Total Maximum Daily Loads for Fecal Coliform for Queens Creek, North Carolina

[Waterbody IDs: 19-41-16-1; 19-41-16-5; 19-41-16-3; 19-41-16-4a; 19-41-16-4b; 19-41-16-2; 19-41-16a; 19-41-16b1; 19-41-16b2; 19-41-16c; 19-41-16d]

Final Report

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White Oak River Basin

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List of Abbreviations

BMP	Best Management Practice
CFR	Code of Federal Regulations
CWA	Clean Water Act
EPA	Environmental Protection Agency
FC	Fecal Coliform Bacteria
HQW	High Quality Water supplemental classification
HUC	Hydrologic Unit Code
LA	Load Allocation
MF	MF is an abbreviation for the membrane filter procedure for bacteriological analysis.
ml	Milliliter(s)
MOS	Margin of Safety
MPN	Most Probable Number
NCAC	NC Administration Code
NCDEH	North Carolina Division of Environmental Health
NCDOT	North Carolina Department of Transportation
NCDWQ	North Carolina Division of Water Quality
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NSSP	National Shellfish Sanitation Program
ROW	NCDOT road right of way
SA	Class SA water body: suitable for commercial shellfishing and all other tidal saltwater use
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WLA	Waste Load Allocation

SUMMARY

Total Maximum Daily Load (TMDL)

1. 303(d) Listed Waterbody Information

State: North Carolina

County: Onslow

Major River Basin: White Oak River Basin

Watershed: USGS HUC 03020106020060

Impaired Waterbody (2010 303(d) List):

Waterbody Name – [AU]	Description	Water Quality Classification	Acres
Bell Swamp - [19-41-16-1]	From source to Queen Creek	SA;HQW	1
Dicks Creek - [19-41-16-5]	From source to Queen Creek	SA;HQW	22.8
Halls Creek - [19-41-16-3]	From source to Queen Creek	SA;HQW	26.9
Parrot Swamp - [19-41-16-4a]	From source to DEH closure line.	SA;HQW	65.3
Parrot Swamp - [19-41-16-4b]	From DEH closure line to Queen Creek	SA;HQW	46.3
Pasture Branch - [19-41-16-2]	From source to Queen Creek	SA;HQW	1
Queen Creek - [19-41-16a]	DEH closed area from source to DEH Conditionally Approved closed line at Queens Creek Road Bridge.	SA;HQW	283.7
Queen Creek - [19-41-16b1]	From DEH Conditionally Approved closed line at Queens Creek Road Bridge to DEH Conditionally Approved Open line at northeast mouth of Parrot Swamp.	SA;HQW	150.8
Queen Creek - [19-41-16b2]	From DEH Conditionally Approved closed line at Queens Creek Road Bridge to DEH Conditionally Approved Open line at northeast mouth of Parrot Swamp.	SA;HQW	11.6
Queen Creek - [19-41-16c]	From DEH Conditionally Approved Open line at northeast mouth of Parrot Swamp to Intracoastal Waterway.	SA;HQW	283.8
Queen Creek - [19-41-16d]	DEH closed area at mouth of Dicks Creek	SA;HQW	3

Constituent(s) of Concern: Fecal Coliform Bacteria

Designated Uses: Shellfish harvesting, biological integrity, propagation of aquatic life, and recreation.

Applicable Tidal Salt Water Quality Standards for Class SA Waters:

"Organisms of coliform group: fecal coliform group not to exceed a median MF count 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 the approval of shellfish growing areas "the median fecal coliform Most Probable Number (MPN) or the geometric mean MPN of water shall not exceed 14 per 100 milliliters, and not more than 10 percent of the samples shall exceed a fecal coliform MPN of 43 per 100 milliliters (per five tube decimal dilution) in those portions of areas most probably exposed to fecal contamination during most unfavorable hydrographic conditions" (15A NCAC 18A .0431 Standards for an Approved Shellfish Growing Area). In addition, "a minimum of the 30 most recent randomly collected samples from each sample station shall be used to calculate the median or geometric mean and 90th percentile to determine compliance with this standard" (NSSP, 2007).

2. TMDL Development

Development Tools (Analysis/Modeling): Spreadsheet-based steady-state tidal prism model

Critical Condition: The 90th percentile concentration is the concentration exceeded only 10% of the time. Since the data used for model simulation spans 5 years, the critical condition is implicitly included in the value of the 90th percentile of model results.

Seasonal Variation: Given the long-term flow and water quality data record used to estimate the fecal coliform load, the seasonal variability is implicitly included in the analysis.

3. TMDL Allocation Summary

		Fecal Coliform Load (MPN/day)					
Waterbody	**AUs**	**Existing Load[1]**	**WLA[2]**	**LA**	**MOS**	**TMDL**	**% Reduction**
Lower Queens	19-41-16c; 19-41-16d	Less than TMDL	1.16E+10	1.68E+12	1.88E+11	1.88E+12	0%
Middle Queens	19-41-16b1; 19-41-16b2	Less than TMDL	5.17E+09	3.57E+11	4.02E+10	4.02E+11	0%
Upper Queens, Pasture Branch, Bells Swamp	19-41-16a; 19-41-16-2; 19-41-16-1	8.61E+11	7.72E+09	2.81E+11	3.21E+10	3.21E+11	63%
Dicks Creek	19-41-16-5	Less than TMDL	1.12E+09	3.39E+10	3.89E+09	3.89E+10	0%
Parrot Swamp	19-41-16-4a; 19-41-16-4b	1.07E+11	2.14E+09	8.33E+10	9.49E+09	9.49E+10	11%
Halls Creek	19-41-16-3	2.58E+11	7.23E+08	3.03E+10	3.45E+09	3.45E+10	87%

1. *For Lower Queens, Middle Queens, and Dicks Creek, the calculated existing loads are less than the TMDL, and hence no reduction is needed from those subwatersheds.*
2. *WLA applies solely to NCDOT.*

4. Public Notice Date: June 27, 2011

5. Submittal Date: August 1, 2011

6. Establishment Date: August 18, 2011

7. EPA Lead on TMDL (EPA or blank):

8. Endangered Species (yes or blank):

9. MS4s Contributions to Impairment (Yes or Blank):

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

1 INTRODUCTION

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 develop a Total Maximum Daily Load (TMDL) for each impaired water quality limited segment 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 that 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.

The Queens Creek watershed is located in the White Oak River Basin (NC Subbasin 03-05-01 – HUC 03020106020060) along the North Carolina coast in Onslow County. The river is located within the shellfish area designated D-2 by the North Carolina Division of Environmental Health (NCDEH). Most of the shellfish growing area is conditionally open or closed, or prohibited (Figure 1.1).

When shellfish harvesting is the designated use, the primary parameter of concern is fecal coliform bacteria (FC). 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 in surface waters may come from point sources (e.g., NPDES stormwater conveyances) and nonpoint sources.

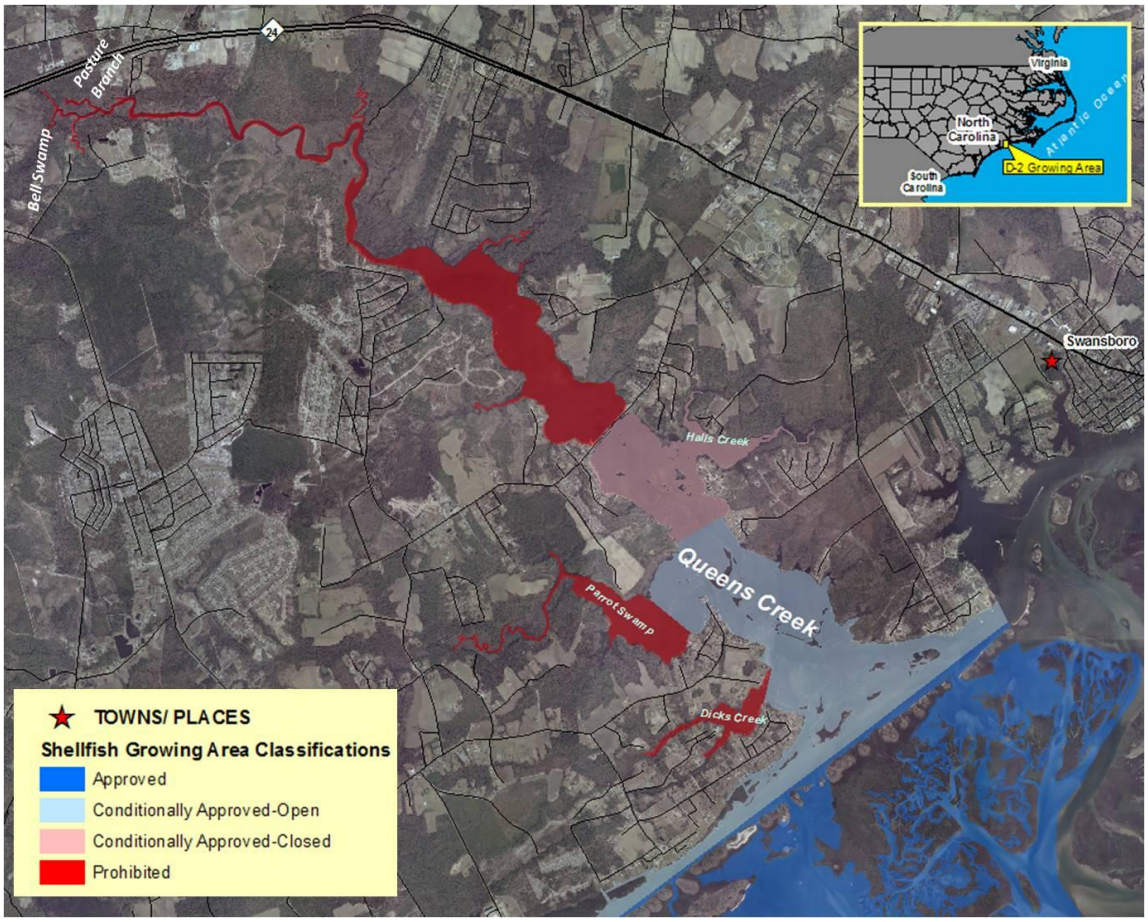

Figure 1.1 – Queens Creek Shellfish Growing Area (D-2) Classifications

1.1 TMDL Components

The 303(d) process requires that a TMDL be developed for each of the waters appearing in Category 5 of a state's Integrated Report. 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). This TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving 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.

Generally, the primary components of a TMDL, as identified by EPA (1991, 2000) and the Federal Advisory Committee (USEPA, 1998) are as follows:

Target Identification or selection of pollutant(s) and end-point(s) for consideration. The pollutant and end-point 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 end-point. 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 non-point 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 (USEPA, 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 end-point. 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 requires EPA to review all TMDLs for approval or disapproval. Once EPA approves a TMDL, then the waterbody may be moved to Category 4a of the Integrated Report. Waterbodies remain in Category 4a 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.

1.2 Documentation of Impairment

The North Carolina Division of Water Quality (NCDWQ) Surface Water and Wetlands classification for these impaired waters is Class SA, HQW Waters – Shellfish Harvesting Waters (15A NCAC 02B.0221 Tidal Salt Water Quality Standards for Class SA Waters). Class SA waters are waterbodies suitable for commercial shellfishing and all other tidal saltwater use (NCAD, 2003).

Eleven segments, or assessment units (AUs), of Queens Creek and its tributaries have been included in Category 5 of the 2010 North Carolina Integrated Report, as shown below in Table 1.1.

Table 1.1 – Queens Creek Impaired Assessment Units

Waterbody Name – [AU]	Description	Water Quality Classification	Acres
Bell Swamp - [19-41-16-1]	From source to Queen Creek	SA;HQW	1
Dicks Creek - [19-41-16-5]	From source to Queen Creek	SA;HQW	22.8
Halls Creek - [19-41-16-3]	From source to Queen Creek	SA;HQW	26.9
Parrot Swamp - [19-41-16-4a]	From source to DEH closure line.	SA;HQW	65.3
Parrot Swamp - [19-41-16-4b]	From DEH closure line to Queen Creek	SA;HQW	46.3
Pasture Branch - [19-41-16-2]	From source to Queen Creek	SA;HQW	1
Queen Creek - [19-41-16a]	DEH closed area from source to DEH Conditionally Approved closed line at Queens Creek Road Bridge.	SA;HQW	283.7
Queen Creek - [19-41-16b1]	From DEH Conditionally Approved closed line at Queens Creek Road Bridge to DEH Conditionally Approved Open line at northeast mouth of Parrot Swamp.	SA;HQW	150.8
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Queen Creek - [19-41-16c]	From DEH Conditionally Approved Open line at northeast mouth of Parrot Swamp to Intracoastal Waterway.	SA;HQW	283.8
Queen Creek - [19-41-16d]	DEH closed area at mouth of Dicks Creek	SA;HQW	3

These restricted shellfish harvesting areas are identified as areas that do not meet their designated uses. Waters within this classification, according to 15A NCAC 02B.0221

(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 count 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.*

In addition, for approval of shellfish growing areas "the median fecal coliform Most Probable Number (MPN) or the geometric mean MPN of water shall not exceed 14 per 100 milliliters, and not more than 10 percent of the samples shall exceed a fecal coliform MPN of 43 per 100 milliliters (per five tube decimal dilution) in those portions of areas most probably exposed to fecal contamination during most unfavorable hydrographic conditions" (15A NCAC 18A .0431 Standards for an Approved Shellfish Growing Area).

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 of an MPN of 14 per 100 ml and the 90th percentile of an MPN of 43 per 100 ml. The averaging period for the monitoring data required at least 30 samples per station within the most recent five-year period, September 2005 – August 2010. A detailed analysis of the data used can be found in Appendix A.

1.3 Watershed Description

Queens Creek and its tributaries fall within the NCDEH D-2 Growing Area in Onslow County. The Queens Creek watershed was delineated using EPA BASINS (http://water.epa.gov/scitech/datait/models/basins/). The resulting watershed outline is provided below in Figure 1.2. The watershed covers about 36 square miles. The towns of Swansboro and Hubert are within the watershed. Oyster and clam production are good throughout the area, however most of the shellfish beds areas are prohibited, or conditionally closed or open, due to high fecal coliform levels.

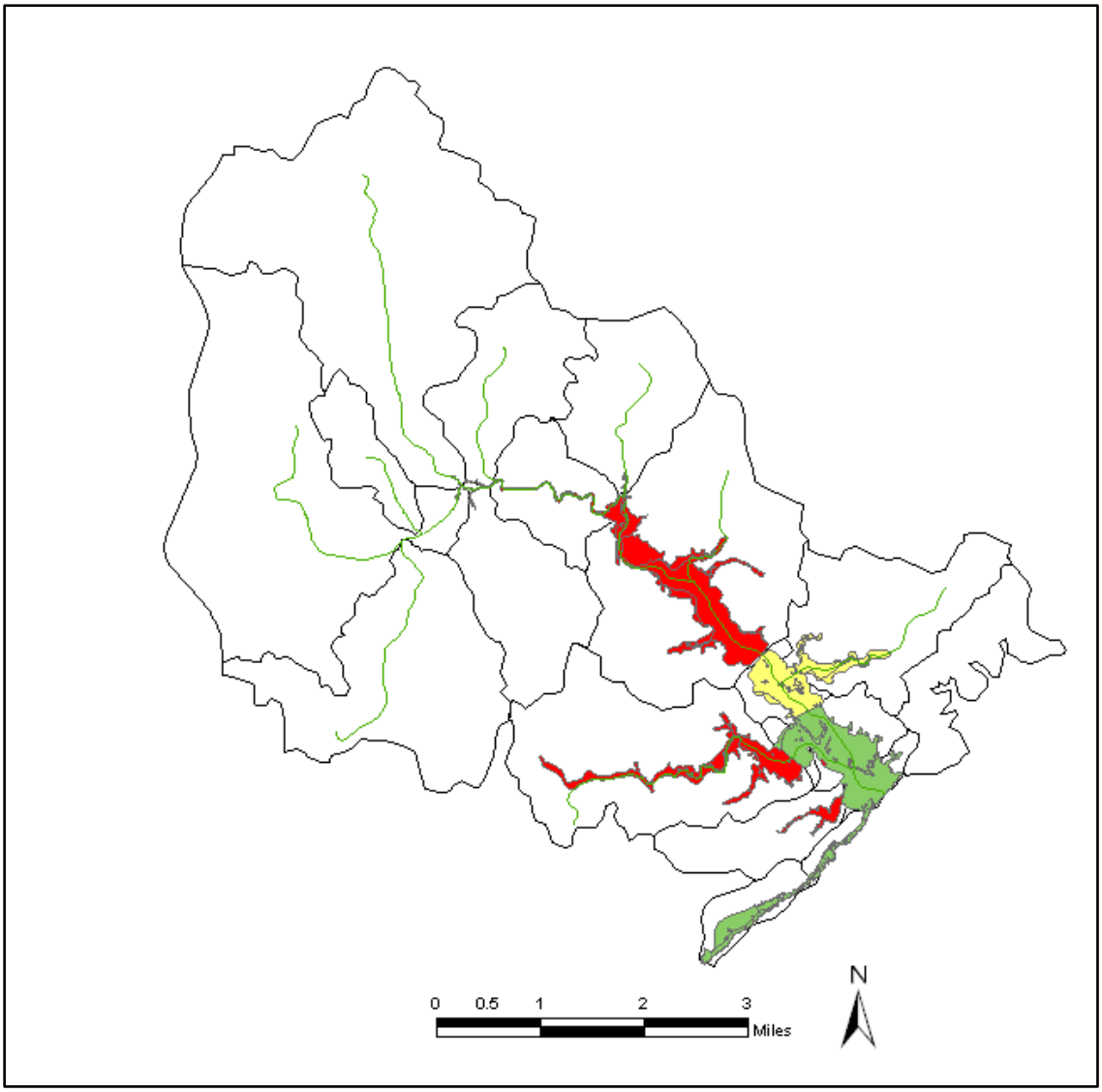

Figure 1.2 – Queens Creek Watershed Delineation

The dominant tide in this region is the lunar semi-diurnal (M_2) tide with a mean tidal range of 3.11 ft based on the NOAA station at Beaufort, NC (NOAA, 2010).

The 2006 National Land Cover Database (NLCD) was used to obtain land cover characteristics of the watershed (http://www.mrlc.gov/nlcd2006_downloads.php). Land cover distribution is shown in Figure 1.3 and land cover acreages are provided in Table 1.2. The dominant land covers in this watershed are forest (26%), crops and pasture lands (18%), wetlands (17%), shrub/scrub areas (14%), and developed lands (14%).

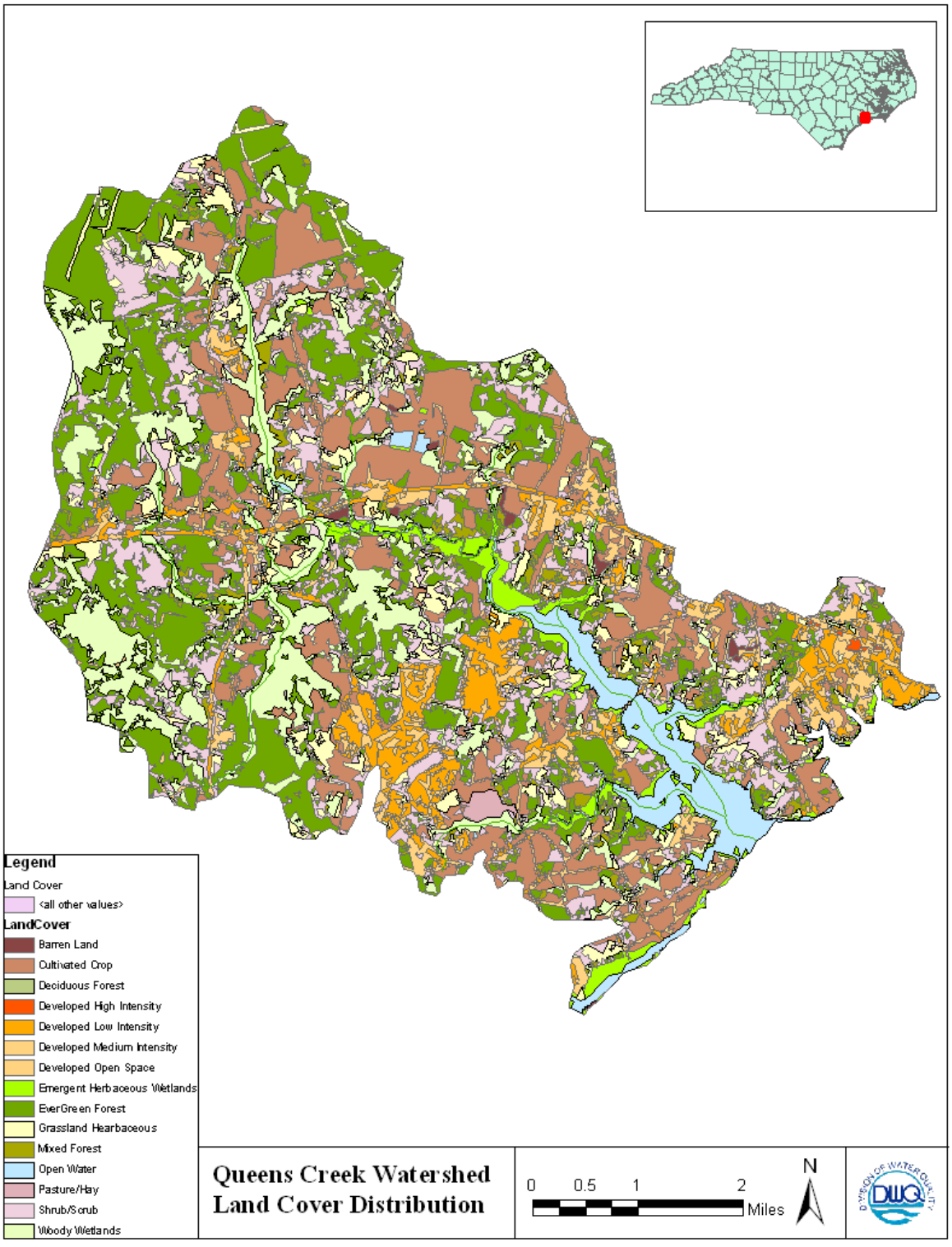

Figure 1.3 – 2006 NLCD Land Cover of the Queens Creek Watershed

Table 1.2 – 2006 Land Cover Distribution of the Queens Creek Watershed

Land Cover Category	Area (acres)	Percent Total
Cultivated Crop	4,109.9	17.7%
Pasture/Hay	62.5	0.3%
Deciduous Forest	4.6	0.0%
Evergreen Forest	5,566.2	24.0%
Mixed Forest	643.2	2.8%
Developed High Intensity	14.1	0.1%
Developed Low Intensity	1,412.1	6.1%
Developed Medium Intensity	108.5	0.5%
Developed Open Space	1,607.7	6.9%
Grassland Herbaceous	1,584.5	6.8%
Shrub/Scrub	3,175.7	13.7%
Emergent Herbaceous Wetlands	636.7	2.7%
Woody Wetlands	3,225.1	13.9%
Barren Land	63.7	0.3%
Open Water	1,025.9	4.4%
Total Area	23,240.2	100.0%

1.4 Water Quality Characterization

The Shellfish Sanitation and Recreational Water Quality Section of the NCDEH is responsible for classifying shellfish harvesting waters to ensure 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. 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 closed to harvest, at least temporarily, and consequently the designated use is not being achieved.

NCDEH has monitored shellfish growing regions throughout North Carolina for the past several decades. Queens Creek is sampled using the systematic random sampling strategy as outlined in the National Shellfish Sanitation Program's Model Ordinance and guidance document. In addition to the routine random monitoring of the areas, conditional area samples are collected after rainfall events for some stations.

There are 27 fecal coliform monitoring stations sampled by the NCDEH in the D-2 Growing Area, as shown in Figure 1.4. Of these, 16 are within the Queens Creek watershed. Most of the data available were collected through the random monitoring

strategy, although four stations (7, 9, 11, and 16) are sampled under the conditional monitoring strategy which is targeted towards measuring fecal coliform concentrations after rainfall events, typically in conditionally-approved open growing areas. NCDEH data from September 2005-August 2010 are summarized in Appendix A for those stations within the Queens Creek watershed. The 2010 NCDEH Sanitary Survey Report notes four stations did not meet standards for growing area criteria (NCDEH, 2010). The report also notes that there was widespread improvement in bacteriological water quality within the D-2 area since the previous Sanitary Survey Report in 2006.

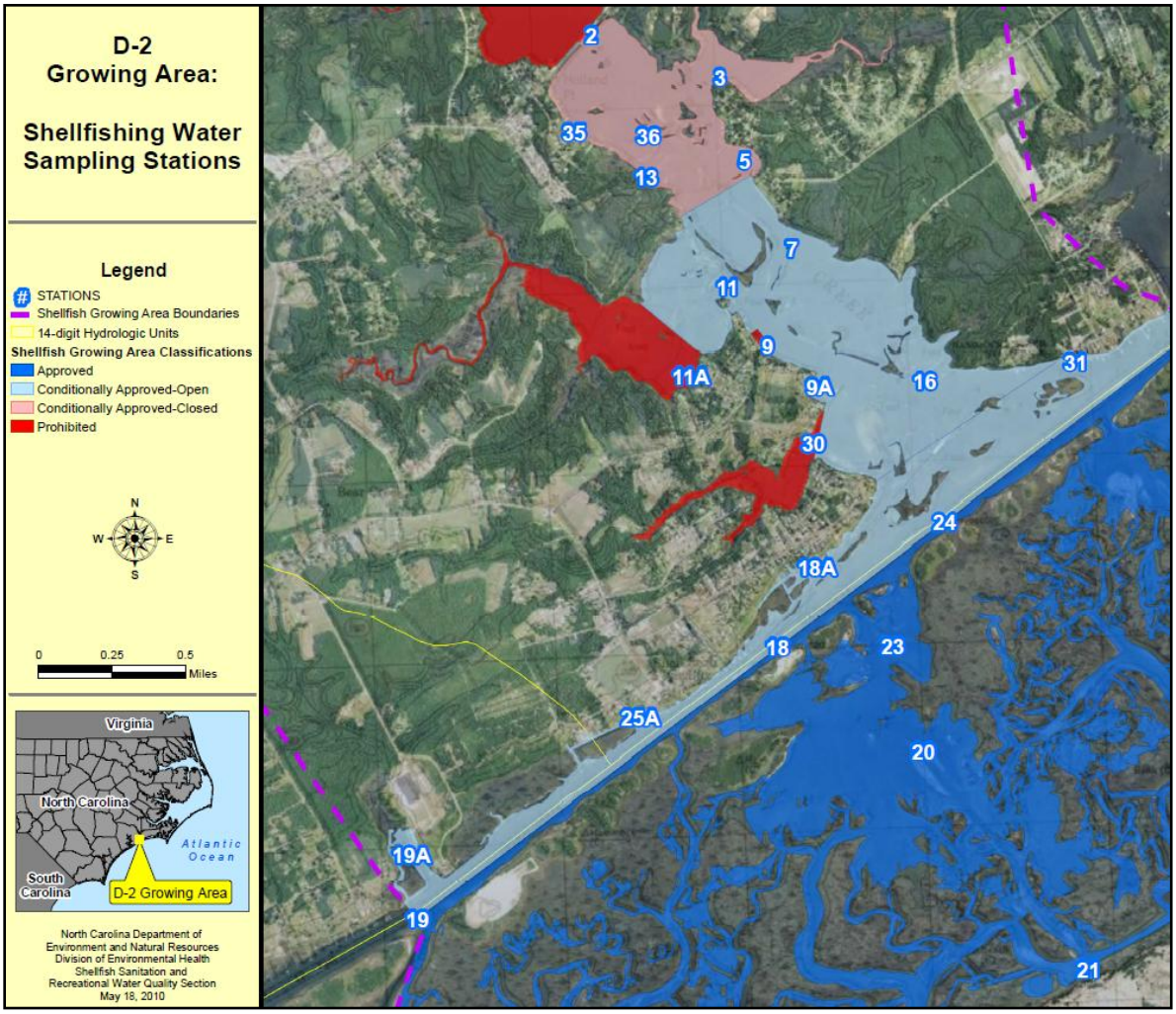

Figure 1.4 – NCDEH Fecal Coliform Monitoring Stations

2 SOURCE ASSESSMENT

2.1 Nonpoint Source Assessment

Non-point sources are diffuse sources that typically cannot be identified as entering a water body at a single location. Nonpoint source loading typically occurs during rain events when surface runoff transports water carrying fecal coliform over the land surface and discharges it into the stream network. The transport of fecal coliform from the land to the restricted shellfish harvesting area is dictated by the hydrology, soil type, land use, and topography of the watershed.

There are many types of nonpoint sources in watersheds that contribute to the restricted shellfish harvesting areas. The most recent NCDEH Shoreline Survey (NCDEH, 2010) documented and mapped potential sources of fecal coliform in Queens Creek. The resulting map is provided in Appendix B. The survey found that stormwater draining into Queens Creek and its tributaries is of particular concern due to the steep grades along the shoreline throughout the area. Runoff is conveyed rapidly via ditches, pipes, and lawns into shellfishing waters. With the increasing development in the region, the majority of the stormwater reaching Queens Creek originates in residential neighborhoods and roadways. Growth in the area continues to proceed at a high rate. Overall, 56 subdivisions were noted in the D-2 growing area during the shoreline survey. Ten of these subdivisions are new, and several of the pre-existing subdivisions surveyed are now at or near capacity. Over 700 new homes have been constructed within the various subdivisions of the D-2 watershed since the last survey was conducted in 2006.

Wildlife in the watershed are considered to make up background concentrations of fecal coliform. There are various forested areas and agricultural fields scattered throughout the watershed, so wildlife is prevalent throughout the majority of this region. Large populations of deer, foxes, raccoons, and other small mammals are found in the area, as well as waterfowl and other birds. Waste from these animals can be transported through stormwater ditches into shellfishing waters, and have some impact on the growing area during rainfall events.

Grazing animals contribute fecal coliform through either direct access to streams or runoff from deposition or manure spreading. According to the shoreline survey, there are several small horse farms within the D-2 watershed. There are also four cattle farms and two residences where a small number of chickens are kept penned. It is not likely that any of these farms has a significant impact on water quality within the area, as most are located well away from the water, and those that are not contain only a few animals within large pastures (NCDEH, 2010). Land cover data for the watershed indicates that pasture/hay land area (grazing land) represents less than 1 percent of the watershed.

Agricultural fields of soybeans, corn, tobacco, and winter wheat, as well as a few large forested areas are also likely to contribute contaminants to the creeks and waterways following rain events.

Nonpoint source contributions to the bacterial levels from human activities generally arise from malfunctioning or improperly-sited septic systems and their associated drain fields, or illicit connections of sanitary sewage to the stormwater conveyance system. The majority of onsite systems in the growing area were visited and inspected during the shoreline survey (NCDEH, 2010) and most were found to be functioning properly. Several issues were located, however, and were reported to the Onslow County Health Department for corrective action.

2.2 Point Source Assessment

All wastewater discharges to surface water in the State of North Carolina must receive a permit to control water pollution. The CWA initiated strict control of wastewater discharges with responsibility of enforcement given to the Environmental Protection Agency (EPA). The EPA then created the National Pollutant Discharge Elimination System (NPDES) to track and control point sources of pollution. The primary method of control is by issuing permits to discharge with limitations on wastewater flow and constituents. The EPA delegated permitting authority to the State of North Carolina in 1975.

While there are two operating wastewater treatment plants within the D-2 growing area, neither contains an outfall that discharges to waters in the Queens Creek watershed. Therefore, neither plant is considered to be contributing to the fecal coliform impairment. The first plant is the Kingsbridge Package Wastewater Treatment Plant and serves the Kingsbridge II subdivision. This plant does not have an outfall. After treatment and chlorine disinfection, effluent is pumped into one of two low-pressure pipe nitrification fields. The daily flow of the plant averages only 3,000 gallons per day, even though the plant is permitted for up to 48,000 gallons per day. The second plant is the Webb Creek WWTP (NC0062642), which discharges outside the Queens Creek watershed into Wallace Creek.

The NC Department of Transportation (NCDOT) has a number of roads in the project area, including Highway 24, and has a statewide Phase I NPDES stormwater permit (NCS000250). Stormwater has previously been considered to be a nonpoint source; however, NPDES-permitted sources are to be included in the wasteload allocation (WLA) per EPA guidance (USEPA, 2002).

3 TOTAL MAXIMUM DAILY LOADS AND LOAD ALLOCATION

3.1 TMDL Objective

The TMDL objective is to meet North Carolina water quality fecal coliform standards of a median MF count of 14 per 100 ml and not more than 10 percent of the samples shall exceed an MF count of 43 per 100 ml. In addition, the National Shellfish Sanitation Program (NSSP) standard for the approved classification of growing areas requires that fecal coliform concentrations not exceed a median or geometric mean of a MPN of 14 per 100 ml and the 90^{th} percentile of a MPN of 43 per 100 ml, with a minimum of the 30 most recent samples used to calculate compliance.

Both standards have the same numeric targets but the NSSP standard uses a minimum 30- sample averaging period. Data collected from September 2005 through August 2010 were used for the purpose of this TMDL.

3.2 Modeling

3.2.1 Approach

Bay and coastal waters such as Queens Creek and its tributaries are subject to the action of the tides. The ebb and flood of the tide serves to move water between locations exchanging and mixing with other water. The tide and amount of freshwater discharge into the embayment are the dominant influences on the transport of fecal coliform. Therefore, the TMDL was calculated using the spreadsheet-based steady-state tidal prism model. This modeling approach has been used in approved TMDLs in several other states (VADEQ, 2005; MDE, 2004).

The steady-state tidal prism model is spreadsheet-based and incorporates the influences of tidally induced transport, freshwater input, and removal of fecal coliform via decay. Depending on the geometry of the embayment, the model may have multiple segments. The model assumes that the embayment is well mixed within a single segment, and freshwater input, tidal range, and the first-order decay of fecal coliform are all constant. A brief description of the model is presented below.

The steady-state tidal prism model calculates fecal coliform load using equation 3.1:

$$L = [C(Q_b + kV) - Q_0C_0] \times Cf \qquad (3.1)$$

where:

- L = fecal coliform load (counts per day)
- C = mean fecal coliform concentration (MPN /100ml) of the segment
- k = the fecal coliform removal/decay rate (per day)

C_0 = the fecal coliform concentration (MPN/100ml) entering the segment on the flood tide
Q_0 = the quantity of water that enters the segment on the flood tide that did not flow out of the segment on the previous ebb tide (m^3 per tidal cycle)
Q_b = the quantity of mixed water that leaves the segment on the ebb tide that did not enter the segment on the previous flood tide (m^3 per tidal cycle)
V = the mean volume of the segment (m^3)
Cf = the unit conversion factor

The fecal coliform decay rate, *k*, was set at 0.36 per day, which is considered a conservative estimate. The value of the decay rate varies from between 0.3 and 3.0 in salt water (Thomann and Mueller, 1987). *Qb* and *Q0* are estimated based on the steady state condition as follows:

$$Q_b = Q_0 + Q_f$$
$$Q_0 = \beta Q_T$$

where:
Q_f = mean freshwater input during one tidal cycle
β = exchange ratio
Q_T = the quantity of water that enters the segment on the flood tide

Q_T is calculated based on the tidal range. The mean tidal range is assumed to be 3.11 ft, as monitored at a nearby NOAA station at Beaufort, NC. The dominant tide in this region is the lunar semi-diurnal (M_2) tide with a tidal period of 12.42 hours. Therefore, the M_2 tide is used as the representative tidal cycle. In general, the exchange ratio varies from 0.3 to 0.7, based on the previous model tests in coastal embayments (Kuo et al., 1998; Shen et al., 2002). A mean value of 0.5 was used for the exchange ratio.

The stream flow (Q_f) used to represent the fresh water inflow was based on a ratio of the drainage area of the Queens Creek watershed as compared to the drainage area and the stream flows measured by the U.S. Geological Survey at the New River gaging station (USGS 02093000) near Gum Branch, NC. The selection of the gaging station for use in the model is determined by its similarity in watershed characteristics to Queens Creek watershed and the proximity of the station to the TMDL study area.

3.2.2 Existing Load Calculation

Model segmentation is provided below in Figure 3.1. Existing median and 90th percentile concentrations are required for each segment as model inputs. These were calculated by combining monitoring data from all monitoring stations within each segment and calculating the overall median and the 90th percentile fecal coliform

concentrations. Table 3.1 provides the monitoring stations used in each model segment and the overall median and 90th percentile concentrations.

NCDEH conditional monitoring data were not used to calculate existing concentrations. Conditional monitoring only takes place in a few stations in the conditionally-approved open growing area in lower Queens Creek (segment m1) after rainfall events to see if waters can be reopened to shellfishing. These concentrations tend to be inconsistently higher compared to stations where conditional monitoring data were not collected (as shown in Appendix A, Table A.1). Therefore, to avoid creating bias in the model, conditional data were not used to calculate existing loads.

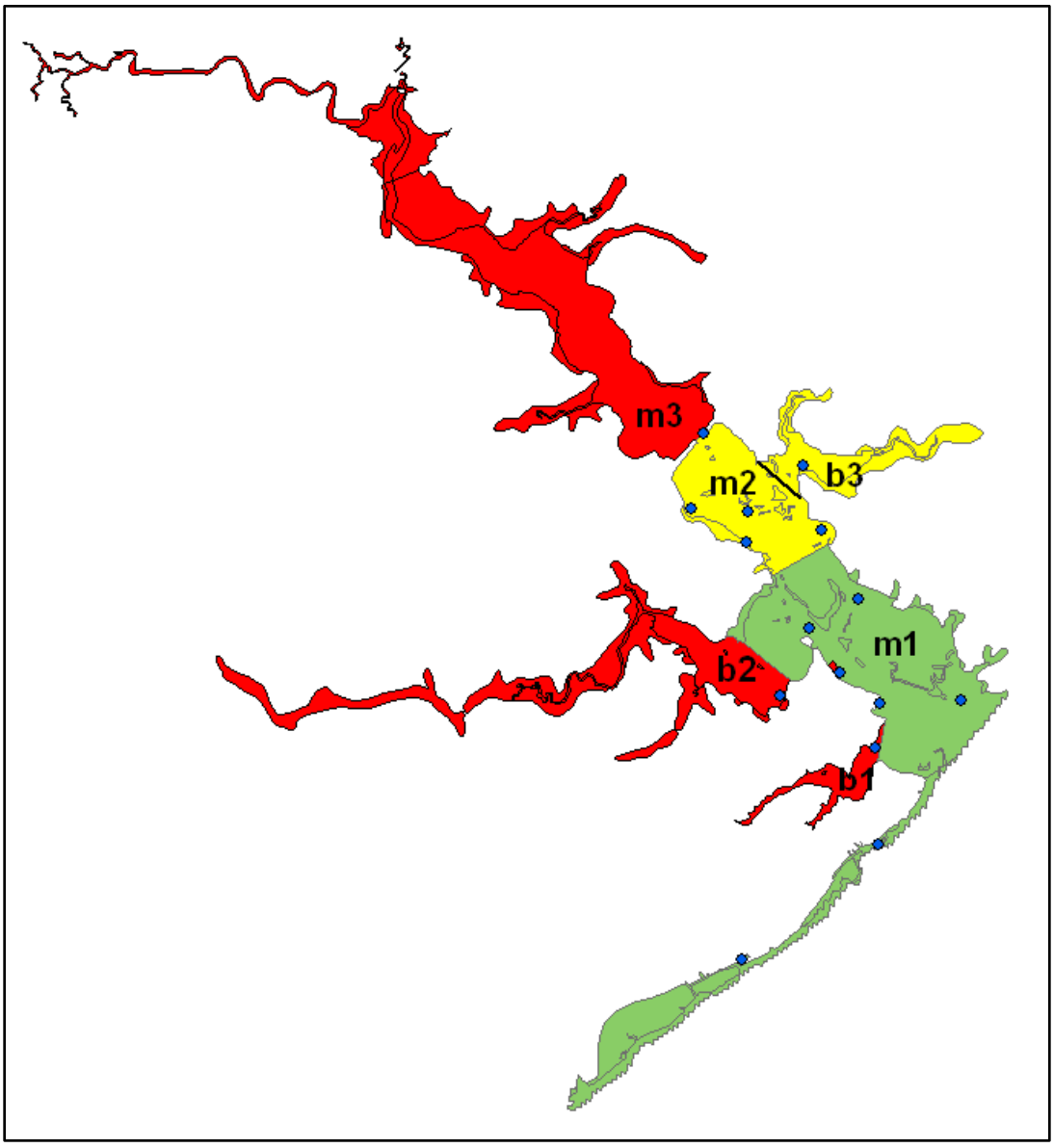

Figure 3.1 – Model Segmentation

Table 3.1 – Monitoring stations associated with each model segment

Model Segment #	Waterbodies	AU#	NCDEH Monitoring Station(s)	Median FC (MPN/100 ml)	90th Percentile FC (MPN/100ml)
m0	Ocean Boundary		18, 31, 24	4.0	11.0
m1	Lower Queens	19-41-16c; 19-41-16d	7, 9, 9A, 11, 16	7.3	30.0
m2	Middle Queens	19-41-16b1; 19-41-16b2	2, 5, 13, 35, 36	7.8	45.0
m3	Upper Queens, Pasture Branch, Bells Swamp	19-41-16a; 19-41-16-2; 19-41-16-1	2	13.5	75.0
b1	Dicks Creek	19-41-16-5	30	7.8	26.0
b2	Parrot Swamp	19-41-16-4a; 19-41-16-4b	11A	11.0	38.0
b3	Halls Creek	19-41-16-3	3	49.0	168.0

The concentrations listed in Table 3.1 were then used in Equation 3.1 to calculate the existing fecal coliform loads associated with both the median and the 90th percentile concentrations. Table 3.2 presents the estimated existing loads for each segment.

3.2.3 TMDL Calculation

The TMDL was calculated by using Equation 3.1 and the North Carolina water quality fecal coliform standards of a median of 14 counts per 100 ml and a 90th percentile of 43 counts per 100 ml. Table 3.2 presents the estimated TMDL for each segment.

The percent load reduction needed to meet the fecal coliform standard was estimated using equation 3.2:

$$Reduction = (Existing\ Load - TMDL)/Existing\ Load \quad (3.2)$$

Table 3.2 – Load reduction requirements under variations of standard criteria

Standard Category	Segment #	AU#	Standard (MPN/100ml)	Existing Load (MPN/day)	TMDL (MPN/day)	Percent Reduction Required
Median	m1	19-41-16c; 19-41-16d	14	Less than TMDL	5.98E+11	0%
	m2	19-41-16b1; 19-41-16b2	14	Less than TMDL	1.31E+11	0%
	m3	19-41-16a; 19-41-16-2; 19-41-16-1	14	1.58E+11	1.05E+11	34%
	b1	19-41-16-5	14	Less than TMDL	1.27E+10	0%
	b2	19-41-16-4a; 19-41-16-4b	14	3.48E+10	3.09E+10	11%
	b3	19-41-16-3	14	8.05E+10	1.12E+10	86%
90th Percentile	m1	19-41-16c; 19-41-16d	43	Less than TMDL	1.88E+12	0%
	m2	19-41-16b1; 19-41-16b2	43	Less than TMDL	4.02E+11	0%
	m3	19-41-16a; 19-41-16-2; 19-41-16-1	43	8.61E+11	3.21E+11	63%
	b1	19-41-16-5	43	Less than TMDL	3.89E+10	0%
	b2	19-41-16-4a; 19-41-16-4b	43	1.07E+11	9.49E+10	11%
	b3	19-41-16-3	43	2.58E+11	3.45E+10	87%

For segments m1, m2, and b1, the calculated existing loads are less than the TMDL, and hence no reduction in loading from these watersheds is needed. The FC water quality standard will be met in these segments once TMDLs are implemented and loading is reduced from the watersheds of the other segments.

Required reductions in loading are higher for the 90th percentile model results (highlighted in orange in Table 3.2) and allow for both standards to be met. Therefore, the TMDLs were calculated using the 90th percentile criterion.

3.3 TMDL Allocation

Total Maximum Daily Load (TMDL) can be defined as the total amount of pollutant that can be assimilated by the receiving water body while achieving water quality standards. A TMDL can be expressed as the sum of all point source allocations (WLAs), nonpoint source allocations (LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality. This definition can be expressed by equation 3.3.

$$TMDL = \sum WLAs + \sum LAs + MOS \quad (3.3)$$

The goal of the TMDL is to estimate allowable pollutant loads and to allocate those loads in order to implement control measures and to achieve water quality standards. The Code of Federal Regulations (40 CFR § 130.2 (1)) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. The systematic procedures adopted to estimate TMDL allocations are described below.

3.3.1 Margin of Safety (MOS)

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.

As a conservative estimate in the TMDL calculation, an explicit MOS of 10% is included. The explicit MOS was achieved by multiplying the TMDL by 10%. These loads are shown in Table 3.3.

Table 3.3 – Margin of Safety Allocation

		Fecal Coliform Load (MPN/day)		
Standard Category	**Segment #**	**TMDL**	**MOS**	**Allowable Load (TMDL – MOS)**
90th Percentile	m1	1.88E+12	1.88E+11	1.69E+12
	m2	4.02E+11	4.02E+10	3.62E+11
	m3	3.21E+11	3.21E+10	2.89E+11
	b1	3.89E+10	3.89E+09	3.50E+10
	b2	9.49E+10	9.49E+09	8.54E+10
	b3	3.45E+10	3.45E+09	3.10E+10

3.3.2 Waste Load Allocation (WLA)

As described in Section 2.2, NCDOT is the only NPDES-permitted discharge in the watershed included in the WLA as a contributing source. Data is not available to calculate the existing load for the NCDOT.

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 subwatershed 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. The NCDOT ROW is 2.6% of the total watershed area, as shown below in Table 3.4. The resulting WLA for NCDOT is provided below in Table 3.5.

NCDOT should 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.

Table 3.4 - Queens Creek Watershed NCDOT Contributing Area by Subwatershed

Segment #	Total Sub-Watershed Area (acres)	NCDOT Land Area (acres)	NCDOT Land Area (% of total)
m1	652.7	4.5	0.7%
m2	252.2	3.6	1.4%
m3	17,080.8	456.3	2.7%
b1	579.4	18.6	3.2%
b2	2137.8	53.5	2.5%
b3	1366.0	31.8	2.3%
Total	22,068.9	568.3	2.6%

Table 3.5 – NPDES Wasteload Allocations

NPDES Permittee	Segment #	NCDOT Existing Load (MPN/day)	WLA (MPN/day)
NCDOT	m1	N/A	1.16E+10
	m2	N/A	5.17E+09
	m3	N/A	7.72E+09
	b1	N/A	1.12E+09
	b2	N/A	2.14E+09
	b3	N/A	7.23E+08

3.3.3 Load Allocation (LA)

All fecal coliform loadings from nonpoint sources such as non-MS4 urban land, agriculture land, and forestlands are reported as LAs. The LA allocations were estimated by subtracting the MOS and WLA allocations from the TMDL. The estimated allocations of fecal coliform loading for nonpoint sources are presented in Table 3.6.

Table 3.6 – Nonpoint Source Allocation

Segment #	LA (MPN/day)
m1	1.68E+12
m2	3.57E+11
m3	2.81E+11
b1	3.39E+10
b2	8.33E+10
b3	3.03E+10

3.3.4 Critical Condition and Seasonal Variation

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 used for model simulation spans 5 years, the critical condition is implicitly included in the value of the 90th percentile of model results. Given the length of the monitoring record and the standard's recognition of unusual and infrequent events, the 90th percentile is used instead of the absolute maximum.

The EPA also requires that these TMDL studies take into account seasonal variations. The consideration of critical condition and seasonal variation is to account for the hydrologic and source variations. Seasonal variations involve changes in surface runoff, stream flow, and water quality as a result of hydrologic and climatologic patterns. For the Queens Creek TMDL study, variations due to changes in the hydrologic cycle as well as temporal variability in fecal coliform sources are accounted for by the use of the long-term data record to estimate the current load.

The seasonal fecal coliform distribution for the stations in Segment m1 of Queens Creek is presented in Figure 3.2 and includes both the random and conditional monitoring data. The seasonal distributions of fecal coliform concentrations for the other segments are presented in Appendix A. The results show that high fecal coliform levels occur throughout the year in the estuary. The largest standard deviation corresponds to the highest concentration for each station. These high concentrations result in a high 90^{th} percentile concentration. Given the long-term flow and water quality data record used to estimate the fecal coliform load, the seasonal variability is implicitly included in the analysis.

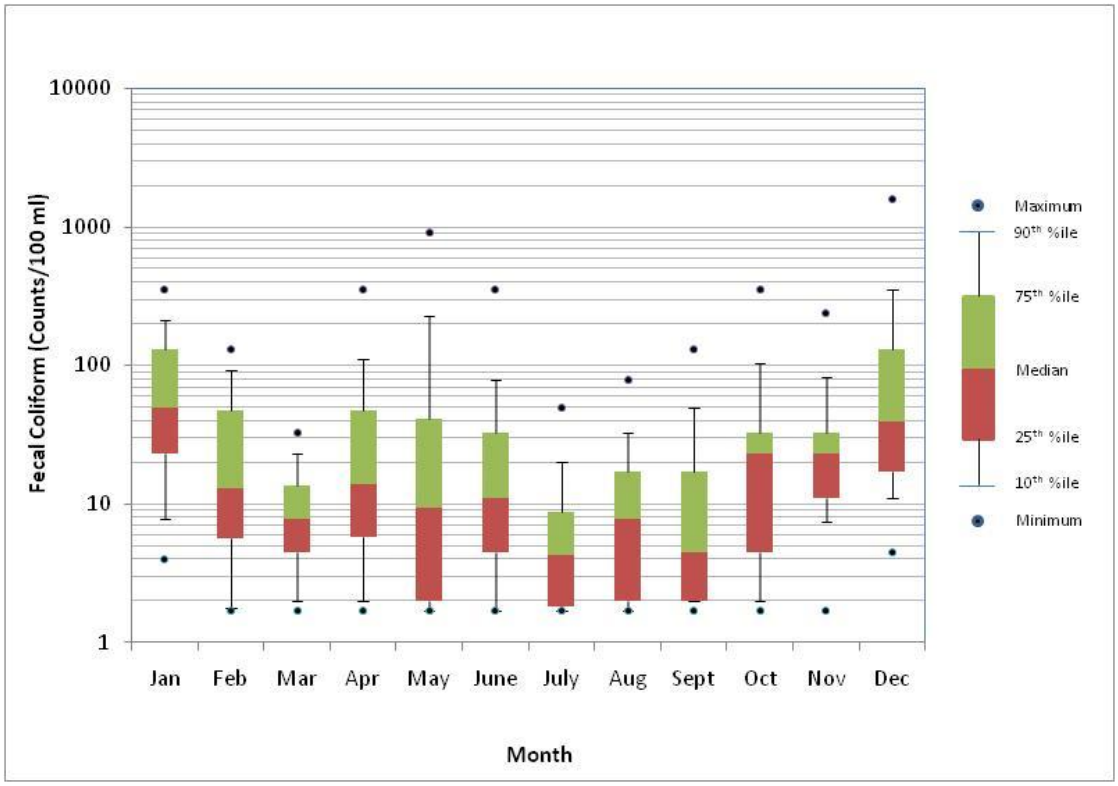

Figure 3.2 - Seasonal distribution of fecal coliform concentrations (random and conditional monitoring data combined) in Segment m1 (log scale)

3.3.5 TMDL Summary

A summary of the TMDL is provided below in Table 3.7. Reductions in fecal coliform loading are required for Upper Queens Creek (including Pasture Branch and Bells Swamp), Parrot Swamp, and Halls Creek. Reductions in loading from these watersheds allow for standards to be met throughout Queens Creek.

The largest percent reduction is needed from the Halls Creek area. Land cover in this subwatershed is primarily mixed between developed land (28%), shrub/scrub (20%), forest (19%), and cropland (14%). The potential sources map produced by NCDEH (Appendix B) shows a concentrated amount of stormwater outfalls in this watershed.

Table 3.7 – Estimated TMDL and Load Allocation for Fecal Coliform for Queens Creek

		Fecal Coliform Load (MPN/day)					
Waterbodies	**AUs**	**Existing Load[1]**	**WLA**	**LA**	**MOS**	**TMDL**	**% Reduction**
Lower Queens	19-41-16c; 19-41-16d	Less than TMDL	1.16E+10	1.68E+12	1.88E+11	1.88E+12	0%
Middle Queens	19-41-16b1; 19-41-16b2	Less than TMDL	5.17E+09	3.57E+11	4.02E+10	4.02E+11	0%
Upper Queens, Pasture Branch, Bells Swamp	19-41-16a; 19-41-16-2; 19-41-16-1	8.61E+11	7.72E+09	2.81E+11	3.21E+10	3.21E+11	63%
Dicks Creek	19-41-16-5	Less than TMDL	1.12E+09	3.39E+10	3.89E+09	3.89E+10	0%
Parrot Swamp	19-41-16-4a; 19-41-16-4b	1.07E+11	2.14E+09	8.33E+10	9.49E+09	9.49E+10	11%
Halls Creek	19-41-16-3	2.58E+11	7.23E+08	3.03E+10	3.45E+09	3.45E+10	87%

1. *For Lower Queens, Middle Queens, and Dicks Creek, the calculated existing loads are less than the TMDL, and hence no reduction is needed from those subwatersheds.*

4 TMDL IMPLEMENTATION PLAN

An implementation plan is not included in this TMDL. Local stakeholder groups, governments, and agencies are encouraged to develop an implementation plan and utilize funding sources for water quality improvement projects targeted at BMP construction and public outreach. Some potential funding sources include the North Carolina Clean Water Management Trust Fund, and Section 319 and 205j funds. Individual land owners may apply for the Community Conservation Assistance Program and Agriculture Cost Share Program to improve the condition of their property. The next NCDEH Sanitary Survey for the D-2 shellfish growing area will help further identify current sources of bacteria and drainage pathways that allow bacteria to enter Queens Creek and its tributaries.

NCDEH will continue to monitor water quality in Queens Creek using the systematic random sampling strategy as outlined in the National Shellfish Sanitation Program's Model Ordinance and guidance document. This data will be used to evaluate progress towards the goal of reaching water quality standards.

5 PUBLIC PARTICIPATION

A draft of the TMDL was publicly noticed through various means. NCDWQ electronically distributed the draft TMDL and public comment information to known interested parties. The announcement is provided in Appendix C. The TMDL was also available from the NCDWQ's website at http://portal.ncdenr.org/web/wq/ps/mtu/tmdl/tmdls during the comment period. The public comment period lasted from June 27 – July 27, 2011. NCDWQ received two comments from NCDOT. A summary of their comments and NCDWQ's response is provided in Appendix D.

6 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

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

Pam Behm
e-mail: pamela.behm@ncdenr.gov

Kathy Stecker
e-mail: kathy.stecker@ncdenr.gov

7 REFERENCES

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VADEQ. 2005. Total Maximum Daily Load Report for Shellfish Areas Listed Due to Bacterial Contamination.

Appendix A: NCDEH Monitoring Data Summary

Table A.1 – Queens Creek NCDEH Monitoring Data Summary, September 2005 - August 2010

			Fecal Coliform Bacteria Concentration (MPN/100 ml)		
Station	**# Samples**	**Type of Sampling**	**Median**	**Geometric Mean**	**90th Percentile**
2	30	Random	13.5	13.7	75
3	30	Random	49	37.6	168
5	30	Random	7.8	10.3	48
7	30	Random	5.8	7.6	43
	115	Conditional	23	25.4	168
9A	30	Random	10.1	8.9	35
9	30	Random	4.5	5.9	22
	120	Conditional	23	22.0	157
11A	30	Random	11	8.9	38
11	30	Random	6.8	7.4	34
	110	Conditional	23	22.8	133
13	30	Random	7.8	7.7	28
16	30	Random	6.2	5.2	18
	118	Conditional	22	18.4	105
18	30	Random	3	3.9	12
24	29	Random	2	3.9	14
30	30	Random	7.8	7.3	26
31	30	Random	4.25	3.5	8
35	30	Random	7.8	9.5	62
36	30	Random	6.8	6.1	25

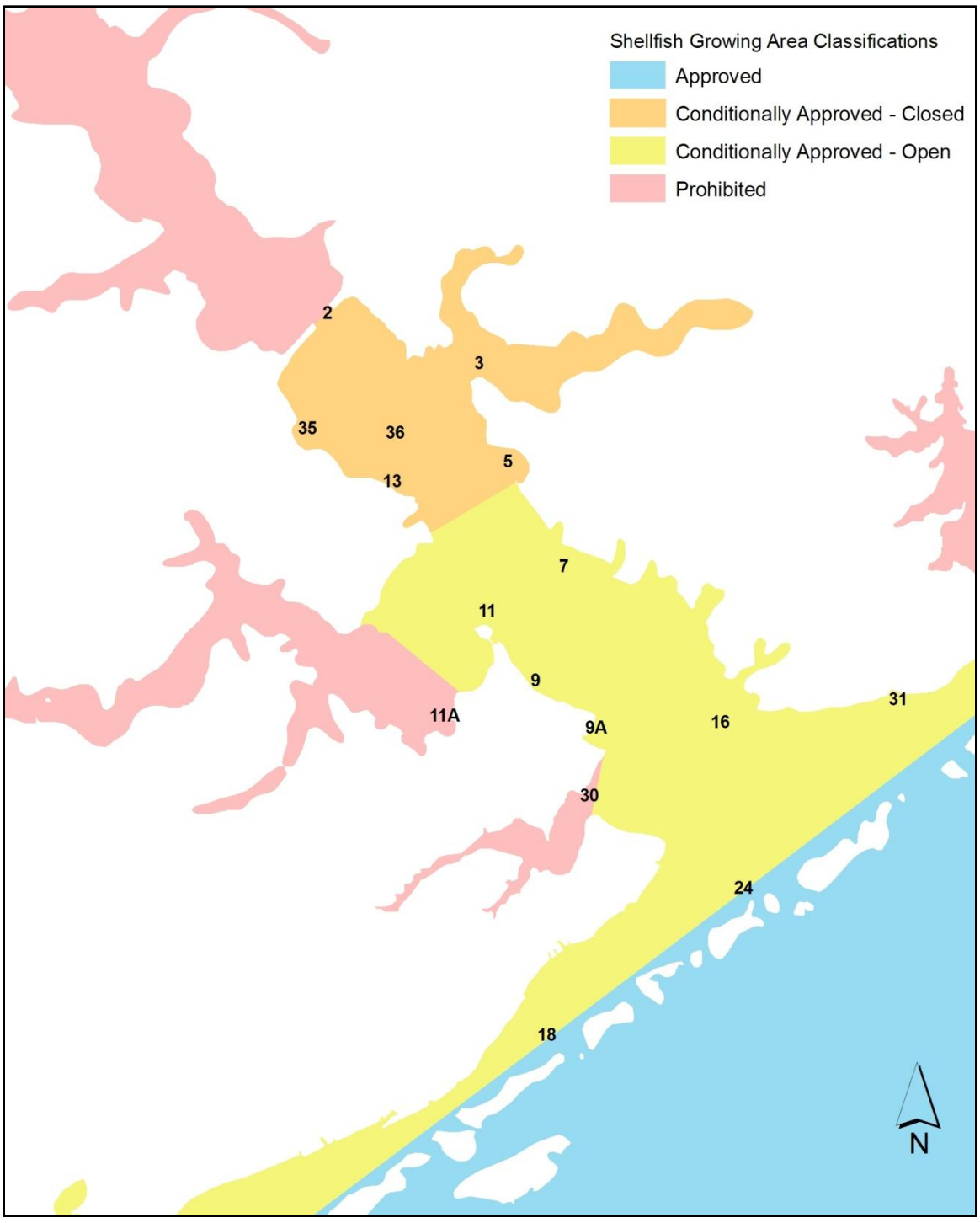

Figure A.1 – NCDEH Monitoring Stations

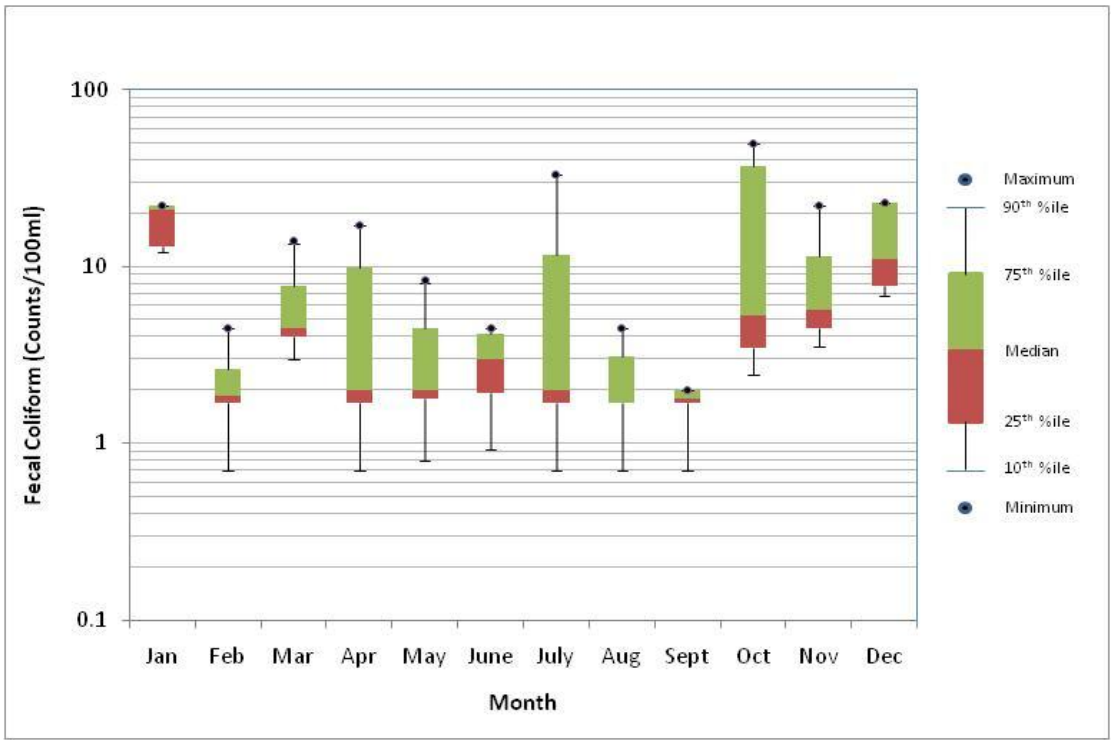

Figure A.2 - Seasonal distribution of fecal coliform concentrations in Segment m0 (log scale)

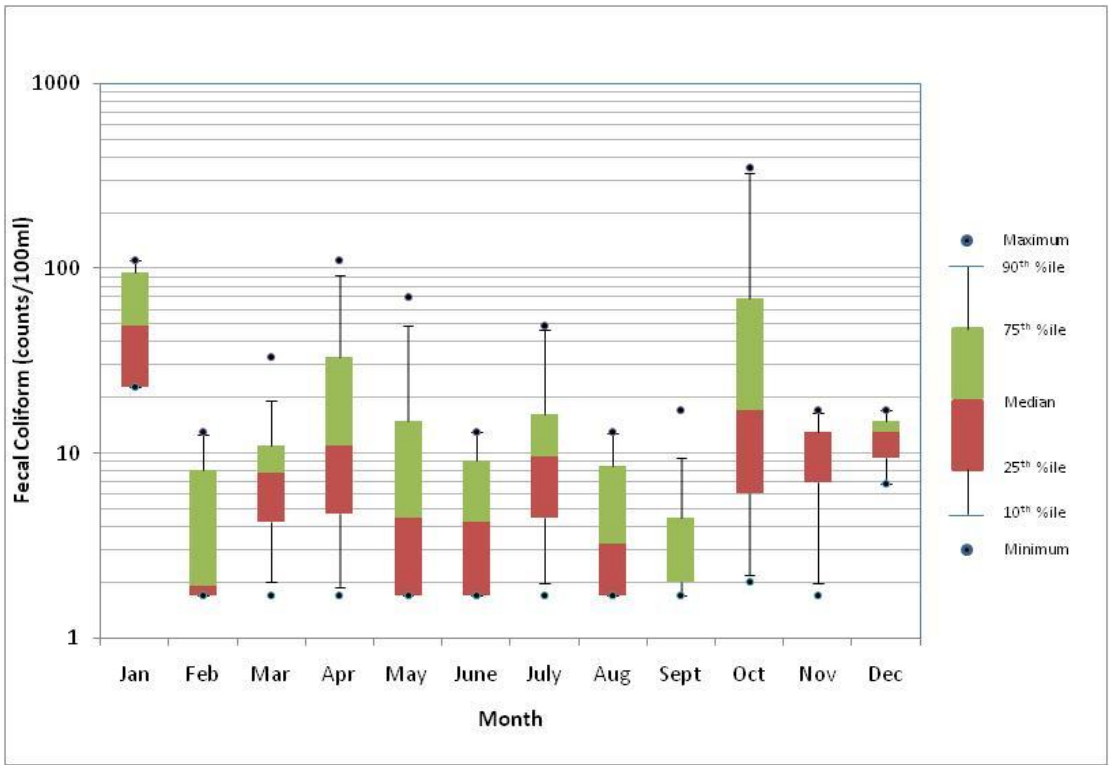

Figure A.3 - Seasonal distribution of RANDOM monitoring fecal coliform concentrations in Segment m1 (log scale)

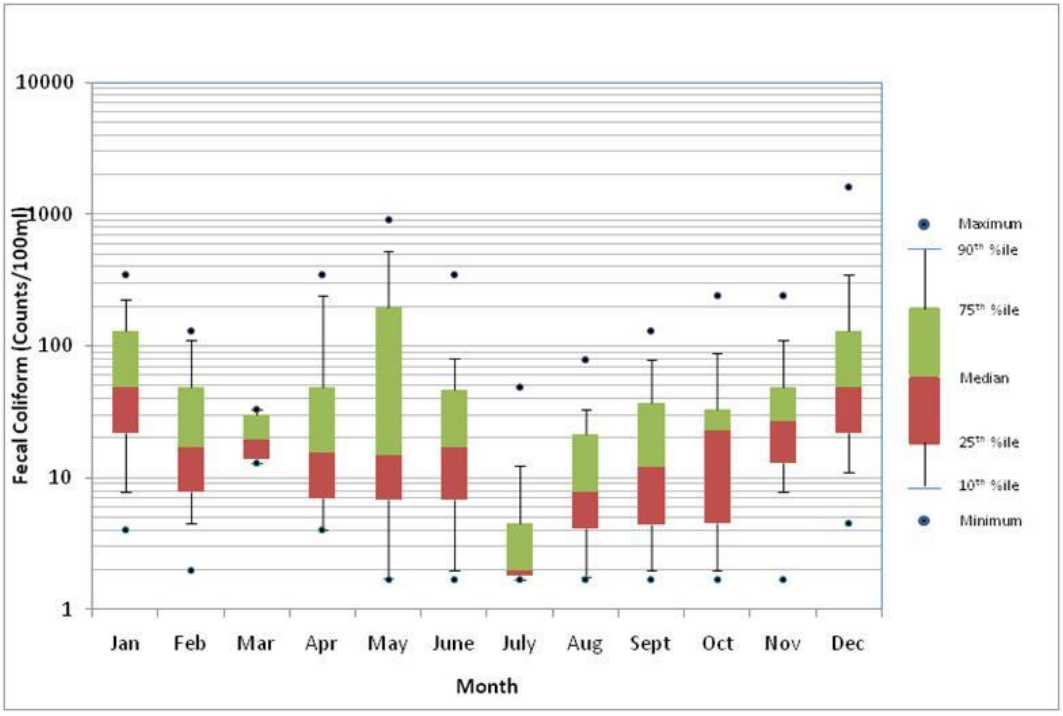

Figure A.4 - Seasonal distribution of CONDITIONAL monitoring fecal coliform concentrations in Segment m1 (log scale)

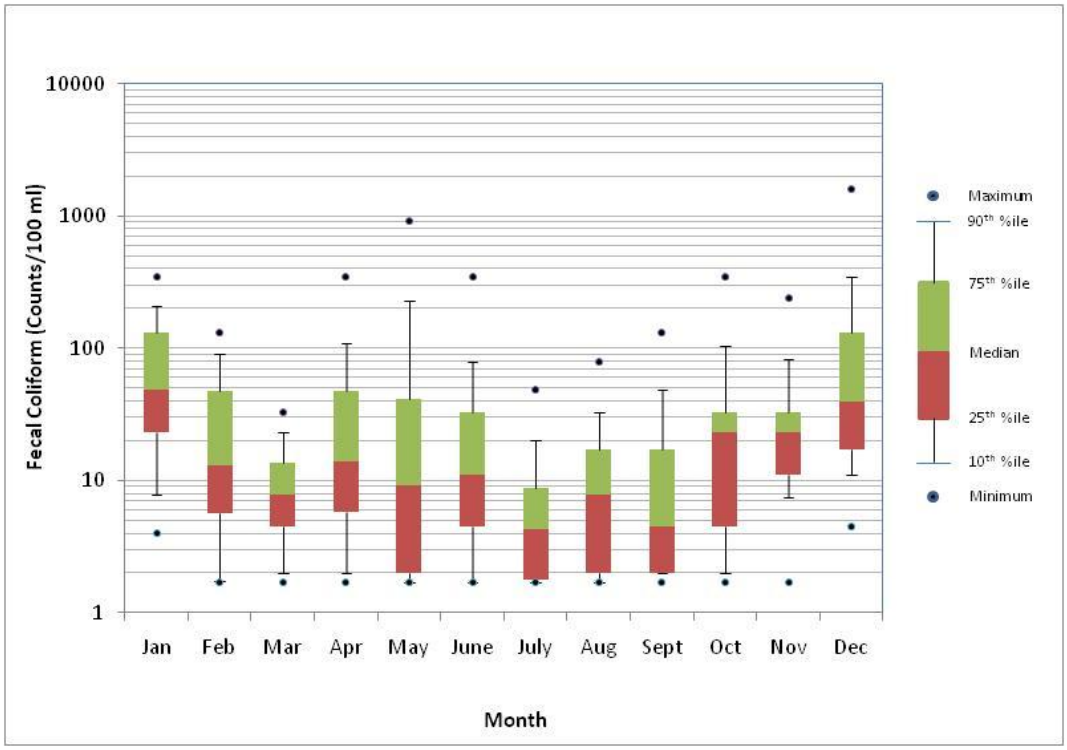

Figure A.5 - Seasonal distribution of fecal coliform concentrations (random and conditional monitoring data combined) in Segment m1 (log scale)

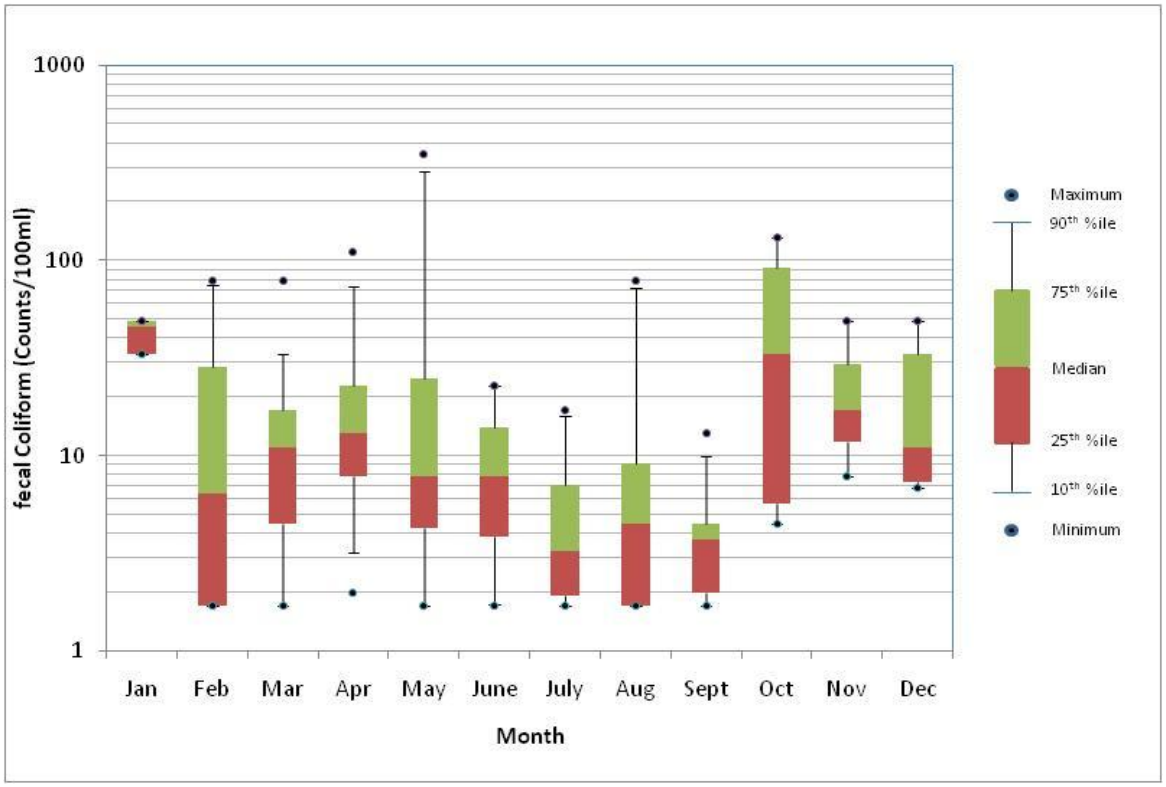

Figure A.6 - Seasonal distribution of fecal coliform concentrations in Segment m2 (log scale)

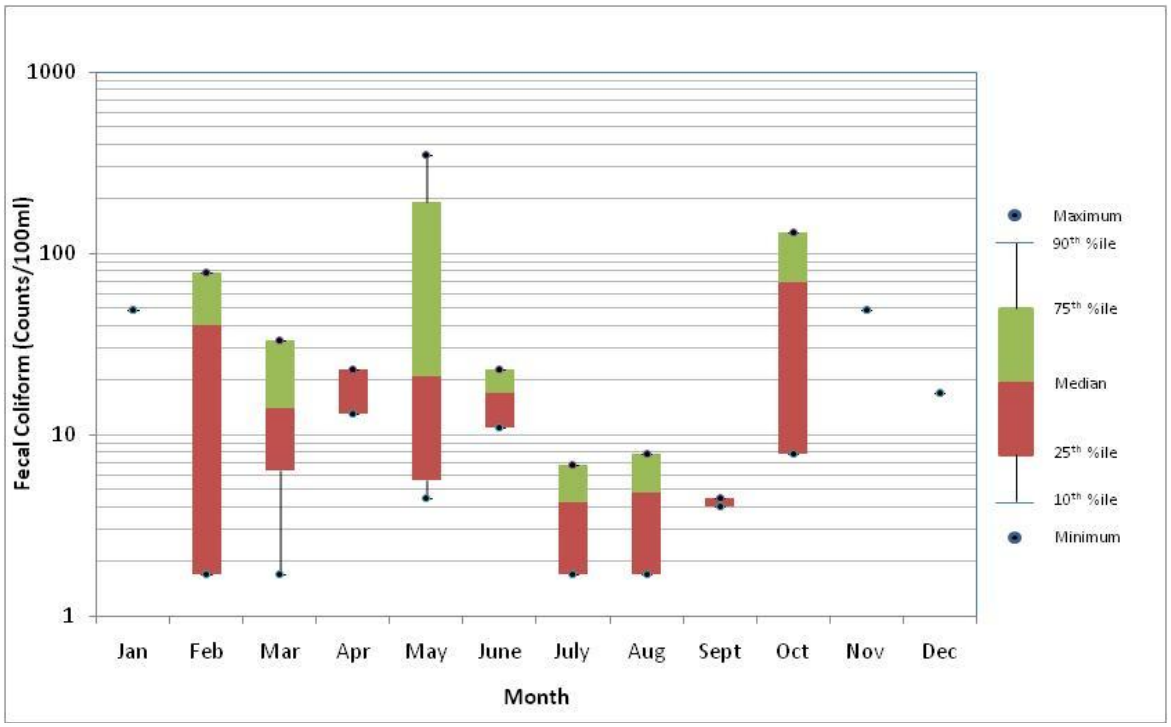

Figure A.7 - Seasonal distribution of fecal coliform concentrations in Segment m3 (log scale)

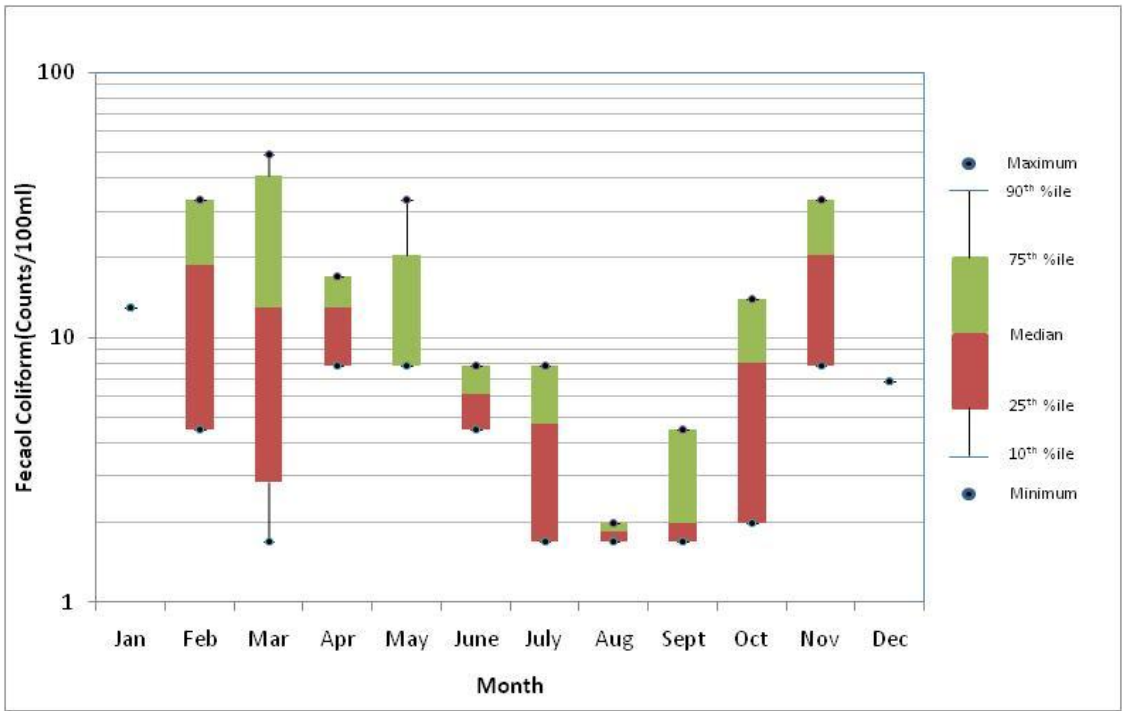

Figure A.8- Seasonal distribution of fecal coliform concentrations in Segment b1 (log scale)

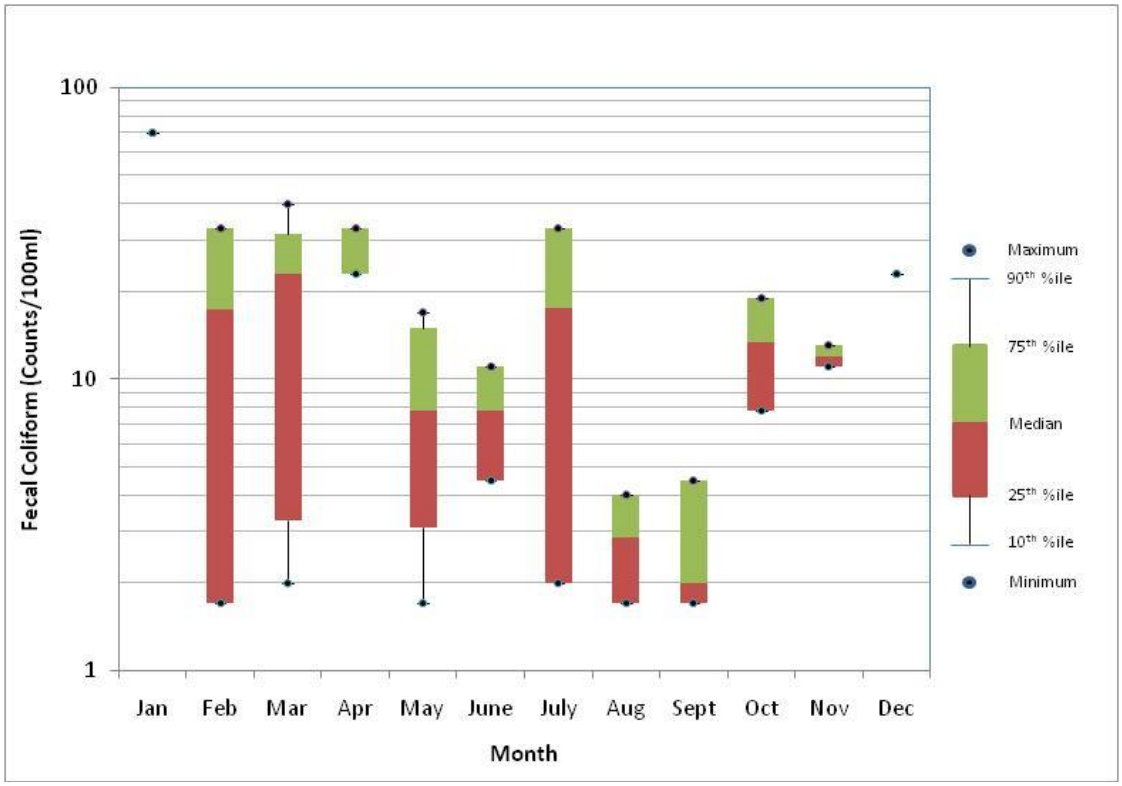

Figure A.9- Seasonal distribution of fecal coliform concentrations in Segment b2 (log scale)

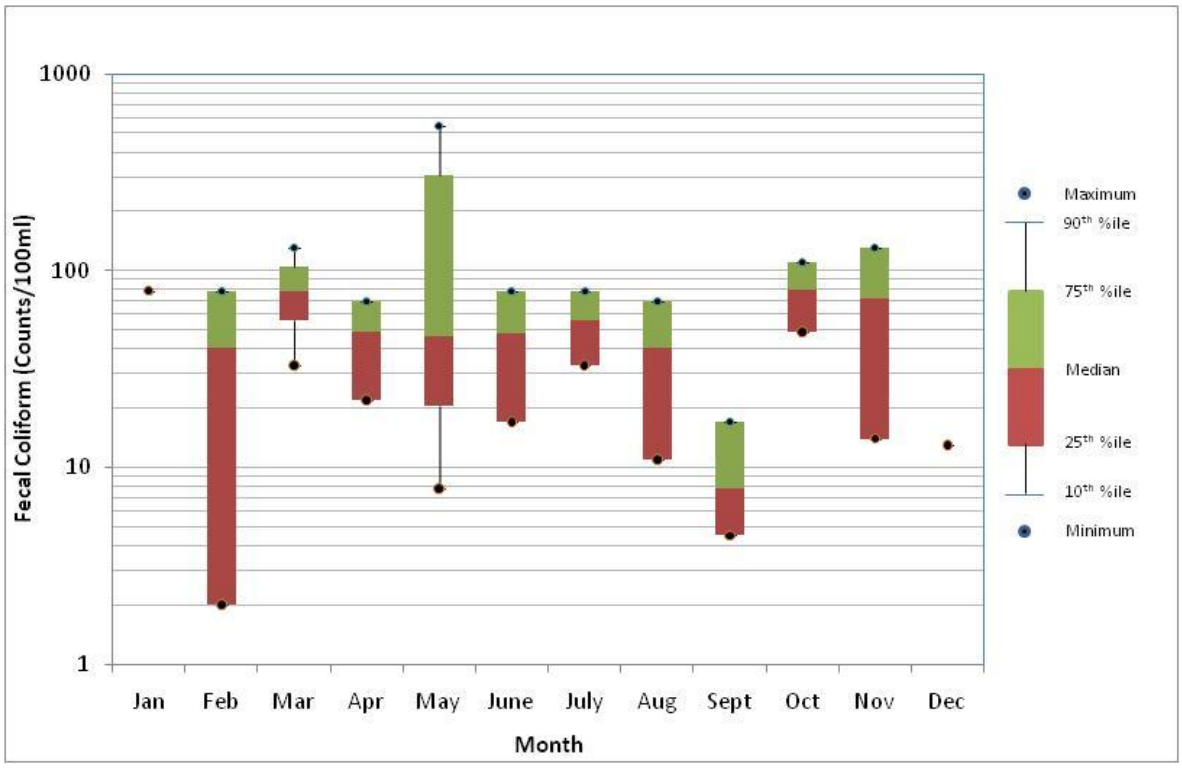

Figure A.10- Seasonal distribution of fecal coliform concentrations in Segment b3 (log scale)

Appendix B: NCDEH Mapping of Potential Pollution Sources in D-2 Growing Area

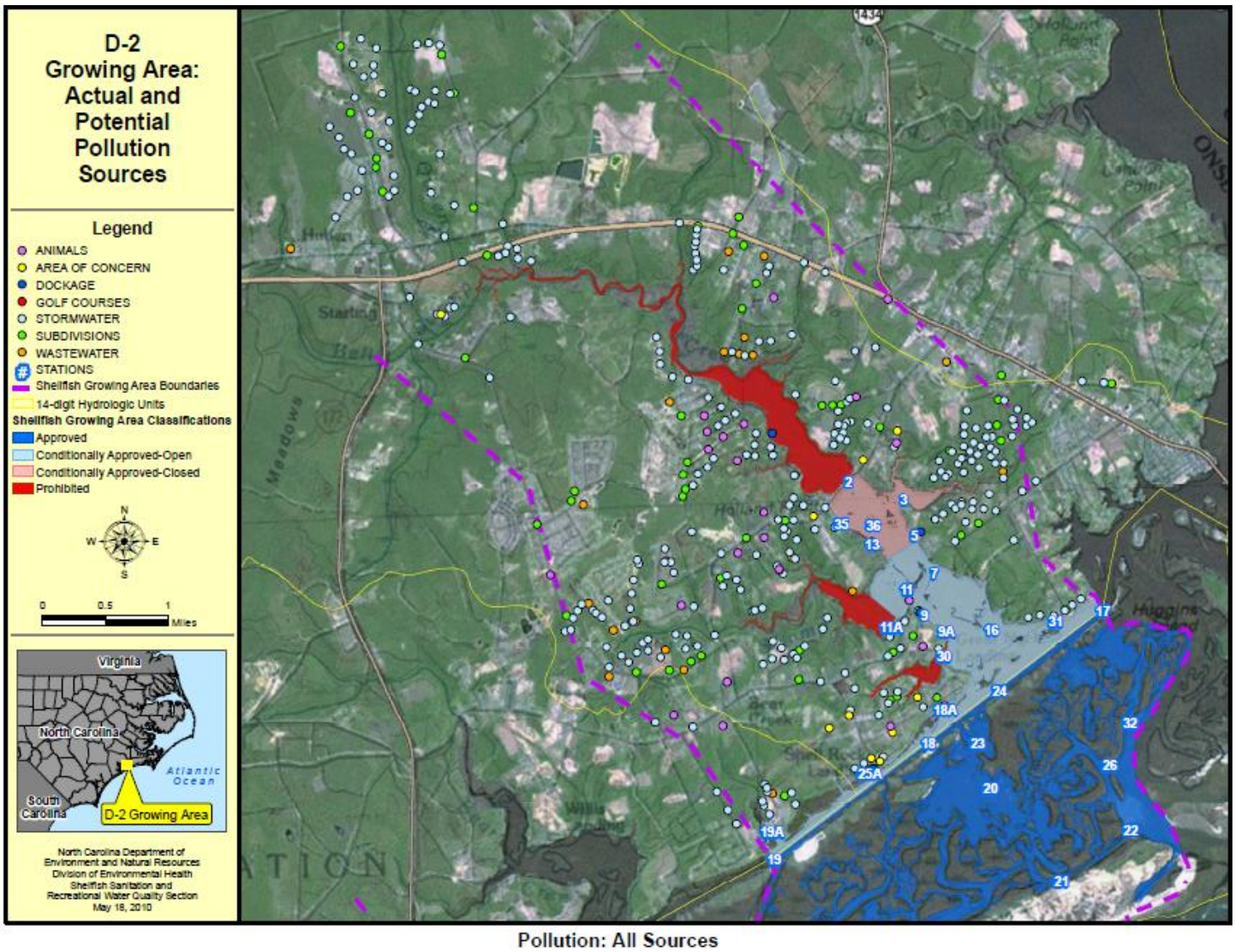

Figure B.1 - NCDEH Mapping of Potential Pollution Sources in D-2 Growing Area (NCDEH, 2010)

Appendix C: Public Announcement

-----Original Message-----
From: wrri-news-owner@lists.ncsu.edu [mailto:wrri-news-owner@lists.ncsu.edu]
Sent: Tuesday, June 28, 2011 4:21 AM
To: wrri-news@lists.ncsu.edu
Subject: [wrri-news] Digest (1 messages)

The WRRI Daily Digest
Volume 1 : Issue 778 : "mime" Format

June 27, 2011
North Carolina Department of Environment and Natural Resources, Division of Water Quality

Now Available for Public Comment
DRAFT Total Maximum Daily Load for Fecal Coliform for Queens Creek, White Oak River Basin, North Carolina

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 July 27, 2011. Comments concerning the report should be directed to Pam Behm at pamela.behm@ncdenr.gov or write to:

Pam Behm
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#QueensCreek

****
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NC DWQ Modeling and TMDL Unit
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Fax: 919-807-6497

E-mail correspondence to and from this address may be subject to the North Carolina Public Records Law and may be disclosed to third parties.

Appendix D: Public Comments Responsiveness Summary

The public comment period lasted from June 27 – July 27, 2011. Two comments were received from NCDOT. A summary of their comments and NCDWQ's response is provided below.

Comment 1

NCDOT commented that there is insufficient information on model inputs and outputs provided in the report. For example, existing fecal coliform loads to seven of the assessment units, as well as existing loads from NCDOT, are omitted from the report.

Response: The model used for this study is a spreadsheet-based, simplified, steady-state tidal prism model. As described in Section 3.2.1., existing loadings (as the model output) are calculated based on the median and the 90th percentile of the observed data from each segment (the values used are listed in Table 3.1 and these are model inputs). Similarly, the TMDL loadings were calculated based on the median and 90th percentile standard (14 and 43 MPN/100ml, respectively). Model parameters such as exchange ratio and mean tidal range are described and the values used are given in section 3.2.1. The value used for the fecal coliform decay rate has been added to section 3.2.1.

The model is structured in such a way that multiple assessment units can be included in a single segment as shown in Table 3.1. Therefore, the load calculated for the segment applies to all the assessment units in the same segment. Table 3.2 is revised to show the assessment units included in each model segment. Existing loadings are not included in the report for those model segments and associated assessment units where the calculated existing load was less than the calculated TMDL load and therefore received a 0% required reduction. Five of the eleven assessment units received a 0% required reduction. In addition, as explained in section 3.3.2, data is not available to calculate the existing load specifically for the NCDOT.

Comment 2

NCDOT requested clarification on the averaging period used as the basis for NCDOT's WLA and the time period used for compliance evaluation.

Response: The averaging period used to develop the NCDOT's WLA was September 2005 through August 2010. NCDEH will continue to monitor Queens Creek and its tributaries using the systematic random sampling strategy as outlined in the National Shellfish Sanitation Program's Model Ordinance and guidance document. This data will be used to assess overall progress towards meeting TMDL goals and determine if the water quality criteria are being met. Section 4 was modified to clarify compliance evaluation.