Total Maximum Daily Load for Fecal Coliform for Crowders Creek North Carolina and South Carolina

Final Report
June 2004
Approved July 1, 2004

Catawba River Basin

Prepared by:
**NC Department of Environment
and Natural Resources**
Division of Water Quality
Water Quality Section
1617 Mail Service Center
Raleigh, NC 27699-1617
(919) 733-5083

Summary Sheet

Total Maximum Daily Load (TMDL)

1. 303(d) List Information

State: North Carolina, South Carolina

County: Gaston (NC), York (SC)

Major River Basin: Catawba River Basin

Watershed: Crowders Creek, HUC 3050101180010

303(d) Listed Waters (North Carolina)

Name of Stream	Description	Class	Index #	Subbasin	Miles
Crowders Creek	SR 1108 to NC 321	C	11-135e	30837	1.4
Crowders Creek	US 321 to SR 2424	C	11-135f	30837	1.4
Crowders Creek	SR 2424 to NC/SC line	C	11-135g	30837	0.8

Constituent of Concern: Fecal Coliform

Designated NC Uses: Biological integrity, propagation of aquatic life, secondary recreation

Applicable Water Quality Standards for Class C Waters in NC: Fecal coliforms shall not exceed a geometric mean of 200/100ml (membrane filter count) based upon at least five consecutive samples examined during any 30 day period, nor exceed 400/100 ml in more than 20 percent of the samples examined during such period.

303(d) Listed Waters (South Carolina)

Name of Stream	Station Description	Class	Station	Impaired Use	Cause
Crowders Creek	At S-46 564 NE Clover	Freshwater	CW-023	REC	FC
Crowders Creek	S-46-1104	Freshwater	CW-024	REC	FC
South Fork Crowders Creek	At S-46-79 4.5 mi NW Clover	Freshwater	CW-192	REC	FC

REC=recreation; FC=fecal coliform

Constituent of Concern: Fecal Coliform

Designated SC Uses: Primary and secondary contact recreation, a source for drinking water supply after conventional treatment in accordance with the requirements of SC, fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora, and industrial and agricultural uses.

Applicable Water Quality Standards for Freshwater in SC: Not to exceed a geometric mean of 200/100 ml, based on five consecutive samples during any 30 day period; nor shall more than 10% of the total samples during any 30 day period exceed 400/100ml.

2. TMDL Development

Development tools: WARMF model

Critical condition: Exceedances of the fecal coliform occur during both wet and dry conditions, and all seasons. The TMDL has been determined using a 5-year simulation (1998-2002) covering a wide range of hydrologic conditions.

Seasonality: Seasonal variation in hydrology, climatic conditions, and watershed activities are represented through the use of a continuous flow gage and the use of all readily available water quality data collected in the watershed.

3. Allocation Watershed/Stream Reach

Crowders Creek Fecal Coliform TMDL

	Units per day	% Reduction
TMDL	2.21E+11	
NC Continuous WLA[1]	8.27E+09	0%
NC MS4 WLA	7.45E+10	79%
NC LA	1.15E+11	79%
SC LA	2.36E+10	79%
Station CW-023	--	79%
Station CW-024	--	79%
Station CW-192	--	79%

[1] Continuous point sources must meet monthly geometric mean of 200 cfu/100ml and cannot exceed 400 cfu/100ml maximum.

Total maximum daily load (TMDL): 2.21E+11 units per day

Waste load allocation (WLA): 8.287E+10 units per day

Load allocation (LA): 1.384E+11 units per day

Margin of Safety (applied to the water quality criteria): This TMDL utilizes an explicit margin of safety (MOS): the geometric mean target is set at 175 cfu/100ml (MOS = 25 cfu/100ml) and the instantaneous limit is set to 360 cfu/100ml (MOS = 40 cfu/100ml).

This TMDL is set at the confluence of Crowders Creek and Beaverdam Creek in SC. The TMDL applies to all impaired segments identified in (1).

4. Public Notice Date: 5/23/2004

5. Submittal Date: 6/10/2004

6. Establishment Date: 7/1/2004

7. Endangered Species (yes or blank):

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

9. TMDL Considers Point Source, Nonpoint Source, or both: both

TABLE OF CONTENTS

1 Introduction ... 1
1.1 Watershed Description ... 2
1.2 Water Quality Target ... 3
1.3 Water Quality Assessment ... 5
2 Source Assessment ... 11
2.1 Point Source Assessment ... 11
2.2 Non-Point Source Assessment ... 12
2.2.1 Urban Development and Sewer Systems ... 12
2.2.2 Septic Systems ... 13
2.2.3 Livestock ... 14
2.2.4 Waste Application ... 15
2.2.5 Wildlife ... 15
3 Modeling Approach ... 16
3.1.1 Model Framework ... 16
3.1.2 Model Setup ... 16
3.1.2.1 Observed Data Input ... 17
3.1.2.2 Fecal Loading Initial Inputs ... 18
3.1.2.3 Fecal Coliform Decay ... 19
3.1.3 Calibration ... 20
3.1.3.1 Flow and Temperature ... 20
3.1.3.2 Fecal Coliform ... 24
3.1.4 Model Output ... 27
4 Allocation ... 28
4.1 Total Maximum Daily Load (TMDL) ... 28
4.2 Critical Conditions ... 29
4.3 Seasonal Variation ... 30
4.4 Model Uncertainty and Margin of Safety ... 30
4.5 Allocation ... 31
5 Implementation Plan ... 33
6 Stream Monitoring ... 33
7 Future Efforts ... 33
8 Public Participation ... 34
9 Further Information ... 34

10 References 35
11 Appendix 37

Appendix I. Water quality data collected in the Crowders Creek watershed (1997-2002)...........38
Appendix II. Land use by WARMF subwatershed based on 1993-1996 landcover in the Crowders Creek watershed. 43
Appendix III. Calibrated soil layer parameters. 47
Appendix IV. Load allocation calculation for Kings Mountain...49
Appendix V. Modeled fecal coliform loading scenarios...51
Appendix VI. Load allocation calculations for South Carolina portion of Crowders Creek. 52
Appendix VII. Crowders Creek Fecal Coliform TMDL Allocation Worksheet...........................54
Appendix VIII. Septic system loading estimates for the Crowders Creek watershed. 55
Appendix IX. Affidavits of Publication for Public Notices...56
Appendix X. Comments on the Crowders Creek TMDL 58

TABLES

Table 1. Monitoring locations in the Crowders Creek watershed. 6
Table 2. Summary of fecal coliform monitoring in the Crowders Creek watershed (1997-2002) 6
Table 3. Potential sources of fecal coliform bacteria in watersheds. 11
Table 4. Summary of septic usage in Crowder's Creek watershed (NC portion) based on data taken from Gordon (2003) 14
Table 5. Septic data used in the WARMF model for Crowders Creek. 19
Table 6. Livestock data used in the WARMF model for Crowders Creek. 19
Table 7. Precipitation weighting factors and temperature lapse for the Crowders Creek watershed. 21
Table 8. Calibration statistics for temperature and flow in subwatershed 11. 21
Table 9. Calibration statistics for fecal coliform (#/100ml) in subwatershed 11 (downstream station). 24
Table 10. Existing fecal coliform loading (1998-2002) by source in the Crowders Creek watershed. 27
Table 11. Total maximum daily load allocation for the Crowders Creek watershed (detailed in Appendix). 31
Table 12. Relative fecal coliform loading rates in the Crowders Creek watershed. 32

FIGURES

Figure 1. Location map for the Crowders Creek watershed....4
Figure 2. North Carolina monitoring stations within the Crowders Creek watershed. Numbered stations correspond to sites in Table 1....7
Figure 3. Fecal coliform concentrations at the NCDWQ ambient station for the period 1997 – 2002. A value >2000 from 1/8/98 is not shown....8
Figure 4. Geometric mean fecal coliform concentrations in the Crowders Creek watershed, 2001. 9
Figure 5. Load duration curve at the Crowders Creek NCDWQ ambient station for the period, 1998-2002....10
Figure 6. Load duration curve at the Crowders Creek station SR 2424 for the period, 2001-2002. 10
Figure 7. Crowders Creek watershed with subwatersheds (WS) as depicted in the WARMF model. Primary stations used for calibration have been labeled. 17
Figure 8. Observed vs. simulated temperature at the downstream calibration station in subwatershed 11 (R^2=0.86)....22
Figure 9. Observed versus simulated temperature at the upstream calibration station in subwatershed 5 (R^2=0.98)....22
Figure 10. Observed versus simulated flow at the downstream calibration station in subwatershed 11 (R^2=0.50). 23
Figure 11. Observed versus simulated flow at the upstream calibration station in subwatershed 5 (R^2=0.43). 23
Figure 12. Observed versus simulated fecal coliform at subwatershed 11. 25
Figure 13. Observed versus simulated fecal coliform at SR 1131 in subwatershed 5. 26
Figure 14. Rolling 30-day geometric means of observed fecal coliform at SR 2424 and simulated fecal coliform at the subwatershed 11 outlet....26
Figure 15. Results of TMDL simulation for a rolling 30-day geometric mean for fecal coliform in the Crowders Creek watershed....29

1 Introduction

Crowders Creek is currently on 303(d) lists of impaired waters in North Carolina (NC) and South Carolina (SC). The NC Division of Water Quality (NCDWQ) has identified a 3.6-mile segment of Crowders Creek in the Catawba River Basin as impaired by fecal coliform bacteria, stretching from state road (SR) 1108 to the state line. The SC Department of Environmental Health and Control (SCDHEC) considers the South Fork Crowders Creek and Crowders Creek impaired due to elevated levels of fecal coliform bacteria in South Carolina.

Section 303(d) of the Clean Water Act (CWA) requires states to develop a list of waters not meeting water quality standards or which have impaired uses. This list, referred to as the 303(d) list, is submitted biennially to the U.S. Environmental Protection Agency (EPA) for review.

The 303(d) process requires that a Total Maximum Daily Load (TMDL) be developed for each of the waters appearing on Part I of the 303(d) list. The objective of a TMDL is to estimate allowable pollutant loads and allocate the loads to known sources so that actions may be taken to restore the water to its intended uses (USEPA, 1991). Generally, the primary components of a TMDL, as identified by EPA (1991, 2000a) and the Federal Advisory Committee (FACA, 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 of the 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 (2000a), 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 and the Water Quality Planning and Management regulation (USEPA, 2000a) require 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.

The goal of the TMDL program is to restore designated uses to water bodies. Thus, the implementation of source controls throughout the watershed will be necessary to restore uses in Crowders Creek. Although an implementation plan is not included as part of this TMDL, reduction strategies for point and nonpoint sources will be needed. The involvement of local governments and agencies will be critical in order to develop implementation plans and reduction strategies.

1.1 Watershed Description

Crowders Creek, a tributary to Lake Wylie (NCDWQ subbasin 030837) in the Catawba River Basin, drains 92.9 mi^2 at its confluence with Beaverdam Creek in South Carolina (Figure 1). Most of the NC portion of Crowders Creek is located within Gaston County in the piedmont physiographic region. A small portion is located in Cleveland County. Approximately 16% of the watershed area (excluding Beaverdam Creek) is located within South Carolina (York County). The watershed includes the municipalities of Gastonia, Kings Mountain and Bessemer City in NC, and Bowling Green in SC.

The land use and land cover characteristics of the watershed were determined using 1996 land cover data that were developed from 1993-94 LANDSAT satellite imagery (included within the WARMF model). Land use was 57% forest, 9% pasture, 11% cultivated, and 13% developed (low and high intensity residential, commercial/industrial).

As reported by the USGS, the average flow of the creek below SR 2424 is approximately 91 cubic feet per second (cfs), with a summer 7Q10 of 6.7 cfs. The drainage area at this point is 79.4 mi^2. The predominant soils are Cecil-Appling-Pacolet and Nason-Tatum associations, underlain by gneiss/schist/slate and schistose rocks, respectively.

Surface water classifications are designations applied to surface water bodies that define the best uses to be protected within these waters (e.g., swimming, fishing, and drinking water supply) and carry with them an associated set of water quality standards to protect those uses. Crowders Creek (and its tributaries) is classified as a class C waterbody in NC. The waters are protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses suitable for *Class C*. Secondary recreation includes wading, boating, and other uses involving human body contact with water where such activities take place in an infrequent, unorganized, or incidental manner.

South Carolina classifies Crowders Creek and its tributaries as *Freshwaters*. Freshwaters are suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of SC. In addition, the waters are suitable for fishing, the survival and propagation of a balanced indigenous aquatic community of fauna and flora, and industrial and agricultural uses.

1.2 Water Quality Target

The North Carolina fresh water quality standard for fecal coliform in Class C waters (T15A: 02B.0211) states:

Organisms of the coliform group: fecal coliforms shall not exceed a geometric mean of 200/100ml (membrane filter count) based upon at least five consecutive samples examined during any 30 day period, nor exceed 400/100 ml in more than 20 percent of the samples examined during such period; violations of the fecal coliform standard are expected during rainfall events and, in some cases, this violation is expected to be caused by uncontrollable nonpoint source pollution; all coliform concentrations are to be analyzed using the membrane filter technique unless high turbidity or other adverse conditions necessitate the tube dilution method; in case of controversy over results, the MPN 5-tube dilution technique will be used as the reference method.

South Carolina's standard for fecal coliform in Freshwater is:

Not to exceed a geometric mean of 200/100 ml, based on five consecutive samples during any 30-day period; nor shall more than 10% of the total samples during any 30-day period exceed 400/100ml.

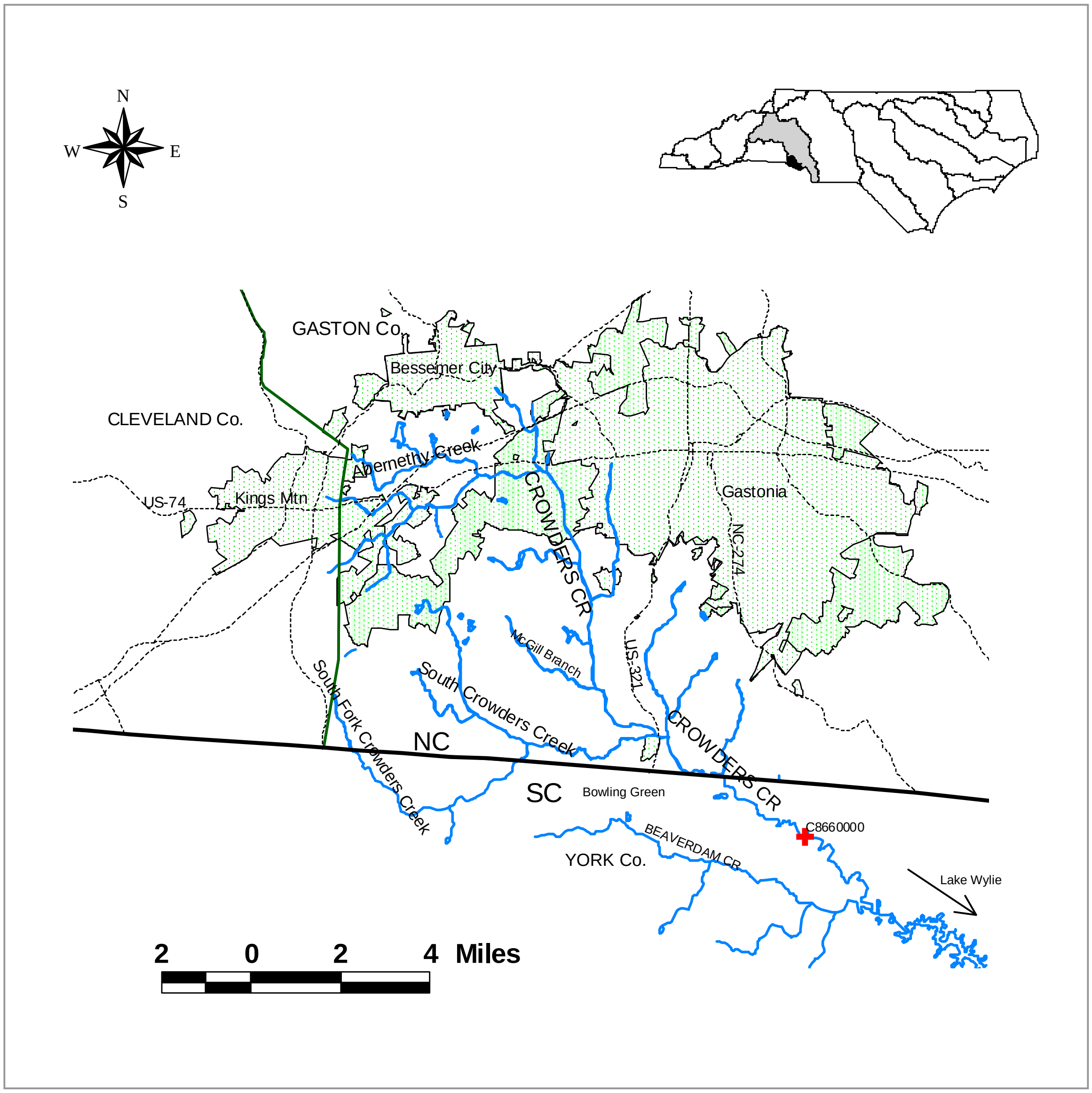

Figure 1. Location map for the Crowders Creek watershed.

The instream numeric target, or endpoint, is the restoration objective associated with implementing the specified load reductions in the TMDL. The target allows for the evaluation of progress towards the goal of reaching water quality standards for the impaired stream by comparing the instream data to the target. For this TMDL the water quality target is South Carolina's standard: it is more stringent based on the portion relating to 10% of samples during 30 days versus a 20% allowance in NC. Both portions of the SC standard will be evaluated for TMDL purposes. Note that the unit for fecal coliform bacteria is colony-forming units (cfu), but may also be referred to as "counts" or "#" throughout this assessment.

1.3 Water Quality Assessment

NCDWQ collects samples monthly at a fixed ambient monitoring station (C8660000) on Crowders Creek at Ridge Rd near Bowling Green, SC (Figure 2).[1] In 2001, NCDWQ, the Gaston County Cooperative Extension Service, and the City of Gastonia agreed to conduct intensive surveys of water quality in the Crowders Creek watershed. Six locations were selected for intensive monitoring (Table 1). Samples were collected weekly for six weeks in the spring and 10 weeks in the summer. As such, eight running geometric means could be calculated using the data from this study.

During 2002, NCDWQ conducted additional sampling of Crowders Creek to supplement 2001 sampling. Samples were collected at Blackwood Creek, Crowders Creek at SR 1108, and Crowders Creek at SR 2424. A summary of all recent data is presented in Table 2.

Sampling at the ambient station near the base of the watershed indicates that fecal coliform concentrations have been elevated for several years (Figure 3). Further sampling to evaluate the geometric mean fecal coliform standard suggests elevated concentrations at a number of locations throughout the watershed including the upper portion at SR 1131 and the southwest portion at SR 1109 (Figure 4). The geometric means of 9/4/2001 include a significant storm event that appears to have contributed to high concentrations. Blackwood Creek fecal coliform levels are consistently higher than other locations throughout the study. This subwatershed contains primarily suburban development and many older south Gastonia neighborhoods.

---

[1] SCDHEC also monitors fecal coliform bacteria in Crowders Creek at US 321 0.5 miles north of the NC/SC border (CW- 152) and at S-91-79 4.5 miles northwest of Clover (CW-192). SC's CW-024 is co-located with NC's ambient station.

Table 1. Monitoring locations in the Crowders Creek watershed.

1 Crowders Creek at Linwood Road (SR1131)
2 Blackwood Creek at SR 1136
3 Crowders Creek at SR 1108
4 South Crowders Creek at Crowders Creek Rd (SR1103)
5 South Fork Crowders Creek at Ferguson Ridge Rd (SR1109)
6 Crowders Creek at SR 2424
7 DWQ Ambient Station

Table 2. Summary of fecal coliform monitoring in the Crowders Creek watershed (1997-2002).

Site	Period	Number of Samples	Number greater than 400 cfu/100ml [a]	Number greater than 200cfu/100ml geometric mean [b]
Crowders Creek at Linwood Road (SR1131)	2001	16	3	5
Blackwood Creek at SR 1136	2001-2002	25	14	13
Crowders Creek at SR 1108	2001-2002	25	8	6
South Crowders Creek at Crowders Creek Rd (SR1103)	2001	16	3	3
South Fork Crowders Creek at Ferguson Ridge Rd (SR1109)	2001	16	4	5
Crowders Creek at SR 2424	2001-2002	25	6	6
Crowders Creek NCDWQ Ambient	1997-2002	67	10	-- [c]

[a] Instantaneous fecal coliform measurements greater than 400cfu/100ml

[b] 30-day geometric mean of fecal coliform measurements greater than 200cfu/100ml based on at least 5 samples in 30 days.

[C] Data collected monthly; insufficient frequency to calculate a 30-day geometric mean.

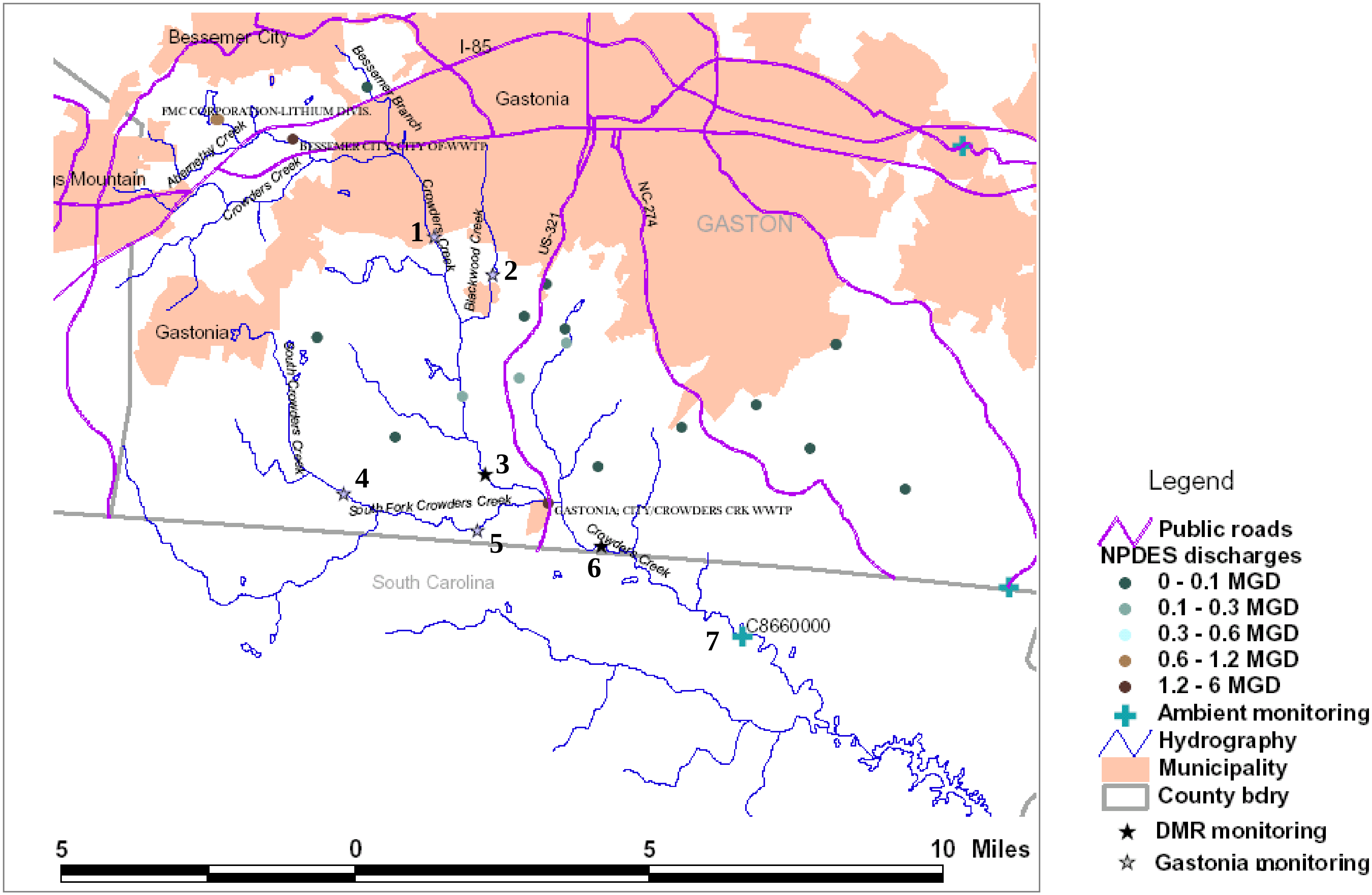

Figure 2. North Carolina monitoring stations within the Crowders Creek watershed. Numbered stations correspond to sites in Table 1.

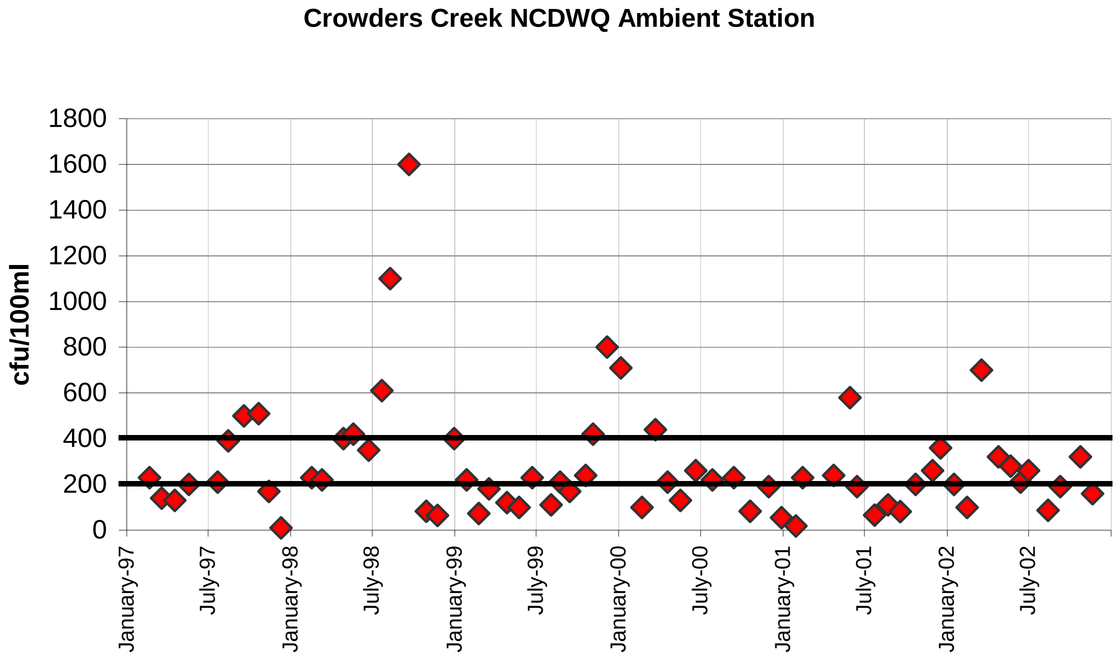

Figure 3. Fecal coliform concentrations at the NCDWQ ambient station for the period 1997 – 2002. A value >2000 from 1/8/98 is not shown.

A load duration curve analysis (Stiles 2002, Cleland 2002) was used to evaluate flow conditions under which the standard is violated and also help identify the sources contributing to impairment. Exceedances that occur only during low-flow events are likely caused by continuous or point source discharges, which are generally diluted during storm events. Livestock deposits directly to the stream may also be noticeable during low flow events. Exceedances that occur during higher flow events are generally driven by storm-event runoff. A mixture of point and nonpoint sources may cause exceedances during normal flows.

The load duration method plots observed data with flow. Data is available for only 2000 to present for a gage on Crowders Creek (USGS 02145642). Since a long historical flow series is recommended for use in flow and load duration analyses, data from nearby gage was used: USGS 02144000 on Long Creek near Bessemer City. The Long Creek gage is in the neighboring watershed to the north of Crowders Creek and has a drainage area of 31.8 mi^2. Daily flow data for the period from 1/1953 through 9/2002 was used to establish the historic flow regimes. Drainage area (DA) ratios were used to create flow series for the DWQ ambient station on Crowders Creek (DA = 88.9 mi^2) and the station at SR 2424 (DA = 79.4 mi^2).

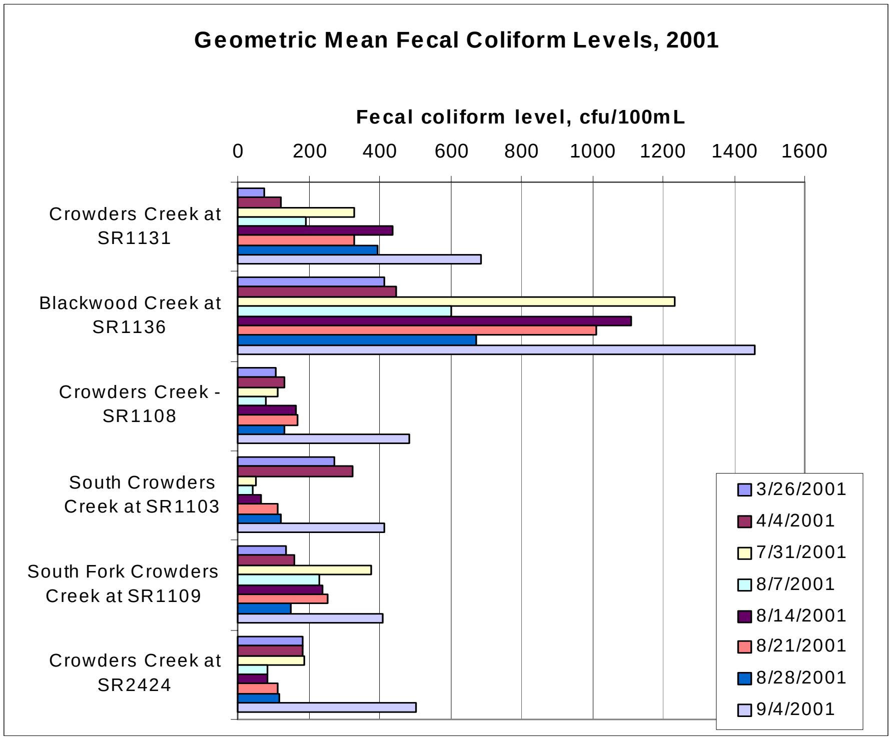

Figure 4. Geometric mean fecal coliform concentrations in the Crowders Creek watershed, 2001.

Observed flow is plotted based on the percent of time that historic flows exceed the value on the date collected. Once the relative rankings were calculated for flow, monitoring data were matched by date to compare observed water quality to the flow ranking. The curves approximate the allowable load that meets the water quality standard for fecal coliform (flow * standard; see Figure 5).

In the Crowders Creek watershed, water quality violations of fecal coliform occur during both wet and dry periods, and during most times of the year (Figures 5-6). All data points in Figures 5 and 6 are based on instantaneous samples.[2] A greater number of exceedances occurred during April – October and in mid-range to drier flows.

[2] The geometric mean line is provided only as an additional reference; geometric mean values have not been plotted.

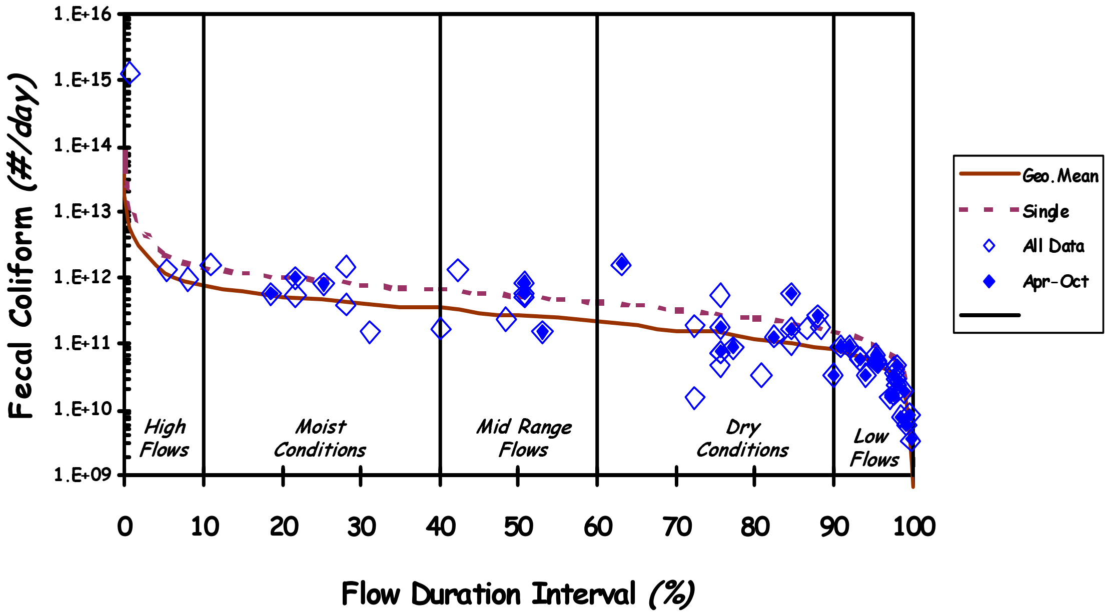

Figure 5. Load duration curve at the Crowders Creek NCDWQ ambient station for the period, 1998-2002.

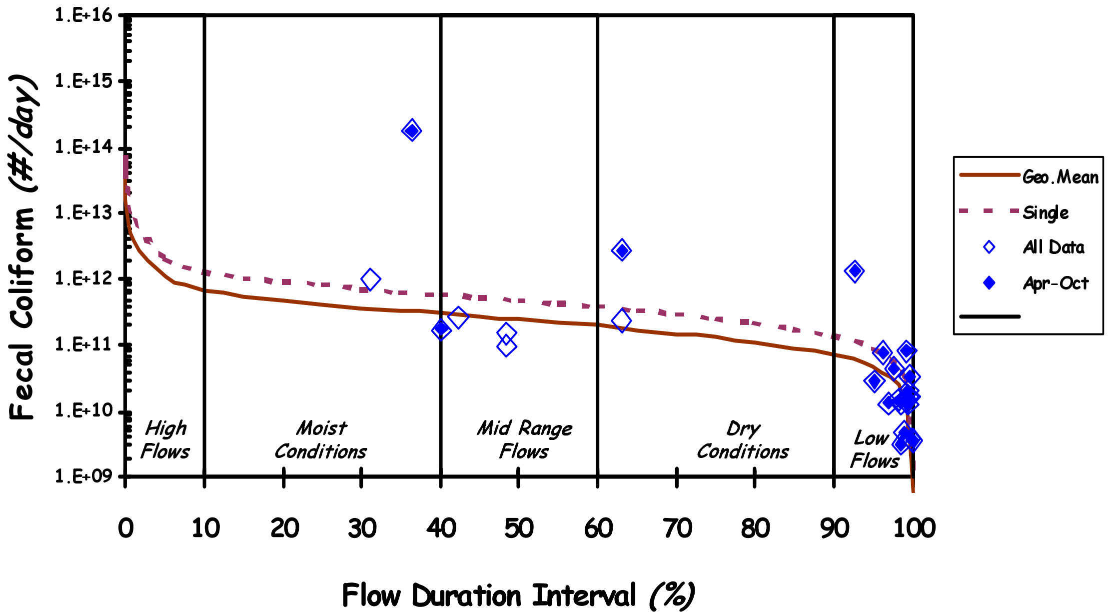

Figure 6. Load duration curve at the Crowders Creek station SR 2424 for the period, 2001-2002.

2 Source Assessment

Both point and nonpoint sources may contribute fecal coliform to waterbodies. In rural areas, stormwater runoff can transport fecal coliform from livestock operations, septic systems, and wildlife deposits. Sewer systems, pets, and wildlife are potential sources in urbanized areas (septic systems to a lesser extent). Wastewater treatment plants (WWTP), both municipal and package plants, are another source of fecal coliform.

Potential sources of fecal coliform loading in the watershed were identified based on an evaluation of land use data, septic and sewer service areas, discharge monitoring data, and agricultural information. The source assessment was used as the basis for development of the watershed model and ultimate analysis of the TMDL allocations. Table 3 lists the potential human and animal sources of fecal coliform bacteria.

Table 3. Potential sources of fecal coliform bacteria in watersheds.

Source Origin	Type	Source
Human Sources	Sewered watershed	Combined sewer overflows; Sanitary sewer overflows; leaking sanitary sewers
		Wastewater treatment plants (POTWs)
		Illegal sanitary connections to storm drains
		Illegal disposal to storm drains
	Non-sewered watershed	Septic systems
		Package WWTP plants
Non-human Sources	Domestic animals and urban wildlife	Dogs, cat, rats, raccoons, opossum, squirrels, pigeons, waterfowl
	Livestock and rural wildlife	Beef and dairy cows, horses, poultry, swine, beaver, deer, waterfowl

2.1 Point Source Assessment

Point sources are regulated under the National Pollutant Discharge Elimination System (NPDES) and include continuous municipal and industrial sources and regulated stormwater (NPDES Phase I and II). The major point source of fecal coliform in the Crowders Creek watershed is Gastonia's Crowders Creek Wastewater Treatment Plant (NC0074268), which is currently permitted to discharge 6 MGD (see Figure 2 for location).

There are no point sources, neither continuous or MS4 stormwater, within the South Carolina portion of the watershed (Giffin, 2003).

Additional minor point sources discharging domestic waste include Berkley Oaks (NC0062278), CWS Saddlewood WWTP (NC0060755), Ridge Community WWTP (NC0069175) and Pines Mobile Home Park (NC007499), totaling approximately 0.07 MGD in permitted capacity. Facilities not listed are either inactive or contain waste streams lacking significant fecal coliform (e.g., some industrial process water).

CBP Resources, a chicken processing plant, ceased its discharge to Crowders Creek in December 1998 by connecting to the Gastonia Crowders Creek WWTP. The Bessemer City WWTP (1.5 MGD; NC0020826) connected to the Crowders Creek WWTP in March 2002. Prior to this, the Bessemer City WWTP discharged into Abernathy Creek, a tributary to Crowders Creek.

EPA requires that loads allocated to NPDES permitted stormwater be placed in the wasteload allocation (WLA), which had previously been reserved for continuous point source loads (Wayland, 2002). The three MS4 entities that are permitted through Phase II of the NPDES stormwater program in the Crowders Creek watershed are Gastonia (NCS000429), Bessemer City (NCS000412), and Gaston County (NCS000411). Their entire jurisdiction is covered under the permits. The NC Department of Transportation also has a NPDES stormwater permit in this watershed (statewide_. Kings Mountain, with approximately 5.4 mi^2 of area in northwest corner of the watershed, is not currently regulated under the Phase II program.

2.2 Non-Point Source Assessment

Nonpoint sources of fecal coliform bacteria include those sources that cannot be identified as entering the waterbody at a specific location such as a NPDES permitted pipe or stormwater outfall. Diffuse sources of fecal coliform bacteria may originate from human and non-human sources (livestock, pets, wildlife).

2.2.1 Urban Development and Sewer Systems

Developed land typically generates greater areal pollutant loads relative to rural land uses. Mallin et al. (2000) found a strong relationship between the percentage of watershed imperviousness and fecal coliform density. Higher amounts of impervious surface result in less opportunity for infiltration, increasing high flow volumes, peak flows and velocities. The resultant stormwater runoff carries with it waste from pets, wildlife, and other sources.

Sewer systems for Gastonia (WQCS00017) and Bessemer City (WQCS00107) may also contribute fecal coliform to waterways during overflows and as a result of other defects. Kings Mountain also has a collection system (WQCS 00036) and sends a portion of its waste to the Crowders Creek WWTP. Sewer pipes may become blocked, damaged, or flooded by stormwater. Sanitary sewer overflows (SSO) may occur due to pump station failures caused by stormwater infiltration into the pipes through leaks. Sewer pipe leaks may also contribute to elevated levels of fecal coliform during low flow periods via exfiltration. Between 1997 and 2002, there were six SSOs reported by Gastonia (collection system associated with the Crowders Creek WWTP), twenty by Bessemer City and three by Kings Mountain. Not all the SSOs in Bessemer City and Kings Mountain occurred within the Crowders Creek watershed.

Site-specific information for fecal coliform loading from urban runoff in the Crowders Creek watershed was not available. However, studies from nearby Mecklenburg County can be used to provide initial estimates of fecal loads. The USGS calculated build-up and wash-off rates for developed land uses based on stormwater samples collected from 1993-1997 (Bales et al., 1999). Fecal coliform rates of accumulation for light residential, heavy residential/industrial, and heavy commercial/industrial were 5.3 x 10^11 counts/ha/mo, 6.9 x10^11 counts/ha/mo, and 2.1 x 10^11 counts/ha/mo, respectively.

2.2.2 Septic Systems

Failing septic systems are a potential source of fecal coliform to water bodies. Lack of maintenance and improper use can cause systems to fail, creating the potential for discharge to water bodies. A study by the NC Office of Budget and Management suggested that 11% of systems surveyed had malfunctions or failures (NC DEH, 2000). In Gaston County, the septic failure rate is thought to be near 4% (Gordon, 2003). Septic usage in the Catawba River Basin portion of Gaston County was approximately 45% based on 1990 census (NC DEH, 1999). The 2000 census did not collect information on sewage and septic. Since that time, the percentage may have decreased as more areas are developed and sewer service expands.

Gordon (2003) analyzed septic usage in the Crowders Creek watershed using GIS layers of residential parcel data, census data, and utility customers to determine the number of septic tanks by subwatershed. It was assumed that all residential households that were not municipal utility customers relied on septic. Results of the analysis indicated that nearly 5,000 septic systems were in use within the NC portion of the watershed (Table 4). Resulting septic densities were extrapolated to SC by NCDWQ resulting in an estimated 18,710 people served by septic in the watershed.

Table 4. Summary of septic usage in Crowder's Creek watershed (NC portion) based on data taken from Gordon (2003)

Subwatershed Description	Septic Systems	Avg. # persons/system	Acres	Population served	Persons per mi^2
North Crowders	857	2.78	13737	2363	110
Central Crowders	1115	2.95	9175	3290	229
Blackwood Creek	422	3.03	2202	1382	402
South Crowders	1119	2.79	10686	3023	181
Lower Crowders	1457	2.48	8792	3334	243

2.2.3 Livestock

According to the NC Department of Agriculture's (2001) livestock population census, Gaston County has approximately 9,100 head of cattle. However, only a small portion is located within the Crowders Creek watershed. There were relatively small amounts of other animal agriculture. Within the Crowders Creek watershed, there are no large concentrated animal operations. At NCDWQ's request, a livestock survey of the watershed was conducted by the Gaston County Cooperative Extension Service (Hudson, 2003). Estimates from the survey were approximately 160 beef cattle and 280 dairy cattle, located mostly in the southwest portion of the watershed. In addition, there are an estimated 150 horses.

Waste produced by cattle that is deposited on pasture or directly into streams can be a significant source of fecal coliform. Beef cows, dairy cows and horses produce on average 1.06 x 10^11 counts/day, 1.04 x10^11 counts/day, and 4.2 x 10^8 counts/day, respectively (NCSU, 1994). A watershed survey in July 2003 by NCDWQ indicated that some of the cattle had access to streams. The Gaston County Natural Resources Department estimates 30 to 50% of livestock within the watershed are permanently fenced out of streams based on its implementation of cost share program funding for livestock exclusion and alternate water sources (Gordon, 2003).

2.2.4 Waste Application

Cattle and horses that graze on pasture land deposit waste directly onto the land. Runoff during storm events can transport fecal coliform in the waste to water bodies, particularly when there is a lack of stream buffer or cattle have access to the buffer and stream. Confined dairy operations must properly apply manure collected in feedlots onto cropland or pastureland. Manure is applied to cropland in the Crowders Creek watershed, primarily during March, April, September and October.

Biosolids application is permitted in the watershed for Gastonia (WQ0001793) and Bessemer City (WQ0002264). Sludge byproducts of the wastewater treatment process, which may contain fecal coliform, is applied to agricultural land at approved rates. Anaerobic digestion is used to reduce pathogens. NCDWQ records for 2002 indicated that 1,300 acres were permitted for Gastonia. Only a portion of this acreage is located within the watershed. The Crowders Creek WWTP plant produced approximately 804 dry tons of biosolids during 2002, accounting for approximately 22% of the total tonnage applied by Gastonia. There were no recent records of residuals application under the Bessemer City permit since it connected to Gastonia.

2.2.5 Wildlife

Wildlife deposit fecal-containing waste throughout the landscape, but likely deposit more heavily in rural and forested areas where populations are larger. Loadings from wildlife are a background source. Population estimates for many types of wildlife are not available. The deer population is estimated to be 20 to 30 animals per square mile (NC DWQ, 2002). An upper limit of 30 was chosen to account for other wildlife. Fecal loading rates for deer have been estimated at 5.0 x 10^8 #/animal/day (US EPA, 2000c).

3 Modeling Approach

3.1.1 Model Framework

Due to the watershed size and variable sources of fecal coliform, the watershed model Watershed Analysis Risk Management Framework (WARMF) was selected to evaluate fecal coliform in the Crowders Creek watershed. WARMF is a decision support system designed to support the watershed approach and TMDL calculations. The model has been applied to watershed regions in the USA and Taiwan (Systech Engineering, 2001).

WARMF contains several embedded models adapted from the ILWAS model, ANSWERS, SWMM, and WASP. The model simulates hydrology and water quality for the landscape of a river basin. WARMF divides a watershed into land catchments, river segments, and reservoirs and uses the continuously stirred tank reactor (CSTR) model for flow routing and mass balance within a given soil layer or river segment.

Simulated parameters include flow, temperature, water depth and velocity, and constituent concentrations. In the case of fecal coliform bacteria, the model simulates the deposition and transportation of the bacteria from land surface loading and point source discharge. The model then computes the resulting water quality response instream using first order kinetics. The model also includes a facility for calculating TMDLs for non-point source loads under different control levels of point source loads and vice versa.

3.1.2 Model Setup

The Crowders Creek watershed is represented as eleven catchments within the model (Figure 7). The Beaverdam Creek tributary to Crowders Creek located in South Carolina is not modeled in this project. The confluence of these two creeks is located downstream of DWQ’s ambient station. A TMDL for fecal coliform in the Beaverdam Creek watershed has been prepared and approved for South Carolina. Both point and nonpoint sources are represented in the water quality model. The model was run for a continuous simulation period of January 1, 1998 through December 31, 2002.

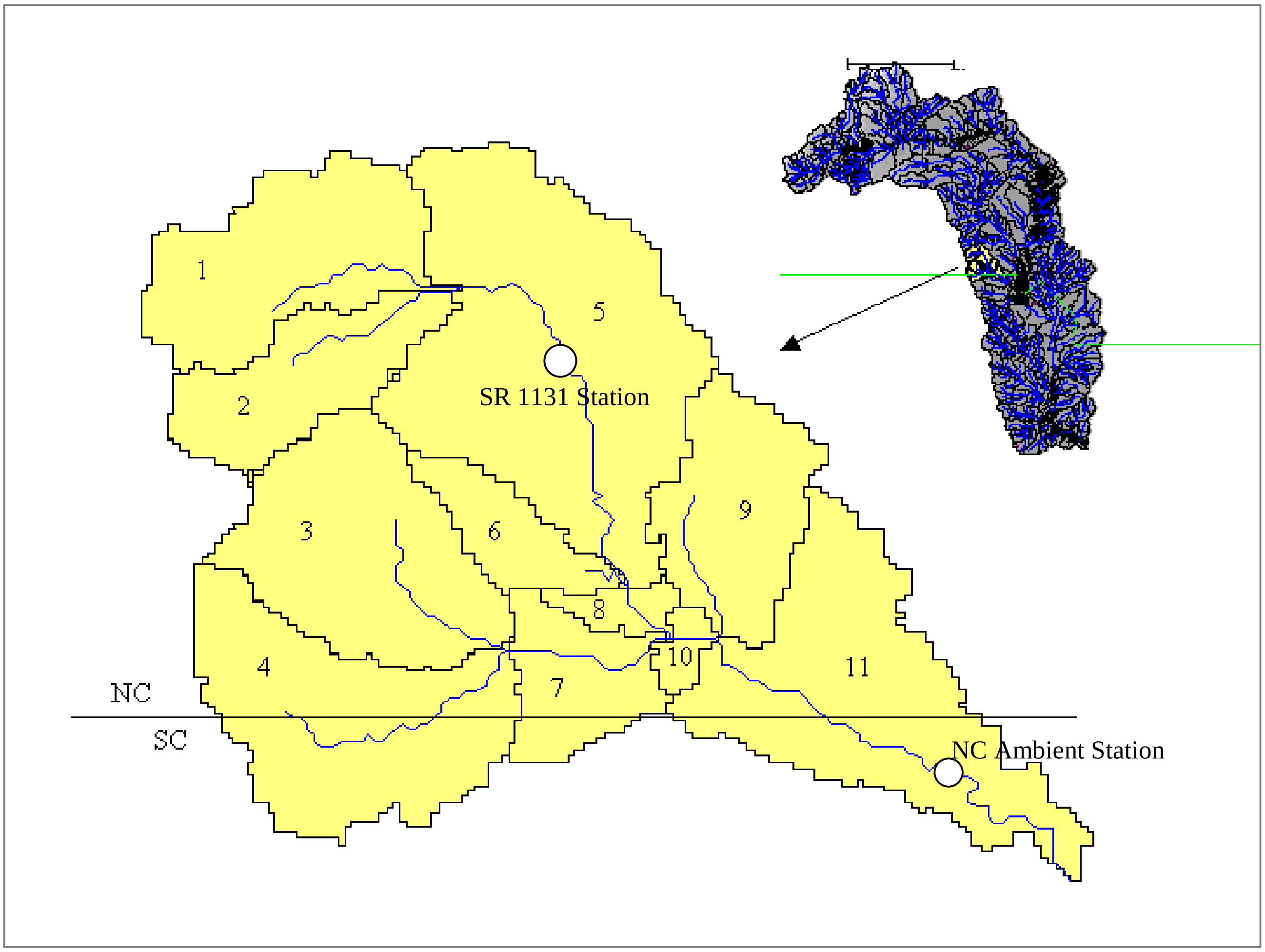

Figure 7. Crowders Creek watershed with subwatersheds (WS) as depicted in the WARMF model. Primary stations used for calibration have been labeled.

3.1.2.1 Observed Data Input

Water quality data collected at the NCDWQ ambient station located in subwatershed (WS) 11 and the station at SR 1131 in WS 5 were used as primary calibration points (Figure 7). Other data stations supplemented the calibration process. Since there are no meteorological data stations located within the watershed, meteorological data collected at nearby Long Creek, located immediately north of the Crowders Creek watershed, were associated with WS 1-4. The other subwatersheds were associated with data collected at Gastonia to the east (NCDC station 313356). Precipitation and temperature lapse factors were applied during the calibration process.

Flow data from Long Creek, adjusted for drainage area and the Bessemer City WWTP, was associated with the upper portion of the watershed. Data from a station on Crowders Creek (USGS 02145642) that is co-located with the ambient station was used for the lower part of the watershed. Flow data at the Crowders Creek USGS station was only available for October 2000 to present. Since flow data for a 5-year period (1998 – 2002) was needed, a regression between Crowders Creek and Long Creek was used to fill in the missing values (Crowders Flow = 2.4513*Long Creek Flow + 12.889; R^2 = 0.88). Finally, a DA ratio was used to adjust upward the Crowders Creek flow to represent the remaining portion of the watershed (to the confluence with Beaverdam Creek).

3.1.2.2 Fecal Loading Initial Inputs

Initial values for fecal loading (kg/ha/mo) by land use and by subwatershed were input into the model. In addition, fecal loading based on discharge monitoring data from the two primary point sources, the Crowders Creek WWTP and Bessemer City WWTP, were input into the model.

The initial fecal coliform rates of accumulation for light residential, heavy residential/industrial, and heavy commercial/industrial are from Bales et al. (1999). An initial background loading of 1.8x10^9 #/ha/mo was applied to forested land uses to account for wildlife.

The population served by septic was input to the model according to Table 5. These figures were obtained from some of the previous analysis discussed in Section 2.2.2. A failure rate of 4% based on Gaston County data is used. Septic loading assumes 265 L/cap/day and a fecal coliform concentration of 10,000 cfu/100ml for the load associated with failure (Horsley and Whitten, 1996).

Livestock loading of fecal coliform was input into the model using estimated livestock numbers (Table 6) and fecal production based on NCSU (1994). Loading was generally associated with pasture. Additional loading associated with dairy manure application to cultivated land was incorporated during March/April and September/October in subwatersheds 4 and 6. Loading is also associated with direct deposit when livestock have access to streams. Initially, the model assumed that 40% of livestock were excluded from streams (increased to 70% during calibration).

Table 5. Septic data used in the WARMF model for Crowders Creek.

Subwatershed	Septic population/mi^2	Area (mi^2)	Septic population
1	110	9.6	1056
2	110	6.3	693
3	181	11.5	2082
4	181	12.5	2263
5	247 *	21.3	5261
6	229	3.2	733
7	181	4.4	796
8	229	1.2	275
9	243	7.3	1774
10	229	0.9	206
11	243	14.7	3572

* Average of North and Central Crowders, and Blackwood Creek subwatersheds in Gordon (2003).

Table 6. Livestock data used in the WARMF model for Crowders Creek.

Subwatershed	Pasture Area (ha)	Estimated Number of Animals		
		dairy	beef	horses
1	168.35	0	0	0
2	88.06	0	0	0
3	155.4	0	50	50
4	577.57	200	50	50
5	235.69	0	0	0
6	41.44	80	0	0
7	238.28	0	40	50
8	25.9	0	0	0
9	248.64	0	20	0
10	69.93	0	0	0
11	367.78	0	0	0

3.1.2.3 Fecal Coliform Decay

Fecal coliform bacteria produced in a watershed are subject to die-off in the soil and water environment. Factors that influence their survival include sunlight, temperature, moisture conditions, salinity, soil conditions, waterbody conditions, settling, and association with particles (USEPA, 2001). For example, bacteria survival decreases as temperature increases.

Decomposition of fecal coliform in the soil was initially set at 0.27 day^{-1} based on the median value for the soil environment in Crane and Moore (1986). The initial value of coliform decay in stream was set at 1.0 day^{-1} based on the median value of the data in Bowie et al. (1985).

3.1.3 Calibration

Calibration of a dynamic loading model involves both hydrologic and water quality components. First, the model must be calibrated to represent flow and temperature in the watershed. Next, water quality simulations and calibration can be performed. The hydrologic calibration involves comparison of simulated streamflows to observed streamflow data. Simulated streamflows are generated from input and adjustment of model parameters, including meteorological, physical and hydrologic response. Parameters are adjusted within defensible ranges until an acceptable agreement is achieved between simulated and observed results. The ambient station, located in WS 11, and the station at SR 1131 in WS 5 were used as primary calibration points. Qualitative (seasonal trends, magnitude and timing of peaks) and quantitative (calibration statistics) measures were used to evaluate calibration.

3.1.3.1 Flow and Temperature

Precipitation weighting factors and temperature lapse were applied by subwatershed during the calibration process to improve the relationship between observed and simulated values (Table 7). Precipitation weighting factors are multipliers applied to the precipitation in the meteorological file to account for local variations in precipitation amount from orographic effects (varies from 1, unitless). Average temperature lapse is the average amount subtracted from the temperature in the meteorological file to account for regional variations in temperature from orographic effects. A positive value indicates that the catchment is cooler than its meteorological station (varies from 0, degrees C).

The parameters associated with soil layers were also adjusted to represent hydrologic response. Four soil layers are simulated in WARMF with saturated lower layers generally providing baseflow and the upper layers providing stormflow. Thicker soil layers with lower horizontal conductivity tended to provide greater baseflow, while thinner layers with higher conductivity often resulted in sharper peaks. The final calibrated parameters are presented in Appendix III.

Table 7. Precipitation weighting factors and temperature lapse for the Crowders Creek watershed.

Subwatershed	Meteorological Station	Average Temperature Lapse	Precipitation Weighting Factor
1	Long Creek	1.4	1.05
2	Long Creek	1.4	1.05
3	Long Creek	1.4	1.15
4	Long Creek	1.4	1.20
5	Gastonia	1.25	1.10
6	Gastonia	1.25	1.10
7	Gastonia	1.25	1.15
8	Gastonia	1.25	1.10
9	Gastonia	1.25	1.10
10	Gastonia	1.25	1.10
11	Gastonia	1.25	1.10

The time series of simulated versus observed temperature and flow are presented in Figures 8 through 11. There were only 16 observed temperature values for the upstream station (Figure 9). Calibration statistics for the downstream station, which is located upstream of the outlet, are presented in Table 8. R^2 is the square of the correlation coefficient between simulated results and observed data over all time steps for which both exist. A perfect correlation has a value of 1. Relative Error is the average of all errors (difference between simulated and observed values) over all time steps for which it can be calculated. It is a measure of model accuracy. Absolute Error, a measure of model precision, is the average of the absolute value of all errors over all time steps for which it can be calculated. Unlike relative error, overpredictions and underpredictions do not cancel each other out with absolute error. RMS Error is the root-mean-square error, which is the square root of the average of the squares of all errors over all time steps for which it can be calculated. This magnifies the effect of larger than average errors.

Table 8. Calibration statistics for temperature and flow in subwatershed 11.

	Flow (cms)	Temperature (°C)
Simulated Mean	1.78	15.92
Observed Mean	1.76	15.71
Simulated Range	0.38 to 26.87	2.06 to 27.72
Observed Range	0.12 to 43.30	4.00 to 25.00
Relative Error	0.02	0.49
Absolute Error	0.76	2.15
RMS Error	2.07	2.65
R^2	0.50	0.86

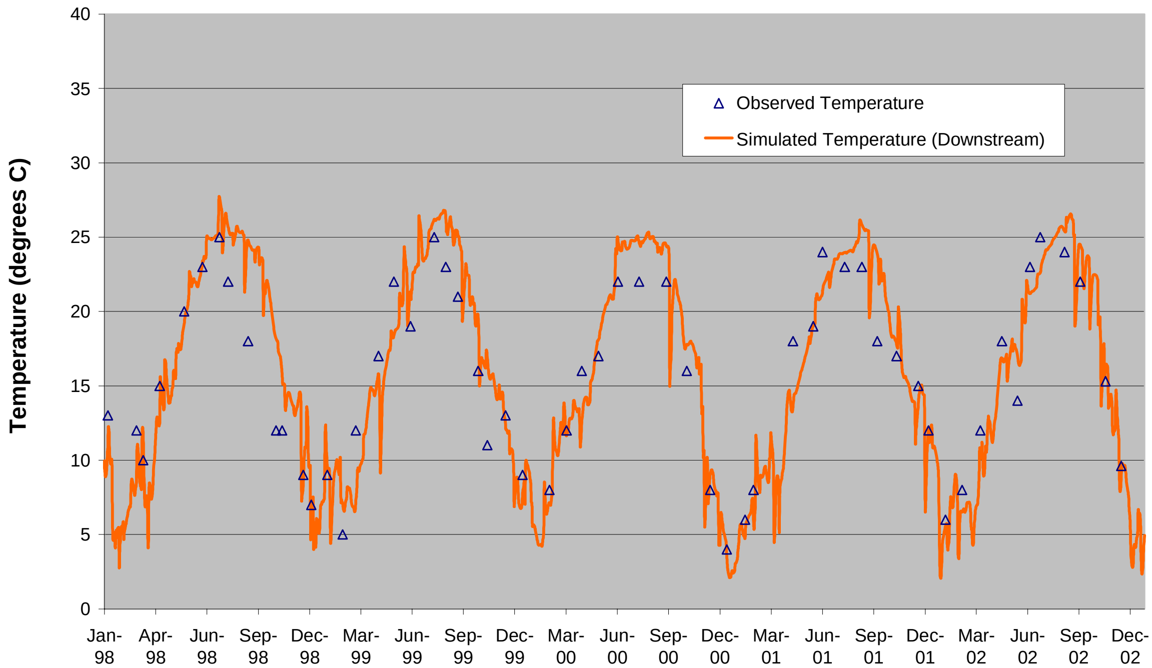

Figure 8. Observed vs. simulated temperature at the downstream calibration station in subwatershed 11 (R^2=0.86).

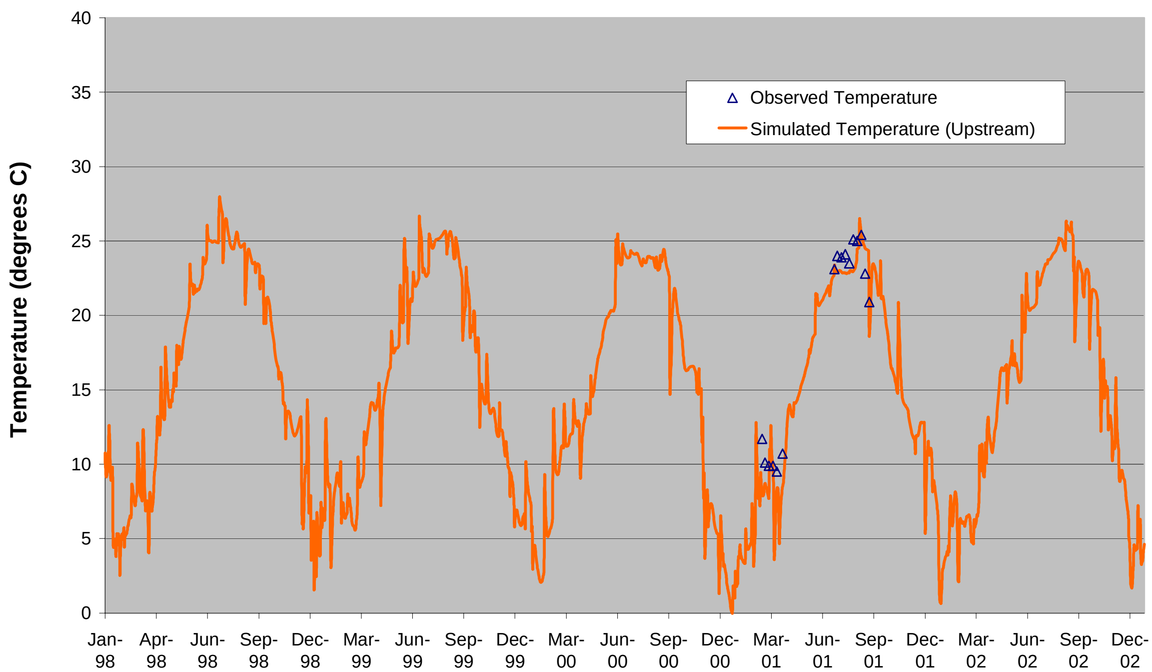

Figure 9. Observed versus simulated temperature at the upstream calibration station in subwatershed 5 (R^2=0.98).

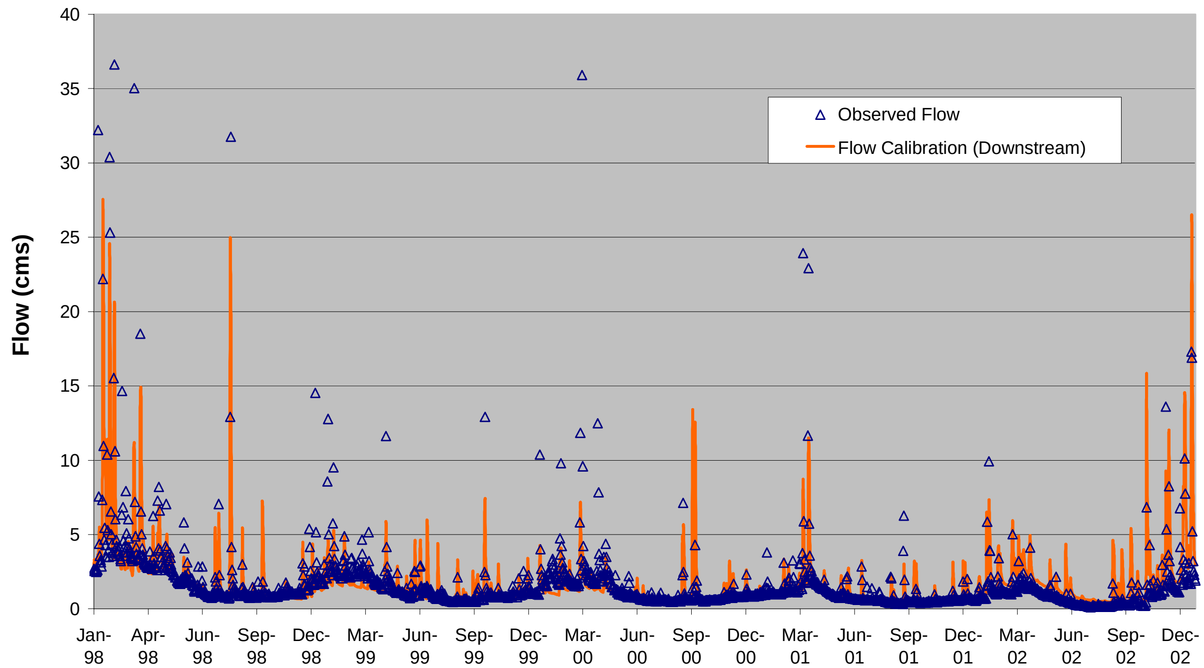

Figure 10. Observed versus simulated flow at the downstream calibration station in subwatershed 11 (R^2=0.50).

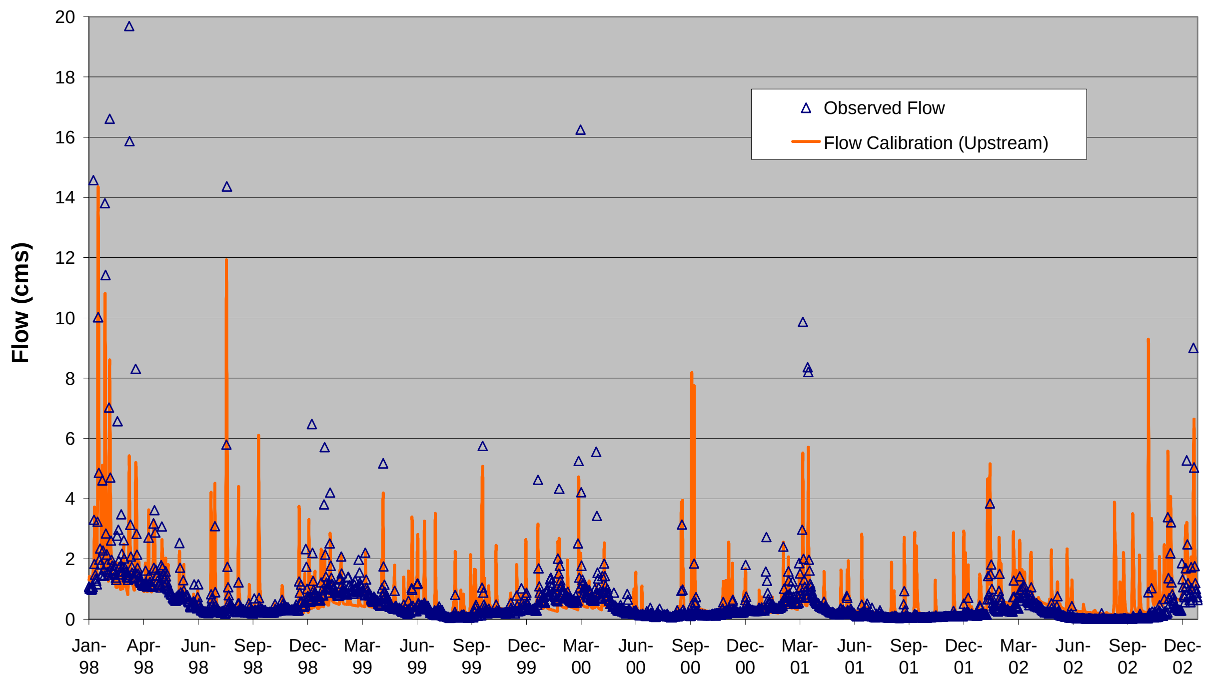

Figure 11. Observed versus simulated flow at the upstream calibration station in subwatershed 5 (R^2=0.43).

3.1.3.2 Fecal Coliform

Fecal coliform loading rates by land use adjusted during calibration are associated with "land application" in the WARMF model. Forested land uses were reduced to 500 E6 #/ha. Pasture rates ranged from 10,000 to 30,000 E6 #/ha for the populated subwatersheds (WS) in Table 6. In WS 4 and 6, cultivated land received 1800 and 2000 E6 #/ha, respectively during March, April, October, and September due to dairy manure application. Finally, low intensity, high intensity, and commercial/industrial development received 25,000, 30,000, and 15,000 E6 #/ha, respectively. The fraction of impervious surface associated with each of these land uses was 0.3, 0.65, and 0.75, respectively. Final calibrated decay rates for fecal coliform were 0.35 day^{-1} in the soil environment and 0.9 day^{-1} in the stream.

Calibration statistics for instream fecal coliform are presented in Table 9. While R^2 is a measure of the model's ability to predict trends in the data, is often not very useful when there is a large amount of scatter in observed data. For example, the overall R^2 for the complete fecal coliform time series is 0.02. However, individual statistics by year may be more insightful with values of 0.16, 0.86, 0.08, 0.56, and 0.55 for 1998 through 2002, indicating improvement in prediction in the last two years.

The time series of observed versus simulated fecal coliform at subwatershed 11 is presented in Figure 12. The capture of patterns is reasonable, although not all values are predicted well. At SR 1131 in subwatershed 5, fecal coliform data was only available for 2001, which limits the comparison (Figure 13).

Table 9. Calibration statistics for fecal coliform (#/100ml) in subwatershed 11 (downstream station).

	Simulated	Observed
Mean	376.1	515.9
Minimum	45.44	18
Maximum	3695	4200
# of pts to compare	67	
Relative Error	-156.8	
Absolute Error	459.9	
RMS Error	967.8	

A rolling 30-day geometric mean of observed fecal coliform at SR 2424 and simulated fecal coliform at the subwatershed 11 outlet also suggests that the pattern is tracked, but with a few discrepancies (Figure 14).

This observed station is near the state line, upstream from the point where simulated results are provided (Figure 7). A 30-day geometric mean is determined by calculating the geometric mean of an individual day's fecal concentration and the daily predictions for the 29 days that precede it. The rolling aspect is achieved by moving to the next day and performing the same calculation.

It is important to note that in addition to the inherent difficulty in predicting fecal coliform, both sets of observed data are from points upstream of the WS outlet where the simulated results are given.
This may account for some of the differences in modeled and observed values. Land based inputs as well as instream decay are expected between the station and the watershed outlet.

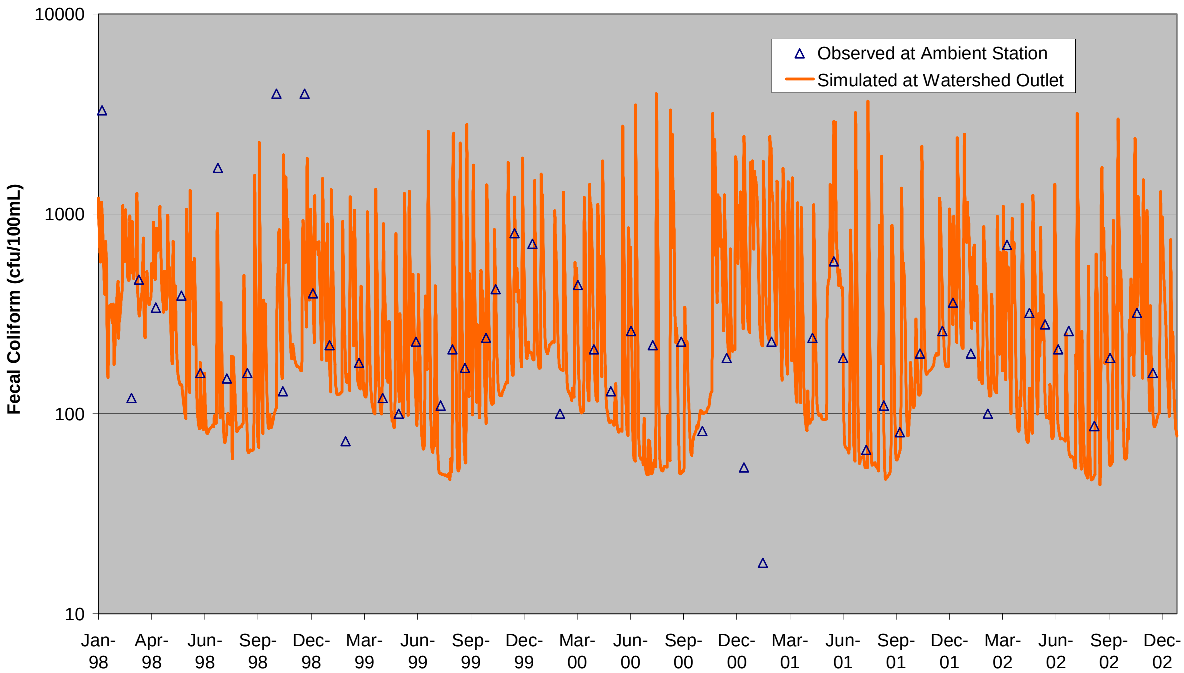

Figure 12. Observed versus simulated fecal coliform at subwatershed 11.

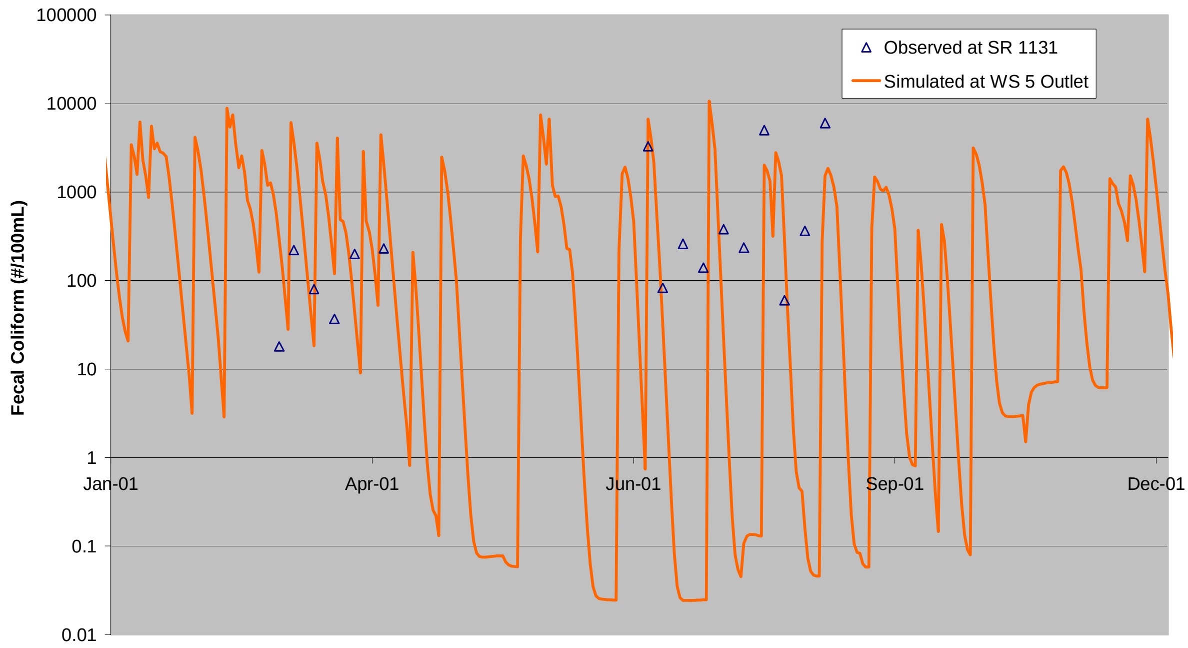

Figure 13. Observed versus simulated fecal coliform at SR 1131 in subwatershed 5.

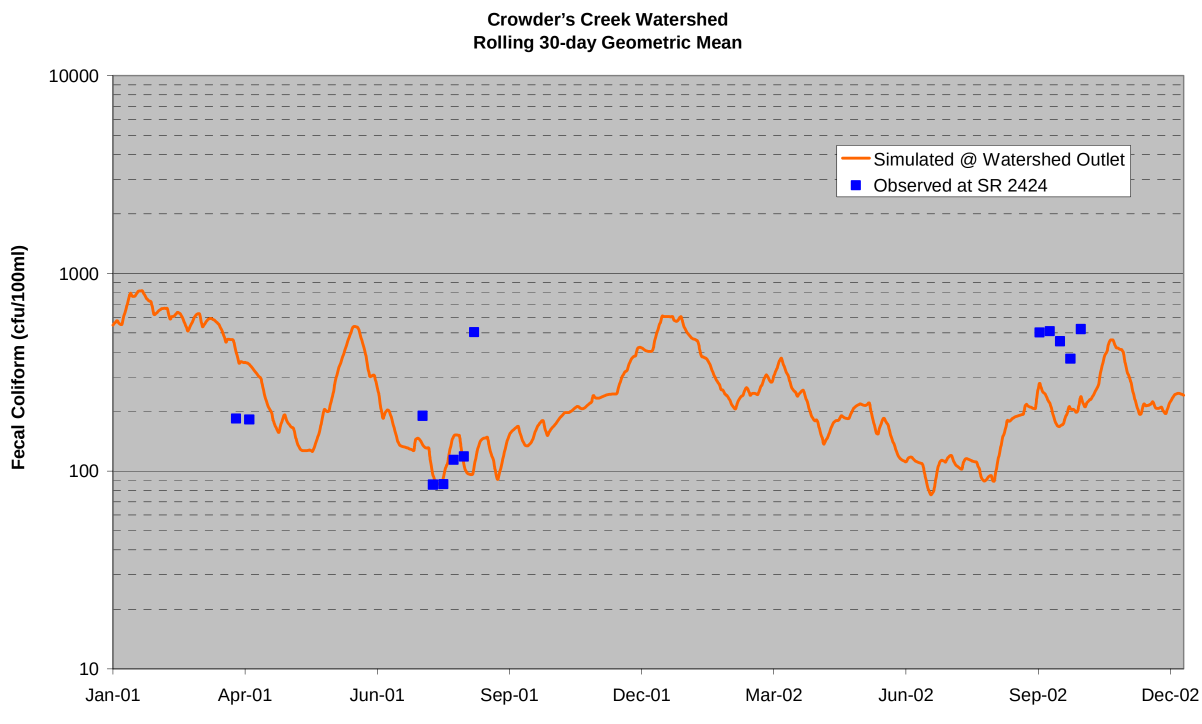

Figure 14. Rolling 30-day geometric means of observed fecal coliform at SR 2424 and simulated fecal coliform at the subwatershed 11 outlet.

3.1.4 Model Output

Existing fecal coliform loading (1998-2002) predicted by the calibrated model is given in Table 10. Urban land uses contributed 62% of the fecal loading and had the highest loading per unit area. Livestock agriculture generated the second most fecal loading. Background loading associated with wildlife in forested land uses was greater than both septic and point sources.

Table 10. Existing fecal coliform loading (1998-2002) by source in the Crowders Creek watershed.

	Simulated Land-based Load (1E6/d)	Percent	Loading per unit area 1E6/ha/yr
Deciduous Forest	29,100	3	1,260
Evergreen Forest	18,100	2	1,720
Mixed Forest	12,400	1	1,890
Pasture	284,000	28	46,700
Cultivated	14,300	1	1,760
Recr. Grasses	817	0	1,000
Water	270	0	1,400
Barren	300	0	678
Low Int. Develop.	304,000	30	54,700
High Int. Develop.	155,000	15	121,000
Comm / Industrial	179,000	17	66,600
Wetlands	0	0	0
Type 1 Septic System [1]	6,670	1	--
Type 2 Septic System	0	0	--
Type 3 Septic System	2,780	0	--
General Point Sources	25,300	2	--
TOTAL	1,030,000	100	--

[1] WARMF accepts inputs for 3 types of septic systems: standard, advanced, and failing.

4 Allocation

4.1 Total Maximum Daily Load (TMDL)

A Total Maximum Daily Load is the maximum amount of a pollutant that a water body can receive and still meet water quality standards, partitioned among point and nonpoint sources. A TMDL is comprised of the sum of wasteload allocations (WLA) for point sources, load allocations (LA) for nonpoint sources, and a margin of safety (MOS), expressed by the equation:

$$TMDL = \Sigma\ WLA + \Sigma\ LA + MOS$$

The objectives of the TMDL are to estimate allowable pollutant loads, and to allocate them among the general pollutant sources in the watershed. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time (e.g. pounds per day), toxicity, or other appropriate measures. This TMDL will be expressed in terms of % load reduction and allowable load of fecal coliform. It will be set at the outlet of the modeled watershed, the confluence of Crowders Creek and Beaverdam Creek in South Carolina.

Two separate model runs were performed to evaluate the fecal coliform standards: a geometric mean standard (200 cfu/100ml) and South Carolina's instantaneous standard discussed in Section 1.2. The WARMF model provides a facility in the TMDL module to evaluate each of these directly with a margin of safety.

Initially, since total existing loading for the point sources was below their allowable load would indicate, the model was run with existing point source loading and reductions were applied to nonpoint sources only. However, these initial runs indicated that a TMDL could not be calculated because the fecal standard could not be met even at zero nonpoint loading. This was due to several observed values in the point source data file above 400 cfu/100ml. Therefore, the file was adjusted so that all values fell below 400. Simulations were then run for the two standard evaluations. In order to meet SC's instantaneous standard, a 61% reduction would be needed in total loading versus a 79% reduction needed to meet the geometric mean standard (Figure 15). The higher percentage was chosen since both standards must be met.

The fecal coliform geometric mean reductions were used to develop the TMDL loading. Further analysis was required to determine the breakdown between point source (WLA) and nonpoint source (LA) loadings that meet the TMDL objectives.

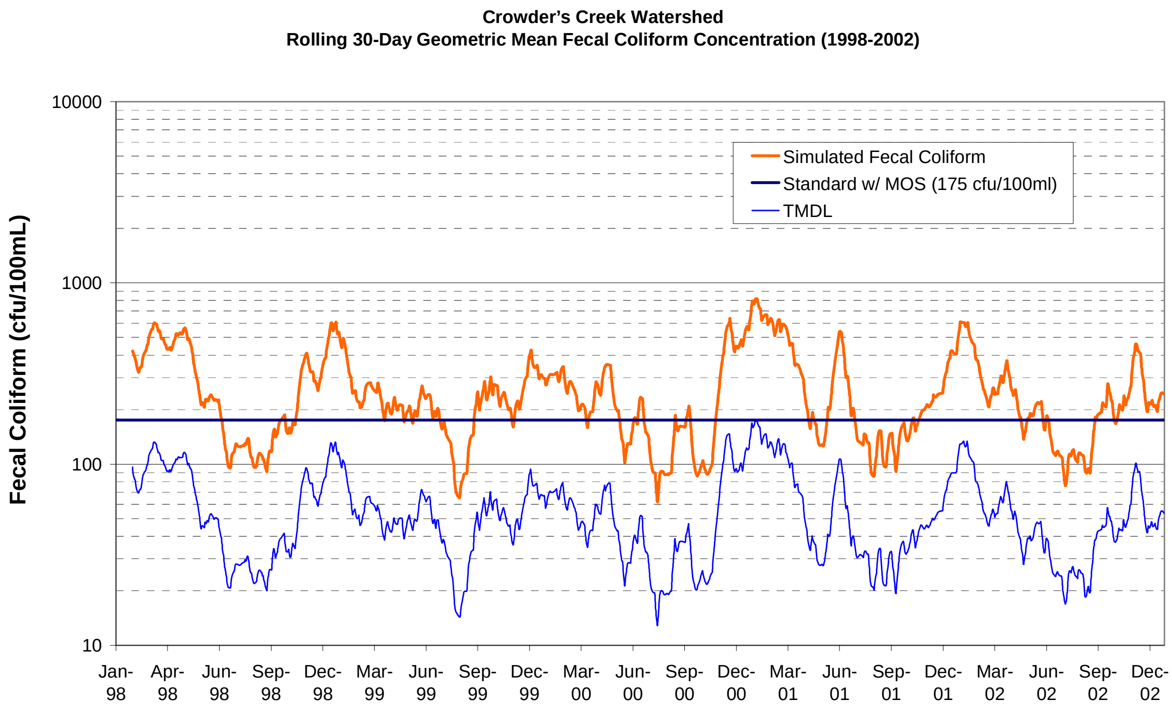

Figure 15. Results of TMDL simulation for a rolling 30-day geometric mean for fecal coliform in the Crowders Creek watershed.

4.2 Critical Conditions

Critical conditions can be considered a subset of seasonality: the most stringent of the seasons. In the Crowders Creek watershed, water quality violations of fecal coliform appear to occur during both wet and dry periods (Figure 5 and 6). Recent ambient data collected in the Crowders Creek watershed indicate observed exceedances may occur during all times of the year, with the four highest values in August/September and December/January (Figure 3). The three highest simulated geometric means occurred in January (Figure 15). However, a greater number of observed exceedances occurred during April – October and in mid-range to drier flows (Figures 5 and 6). The TMDL has been set such that the standard is met during all times of the modeled period (1998-2002).

4.3 Seasonal Variation

Seasonal variation is considered in the development of the TMDL because the allocation applies to all seasons. Seasonal variation in hydrology, climatic conditions, and watershed activities are represented through the use of a continuous flow gage and the use of all readily available water quality data collected in the watershed. A wide range of flow conditions is modeled for this TMDL, demonstrated by the interannual variation in hydrology seen in Figure 5.

4.4 Model Uncertainty and Margin of Safety

The lack of agreement between modeled and observed fecal coliform concentrations is due in part to the high degree of uncertainty associated with predicting fecal coliform bacteria. The inability to accurately predict specific observed fecal coliform concentrations can be attributed to many sources: model error, lack of sufficient information in source assessment, gaps in our scientific knowledge, natural variability in instream fecal coliform concentrations, field and laboratory measurement error, and lack of current site specific model input parameters including decay rate, flow, rainfall data, and land use information. The watershed model used in this project estimates daily average fecal coliform concentrations based on land use information. Because of certain lack of site-specific information, professional judgment and literature values were sometimes used to calculate the fecal coliform loading from the various land uses. In sum, the model results should be interpreted in light of the model limitations and prediction uncertainty.

The margin of safety is an additional factor of the TMDL that accounts for some of the uncertainty in the relationship between pollutant loads and receiving water quality. This margin of safety can be provided implicitly through conservative analytical assumptions and/or explicitly by reserving a portion of the load capacity. This TMDL utilizes an explicit margin of safety (MOS): the geometric mean target is set at 175 cfu/100ml (MOS = 25 cfu/100ml) and the instantaneous limit is set to 360 cfu/100ml (MOS = 40 cfu/100ml).

4.5 Allocation

The continuous waste load allocation (Table 11) is based on the maximum permitted loading, calculated as permitted flow for the Crowders Creek WWTP plus the minor point sources (6.07 MGD times the 200 cfu/100mL fecal coliform standard). The Crowders Creek WWTP must also must meet monthly geometric mean of 200 cfu/100ml and cannot exceed 400 cfu/100ml maximum.

Table 11. Total maximum daily load allocation for the Crowders Creek watershed (detailed in Appendix).

	Units per day	% Reduction	% of TMDL
TMDL [1]	**2.21E+11**		
NC Continuous WLA	**8.27E+09**	**0%**	3.7%
NC MS4 WLA plus LA [2]	2.13E+11	79%	
NC MS4 WLA	**7.45E+10**	**79%**	33.7%
NC LA	**1.15E+11**	**79%**	51.8%
SC LA	**2.36E+10**	**79%**	10.7%
Station CW-023	--	79%	
Station CW-024	--	79%	
Station CW-192	--	79%	

[1] Equivalent to a 79% reduction in existing loading (1998-2002).

[2] TMDL minus continuous WLA

NPDES permitted stormwater including that associated with MS4s (small municipal separate storm sewer systems) must also be included in the wasteload allocation.[3] Kings Mountain is not an MS4 town, therefore, their jurisdiction within Crowders Creek must be broken out to calculate this portion of the WLA. Kings Mountain covers 34.1% of the area in WS 1 and 2. The nonpoint source load from these two subwatersheds is 19.5% of the total watershed nonpoint loading. Accordingly, a ratio of 6.65% (34.1%*19.5%) is used to separate the Kings Mountain LA (1.4E+10 units/d) from the nonpoint source loading in the remainder of the watershed (Appendix IV).

[3] According to the Phase II rules, MS4 permittees are responsible for reducing the loads associated with stormwater outfalls for which it owns or otherwise has responsible control.

Except for Kings Mountain, the entire NC portion of the Crowders Creek watershed falls within Phase II boundaries. Therefore, all fecal loadings from urban land uses within this area were assigned to the WLA component. Loadings from land uses such as agricultural and forested areas are considered nonpoint sources and are reported as LAs. A loading ratio based on relative land use and loading rate is used to apportion the load between WLA and LA (Table 12). The distribution of the urban (developed land uses) and non-urban land uses, 14.5 % and 86.5%, respectively, was determined from the landuse coverage within WARMF. In addition, the relative loading rates between the urban and rural landuse types were determined based modeled unit-loading rates (Table 10).

A load is allocated to SC based on land use and unit loading rates in the border subwatersheds. Subwatersheds 4, 7, and 11 are split between SC and NC. The land uses are relatively homogenous within each subwatershed. These watersheds are predominately rural in character. WS 4 and 11 are approximately one half in SC and WS 7 is approximately one quarter in SC. The TMDL loading per unit area was multiply by the land use area to generate fecal loading in each of these subwatersheds. As a result, SC is approximately 16% of the watershed and will receive a load allocation that is 10.7% of the total nonpoint source load (see Appendix VI for detail).

Table 12. Relative fecal coliform loading rates in the Crowders Creek watershed.

	Relative Land Use	Relative Loading Rate	Loading Ratio
Urban Land	14.5%	81.3%	42.6%
Non-Urban Land	85.5%	18.6%	57.4%

5 Implementation Plan

The TMDL analysis was performed using the best data available to specify the fecal coliform reductions necessary to achieve water quality criteria. The intent of meeting the criteria is to support the designated use classifications in the watershed. A detailed implementation plan is not included in this TMDL. The involvement of local governments and agencies in both NC and SC will be needed in order to develop the implementation plan. An implementation plan will be developed under a NC 319 grant to Dr. Jy Wu with the University of North Carolina at Charlotte (refer to section 7).

6 Stream Monitoring

Fecal coliform monitoring will continue on a monthly interval at the ambient monitoring sites on Crowders Creek. Monitoring of fecal coliform concentrations will allow evaluation of progress towards the goal of achieving water quality standards and intended best uses.

7 Future Efforts

This TMDL represents an early phase of a long-term restoration project to reduce fecal coliform loading to acceptable levels in the Crowders Creek watershed. NCDWQ in cooperation with SC and local governments should evaluate the progress of implementation strategies and refine the TMDL as necessary, in the next phase based on NC's five-year basin management cycle. This will include recommending specific implementation plans for reduction of fecal coliform loading.

The NC 319 Grant program has recently funded a project entitled, *Restoring and Assessing Fecal Coliform Impairment of Crowders Creek*. The principal investigator is Dr. Jy S. Wu with the Department of Civil Engineering, University of North Carolina at Charlotte. The project, an extension of work associated with the TMDL, aims to begin restoring the impaired section of the Crowder Creek due to fecal coliform.

Components of the project include installation of new and/or retrofit of existing structural best management practices (BMPs) and/or low impact design (LIDs) at strategic locations of the Crowders Creek watershed or at its Blackwood Creek sub-watershed. In addition, a watershed restoration plan for long-term fecal coliform mitigation for the Crowders Creek watershed will be developed. The plan will integrate the efforts of TMDL modeling, a bacterial source tracking (BST) study by NCDWQ (scheduled for summer 2004), and additional monitoring and analyses to be performed by the investigators.

8 Public Participation

A draft of the Crowders Creek TMDL was publicly noticed through various means, including notification in the local newspapers of NC and SC. Copies of the affidavits of publication are provided in Appendix IX. The draft TMDL and public comment information was distributed electronically to known interested parties. The TMDL was also available from the Division of Water Quality's website at http://h2o.enr.state.nc.us/tmdl/ during the comment period. The comment period occurred from March 23, 2004 through May 6, 2004. A public meeting was held on April 28 at the Gaston Citizen's Resource Center in Dallas, NC to present the TMDL and answer questions. Nine citizens attended the public meeting. One comment was received from Mr. Alton C. Boozer, Chief of the South Carolina Bureau of Water. A copy of the letter is located in Appendix X. The comments were positive and no response is needed.

9 Further Information

Further information concerning North Carolina's TMDL program can be found on the Internet at the Division of Water Quality website**:** http://h2o.enr.state.nc.us/tmdl/.

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

J. Todd Kennedy, Modeler (todd.kennedy@ncmail.net),
Michelle Woolfolk, Supervisor (michelle.woolfolk@ncmail.net).

10 References

Bowie, G.L, W.B. Mills, D.B. Porcella, C.L. Campbell, J.R. Pagenkopf, G.L. Rupp, K.M. Johnson, P.W.H. Chan, and S.A. Gherini. 1985. *Rates, constants, and kinetic formulations in surface water quality modeling.* 2nd edition. EPA/600/3-85/040. Environmental Research Laboratory, Athens, GA.

Canale, R. P., M.T. Auer, E.M. Owens, T.M. Heidtke, S.W. Effler. 1993. Modeling Fecal Coliform Bacteria –II. Model Development and Application. Water Research, 27(4):703-714.

Crane, S.R. and J. A. Moore. 1986. Modeling enteric bacterial die-off: A review. *Water, Air, and Soil Pollution* 27:411-439.

Cleland, B.R. 2002. TMDL Development from the "Bottom Up" – Part II: Using load duration curves to connect the pieces. Proceedings from the WEF National TMDL Science and Policy 2002 Conference.

Giese, G.L. and R.R. Mason, Jr. 1993. Low-flow characteristics of streams in North Carolina. U.S. Geological Survey water-supply paper 2403.

Giffin, Mark. 2003. South Carolina DEHC. Personal Communication.

Gordon, R.D. 2003. A fecal coliform source assessment for the Crowders Creek watershed. Gaston County, North Carolina. Civil Engineering Independent Study. Final Project. UNC Charlotte.

Hudson, Craven. 2002. Gaston County Cooperative Extension. Personal communication.

Mallin, M.A., K.E. Williams, E.C. Esham, and R.P. Lowe. 2000. Effect of human development on bacteriological water quality in coastal watersheds. *Ecological Applications*, 10(4):1047-1056.

North Carolina Department of Agriculture. 2001. Agricultural Statistics Division-County Statistics. www.ncagr.com/stats/cntysumm/ and http://govinfo.library.orst.edu/cgi-bin/agstate?North+Carolina.

North Carolina Cooperative Extension Service, North Carolina State University (NCSU), College of Agriculture and Life Sciences, Raleigh, Livestock Manure Production and Characterization in North Carolina. January 1994.

North Carolina Division of Environmental Health (NCDEH). NCDENR. 1999. North Carolina On-Site Wastewater Non-Point Source (NPS) Pollution Program. www.deh.enr.state.nc.us/oww/nonpointsource/ NPS.htm June 24, 1999.

North Carolina Division of Environmental Health (NCDEH). NCDENR. 2000. Report on the Proper Maintenance of Septic Tank Systems in Accordance with Section 13.5 of HB 1160 (Clean Water Act of 1999). http://www.deh.enr.state.nc.us/oww/Maintenance.PDF. March 15, 2000.

North Carolina Equine Survey. 1996. North Carolina Agricultural Statistics. NC Department of Agriculture and Consumer Services, Raleigh, NC – 27611. http://www.agr.state.nc.us/stats.

North Carolina Division of Water Quality. February 2002. Fecal Coliform Total Maximum Daily Load for the Irwin, McAlpine, Little Sugar and Sugar Creek Watersheds, Mecklenburg County. Catawba River Basin. Final report submitted to EPA.

North Carolina Division of Water Quality. August 2002. Fecal Coliform Total Maximum Daily Load for the Clark Creek Watershed, Catawba and Lincoln County. Catawba River Basin. Final Report.

Office of Water. 1997. Guidelines for preparation of the comprehensive state water quality assessments. EPA-841-B-97-00. U.S. Environmental Protection Agency, Washington D.C.

Stiles, T.C. 2002. Incorporating hydrology in determining TMDL endpoints and allocations. Proceedings from the WEF National TMDL Science and Policy 2002 Conference.

Systech Engineering. October 2001. Watershed Analysis Risk Management Frame Work (WARMF): Update One: A Decision Support System for Watershed Analysis and Total Maximum Daily Load Calculation, Allocation and Implementation. EPRI, Palo Alto, CA:1005181.

Thomann, R.V. and Mueller, J.A. 1987. *Principles of Surface Water Quality Modeling and Control*. Harper and Row, New York, NY.

U.S. Environmental Protection Agency (USEPA) 1985. Rates, constants, and kinetics formulations in surface water quality modeling (II ed.). Athens, GA: EPA-600-3-85-040.

U.S. Environmental Protection Agency (USEPA). 1991. Guidance for Water Quality-Based Decisions: The TMDL Process. Assessment and Watershed Protection Division, Washington, DC.

U.S. Environmental Protection Agency, Federal Advisory Committee (FACA). Draft final TMDL Federal Advisory Committee Report. 4/28/98.

U.S. Environmental Protection Agency (USEPA) 2000a. Revisions to the Water Quality Planning and Management Regulation and Revisions to the National Pollutant Discharge Elimination System Program in Support of Revisions to the Water Quality Planning and management Regulation; Final Rule. Fed. Reg. 65:43586-43670 (July 13, 2000).

U.S.Environmental Protection Agency (USEPA) 2000b. Implementation Guidance for Ambient Water Quality Criteria for Bacteria – 1986. DRAFT. Office of Water. EPA-823- D-00-001.

U.S. Environmental Protection Agency (USEPA) 2000c. Bacterial Indicator Tool. User's Guide. Office of Water. EPA-823-B-01-003. March 2000.

U.S.Environmental Protection Agency (USEPA). January 2001. Protocol for Developing Pathogen TMDLs: First Edition. http://www.epa.gov/owow/tmdl/techsupp.html.

11 Appendix

Appendix I. Water quality data collected in the Crowders Creek watershed (1997-2002).

Station #	Station Description	Date	Fecal Coliform	Temp
BWC	Blackwood Creek at SR 1136	2/28/2001	280	11.7
BWC	Blackwood Creek at SR 1136	3/5/2001	320	10.8
BWC	Blackwood Creek at SR 1136	3/12/2001	270	10.7
BWC	Blackwood Creek at SR 1136	3/19/2001	400	10.1
BWC	Blackwood Creek at SR 1136	3/26/2001	1285	10.0
BWC	Blackwood Creek at SR 1136	4/5/2001	400	13.8
BWC	Blackwood Creek at SR 1136	7/5/2001	4700	22.5
BWC	Blackwood Creek at SR 1136	7/10/2001	265	22.4
BWC	Blackwood Creek at SR 1136	7/17/2001	395	23.0
BWC	Blackwood Creek at SR 1136	7/24/2001	2900	23.0
BWC	Blackwood Creek at SR 1136	7/31/2001	2000	22.1
BWC	Blackwood Creek at SR 1136	8/7/2001	132	23.2
BWC	Blackwood Creek at SR 1136	8/14/2001	5600	23.7
BWC	Blackwood Creek at SR 1136	8/21/2001	245	22.5
BWC	Blackwood Creek at SR 1136	8/28/2001	375	21.9
BWC	Blackwood Creek at SR 1136	9/4/2001	97000	20.7
BWC	Blackwood Creek at SR 1136	9/10/2002	410	
BWC	Blackwood Creek at SR 1136	9/12/2002	240	
BWC	Blackwood Creek at SR 1136	9/17/2002	2800	
BWC	Blackwood Creek at SR 1136	9/19/2002	1200	
BWC	Blackwood Creek at SR 1136	9/24/2002	900	
BWC	Blackwood Creek at SR 1136	10/1/2002	520	
BWC	Blackwood Creek at SR 1136	10/8/2002	3000	
BWC	Blackwood Creek at SR 1136	10/15/2002	2400	
BWC	Blackwood Creek at SR 1136	10/22/2002	5900	
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	2/28/2001	41	11.2
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	3/5/2001	210	10.8
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	3/12/2001	76	10.6
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	3/19/2001	66	8.6
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	3/26/2001	315	10.1
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	4/5/2001	115	13.5
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	7/5/2001	265	21.9
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	7/10/2001	84	22.7
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	7/17/2001	50	22.1
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	7/24/2001	330	22.7
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	7/31/2001	50	22.4
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	8/7/2001	41	23.6
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	8/14/2001	3600	24.1
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	8/21/2001	60	23.3
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	8/28/2001	83	23.0
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	9/4/2001	36000	20.7
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	9/10/2002	2600	

CC2	Crowders Creek at SR 1108 (Upstream WWTP)	9/12/2002	130	
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	9/17/2002	1000	
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	9/19/2002	2200	
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	9/24/2002	370	
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	10/1/2002	520	
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	10/8/2002	670	
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	10/15/2002	400	
CC2	Crowders Creek at SR 1108 (Upstream WWTP)	10/22/2002	5800	
CC3	Crowders Crk at SR 2424 at NC/SC state line	2/28/2001	120	11.2
CC3	Crowders Crk at SR 2424 at NC/SC state line	3/5/2001	550	11.3
CC3	Crowders Crk at SR 2424 at NC/SC state line	3/12/2001	250	11.2
CC3	Crowders Crk at SR 2424 at NC/SC state line	3/19/2001	74	10.3
CC3	Crowders Crk at SR 2424 at NC/SC state line	3/26/2001	174	11.1
CC3	Crowders Crk at SR 2424 at NC/SC state line	4/5/2001	114	13.8
CC3	Crowders Crk at SR 2424 at NC/SC state line	7/5/2001	3000	22.1
CC3	Crowders Crk at SR 2424 at NC/SC state line	7/10/2001	120	24.2
CC3	Crowders Crk at SR 2424 at NC/SC state line	7/17/2001	29	23.5
CC3	Crowders Crk at SR 2424 at NC/SC state line	7/24/2001	305	24.4
CC3	Crowders Crk at SR 2424 at NC/SC state line	7/31/2001	78	23.5
CC3	Crowders Crk at SR 2424 at NC/SC state line	8/7/2001	55	25.0
CC3	Crowders Crk at SR 2424 at NC/SC state line	8/14/2001	122	24.6
CC3	Crowders Crk at SR 2424 at NC/SC state line	8/21/2001	120	24.2
CC3	Crowders Crk at SR 2424 at NC/SC state line	8/28/2001	375	24.4
CC3	Crowders Crk at SR 2424 at NC/SC state line	9/4/2001	107000	20.4
CC3	Crowders Crk at SR 2424 at NC/SC state line	9/10/2002	250	
CC3	Crowders Crk at SR 2424 at NC/SC state line	9/12/2002	400	
CC3	Crowders Crk at SR 2424 at NC/SC state line	9/17/2002	1100	
CC3	Crowders Crk at SR 2424 at NC/SC state line	9/19/2002	770	
CC3	Crowders Crk at SR 2424 at NC/SC state line	9/24/2002	380	
CC3	Crowders Crk at SR 2424 at NC/SC state line	10/1/2002	270	
CC3	Crowders Crk at SR 2424 at NC/SC state line	10/8/2002	220	
CC3	Crowders Crk at SR 2424 at NC/SC state line	10/15/2002	400	
CC3	Crowders Crk at SR 2424 at NC/SC state line	10/22/2002	4300	
CC1	Crowders Creek at SR 1131	2/28/2001	18	11.7
CC1	Crowders Creek at SR 1131	3/5/2001	220	10.1
CC1	Crowders Creek at SR 1131	3/12/2001	80	9.9
CC1	Crowders Creek at SR 1131	3/19/2001	37	9.9
CC1	Crowders Creek at SR 1131	3/26/2001	200	9.5
CC1	Crowders Creek at SR 1131	4/5/2001	230	10.7
CC1	Crowders Creek at SR 1131	7/5/2001	3300	23.1
CC1	Crowders Creek at SR 1131	7/10/2001	83	24.0
CC1	Crowders Creek at SR 1131	7/17/2001	260	23.9
CC1	Crowders Creek at SR 1131	7/24/2001	140	24.1
CC1	Crowders Creek at SR 1131	7/31/2001	380	23.5
CC1	Crowders Creek at SR 1131	8/7/2001	235	25.1
CC1	Crowders Creek at SR 1131	8/14/2001	5000	25.0
CC1	Crowders Creek at SR 1131	8/21/2001	60	25.4
CC1	Crowders Creek at SR 1131	8/28/2001	365	22.8
CC1	Crowders Creek at SR 1131	9/4/2001	6000	20.9

CCE	Crowders Creek WWTP effluent	2/28/2001	106	11.3
CCE	Crowders Creek WWTP effluent	3/5/2001	370	11.2
CCE	Crowders Creek WWTP effluent	3/12/2001	90	11.5
CCE	Crowders Creek WWTP effluent	3/19/2001	72	10.4
CCE	Crowders Creek WWTP effluent	3/26/2001	145	10.7
CCE	Crowders Creek WWTP effluent	4/5/2001	92	13.9
CCE	Crowders Creek WWTP effluent	7/5/2001	1603	21.4
CCE	Crowders Creek WWTP effluent	7/10/2001	33	26.3
CCE	Crowders Creek WWTP effluent	7/17/2001	9	27.0
CCE	Crowders Creek WWTP effluent	7/24/2001	36	27.5
CCE	Crowders Creek WWTP effluent	7/31/2001	6	27.2
CCE	Crowders Creek WWTP effluent	8/7/2001	12	28.2
CCE	Crowders Creek WWTP effluent	8/14/2001	152	26.9
CCE	Crowders Creek WWTP effluent	8/21/2001	23	27.8
CCE	Crowders Creek WWTP effluent	8/28/2001	20	27.9
CCE	Crowders Creek WWTP effluent	9/4/2001	21500	21.3
SCC	South Crowders Creek at SR 1103	2/28/2001	270	11.2
SCC	South Crowders Creek at SR 1103	3/5/2001	300	10.8
SCC	South Crowders Creek at SR 1103	3/12/2001	220	10.6
SCC	South Crowders Creek at SR 1103	3/19/2001	76	8.6
SCC	South Crowders Creek at SR 1103	3/26/2001	1125	10.1
SCC	South Crowders Creek at SR 1103	4/5/2001	630	13.5
SCC	South Crowders Creek at SR 1103	7/5/2001	44	21.9
SCC	South Crowders Creek at SR 1103	7/10/2001	48	22.7
SCC	South Crowders Creek at SR 1103	7/17/2001	35	22.1
SCC	South Crowders Creek at SR 1103	7/24/2001	86	22.7
SCC	South Crowders Creek at SR 1103	7/31/2001	58	22.4
SCC	South Crowders Creek at SR 1103	8/7/2001	20	23.6
SCC	South Crowders Creek at SR 1103	8/14/2001	385	24.1
SCC	South Crowders Creek at SR 1103	8/21/2001	530	23.3
SCC	South Crowders Creek at SR 1103	8/28/2001	108	23.0
SCC	South Crowders Creek at SR 1103	9/4/2001	28000	20.7
SFCC	South Fork Crowders Creek at SR 1109	2/28/2001	94	11.3
SFCC	South Fork Crowders Creek at SR 1109	3/5/2001	330	11.1
SFCC	South Fork Crowders Creek at SR 1109	3/12/2001	240	10.7
SFCC	South Fork Crowders Creek at SR 1109	3/19/2001	60	10.0
SFCC	South Fork Crowders Creek at SR 1109	3/26/2001	106	10.6
SFCC	South Fork Crowders Creek at SR 1109	4/5/2001	215	13.6
SFCC	South Fork Crowders Creek at SR 1109	7/5/2001	4000	22.7
SFCC	South Fork Crowders Creek at SR 1109	7/10/2001	465	23.0
SFCC	South Fork Crowders Creek at SR 1109	7/17/2001	35	22.4
SFCC	South Fork Crowders Creek at SR 1109	7/24/2001	365	22.6
SFCC	South Fork Crowders Creek at SR 1109	7/31/2001	320	22.5
SFCC	South Fork Crowders Creek at SR 1109	8/7/2001	335	23.7
SFCC	South Fork Crowders Creek at SR 1109	8/14/2001	555	24.0
SFCC	South Fork Crowders Creek at SR 1109	8/21/2001	50	23.2
SFCC	South Fork Crowders Creek at SR 1109	8/28/2001	27	22.7
SFCC	South Fork Crowders Creek at SR 1109	9/4/2001	46000	20.6
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	1/8/1998	42000	15

CC4	CROWDERS CRK AT SC 564 (NC Ambient)	2/16/1998	230	8
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	3/11/1998	220	8
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	4/28/1998	400	15
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	5/20/1998	420	21
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	6/23/1998	350	23
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	7/22/1998	610	26
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	8/10/1998	1100	23
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	9/21/1998	1600	23
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	10/29/1998	82	16
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	11/23/1998	64	10
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	12/30/1998	400	7
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	1/27/1999	220	9
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	2/23/1999	73	5
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	3/18/1999	180	12
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	4/27/1999	120	17
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	5/24/1999	100	22
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	6/22/1999	230	19
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	8/3/1999	110	25
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	8/23/1999	210	23
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	9/13/1999	170	21
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	10/19/1999	240	16
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	11/4/1999	420	11
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	12/6/1999	800	13
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	1/5/2000	710	9
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	2/21/2000	100	8
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	3/22/2000	440	12
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	4/18/2000	210	16
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	5/17/2000	130	17
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	6/20/2000	260	22
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	7/27/2000	220	22
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	9/13/2000	230	22
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	10/19/2000	82	16
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	11/29/2000	190	8
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	12/28/2000	54	4
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	1/29/2001	18	6
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	2/13/2001	230	8
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	4/23/2001	240	18
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	5/29/2001	580	19
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	6/14/2001	190	24
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	7/23/2001	66	23
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	8/22/2001	110	23
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	9/18/2001	81	18
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	10/22/2001	200	17
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	11/29/2001	260	15
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	12/17/2001	360	12
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	1/16/2002	200	6
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	2/14/2002	100	8
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	3/18/2002	700	12
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	4/25/2002	320	18

CC4	CROWDERS CRK AT SC 564 (NC Ambient)	5/22/2002	280	14
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	6/13/2002	210	23
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	7/1/2002	260	25
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	8/13/2002	87	24
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	9/9/2002	190	22
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	10/24/2002	320	15.3
CC4	CROWDERS CRK AT SC 564 (NC Ambient)	11/20/2002	160	9.6

Appendix II. Land use by WARMF subwatershed based on 1993-1996 landcover in the Crowders Creek watershed.

	WARMF LU	%	m^2	mi^2
1	1119			
	Deciduous Forest	27.59	6.85E+06	2.64
	Evergreen Forest	12.9	3.20E+06	1.24
	Mixed Forest	7.19	1.79E+06	0.69
	Pasture	6.77	1.68E+06	0.65
	Cultivated	14.55	3.61E+06	1.39
	Recr. Grasses	2.46	6.11E+05	0.24
	Water	0.24	5.96E+04	0.02
	Barren	1.21	3.00E+05	0.12
	Low Int. Develop.	12.63	3.14E+06	1.21
	High Int. Develop.	3.49	8.67E+05	0.33
	Comm / Industrial	10.24	2.54E+06	0.98
	Wetlands	0.74	1.84E+05	0.07
	TOTAL	100		9.59
		2.48E+07		
2	1118	%		
	Deciduous Forest	56.8	9.27E+06	3.58
	Evergreen Forest	11.41	1.86E+06	0.72
	Mixed Forest	5.8	9.47E+05	0.37
	Pasture	5.4	8.81E+05	0.34
	Cultivated	7.72	1.26E+06	0.49
	Recr. Grasses	2.35	3.84E+05	0.15
	Water	0.13	2.12E+04	0.01
	Barren	0.32	5.22E+04	0.02
	Low Int. Develop.	4.74	7.74E+05	0.30
	High Int. Develop.	1.6	2.61E+05	0.10
	Comm / Industrial	2.78	4.54E+05	0.18
	Wetlands	0.92	1.50E+05	0.06
	TOTAL	100		6.30
		1.63E+07		
3	1102	%		
	Deciduous Forest	65.61	1.95E+07	7.53
	Evergreen Forest	11.01	3.27E+06	1.26
	Mixed Forest	7.8	2.32E+06	0.89
	Pasture	5.22	1.55E+06	0.60
	Cultivated	7	2.08E+06	0.80
	Recr. Grasses	0.08	2.38E+04	0.01
	Water	0.37	1.10E+05	0.04
	Barren	0.16	4.75E+04	0.02
	Low Int. Develop.	1.71	5.08E+05	0.20
	High Int. Develop.	0	0.00E+00	0.00
	Comm / Industrial	0.48	1.43E+05	0.06
	Wetlands	0.54	1.60E+05	0.06
	TOTAL	100		

		2.97E+07		
4	1106	%		
	Deciduous Forest	15.05	4.89E+06	1.89
	Evergreen Forest	23.78	7.73E+06	2.98
	Mixed Forest	14.75	4.79E+06	1.85
	Pasture	17.74	5.77E+06	2.23
	Cultivated	22.79	7.41E+06	2.86
	Recr. Grasses	0.23	7.48E+04	0.03
	Water	0.28	9.10E+04	0.04
	Barren	2.17	7.05E+05	0.27
	Low Int. Develop.	1.65	5.36E+05	0.21
	High Int. Develop.	0	0.00E+00	0.00
	Comm / Industrial	0.36	1.17E+05	0.05
	Wetlands	1.21	3.93E+05	0.15
	TOTAL	100		
		3.25E+07		
5	1111	%		
	Deciduous Forest	34.16	1.89E+07	7.28
	Evergreen Forest	13.76	7.60E+06	2.93
	Mixed Forest	8.18	4.52E+06	1.74
	Pasture	4.29	2.37E+06	0.91
	Cultivated	5.94	3.28E+06	1.27
	Recr. Grasses	1.85	1.02E+06	0.39
	Water	0.3	1.66E+05	0.06
	Barren	0.38	2.10E+05	0.08
	Low Int. Develop.	16.86	9.31E+06	3.59
	High Int. Develop.	5.45	3.01E+06	1.16
	Comm / Industrial	8.35	4.61E+06	1.78
	Wetlands	0.47	2.59E+05	0.10
	TOTAL	100		
		5.52E+07		
6	1110	%		
	Deciduous Forest	43.52	3.64E+06	1.40
	Evergreen Forest	15.63	1.31E+06	0.50
	Mixed Forest	8.34	6.97E+05	0.27
	Pasture	4.85	4.05E+05	0.16
	Cultivated	8.1	6.77E+05	0.26
	Recr. Grasses	0.85	7.10E+04	0.03
	Water	0.1	8.35E+03	0.00
	Barren	0.17	1.42E+04	0.01
	Low Int. Develop.	14.58	1.22E+06	0.47
	High Int. Develop.	1.61	1.35E+05	0.05
	Comm / Industrial	1.69	1.41E+05	0.05
	Wetlands	0.56	4.68E+04	0.02
	TOTAL	100		
		8.35E+06		
7	1101	%		
	Deciduous Forest	0	0.00E+00	0.00

	Evergreen Forest	24.13	2.78E+06	1.07
	Mixed Forest	20.68	2.38E+06	0.92
	Pasture	20.74	2.39E+06	0.92
	Cultivated	27.08	3.12E+06	1.20
	Recr. Grasses	0	0.00E+00	0.00
	Water	0.29	3.34E+04	0.01
	Barren	0.18	2.07E+04	0.01
	Low Int. Develop.	4	4.60E+05	0.18
	High Int. Develop.	0.02	2.30E+03	0.00
	Comm / Industrial	0.51	5.87E+04	0.02
	Wetlands	2.36	2.72E+05	0.10
	TOTAL	100		
		1.15E+07		
8	1108	%		
	Deciduous Forest	53.53	1.64E+06	0.63
	Evergreen Forest	11.97	3.66E+05	0.14
	Mixed Forest	12.69	3.88E+05	0.15
	Pasture	8.6	2.63E+05	0.10
	Cultivated	7.75	2.37E+05	0.09
	Recr. Grasses	0.21	6.42E+03	0.00
	Water	0	0.00E+00	0.00
	Barren	0.21	6.42E+03	0.00
	Low Int. Develop.	1.92	5.87E+04	0.02
	High Int. Develop.	0	0.00E+00	0.00
	Comm / Industrial	1.58	4.83E+04	0.02
	Wetlands	1.53	4.68E+04	0.02
	TOTAL	100		
		3.06E+06		
9	1099	%		
	Deciduous Forest	19.96	3.75E+06	1.45
	Evergreen Forest	18.82	3.53E+06	1.36
	Mixed Forest	9.15	1.72E+06	0.66
	Pasture	13.28	2.49E+06	0.96
	Cultivated	16.27	3.06E+06	1.18
	Recr. Grasses	2.12	3.98E+05	0.15
	Water	0.27	5.07E+04	0.02
	Barren	0.75	1.41E+05	0.05
	Low Int. Develop.	11.28	2.12E+06	0.82
	High Int. Develop.	1.2	2.25E+05	0.09
	Comm / Industrial	6.54	1.23E+06	0.47
	Wetlands	0.36	6.76E+04	0.03
	TOTAL	100		
		1.88E+07		
10	1100	%		
	Deciduous Forest	6.32	1.46E+05	0.06
	Evergreen Forest	12.28	2.84E+05	0.11
	Mixed Forest	18.38	4.26E+05	0.16
	Pasture	30.22	7.00E+05	0.27

	Cultivated	20.81	4.82E+05	0.19
	Recr. Grasses	0.74	1.71E+04	0.01
	Water	0.59	1.37E+04	0.01
	Barren	1.69	3.91E+04	0.02
	Low Int. Develop.	4.63	1.07E+05	0.04
	High Int. Develop.	0	0.00E+00	0.00
	Comm / Industrial	1.25	2.89E+04	0.01
	Wetlands	3.09	7.16E+04	0.03
	TOTAL	100		
		2.32E+06		
11	1095	%		
	Deciduous Forest	41.83	1.59E+07	6.15
	Evergreen Forest	17.08	6.50E+06	2.51
	Mixed Forest	10.39	3.96E+06	1.53
	Pasture	9.68	3.68E+06	1.42
	Cultivated	11.88	4.52E+06	1.75
	Recr. Grasses	0.97	3.69E+05	0.14
	Water	0.4	1.52E+05	0.06
	Barren	0.2	7.61E+04	0.03
	Low Int. Develop.	5.45	2.07E+06	0.80
	High Int. Develop.	0.5	1.90E+05	0.07
	Comm / Industrial	1.11	4.23E+05	0.16
	Wetlands	0.5	1.90E+05	0.07
	TOTAL	100		
		3.81E+07	2.41E+08	108.79

Appendix III. Calibrated soil layer parameters.

Subwatershed	Soil Layer	Area m2	Thickness cm	Initial Moisture	Field Capacity	Sat. Moisture	Horizontal Cond. cm/d	Vertical Cond. cm/d	Root Distr.	Density g/cm3	Soil Tortuosity
1	1	24829000	25	0.20	0.15	0.20	9800	3	0.75	0.2	10
	2	24829000	60	0.28	0.20	0.30	3000	40	0.1	1.3	10
	3	24829000	50	0.30	0.25	0.30	2500	80	0.1	1.3	10
	4	23180000	100	0.37	0.28	0.37	1500	60	0.05	1.5	10
2	1	16321000	25	0.20	0.15	0.20	9800	3	0.75	0.2	10
	2	16321000	60	0.30	0.20	0.30	3000	40	0.1	1.3	10
	3	16321000	50	0.35	0.25	0.30	2500	80	0.1	1.3	10
	4	15239000	100	0.37	0.28	0.37	1500	60	0.05	1.5	10
		15239000	100	0.37	0.28	0.37	1500	60	0.05	1.5	10
3	1	29711000	25	0.22	0.15	0.20	9800	3	0.75	0.2	10
	2	29711000	60	0.30	0.20	0.30	3000	40	0.1	1.3	10
	3	29711000	75	0.35	0.25	0.30	1000	80	0.1	1.3	10
	4	27737000	150	0.37	0.28	0.37	300	60	0.05	1.5	10
4	1	32506000	25	0.22	0.15	0.20	9800	3	0.75	0.2	10
	2	32506000	60	0.30	0.20	0.30	3000	40	0.1	1.3	10
	3	32506000	75	0.35	0.25	0.30	1000	80	0.1	1.3	10
	4	30343000	150	0.37	0.28	0.37	300	60	0.05	1.5	10
5	1	55196000	40	0.24	0.15	0.20	9700	25	0.75	0.2	10
	2	55196000	80	0.32	0.20	0.35	2000	40	0.1	1.3	10
	3	55196000	50	0.38	0.28	0.35	2000	60	0.1	1.3	10
	4	51529000	150	0.38	0.22	0.36	300	60	0.05	1.5	10
6	1	8354000	40	0.22	0.15	0.20	9700	25	0.75	0.2	10
	2	8354000	80	0.30	0.20	0.35	2000	40	0.1	1.3	10
	3	8354000	75	0.38	0.28	0.35	2000	60	0.1	1.3	10
	4	7798700	150	0.38	0.22	0.36	300	60	0.05	1.5	10
7	1	11509000	40	0.22	0.15	0.20	9700	25	0.75	0.2	10

	2	11509000	80	0.30	0.20	0.35	2000	40	0.1	1.3	10
	3	11509000	75	0.38	0.28	0.35	2000	60	0.1	1.3	10
	4	10743000	150	0.38	0.22	0.36	300	60	0.05	1.5	10
8	1	3056600	40	0.22	0.15	0.20	9700	25	0.75	0.2	10
	2	3056600	80	0.30	0.20	0.35	2000	40	0.1	1.3	10
	3	3056600	75	0.38	0.28	0.35	2000	60	0.1	1.3	10
	4	2853600	150	0.38	0.22	0.36	300	60	0.05	1.5	10
9	1	18777000	40	0.22	0.15	0.20	9700	25	0.75	0.2	10
	2	18777000	80	0.30	0.20	0.35	2000	40	0.1	1.3	10
	3	18777000	75	0.38	0.28	0.35	2000	60	0.1	1.3	10
	4	17530000	150	0.38	0.22	0.36	300	60	0.05	1.5	10
10	1	2315900	40	0.20	0.15	0.20	9700	25	0.75	0.2	10
	2	2315900	80	0.30	0.20	0.35	2000	40	0.1	1.3	10
	3	2315900	75	0.38	0.28	0.35	2000	60	0.1	1.3	10
	4	2161800	150	0.38	0.22	0.36	300	60	0.05	1.5	10
11	1	38067000	40	0.22	0.15	0.20	9700	25	0.75	0.2	10
	2	38067000	80	0.30	0.20	0.35	2000	40	0.1	1.3	10
	3	38067000	75	0.38	0.28	0.35	2000	60	0.1	1.3	10
	4	35537000	150	0.38	0.22	0.36	300	60	0.05	1.5	10

Appendix IV. Load allocation calculation for Kings Mountain.

							TMDL Loading			
							Loading per unit area		Fecal Loading	
	WARMF LU	%	m^2	mi^2	ha			1E6/ha/yr		1E6/yr
1	1119									
	Deciduous Forest	27.59	6850404	2.644941	685.0397		Deciduous Forest	282		193181.196
	Evergreen Forest	12.9	3202980	1.23667	320.2976		Evergreen Forest	380		121713.1069
	Mixed Forest	7.19	1785227	0.689276	178.5225		Mixed Forest	415		74086.83272
	Pasture	6.77	1680944	0.649012	168.0942		Pasture	9910		1665813.452
	Cultivated	14.55	3612663	1.394849	361.266		Cultivated	388		140171.19
	Recr. Grasses	2.46	610800.8	0.23583	61.08002		Recr. Grasses	217		13254.36367
	Water	0.24	59590.32	0.023008	5.959026		Water	312		1859.216125
	Barren	1.21	300434.5	0.115998	30.04342		Barren	166		4987.208211
	Low Int. Develop.	12.63	3135941	1.210787	313.5937		Low Int. Develop.	11600		3637687.447
	High Int. Develop.	3.49	866542.6	0.334572	86.65417		High Int. Develop.	25600		2218346.761
	Comm / Industrial	10.24	2542520	0.981667	254.2518		Comm / Industrial	14100		3584950.066
	Wetlands	0.74	183736.8	0.070941	18.37366		Wetlands	0		0
									Sum	11656050.84
2	1118	%								
	Deciduous Forest	56.8	9270442	3.579318	927.0432		Deciduous Forest	282		261426.1917
	Evergreen Forest	11.41	1862249	0.719014	186.2247		Evergreen Forest	380		70765.38819
	Mixed Forest	5.8	946629.6	0.365494	94.66287		Mixed Forest	415		39285.08911
	Pasture	5.4	881344.8	0.340287	88.13439		Pasture	9910		873411.8234
	Cultivated	7.72	1259997	0.486485	125.9995		Cultivated	388		48887.82074
	Recr. Grasses	2.35	383548.2	0.148088	38.35478		Recr. Grasses	217		8322.987617
	Water	0.13	21217.56	0.008192	2.121754		Water	312		661.98721
	Barren	0.32	52227.84	0.020165	5.222779		Barren	166		866.981277
	Low Int. Develop.	4.74	773624.9	0.298697	77.36241		Low Int. Develop.	11600		897403.9634
	High Int. Develop.	1.6	261139.2	0.100826	26.11389		High Int. Develop.	25600		668515.6835
	Comm / Industrial	2.78	453729.4	0.175185	45.37289		Comm / Industrial	14100		639757.7578
	Wetlands	0.92	150155	0.057975	15.01549		Wetlands	0		0
									Sum	3509305.674
										in units/d

	Grand Sum for entire Crowders=			2.13E+11			Grand Sum		15165357	4.15E+10
	Grand Sum for WS 1 and 2			4.15E+10	19.51%				34.10%	
							Kings Mtn LA		5171387	
				212980.7						
			19.51%	34.10%	6.65%				5.17E+12	1.42E+10

Appendix V. Modeled fecal coliform loading scenarios.

Simulated Fecal Coliform Loading	Current Conditions	Geometric Mean	SC Instantaneous	SC Instantaneous
1E6/d		w/ modified point source		w/ modified point source
	crowd_calibfin	crowd_tmdl	crowd_tmdl_2	crowd_tmdl_3
Managed Flow	0	0	0	0
Groundwater Pumping	0	0	0	0
Deciduous Forest	29100	6510	10900	11900
Evergreen Forest	18100	3990	6680	7290
Mixed Forest	12400	2720	4550	4970
Pasture	284000	60200	101000	110000
Cultivated	14300	3160	5280	5770
Recr. Grasses	817	177	296	323
Water	270	60	101	110
Barren	300	74	122	133
Low Int. Develop.	304000	64400	108000	118000
High Int. Develop.	155000	32800	54900	59900
Comm / Industrial	179000	37900	63400	69200
Wetlands	0	0	0	0
General Nonpoint Sources	0	0	0	0
Direct Precipitation	0	0	0	0
Direct Dry Deposition	0	0	0	0
Type 1 Septic System	6670	699	1200	1310
Type 2 Septic System	0	0	0	0
Type 3 Septic System	2780	291	498	547
Unpermitted Surface Mines	0	0	0	0
Unpermitted Deep Mines	0	0	0	0
Permitted Surface Mines	0	0	0	0
Permitted Deep Mines	0	0	0	0
General Point Sources	25300	8220	25300	8220
Nonpoint Total	1006737	212981	356927	389453
TOTAL	1030000	221000	382000	397000
Reduction Required		79%	63%	61%

Appendix VI. Load allocation calculations for South Carolina portion of Crowders Creek.

Subwatersheds 4,7, and 11 are split between SC and NC.
The landuses are relatively homogenous within each subwatershed. These watersheds are predominately rural in character.
4 and 11 are 1/2 in SC and 7 is 1/4 in SC.

						TMDL Loading				
WARMF LU	%	m^2	mi^2	ha		Loading per unit area		Fecal Loading	NC	SC
Subwatershed 4							1E6/ha/yr	1E6/yr		
1106										
Deciduous Forest	15.05	4892273.40	1.89	489.23		Deciduous Forest	282	137961.97		
Evergreen Forest	23.78	7730117.04	2.98	773.01		Evergreen Forest	380	293744.15		
Mixed Forest	14.75	4794753.00	1.85	479.47		Mixed Forest	415	198982.05		
Pasture	17.74	5766706.32	2.23	576.67		Pasture	9910	5714800.2		
Cultivated	22.79	7408299.72	2.86	740.83		Cultivated	388	287441.74		
Recr. Grasses	0.23	74765.64	0.03	7.48		Recr. Grasses	217	1622.4128		
Water	0.28	91019.04	0.04	9.10		Water	312	2839.7912		
Barren	2.17	705397.56	0.27	70.54		Barren	166	11709.588		
Low Int. Develop.	1.65	536362.20	0.21	53.64		Low Int. Develop.	11600	622179.53		
High Int. Develop.	0.00	0.00	0.00	0.00		High Int. Develop.	25600	0		
Comm / Industrial	0.36	117024.48	0.05	11.70		Comm / Industrial	14100	165004.35		
Wetlands	1.21	393332.28	0.15	39.33		Wetlands	0	0		
			12.55				Sum	7436285.8	3718143	3718143
Subwatershed 7										
1101										
Deciduous Forest	0.00	0.00	0.00	0.00		Deciduous Forest	282	0		
Evergreen Forest	24.13	2777218.22	1.07	277.72		Evergreen Forest	380	105534.19		
Mixed Forest	20.68	2380143.92	0.92	238.01		Mixed Forest	415	98775.874		
Pasture	20.74	2387049.56	0.92	238.70		Pasture	9910	2365563.7		
Cultivated	27.08	3116745.52	1.20	311.67		Cultivated	388	120929.61		
Recr. Grasses	0.00	0.00	0.00	0.00		Recr. Grasses	217	0		
Water	0.29	33377.26	0.01	3.34		Water	312	1041.3695		
Barren	0.18	20716.92	0.01	2.07		Barren	166	343.90053		
Low Int. Develop.	4.00	460376.00	0.18	46.04		Low Int. Develop.	11600	534035.63		
High Int. Develop.	0.02	2301.88	0.00	0.23		High Int. Develop.	25600	5892.8069		

Comm / Industrial	0.51	58697.94	0.02	5.87		Comm / Industrial	14100	82764.013		
Wetlands	2.36	271621.84	0.10	27.16		Wetlands	0	0		
			4.44				Sum	3314881.1	2486161	828720
Subwatershed 11										
1095										
Deciduous Forest	41.83	15923802.57	6.15	1592.38		Deciduous Forest	282	449050.78		
Evergreen Forest	17.08	6501997.32	2.51	650.20		Evergreen Forest	380	247075.65		
Mixed Forest	10.39	3955254.81	1.53	395.53		Mixed Forest	415	164142.91		
Pasture	9.68	3684972.72	1.42	368.50		Pasture	9910	3651804.3		
Cultivated	11.88	4522466.52	1.75	452.25		Cultivated	388	175471.53		
Recr. Grasses	0.97	369258.63	0.14	36.93		Recr. Grasses	217	8012.9043		
Water	0.40	152271.60	0.06	15.23		Water	312	4750.8692		
Barren	0.20	76135.80	0.03	7.61		Barren	166	1263.853		
Low Int. Develop.	5.45	2074700.55	0.80	207.47		Low Int. Develop.	11600	2406650.2		
High Int. Develop.	0.50	190339.50	0.07	19.03		High Int. Develop.	25600	487268.63		
Comm / Industrial	1.11	422553.69	0.16	42.26		Comm / Industrial	14100	595800.11		
Wetlands	0.50	190339.50	0.07	19.03		Wetlands	0	0		
			14.70				Sum	8191291.8	4095646	4095646
						Units are 1E6/yr				
	Grand Total		31.69				Grand Sum	18942459	10299950	8642509
	SC		14.7352	15.9%					54.37%	45.63%
	Total Crowder		92.9			Total Nonpoint Crowder Loading		77737956		
						4,7,11 percent of total		24.37%	13.25%	11.12%

Appendix VII. Crowders Creek Fecal Coliform TMDL Allocation Worksheet

Crowder's Creek Watershed		
Fecal Coliform Allocation Worksheet		
	units/d	% of TMDL
TMDL	2.21E+11	
Continuos WLA *	8.27E+09	3.7%
Background LA **	1.30E+10	
MS4 WLA plus LA ***	2.13E+11	
SC LA ****	2.36E+10	10.7%
Kings Mtn LA	1.41E+10	
MS4 WLA plus NC LA	1.89E+11	
MS4 WLA	7.45E+10	33.7%
NC LA	1.15E+11	51.8%
		100%
* Based on maximum permitted loading, calculated as permitted flow (wwtp plus small pt. Sources = 6.07 mgd) times 200 cfu/mL standard.		
Crowders Creek WWTP will need to reduce loading to also meet the 400 cfu/100ml instantaneous standard.		
** Background is based on 5.9% loading derived from this landuse(forested/wetland/greenspace.		
***TMDL minus continous WLA minus Background LA.		
**** Based on landuse and unit load rates in border watersheds.		

Appendix VIII. Septic system loading estimates for the Crowders Creek watershed.

			acres	population served	pop/acre	pop/sqmi
North Crowders Subwatershed						
Census Tract	Septic Systems	Density	13737			
	(number)	(people/system)				
316*	259	2.78		*720*		
318	88	2.89		*254*		
331	107	2.78		*296*		
317.02	167	2.77		*463*		
317.01*	237	2.66		*629*		
				2363	*0.17*	*110*
Central Crowders Subwatershed						
Census Tract	Septic Systems	Density	9175			
	(number)	(people/system)				
332.01	181	3.41		*616*		
317.02	229	2.77		*633*		
317.01	127	2.66		*339*		
334	579	2.94		*1702*		
				3290	*0.36*	*229*
Blackwood Creek Subwatershed						
Census Tract	Septic Systems	Density	2202			
	(number)	(people/system)				
318	20	2.89		*58*		
331	73	2.78		*204*		
332.01	328	3.41		*1119*		
				1382	*0.63*	*402*
South Crowders Subwatershed						
Census Tract	Septic Systems	Density	10686			
	(number)	(people/system)				
317.02	13	2.77		*36*		
334	163	2.94		*480*		
317.01	942	2.66		*2507*		
				3023	*0.28*	*181*
Lower Crowders Subwatershed						
Census Tract	Septic Systems	Density	8792			
	(number)	(people/system)				
332.02	409	2.71		*1108*		
333.02	744	1.79		*1331*		
334	304	2.94		*894*		
				3334	*0.38*	*243*
			Grand Total	*13391*	*0.36*	*233*

Notes: Data from Gordon (2003). Per Gordon (2003), because tract boundaries do not exactly follow watershed boundaries, tract % and acreages may not add correctly. For tracts that lie significantly outside of watershed boundaries, population estimates were adjusted accordingly. Calculations in italics are by NC DWQ.

Appendix IX. Affidavits of Publication for Public Notices

AFFIDAVIT OF INSERTION OF ADVERTISEMENT
The Gaston Gazette

Gastonia, NC
Gaston County

I, Melissa Birchfield Legal Advertising Manager of the **The Gaston Gazette,** do certify that the advertisement of

PUBLIC NOTICE-TOTAL MAXIMUM DAILY LOAD (TMDL) FOR CROWDERS CREEK

Measuring 3.79 newspaper published in Gaston County, Gastonia, NC, in issues

MARCH 29, 2004

Melissa Birchfield
Melissa Birchfield
Legal Advertising

Sworn to and subscribed before me this 3 day of May, 2004

Carla Norris Potter
Carla Norris Potter, Notary Public
My Commission Expires September 14, 2008

PUBLIC NOTICE

State of North Carolina
Division of Water Quality

Availability of the Fecal Coliform Total Maximum Daily Load (TMDL) for Crowders Creek

Copies of the TMDL may be obtained by calling J. Todd Kennedy at (919) 733-5083, ext. 514 or on the Internet at http://h2o.enr.state.nc.us/tmdl. A public meeting to discuss the TMDL will be held on April 28 at 1:30 PM at the following address: Gaston Citizen Resource Center, 1303 Dallas-Cherryville Hwy in Dallas, NC 28034 (Phone 704-922-0301). Written comments regarding this TMDL will be accepted until May 6, 2004. Please mail comments to NCDWQ Planning Branch, attn: J. Todd Kennedy, 1617 Mail Service Center, Raleigh NC 27699.

1C-March 29, 2004

State of South Carolina
COUNTY OF YORK

Jamie Hamilton being duly sworn, says that she is the advertising manager of The Yorkville Enquirer - a newspaper published in York, S.C., and that the advertisement hereunto annexed, was published in said newspaper, once in each week for 1 **Successive Weeks** - first publication being on the 8th day of April, 2004, and the last on the 8th day of April, 2004.

Sworn to and subscribed before me this 13 day of April, 2004.

Jamie Hamilton

Notary Public

My commission expires My Commission Expires February 12, 2014

Appendix X. Comments on the Crowders Creek TMDL

D H E C

PROMOTE PROTECT PROSPER

C. Earl Hunter, Commissioner

Promoting and protecting the health of the public and the environment.

April 6, 2004

J. Todd Kennedy
Water Quality Planning Branch
NC Division of Water Quality
1617 Mail Service Center
Raleigh, NC 27699-1617

Subject: Comment on Crowders Creek Fecal Coliform TMDL

Dear Mr. Kennedy:

The South Carolina Department of Health and Environmental Control (SCDHEC) has reviewed the *Total Maximum Daily Load for Fecal Coliform for Crowders Creek, North Carolina and South Carolina*. Crowders Creek arises near Gastonia, NC, and flows into York County, SC. The stream has been found to be impaired by fecal coliform bacteria in both states and placed on both 303(d) lists. The TMDL calls for a 79 % reduction in nonpoint source loading throughout the watershed.

SCDHEC supports the TMDL and concurs with its recommendations. The target concentration of fecal coliform bacteria in the stream is South Carolina's water quality standard. The modeling indicates that the proposed reduction in loading will cause the stream to meet both the instantaneous and geometric mean parts of South Carolina's standard. The TMDL also provides a large Margin of Safety. The TMDL will affect three 303(d) listed sites in South Carolina: CW-023, CW-024, and CW-192.

In addition, NCDWQ has funded a 319 project to develop an implementation plan for this TMDL. SCDHEC appreciates NCDWQ's attention to the clean up of Crowders Creek.

Sincerely,

Alton C. Boozer

Alton C. Boozer
Chief, Bureau of Water

cc: Wayne Harden
Mark Giffin
Kathy Stecker
Craig Hesterlee, EPA Region 4

SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL
2600 Bull Street • Columbia, SC 29201 • Phone: (803) 898-3432 • www.scdhec.net