Total Maximum Daily Loads for Fecal Coliform for the Shallotte River, North Carolina

[Waterbody IDs: 15-25-2-(10)a, 15-25-2-(10)b, 15-25-2-(10)c, 15-25-2-(10)d1, 15-25-2-(10)d2, 15-25-2-11-(2), 15-25-2-12-(2), 15-25-2-14, 15-25-2-15-(3), 15-25-2-16, 15-25-2-16-1-(2), 15-25-2-16-4-(2)]

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Lumber 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
NCDMF	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: Brunswick

Major River Basin: Lumber River Basin

Watershed: USGS HUC 030402080201, 030402080202, 030402080203, 030402080204

Impaired Waterbody (2010 303(d) List):

Waterbody Name – [AU]	Description	Water Quality Classification	Acres
Shallotte River – 15-25-2-(10)a	From mouth of Mill Pond to a line crossing the Shallotte River from a point 948 meters north of Shell Point on the east bank across to the south mouth of Middle Dam Creek.	SA;HQW	158.3
Shallotte River - 15-25-2-(10)b	From a line crossing the Shallotte River from a point 948 meters north of Shell Point on the east bank across to the south mouth of Middle Dam Creek to a line crossing the Shallotte River 459 meters north of Shell Point on the east bank across to a point	SA;HQW	59.4
Shallotte River - 15-25-2-(10)c	From a line crossing the Shallotte River 459 meters north of Shell Point on the east bank across to a point 651 meters north of the Swash to a line crossing the Shallotte River from Shell Point across to the Swash.	SA;HQW	89
Shallotte River - 15-25-2-(10)d1	From a line crossing the Shallotte River from Shell Point across to the Swash to the Intracoastal Waterway.	SA;HQW	336.5
Shallotte River - 15-25-2-(10)d2	Hughes Marina	SA;HQW	4.2
The Mill Pond – 15-25-2-11-(2)	From a point 1.0 mile below Brunswick County SR 1145 to Shallotte River	SA;HQW	2.9
Sams Branch – 15-25-2-12-(2)	From proposed dam approximately	SA;HQW	3.6

Waterbody Name – [AU]	Description	Water Quality Classification	Acres
	3/4 mile upstream from Shallotte River channel to Shallotte River (0.585717439651489 S Miles)		
The Swash – 15-25-2-14	From source to Shallotte River	SA;HQW	3.9
Shallotte Creek – 15-25-2-15-(3)	From Bell Branch to Shallotte River	SA;HQW	135.6
Saucepan Creek – 15-25-2-16	From source to Shallotte River	SA;HQW	62.6
Jinnys Branch – 15-25-2-16-1-(2)	From Brunswick County SR 1143 to Saucepan Creek	SA;HQW	1
Goose Creek – 15-25-2-16-4-(2)	From Brunswick County SR 1143 to Saucepan Creek	SA;HQW	4.2

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

Model Segment	AUs	Fecal Coliform Load (MPN/day)					% Reduction
		Existing Load[1]	WLA[2]	LA	MOS	TMDL	
m1	15-25-2-(10)d1 15-25-2-(10)d2 15-25-2-14	Less than TMDL	1.73E+10	1.41E+12	1.59E+11	1.59E+12	0%
m2	15-25-2-(10)c	6.41E+11	6.30E+09	2.67E+11	3.04E+10	3.04E+11	53%
m3	15-25-2-(10)a 15-25-2-(10)b 15-25-2-11-(2) 15-25-2-12-(2)	7.12E+11	4.66E+09	1.84E+11	2.09E+10	2.09E+11	71%
b1	15-25-2-15-(3)	4.22E+11	3.52E+09	1.49E+11	1.69E+10	1.69E+11	60%
b2	15-25-2-16 15-25-2-16-1-(2) 15-25-2-16-4-(2)	3.20E+11	1.85E+09	7.74E+10	8.81E+09	8.81E+10	72%

1. *For Segment m1, 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:

5. Submittal Date:

6. Establishment Date:

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 water body 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 Shallotte River watershed is located in the Lumber River Basin along the North Carolina coast in Brunswick County (Figure 1.1). The river is located within the shellfish area designated A-2 by the North Carolina Division of Marine Fisheries (NCDMF). All of the shellfish growing area of the Shallotte River is conditionally open or closed, or prohibited.

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 gastr*oente*ritis and hepatitis A. Fecal coliform in surface waters may come from point sources (e.g., NPDES stormwater conveyances) 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 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 4 of the Integrated Report. Waterbodies remain in Category 4 until compliance with water quality standards is achieved.

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).

Twelve segments, or assessment units (AUs), of the Shallotte River and its tributaries have been included in Category 5 of the 2012 North Carolina Integrated Report, as shown below in Table 1.1.

1.1 - Shallotte River Impaired Assessment Units

Waterbody Name – [AU]	Description	Water Quality Classification	Acres
Shallotte River – 15-25-2-(10)a	From mouth of Mill Pond to a line crossing the Shallotte River from a point 948 meters north of Shell Point on the east bank across to the south mouth of Middle Dam Creek.	SA;HQW	158.3
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Shallotte River - 15-25-2-(10)d2	Hughes Marina	SA;HQW	4.2
The Mill Pond – 15-25-2-11-(2)	From a point 1.0 mile below Brunswick County SR 1145 to Shallotte River	SA;HQW	2.9
Sams Branch – 15-25-2-12-(2)	From proposed dam approximately 3/4 mile upstream from Shallotte River channel to Shallotte River (0.585717439651489 S Miles)	SA;HQW	3.6
The Swash – 15-25-2-14	From source to Shallotte River	SA;HQW	3.9
Shallotte Creek – 15-25-2-15-(3)	From Bell Branch to Shallotte River	SA;HQW	135.6
Saucepan Creek – 15-25-2-16	From source to Shallotte River	SA;HQW	62.6
Jinnys Branch – 15-25-2-16-1-(2)	From Brunswick County SR 1143 to Saucepan Creek	SA;HQW	1
Goose Creek – 15-25-2-16-4-(2)	From Brunswick County SR 1143 to Saucepan Creek	SA;HQW	4.2

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, August 2006 – September 2011. A detailed analysis of the data used can be found in Appendix A.

1.3 Watershed Description

The Shallotte River and its tributaries fall within the NCDMF A-2 Growing Area in Brunswick County. The headwaters of the Shallotte and its tributaries drain portions of the Green Swamp to the north. The river flows east to the town of Shallotte, then south were it empties into the Intracoastal Waterway. The Shallotte Inlet is located approximately a mile south of the mouth of the Shallotte River.

The watershed was delineated using the USGS 12-Digit Hydrologic Units (HUC). The Lower Shallotte River 12-Digit HUC was modified using EPA Basins catchment boundaries to exclude the area of Carolina Shores and Holden Beach, which drain to the Intracoastal Waterway. The watershed covers 75 square miles (Figure 1.1). All of the shellfish beds areas are prohibited, or conditionally closed or open, due to high fecal coliform levels.

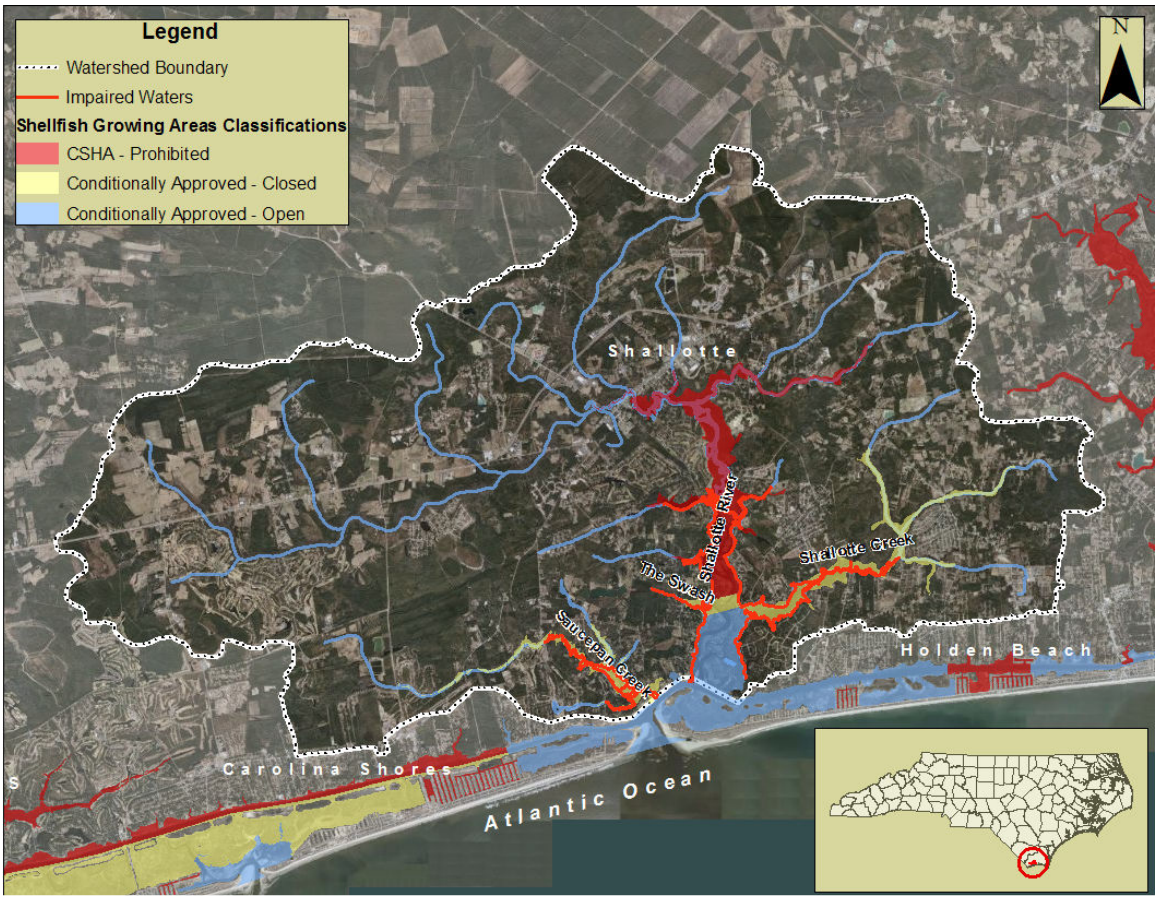

Figure 1.1 - Shallotte River Watershed

The dominant tide in this region is the lunar semi-diurnal (M_2) tide with a mean tidal range of 4.72 ft based on the NOAA station at Sunset Beach, NC (NOAA, 2010).

The 2006 National Land Cover Database (NLCD) was used to obtain land cover characteristics of the watershed. The NCDOT also helped integrate the road network right-of-way into the land cover as an additional land classification. Land cover distribution is shown in Figure 1.2 and land cover acreages are provided in Table 1.2. The dominant land covers in this watershed are forest (36%), shrub/grassland areas (18%), developed lands including NCDOT (16%), wetlands (15%), and crops and pasture lands (12%).

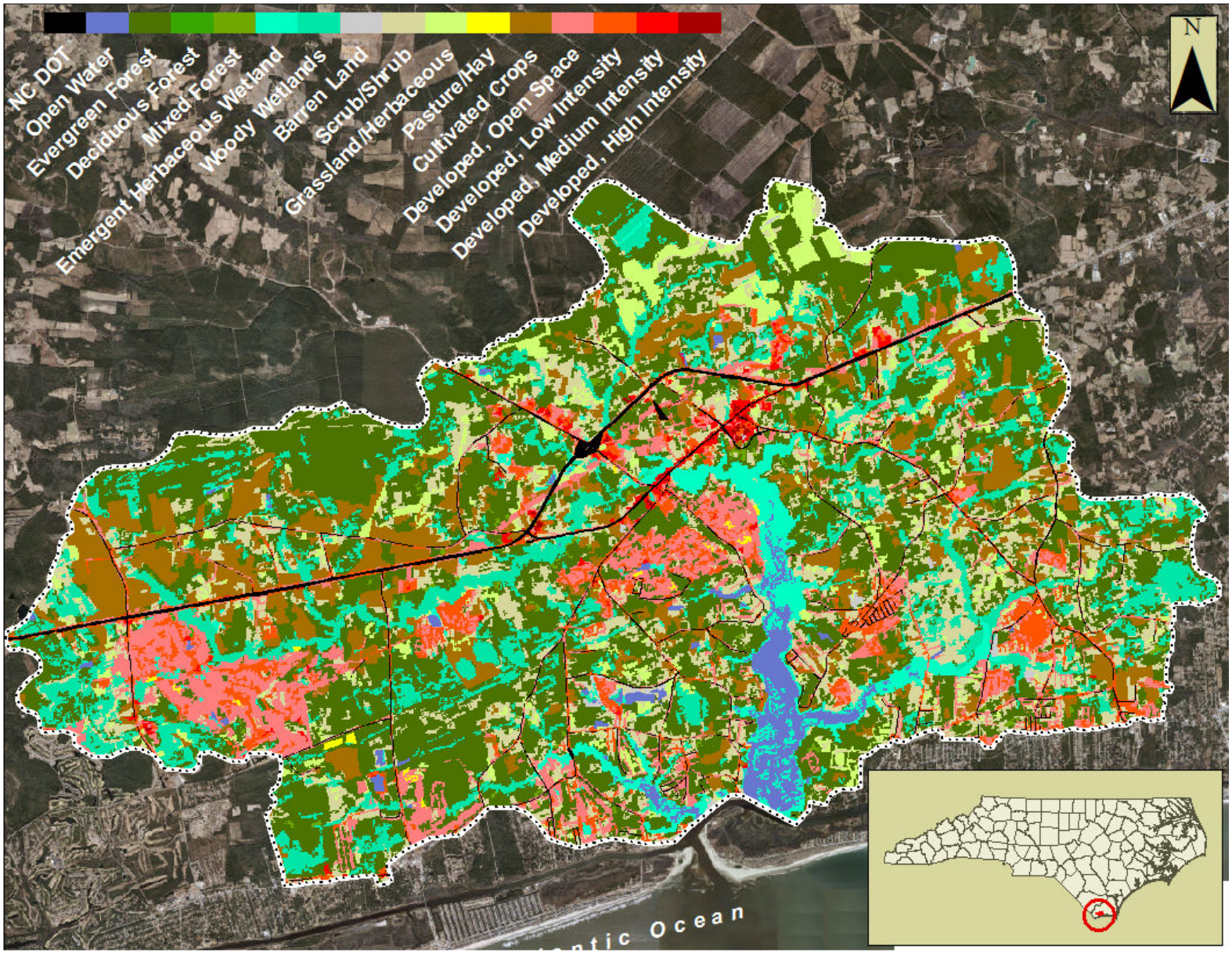

Figure 1.2 - 2006 NLCD Land Cover of the Shallotte River Watershed

Table 1.2 - 2006 Land Cover Distribution of the Shallotte River Watershed

Description	Square Miles	% of Total
Barren Land	0.2	0.3%
Cultivated Crops	8.4	11.3%
Deciduous Forest	0.0	0.0%
Developed, High Intensity	0.1	0.1%
Developed, Low Intensity	3.4	4.5%
Developed, Medium Intensity	0.5	0.7%
Developed, Open Space	6.5	8.7%
Emergent Herbaceous Wetland	2.5	3.3%
Evergreen Forest	26.5	35.6%
Grassland/Herbaceous	3.2	4.3%
Mixed Forest	0.4	0.6%
NCDOT	1.8	2.4%
Open Water	1.6	2.1%
Pasture/Hay	0.1	0.1%
Scrub/Shrub	10.4	14.0%
Woody Wetlands	8.9	11.9%
Total	**74.5**	**100.0%**

1.4 Water Quality Characterization

The Shellfish Sanitation and Recreational Water Quality Section of the NCDMF is responsible for classifying shellfish harvesting waters to ensure oysters and clams are safe for human consumption. NCDMF adheres to the requirements of the National Shellfish Sanitation Program (NSSP), with oversight by the U.S. Food and Drug Administration. NCDMF 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.

NCDMF has monitored shellfish growing regions throughout North Carolina for the past several decades. The Shallotte River is sampled using the systematic random sampling strategy as outlined in the National Shellfish Sanitation Program's (NSSP) Model Ordinance and guidance document (NSSP, 2007). In addition to the routine random monitoring of the areas, conditional area samples are collected after rainfall events for some stations.

There are 30 active and inactive fecal coliform monitoring stations sampled by the NCDMF in the A-2 Growing Area. Of these, 19 (9 inactive and 10 active stations) are within the Shallotte River watershed as shown in Figure 1.3. Most of the data available were collected through the random monitoring strategy, although six stations (6, 8, 10, 11, 12 and 13) are also sampled under the conditional monitoring strategy which is targeted towards measuring fecal coliform concentrations after rainfall events, typically in conditionally-approved open growing areas. NCDMF monitoring data are summarized in Appendix A for those stations within the Shallotte River watershed. The data analysis shows seven stations did not meet standards for growing area criteria.

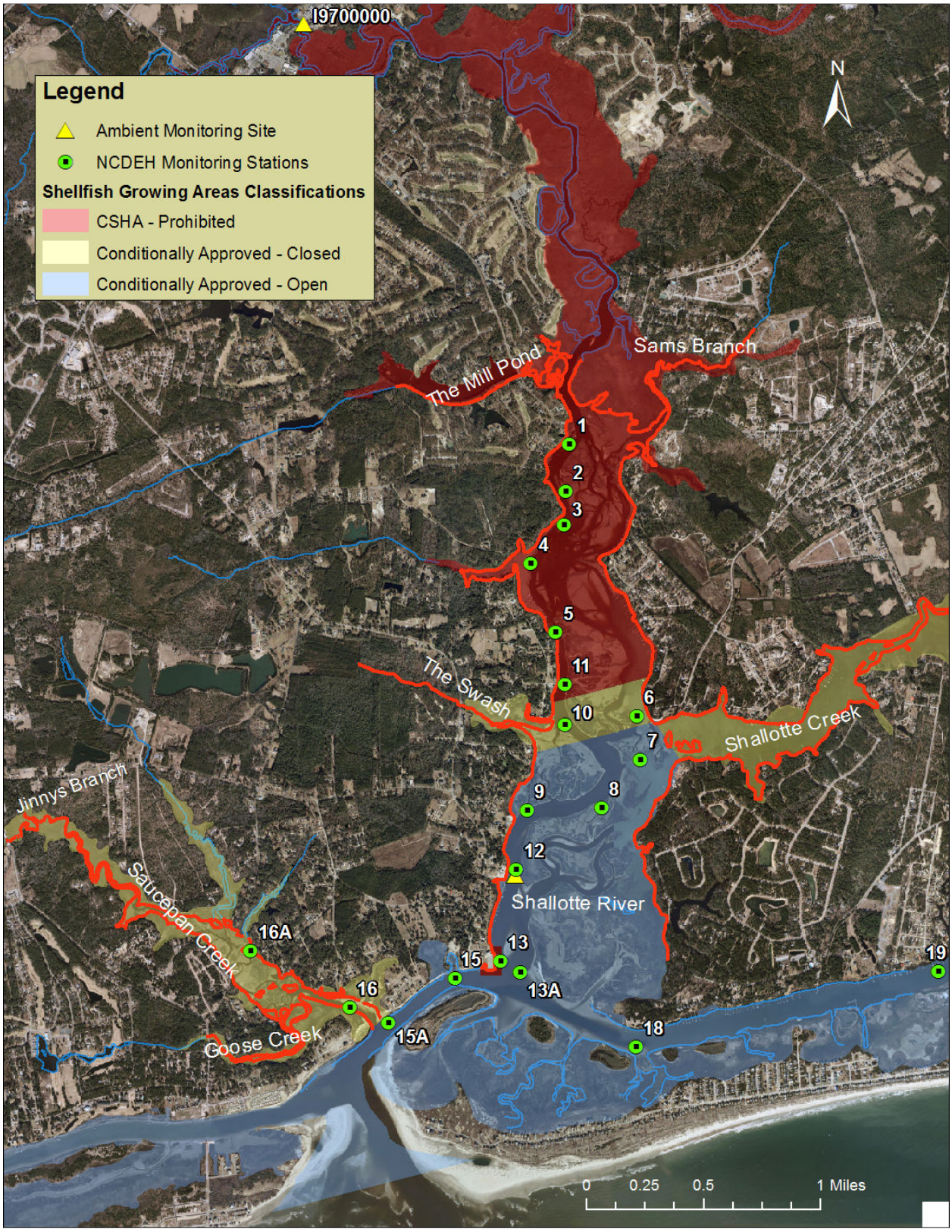

Figure 1.3 - NCDMF Fecal Coliform Monitoring Stations

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 NCDMF Shoreline Survey (NCDMF, 2010) documented and mapped potential sources of fecal coliform in the Shallotte River. The survey identified that runoff from impervious surfaces, subdivisions, and other cleared land is the primary contributor of fecal coliform. The Town of Shallotte is the primary source of stormwater in the area and has many stormwater ditches, pipes, culverts and stormwater ponds that drain to the Shallotte River. Figure 2.1 shows fecal coliform data from the DWQ ambient monitoring station I9700000 (Figure 1.3) located on the Shallotte River in the Town of Shallotte. The geometric mean of this dataset is 244 cfu/100ml from 2006 to 2010 and only 15% of the samples are above 400 cfu/100ml. This station is located in tidal salt water (class SC) just below where the river changes from a freshwater to saltwater classification.

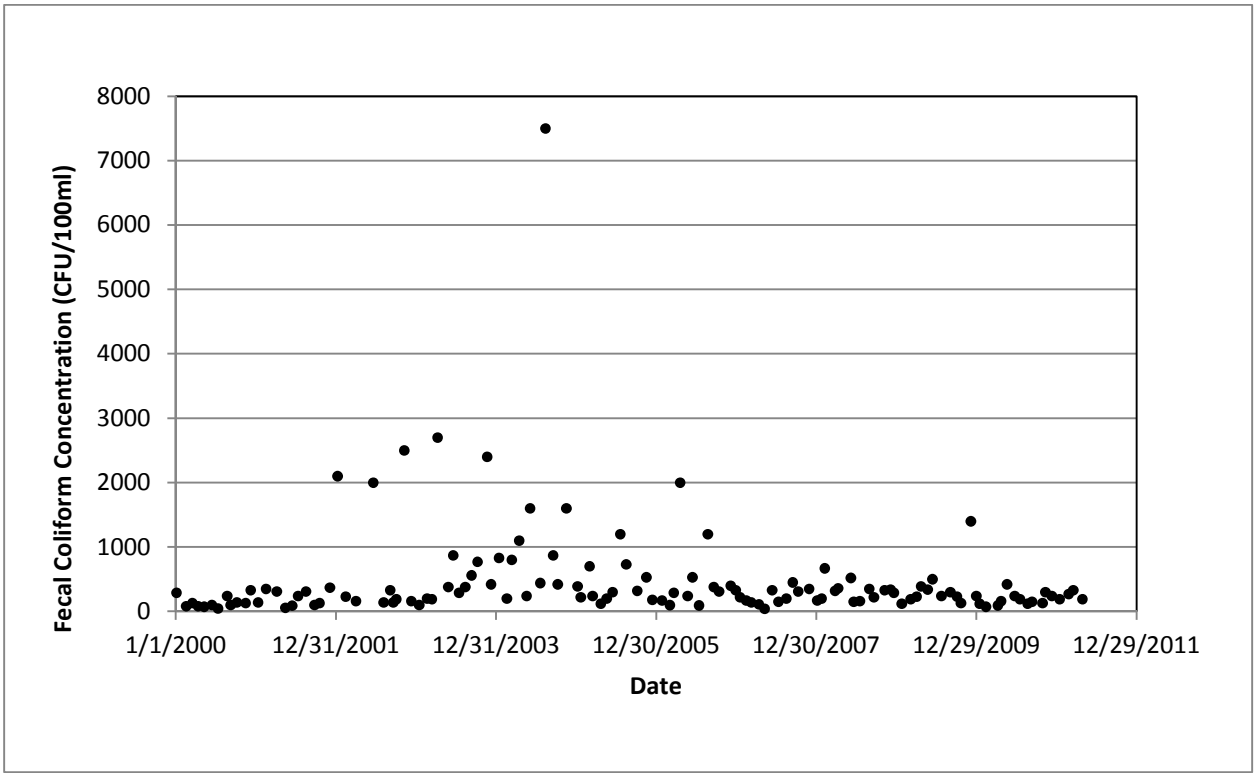

Figure 2.1 Ambient Monitoring Site I9700000 Fecal Coliform Concentrations

Wildlife in the watershed are considered to make up background concentrations of fecal coliform. 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.

One horse stable and one goat farm were observed in the watershed during the sanitary survey; both are unlikely to have an effect on bacteria levels in shellfish harvesting areas.

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. Failing septic systems were not observed during the most recent shoreline survey and previously failing systems were found to be in good repair.

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 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.

There are four non-discharge wastewater treatment plants within the Shallotte River watershed. The Shallotte WWTP is located just north of Shallotte. After treatment the chlorinated effluent from the plant is sprayed on spray fields. The Ocean Isle, Ocean Ridge Plantation, and KOA Campground WWTPs are all located in the far western portion of the watershed and all treat their effluent for reuse or sprayed onto sprayfields. None of these plants are considered to be contributing to the fecal coliform impairment in the shellfish growing areas, however, it should be noted that in July 2009 fecal coliform concentrations of > 6000 CFU/100 ml were reported from two groundwater monitoring wells at the Ocean Ridge Plantation site. A Notice of Violation was issued to the Ocean Ridge Plantation as a result of the high fecal coliform concentrations. The subsequent groundwater sampling event in 2011 showed fecal coliform concentrations in these wells ranged from 0 to 4 CFU/100ml.

The NC Department of Transportation (NCDOT) has a number of roads in the project area, including Highway 17, 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 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 90th 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 August 2006 through September 2011 were used for the purpose of this TMDL.

3.2 Modeling

3.2.1 Approach

Bay and coastal waters such as Shallotte River 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 North Carolina and in several other states (MDE, 2004; NCDWQ, 2011; VADEQ, 2005).

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 Q_0 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 4.72 ft, as monitored at a nearby NOAA station at Sunset Beach, NC. The dominant tide in this region is the lunar semi-diurnal (M2) tide with a tidal period of 12.42 hours. Therefore, the M2 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 Shallotte River watershed as compared to the drainage area and the stream flows measured by the U.S. Geological Survey at Hood Creek gaging station (USGS 02105900) near Leland, NC. The Shallotte Creek watershed delineation is shown in Figure 3.1. The selection of the gaging station for use in the model is determined by its similarity in watershed characteristics to Shallotte River 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. For those segments where there are no active stations, available historical data was used to calculate the 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.

NCDMF 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 Shallotte River 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.

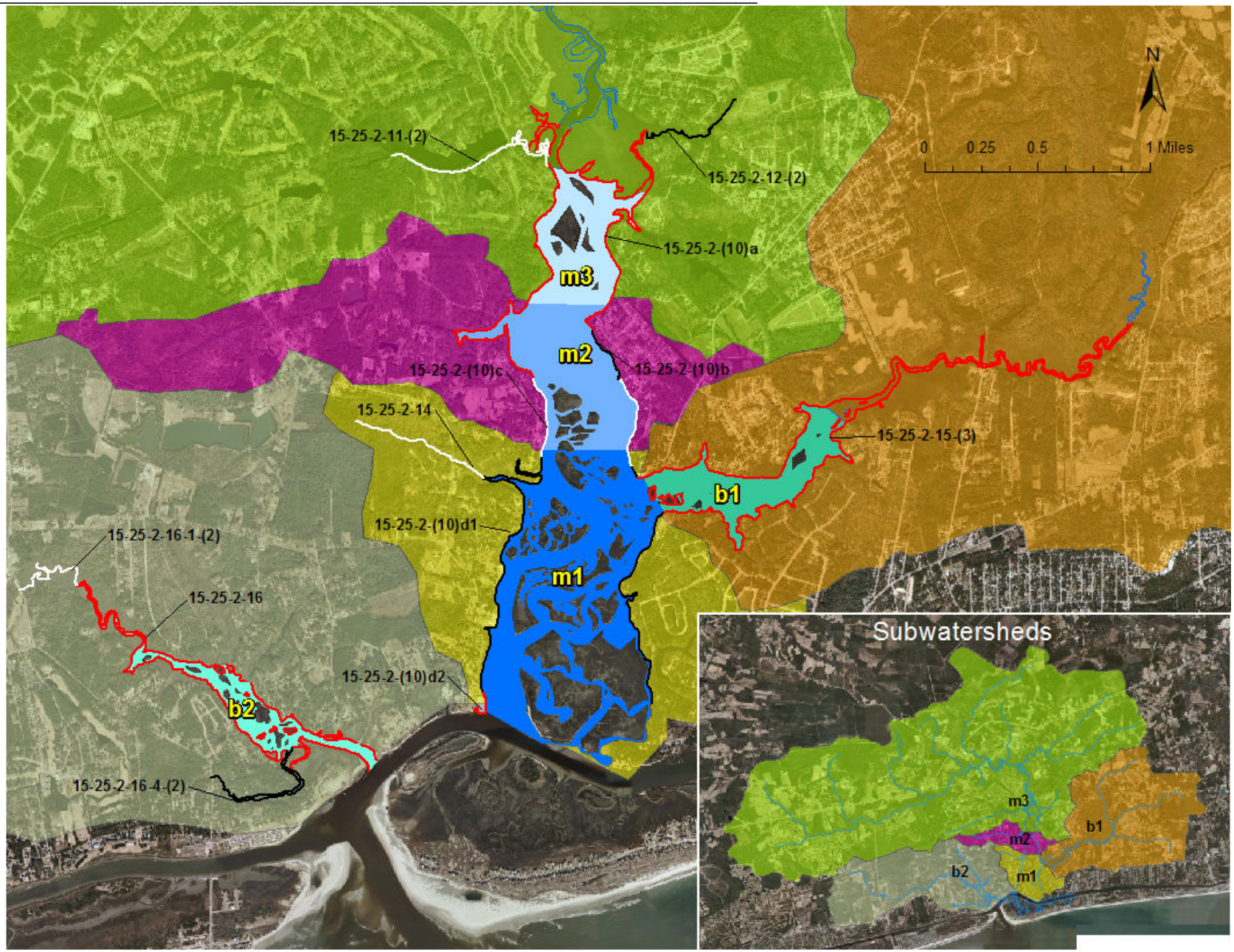

Figure 3.1 - Model Segmentation and Assessment Units

Table 3.1 – Monitoring stations associated with each model segment

Model Segment	Waterbodies	AU#	NCDMF Monitoring Station(s)	Median FC (MPN/100 ml)	90th Percentile FC (MPN/100ml)
m0	Ocean Boundary		15, 18	4.5	22.0
m1	Lower Shallotte River, the Swash	15-25-2-(10)d1 15-25-2-(10)d2 15-25-2-14	6, 7, 8, 9, 10, 12, 13, 13A	5.7	33.0
m2	Middle Shallotte River	15-25-2-(10)c	4, 5, 11	13	65.0
m3	Upper Shallotte River, the Mill Pond, Sams Branch	15-25-2-(10)a 15-25-2-(10)b 15-25-2-11-(2) 15-25-2-12-(2)	1, 2, 3	33.0	103.0
b1	Shallotte Creek	15-25-2-15-(3)	6,7	13.0	65.0
b2	Saucepan Creek, Jinnys Branch, Goose Creek	15-25-2-16 15-25-2-16-1-(2) 15-25-2-16-4-(2)	16, 16A	14.0	156.0

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	15-25-2-(10)d1 15-25-2-(10)d2 15-25-2-14	14	Less than TMDL	6.22E+11	0%
	m2	15-25-2-(10)c	14	1.41E+11	9.89E+10	30%
	m3	15-25-2-(10)a 15-25-2-(10)b 15-25-2-11-(2) 15-25-2-12-(2)	14	1.36E+11	6.82E+10	50%
	b1	15-25-2-15-(3)	14	8.20E+10	5.52E+10	33%
	b2	15-25-2-16, 15-25-2-16-1-(2) 15-25-2-16-4-(2)	14	2.87E+10	2.87E+10	0%
90th Percentile	m1	15-25-2-(10)d1 15-25-2-(10)d2 15-25-2-14	43	Less than TMDL	1.59E+12	0%
	m2	15-25-2-(10)c	43	6.41E+11	3.04E+11	53%
	m3	15-25-2-(10)a 15-25-2-(10)b 15-25-2-11-(2) 15-25-2-12-(2)	43	7.12E+11	2.09E+11	71%
	b1	15-25-2-15-(3)	43	4.22E+11	1.69E+11	60%
	b2	15-25-2-16, 15-25-2-16-1-(2) 15-25-2-16-4-(2)	43	3.20E+11	8.81E+10	72%

For segment m1, 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 this segment once TMDLs are implemented and loading is reduced from the watersheds draining to 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	1.59E+12	1.59E+11	1.43E+12
	m2	3.04E+11	3.04E+10	2.73E+11
	m3	2.09E+11	2.09E+10	1.88E+11
	b1	1.69E+11	1.69E+10	1.52E+11
	b2	8.81E+10	8.81E+09	7.93E+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 2.4% 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 – Shallotte River Watershed NCDOT Contributing Area by Subwatershed

Segment #	Total Sub-Watershed Area (acres)	NCDOT Land Area (acres)	NCDOT Land Area (% of total)
m1	1245	15.0	1.2%
m2	931	21.5	2.3%
m3	31421	777.4	2.5%
b1	7881	181.8	2.3%
b2	6169	143.8	2.3%
Total	47647	1139.5	2.4%

Table 3.5 – NPDES Wasteload Allocations

NPDES Permittee	Segment #	NCDOT Existing Load (MPN/day)	WLA (MPN/day)
NCDOT	m1	N/A	1.73E+10
	m2	N/A	6.30E+09
	m3	N/A	4.66E+09
	b1	N/A	3.52E+09
	b2	N/A	1.85E+09

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	1.41E+12
m2	2.67E+11
m3	1.84E+11
b1	1.49E+11
b2	7.74E+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 Shallotte River 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 the Shallotte River 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. 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.

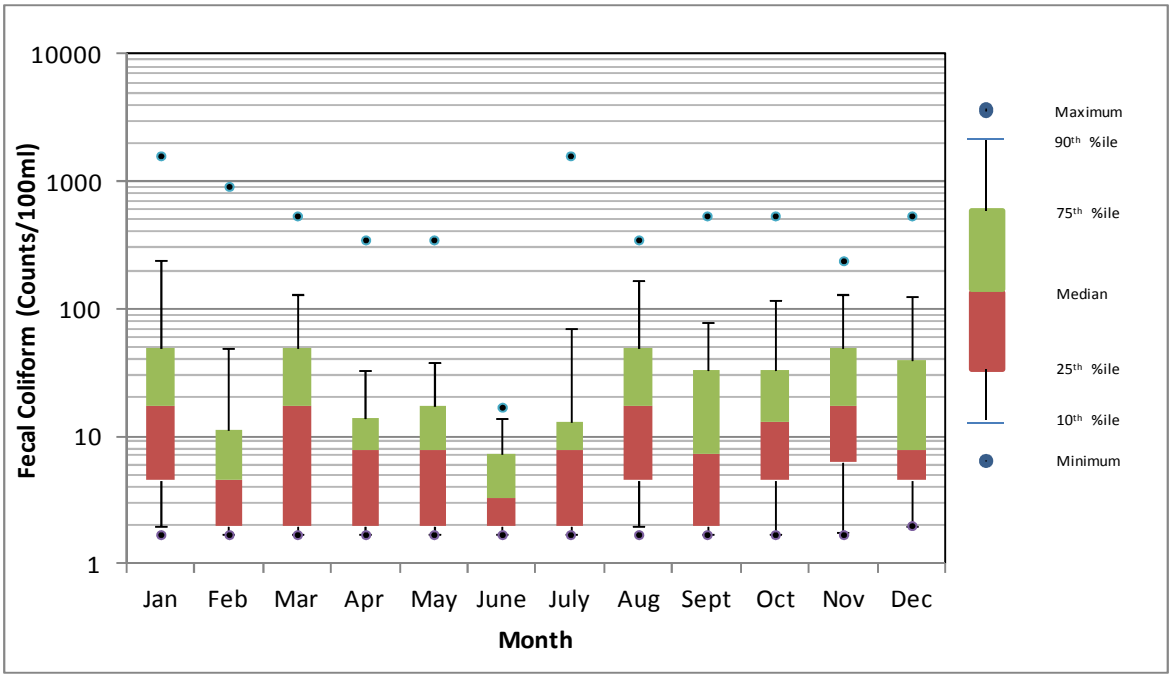

Figure 3.2 - Seasonal distribution of fecal coliform concentrations (random and conditional monitoring data combined) in Segment m1 (log scale)

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 Shallotte River, Shallotte Creek, Sams Branch, the Mill Pond, the Swash, and Saucepan Creek (including Jinnys Branch and Goose Creek). Reductions in loading from these watersheds allow for standards to be met throughout the Shallotte River.

The largest percent reduction is needed from the upper Shallotte River (including Sams Branch and the Mill Pond) and Saucepan Creek (including Jinnys Branch and Goose Creek). Land cover in these subwatersheds (Appendix B) is primarily mixed between forest (42.5%), wetlands (14.9%), developed land (14.5%), shrub/scrub (12.6%), and cropland (11.7%). A stormwater sources map produced by NCDMF (Appendix C) shows a concentrated amount of stormwater outfalls in this watershed that could be transporting fecal coliform bacteria to the impaired waters.

Table 3.7 – Estimated TMDL and Load Allocation for Fecal Coliform for Shallotte River

Model Segment	AUs	Fecal Coliform Load (MPN/day)					% Reduction
		Existing Load[1]	WLA[2]	LA	MOS	TMDL	
m1	15-25-2-(10)d1 15-25-2-(10)d2 15-25-2-14	Less than TMDL	1.73E+10	1.41E+12	1.59E+11	1.59E+12	0%
m2	15-25-2-(10)c	6.41E+11	6.30E+09	2.67E+11	3.04E+10	3.04E+11	53%
m3	15-25-2-(10)a 15-25-2-(10)b 15-25-2-11-(2) 15-25-2-12-(2)	7.12E+11	4.66E+09	1.84E+11	2.09E+10	2.09E+11	71%
b1	15-25-2-15-(3)	4.22E+11	3.52E+09	1.49E+11	1.69E+10	1.69E+11	60%
b2	15-25-2-16 15-25-2-16-1-(2) 15-25-2-16-4-(2)	3.20E+11	1.85E+09	7.74E+10	8.81E+09	8.81E+10	72%

1. *For Segment m1, 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 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 NCDMF Sanitary Survey for the A-2 shellfish growing area is a useful resource for identifying current sources of bacteria and drainage pathways that allow bacteria to enter Shallotte River and its tributaries. Contact the Shellfish Sanitation Office at 252-726-6827 for information on how to obtain a copy of the Sanitary Survey.

NCDMF will continue to monitor water quality in Shallotte River 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 D. 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 September 18 – October 19, 2012. NCDWQ received comments from NCDOT. A summary of their comments and NCDWQ's response is provided in Appendix E.

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:

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Appendix A: NCDMF Monitoring Data Summary

Table A.1 – Shallotte River NCDMF Fecal Coliform Monitoring Data Summary

	Random Monitoring (MPN/100 ml)				Random & Conditional Monitoring (MPN/100 ml)			
Station	**Median**	**Geomean**	**90th %tile**	**Time Period**	**Median**	**Geomean**	**90th %tile**	**Time Period**
1	49	51	130	01/15/1990 - 01/22/1997				
2	146	33	39	01/15/1990 - 01/22/1997				
3	60	20	20	01/15/1990 - 01/22/1997				
4	22	22.2	67	12/16/1999 - 04/08/2002	-	-	-	-
5	13	12.9	83	10/09/2000 - 07/29/2005	-	-	-	-
6	9.4	8.8	45	02/22/2007 - 09/07/2011	9.4	8.8	45	02/22/2007 - 09/07/2011
7	6.2	6.3	33	02/22/2007 - 09/07/2011	-	-	-	-
8	-	-	-		12.5	11.9	72	05/03/2000 - 04/08/2002
9	6.2	6.4	28	04/24/2007 - 09/07/2011	-	-	-	-
10	7.8	9.9	61	02/22/2007 - 09/07/2011	9.9	10.9	57	10/21/2009 - 09/07/2011
11	12	12.2	60	02/22/2007 - 09/07/2011	12	-	60	02/22/2007 - 09/07/2011
12	4.3	5.1	24	02/22/2007 - 09/07/2011	5.7	7.4	41	10/01/2009 - 09/07/2011
13	3	3.9	12	10/09/2000 - 07/29/2005	6.8	10.1	80	10/01/2009 - 07/29/2005
13A	4.5	6	23		-	-	-	-
15	-	-	-		-	-	-	-
15A	4.5	5.2	24	02/22/2007 - 09/07/2011	4.5	5	19	05/19/2008 - 09/07/2011
16	14	13.7	156	02/22/2007 - 09/07/2011	-	-	-	-
16A								
18	4.5	5.7	23	02/22/2007 - 09/07/2011	-	-	-	-

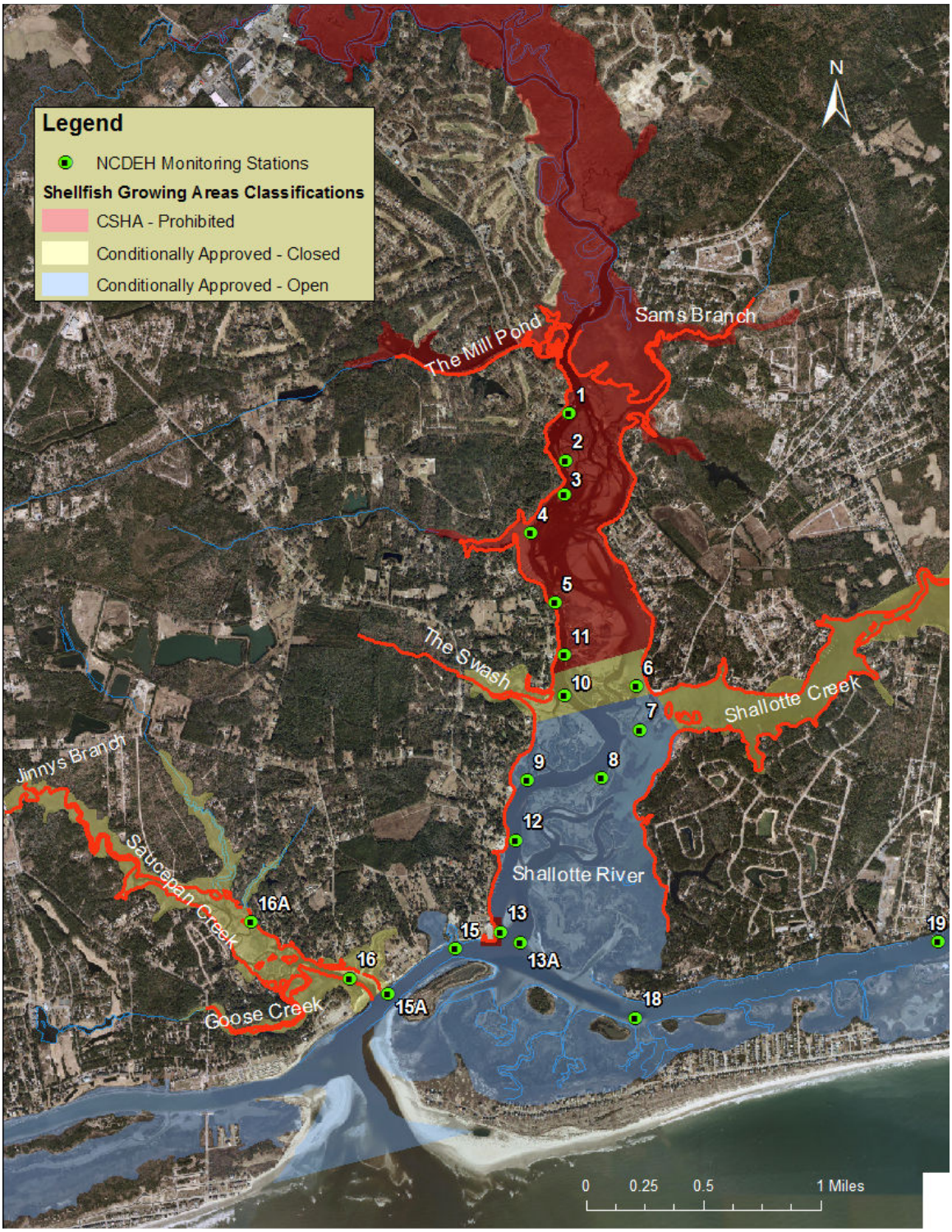


Figure A.1 – NCDMF Monitoring Stations

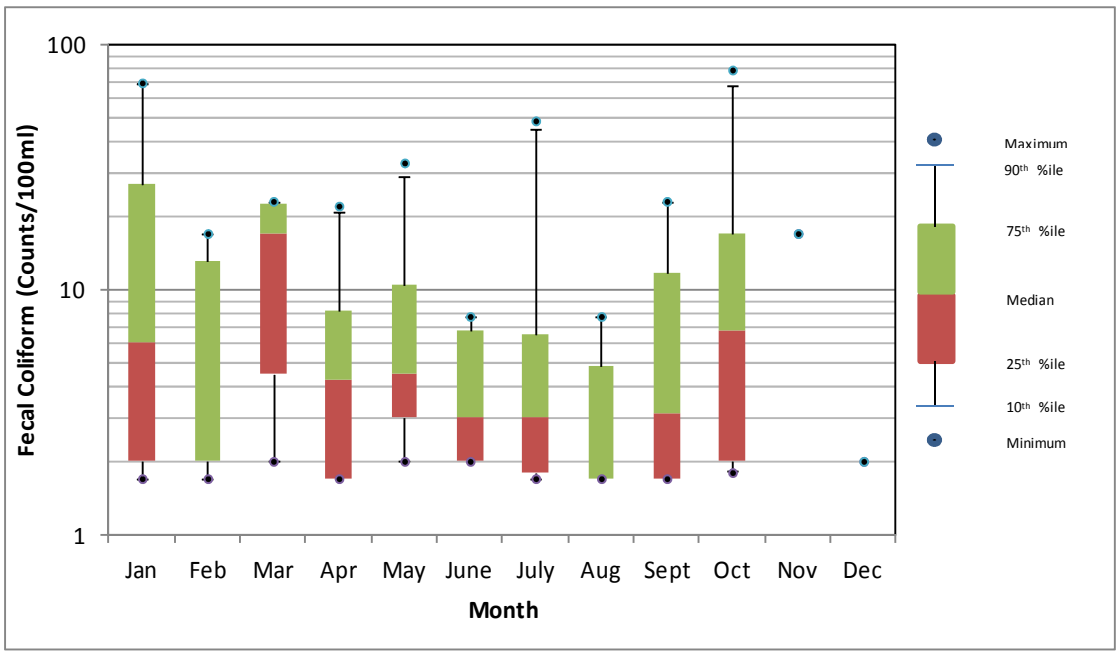


Figure A.2 - Seasonal distribution of fecal coliform concentrations in Segment m0 (log scale)

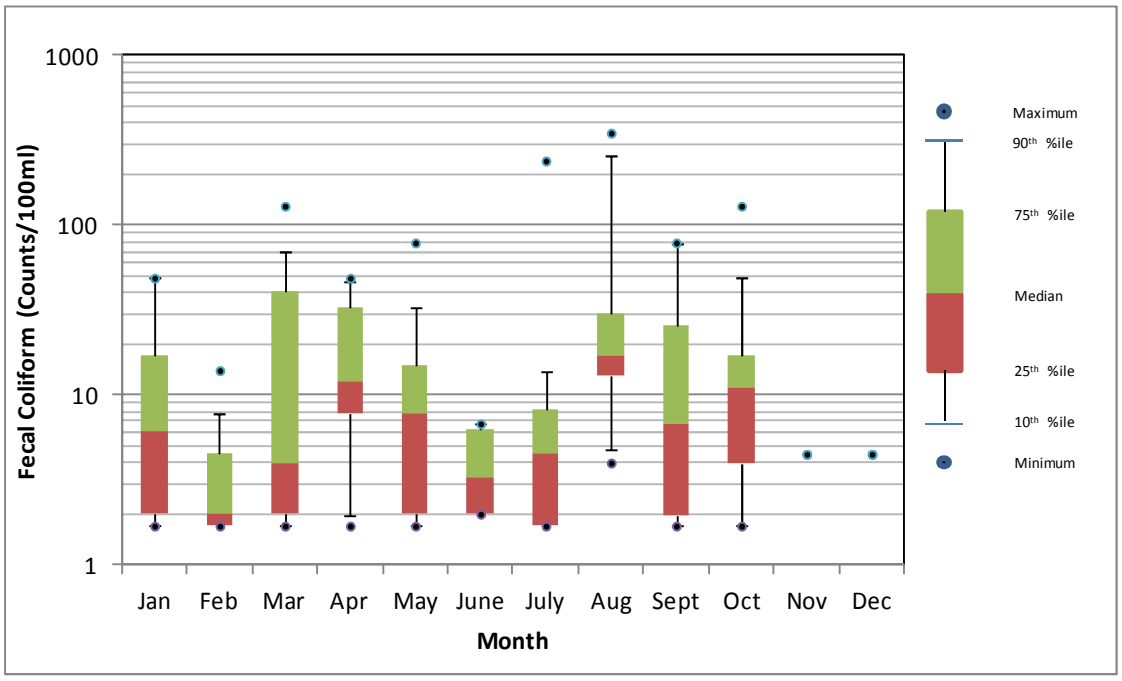


Figure A.3 - Seasonal distribution of RANDOM monitoring fecal coliform concentrations in Segment m1 (log scale)

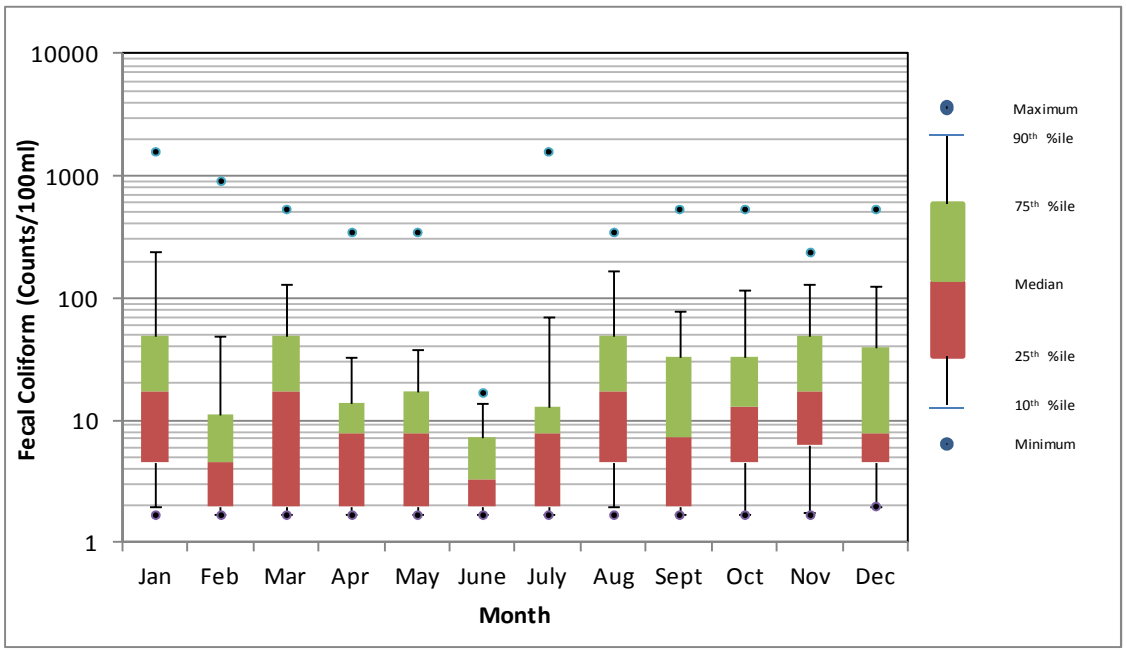


Figure A.4 - Seasonal distribution of fecal coliform concentrations (random and conditional monitoring data combined) in Segment m1 (log scale)

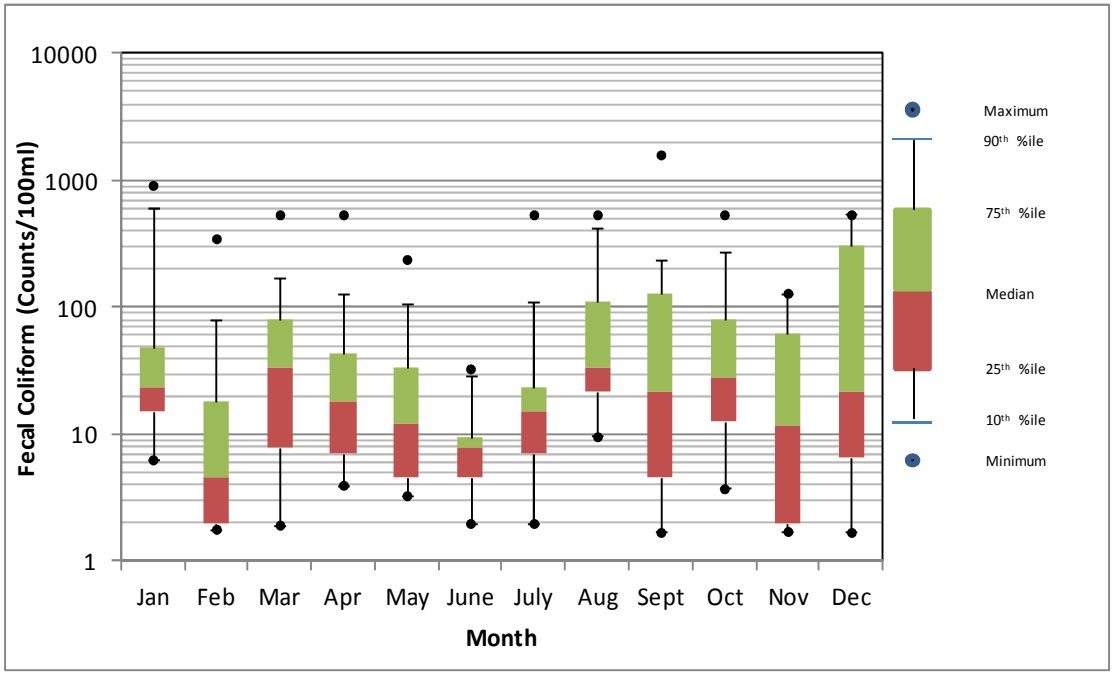


Figure A.5 - Seasonal distribution of fecal coliform concentrations in Segment m2 (log scale)

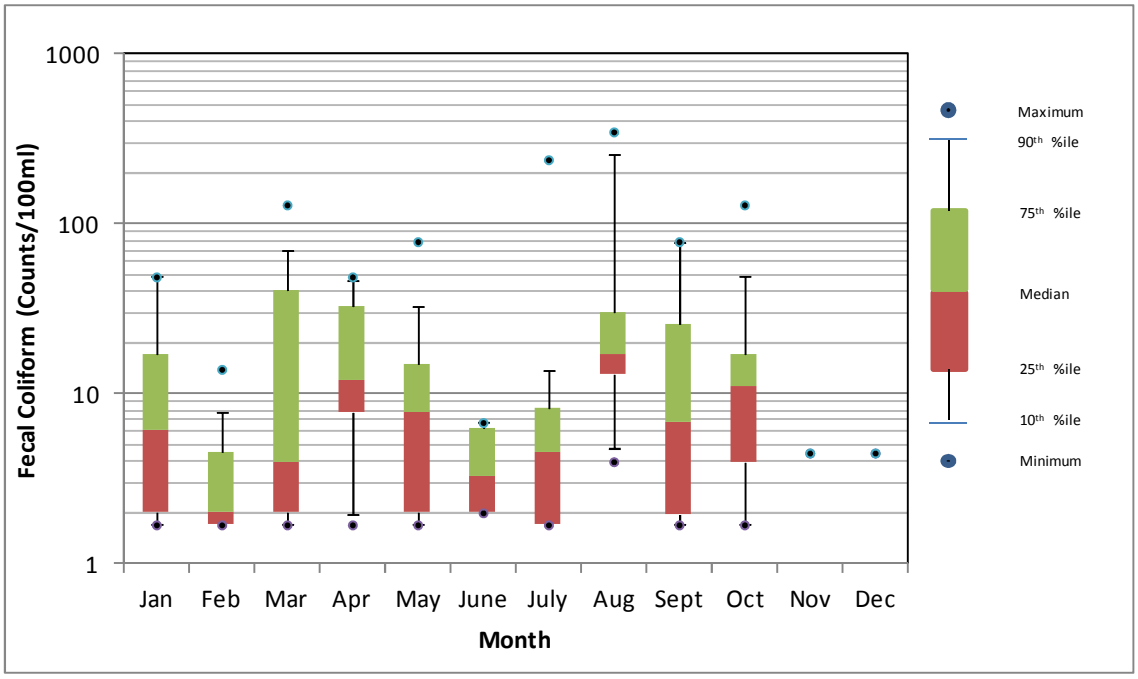


Figure A.6 - Seasonal distribution of fecal coliform concentrations in Segment m3 (log scale)

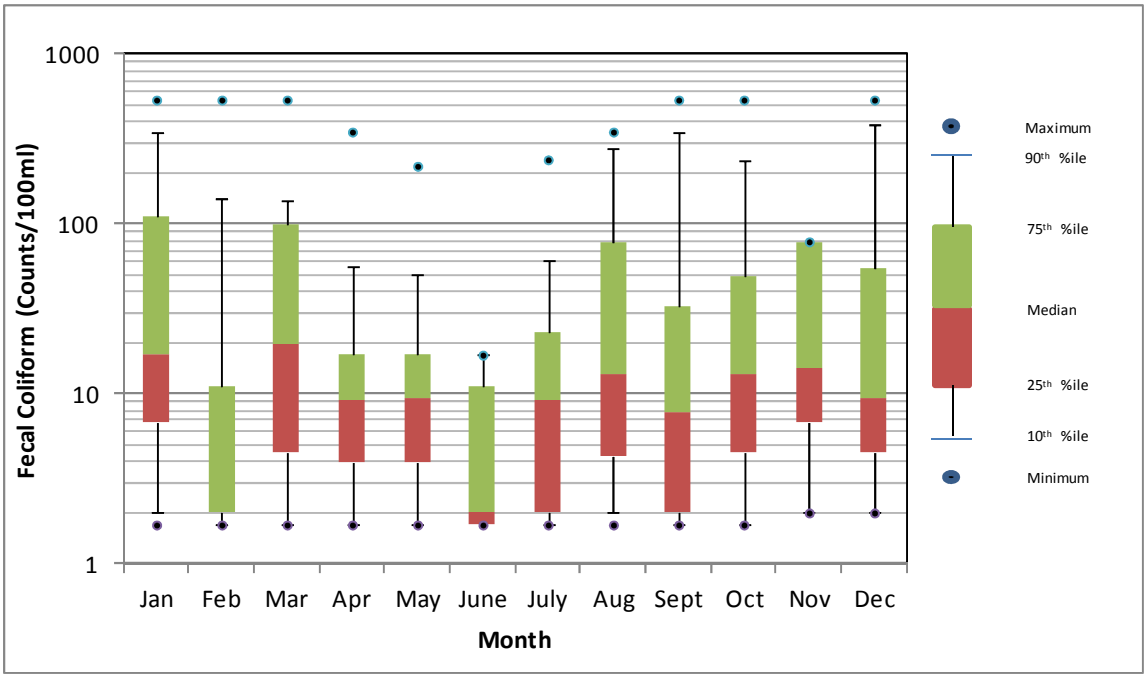


Figure A.7- Seasonal distribution of fecal coliform concentrations (Random and Conditional) in Segment b1 (log scale)

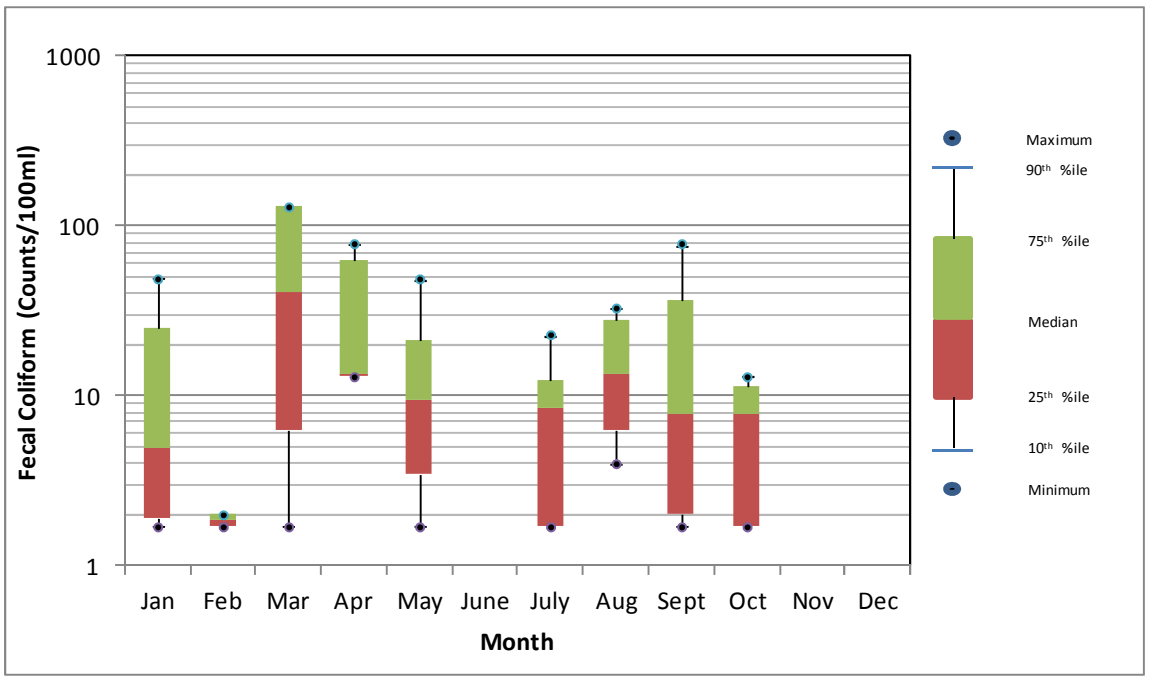


Figure A.8- Seasonal distribution of fecal coliform concentrations (Random Sampling) in Segment b1 (log scale)

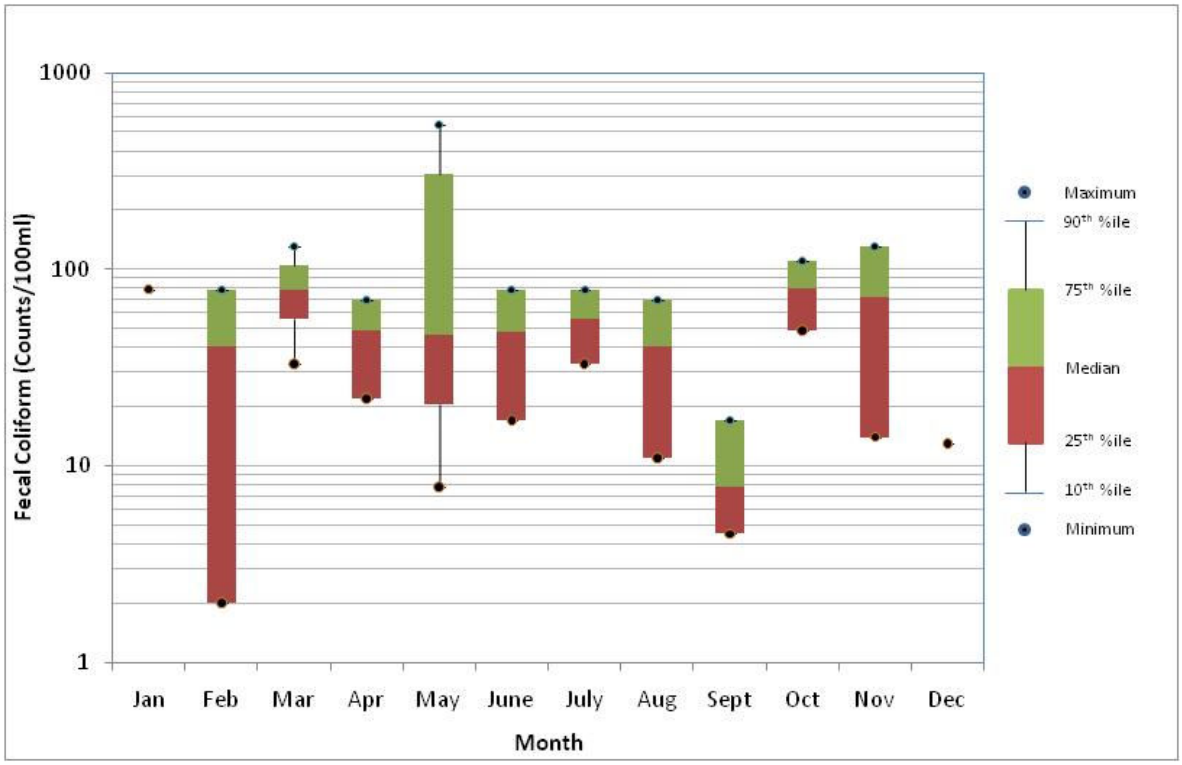
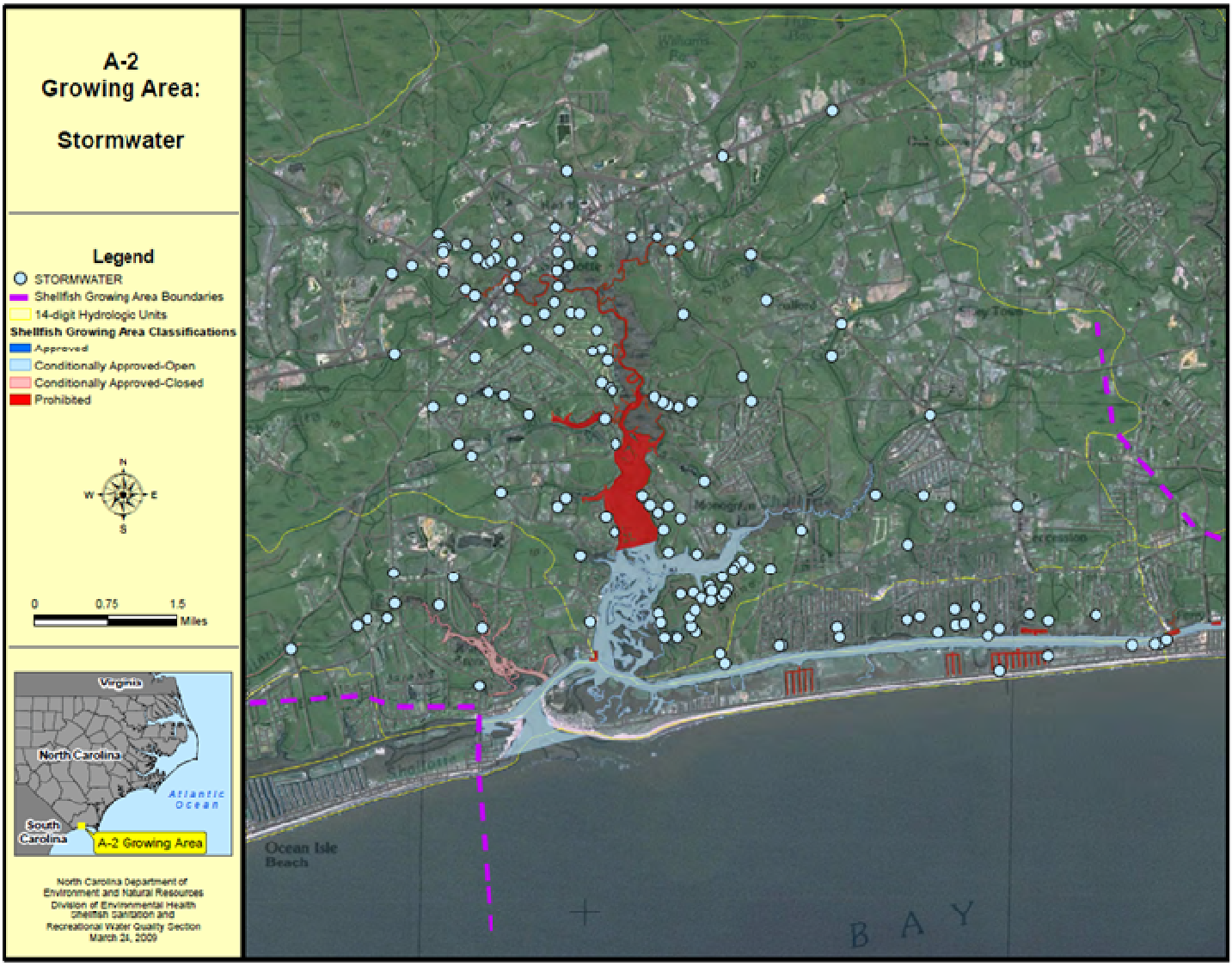


Figure A.9 - Seasonal distribution of fecal coliform concentrations in Segment b2 (log scale)

Appendix B: Land Cover by Watershed

Description	Model Segment Watershed									
	M1		M2		M3		B1		B2	
	sqmi	% of total	sqmi	% of total	sqmi	% of total	sqmi	% of total	sqmi	% of total
Barren Land		0.0%	0.00	0.0%	0.07	0.1%	0.05	0.4%	0.07	0.8%
Cultivated Crops	0.06	3.3%	0.18	12.6%	6.57	13.4%	1.28	10.4%	0.30	3.1%
Deciduous Forest		0.0%		0.0%	0.01	0.0%		0.0%	0.00	0.0%
Developed, High Intensity		0.0%		0.0%	0.08	0.2%		0.0%		0.0%
Developed, Low Intensity	0.02	1.1%	0.03	2.1%	2.12	4.3%	0.80	6.5%	0.39	4.0%
Developed, Medium Intensity	0.00	0.2%		0.0%	0.47	1.0%	0.01	0.1%	0.03	0.3%
Developed, Open Space	0.07	3.7%	0.05	3.7%	4.35	8.9%	0.92	7.5%	1.06	11.0%
Emergent Herbaceous Wetland	0.29	14.8%	0.08	5.5%	1.31	2.7%	0.39	3.2%	0.40	4.1%
Evergreen Forest	0.58	29.8%	0.48	33.1%	17.41	35.5%	3.52	28.7%	4.47	46.5%
Grassland/Herbaceous	0.07	3.6%	0.06	4.3%	2.44	5.0%	0.38	3.1%	0.24	2.5%
Mixed Forest	0.01	0.6%	0.01	0.9%	0.27	0.6%	0.10	0.9%	0.05	0.5%
NCDOT	0.02	1.2%	0.03	2.3%	1.21	2.5%	0.28	2.3%	0.22	2.3%
Open Water	0.59	30.4%	0.24	16.5%	0.39	0.8%	0.13	1.1%	0.22	2.3%
Pasture/Hay		0.0%		0.0%	0.06	0.1%		0.0%	0.05	0.5%
Scrub/Shrub	0.16	8.5%	0.25	16.9%	6.08	12.4%	2.64	21.4%	1.30	13.5%
Woody Wetlands	0.05	2.8%	0.03	2.0%	6.19	12.6%	1.77	14.4%	0.81	8.5%
Grand Total	**1.94**	**100.0%**	**1.45**	**100.0%**	**49.03**	**100.0%**	**12.29**	**100.0%**	**9.62**	**100.0%**

Appendix C: NCDMF Mapping of Stormwater Sources in the A-2 Growing Area



Appendix D: Public Comment Announcement

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

September 18, 2012

Draft Total Maximum Daily Load for Fecal Coliform for Impaired Segments in the Shallotte River Watershed

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 October 19, 2012. Comments concerning the report should be directed to Andy Painter at andy.painter@ncdenr.gov or write to:

Andy Painter
NC Division of Water Quality
Planning Section
1617 Mail Service Center
Raleigh, NC 27699

The draft TMDL can be downloaded from the following website:
http://portal.ncdenr.org/c/document_library/get_file?uuid=c5b63f20-11d9-48f7-8c26-746b0e16a5bc&groupId=38364

Appendix E: Public Comments and Response

The public comment period lasted from September 18 – October 19, 2012. Comments were received from NCDOT. A summary of their comments and NCDWQ's response is provided below.

1. Please indicate in the TMDL report from whom DWQ acquired the spreadsheet-based model.

DWQ Response: As indicated in the TMDL document Section 3.2, the simplified steady-state tidal prism model computations are based on equation 3.1; and the implementation of the simplified model is site-specific. While the simplified spreadsheet-based steady-state tidal prism model was first used for TMDLs in Virginia and Maryland (MDE, 2004; VADEQ, 2005), the implementation of the simplified equation for Shallotte River was done in-house by NCDWQ Modeling and TMDL Unit.

2. Please identify the developers of the spreadsheet-based model.

DWQ Response: The particular application of the spreadsheet-based simplified steady-state tidal prism model for the Shallotte River TMDL was developed in the Modeling and TMDL unit of NCDWQ.

3. EPA's Watershed & Water Quality Modeling Technical Support Center distributes numerous models used for TMDL development along with supporting documentation and fact sheets. It is not apparent from The Center's website that EPA is distributing the spreadsheet-based model used in the Shallotte River TMDL. Please indicate in the TMDL report what organization is distributing and supporting the model.

DWQ Response: EPA approves the use of the tidal prism model. The spreadsheet-based simplified steady-state tidal prism model used for the Shallotte River TMDL and several other EPA approved TMDLs in North Carolina is a tool used to solve the fairly simple tidal prism equation. The spreadsheet-based tool is a simplified application that is, in a way, self-explanatory through exploration of the formulas in the cells. The spreadsheet application to solve this equation was first used in Virginia as stated above, and ideally the NCDOT could easily recreate this spreadsheet tool by applying the equation to excel. The spreadsheet-based simplified steady-state tidal prism model used for the Shallotte River TMDL is distributed and supported by NCDWQ and can be obtained from the MTU of NCDWQ.

4. Based on responses to comments provided for the Bear Creek TMDL, it does not appear that any separate written documentation exists specifically for this spreadsheet model. Such documentation is an important component of a system for ensuring version control and model integrity. Please verify in the TMDL report whether or not separate model documentation exists and is publically available. If no documentation is available, NCDOT recommends that EPA develop appropriate documentation and distribute it along with the model on their Modeling Technical Support Center website.

DWQ Response: Section 3.2 of the TMDL document provided description of the simplified steady-state tidal prism model and additional guidance has been provided in the spreadsheet for the site specific application for the Shallotte River. The spreadsheet used for the Shallotte Creek TMDL is available upon request. A detailed description of the tidal prism model concept is provided by Kuo et al., 2005. The reference for this document is

provided in the References section. In addition, a PowerPoint presentation on the tidal prism water quality model segmentation (in general) can be provided upon request.

5. The Shallotte River TMDL report does not document all the model input variables used to run the model. Please add an appendix to the report which includes screen captures or other appropriate means to document model input and output variables. This information will be valuable to future users of this TMDL model and will help verify they are using an unaltered version from the spreadsheet as compared to the version DWQ used to develop the TMDL.

DWQ Response: The original spreadsheet-based model used for the Shallotte River TMDL will be maintained by the MTU of NCDWQ. The MTU recommends requesting a copy of the spreadsheet to view input variables and outputs.