µg/L) value After UV exposure	Average OB Decline (%)	HS-HF183
10	66.3	57.2	14	-
10	68.2	55.5	19	-
10	62.3	61.3	2	-
10A	65.3	61.7	5	-
10A	68.9	60.0	13	-
10A	62.9	55.9	11	-
10B	103.7	72.9	30	-
10B	103.7	72.5	30	-
10B	110.6	67.5	39	+
OC1A	139.0	110.6	20	-
OC1A	151.5	108.2	29	-
OC1A	156.5	114.2	27	+
OC1B	162.7	105.7	35	+
OC1B	151.4	104.8	31	-
OC1B	144.9	110.4	24	-
OC2	158.9	102.0	36	+
OC2	144.8	96.5	33	-
OC2	137.3	97.3	29	-
OC3	148.4	94.4	36	+
OC3	144.0	95.9	33	-
OC3	136.5	100.2	27	-
OC4	153.8	94.9	38	+
OC4	141.9	100.9	29	-
OC4	154.3	98.5	36	-
OC5	149.1	91.7	39	+
OC5	152.7	93.0	39	-
OC5	139.2	100.9	27	-
OC6	139.0	97.2	30	-
OC6	150.1	91.3	39	-
OC6	151.9	101.3	33	+
OC7	145.5	89.6	38	+
OC7	140.2	80.9	42	-
OC7	140.3	89.5	36	-
OC8	136.7	82.6	40	+
OC8	140.6	87.9	37	+
OC8	130.7	92.6	29	-
OC9	148.9	97.4	35	+

Station	Average OB (µg/L) value Before UV exposure	Average OB (µg/L) value After UV exposure	Average OB Decline (%)	HS-HF183
OC9	133.4	85.3	36	-
OC9	137.6	85.2	38	+
OC10	113.0	66.9	41	+
OC10	107.7	72.2	33	+
OC10	97.3	80.8	17	-
OC11	124.3	68.4	45	+
OC11	108.5	81.0	25	-
OC11	118.2	80.0	32	-
OC12	136.4	100.5	26	-
OC12	138.4	90.4	35	+
OC12	151.2	87.1	42	+
OC13	125.2	77.7	38	+
OC13	111.6	65.6	41	+
OC13	111.2	77.8	30	-
OC14	135.9	69.9	49	-
OC14	118.4	82.5	30	-
OC14	123.7	81.5	34	-
OC15	82.5	57.8	30	-
OC15	88.2	71.7	19	-
OC15	90.3	64.0	29	-
OC16	135.4	108.4	20	-
OC16	133.0	94.5	29	-
OC16	127.6	103.1	19	-
OC17	164.1	126.2	23	-
OC17	156.5	138.1	12	-
OC17	162.4	125.7	23	-
OC18	46.0	40.3	12	-
OC18	53.9	34.3	36	-
OC18	48.9	37.9	22	0

Appendix C. Model Inputs and Simulation Results

Table C1: Geometric Information Used for Each Segment

Segment	Surface Area (m^2)	Mean Depth (m)	Cross Section Area (m^2)	Dispersion Coefficient (m^3/s)	Watershed Flow (m^3/s)	
					Median	90th Percentile
1	1616	0.5	14.9	11.7	1.65×10^{-1}	3.86×10^{-1}
2	3246	0.6	22.8	14.4	8.70×10^{-2}	2.03×10^{-1}
3	6346	0.7	37.5	20.6	7.55×10^{-3}	1.77×10^{-2}
4	7816	0.8	75.7	38.2	1.52×10^{-3}	3.56×10^{-3}
5	12604	0.9	104.5	44.0	5.00×10^{-3}	1.17×10^{-2}
6	20228	1.0	182.6	76.9	1.46×10^{-3}	3.41×10^{-3}
7	21356	1.2	193.1	71.7	7.82×10^{-4}	1.83×10^{-3}
8	29236	1.5	323.0	31.4	2.83×10^{-4}	6.62×10^{-3}
B4	1439	0.6	35.0	24.6	4.39×10^{-4}	1.03×10^{-3}
B7	8451	0.8	63.0	22.7	5.05×10^{-3}	1.18×10^{-2}
B8	26619	1.0	222.5	46.9	5.38×10^{-3}	1.26×10^{-2}

Table C2: WinBUGS Simulation Results of Fecal Coliform Concentrations (MPN/100ml) in Each Segment Using Median and 90th Percentile of the Observational Data (2005-2010)

Endpoint	Segment	mean	2.50%	median	97.50%
Median	1	17.98	13.67	17.85	23.04
	2	17.02	13.29	16.92	21.46
	3	14.89	12.00	14.72	18.83
	4	12.57	10.06	12.34	16.35
	5	10.57	8.28	10.35	14.17
	6	8.63	6.53	8.41	11.94
	7	7.36	5.40	7.15	10.53
	8	5.53	3.92	5.36	8.26
	B4	13.09	10.31	12.83	17.32
	B7	8.19	5.67	7.89	12.43
	B8	5.95	4.03	5.70	9.32
90th Percentile	1	267.70	210.80	265.40	338.50
	2	261.90	209.90	260.20	324.40
	3	239.50	197.60	237.40	293.30
	4	209.70	173.20	207.20	260.40
	5	180.70	147.60	178.50	227.20
	6	153.90	121.80	151.90	197.70
	7	136.00	104.70	134.20	178.10
	8	105.50	77.99	103.70	143.50
	B4	218.20	177.70	215.10	276.50
	B7	159.10	113.00	155.40	225.70
	B8	116.50	81.07	113.30	170.10

Table C3: Fecal Coliform Loadings ($\times 10^4$ Counts/Second) in Each Segment using Median, and 90th Percentile of the Observational Data (2005-2010)

Endpoint	Segment	mean	2.50%	median	97.50%
Median	1	14.28	0.49	11.97	40.04
	2	20.97	0.75	18.24	55.48
	3	17.47	0.52	13.55	54.91
	4	15.61	0.45	11.61	52.60
	5	16.41	0.41	11.89	56.77
	6	18.48	0.51	13.21	64.96
	7	20.06	0.54	14.06	72.85
	8	0.25	0.01	0.17	0.91
	B4	12.91	0.35	9.48	44.44
	B7	19.39	0.58	14.41	64.61
	B8	20.86	0.59	14.55	76.48
90th Percentile	1	172.90	5.57	137.70	532.00
	2	309.90	11.45	271.10	821.80
	3	291.50	9.38	228.00	900.80
	4	274.70	8.01	202.70	923.00
	5	332.80	9.49	246.40	1134.00
	6	427.20	13.01	318.10	1434.00
	7	497.90	13.47	366.30	1677.00
	8	6.28	0.17	4.72	20.90
	B4	212.50	6.26	154.10	734.10
	B7	535.30	19.01	446.60	1529.00
	B8	541.80	16.76	415.80	1760.00

Appendix D. Fecal Indicator Data

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
11/22/2008	35°23'34.13"N	76°18'40.04"W	*E. coli*	26.5	14.2	44	OC-4
11/22/2008	35°23'30.21"N	76°18'43.69"W	*E. coli*	83.9	56.5	119.4	OC-2
11/22/2008	35°23'27.81"N	76°18'45.68"W	*E. coli*	60.3	39.4	88.4	OC-8
11/22/2008	35°23'26.51"N	76°18'47.57"W	*E. coli*	76.8	51.7	110.7	OC-11
11/22/2008	35°23'18.82"N	76°18'50.82"W	*E. coli*	37	22	58.4	OC-15
11/22/2008	35°23'22.07"N	76°18'51.17"W	*E. coli*	49.2	30.3	75.3	10B
11/22/2008	35°23'24.69"N	76°18'51.43"W	*E. coli*	27	15.6	46.8	OC-14
11/22/2008	35°23'14.11"N	76°18'51.64"W	*E. coli*	21.6	10.3	37.2	OC-16
11/22/2008	35°23'5.62"N	76°18'58.97"W	*E. coli*	19.2	8.8	33.9	10A
11/22/2008	35°23'6.13"N	76°19'21.80"W	*E. coli*	10.4	4.6	23.9	10
11/22/2008	35°23'34.13"N	76°18'40.04"W	Enterococci	107.2	76.4	146	OC-4
11/22/2008	35°23'30.21"N	76°18'43.69"W	Enterococci	76.2	52.9	105.6	OC-2
11/22/2008	35°23'27.81"N	76°18'45.68"W	Enterococci	226	165.5	298.1	OC-8
11/22/2008	35°23'26.51"N	76°18'47.57"W	Enterococci	186.8	140.5	243.8	OC-11
11/22/2008	35°23'18.82"N	76°18'50.82"W	Enterococci	96.2	66.7	132.2	OC-15
11/22/2008	35°23'22.07"N	76°18'51.17"W	Enterococci	128.9	91.9	174.6	10B
11/22/2008	35°23'24.69"N	76°18'51.43"W	Enterococci	157.6	115.4	207.2	OC-14
11/22/2008	35°23'14.11"N	76°18'51.64"W	Enterococci	41.7	24.9	64.6	OC-16
11/22/2008	35°23'5.62"N	76°18'58.97"W	Enterococci	51.9	33.9	76.2	10A
11/22/2008	35°23'6.13"N	76°19'21.80"W	Enterococci	43.6	26.8	66.2	10
12/20/2008	35°23'22.07"N	76°18'51.17"W	*E. coli*	29	15.6	47.1	10B
12/20/2008	35°23'14.11"N	76°18'51.64"W	*E. coli*	6.1	1.4	17.9	OC-16
12/20/2008	35°23'9.19"N	76°18'52.37"W	*E. coli*	< 2.0	0	7.3	OC-17
12/20/2008	35°23'1.70"N	76°18'53.79"W	*E. coli*	4	0.5	11.8	OC-18
12/20/2008	35°23'5.62"N	76°18'58.97"W	*E. coli*	12.3	4.7	24.3	10A
12/20/2008	35°23'6.13"N	76°19'21.80"W	*E. coli*	4	0.5	14.3	10

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
12/20/2008	35°23'22.07"N	76°18'51.17"W	Enterococci	397.8	283.6	546.7	10B
12/20/2008	35°23'14.11"N	76°18'51.64"W	Enterococci	207.9	152.3	274	OC-16
12/20/2008	35°23'9.19"N	76°18'52.37"W	Enterococci	439.6	347.8	546.7	OC-17
12/20/2008	35°23'1.70"N	76°18'53.79"W	Enterococci	235.5	172.5	316.5	OC-18
12/20/2008	35°23'5.62"N	76°18'58.97"W	Enterococci	821.2	521.2	1237.8	10A
12/20/2008	35°23'6.13"N	76°19'21.80"W	Enterococci	651.1	413.3	996.2	10
02/27/2009	35°23'34.13"N	76°18'40.04"W	*E. coli*	77.5	52.2	109.5	OC-4
02/27/2009	35°23'30.94"N	76°18'42.20"W	*E. coli*	60.3	39.4	88.4	OC-3
02/27/2009	35°23'30.21"N	76°18'43.69"W	*E. coli*	64.5	42.2	94.3	OC-2
02/27/2009	35°23'31.96"N	76°18'43.86"W	*E. coli*	43.6	26.8	67.8	OC-1B
02/27/2009	35°23'31.89"N	76°18'44.06"W	*E. coli*	2	0.1	7.3	OC-1A
02/27/2009	35°23'28.78"N	76°18'44.43"W	*E. coli*	48.1	29.6	72.9	OC-7
02/27/2009	35°23'29.46"N	76°18'44.46"W	*E. coli*	55	34.9	82.4	OC-5
02/27/2009	35°23'29.20"N	76°18'44.94"W	*E. coli*	380.8	271.4	508.2	OC-6
02/27/2009	35°23'27.81"N	76°18'45.68"W	*E. coli*	31.3	17.4	50.5	OC-8
02/27/2009	35°23'27.37"N	76°18'46.43"W	*E. coli*	52.4	33.3	79.4	OC-9
02/27/2009	35°23'25.28"N	76°18'48.92"W	*E. coli*	37.4	21.5	60	OC-13
02/27/2009	35°23'29.11"N	76°18'49.20"W	*E. coli*	77.9	52.5	111.8	OC-10
02/27/2009	35°23'28.81"N	76°18'50.30"W	*E. coli*	45.1	27.7	68.9	OC-12
02/27/2009	35°23'18.82"N	76°18'50.82"W	*E. coli*	24.2	13	42.2	OC-15
02/27/2009	35°23'22.07"N	76°18'51.17"W	*E. coli*	126.3	90	173.9	10B
02/27/2009	35°23'24.69"N	76°18'51.43"W	*E. coli*	31.6	17.6	51.4	OC-14
02/27/2009	35°23'5.62"N	76°18'58.97"W	*E. coli*	10.4	4.6	23.9	10A
02/27/2009	35°23'6.13"N	76°19'21.80"W	*E. coli*	4	0.5	14.3	10
02/27/2009	35°23'34.13"N	76°18'40.04"W	Enterococci	14.8	6.5	28.8	OC-4
02/27/2009	35°23'30.94"N	76°18'42.20"W	Enterococci	12.6	5.8	27.4	OC-3
02/27/2009	35°23'30.21"N	76°18'43.69"W	Enterococci	24	11.9	40.5	OC-2
02/27/2009	35°23'31.96"N	76°18'43.86"W	Enterococci	46.7	28.7	72.2	OC-1B
02/27/2009	35°23'31.89"N	76°18'44.06"W	Enterococci	28.7	15.4	47.1	OC-1A

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
02/27/2009	35°23'28.78"N	76°18'44.43"W	Enterococci	12.6	5.8	27.4	OC-7
02/27/2009	35°23'29.46"N	76°18'44.46"W	Enterococci	8.2	2.3	18.1	OC-5
02/27/2009	35°23'29.20"N	76°18'44.94"W	Enterococci	289.9	229.3	363.7	OC-6
02/27/2009	35°23'27.81"N	76°18'45.68"W	Enterococci	17	7.8	31.3	OC-8
02/27/2009	35°23'27.37"N	76°18'46.43"W	Enterococci	6.1	1.4	17.9	OC-9
02/27/2009	35°23'25.28"N	76°18'48.92"W	Enterococci	23.3	12.1	40.2	OC-13
02/27/2009	35°23'29.11"N	76°18'49.20"W	Enterococci	8.2	2.3	18.1	OC-10
02/27/2009	35°23'28.81"N	76°18'50.30"W	Enterococci	8.3	3.3	19	OC-12
02/27/2009	35°23'18.82"N	76°18'50.82"W	Enterococci	4	0.5	14.3	OC-15
02/27/2009	35°23'22.07"N	76°18'51.17"W	Enterococci	37	22	58.4	10B
02/27/2009	35°23'24.69"N	76°18'51.43"W	Enterococci	12.6	5.8	27.4	OC-14
02/27/2009	35°23'5.62"N	76°18'58.97"W	Enterococci	6.1	1.4	17.9	10A
02/27/2009	35°23'6.13"N	76°19'21.80"W	Enterococci	2	0.1	11	10
05/08/2009	35°23'34.13"N	76°18'40.04"W	*E. coli*	89.6	60.4	126.7	OC-4
05/08/2009	35°23'30.94"N	76°18'42.20"W	*E. coli*	21.4	10.2	37.1	OC-3
05/08/2009	35°23'30.21"N	76°18'43.69"W	*E. coli*	30.9	17.2	50.2	OC-2
05/08/2009	35°23'31.96"N	76°18'43.86"W	*E. coli*	6.1	1.4	17.9	OC-1B
05/08/2009	35°23'31.89"N	76°18'44.06"W	*E. coli*	10.4	4.6	23.9	OC-1A
05/08/2009	35°23'28.78"N	76°18'44.43"W	*E. coli*	68.1	44.6	98.4	OC-7
05/08/2009	35°23'29.46"N	76°18'44.46"W	*E. coli*	46.7	28.7	72.2	OC-5
05/08/2009	35°23'29.20"N	76°18'44.94"W	*E. coli*	54.4	34.5	80.4	OC-6
05/08/2009	35°23'27.81"N	76°18'45.68"W	*E. coli*	39.3	23.4	61.4	OC-8
05/08/2009	35°23'27.37"N	76°18'46.43"W	*E. coli*	36.6	21.1	57.6	OC-9
05/08/2009	35°23'26.51"N	76°18'47.57"W	*E. coli*	46.1	28.4	71.4	OC-11
05/08/2009	35°23'25.28"N	76°18'48.92"W	*E. coli*	44.1	27.1	67.4	OC-13
05/08/2009	35°23'29.11"N	76°18'49.20"W	*E. coli*	19.4	8.9	34.3	OC-10
05/08/2009	35°23'28.81"N	76°18'50.30"W	*E. coli*	31.3	17.4	50.5	OC-12
05/08/2009	35°23'18.82"N	76°18'50.82"W	*E. coli*	< 2.0	0	7.3	OC-15
05/08/2009	35°23'22.07"N	76°18'51.17"W	*E. coli*	4	0.5	14.3	10B

Sample Date	**Latitude**	**Longitude**	**Analyte**	**MPN/100mL**	**Lower Limit**	**Upper Limit**	**Sample Code**
05/08/2009	35°23'24.69"N	76°18'51.43"W	*E. coli*	4	0.5	14.3	OC-14
05/08/2009	35°23'5.62"N	76°18'58.97"W	*E. coli*	< 2.0	0	7.3	10A
05/08/2009	35°23'6.13"N	76°19'21.80"W	*E. coli*	2	0.1	11	10
05/08/2009	35°23'34.13"N	76°18'40.04"W	Enterococci	2406.7	1621.7	3501.4	OC-4
05/08/2009	35°23'30.94"N	76°18'42.20"W	Enterococci	2599.3	1700.7	3793.1	OC-3
05/08/2009	35°23'30.21"N	76°18'43.69"W	Enterococci	4839.1	3260.7	9432.2	OC-2
05/08/2009	35°23'31.96"N	76°18'43.86"W	Enterococci	1841.7	1241	2564	OC-1B
05/08/2009	35°23'31.89"N	76°18'44.06"W	Enterococci	> 4839.2	2879	infini.e	OC-1A
05/08/2009	35°23'28.78"N	76°18'44.43"W	Enterococci	1960.8	1321.2	2820.3	OC-7
05/08/2009	35°23'29.46"N	76°18'44.46"W	Enterococci	1732.9	1167.7	2490.8	OC-5
05/08/2009	35°23'29.20"N	76°18'44.94"W	Enterococci	1454	951.3	2097.7	OC-6
05/08/2009	35°23'27.81"N	76°18'45.68"W	Enterococci	2092.5	1410	3018.1	OC-8
05/08/2009	35°23'27.37"N	76°18'46.43"W	Enterococci	730.8	463.9	1110.9	OC-9
05/08/2009	35°23'26.51"N	76°18'47.57"W	Enterococci	1373.3	898.6	1948.8	OC-11
05/08/2009	35°23'25.28"N	76°18'48.92"W	Enterococci	651.1	413.3	996.2	OC-13
05/08/2009	35°23'29.11"N	76°18'49.20"W	Enterococci	1373.3	898.6	1948.8	OC-10
05/08/2009	35°23'28.81"N	76°18'50.30"W	Enterococci	1034.4	676.8	1527.1	OC-12
05/08/2009	35°23'18.82"N	76°18'50.82"W	Enterococci	172.5	126.3	230.7	OC-15
05/08/2009	35°23'22.07"N	76°18'51.17"W	Enterococci	197.3	144.5	267.3	10B
05/08/2009	35°23'24.69"N	76°18'51.43"W	Enterococci	291	213.1	386.3	OC-14
05/08/2009	35°23'5.62"N	76°18'58.97"W	Enterococci	366.9	268.8	486.3	10A
05/08/2009	35°23'6.13"N	76°19'21.80"W	Enterococci	171.5	122.3	234.4	10
06/20/2009	35°23'34.13"N	76°18'40.04"W	*E. coli*	95.7	64.5	135	OC-4
06/20/2009	35°23'30.94"N	76°18'42.20"W	*E. coli*	100.8	69.9	138.2	OC-3
06/20/2009	35°23'30.21"N	76°18'43.69"W	*E. coli*	49.2	30.3	75.3	OC-2
06/20/2009	35°23'31.96"N	76°18'43.86"W	*E. coli*	70	47.1	100.7	OC-1B
06/20/2009	35°23'31.89"N	76°18'44.06"W	*E. coli*	60.3	39.4	88.4	OC-1A
06/20/2009	35°23'28.78"N	76°18'44.43"W	*E. coli*	97.5	67.6	136	OC-7
06/20/2009	35°23'29.46"N	76°18'44.46"W	*E. coli*	116.7	80.9	161.2	OC-5

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
06/20/2009	35°23'29.20"N	76°18'44.94"W	*E. coli*	159.5	113.7	213.9	OC-6
06/20/2009	35°23'27.81"N	76°18'45.68"W	*E. coli*	115.1	79.8	160	OC-8
06/20/2009	35°23'27.37"N	76°18'46.43"W	*E. coli*	131.3	91	180.6	OC-9
06/20/2009	35°23'26.51"N	76°18'47.57"W	*E. coli*	111.1	77	154.3	OC-11
06/20/2009	35°23'25.28"N	76°18'48.92"W	*E. coli*	88.2	61.2	125	OC-13
06/20/2009	35°23'29.11"N	76°18'49.20"W	*E. coli*	157.9	112.6	217.6	OC-10
06/20/2009	35°23'28.81"N	76°18'50.30"W	*E. coli*	136.6	97.4	185.9	OC-12
06/20/2009	35°23'22.07"N	76°18'51.17"W	*E. coli*	63.7	41.7	92.7	10B
06/20/2009	35°23'24.69"N	76°18'51.43"W	*E. coli*	61	38.7	89.5	OC-14
06/20/2009	35°23'14.11"N	76°18'51.64"W	*E. coli*	21.8	11.3	39	OC-16
06/20/2009	35°23'9.19"N	76°18'52.37"W	*E. coli*	31.6	17.6	51.4	OC-17
06/20/2009	35°23'5.62"N	76°18'58.97"W	*E. coli*	48.1	29.6	72.9	10A
06/20/2009	35°23'6.13"N	76°19'21.80"W	*E. coli*	19.6	9.4	36.7	10
06/20/2009	35°23'34.13"N	76°18'40.04"W	Enterococci	441.2	305.9	625.2	OC-4
06/20/2009	35°23'30.94"N	76°18'42.20"W	Enterococci	271.8	172.5	401.9	OC-3
06/20/2009	35°23'30.21"N	76°18'43.69"W	Enterococci	186.9	107.7	299.8	OC-2
06/20/2009	35°23'31.96"N	76°18'43.86"W	Enterococci	318.4	208.4	463.7	OC-1B
06/20/2009	35°23'31.89"N	76°18'44.06"W	Enterococci	173.1	103.1	281.5	OC-1A
06/20/2009	35°23'28.78"N	76°18'44.43"W	Enterococci	669.5	477.3	915.1	OC-7
06/20/2009	35°23'29.46"N	76°18'44.46"W	Enterococci	410.3	276.5	587.9	OC-5
06/20/2009	35°23'29.20"N	76°18'44.94"W	Enterococci	354.5	238.8	510.2	OC-6
06/20/2009	35°23'27.81"N	76°18'45.68"W	Enterococci	383.9	258.7	553.5	OC-8
06/20/2009	35°23'27.37"N	76°18'46.43"W	Enterococci	173.1	103.1	281.5	OC-9
06/20/2009	35°23'26.51"N	76°18'47.57"W	Enterococci	240.5	148	364.5	OC-11
06/20/2009	35°23'25.28"N	76°18'48.92"W	Enterococci	184.9	110.1	292.2	OC-13
06/20/2009	35°23'29.11"N	76°18'49.20"W	Enterococci	331	216.6	481.3	OC-10
06/20/2009	35°23'28.81"N	76°18'50.30"W	Enterococci	246.2	151.4	376.4	OC-12
06/20/2009	35°23'22.07"N	76°18'51.17"W	Enterococci	96.9	44.5	171.6	10B
06/20/2009	35°23'24.69"N	76°18'51.43"W	Enterococci	20.2	2.6	71.3	OC-14

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
06/20/2009	35°23'14.11"N	76°18'51.64"W	Enterococci	132.3	71	220.1	OC-16
06/20/2009	35°23'9.19"N	76°18'52.37"W	Enterococci	< 10.0	0	36.7	OC-17
06/20/2009	35°23'5.62"N	76°18'58.97"W	Enterococci	62.6	25.1	127.3	10A
06/20/2009	35°23'6.13"N	76°19'21.80"W	Enterococci	10	0.5	54.9	10
07/10/2009	35°23'34.13"N	76°18'40.04"W	*E. coli*	544.6	367	765.8	OC-4
07/10/2009	35°23'30.94"N	76°18'42.20"W	*E. coli*	570.2	395.4	797.5	OC-3
07/10/2009	35°23'30.21"N	76°18'43.69"W	*E. coli*	456.4	316.4	646.2	OC-2
07/10/2009	35°23'31.96"N	76°18'43.86"W	*E. coli*	480.1	351.6	657.1	OC-1B
07/10/2009	35°23'31.89"N	76°18'44.06"W	*E. coli*	380.8	271.4	508.2	OC-1A
07/10/2009	35°23'28.78"N	76°18'44.43"W	*E. coli*	1540.2	1098	2188.1	OC-7
07/10/2009	35°23'29.46"N	76°18'44.46"W	*E. coli*	497.8	345.2	700.5	OC-5
07/10/2009	35°23'29.20"N	76°18'44.94"W	*E. coli*	1632.8	1100.2	2349.2	OC-6
07/10/2009	35°23'27.81"N	76°18'45.68"W	*E. coli*	688.2	490.6	944.9	OC-8
07/10/2009	35°23'27.37"N	76°18'46.43"W	*E. coli*	380.8	271.4	508.2	OC-9
07/10/2009	35°23'26.51"N	76°18'47.57"W	*E. coli*	1297.6	849	1882.9	OC-11
07/10/2009	35°23'25.28"N	76°18'48.92"W	*E. coli*	774.6	491.7	1134.1	OC-13
07/10/2009	35°23'29.11"N	76°18'49.20"W	*E. coli*	1960.8	1321.2	2820.3	OC-10
07/10/2009	35°23'28.81"N	76°18'50.30"W	*E. coli*	368.4	269.8	502.7	OC-12
07/10/2009	35°23'18.82"N	76°18'50.82"W	*E. coli*	357.1	247.6	500.9	OC-15
07/10/2009	35°23'22.07"N	76°18'51.17"W	*E. coli*	368.4	269.8	502.7	10B
07/10/2009	35°23'9.19"N	76°18'52.37"W	*E. coli*	437.4	303.3	629.1	OC-17
07/10/2009	35°23'5.62"N	76°18'58.97"W	*E. coli*	407.1	298.2	540.6	10A
07/10/2009	35°23'6.13"N	76°19'21.80"W	*E. coli*	181.3	129.2	248.1	10
07/10/2009	35°23'34.13"N	76°18'40.04"W	Enterococci	836.1	596.1	1138.3	OC-4
07/10/2009	35°23'30.94"N	76°18'42.20"W	Enterococci	364.1	238.2	525.5	OC-3
07/10/2009	35°23'30.21"N	76°18'43.69"W	Enterococci	246.2	151.4	376.4	OC-2
07/10/2009	35°23'31.96"N	76°18'43.86"W	Enterococci	624.4	432.9	861.7	OC-1B
07/10/2009	35°23'31.89"N	76°18'44.06"W	Enterococci	690.7	478.9	955.6	OC-1A
07/10/2009	35°23'28.78"N	76°18'44.43"W	Enterococci	486.6	327.9	690.1	OC-7

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
07/10/2009	35°23'29.46"N	76°18'44.46"W	Enterococci	404.4	272.5	574.1	OC-5
07/10/2009	35°23'29.20"N	76°18'44.94"W	Enterococci	382.5	257.7	537.5	OC-6
07/10/2009	35°23'27.81"N	76°18'45.68"W	Enterococci	1624.2	1189.6	2156.7	OC-8
07/10/2009	35°23'27.37"N	76°18'46.43"W	Enterococci	860	613.1	1155.1	OC-9
07/10/2009	35°23'26.51"N	76°18'47.57"W	Enterococci	40.5	11.5	89.5	OC-11
07/10/2009	35°23'25.28"N	76°18'48.92"W	Enterococci	186.9	107.7	299.8	OC-13
07/10/2009	35°23'29.11"N	76°18'49.20"W	Enterococci	1552.5	1076.5	2187.2	OC-10
07/10/2009	35°23'28.81"N	76°18'50.30"W	Enterococci	988.1	704.4	1353.4	OC-12
07/10/2009	35°23'18.82"N	76°18'50.82"W	Enterococci	1841.7	1241	2564	OC-15
07/10/2009	35°23'22.07"N	76°18'51.17"W	Enterococci	1540.2	1098	2188.1	10B
07/10/2009	35°23'9.19"N	76°18'52.37"W	Enterococci	1841.7	1241	2564	OC-17
07/10/2009	35°23'5.62"N	76°18'58.97"W	Enterococci	1841.7	1241	2564	10A
07/10/2009	35°23'6.13"N	76°19'21.80"W	Enterococci	1095	716.5	1608.9	10
08/18/2009	35°23'34.13"N	76°18'40.04"W	*E. coli*	1158.9	758.2	1694.3	OC-4
08/18/2009	35°23'30.94"N	76°18'42.20"W	*E. coli*	756.9	524.8	1052.3	OC-3
08/18/2009	35°23'30.21"N	76°18'43.69"W	*E. coli*	821.2	521.2	1237.8	OC-2
08/18/2009	35°23'31.96"N	76°18'43.86"W	*E. coli*	689.6	437.7	1041.3	OC-1B
08/18/2009	35°23'31.89"N	76°18'44.06"W	*E. coli*	626	434.1	879	OC-1A
08/18/2009	35°23'28.78"N	76°18'44.43"W	*E. coli*	2599.3	1700.7	3793.1	OC-7
08/18/2009	35°23'29.46"N	76°18'44.46"W	*E. coli*	730.8	463.9	1110.9	OC-5
08/18/2009	35°23'29.20"N	76°18'44.94"W	*E. coli*	3972.6	2444.1	6600.5	OC-6
08/18/2009	35°23'27.81"N	76°18'45.68"W	*E. coli*	1095	716.5	1608.9	OC-8
08/18/2009	35°23'27.37"N	76°18'46.43"W	*E. coli*	626	434.1	879	OC-9
08/18/2009	35°23'26.51"N	76°18'47.57"W	*E. coli*	1226.3	802.4	1758.4	OC-11
08/18/2009	35°23'25.28"N	76°18'48.92"W	*E. coli*	922.2	585.4	1375.8	OC-13
08/18/2009	35°23'29.11"N	76°18'49.20"W	*E. coli*	2239.7	1509.2	3228	OC-10
08/18/2009	35°23'28.81"N	76°18'50.30"W	*E. coli*	976.9	620.1	1442.9	OC-12
08/18/2009	35°23'18.82"N	76°18'50.82"W	*E. coli*	497.8	345.2	700.5	OC-15
08/18/2009	35°23'22.07"N	76°18'51.17"W	*E. coli*	730.8	463.9	1110.9	10B

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
08/18/2009	35°23'9.19"N	76°18'52.37"W	*E. coli*	497.8	345.2	700.5	OC-17
08/18/2009	35°23'5.62"N	76°18'58.97"W	*E. coli*	519	370	687.1	10A
08/18/2009	35°23'6.13"N	76°19'21.80"W	*E. coli*	126.6	92.8	170.5	10
08/18/2009	35°23'34.13"N	76°18'40.04"W	Enterococci	844.8	618.7	1118.4	OC-4
08/18/2009	35°23'30.94"N	76°18'42.20"W	Enterococci	189	112.6	303.6	OC-3
08/18/2009	35°23'30.21"N	76°18'43.69"W	Enterococci	354.5	238.8	510.2	OC-2
08/18/2009	35°23'31.96"N	76°18'43.86"W	Enterococci	487.4	338	680.2	OC-1B
08/18/2009	35°23'31.89"N	76°18'44.06"W	Enterococci	463.8	312.5	653.5	OC-1A
08/18/2009	35°23'28.78"N	76°18'44.43"W	Enterococci	565.3	392	785.5	OC-7
08/18/2009	35°23'29.46"N	76°18'44.46"W	Enterococci	447.9	301.8	633.6	OC-5
08/18/2009	35°23'29.20"N	76°18'44.94"W	Enterococci	520.4	360.8	722.1	OC-6
08/18/2009	35°23'27.81"N	76°18'45.68"W	Enterococci	1723.3	1194.9	2422.2	OC-8
08/18/2009	35°23'27.37"N	76°18'46.43"W	Enterococci	1086	774.2	1499.9	OC-9
08/18/2009	35°23'26.51"N	76°18'47.57"W	Enterococci	20.2	2.6	71.3	OC-11
08/18/2009	35°23'25.28"N	76°18'48.92"W	Enterococci	171.2	98.7	273.9	OC-13
08/18/2009	35°23'29.11"N	76°18'49.20"W	Enterococci	1259.1	922.2	1719.6	OC-10
08/18/2009	35°23'28.81"N	76°18'50.30"W	Enterococci	909.7	666.3	1210	OC-12
08/18/2009	35°23'18.82"N	76°18'50.82"W	Enterococci	1632.8	1100.2	2349.2	OC-15
08/18/2009	35°23'22.07"N	76°18'51.17"W	Enterococci	2406.7	1621.7	3501.4	10B
08/18/2009	35°23'9.19"N	76°18'52.37"W	Enterococci	1540.2	1098	2188.1	OC-17
08/18/2009	35°23'5.62"N	76°18'58.97"W	Enterococci	2239.7	1509.2	3228	10A
08/18/2009	35°23'6.13"N	76°19'21.80"W	Enterococci	476.4	330.4	681.6	10
09/24/2009	35°23'34.13"N	76°18'40.04"W	*E. coli*	756.9	524.8	1052.3	OC-4
09/24/2009	35°23'30.94"N	76°18'42.20"W	*E. coli*	615.2	390.5	942.5	OC-3
09/24/2009	35°23'30.21"N	76°18'43.69"W	*E. coli*	561.8	411.5	756.6	OC-2
09/24/2009	35°23'31.96"N	76°18'43.86"W	*E. coli*	321.4	222.9	452.7	OC-1B
09/24/2009	35°23'31.89"N	76°18'44.06"W	*E. coli*	821.2	521.2	1237.8	OC-1A
09/24/2009	35°23'28.78"N	76°18'44.43"W	*E. coli*	355.9	260.7	471	OC-7
09/24/2009	35°23'29.46"N	76°18'44.46"W	*E. coli*	444.7	317	606.5	OC-5

Sample Date	**Latitude**	**Longitude**	**Analyte**	**MPN/100mL**	**Lower Limit**	**Upper Limit**	**Sample Code**
09/24/2009	35°23'29.20"N	76°18'44.94"W	*E. coli*	721.7	514.5	997.4	OC-6
09/24/2009	35°23'27.81"N	76°18'45.68"W	*E. coli*	615.2	390.5	942.5	OC-8
09/24/2009	35°23'27.37"N	76°18'46.43"W	*E. coli*	497.8	345.2	700.5	OC-9
09/24/2009	35°23'26.51"N	76°18'47.57"W	*E. coli*	246.4	190.1	316.5	OC-11
09/24/2009	35°23'25.28"N	76°18'48.92"W	*E. coli*	263.9	198.5	344.8	OC-13
09/24/2009	35°23'29.11"N	76°18'49.20"W	*E. coli*	476.4	330.4	681.6	OC-10
09/24/2009	35°23'28.81"N	76°18'50.30"W	*E. coli*	284.2	202.6	393.7	OC-12
09/24/2009	35°23'22.07"N	76°18'51.17"W	*E. coli*	207.3	151.8	270.7	10B
09/24/2009	35°23'24.69"N	76°18'51.43"W	*E. coli*	246.7	185.5	327.4	OC-14
09/24/2009	35°23'14.11"N	76°18'51.64"W	*E. coli*	240.1	175.9	319.5	OC-16
09/24/2009	35°23'9.19"N	76°18'52.37"W	*E. coli*	428.3	305.3	588.8	OC-17
09/24/2009	35°23'1.70"N	76°18'53.79"W	*E. coli*	412.7	294.2	566.2	OC-18
09/24/2009	35°23'5.62"N	76°18'58.97"W	*E. coli*	226	165.5	298.1	10A
09/24/2009	35°23'6.13"N	76°19'21.80"W	*E. coli*	143.5	102.3	194.9	10
09/24/2009	35°23'34.13"N	76°18'40.04"W	Enterococci	728.5	547.8	946.4	OC-4
09/24/2009	35°23'30.94"N	76°18'42.20"W	Enterococci	208.6	124.3	323	OC-3
09/24/2009	35°23'30.21"N	76°18'43.69"W	Enterococci	51.6	17.6	107.6	OC-2
09/24/2009	35°23'31.96"N	76°18'43.86"W	Enterococci	96	44.1	169.3	OC-1B
09/24/2009	35°23'31.89"N	76°18'44.06"W	Enterococci	107.8	51.6	186.1	OC-1A
09/24/2009	35°23'28.78"N	76°18'44.43"W	Enterococci	331	216.6	481.3	OC-7
09/24/2009	35°23'29.46"N	76°18'44.46"W	Enterococci	680.3	511.5	894.5	OC-5
09/24/2009	35°23'29.20"N	76°18'44.94"W	Enterococci	143.5	77.1	235.5	OC-6
09/24/2009	35°23'27.81"N	76°18'45.68"W	Enterococci	232.5	147.6	350.4	OC-8
09/24/2009	35°23'27.37"N	76°18'46.43"W	Enterococci	154.7	86.1	251	OC-9
09/24/2009	35°23'26.51"N	76°18'47.57"W	Enterococci	62.6	25.1	127.3	OC-11
09/24/2009	35°23'25.28"N	76°18'48.92"W	Enterococci	108.9	56.3	194.9	OC-13
09/24/2009	35°23'29.11"N	76°18'49.20"W	Enterococci	51.6	17.6	107.6	OC-10
09/24/2009	35°23'28.81"N	76°18'50.30"W	Enterococci	121.1	65	210.9	OC-12
09/24/2009	35°23'22.07"N	76°18'51.17"W	Enterococci	74.5	35.6	148.7	10B

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
09/24/2009	35°23'24.69"N	76°18'51.43"W	Enterococci	20.2	2.6	71.3	OC-14
09/24/2009	35°23'14.11"N	76°18'51.64"W	Enterococci	235.1	149.2	352	OC-16
09/24/2009	35°23'9.19"N	76°18'52.37"W	Enterococci	349.8	235.7	503.4	OC-17
09/24/2009	35°23'1.70"N	76°18'53.79"W	Enterococci	121.1	65	210.9	OC-18
09/24/2009	35°23'5.62"N	76°18'58.97"W	Enterococci	271.8	172.5	401.9	10A
9/24/2009	35°23'6.13"N	76°19'21.80"W	Enterococci	171.2	98.7	273.9	10
10/16/2009	35°23'34.13"N	76°18'40.04"W	*E. coli*	870.3	552.5	1300.1	OC-4
10/16/2009	35°23'30.94"N	76°18'42.20"W	*E. coli*	428.3	305.3	588.8	OC-3
10/16/2009	35°23'30.21"N	76°18'43.69"W	*E. coli*	476.4	330.4	681.6	OC-2
10/16/2009	35°23'31.96"N	76°18'43.86"W	*E. coli*	220.1	161.2	292.3	OC-1B
10/16/2009	35°23'31.89"N	76°18'44.06"W	*E. coli*	721.7	514.5	997.4	OC-1A
10/16/2009	35°23'28.78"N	76°18'44.43"W	*E. coli*	345.4	259.7	452.7	OC-7
10/16/2009	35°23'29.46"N	76°18'44.46"W	*E. coli*	393.7	288.3	521.7	OC-5
10/16/2009	35°23'29.20"N	76°18'44.94"W	*E. coli*	626	434.1	879	OC-6
10/16/2009	35°23'27.81"N	76°18'45.68"W	*E. coli*	922.2	585.4	1375.8	OC-8
10/16/2009	35°23'27.37"N	76°18'46.43"W	*E. coli*	419.6	291	602.2	OC-9
10/16/2009	35°23'26.51"N	76°18'47.57"W	*E. coli*	383.6	273.5	529	OC-11
10/16/2009	35°23'25.28"N	76°18'48.92"W	*E. coli*	570.2	395.4	797.5	OC-13
10/16/2009	35°23'29.11"N	76°18'49.20"W	*E. coli*	444.7	317	606.5	OC-10
10/16/2009	35°23'28.81"N	76°18'50.30"W	*E. coli*	296.6	211.4	399.8	OC-12
10/16/2009	35°23'22.07"N	76°18'51.17"W	*E. coli*	520.5	350.7	730.4	10B
10/16/2009	35°23'24.69"N	76°18'51.43"W	*E. coli*	356.4	261.1	486.3	OC-14
10/16/2009	35°23'14.11"N	76°18'51.64"W	*E. coli*	387	260.8	558.9	OC-16
10/16/2009	35°23'9.19"N	76°18'52.37"W	*E. coli*	238.2	179.1	312.2	OC-17
10/16/2009	35°23'1.70"N	76°18'53.79"W	*E. coli*	476.4	330.4	681.6	OC-18
10/16/2009	35°23'5.62"N	76°18'58.97"W	*E. coli*	274.7	195.8	365.9	10A
10/16/2009	35°23'6.13"N	76°19'21.80"W	*E. coli*	215.2	157.6	290.8	10
10/16/2009	35°23'34.13"N	76°18'40.04"W	Enterococci	84.4	37.1	153.4	OC-4
10/16/2009	35°23'30.94"N	76°18'42.20"W	Enterococci	179.1	106.7	281.7	OC-3

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
10/16/2009	35°23'30.21"N	76°18'43.69"W	Enterococci	265.5	168.5	391.6	OC-2
10/16/2009	35°23'31.96"N	76°18'43.86"W	Enterococci	63.2	29	137.1	OC-1B
10/16/2009	35°23'31.89"N	76°18'44.06"W	Enterococci	73.8	32.4	144	OC-1A
10/16/2009	35°23'28.78"N	76°18'44.43"W	Enterococci	294.1	192.4	427.1	OC-7
10/16/2009	35°23'29.46"N	76°18'44.46"W	Enterococci	278	181.9	405.7	OC-5
10/16/2009	35°23'29.20"N	76°18'44.94"W	Enterococci	184.9	110.1	292.2	OC-6
10/16/2009	35°23'27.81"N	76°18'45.68"W	Enterococci	208.6	124.3	323	OC-8
10/16/2009	35°23'27.37"N	76°18'46.43"W	Enterococci	184.9	110.1	292.2	OC-9
10/16/2009	35°23'26.51"N	76°18'47.57"W	Enterococci	171.2	98.7	273.9	OC-11
10/16/2009	35°23'25.28"N	76°18'48.92"W	Enterococci	73.8	32.4	144	OC-13
10/16/2009	35°23'29.11"N	76°18'49.20"W	Enterococci	133.6	74.4	223.1	OC-10
10/16/2009	35°23'28.81"N	76°18'50.30"W	Enterococci	310.6	209.3	449.2	OC-12
10/16/2009	35°23'22.07"N	76°18'51.17"W	Enterococci	52.1	22.9	119.4	10B
10/16/2009	35°23'24.69"N	76°18'51.43"W	Enterococci	52.1	22.9	119.4	OC-14
10/16/2009	35°23'14.11"N	76°18'51.64"W	Enterococci	119.9	59.7	202.7	OC-16
10/16/2009	35°23'9.19"N	76°18'52.37"W	Enterococci	232.5	147.6	350.4	OC-17
10/16/2009	35°23'1.70"N	76°18'53.79"W	Enterococci	85.2	39.1	156.4	OC-18
10/16/2009	35°23'5.62"N	76°18'58.97"W	Enterococci	210.9	125.6	325.6	10A
10/16/2009	35°23'6.13"N	76°19'21.80"W	Enterococci	62.6	25.1	127.3	10
11/23/2009	35°23'34.13"N	76°18'40.04"W	*E. coli*	56.9	36.1	83.6	OC-4
11/23/2009	35°23'30.94"N	76°18'42.20"W	*E. coli*	64.5	42.2	94.3	OC-3
11/23/2009	35°23'30.21"N	76°18'43.69"W	*E. coli*	48.1	29.6	72.9	OC-2
11/23/2009	35°23'31.96"N	76°18'43.86"W	*E. coli*	51.2	31.5	76.7	OC-1B
11/23/2009	35°23'31.89"N	76°18'44.06"W	*E. coli*	51.2	31.5	76.7	OC-1A
11/23/2009	35°23'28.78"N	76°18'44.43"W	*E. coli*	24.5	13.6	42.8	OC-7
11/23/2009	35°23'29.46"N	76°18'44.46"W	*E. coli*	48.7	30.9	74.1	OC-5
11/23/2009	35°23'29.20"N	76°18'44.94"W	*E. coli*	35	20.2	57.1	OC-6
11/23/2009	35°23'27.81"N	76°18'45.68"W	*E. coli*	64.5	42.2	94.3	OC-8
11/23/2009	35°23'27.37"N	76°18'46.43"W	*E. coli*	63.7	41.7	92.7	OC-9

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
11/23/2009	35°23'26.51"N	76°18'47.57"W	*E. coli*	40.7	24.2	64.4	OC-11
11/23/2009	35°23'25.28"N	76°18'48.92"W	*E. coli*	37	22	58.4	OC-13
11/23/2009	35°23'29.11"N	76°18'49.20"W	*E. coli*	92.8	62.5	130.7	OC-10
11/23/2009	35°23'28.81"N	76°18'50.30"W	*E. coli*	52.5	34.3	77	OC-12
11/23/2009	35°23'18.82"N	76°18'50.82"W	*E. coli*	22	11.4	40.2	OC-15
11/23/2009	35°23'22.07"N	76°18'51.17"W	*E. coli*	39.3	23.4	61.4	10B
11/23/2009	35°23'14.11"N	76°18'51.64"W	*E. coli*	35.1	20.9	54.1	OC-16
11/23/2009	35°23'9.19"N	76°18'52.37"W	*E. coli*	40.8	25.1	62.4	OC-17
11/23/2009	35°23'1.70"N	76°18'53.79"W	*E. coli*	23.3	12.1	40.2	OC-18
11/23/2009	35°23'5.62"N	76°18'58.97"W	*E. coli*	43.2	27.4	65.1	10A
11/23/2009	35°23'6.13"N	76°19'21.80"W	*E. coli*	28.1	15.7	46.8	10
11/23/2009	35°23'34.13"N	76°18'40.04"W	Enterococci	157.9	87.9	257.1	OC-4
11/23/2009	35°23'30.94"N	76°18'42.20"W	Enterococci	811.7	610.4	1062	OC-3
11/23/2009	35°23'30.21"N	76°18'43.69"W	Enterococci	767.8	562.3	1010.1	OC-2
11/23/2009	35°23'31.96"N	76°18'43.86"W	Enterococci	465.4	322.7	647.4	OC-1B
11/23/2009	35°23'31.89"N	76°18'44.06"W	Enterococci	512.1	355.1	706.9	OC-1A
11/23/2009	35°23'28.78"N	76°18'44.43"W	Enterococci	331.9	217.1	479	OC-7
11/23/2009	35°23'29.46"N	76°18'44.46"W	Enterococci	1233.5	927.5	1637.2	OC-5
11/23/2009	35°23'29.20"N	76°18'44.94"W	Enterococci	619.8	441.8	851.1	OC-6
11/23/2009	35°23'27.81"N	76°18'45.68"W	Enterococci	1144.6	816	1554.8	OC-8
11/23/2009	35°23'27.37"N	76°18'46.43"W	Enterococci	842	616.7	1121.5	OC-9
11/23/2009	35°23'26.51"N	76°18'47.57"W	Enterococci	1785.3	1237.8	2504.6	OC-11
11/23/2009	35°23'25.28"N	76°18'48.92"W	Enterococci	368.4	248.3	522.1	OC-13
11/23/2009	35°23'29.11"N	76°18'49.20"W	Enterococci	2612.5	1709.4	3984.5	OC-10
11/23/2009	35°23'28.81"N	76°18'50.30"W	Enterococci	460.1	328	629.8	OC-12
11/23/2009	35°23'18.82"N	76°18'50.82"W	Enterococci	612.7	436.8	845.7	OC-15
11/23/2009	35°23'22.07"N	76°18'51.17"W	Enterococci	387.7	261.2	547.4	10B
11/23/2009	35°23'14.11"N	76°18'51.64"W	Enterococci	208.6	124.3	323	OC-16
11/23/2009	35°23'9.19"N	76°18'52.37"W	Enterococci	335.5	219.5	489.3	OC-17

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
11/23/2009	35°23'1.70"N	76°18'53.79"W	Enterococci	173.1	103.1	281.5	OC-18
11/23/2009	35°23'5.62"N	76°18'58.97"W	Enterococci	63.2	29	137.1	10A
11/23/2009	35°23'6.13"N	76°19'21.80"W	Enterococci	167.7	96.6	268.3	10
12/22/2009	35°23'34.13"N	76°18'40.04"W	*E. coli*	32.3	18.6	53.6	OC-4
12/22/2009	35°23'30.94"N	76°18'42.20"W	*E. coli*	49.2	30.3	75.3	OC-3
12/22/2009	35°23'30.21"N	76°18'43.69"W	*E. coli*	97.8	69.7	133.1	OC-2
12/22/2009	35°23'31.96"N	76°18'43.86"W	*E. coli*	57.6	36.6	85.4	OC-1B
12/22/2009	35°23'31.89"N	76°18'44.06"W	*E. coli*	37.4	21.5	60	OC-1A
12/22/2009	35°23'28.78"N	76°18'44.43"W	*E. coli*	33.5	19.3	53.7	OC-7
12/22/2009	35°23'29.46"N	76°18'44.46"W	*E. coli*	60.3	39.4	88.4	OC-5
12/22/2009	35°23'29.20"N	76°18'44.94"W	*E. coli*	37.7	23.2	57.7	OC-6
12/22/2009	35°23'27.81"N	76°18'45.68"W	*E. coli*	51.8	32.9	78.2	OC-8
12/22/2009	35°23'27.37"N	76°18'46.43"W	*E. coli*	39.3	23.4	61.4	OC-9
12/22/2009	35°23'26.51"N	76°18'47.57"W	*E. coli*	71.8	48.4	103.7	OC-11
12/22/2009	35°23'25.28"N	76°18'48.92"W	*E. coli*	61.4	41.4	88.4	OC-13
12/22/2009	35°23'29.11"N	76°18'49.20"W	*E. coli*	110.8	79	151.6	OC-10
12/22/2009	35°23'28.81"N	76°18'50.30"W	*E. coli*	23.5	12.2	40.2	OC-12
12/22/2009	35°23'18.82"N	76°18'50.82"W	*E. coli*	36.6	21.1	57.6	OC-15
12/22/2009	35°23'22.07"N	76°18'51.17"W	*E. coli*	41.7	24.9	64.6	10B
12/22/2009	35°23'14.11"N	76°18'51.64"W	*E. coli*	36.2	20.9	57.3	OC-16
12/22/2009	35°23'9.19"N	76°18'52.37"W	*E. coli*	50	31.7	74.2	OC-17
12/22/2009	35°23'1.70"N	76°18'53.79"W	*E. coli*	60.6	40.9	86.9	OC-18
12/22/2009	35°23'5.62"N	76°18'58.97"W	*E. coli*	44.5	28.3	66.2	10A
12/22/2009	35°23'6.13"N	76°19'21.80"W	*E. coli*	22	11.4	40.2	10
12/22/2009	35°23'34.13"N	76°18'40.04"W	Enterococci	182.9	105.4	288.2	OC-4
12/22/2009	35°23'30.94"N	76°18'42.20"W	Enterococci	811.7	610.4	1062	OC-3
12/22/2009	35°23'30.21"N	76°18'43.69"W	Enterococci	1828.6	1375.1	2355	OC-2
12/22/2009	35°23'31.96"N	76°18'43.86"W	Enterococci	2602.5	1753.6	3651.9	OC-1B
12/22/2009	35°23'31.89"N	76°18'44.06"W	Enterococci	443.4	307.4	618.4	OC-1A

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
12/22/2009	35°23'28.78"N	76°18'44.43"W	Enterococci	154.7	86.1	251	OC-7
12/22/2009	35°23'29.46"N	76°18'44.46"W	Enterococci	488.2	338.5	674.8	OC-5
12/22/2009	35°23'29.20"N	76°18'44.94"W	Enterococci	1319.7	992.4	1724.2	OC-6
12/22/2009	35°23'27.81"N	76°18'45.68"W	Enterococci	1112.3	792.9	1516.7	OC-8
12/22/2009	35°23'27.37"N	76°18'46.43"W	Enterococci	553.9	394.8	758	OC-9
12/22/2009	35°23'26.51"N	76°18'47.57"W	Enterococci	8164.1	5501.2	11745.9	OC-11
12/22/2009	35°23'25.28"N	76°18'48.92"W	Enterococci	407.7	282.7	573.4	OC-13
12/22/2009	35°23'29.11"N	76°18'49.20"W	Enterococci	912.6	686.3	1182.5	OC-10
12/22/2009	35°23'28.81"N	76°18'50.30"W	Enterococci	559.6	409.9	750.4	OC-12
12/22/2009	35°23'18.82"N	76°18'50.82"W	Enterococci	354.5	238.8	510.2	OC-15
12/22/2009	35°23'22.07"N	76°18'51.17"W	Enterococci	1354	965.3	1840.1	10B
12/22/2009	35°23'14.11"N	76°18'51.64"W	Enterococci	122.3	68.1	214	OC-16
12/22/2009	35°23'9.19"N	76°18'52.37"W	Enterococci	184.9	110.1	292.2	OC-17
12/22/2009	35°23'1.70"N	76°18'53.79"W	Enterococci	20.2	2.6	71.3	OC-18
12/22/2009	35°23'5.62"N	76°18'58.97"W	Enterococci	30.6	6.9	89.4	10A
12/22/2009	35°23'6.13"N	76°19'21.80"W	Enterococci	255.9	157.4	383.6	10
01/11/2010	35°23'34.13"N	76°18'40.04"W	*E. coli*	43.6	26.8	67.8	OC-4
01/11/2010	35°23'30.94"N	76°18'42.20"W	*E. coli*	49.2	30.3	75.3	OC-3
01/11/2010	35°23'30.21"N	76°18'43.69"W	*E. coli*	60.3	39.4	88.4	OC-2
01/11/2010	35°23'31.96"N	76°18'43.86"W	*E. coli*	40.2	24.7	63.7	OC-1B
01/11/2010	35°23'31.89"N	76°18'44.06"W	*E. coli*	37.4	21.5	60	OC-1A
01/11/2010	35°23'28.78"N	76°18'44.43"W	*E. coli*	24	11.9	40.5	OC-7
01/11/2010	35°23'29.46"N	76°18'44.46"W	*E. coli*	51.2	31.5	76.7	OC-5
01/11/2010	35°23'29.20"N	76°18'44.94"W	*E. coli*	38.9	23.2	60.9	OC-6
01/11/2010	35°23'27.81"N	76°18'45.68"W	*E. coli*	45.6	28.1	70.1	OC-8
01/11/2010	35°23'27.37"N	76°18'46.43"W	*E. coli*	28.7	15.4	47.1	OC-9
01/11/2010	35°23'26.51"N	76°18'47.57"W	*E. coli*	19.6	9.4	36.7	OC-11
01/11/2010	35°23'25.28"N	76°18'48.92"W	*E. coli*	28.7	15.4	47.1	OC-13
01/11/2010	35°23'29.11"N	76°18'49.20"W	*E. coli*	94.5	65.5	131.8	OC-10

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
01/11/2010	35°23'28.81"N	76°18'50.30"W	*E. coli*	24	11.9	40.5	OC-12
01/11/2010	35°23'18.82"N	76°18'50.82"W	*E. coli*	26.2	13.6	43.5	OC-15
01/11/2010	35°23'22.07"N	76°18'51.17"W	*E. coli*	36.6	21.1	57.6	10B
01/11/2010	35°23'14.11"N	76°18'51.64"W	*E. coli*	37.3	23	57.3	OC-16
01/11/2010	35°23'9.19"N	76°18'52.37"W	*E. coli*	28.4	15.3	46.9	OC-17
01/11/2010	35°23'1.70"N	76°18'53.79"W	*E. coli*	21.1	10.5	37	OC-18
01/11/2010	35°23'5.62"N	76°18'58.97"W	*E. coli*	16.9	7.4	30.7	10A
01/11/2010	35°23'6.13"N	76°19'21.80"W	*E. coli*	17	7.8	31.3	10
01/11/2010	35°23'34.13"N	76°18'40.04"W	Enterococci	30.4	6.8	73.7	OC-4
01/11/2010	35°23'30.94"N	76°18'42.20"W	Enterococci	624.3	457.3	822.8	OC-3
01/11/2010	35°23'30.21"N	76°18'43.69"W	Enterococci	624.3	457.3	822.8	OC-2
01/11/2010	35°23'31.96"N	76°18'43.86"W	Enterococci	387.7	261.2	547.4	OC-1B
01/11/2010	35°23'31.89"N	76°18'44.06"W	Enterococci	650.4	463.6	891.5	OC-1A
01/11/2010	35°23'28.78"N	76°18'44.43"W	Enterococci	416.5	288.8	580.2	OC-7
01/11/2010	35°23'29.46"N	76°18'44.46"W	Enterococci	668.5	502.7	873.2	OC-5
01/11/2010	35°23'29.20"N	76°18'44.94"W	Enterococci	705.3	516.6	938.8	OC-6
01/11/2010	35°23'27.81"N	76°18'45.68"W	Enterococci	812.6	579.3	1113.9	OC-8
01/11/2010	35°23'27.37"N	76°18'46.43"W	Enterococci	816.2	581.9	1103.2	OC-9
01/11/2010	35°23'26.51"N	76°18'47.57"W	Enterococci	2755.1	1856.5	4167.6	OC-11
01/11/2010	35°23'25.28"N	76°18'48.92"W	Enterococci	393.1	264.9	558.9	OC-13
01/11/2010	35°23'29.11"N	76°18'49.20"W	Enterococci	6488.2	4245.2	9414.6	OC-10
01/11/2010	35°23'28.81"N	76°18'50.30"W	Enterococci	1413.7	1035.4	1878.3	OC-12
01/11/2010	35°23'18.82"N	76°18'50.82"W	Enterococci	538.1	373.1	750.4	OC-15
01/11/2010	35°23'22.07"N	76°18'51.17"W	Enterococci	1395.8	995	1899.6	10B
01/11/2010	35°23'14.11"N	76°18'51.64"W	Enterococci	218.2	134.2	339	OC-16
01/11/2010	35°23'9.19"N	76°18'52.37"W	Enterococci	237.8	146.3	357.7	OC-17
01/11/2010	35°23'1.70"N	76°18'53.79"W	Enterococci	73.8	32.4	144	OC-18
01/11/2010	35°23'5.62"N	76°18'58.97"W	Enterococci	41.3	16.5	95.2	10A
01/11/2010	35°23'6.13"N	76°19'21.80"W	Enterococci	110	56.9	200.8	10

Sample Date	**Latitude**	**Longitude**	**Analyte**	**MPN/100mL**	**Lower Limit**	**Upper Limit**	**Sample Code**
Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
11/22/2008	35°23'34.13"N	76°18'40.04"W	Fecal Coliform	31.8	17.0	52.8	OC-4
11/22/2008	35°23'30.21"N	76°18'43.69"W	Fecal Coliform	100.6	67.8	143.2	OC-2
11/22/2008	35°23'27.81"N	76°18'45.68"W	Fecal Coliform	72.3	47.2	106.0	OC-8
11/22/2008	35°23'26.51"N	76°18'47.57"W	Fecal Coliform	92.1	62.0	132.8	OC-11
11/22/2008	35°23'18.82"N	76°18'50.82"W	Fecal Coliform	44.4	26.4	70.0	OC-15
11/22/2008	35°23'22.07"N	76°18'51.17"W	Fecal Coliform	59.0	36.3	90.3	10B
11/22/2008	35°23'24.69"N	76°18'51.43"W	Fecal Coliform	32.4	18.7	56.1	OC-14
11/22/2008	35°23'14.11"N	76°18'51.64"W	Fecal Coliform	25.9	12.3	44.6	OC-16
11/22/2008	35°23'5.62"N	76°18'58.97"W	Fecal Coliform	23.0	10.5	40.6	10A
11/22/2008	35°23'6.13"N	76°19'21.80"W	Fecal Coliform	12.4	5.5	28.6	10
12/20/2008	35°23'22.07"N	76°18'51.17"W	Fecal Coliform	34.8	18.7	56.5	10B
12/20/2008	35°23'14.11"N	76°18'51.64"W	Fecal Coliform	7.3	1.6	21.4	OC-16
12/20/2008	35°23'9.19"N	76°18'52.37"W	Fecal Coliform	2.4	0.0	8.7	OC-17
12/20/2008	35°23'1.70"N	76°18'53.79"W	Fecal Coliform	4.8	0.6	14.1	OC-18
12/20/2008	35°23'5.62"N	76°18'58.97"W	Fecal Coliform	14.7	5.6	29.1	10A
12/20/2008	35°23'6.13"N	76°19'21.80"W	Fecal Coliform	4.8	0.6	17.1	10
02/27/2009	35°23'34.13"N	76°18'40.04"W	Fecal Coliform	106.9	72.0	151.1	OC-4
02/27/2009	35°23'30.94"N	76°18'42.20"W	Fecal Coliform	83.2	54.3	121.9	OC-3
02/27/2009	35°23'30.21"N	76°18'43.69"W	Fecal Coliform	89.0	58.2	130.1	OC-2
02/27/2009	35°23'31.96"N	76°18'43.86"W	Fecal Coliform	60.1	36.9	93.5	OC-1B
02/27/2009	35°23'31.89"N	76°18'44.06"W	Fecal Coliform	2.7	0.1	10.0	OC-1A
02/27/2009	35°23'28.78"N	76°18'44.43"W	Fecal Coliform	66.3	40.8	100.6	OC-7
02/27/2009	35°23'29.46"N	76°18'44.46"W	Fecal Coliform	75.9	48.1	113.7	OC-5
02/27/2009	35°23'29.20"N	76°18'44.94"W	Fecal Coliform	525.5	374.5	701.3	OC-6
02/27/2009	35°23'27.81"N	76°18'45.68"W	Fecal Coliform	43.1	24.0	69.6	OC-8
02/27/2009	35°23'27.37"N	76°18'46.43"W	Fecal Coliform	72.3	45.9	109.5	OC-9
02/27/2009	35°23'25.28"N	76°18'48.92"W	Fecal Coliform	51.6	29.6	82.8	OC-13
02/27/2009	35°23'29.11"N	76°18'49.20"W	Fecal Coliform	107.5	72.4	154.2	OC-10

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
02/27/2009	35°23'28.81"N	76°18'50.30"W	Fecal Coliform	62.2	38.2	95.0	OC-12
02/27/2009	35°23'18.82"N	76°18'50.82"W	Fecal Coliform	33.3	17.9	58.2	OC-15
02/27/2009	35°23'22.07"N	76°18'51.17"W	Fecal Coliform	174.2	124.2	239.9	10B
02/27/2009	35°23'24.69"N	76°18'51.43"W	Fecal Coliform	43.6	24.2	70.9	OC-14
02/27/2009	35°23'5.62"N	76°18'58.97"W	Fecal Coliform	14.3	6.3	32.9	10A
02/27/2009	35°23'6.13"N	76°19'21.80"W	Fecal Coliform	5.5	0.6	19.7	10
05/08/2009	35°23'34.13"N	76°18'40.04"W	Fecal Coliform	142.4	96.0	201.4	OC-4
05/08/2009	35°23'30.94"N	76°18'42.20"W	Fecal Coliform	34.0	16.2	58.9	OC-3
05/08/2009	35°23'30.21"N	76°18'43.69"W	Fecal Coliform	49.1	27.3	79.8	OC-2
05/08/2009	35°23'31.96"N	76°18'43.86"W	Fecal Coliform	9.6	2.2	28.5	OC-1B
05/08/2009	35°23'31.89"N	76°18'44.06"W	Fecal Coliform	16.5	7.3	38.0	OC-1A
05/08/2009	35°23'28.78"N	76°18'44.43"W	Fecal Coliform	108.2	70.9	156.5	OC-7
05/08/2009	35°23'29.46"N	76°18'44.46"W	Fecal Coliform	74.2	45.6	114.8	OC-5
05/08/2009	35°23'29.20"N	76°18'44.94"W	Fecal Coliform	86.4	54.8	127.8	OC-6
05/08/2009	35°23'27.81"N	76°18'45.68"W	Fecal Coliform	62.4	37.2	97.6	OC-8
05/08/2009	35°23'27.37"N	76°18'46.43"W	Fecal Coliform	58.1	33.5	91.6	OC-9
05/08/2009	35°23'26.51"N	76°18'47.57"W	Fecal Coliform	73.2	45.2	113.5	OC-11
05/08/2009	35°23'25.28"N	76°18'48.92"W	Fecal Coliform	70.1	43.1	107.1	OC-13
05/08/2009	35°23'29.11"N	76°18'49.20"W	Fecal Coliform	30.8	14.1	54.5	OC-10
05/08/2009	35°23'28.81"N	76°18'50.30"W	Fecal Coliform	49.7	27.6	80.3	OC-12
05/08/2009	35°23'18.82"N	76°18'50.82"W	Fecal Coliform	3.1	0.0	11.6	OC-15
05/08/2009	35°23'22.07"N	76°18'51.17"W	Fecal Coliform	6.3	0.8	22.7	10B
05/08/2009	35°23'24.69"N	76°18'51.43"W	Fecal Coliform	6.3	0.8	22.7	OC-14
05/08/2009	35°23'5.62"N	76°18'58.97"W	Fecal Coliform	3.1	0.0	11.6	10A
05/08/2009	35°23'6.13"N	76°19'21.80"W	Fecal Coliform	3.1	0.2	17.5	10
06/20/2009	35°23'34.13"N	76°18'40.04"W	Fecal Coliform	142.5	96.1	201.1	OC-4
06/20/2009	35°23'30.94"N	76°18'42.20"W	Fecal Coliform	150.1	104.1	205.9	OC-3
06/20/2009	35°23'30.21"N	76°18'43.69"W	Fecal Coliform	73.3	45.1	112.1	OC-2
06/20/2009	35°23'31.96"N	76°18'43.86"W	Fecal Coliform	104.3	70.1	150.0	OC-1B

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
06/20/2009	35°23'31.89"N	76°18'44.06"W	Fecal Coliform	89.8	58.7	131.7	OC-1A
06/20/2009	35°23'28.78"N	76°18'44.43"W	Fecal Coliform	145.2	100.7	202.6	OC-7
06/20/2009	35°23'29.46"N	76°18'44.46"W	Fecal Coliform	173.8	120.5	240.1	OC-5
06/20/2009	35°23'29.20"N	76°18'44.94"W	Fecal Coliform	237.6	169.4	318.7	OC-6
06/20/2009	35°23'27.81"N	76°18'45.68"W	Fecal Coliform	171.4	118.9	238.4	OC-8
06/20/2009	35°23'27.37"N	76°18'46.43"W	Fecal Coliform	195.6	135.5	269.0	OC-9
06/20/2009	35°23'26.51"N	76°18'47.57"W	Fecal Coliform	165.5	114.7	229.9	OC-11
06/20/2009	35°23'25.28"N	76°18'48.92"W	Fecal Coliform	131.4	91.1	186.2	OC-13
06/20/2009	35°23'29.11"N	76°18'49.20"W	Fecal Coliform	235.2	167.7	324.2	OC-10
06/20/2009	35°23'28.81"N	76°18'50.30"W	Fecal Coliform	203.5	145.1	276.9	OC-12
06/20/2009	35°23'22.07"N	76°18'51.17"W	Fecal Coliform	94.9	62.1	138.1	10B
06/20/2009	35°23'24.69"N	76°18'51.43"W	Fecal Coliform	90.8	57.6	133.3	OC-14
06/20/2009	35°23'14.11"N	76°18'51.64"W	Fecal Coliform	32.4	16.8	58.1	OC-16
06/20/2009	35°23'9.19"N	76°18'52.37"W	Fecal Coliform	47.0	26.2	76.5	OC-17
06/20/2009	35°23'5.62"N	76°18'58.97"W	Fecal Coliform	71.6	44.1	108.6	10A
06/20/2009	35°23'6.13"N	76°19'21.80"W	Fecal Coliform	29.2	14.0	54.6	10
07/10/2009	35°23'34.13"N	76°18'40.04"W	Fecal Coliform	887.6	598.2	1248.2	OC-4
07/10/2009	35°23'30.94"N	76°18'42.20"W	Fecal Coliform	929.4	644.5	1299.9	OC-3
07/10/2009	35°23'30.21"N	76°18'43.69"W	Fecal Coliform	743.9	515.7	1053.3	OC-2
07/10/2009	35°23'31.96"N	76°18'43.86"W	Fecal Coliform	782.5	573.1	1071.0	OC-1B
07/10/2009	35°23'31.89"N	76°18'44.06"W	Fecal Coliform	620.7	442.3	828.3	OC-1A
07/10/2009	35°23'28.78"N	76°18'44.43"W	Fecal Coliform	2510.5	1789.7	3566.6	OC-7
07/10/2009	35°23'29.46"N	76°18'44.46"W	Fecal Coliform	811.4	562.6	1141.8	OC-5
07/10/2009	35°23'29.20"N	76°18'44.94"W	Fecal Coliform	2661.4	1793.3	3829.1	OC-6
07/10/2009	35°23'27.81"N	76°18'45.68"W	Fecal Coliform	1121.7	799.6	1540.1	OC-8
07/10/2009	35°23'27.37"N	76°18'46.43"W	Fecal Coliform	620.7	442.3	828.3	OC-9
07/10/2009	35°23'26.51"N	76°18'47.57"W	Fecal Coliform	2115.0	1383.8	3069.1	OC-11
07/10/2009	35°23'25.28"N	76°18'48.92"W	Fecal Coliform	1262.5	801.4	1848.5	OC-13
07/10/2009	35°23'29.11"N	76°18'49.20"W	Fecal Coliform	3196.1	2153.5	4597.0	OC-10

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
07/10/2009	35°23'28.81"N	76°18'50.30"W	Fecal Coliform	600.4	439.7	819.4	OC-12
07/10/2009	35°23'18.82"N	76°18'50.82"W	Fecal Coliform	582.0	403.5	816.4	OC-15
07/10/2009	35°23'22.07"N	76°18'51.17"W	Fecal Coliform	600.4	439.7	819.4	10B
07/10/2009	35°23'9.19"N	76°18'52.37"W	Fecal Coliform	712.9	494.3	1025.4	OC-17
07/10/2009	35°23'5.62"N	76°18'58.97"W	Fecal Coliform	663.5	486.0	881.1	10A
07/10/2009	35°23'6.13"N	76°19'21.80"W	Fecal Coliform	295.5	210.5	404.4	10
08/18/2009	35°23'34.13"N	76°18'40.04"W	Fecal Coliform	1865.8	1220.7	2727.8	OC-4
08/18/2009	35°23'30.94"N	76°18'42.20"W	Fecal Coliform	1218.6	844.9	1694.2	OC-3
08/18/2009	35°23'30.21"N	76°18'43.69"W	Fecal Coliform	1322.1	839.1	1992.8	OC-2
08/18/2009	35°23'31.96"N	76°18'43.86"W	Fecal Coliform	1110.2	704.6	1676.4	OC-1B
08/18/2009	35°23'31.89"N	76°18'44.06"W	Fecal Coliform	1007.8	698.9	1415.1	OC-1A
08/18/2009	35°23'28.78"N	76°18'44.43"W	Fecal Coliform	4184.8	2738.1	6106.8	OC-7
08/18/2009	35°23'29.46"N	76°18'44.46"W	Fecal Coliform	1176.5	746.8	1788.5	OC-5
08/18/2009	35°23'29.20"N	76°18'44.94"W	Fecal Coliform	6395.8	3935.0	10626.8	OC-6
08/18/2009	35°23'27.81"N	76°18'45.68"W	Fecal Coliform	1762.9	1153.5	2590.3	OC-8
08/18/2009	35°23'27.37"N	76°18'46.43"W	Fecal Coliform	1007.8	698.9	1415.1	OC-9
08/18/2009	35°23'26.51"N	76°18'47.57"W	Fecal Coliform	1974.3	1291.8	2831.0	OC-11
08/18/2009	35°23'25.28"N	76°18'48.92"W	Fecal Coliform	1484.7	942.4	2215.0	OC-13
08/18/2009	35°23'29.11"N	76°18'49.20"W	Fecal Coliform	3605.9	2429.8	5197.0	OC-10
08/18/2009	35°23'28.81"N	76°18'50.30"W	Fecal Coliform	1572.0	998.3	2323.0	OC-12
08/18/2009	35°23'18.82"N	76°18'50.82"W	Fecal Coliform	801.4	555.7	1127.8	OC-15
08/18/2009	35°23'22.07"N	76°18'51.17"W	Fecal Coliform	1176.5	746.8	1788.5	10B
08/18/2009	35°23'9.19"N	76°18'52.37"W	Fecal Coliform	801.4	555.7	1127.8	OC-17
08/18/2009	35°23'5.62"N	76°18'58.97"W	Fecal Coliform	835.5	595.7	1106.2	10A
08/18/2009	35°23'6.13"N	76°19'21.80"W	Fecal Coliform	203.8	149.4	274.5	10
09/24/2009	35°23'34.13"N	76°18'40.04"W	Fecal Coliform	1105.0	766.2	1536.3	OC-4
09/24/2009	35°23'30.94"N	76°18'42.20"W	Fecal Coliform	898.1	570.1	1376.0	OC-3
09/24/2009	35°23'30.21"N	76°18'43.69"W	Fecal Coliform	820.2	600.7	1104.6	OC-2
09/24/2009	35°23'31.96"N	76°18'43.86"W	Fecal Coliform	469.2	325.4	660.9	OC-1B

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
09/24/2009	35°23'31.89"N	76°18'44.06"W	Fecal Coliform	1198.9	760.9	1807.1	OC-1A
09/24/2009	35°23'28.78"N	76°18'44.43"W	Fecal Coliform	519.6	380.6	687.6	OC-7
09/24/2009	35°23'29.46"N	76°18'44.46"W	Fecal Coliform	649.2	462.8	885.4	OC-5
09/24/2009	35°23'29.20"N	76°18'44.94"W	Fecal Coliform	1053.6	751.1	1456.2	OC-6
09/24/2009	35°23'27.81"N	76°18'45.68"W	Fecal Coliform	898.1	570.1	1376.0	OC-8
09/24/2009	35°23'27.37"N	76°18'46.43"W	Fecal Coliform	726.7	503.9	1022.7	OC-9
09/24/2009	35°23'26.51"N	76°18'47.57"W	Fecal Coliform	359.7	277.5	462.0	OC-11
09/24/2009	35°23'25.28"N	76°18'48.92"W	Fecal Coliform	385.2	289.8	503.4	OC-13
09/24/2009	35°23'29.11"N	76°18'49.20"W	Fecal Coliform	695.5	482.3	995.1	OC-10
09/24/2009	35°23'28.81"N	76°18'50.30"W	Fecal Coliform	414.9	295.7	574.8	OC-12
09/24/2009	35°23'22.07"N	76°18'51.17"W	Fecal Coliform	302.6	221.6	395.2	10B
09/24/2009	35°23'24.69"N	76°18'51.43"W	Fecal Coliform	360.1	270.8	478.0	OC-14
09/24/2009	35°23'14.11"N	76°18'51.64"W	Fecal Coliform	350.5	256.8	466.4	OC-16
09/24/2009	35°23'9.19"N	76°18'52.37"W	Fecal Coliform	625.3	445.7	859.6	OC-17
09/24/2009	35°23'1.70"N	76°18'53.79"W	Fecal Coliform	602.5	429.5	826.6	OC-18
09/24/2009	35°23'5.62"N	76°18'58.97"W	Fecal Coliform	329.9	241.6	435.2	10A
09/24/2009	35°23'6.13"N	76°19'21.80"W	Fecal Coliform	209.5	149.3	284.5	10
10/16/2009	35°23'34.13"N	76°18'40.04"W	Fecal Coliform	1044.3	663.0	1560.1	OC-4
10/16/2009	35°23'30.94"N	76°18'42.20"W	Fecal Coliform	513.9	366.3	706.5	OC-3
10/16/2009	35°23'30.21"N	76°18'43.69"W	Fecal Coliform	571.6	396.4	817.9	OC-2
10/16/2009	35°23'31.96"N	76°18'43.86"W	Fecal Coliform	264.1	193.4	350.7	OC-1B
10/16/2009	35°23'31.89"N	76°18'44.06"W	Fecal Coliform	866.0	617.4	1196.8	OC-1A
10/16/2009	35°23'28.78"N	76°18'44.43"W	Fecal Coliform	414.4	311.6	543.2	OC-7
10/16/2009	35°23'29.46"N	76°18'44.46"W	Fecal Coliform	472.4	345.9	626.0	OC-5
10/16/2009	35°23'29.20"N	76°18'44.94"W	Fecal Coliform	751.2	520.9	1054.8	OC-6
10/16/2009	35°23'27.81"N	76°18'45.68"W	Fecal Coliform	1106.6	702.4	1650.9	OC-8
10/16/2009	35°23'27.37"N	76°18'46.43"W	Fecal Coliform	503.5	349.2	722.6	OC-9
10/16/2009	35°23'26.51"N	76°18'47.57"W	Fecal Coliform	460.3	328.2	634.8	OC-11
10/16/2009	35°23'25.28"N	76°18'48.92"W	Fecal Coliform	684.2	474.4	957.0	OC-13

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
10/16/2009	35°23'29.11"N	76°18'49.20"W	Fecal Coliform	533.6	380.4	727.8	OC-10
10/16/2009	35°23'28.81"N	76°18'50.30"W	Fecal Coliform	355.9	253.6	479.7	OC-12
10/16/2009	35°23'22.07"N	76°18'51.17"W	Fecal Coliform	624.6	420.8	876.4	10B
10/16/2009	35°23'24.69"N	76°18'51.43"W	Fecal Coliform	427.6	313.3	583.5	OC-14
10/16/2009	35°23'14.11"N	76°18'51.64"W	Fecal Coliform	464.4	312.9	670.6	OC-16
10/16/2009	35°23'9.19"N	76°18'52.37"W	Fecal Coliform	285.8	214.9	374.6	OC-17
10/16/2009	35°23'1.70"N	76°18'53.79"W	Fecal Coliform	571.6	396.4	817.9	OC-18
10/16/2009	35°23'5.62"N	76°18'58.97"W	Fecal Coliform	329.6	234.9	439.0	10A
10/16/2009	35°23'6.13"N	76°19'21.80"W	Fecal Coliform	258.2	189.1	348.9	10
11/23/2009	35°23'34.13"N	76°18'40.04"W	Fecal Coliform	73.4	46.5	107.8	OC-4
11/23/2009	35°23'30.94"N	76°18'42.20"W	Fecal Coliform	83.2	54.4	121.6	OC-3
11/23/2009	35°23'30.21"N	76°18'43.69"W	Fecal Coliform	62.0	38.1	94.0	OC-2
11/23/2009	35°23'31.96"N	76°18'43.86"W	Fecal Coliform	66.0	40.6	98.9	OC-1B
11/23/2009	35°23'31.89"N	76°18'44.06"W	Fecal Coliform	66.0	40.6	98.9	OC-1A
11/23/2009	35°23'28.78"N	76°18'44.43"W	Fecal Coliform	31.6	17.5	55.2	OC-7
11/23/2009	35°23'29.46"N	76°18'44.46"W	Fecal Coliform	62.8	39.8	95.5	OC-5
11/23/2009	35°23'29.20"N	76°18'44.94"W	Fecal Coliform	45.1	26.0	73.6	OC-6
11/23/2009	35°23'27.81"N	76°18'45.68"W	Fecal Coliform	83.2	54.4	121.6	OC-8
11/23/2009	35°23'27.37"N	76°18'46.43"W	Fecal Coliform	82.1	53.7	119.5	OC-9
11/23/2009	35°23'26.51"N	76°18'47.57"W	Fecal Coliform	52.5	31.2	83.0	OC-11
11/23/2009	35°23'25.28"N	76°18'48.92"W	Fecal Coliform	47.7	28.3	75.3	OC-13
11/23/2009	35°23'29.11"N	76°18'49.20"W	Fecal Coliform	119.7	80.6	168.6	OC-10
11/23/2009	35°23'28.81"N	76°18'50.30"W	Fecal Coliform	67.7	44.2	99.3	OC-12
11/23/2009	35°23'18.82"N	76°18'50.82"W	Fecal Coliform	28.3	14.7	51.8	OC-15
11/23/2009	35°23'22.07"N	76°18'51.17"W	Fecal Coliform	50.6	30.1	79.2	10B
11/23/2009	35°23'14.11"N	76°18'51.64"W	Fecal Coliform	45.2	26.9	69.7	OC-16
11/23/2009	35°23'9.19"N	76°18'52.37"W	Fecal Coliform	52.6	32.3	80.4	OC-17
11/23/2009	35°23'1.70"N	76°18'53.79"W	Fecal Coliform	30.0	15.6	51.8	OC-18
11/23/2009	35°23'5.62"N	76°18'58.97"W	Fecal Coliform	55.7	35.3	83.9	10A

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
11/23/2009	35°23'6.13"N	76°19'21.80"W	Fecal Coliform	36.2	20.2	60.3	10
12/22/2009	35°23'34.13"N	76°18'40.04"W	Fecal Coliform	38.7	22.3	64.3	OC-4
12/22/2009	35°23'30.94"N	76°18'42.20"W	Fecal Coliform	59.0	36.3	90.3	OC-3
12/22/2009	35°23'30.21"N	76°18'43.69"W	Fecal Coliform	117.3	83.6	159.7	OC-2
12/22/2009	35°23'31.96"N	76°18'43.86"W	Fecal Coliform	69.1	43.9	102.4	OC-1B
12/22/2009	35°23'31.89"N	76°18'44.06"W	Fecal Coliform	44.8	25.8	72.0	OC-1A
12/22/2009	35°23'28.78"N	76°18'44.43"W	Fecal Coliform	40.2	23.1	64.4	OC-7
12/22/2009	35°23'29.46"N	76°18'44.46"W	Fecal Coliform	72.3	47.2	106.0	OC-5
12/22/2009	35°23'29.20"N	76°18'44.94"W	Fecal Coliform	45.2	27.8	69.2	OC-6
12/22/2009	35°23'27.81"N	76°18'45.68"W	Fecal Coliform	62.1	39.4	93.8	OC-8
12/22/2009	35°23'27.37"N	76°18'46.43"W	Fecal Coliform	47.1	28.0	73.6	OC-9
12/22/2009	35°23'26.51"N	76°18'47.57"W	Fecal Coliform	86.1	58.0	124.4	OC-11
12/22/2009	35°23'25.28"N	76°18'48.92"W	Fecal Coliform	73.6	49.6	106.0	OC-13
12/22/2009	35°23'29.11"N	76°18'49.20"W	Fecal Coliform	132.9	94.8	181.9	OC-10
12/22/2009	35°23'28.81"N	76°18'50.30"W	Fecal Coliform	28.2	14.6	48.2	OC-12
12/22/2009	35°23'18.82"N	76°18'50.82"W	Fecal Coliform	43.9	25.3	69.1	OC-15
12/22/2009	35°23'22.07"N	76°18'51.17"W	Fecal Coliform	50.0	29.8	77.5	10B
12/22/2009	35°23'14.11"N	76°18'51.64"W	Fecal Coliform	43.4	25.0	68.7	OC-16
12/22/2009	35°23'9.19"N	76°18'52.37"W	Fecal Coliform	60.0	38.0	89.0	OC-17
12/22/2009	35°23'1.70"N	76°18'53.79"W	Fecal Coliform	72.7	49.0	104.2	OC-18
12/22/2009	35°23'5.62"N	76°18'58.97"W	Fecal Coliform	53.4	33.9	79.4	10A
12/22/2009	35°23'6.13"N	76°19'21.80"W	Fecal Coliform	26.4	13.6	48.2	10
01/11/2010	35°23'34.13"N	76°18'40.04"W	Fecal Coliform	64.9	39.9	101.0	OC-4
01/11/2010	35°23'30.94"N	76°18'42.20"W	Fecal Coliform	73.3	45.1	112.2	OC-3
01/11/2010	35°23'30.21"N	76°18'43.69"W	Fecal Coliform	89.8	58.7	131.7	OC-2
01/11/2010	35°23'31.96"N	76°18'43.86"W	Fecal Coliform	59.9	36.8	94.9	OC-1B
01/11/2010	35°23'31.89"N	76°18'44.06"W	Fecal Coliform	55.7	32.0	89.4	OC-1A
01/11/2010	35°23'28.78"N	76°18'44.43"W	Fecal Coliform	35.7	17.7	60.3	OC-7
01/11/2010	35°23'29.46"N	76°18'44.46"W	Fecal Coliform	76.3	46.9	114.3	OC-5

Sample Date	Latitude	Longitude	Analyte	MPN/100mL	Lower Limit	Upper Limit	Sample Code
01/11/2010	35°23'29.20"N	76°18'44.94"W	Fecal Coliform	57.9	34.6	90.7	OC-6
01/11/2010	35°23'27.81"N	76°18'45.68"W	Fecal Coliform	67.9	41.9	104.4	OC-8
01/11/2010	35°23'27.37"N	76°18'46.43"W	Fecal Coliform	42.8	22.9	70.2	OC-9
01/11/2010	35°23'26.51"N	76°18'47.57"W	Fecal Coliform	29.2	14.0	54.7	OC-11
01/11/2010	35°23'25.28"N	76°18'48.92"W	Fecal Coliform	42.8	22.9	70.2	OC-13
01/11/2010	35°23'29.11"N	76°18'49.20"W	Fecal Coliform	140.8	97.6	196.4	OC-10
01/11/2010	35°23'28.81"N	76°18'50.30"W	Fecal Coliform	35.7	17.7	60.3	OC-12
01/11/2010	35°23'18.82"N	76°18'50.82"W	Fecal Coliform	39.1	20.3	64.8	OC-15
01/11/2010	35°23'22.07"N	76°18'51.17"W	Fecal Coliform	54.5	31.4	85.8	10B
01/11/2010	35°23'14.11"N	76°18'51.64"W	Fecal Coliform	55.6	34.2	85.4	OC-16
01/11/2010	35°23'9.19"N	76°18'52.37"W	Fecal Coliform	42.3	22.7	69.9	OC-17
01/11/2010	35°23'1.70"N	76°18'53.79"W	Fecal Coliform	31.4	15.6	55.1	OC-18
01/11/2010	35°23'5.62"N	76°18'58.97"W	Fecal Coliform	25.2	11.0	45.7	10A
01/11/2010	35°23'6.13"N	76°19'21.80"W	Fecal Coliform	25.3	11.6	46.6	10

Appendix E. Wasteload Allocation by Subwatershed

Table E1: Ratio of ROW to Total Landuse and WLA by Subwatershed

Subwatershed	ROW/Landuse Area	WLA (Counts/Day)
1	0.73%	8.97×10^{8}
2	1.08%	6.94×10^{8}
3	0.54%	3.04×10^{7}
4	1.50%	1.69×10^{7}
5	0%	0
6	0%	0
7	0%	0
8	0%	0
B4	2.93%	9.54×10^{6}
B7	0%	0
B8	0%	0

Appendix F. Details of the Combined Transport Model and Bayesian Approach to Estimate the Loadings of Oyster Creek

Instream Transport Model

For a coastal basin, the tidal prism model has been applied to develop fecal coliform TMDLs in shellfish growing areas (e.g., NCDENR 2007, 2009). For Oyster Creek, however, as the tidal range is very small (about 0.15 m) and the Creek is narrow, a tidal prism model is not applicable. Therefore, a one-dimensional, tidally-averaged finite difference transport model (Thomann and Mueller, 1987) was applied to simulate the transport of bacteria, and compute the existing loads and TMDLs. Since the long-term median and 90th percentile criteria are used to determine the loads, a steady state modeling approach was used (Shen and Zhao, 2009). The restricted shellfish harvesting area of Oyster Creek was divided into 11 segments according to the water quality monitoring station availability and the geometry of the Creek, and the corresponding watershed was divided into 11 subwatersheds as well (Fig. 3.1.1). Three branches were delineated as tributary segments based on branch area and data availability. The mass balance for fecal coliform can be written as

$$\frac{\partial c}{\partial t}+\frac{1}{A}\frac{\partial (Q\ c)}{\partial x}=\frac{1}{A}\frac{\partial}{\partial x}\left(AE\frac{\partial c}{\partial x}\right)+c_0 \tag{F1}$$

where x is the distance (m), $\overline{A}$ is the tidally averaged cross-section area (m^2), Q is the tidally averaged net transport due to freshwater discharge and tide (m^3·s^{-1}), c is the tidally averaged concentration of dissolved substance (mass·m^{-3}), E is the dispersion coefficient (m^2·s^{-1}), and c_0 is a source/sink or loading term (mass·s^{-1}). Because the width and depth varies along the estuary and the concentration at a specific location is influenced by both upstream and downstream, an analytical solution for the concentration cannot be obtained for this non-linear problem. Therefore, the finite difference method is used to solve the problem. Figure F1 shows the scheme of the model segmentation. Integrate Eq. (F1) for a control volume i, the mass balance for fecal coliform at segment i in the main stream can be written as:

$$V_i\frac{dc_i}{dt}=Q_{i-1}c_{i-1}-Q_ic_i+Q_{ib}C_{ib}+E'_{i-1}(c_{i-1}-c_i)-E'_i(c_i-c_{i+1})+E'_{ib}(c_{ib}-c_i)-kV_ic_i+L_i=0 \tag{F2}$$

and that at Branch ib can be written as:

$$V_{ib}\frac{dc_{ib}}{dt}=-Q_{ib}c_{ib}-E'_{ib}(c_{ib}-c_i)-kV_{ib}c_{ib}+L_{ib}=0 \tag{F3}$$

where E' is the bulk dispersion coefficient across the segment boundary, which is related to the dispersion coefficient E as:

$$E_i^{'}=\frac{E_iA_i}{\Delta x_i} \tag{F4}$$

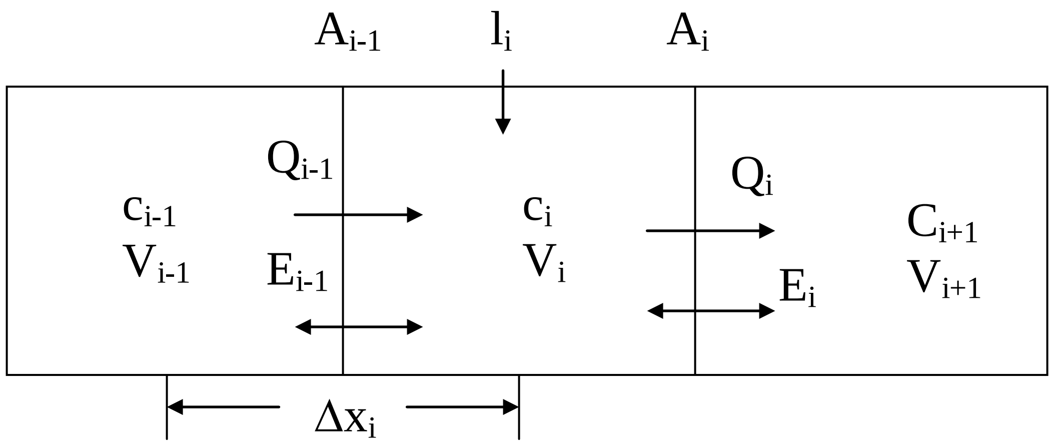

Figure F1. Schematic Graph of Model Segmentation and Notations

Dispersion Coefficient Estimation

There are different ways to estimate dispersion coefficient. A common approach is to use salinity data. For Oyster Creek, Equations (F1) – (F3) and salinity data can be used to compute the dispersion coefficient (Thomann and Mueller, 1987). Because there is no sufficient salinity data available for each segment, we assume that the dispersion coefficients are constant throughout the Creek. Note that there is no salinity source from upstream. Therefore, there is no salinity loading or decay term:

$$0 = -Q_{nb}s_{nb} + E'_{nb}(s_0 - s_{nb}) \tag{F5}$$

Where s_{nb} is the salinity inside the estuary and s_0 is the salinity outside of the open boundary (1st segment). Therefore, the boundary dispersion coefficient can then be simply calculated as:

$$E'_{nb} = \frac{Q_{nb}s_{nb}}{s_0 - s_{nb}} \tag{F6}$$

$$E_{nb} = \frac{Q_{nb}s_{nb}L_n}{(s_0 - s_{nb})A_n} \tag{F7}$$

Where A_n is the cross-section area and L_n is the distance between s_0 and s_{nb}. Salinity data from Stations 10, 10A, and 10B are used, as they have long time monitoring data. The values of the two stations inside the Oyster Creek (10A and 10B) are averaged and used as the inside salinity. Given the mean salinity concentrations of s_0 = 15.26 ppt and s_{nb} = 14.78 ppt, A_n = 162 m^2, Q= 0.28 m^3/s, and L_n = 1140 m, the estimated value of E_{nb} is 63.17 m^2/s.

Numerical Model Solver

The numerical model can be solved using finite difference method. For our case, we solved the steady state of the equation for segment i = 1,2, …, 8:

$$0 = Q_{i-1}c_{i-1} - Q_i c_i + Q_{ib}C_{ib} + E'_{i-1}(c_{i-1} - c_i) - E'_i(c_i - c_{i+1}) + E'_{ib}(c_{ib} - c_i) - kV_i c_i + L_i \tag{F8}$$

and segments B4, B7, and B8:

$$0 = -Q_{ib}c_{ib} - E'_{ib}(c_{ib} - c_i) - kV_{ib}c_{ib} + L_{ib} \tag{F9}$$

This above equations will give us a set of 8+3 algebraic equations, which can be written as:

$$b_{i,i-1}c_{i-1} + b_{i,i}c_i + b_{i,i+1}c_{i+1} + \gamma_i b_{ib}c_{ib} = l_i \tag{F10}$$

$$b_{i,i-1} = -Q_{i-1} - E'_{i-1} \tag{F11}$$

$$b_{i,i} = Q_i + E'_{i-1} + E'_{i+1} + V_i k_i \tag{F12}$$

$$b_{i,i+1} = -E'_{i+1} \tag{F13}$$

With upstream and downstream boundary conditions:

$$b_{1,1}c_1 + b_{1,2}c_2 = l_1 + Q_u c_u = l'_1 \tag{F14}$$
$$b_{N,N-1}c_{N-1} + b_{N,N}c_N = l_N + E'_b c_b = l'_N \tag{F15}$$

where Q_u and c_u are upstream flow and concentration boundary conditions and E'_b and c_b are downstream dispersion and concentration boundary conditions. γ =1 if there is tributary connected to the segment, otherwise γ =0. The equation can be written in a matrix form as:

$$\mathrm{BC} = \mathrm{L} \tag{F16}$$

where B=$\{b_{i,j}\}$, C=$\{c_1, \ldots, c_N\}^T$, and L=$\{l'_1, l_2, l_3, \ldots, \quad l'_N\}^T$. (F17)

The inverse Matrix B can be computed with Microsoft Excel. The concentration can be obtained as if all the loading L_i are provided (i=1, 2, ... , 8, B4, B7, B8) as follows:

$$c_i = \{B\}_i^{-1} L_i \tag{F18}$$

In our case, we know bacteria concentrations c_i and want to estimate loadings L_i. Therefore, the inverse method is used. For a given set of in-stream monitoring data, the true bacterial concentration (C^*) with random measurement error (ε) is given by

$$C = C^* + \varepsilon = B^{-1}L + \varepsilon \tag{F19}$$

or

$$c_i = c_i^* + \varepsilon_i = \{B\}_i^{-1} L_i + \varepsilon_i \qquad \text{for } (i = 1, \ldots, N) \tag{F20}$$

where $\{B\}_i^{-1}$ is the ith row of the inverse matrix of B and ε_i is the error term with mean 0 and variance σ^2 , which links the statistical description of observation error and the error due to model scheme to the modeled bacteria concentration. The Bayesian method is used to obtain loadings. The Bayesian parameter estimation combines the knowledge of prior information of unknown parameter (loadings in our case) and the likelihood of monitoring data to establish a probability of posterior distribution to describe the unknown parameters. Bayes' theorem can be written in the following form:

$$p(\theta \mid C) = \frac{p(C \mid \theta) \times p(\theta)}{P(C)} \tag{F21}$$

In this equation, $p(\theta \mid C)$ is called the Bayesian posterior distribution and expresses the probability of the model parameter values given the observed data. In our case, the parameters are loadings l_i, i.e., $\theta = \{l_1, l_2, ..., l_N\}$. The denominator, $p(C)$, is the expected value of the likelihood function over the parameter distributions as a normalizing constant. $p(\theta)$ is the prior belief of the unknown parameter density distribution function. $p(C \mid \theta)$ is the probability density function of the observations for given parameters, which is referred as likelihood function.

In this study, WinBUGS, free software developed by MRC biostatistics Unit, Cambridge, UK (Spiegelhalter, 2003) was used to conduct the parameter estimation. The fecal coliform concentration was assumed to have a normal distribution, with a variance following a standard non-informative diffuse inverse-Gamma distribution ($1.0*10^{-3}$, $1.0*10^{-3}$). As little information is known, the loading was assumed to have a uniform distribution (0, $1.0*10^{9}$ counts per second). The upper bound of this distribution is set as three orders of magnitude larger than the roughly estimated load (observed concentration times flow). Because we only focused on the estimation of nonpoint source loads, a constant bacteria decay rate of 0.7 per day was used, which is a conservative estimate (MDE, 2004). The observed fecal coliform concentrations and the inverse matrix B were input into WinBUGS to estimate the existing loadings. Similarly, the fecal coliform criteria of 14 MPN/100ml (for median) and 43 MPN/100ml (for 90th percentile) were used in WinBUGS to estimate the TMDLs.

Appendix G. Public Notification of TMDL for Fecal Coliform for Oyster Creek

The TMDL public comment period was announced on the NC Modeling and TMDL Unit website and on NCDWQ TMDL listserv on 7/14/2011, and on the NCWRRI listserv on 7/15/2011.

- **Notice on the Modeling and TMDL Website :**

NCDENR

North Carolina Department of Environment and Natural Resources

Division of Water Quality

Beverly Eaves Perdue
Governor

Coleen H. Sullins
Director

Dee Freeman
Secretary

DRAFT Total Maximum Daily Loads for Fecal Coliform for Oyster Creek, Tar-Pamlico River Basin, North Carolina

March 14, 2011
North Carolina Department of Environment and Natural Resources
Division of Water Quality

Now Available for Public Comment

This draft TMDL report was prepared as a requirement of the Federal Water Pollution Control Act, Section 303(d). Interested parties are invited to comment on the draft TMDL report by April 14, 2011. Comments concerning the report should be directed to Adugna Kebede at adugna.kebede@ncdenr.gov or write to:

Adugna Kebede
NC Division of Water Quality
Planning Section
1617 Mail Service Center
Raleigh, NC 27699

The draft TMDL can also be downloaded from the following website: http://portal.ncdenr.org/web/wq/ps/mtu/tmdl/tmdls

- **Public Announcement from NCDWQ TMDL Listserv:**

From: denr.dwq.tmdl303d@lists.ncmail.net [mailto:denr.dwq.tmdl303d@lists.ncmail.net]
Sent: Monday, March 14, 2011 11:59 AM
To: denr.dwq.TMDL303d@lists.ncmail.net
Subject: TMDL/303(d) Info - Public Review Draft Oyster Creek and Roaring River TMDLs

3/14/2011 Public Review Draft Oyster Creek TMDL is available for review and comment. The comment period extends through April 14, 2011. Comment submittal instructions are available with the above link.

- **WRRI listserv email received regarding public comment period:**

The WRRI Daily Digest Volume 1 : Issue 734 : "text" Format

Messages in this Issue:
201103/8 : DRAFT Total Maximum Daily Loads for Fecal Coliform for Oyster Creek, Tar-Pamlico River Basin, North Carolina
"Kebede, Adugna" <adugna.kebede@ncdenr.gov>

Date: Mon, 14 Mar 2011 10:37:24 -0400
From: "Kebede, Adugna" <adugna.kebede@ncdenr.gov>
To: "wrri-news@lists.ncsu.edu" <wrri-news@lists.ncsu.edu>
Subject: DRAFT Total Maximum Daily Loads for Fecal Coliforms for Oyster Creek, Tar-Pamlico River Basin, North Carolina
Message-ID:
<EE7F3F790126B542902F8DB67800B5D53B6AF7983D@NCWITMXMBEV39.ad.ncmail>

Now Available for Public Comment

DRAFT Total Maximum Daily Load for Fecal Coliform for Oyster Creek, Tar-Pamlico River Basin, North Carolina

March, 2011

North Carolina Department of Environment and Natural Resources, Division of Water Quality

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Adugna Kebede
NC Division of Water Quality
Planning Section
1617 Mail Service Center
Raleigh, NC 27699

The draft TMDL can be downloaded from the following link:
http://portal.ncdenr.org/web/wq/ps/mtu/tmdl/tmdls#Oyster_Creek