Total Maximum Daily Load Development for the Cane Creek Watershed, Interstate Water in SC and NC

Hydrologic Unit Codes: 03050103-040

(Stations: CW-185, CW-047, CW-017, CW-131, CW-151)
Fecal Coliform Bacteria

South Carolina Department of Health and Environmental Control
Bureau of Water

May 22, 2003

DHEC

PROMOTE PROTECT PROSPER

SUMMARY SHEET

Total Maximum Daily Load (TMDL) Development for the Cane Creek Watershed

1. 303(d) Listed Waterbody Information

State	South Carolina and North Carolina
County	Lancaster (SC) and Union (NC)
Major River Basin	Catawba
Watershed	Cane Creek
Constituent(s) Causing Impairments	Fecal Coliform Bacteria
Designated Uses	Recreational

Impaired Stations (2002 Section 303(d) List):

Station	Station Location
CW-151	Upper Bear Creek
CW-185	Upper Cane Creek
CW-047	Gills Creek
CW-131	Bear Creek below confluence with Gills creek
CW-017	Cane Creek above confluence with the Catawba River

Applicable fecal coliform bacteria water quality criteria for recreation (most stringent): The concentration of the fecal coliform bacteria group shall not exceed 200 counts per 100 mL as a geometric mean based on five consecutive samples during any 30 day period (hereafter referred to as the geometric mean standard or criteria); nor shall more than 10 percent of the total samples during any 30 day period exceed 400 counts per 100 mL (hereafter referred to as the instantaneous standard or criteria).

2. TMDL Development

Analysis/Modeling:

EPA's Watershed Characterization System and Fecal Coliform Loading Estimation Spreadsheet were used to assess watershed characteristics and develop estimates of bacteria loading from various sources; EPA's Loading Simulation Program in C++ (LSPC) was used to develop the Cane Creek fecal coliform bacteria TMDLs. An hourly time step was used to simulate hydrologic and water quality conditions with results expressed as daily averages.

Critical Conditions:

A simulation period of 6 years (1995-2000) was considered to determine a critical 30-day period for each impaired location. This time period was selected to reflect the most recent conditions in the watershed. For each subbasin, critical periods were identified for the geometric mean standard. Model results for the identified critical periods are consistent with observation data. A range of hydrologic and meteorological conditions was represented. Extreme low and high flow occurrences were eliminated from consideration in selecting the critical period.

Seasonal Variation:

Although a 6-year period was selected to identify critical conditions and to be consistent with the monitoring period upon which the Section 303(d) listing was based, a longer simulation period, eleven years, was used to assess hydrologic variations for this TMDL. This period was selected to improve the accuracy of the hydrologic model and to represent a wide range of seasonal patterns associated with wet and dry years. A period of eleven years was chosen to better represent the variety of possible weather conditions in the watershed.

3. Fecal Coliform Bacteria Allocations by Impaired Station (Downstream to Upstream)

Impaired Station	LAs (counts/30 days)	WLAs (counts/30 days)	MOS (counts/30 days)	TMDL (counts/30 days)	Percent Reduction
CW-017	1.78E+15	1.28E+09	9.38E+13	1.88E+15	74
CW-131	8.66E+14	0.00E+00	4.56E+13	9.12E+14	69
CW-047	2.39E+14	0.00E+00	1.26E+13	2.52E+14	63
CW-151	2.57E+14	0.00E+00	1.35E+13	2.71E+14	7
CW-185	2.96E+14	0.00E+00	1.56E+13	3.12E+14	39

*Counts/30 days were used as the fecal coliform units for the TMDL development in the Cane Creek watershed because the water quality standards are based on a 30 day period

Notes:

- An explicit margin of safety (MOS) equivalent to five percent was applied
- The percent reduction for fecal coliform bacteria loads is based on the existing and TMDL conditions

4. Public Notice Date:

5. Submittal Date:

6. Establishment Date:

7. Endangered Species (yes or blank):

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

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

10. NPDES Discharges of Fecal Coliform Bacteria

NPDES No.	Facility Name	WLA (counts/30 days)
SC0027383	Mcateer Trailer Park	1.28E+09
SC0022080*	Lancaster Sewerage System	0

*Facility went offline August 1996; not included in TMDL

Notes:
Fecal coliform bacteria reductions are not required from this point source. The WLA for Mcateer Trailer Park represents a constant fecal coliform bacteria load over a 30-day period based on the facility's average flow and fecal coliform bacteria permit limit of a geometric mean of 200 counts per 100mL.

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1.0 INTRODUCTION

1.1 Background

Levels of fecal coliform bacteria can be elevated in waterbodies as the result of both point and nonpoint sources of pollution. Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop total maximum daily loads (TMDLs) for waterbodies that are not meeting designated uses under technology-based pollution controls. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions so that states can establish water quality-based controls to reduce pollution and restore and maintain the quality of water resources (USEPA, 1991).

The state of South Carolina has placed five locations in the Cane Creek watershed on South Carolina's 2002 Section 303(d) list due to fecal coliform bacteria impairments. The impaired locations are identified by the water quality sampling station locations from which the samples that exceeded criteria were taken. The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of humans or other animals. Fecal coliform bacteria indicate the potential presence of pathogens in the waterbody that can be a health risk to individuals exposed to the pathogens.

1.2 Watershed Description

Cane Creek (03050103-040) is located in Lancaster County, SC and Union County, NC (Figure 1-1.) It originates in North Carolina and drains into the Catawba River (03050103-012-030). Several tributaries drain into Cane Creek, and these include: Bear Creek, Gills Creek, Camp Creek and Rum Creek.

The Cane Creek watershed occupies approximately 104,259 acres of the Piedmont region of North and South Carolina (SCDHEC, 1998). Approximately 16,333 acres lie in North Carolina with the remaining 87,926 acres in South Carolina. Based on USGS MRLC land use data representative of the early 1990's (Figure 1-2), land use in the Cane Creek watershed is predominantly forested (64 percent) with 17 percent cropland, 7 percent pastureland, and 9 percent urban land (based on MRLC data). The remaining 3 percent is made up of a combination of wetlands, and barren land. Much of the forested land is abandoned agricultural land that is scrubby hardwoods or pine tree farms. The urban land use is mostly in the central portion of the Cane Creek watershed (the Town of Lancaster).

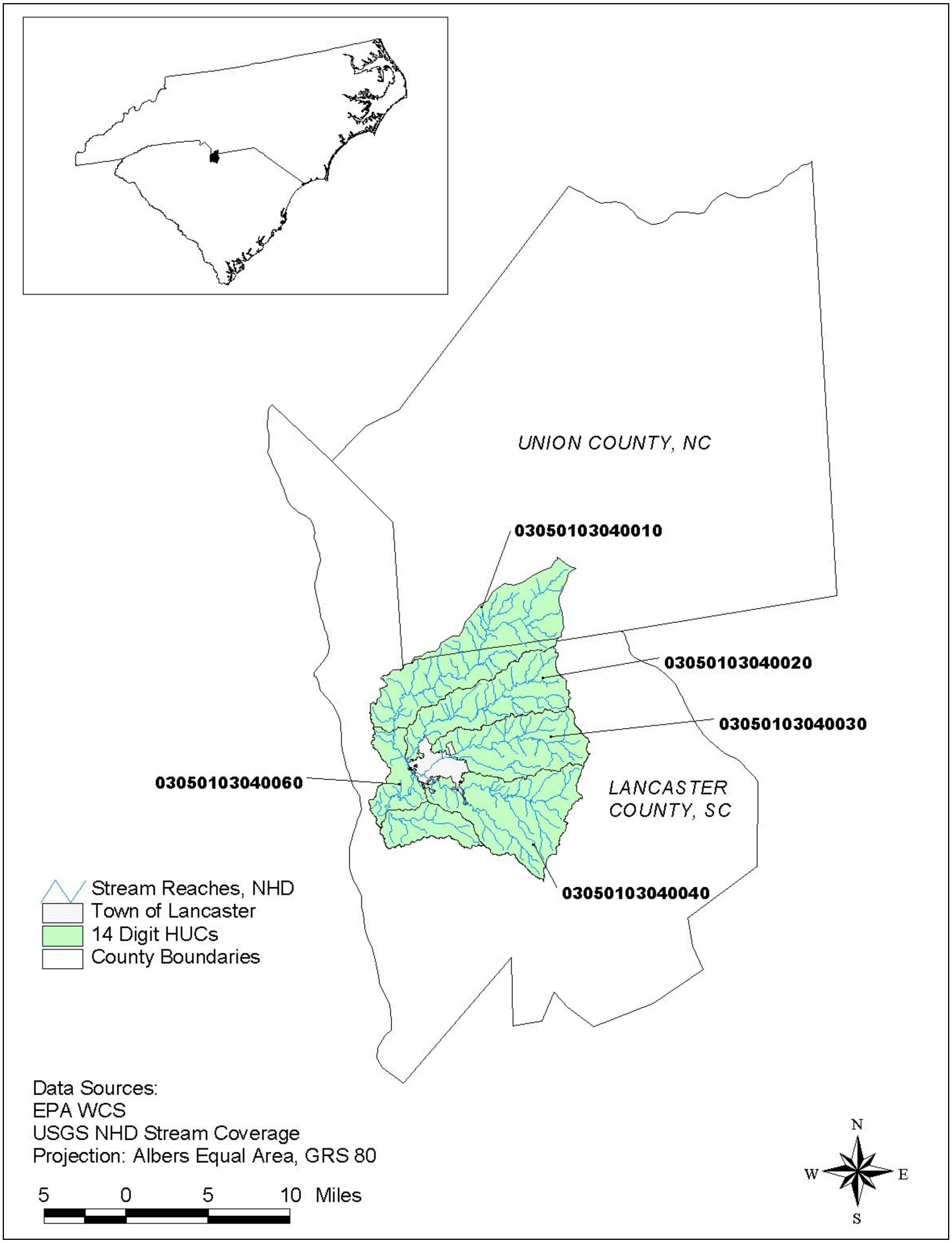


Figure 1-1. The location of the Cane Creek watershed

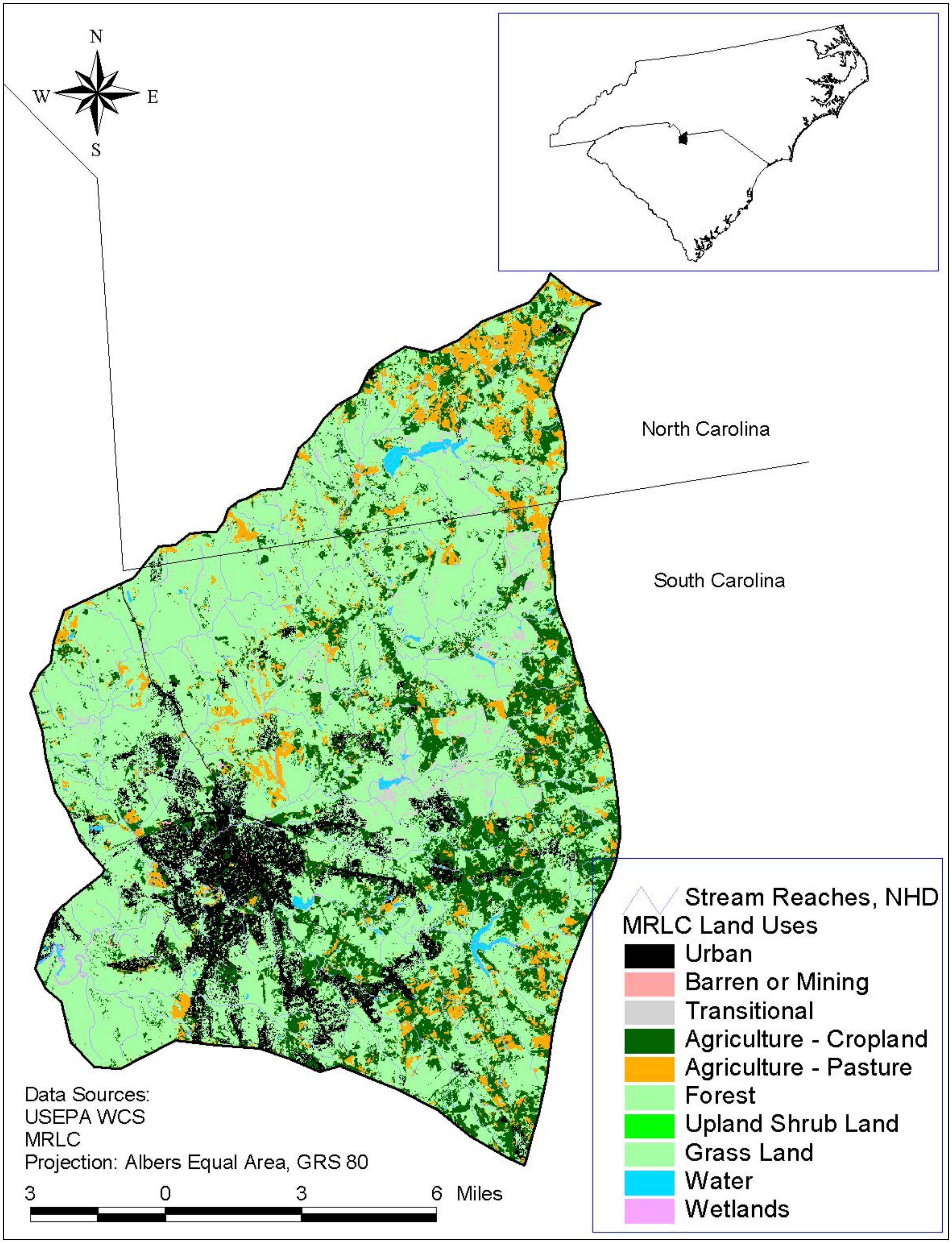


Figure 1-2. Land use coverage in the Cane Creek watershed

1.3 Water Quality Standards

The impaired streams, Cane Creek and its tributaries, are designated as Class “Freshwater.” Waters of this class are described as follows:

> “Freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of fauna and flora. Suitable also for industrial and agricultural uses.” (R.61-68)

South Carolina’s standard for fecal coliform bacteria 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 percent of the total samples during any 30 day period exceed 400/100 mL.” (R.61-68).

2.0 WATER QUALITY ASSESSMENT

The *State of South Carolina Section 303(d) List for 2002* was used to identify impaired water quality stations in the Cane Creek watershed. For fecal coliform bacteria, if 10 percent or less of the samples are greater than 400 counts per 100 mL, then recreational uses are said to be fully supported. A percentage of criteria exceedences greater than 10 percent indicates impairment of recreational uses and the waterbody is placed on the Section 303(d) list. Monitoring data for five stations in the Cane Creek watershed show violations of this condition, causing them to be placed on the Section 303 (d) List for 2002.

Available instream water quality monitoring data were evaluated with respect to seasonality, relation to flows, and magnitude of criteria exceedence. To develop a better understanding of the conditions under which bacteria loads are entering streams in the Cane Creek watershed, several different analyses were performed including an analysis of flow weighted concentration data, monthly concentrations, and load duration curves. The goal of flow weighted concentration analysis is to compare in stream observations with flow values to see whether violations generally occur during low flow periods or high flow periods. Data from all impaired stations in the Cane Creek watershed were evaluated. Results from this analysis indicate that fecal coliform bacteria violations are occurring in the Cane Creek watershed during both high and low flow periods. Load duration curves for the watershed support this assessment as well.

As an example, Figure 2-1 presents the load duration curve for Station 185. Load duration analysis involves using measured or estimated flow data, instream criteria, and fecal coliform observation data to assess flow conditions in which violations are occuring. For this analysis, the flow data was obtained from the modeled flow for the relevant subbasin (which is discussed later in this document). The flow was plotted based on exceedence probability, which indicates the percentage of time in days that the flow (or load) is exceeded. This is a useful technique in examining loading events because it shows the load magnitude and also reveals the corresponding hydrological event. The allowable load is the daily flow record multiplied by the instream fecal coliform criteria minus a five percent margin of safety; it represents the maximum load for the given flow that still satisfies water quality criteria. The line drawn through the allowable load data points is called the target line.

The existing instream fecal coliform load (flow record multiplied by observed fecal coliform concentration) is compared to the allowable load for that flow. Any existing loads above the allowable load curves represent a violation of water quality criteria. For a low flow loading situation, one typically sees observations in excess of criteria at the low flow side of the chart; for a high flow loading situation one would see observations in excess of criteria at the high flow side of the chart. The load duration curve was developed for the time period for which the 303(d) listing was based (1995-2000) and existing loads were plotted. Existing loads are shown as dots; violations as starred dots. The load duration curve for station 185 indicates that there are occasional exceedences of the instantaneous standard under high, average, and low flow conditions. These exceedences are likely due to a combination of wet weather sources (surface runoff) and low flow direct sources. The load duration curves for each impaired station in the Cane Creek watershed show similar loading characteristics (i.e., existing loads above the criteria curve under a range of flow conditions).

The majority of stations in the watershed generally only have data covering the April – November time period. For some subbasins, runoff during storm events is the more significant fecal coliform bacteria source, for others, direct inputs to streams during low flow

Target Line

periods (e.g. in-stream cattle or wildlife) may be equally or even more important. Data are generally not available for winter months, but because land practices and bacteria load delivery mechanisms are relatively consistent over the course of the year, it is assumed that winter loading should be consistent with that of periods for which data do exist.

Examining the data in the context of existing land uses is also helpful in determining what types of sources are probably impacting a particular subbasin. Figure 2-2 shows the location of impaired water quality stations in the Cane Creek watershed based on South Carolina's 2002 303(d) list. From the analysis of bacteria concentrations and flow data, subbasin 5 (CW-185) seems to exhibit loading characteristics of a mostly high-flow dominated situation (although it has experienced low flow violations.) The remaining subbasins clearly show the characteristics of both, although the sources of loading are most likely different. For example, subbasins 15 (CW-017), 7 (CW-047), and 16 (CW-131) have a higher percentage of urban lands than subbasin 6 (CW-151). While all four seem to show similar loading patterns, the first three will be dominated by urban loading while the latter is probably dominated by loading related to agricultural activities or wildlife.

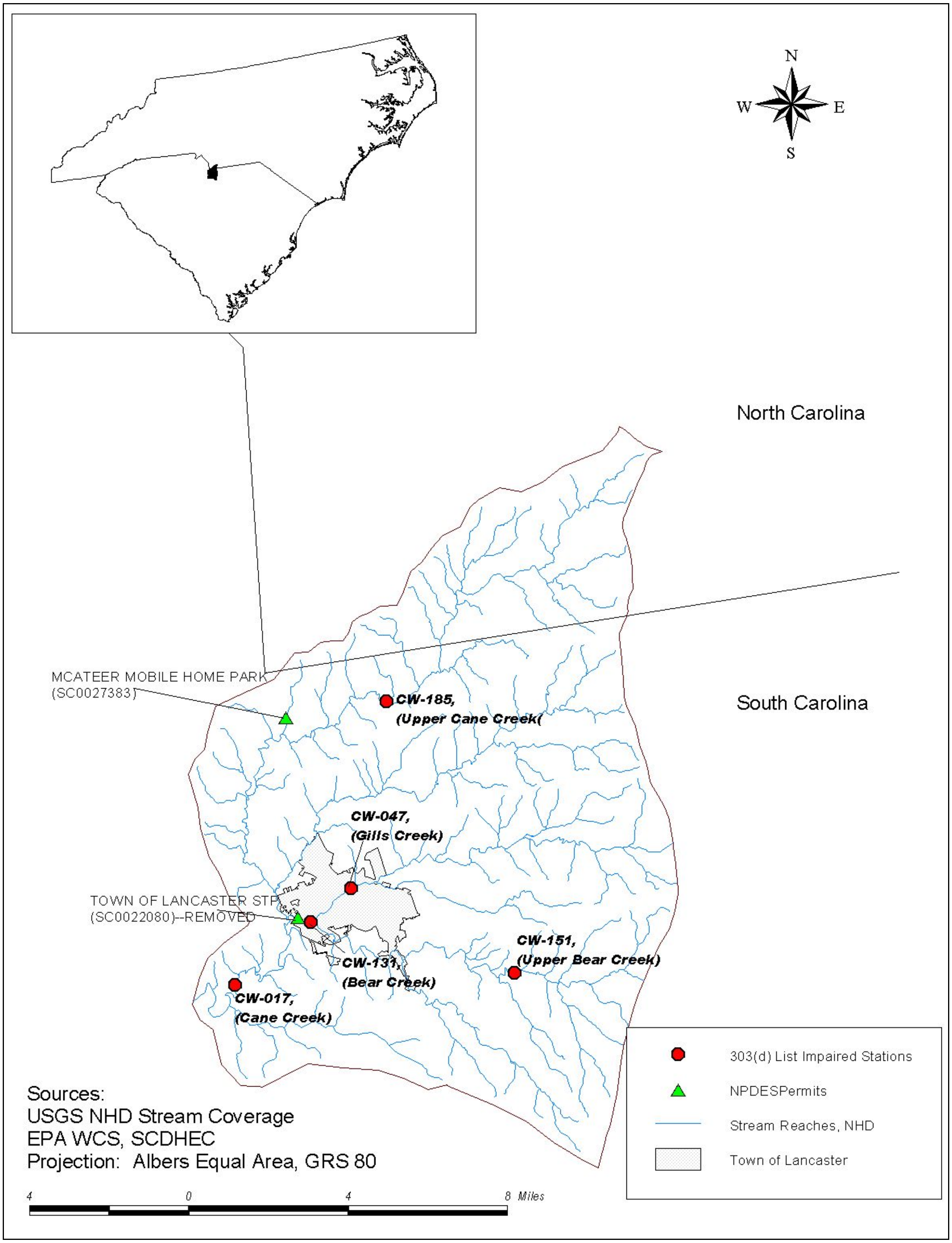


Figure 2-1. Impaired water quality stations and NPDES permits in the Cane Creek watershed

3.0 SOURCE AND LOAD ASSESSMENT

Fecal coliform bacteria enter surface waters from both point and nonpoint sources. Point sources are facilities that discharge at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. All point sources must have a National Pollutant Discharge Elimination System (NPDES) permit. Nonpoint sources are diffuse sources that have multiple routes of entry into surface waters. Some sources are related to land use activities that accumulate fecal coliform bacteria on the land surface (i.e., pasture land) that runs off during storm events. Other sources, such as in-stream cattle, are more or less continuous, at least seasonally. Point source contributions can typically be attributed to the following sources:

- Municipal wastewater facilities,
- Municipal Separate Storm Sewers (MS4s),
- Illicit discharges, and
- Leaking or overflowing sewers.

Municipal wastewater treatment facilities are permitted through the National Pollutant Discharge Elimination System (NPDES). Larger treatment facilities have disinfection systems that remove fecal coliform bacteria in the effluent before it is discharged. Treatment facilities treat human waste received from the collection system and then discharge their effluent into a nearby stream.

Municipal Separate Stormwater Systems (MS4s) are point sources also regulated by the NPDES program. Discharge from stormwater pipes or conveyances potentially include urban runoff high in bacteria and other pollutants.

Illicit discharges are made when facilities or persons discharge fecal coliform bacteria without a permit, or violate their defined permit discharge limit by exceeding the fecal coliform concentration.

In urban settings, sewer lines typically run parallel to the stream in the floodplain. If there is a leaking or overflowing sewer line, high concentrations of fecal coliform can flow into the stream or leach into the groundwater. Groundwater monitoring wells can signal if there are leaking sewer lines contributing to the problem.

3.1 Point Sources

3.1.1 Permitted Point Sources

There is one active point source in the Cane Creek watershed. The McAteer Trailer Park (SC0027383) is a minor domestic wastewater source. The facility discharges to Cane Creek, approximately 17 miles upstream of water quality station CW-017 (see Figure 4-1). This facility is permitted for a discharge of 0.00565 MGD; however, DMR records indicate that this facility has averaged a flow of 0.003 MGD for the period of 1995-2000. In South

Carolina, NPDES permittees that discharge sanitary wastewater must meet the state criteria for fecal coliform bacteria at the point of discharge (i.e., a daily maximum concentration of 400 counts per 100mL, and a 30-day geometric mean of 200 counts per 100mL).

The first *Watershed Water Quality Management Strategy: Catawba-Santee Basin* document (SCDHEC, 1993) identified the Town of Lancaster Sewerage System (SC0022080) as a major municipal treatment facility in the Cane Creek watershed. The facility was located near the confluence of Bear and Cane Creeks in subbasin 16. The update of that document (SC, 1999) does not identify this facility as operating in the watershed any longer. According to information available from the EPA Permit Compliance System database as well as the South Carolina DHEC Division of Water Quality, the Town of Lancaster expanded its treatment capabilities, and took the facility offline in August 1996. The new discharge (SC0046892) was relocated to the Catawba River downstream of the Cane Creek watershed. Therefore this facility is not included in the TMDL.

Table 3-1. Facilities permitted to discharge fecal coliform bacteria into waterbodies of the Cane Creek watershed

NPDES No.	Facility Name	Principal Activity	Receiving Waterbody	Fecal Coliform Bacteria Limit		Flow Limit (MGD)
SC0027383	Mcateer Trailer Park	Wastewater	Cane Creek	Daily Maximum of 400 counts/100mL	30-day geometric mean of 200 counts/100mL	0.00565

Table 3-2 presents facility information for SC0027383. Table 3-3 presents fecal coliform bacteria concentration statistics for facility SC0027383. Estimates of existing fecal coliform bacteria loading for NPDES facility SC0027383 are based on the geometric mean of available DMR data. Tables 3-2 and 3-3 were created using Discharge Monitoring Report (DMR) data provided by SCDHEC. The original DMR data are shown in Appendix A. Table 3-4 shows existing loading information for the facility.

Table 3-2. Facility information for SC0027383

NPDES ID	Count	Mean (counts/100ml)	Maximum (counts/100ml)	Geometric Mean (counts/100ml)	Exceedence Based on 400/100ml	By-passes	Sanitary Sewer Overflow (SSO)
SC0027383	98	30	195	22	None	None*	None*

*Based on SCDHEC information

Table 3-3. Estimated fecal coliform loads from NPDES facility SC0027383 in the Cane Creek watershed

NPDES No.	Facility Name	Pipe	Average Discharge (MGD)	FC Load (counts/30 days)
SC0027383	Mcateer Trailer Park	001	0.003	7.8E+07

3.1.2 Municipal Separate Storm System Permits

In 1990, EPA developed rules establishing Phase I of the National Pollutant Discharge Elimination System (NPDES) storm water program, designed to prevent harmful pollutants from being washed by storm water runoff into Municipal Separate Storm Sewer Systems (MS4s) (or from being dumped directly into the MS4) and then discharged from the MS4 into local waterbodies. Phase I of the program required operators of “medium” and “large” MS4s (those generally serving populations of 100,000 or greater) to implement a storm water management program as a means to control polluted discharges from MS4s. Approved storm water management programs for medium and large MS4s are required to address a variety of water quality related issues including roadway runoff management, municipal owned operations, hazardous waste treatment, etc. There are no large or medium MS4s in the Cane Creek watershed.

Phase II of the rule extends coverage of the NPDES storm water program to certain “small” MS4s. Small MS4s are defined as any MS4 that is not a medium or large MS4 covered by Phase I of the NPDES Storm Water Program. Only a select subset of small MS4s, referred to as “regulated small MS4s”, require an NPDES storm water permit. Regulated small MS4s are defined as all small MS4s located in "urbanized areas" as defined by the Bureau of the Census, and those small MS4s located outside of a UA that are designated by NPDES permitting authorities. The town of Lancaster is located in the central portion of the Cane Creek watershed; however, according to the final Phase II Stormwater NPDES regulations, the Town of Lancaster is not considered a regulated small MS4 nor is it considered a potential small MS4.

3.2 Nonpoint Sources

In addition to point sources, nonpoint sources also contribute fecal coliform bacteria loads into the waters of the Cane Creek watershed. Nonpoint sources represent contributions from diffuse sources, rather than from a defined outlet. On the land surface, fecal coliform bacteria accumulate over time and wash off during rain events. As the runoff transports the sediment over the land surface, more fecal coliform bacteria are collected and carried to the stream. While the concentrations of bacteria are accumulating, they also die. The net loading into the stream is determined by the local watershed hydrology.

The land use distribution of the Cane Creek watershed provides insight into determining nonpoint sources of fecal coliform bacteria (Figure 1-2). The predominant land uses in the

Cane Creek watershed were identified based on the Multi-Resolution Land Characterization (MRLC) land use data (representative of the mid-1990s). Figure 3-1 displays the land use distribution of the catchment area of each impaired water quality station. Key nonpoint sources identified in the watershed include urban areas, failing septic systems, livestock, manure application, and natural sources.

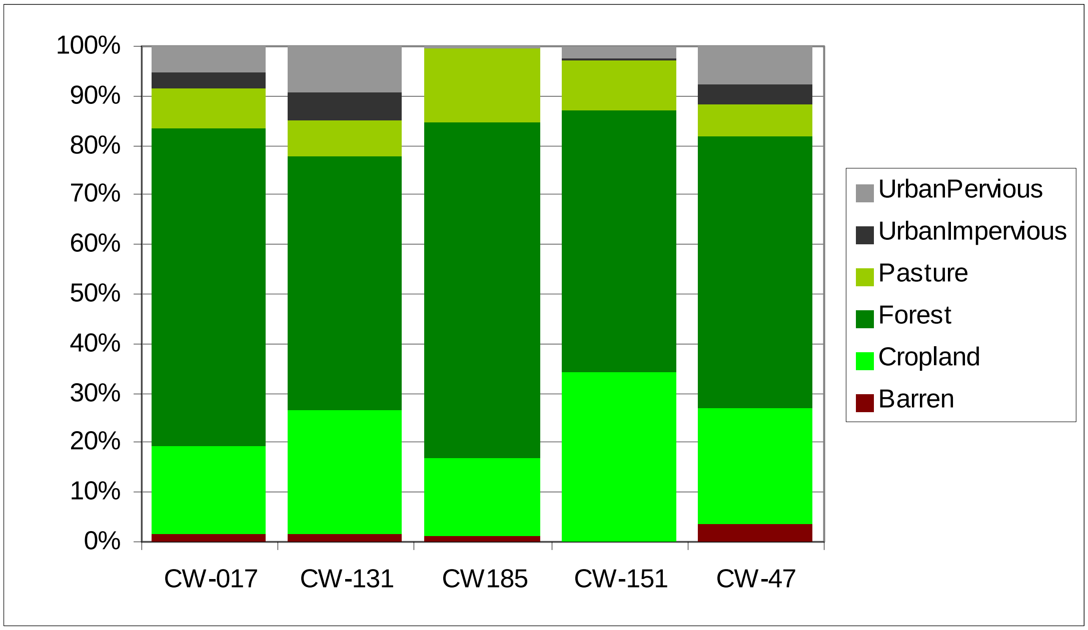


Figure 3-1 Land use distribution in the drainage areas of the impaired stations in the Cane Creek watershed (cumulative)

3.2.1 Urban Areas

Sources of fecal coliform bacteria in urban areas include wildlife and pets, particularly dogs. Much of the loading from urban areas is due simply to the increase in impervious surfaces relative to other land uses and the resulting increase in runoff. In estimating the potential loading of fecal coliform bacteria from urban areas, accumulation rates are often used to represent the aggregate of available sources. For this study, initial accumulation rates assumed for the built-up land were 1.0 x 10^7 counts/acre/day (Horner, 1992) for both the pervious and impervious fractions. The assumed perviousness percentages for built-up land were as follows:

- Low Intensity Residential—88 percent
- High Intensity Residential—35 percent
- High Intensity Commercial/Industrial/Transportation—15 percent

3.2.2 Failing Septic Systems

Failing septic systems represent a nonpoint source that can contribute fecal coliform bacteria to receiving waterbodies through surface or subsurface malfunctions. Loadings from failing septic systems were represented by constant flows and concentrations in the analysis. The estimate was derived by examining a combination of US Census data and technical references:

- Number of septic systems (derived from US Census 1990)
- Estimated population served by the septic systems (an average of 2.5 people per household, US Census 1990)
- An average daily discharge of 70 gallons/person/day (Horsley & Witten, 1996)
- Septic effluent concentration of 10^4 counts/100mL (Horsley & Witten, 1996)
- Septic failure rate of 20 percent (initial estimate)

Since the estimates of the number of septic systems were based on 1990 Census data, population estimates from 1990 were also used in estimating septic loadings. To provide a margin of safety accounting for the uncertainty of the number, location, and behavior (e.g., surface vs. subsurface breakouts; proximity to stream) of these sources, failing septic systems and illegal discharges or leaky sewer lines are represented in the model as direct sources of fecal coliform to the stream reaches. Although quantifying loading from precise contributions from these sources is not feasible, the MOS included in the septic failure rate is assumed to address the uncertainty regarding these sources.

Table 3-4 presents the estimated population on septic systems. Population estimates are cumulative for each station. For example, station CW-017 is associated with a population of 12,520; this incorporates the population for all subbasins upstream of that water quality station.

Table 3-4 Estimated population on septic systems for each impaired station's drainage area (populations are cumulative for each station)

Impaired Station	Population
CW-185	3,073
CW-047	2,157
CW-017	12,520
CW-131	5,125
CW-151	1,121

3.2.3 Agriculture

Agricultural land can also be a significant source of fecal coliform bacteria. Runoff from pastures, livestock operations, improper land application of animal wastes, and livestock with access to waterbodies are all agricultural sources of fecal coliform bacteria. Agricultural Best

Management Practices (BMPs) such as buffer strips, alternative watering sources, limiting livestock access to streams, and the proper land application of animal wastes reduce fecal coliform bacteria loading to waterbodies.

EPA's Fecal Coliform Load Estimation Spreadsheet (FCLES) tool was used to develop initial estimates of the amount of fecal coliform bacteria introduced directly to streams, as well as initial estimates of accumulation rates of fecal coliform bacteria on the land surface (USEPA, 2000.) The FCLES tool quantifies the fecal coliform bacteria component of waste generated by warm-blooded animals and distributes these quantities to streams and to the land surface based on land use type and waste management practices. Estimates derived from the FCLES tool were used as inputs to the watershed loading model. These initial estimates were fine-tuned during the model testing (calibration) process to more closely match available monitoring data.

Grazing cattle are of more relevance in the Cane Creek watershed than confined animal operations. Based on the 1997 USDA census data for Union and Lancaster counties (Table 3-5) and assuming a uniform distribution of animals, it was estimated that 4,881 beef cows, 98 dairy cows, 1,490 hogs, 12 sheep, and 554,256 chickens are found in the watershed. Livestock, except for dairy cattle, are not usually confined and typically graze in pastures. Manure deposited by cattle onto pasture land is a source of nonpoint pollution. It was also assumed that cattle manure is applied to cropland and pasture and hog manure is applied to pasture only. No manure is expected to be exported from or imported to the watershed. Table 3-6 describes literature-based fecal coliform bacteria production rates for various animals. These rates were used to estimate loadings from each livestock category based upon Agricultural Census estimates of livestock population.

Table 3-5. 1997 USDA Agricultural Census information for Union County, NC and Lancaster County, SC

Livestock Type	Number of Animals (Union County)	Number of Animals (Lancaster County)
Cattle	25,217	12,482
Beef Cow	14,416	6,887
Milk Cow	573	112
Hogs	40,728	267
Sheep	332	-
Chickens	-	-
Chickens Sold	69,650,167	-

Table 3-6. Fecal coliform bacteria production rates for various animals

Livestock Animal	Fecal Coliform Bacteria Production Rate*

	(counts/animal/day)
Beef Cow	1.04E+11
Dairy Cow	1.01E+11
Hogs	1.08E+10
Sheep	1.20E+10
Chicken	1.36E+08

*Source: ASAE, 1998

Given the gradually sloping terrain and warm climate of the area (especially during spring and summer months) it is reasonable to expect cattle to spend some time directly in streams. Loading of fecal coliform bacteria from cattle defecating directly into streams was initially estimated based on the number of cattle and assumptions regarding the time cattle are expected to be standing or wading in the streams. This number was refined through model calibration, which considered bacteria monitoring data. The time that cattle spend in-streams was assumed to be 0.015 percent of its total grazing time.

3.2.4 Wildlife

Fecal coliform bacteria also originate in forested areas. Generally, sources include wild animals such as deer, raccoons, wild turkeys, and waterfowl. The Department of Natural Resources in South Carolina estimated a deer density of 45 deer per square mile of deer habitat (Data provided by Charles Ruth, Deer Project Supervisor, DNR, 5/1/01). Deer habitat was assumed to include forest, wetlands, cropland, and pasture. The fecal coliform bacteria production rate for deer was estimated based on best professional judgment using the rates for other animals, such as turkey and cattle, which are available in Metcalf and Eddy (1991). An interpolation was conducted based on animal weight. This method results in a rate of 5×10^8 counts/animal/day for deer. Using this rate and the assumption of an equally distributed population of deer across forest, wetlands, and agricultural land uses, the fecal coliform bacteria accumulation rates from wildlife were determined to be 3.52×10^7 counts/acre/day, which represents background fecal coliform bacteria loading. It is important to note that the accuracy of predicted loading depends upon the accuracy of the various assumptions described above.

4.0 MODELING

Watersheds with varied land uses, dry and wet period loads, and numerous potential sources of pollutants typically require a model to ascertain the effect of source loadings on in-stream water quality. This relationship must be understood in order to develop a TMDL that addresses a water quality standard as well as an effective implementation plan. In this section, the modeling techniques that were applied to simulate fecal coliform bacteria fate and transport in the watershed are discussed for the Cane Creek watershed.

4.1 Model Selection

Selection of the appropriate analytical technique for TMDL development was based on an evaluation of technical and regulatory criteria. Key technical factors that were important in the selection process include:

- Point and nonpoint sources must be considered.
- Fecal coliform bacteria impairments are temporally-variable and occur at low, average, and high flow conditions.
- Time-variable aspects of land practices have a large effect on in-stream bacteria concentrations.
- Bacteria transport mechanisms are highly variable and often weather dependent.

The primary regulatory factor that drove the selection process was South Carolina's water quality standards. Compliance with the standards requires attaining both instantaneous and geometric mean-based criteria. To ensure a valid comparison to these criteria, results from a time-variable analysis are required.

The USEPA has assembled a variety of tools to use in the development of TMDLs. Of these tools, the geographic information system (GIS)-based Watershed Characterization System (WCS), the Fecal Coliform Loading Estimation Spreadsheet (FCLES), and the Loading Simulation Program in C++ (LSPC) were applied to model the Cane Creek watershed. WCS is similar to EPA's BASINS, however, it includes source loading calculation tools, as well as updated agricultural data. WCS, a GIS tool, was used to display and analyze GIS information including land use, land type, point source discharges, soil types, population, and stream characteristics. FCLES is a spreadsheet tool used to quantify nonpoint source bacteria accumulation rates based on watershed-specific information.

LSPC is a system designed to support TMDL development for areas impacted by nonpoint and point sources. The most critical component of LSPC to TMDL development is the dynamic watershed model, because it provides the linkage between source contributions and in-stream response. LSPC is essentially a re-coded C++ version of selected Hydrological Simulation Program FORTRAN (HSPF) modules. LSPC is used to simulate watershed hydrology and pollutant transport as well as stream hydraulics and in-stream water quality. It is capable of simulating different flow regimes and bacteria loading variations. LSPC's algorithms are identical to those in HSPF. Table 4-1 presents the modules from HSPF used in LSPC for this study. Refer to the *Hydrologic Simulation Program FORTRAN User's Manual for Release 11* (USEPA, 1996) for a more detailed discussion of simulated processes and model parameters.

Table 4-1. HSPF modules used in LSPC for the Cane Creek TMDL analysis

RCHRES Modules	HYDR	Simulates hydraulic behavior
	GQUAL	Simulates behavior of a generalized quality constituent
PQUAL and IQUAL Modules	PWATER	Simulates water budget for a pervious land segment
	IQUAL	Uses simple relationships with solids and water yield
	PQUAL	Simple relationships with sediment and water yield

Source: USEPA, 1996

4.2 Model Set Up

LSPC was configured for the Cane Creek watershed to simulate the watershed as a series of hydrologically connected subwatersheds. Configuration of the model involved subdivision of the Cane Creek watershed into modeling units and continuous simulation of flow and water quality for these units using meteorological, land use, point source loading, and stream data.

The Cane Creek watershed was broken into six 14-digit watershed units. The GIS coverage of these units was provided by South Carolina and used as the initial delineation for the model. These subbasins were further subdivided to enable evaluation of water quality and flow at impaired water quality stations and to ensure stream network configuration with the basin. For modeling, the Cane Creek watershed was delineated into 15 subwatersheds (Figure 4-1). Watershed delineation was based on the National Hydrography Dataset (NHD) stream coverage and digital elevation data. Headwater subbasins include some areas within the state of North Carolina. This delineation allows for management and load reduction alternatives to be varied by subwatershed.

A continuous simulation period of eleven years (1990-2000) was used in the hydrologic simulation analysis. This is due to the fact that the period of record for observation data spanned that time period. An important factor driving model simulations is precipitation data. The pattern and intensity of rainfall affects the build-up and wash-off of fecal coliform bacteria from the land into the streams, as well as the dilution potential of the stream. The Lancaster weather station (ID: SC5017) located within the basin was applied to the entire watershed to simulate hydrologic events in the LSPC model.

Modeled land uses contributing to bacteria loads include pasture, cropland, urban pervious lands, urban impervious lands, and forest (including barren and wetlands). Other sources, such as septic systems and livestock in streams were modeled as direct sources in the model. Development of initial loading rates for land uses and direct sources was based on the analysis described in Section 3. These initial estimates are presented in Table 4-2, and they were further refined during the model testing (calibration) process (described in Section 4.3). Table 4-3 presents the final bacteria accumulation rates for land use sources. Loading rates used in the model to represent cattle and septic system contributions are presented in Table 4-4. The septic system contribution represents a failure rate of 2 percent.

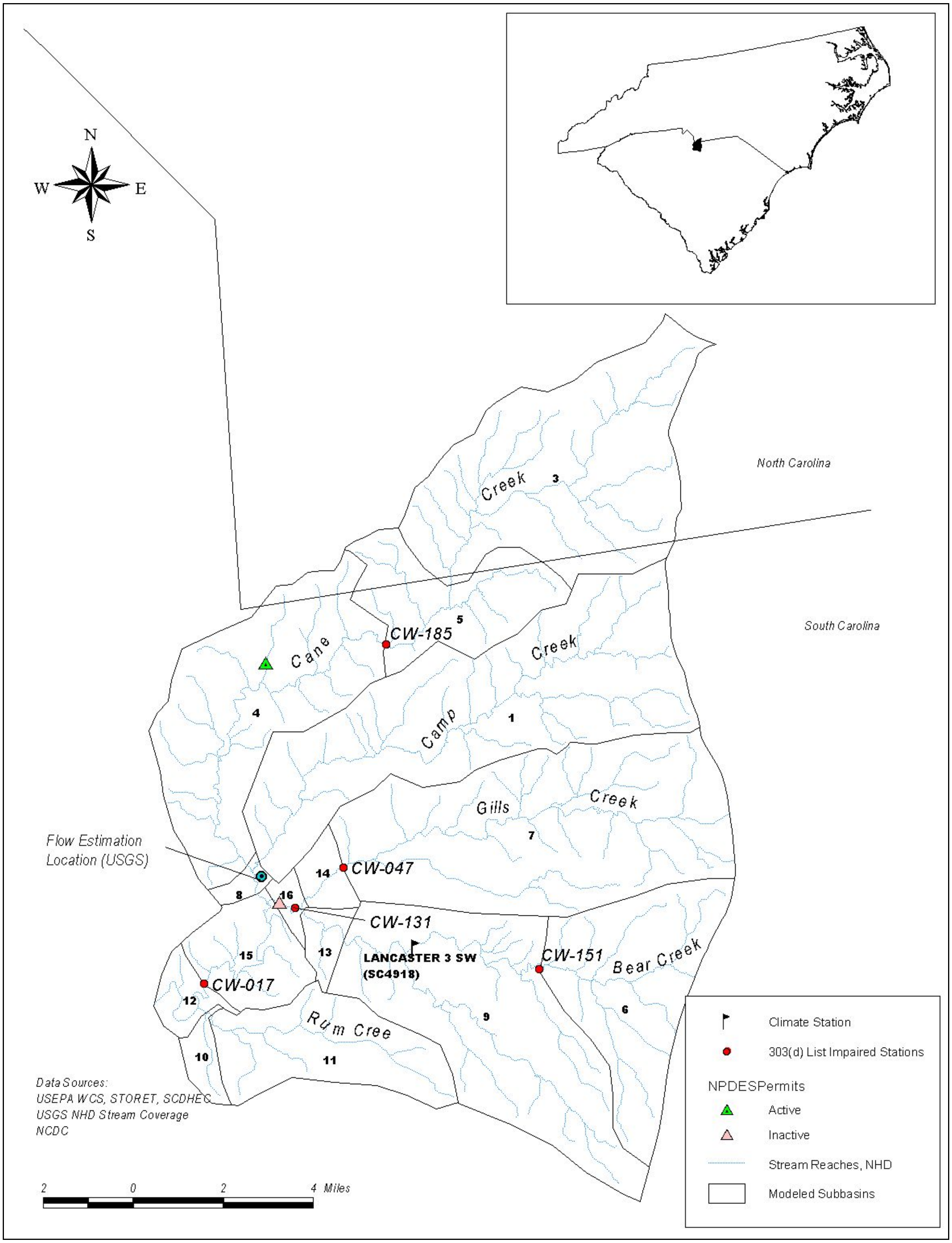


Figure 4-1. Delineated subbasins and station locations used in modeling the Cane Creek watershed.

Table 4-2. Initial monthly accumulation rates (counts/acre/day) derived from FCLES

Lancaster County, SC	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cropland	3.37E+09	3.72E+09	3.37E+09	3.48E+09	3.37E+09	3.48E+09	3.37E+09	3.37E+09	3.48E+09	3.37E+09	3.48E+09	3.37E+09
Forest	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07
Pasture	5.22E+10	5.26E+10	5.22E+10	5.24E+10	5.22E+10	5.24E+10	5.23E+10	5.23E+10	5.24E+10	5.22E+10	5.24E+10	5.22E+10
Urban Pervious and Impervious	7.86E+06	7.86E+06	7.86E+06	7.86E+06	7.86E+06	7.86E+06	7.86E+06	7.86E+06	7.86E+06	7.86E+06	7.86E+06	7.86E+06
Union County, NC	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cropland	1.46E+10	1.61E+10	1.46E+10	1.51E+10	1.46E+10	1.51E+10	1.46E+10	1.46E+10	1.51E+10	1.46E+10	1.51E+10	1.46E+10
Forest	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07
Pasture	2.23E+10	2.27E+10	2.23E+10	2.24E+10	2.23E+10	2.24E+10	2.23E+10	2.23E+10	2.24E+10	2.23E+10	2.24E+10	2.23E+10
Urban Pervious and Impervious	7.29E+06	7.29E+06	7.29E+06	7.29E+06	7.29E+06	7.29E+06	7.29E+06	7.29E+06	7.29E+06	7.29E+06	7.29E+06	7.29E+06

Table 4-3. Final (calibrated) monthly accumulation rates (counts/acre/day) used in the model

Lancaster County, SC	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cropland	3.37E+09	3.72E+09	3.37E+09	3.48E+09	3.37E+09	3.48E+09	3.37E+09	3.37E+09	3.48E+09	3.37E+09	3.48E+09	3.37E+09
Forest	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07
Pasture	5.22E+10	5.26E+10	5.22E+10	5.24E+10	5.22E+10	5.24E+10	5.23E+10	5.23E+10	5.24E+10	5.22E+10	5.24E+10	5.22E+10
Urban Pervious and Impervious	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09
Union County, NC	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cropland	1.46E+10	1.61E+10	1.46E+10	1.51E+10	1.46E+10	1.51E+10	1.46E+10	1.46E+10	1.51E+10	1.46E+10	1.51E+10	1.46E+10
Forest	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07	3.52E+07
Pasture	2.23E+10	2.27E+10	2.23E+10	2.24E+10	2.23E+10	2.24E+10	2.23E+10	2.23E+10	2.24E+10	2.23E+10	2.24E+10	2.23E+10
Urban Pervious and Impervious	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09	1.96E+09

Table 4-4. Final loading rates for cattle and septic systems (counts/day)

	Sub 1	Sub 3	Sub 4	Sub 5	Sub 6	Sub 7	Sub 8	Sub 9	Sub 10	Sub 11	Sub 12	Sub 13	Sub 14	Sub 15	Sub 16
Septic loadings (counts/day)	1.21E+09	1.24E+09	8.37E+08	3.94E+08	5.95E+08	1.14E+09	2.76E+07	9.05E+08	5.53E+07	4.01E+08	7.76E+07	4.45E+07	1.96E+07	2.22E+08	1.01E+07
Cattle loadings (counts/day)	8.73E+09	1.00E+10	2.62E+09	2.05E+09	8.92E+09	1.22E+10	1.75E+08	9.97E+09	3.50E+07	1.90E+09	7.02E+07	1.99E+08	9.37E+07	9.54E+08	1.17E+07

Cane Creek Watershed Model does not have a subbasin 2

4.3 Model Calibration

Hydrology and water quality calibration were performed in sequence, since water quality modeling is dependent on an accurate hydrology simulation. Cane Creek is an ungaged watershed; however the USGS has developed 10-year flow hydrographs for the watershed using regression models (USGS, 2002). These models depend on regional equations developed using data from gaging stations at similar watersheds of same drainage area. The hydrographs were used to calibrate the hydrology of the watershed model.

The hydrographs correspond to a location on Cane Creek near its confluence with Camp Creek (see Figure 4-1). Calibration of the hydrologic model was accomplished by adjusting model parameters such as evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge until the simulated and observed water budgets matched. The intensity and arrival time of storm peaks were then calibrated. The model was calibrated to the observed data recorded from October 1, 1997 to September 30, 1998. The hydrology was validated for the longer time period of October 1, 1990 to September 30, 2000. Results of the hydrology calibration and validation are presented in Appendix B.

Following hydrology calibration, the water quality was calibrated by comparing modeled versus observed in-stream fecal coliform bacteria concentrations . The water quality calibration consisted of executing the watershed model, comparing water quality time series output to available water quality observation data, and adjusting water quality parameters within a reasonable range. The water quality parameters that were adjusted to obtain a calibrated model were the build-up and washoff of fecal coliform bacteria from the land uses and the direct load estimates such as cattle in the streams and the failing septic systems as described in Section 3.2.

The approach taken to calibrate water quality focused on matching trends identified during the water quality analysis. Daily average in-stream fecal coliform bacteria concentrations from the model were compared directly to observed data. Observed fecal coliform bacteria data collected by South Carolina DHEC were obtained from EPA's STORET database for the years 1990 through 2000. The objective was to best simulate concentrations during low flow, mean flow, and storm peaks at representative water quality monitoring stations. Water quality was calibrated at each of the impaired stations. The available water quality data for the five water quality calibration locations are presented in Appendix C.

The time period of the model water quality calibration was from 1995 through 1997. This time period was selected based on the availability and relevance of the observed data to the current conditions in the watershed. The period also includes various wet and dry conditions. Due to the lack of observation data, a one-year period was insufficient for water quality calibration. The validation period was 1998 to 2000. The water quality calibration results are shown in Appendix D. Since the Lancaster Sewage Treatment plant was inactivated in August 1996, The calibration period for station CW-017 began in September 1996.

5.0 MODELING RESULTS

5.1 Existing Conditions

An examination of the Cane Creek watershed indicates that the majority of violations of the instantaneous criterion occur in streams during relatively high-flow conditions in conjunction with a storm event. Storm events create high loading inputs from land surfaces due to the accumulation of fecal coliform bacteria and subsequent washoff. In the upper portion of the watershed, storm events create high loading inputs from crop and pasture land--the dominant land uses in the headwaters of the Cane Creek watershed. About one-third of the Cane Creek watershed consists of urban land uses; these are situated in the lower portion of the watershed. Loadings from upstream agricultural land uses are augmented by the loadings from the urbanized land uses in downstream portions of the watershed. High flow conditions, especially the high flows created by a storm after a long dry period, cause not only violations of the instantaneous criterion, but violations of the geometric mean instantaneous (not to exceed) criterion during winter period.

Existing conditions of each source are determined based on available information or simulated model results. Existing loading (Table 5-1 and Figure 5-1) from land, in-stream cattle, and failing septics are simulated using the LSPC model during the critical condition determined through the procedure described in Section 5.1. Loadings presented in Table 5-1 represent cumulative loadings from the contributions of upper watersheds at each impaired water quality station.

Table 5-1. 30-day existing loadings at impaired water quality stations by source*

Impaired Water Quality Station	FC Loading from the Land (counts/30 days)	FC Loading from In-stream Cattle (counts/30 days)	FC Loading from Point Sources (counts/30 days)	FC Loading from Septic Systems (counts/30 days)
CW-017	6.75E+15	1.71E+12	3.30E+07	2.08E+11
CW-131	2.77E+15	9.97E+11	0.00E+00	9.43E+10
CW-047	6.46E+14	3.66E+11	0.00E+00	3.43E+10
CW-151	2.76E+14	2.68E+11	0.00E+00	1.78E+10
CW-185	4.84E+14	3.63E+11	0.00E+00	4.89E+10

* The 30-day period presented here is based on the critical period identified for the instantaneous standard (described in the TMDL section).

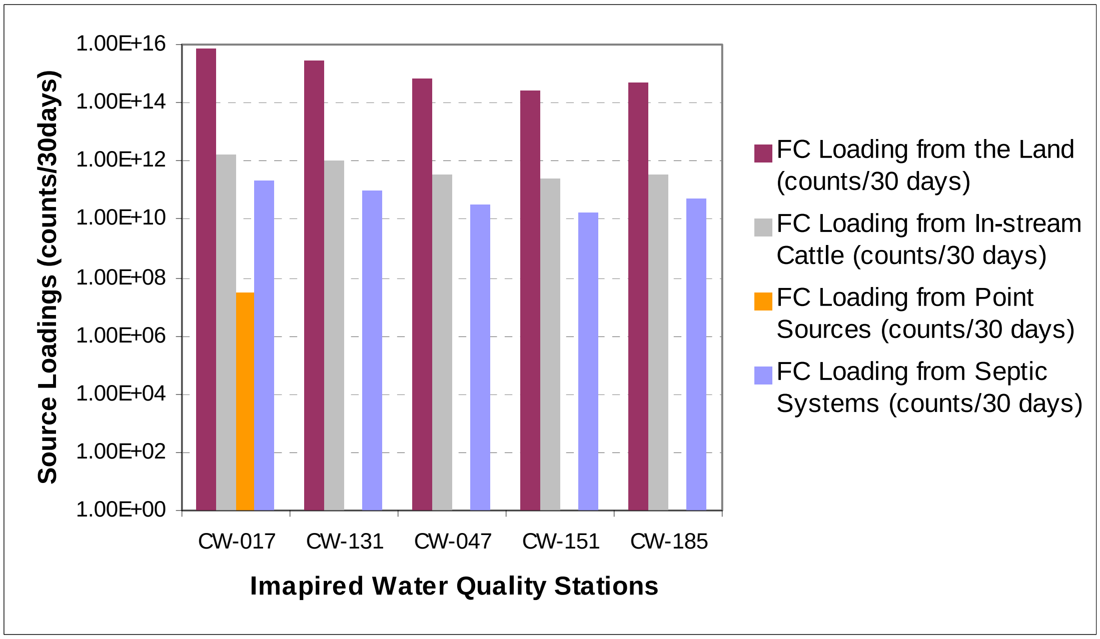


Figure 5-1. Cumulative existing loadings at impaired water quality stations by source (loadings are based on counts/30 days)

6.0 TMDL

A total maximum daily load (TMDL) for a given pollutant and waterbody is comprised of the sum of individual wasteload allocations (WLAs) for point sources, and load allocations (LAs) for both nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is represented by the equation:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

The TMDL is the total amount of pollutant that can be assimilated by the receiving waterbody while still achieving water quality standards. In TMDL development, allowable loadings from all pollutant sources that cumulatively amount to no more than the TMDL must be established and thereby provide the basis to establish water quality-based controls. For some pollutants, TMDLs are expressed on a mass loading basis (e.g., pounds per day). For bacteria, however, TMDLs can be expressed in terms of organism counts (or resulting concentration), in accordance with 40 CFR 130.2(l).

6.1 Critical Conditions

EPA regulations at 40 CFR 130.7(c)(1) requires TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The critical condition for the Cane Creek watershed was selected based on the 6-year simulation of fecal coliform bacteria concentrations from 1995 to 2000. This period is the same for which the 303 (d) listing was based and is considered representative of most recent conditions in the watershed. A summary of how critical conditions were determined for each impaired water quality station is described below:

1. The running geometric mean of simulated concentrations was calculated over the entire simulation period and compared to South Carolina's geometric mean criterion of 200 fecal coliform bacteria counts per 100mL.
2. Each violation of the criterion was compared to the corresponding 30-day geometric mean simulated flow value.
3. If the violation occurred during a flow event that was below the 10^{th} percentile (low flows) or above the 90^{th} percentile (high flows), the violation was ignored because these flows were considered to be extreme conditions (USEPA Region 4, personal communication 12/2002).
4. Of the remaining violations, the largest was then identified. The date on which this violation occurred was determined to be the critical date. The critical period was established so that it represented the 30-day period leading up to the critical date. For example, if the critical date for a subbasin were identified as January 30, the critical period for that subbasin would be January 1 through January 30.

A critical period was determined for each impaired station. For allocations, if unimpaired subbasins were located upstream of an impaired station, they were assigned the same critical date and any reductions were calculated for the same period. The critical dates identified for each impaired station are presented in Table 6-1.

Table 6-1. Critical dates for impaired subbasins in the Cane Creek watershed

Water Quality Station	Critical Date
CW-131	2/14/1997
CW-017	2/14/1997
CW-047	2/14/1997
CW-151	2/14/1997
CW-185	2/14/1997

* The critical date represents the last day of the 30-day critical period.

6.2 TMDL Methodology and Endpoints

TMDLs and source allocations were developed at impaired water quality monitoring stations in the Cane Creek watershed based on the 30-day geometric mean fecal coliform bacteria criteria. A top-down methodology was used to develop these TMDLs and allocate loads to sources. Impaired headwaters were analyzed first, because their impact frequently had a profound effect on down-stream water quality. Loading contributions were reduced from applicable sources for these waterbodies and TMDLs were developed. After meeting water quality criteria for the upper subwatersheds, the results were then routed to downstream stations. In many situations, it was necessary to revisit allocations made at upstream stations (and make additional reductions), in order to meet water quality criteria at downstream stations. Reductions were determined through a comparison to the geometric mean criteria during the geometric mean critical period. The instantaneous portion of the WQS was also evaluated because the standards require that both the geometric mean and instantaneous criteria are met. Reductions required to meet the instantaneous portion were similar to those required to meet the geometric mean standard; therefore the TMDL and reductions are presented in terms of the geometric mean criteria. Appendix E shows both the existing conditions and allocations that achieve the water quality criteria at the impaired water quality stations under the geometric mean critical conditions.

6.3 Wasteload Allocations

Table 6-2 presents the NPDES permitted facility (Mcateer Trailer Park) and its allocated fecal coliform bacteria loading. Since the Mcateer Trailer Park is assumed to be discharging at its permitted limit of 200 counts per 100 mL of fecal coliform bacteria, discharge from the facility does not lead to exceedences of the fecal coliform bacteria water quality criteria, and therefore, it is not considered to be a major contributing source. This assumption was derived from DMR data provided by South Carolina (refer to Table 3-2 and Appendix A).

Table 6-2. Waste load allocations (WLAs) for each NPDES permitted facility

NPDES Permit	Facility Name	Subwatershed	Pipe	Average Fecal Coliform Bacteria Concentration (counts/100mL)	Permitted Flow (MGD)	Fecal Coliform Bacteria Load (counts/30 days)
SC0027383	Mcateer Trailer Park	4	001	200	0.0056	1.28E+09

6.4 Load Allocations

Load allocations were made for the dominant source categories as follows:

- Washoff from urban land uses
- Washoff from agricultural land uses (cropland and pasture land)
- Cattle in the stream reaches
- Failing septic systems and illicit discharges

Nonpoint sources were arranged into three categories for the model: land loading, septic loading, and in-stream livestock loading. The land loading category represents bacteria that accumulate on the land surface (including pasture land, cropland, urban land, forested land, barren land, and wetlands) and are then washed into streams. Septic loading represents bacteria contributed to streams by failing septic systems (including illegal discharges). The in-stream livestock category represents bacteria from animals, primarily cattle in this watershed, which are deposited directly into a waterbody.

Major inputs of fecal coliform bacteria can be periodic in nature, such as from rainfall driven accumulation and wash-off events, or more constant, such as from the regular inputs that would come from in-stream cattle or failing septic systems. Depending on flow conditions, the fecal coliform bacteria in the stream at a given time may originate mostly from in-stream livestock or wildlife, and/or septics (usually during low flow conditions), from build-up/wash-off actions (usually during high flow conditions), or from some combination of both. In order to determine allocation ratios between different sources, the simulated 30-day geometric mean and daily concentrations were considered. Depending on the land uses present in a particular subbasin, as well as its relative location upstream or downstream within the watershed, appropriate reduction scenarios were developed. For example, in a subbasin in which there were substantial agricultural lands but no urban areas, simulated inputs from cattle and septic systems, as well as loading from pasture and croplands were reduced until water quality standards were met. In subbasins where there are more urban areas, reduction scenarios focused more on urban lands.

6.5 Margin of Safety

There are two methods for incorporating the MOS (USEPA, 1991):

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations
- Explicitly specify a portion of the total TMDL as the MOS and use the remainder for Allocations

For the Cane Creek TMDLs, both methods were applied to incorporate a MOS. An implicit MOS was incorporated the following ways:

- The use of a 6-year simulation period enabled the consideration of multiple hydrologic conditions; the TMDL was ultimately based on the most stringent.
- Conservative assumptions were employed in developing the TMDL. Permitted facilities were represented in the model using maximum permitted quantities. All cattle were assumed to have access to streams.

As for the explicit MOS, five percent of the geometric mean water quality criterion was reserved. Specifically, the water quality target was set at 190 counts per 100mL for a 30-day period and 380 counts per 100mL for the instantaneous criterion, which is five percent lower than the water quality criteria of 200 and 400 counts per 100mL, respectively.

6.6 Seasonal Variability

Fecal coliform bacteria data in the Cane Creek watershed show that increased fecal coliform bacteria concentrations occur during both wet and dry weather periods. High concentrations are seen during high flows as well as during low summer flows. To adequately address the wet and dry weather related problems, a long-term simulation period covering a variety of hydrologic and rainfall conditions must be evaluated. By using continuous flow simulation (estimating flow over a period of several years), seasonal hydrologic and source loading was inherently considered.

6.7 TMDL Results

Based on an interpretation of the model results and water quality standards, the TMDL and its components (WLA, LA, and MOS) were derived. The TMDLs are presented in Table 6-3 for the geometric mean criteria. They are presented for each impaired water quality monitoring station, starting with the downstream stations and working upstream. The loadings presented for the downstream stations are cumulative and represent contributions from the upstream drainage area. For example, the TMDL presented for station CW-017, which is near the outlet of the watershed, represents the allowable loading from the entire upstream drainage area.

Table 6-3. TMDL based on geometric mean criteria

Impaired Water Quality Station	Existing Point Source Loads (counts/30 days)	WLAs (counts/30 days)	Existing Nonpoint Source Loads (counts/30 days)	LAs (counts/30 days)	MOS (counts/30 days)	TMDL (counts/30 days)	Percent Reduction
CW-017	7.80E+07	1.28E+09	6.75E+15	1.78E+15	9.38E+13	1.88E+15	74
CW-131	0.00E+00	0.00E+00	2.77E+15	8.66E+14	4.56E+13	9.12E+14	69
CW-047	0.00E+00	0.00E+00	6.46E+14	2.39E+14	1.26E+13	2.52E+14	63
CW-151	0.00E+00	0.00E+00	2.76E+14	2.57E+14	1.35E+13	2.71E+14	7
CW-185	0.00E+00	0.00E+00	4.84E+14	2.96E+14	1.56E+13	3.12E+14	39

7.0 IMPLEMENTATION

South Carolina has several tools available to reduce loading of fecal coliform bacteria due to agricultural activities as discussed in the *Implementation Plan for Achieving Total Maximum Daily Load Reductions From Nonpoint Sources* for the State of South Carolina. Specifically, SCDHEC's animal agriculture permitting program addresses animal operations and land application of animal wastes. In addition, SCDHEC will work with existing agencies in the area to provide nonpoint source education in the Cane Creek Watershed. Local sources of nonpoint source education include Clemson Extension Service, the Natural Resource Conservation Service (NRCS) and the South Carolina Department of Natural Resources. Clemson Extension Service offers a 'Farm-A-Syst' package to farmers. Farm-A-Syst allows the farmer to evaluate practices on their property and determine the nonpoint source impact they may be having. It recommends best management practices (BMPs) to correct nonpoint source problems on the farm. Fencing cattle out of streams and restoring an adequate stream buffer have been shown to reduce pollution entering streams. NRCS can provide cost share money to land owners installing BMPs. SCDHEC employs a nonpoint source educator who can also provide BMP information.

SCDHEC is empowered under the State Pollution Control Act to perform investigations of and pursue enforcement for activities and conditions which threaten the quality of waters of the state. In addition, other interested parties (universities, local watershed groups, etc.) may apply for section 319 grants to install BMPs that will reduce fecal coliform bacteria loading to Cane Creek and its tributuaries.

SCDHEC will work with other Federal, State and Local agencies in the region to provide nonpoint source education in the Cane Creek watershed to reduce pollution from built-up areas. Also, Clemson Extension has developed a Home-A-Syst handbook that can help urban or rural homeowners reduce sources of NPS pollution on their property. This document guides homeowners through a self-assessment, including information on proper maintenance practices for septic tanks. SCDHEC also employs a nonpoint source educator who can assist with distribution of these tools as well as provide additional BMP information. In built-up areas, failing septic systems should be repaired or replaced. Also, maintenance of sanitary sewers and prevention of sewer overflows (from blockages) should be emphasized. Because a portion of the Cane Creek watershed is located in Union County, North Carolina, SCDHEC with cooperate with North Carolina Department of Environment and Natural Resources (NCDENR) to encourage implementation across state boundaries.

DHEC will continue to monitor, according to the basin monitoring schedule, the effectiveness of implementation measures and evaluate stream water quality as the implementation strategy progresses. This TMDL may be revised if additional monitoring data and better modeling tools become available.

REFERENCES

American Society of Agricultural Engineers (ASAE). 1998. *ASAE Standards 1998: Standards Engineering Practices Data.* 45th edition. American Society of Agricultural Engineers, St. Joseph, Michigan.

Horner. 1992. *Water Quality Criteria/Pollutant Loading Estimation/Treatment Effectiveness Estimation*. In R.W. Beck and Associates. Covington Master Drainage Plan. King County Surface Water Management Division, Seattle, WA.

Horsley & Witten, Inc. 1996. *Identification and Evaluation of Nutrient and Bacterial Loadings to Maquoit Bay, Brunswick, and Freeport, Maine*. Casco Bay Estuary Project.

Metcalf and Eddy. 1991. *Wastewater Engineering: Treatment, Disposal, Reuse*. 3rd edition. McGraw-Hill, Inc., New York.

Ruth, Charles, Deer Project Supervisor. May 5, 2001. South Carolina Department of Natural Resources.

South Carolina Department of Health and Environmental Control (SCDHEC). 1993. *Watershed Water Quality Assessment: Catawba River Basin*. Bureau of Water, Columbia, SC.

South Carolina Department of Health and Environmental Control (SCDHEC). 1998. *Implementation Plan for Achieving Total Maximum Daily Load Reductions From Nonpoint Sources for the State of South Carolina*. Bureau of Water, Columbia, SC.

South Carolina Department of Health and Environmental Control (SCDHEC). 1999. *Watershed Water Quality Assessment: Catawba River Basin*. Technical Report No. 011-99. Bureau of Water, Columbia, SC.

South Carolina Department of Health and Environmental Control (SCDHEC). 2002. *NPDES Stormwater Program*. www.scdhec.net (accessed January 8, 2003).

United States Bureau of the Census (US Census). 1990. Http://factfinder.census.gov/. Summary Tape File 3, DP5, Housing Characteristics.

United States Bureau of the Census (US Census). 1990. Http://www.census.gov/main/www/cen1990.html.

United States Department of Agriculture (USDA). 1997. *Agricultural Census*. United States Department of Agriculture. Http://www.nass.usda.gov/census/census97.

United States Environmental Protection Agency (USEPA). 1991. *Guidance for Water Quality- Based Decisions: The TMDL Process*. Office of Water, EPA 440/4-91-001.

United States Environmental Protection Agency (USEPA). 1996. *Hydrological Simulation Program FORTRAN, User's Manual for Release 11*. U.S. Environmental Protection Agency, Athens, GA. September.

United States Environmental Protection Agency (USEPA). 1998. *Better Assessment Science Integrating Point and Nonpoint Sources. BASINS version 2.0*. EPA-823-B-98-006.

United States Environmental Protection Agency (USEPA). 2000. *Bacterial Indicator Tool*. EPA-823-B-01-003.

United States Environmental Protection Agency Region 4 (USEPA Region 4). December 17, 2002. Personal Communication (Conference Call) with Molly Davis, Jim Greenfield, Elizabeth Jones, and Keva Lloyd.

United States Environmental Protection Agency Region 4 (USEPA Region 4). April 3, 2003. Personal Communication (Conference Call) with Molly Davis and Elizabeth Jones.

United States Geological Survey (USGS). 1998. *Water Resources Data South Carolina Water Year 1998*. United States Geological Survey Water-Data Report 98-1.

United States Geological Survey (USGS). 2002. *10-Year Flow Hydrograph for Cane Creek*. May 1, 2002. USGS, Columbia, SC.

Appendix A

DMR Data

DMR data for bacteria concentrations and flow are presented for the permitted facility (McAteer Park, SC0027383) located in the Cane Creek watershed. DMR data for bacteria concentrations and flow are also presented for the Lancaster Sewerage Facility (SC0022080), which discharged to the watershed until August 1996.

Table A-1. DMR Data for Facility SC0027383 Mcateer Mobile Home Park

NPDES	Pipe	Date	Fecal Coliform (#/100 ml)	Avg. Flow MGD	Permit Exceedence
SC0027383	001	2/28/91	80	0.0035	
SC0027383	001	5/31/91	0	0.026	
SC0027383	001	9/30/91	190	0.002	
SC0027383	001	11/30/91	7	0.003	
SC0027383	001	12/31/91	3	0.0175	
SC0027383	001	7/31/92	13	0.0213	
SC0027383	001	8/31/92	13	0.023	
SC0027383	001	9/30/92	60	0.022	
SC0027383	001	10/31/92	1	0.0031	
SC0027383	001	11/30/92	55	0.0021	
SC0027383	001	12/31/92	33	0.0025	
SC0027383	001	3/31/93	0	0.0028	
SC0027383	001	4/30/93	4	0.0021	
SC0027383	001	5/31/93	0	0.0022	
SC0027383	001	7/31/93	5	0.003	
SC0027383	001	8/31/93	0	0.0024	
SC0027383	001	9/30/93	4	0.0027	
SC0027383	001	10/31/93	20	0.0025	
SC0027383	001	11/30/93	20	0.0026	
SC0027383	001	12/31/93	0	0.0022	
SC0027383	001	2/28/94	0	0.0021	
SC0027383	001	3/31/94	0	0.0024	
SC0027383	001	4/30/94	30	0.00221	
SC0027383	001	5/31/94	1	0.0027	
SC0027383	001	6/30/94	17	0.0018	
SC0027383	001	7/31/94	2	0.0027	
SC0027383	001	9/30/94	100	0.00284	
SC0027383	001	11/30/94	20	0.0038	
SC0027383	001	12/31/94	0	0.0031	
SC0027383	001	1/31/95	0	0.0031	
SC0027383	001	2/28/95	100	0.0037	
SC0027383	001	4/30/95	15	0.00261	
SC0027383	001	5/31/95	0	0.0026	
SC0027383	001	6/30/95	56	0.0028	
SC0027383	001	7/31/95	6	0.0032	

NPDES	Pipe	Date	Fecal Coliform (#/100 ml)	Avg. Flow MGD	Permit Exceedence
SC0027383	001	8/31/95	0	0.003	
SC0027383	001	9/30/95	95	0.00275	
SC0027383	001	10/31/95	0	0.0045	
SC0027383	001	11/30/95	0	0.0045	
SC0027383	001	12/31/95	5	0.00248	
SC0027383	001	2/29/96	2	0.0024	
SC0027383	001	3/31/96	0	0.0051	
SC0027383	001	4/30/96	0	0.0044	
SC0027383	001	5/31/96	0	0.0049	
SC0027383	001	6/30/96	2	0.0051	
SC0027383	001	7/31/96	0	0.0041	
SC0027383	001	8/31/96	0	0.0029	
SC0027383	001	9/30/96	0	0.0052	
SC0027383	001	10/31/96	23	0.0048	
SC0027383	001	11/30/96	0	0.0052	
SC0027383	001	12/31/96	0	0.0032	
SC0027383	001	1/31/97	5	0.002	
SC0027383	001	2/28/97	0	0.0019	
SC0027383	001	3/31/97	0	0.0018	
SC0027383	001	4/30/97	0	0.0038	
SC0027383	001	5/31/97	9	0.0039	
SC0027383	001	6/30/97	0	0.0026	
SC0027383	001	7/31/97	73	0.0049	
SC0027383	001	8/31/97	18	0.0028	
SC0027383	001	9/30/97	127	0.0021	
SC0027383	001	10/31/97	18	0.0027	
SC0027383	001	11/30/97	10	0.0043	
SC0027383	001	12/31/97	0	0.005	
SC0027383	001	1/31/98	0	0.0044	
SC0027383	001	2/28/98	91	0.0043	
SC0027383	001	3/31/98	13	0.0039	
SC0027383	001	4/30/98	9	0.0033	
SC0027383	001	5/31/98	40	0.0043	
SC0027383	001	6/30/98	0	0.0041	
SC0027383	001	7/31/98	0	0.0031	
SC0027383	001	8/31/98	155	0.0031	
SC0027383	001	9/30/98	130	0.003	
SC0027383	001	10/31/98	0	0.0029	

NPDES	Pipe	Date	Fecal Coliform (#/100 ml)	Avg. Flow MGD	Permit Exceedence
SC0027383	001	11/30/98	5	0.0026	
SC0027383	001	12/31/98	9	0.0033	
SC0027383	001	1/31/99	27	0.0028	
SC0027383	001	2/28/99	5	0.0028	
SC0027383	001	3/31/99	0	0.0033	
SC0027383	001	4/30/99	0	0.0019	
SC0027383	001	5/31/99	0	0.0013	
SC0027383	001	6/30/99	0	0.0018	
SC0027383	001	7/31/99	0	0.0026	
SC0027383	001	8/31/99	60	0.0016	
SC0027383	001	9/30/99	30	0.0028	
SC0027383	001	10/31/99	0	0.0031	
SC0027383	001	11/30/99	65	0.002	
SC0027383	001	12/31/99	20	0.00342	
SC0027383	001	1/31/00	180	0.0023	
SC0027383	001	2/29/00	170	0.00295	
SC0027383	001	3/31/00	15	0.0022	
SC0027383	001	4/30/00	60	0.0022	
SC0027383	001	5/31/00	195	0.00331	
SC0027383	001	6/30/00	0	0.0028	
SC0027383	001	7/31/00	15	0.002101	
SC0027383	001	8/31/00	0	0.00312	
SC0027383	001	9/30/00	125	0.002687	
SC0027383	001	10/31/00	150	0.0021	
SC0027383	001	11/30/00	85	0.0018	
SC0027383	001	12/31/00	15	0.0013	

Table A-2. DMR Data for facility SC0022080 Lancaster Sewage Treatment Facility*

NPDES	Pipe	Date	Fecal Coliform (#/100 ml)	Avg. Flow MGD	Permit Exceedence
SC0022080	001	1/31/1990	216	2.6	
SC0022080	001	2/28/1990	100	2.9	
SC0022080	001	3/31/1990	433	2.2	X
SC0022080	001	4/30/1990	297	1.7	
SC0022080	001	5/31/1990	508	1.8	X
SC0022080	001	6/30/1990	292	1.8	
SC0022080	001	7/31/1990	195	1.9	
SC0022080	001	8/31/1990	287	2.4	
SC0022080	001	9/30/1990	92	1.6	
SC0022080	001	10/31/1990	104	2.8	
SC0022080	001	11/30/1990	23	2.2	
SC0022080	001	12/31/1990	13	2.4	
SC0022080	001	1/31/1991	112	3.6	
SC0022080	001	2/28/1991	31	3.5	
SC0022080	001	3/31/1991	121	3.7	
SC0022080	001	4/30/1991	462	3.6	X
SC0022080	001	5/31/1991	487	2.5	X
SC0022080	001	6/30/1991	145	2	X
SC0022080	001	7/31/1991	194	1.5	
SC0022080	001	8/31/1991	732	1.7	X
SC0022080	001	9/30/1991	311	2	
SC0022080	001	10/31/1991	317	1.9	
SC0022080	001	11/30/1991	87	2	
SC0022080	001	12/31/1991	37	2.1	
SC0022080	001	1/31/1992	238	2.5	
SC0022080	001	2/29/1992	130	2.6	
SC0022080	001	3/31/1992	101	2.9	
SC0022080	001	4/30/1992	366	2.5	
SC0022080	001	5/31/1992	61	2.2	
SC0022080	001	6/30/1992	163	2.7	
SC0022080	001	7/31/1992	76	1.9	
SC0022080	001	8/31/1992	39	2.3	
SC0022080	001	9/30/1992	19	2	
SC0022080	001	10/31/1992	61	2.5	
SC0022080	001	11/30/1992	91	3	
SC0022080	001	12/31/1992	249	2.6	
SC0022080	001	1/31/1993	59	3.5	
SC0022080	001	2/28/1993	21	3.1	
SC0022080	001	3/31/1993	12	3.6	
SC0022080	001	4/30/1993	49	3	
SC0022080	001	5/31/1993	45	2.3	
SC0022080	001	6/30/1993	38	2	
SC0022080	001	7/31/1993	42	2	
SC0022080	001	8/31/1993	23	2	
SC0022080	001	9/30/1993	37	2	

NPDES	Pipe	Date	Fecal Coliform (#/100 ml)	Avg. Flow MGD	Permit Exceedence
SC0022080	001	10/31/1993	19	2	
SC0022080	001	11/30/1993	129	2.5	
SC0022080	001	12/31/1993	120	3.5	
SC0022080	001	1/31/1994	56	4	
SC0022080	001	2/28/1994	94	4.2	
SC0022080	001	3/31/1994	77	4.1	
SC0022080	001	4/30/1994	47	2.9	
SC0022080	001	5/31/1994	53	2.6	
SC0022080	001	6/30/1994	108	2.4	
SC0022080	001	7/31/1994	81	2.4	
SC0022080	001	8/31/1994	75	2.7	
SC0022080	001	9/30/1994	67	2.4	
SC0022080	001	10/31/1994	72	2.7	
SC0022080	001	11/30/1994	53	2.7	
SC0022080	001	12/31/1994	57	2.97	
SC0022080	001	1/31/1995	61	3.39	
SC0022080	001	2/28/1995	60	3.3	
SC0022080	001	3/31/1995	40	2.83	
SC0022080	001	4/30/1995	51	2.33	
SC0022080	001	5/31/1995	44	2.02	
SC0022080	001	6/30/1995	48	1.91	
SC0022080	001	7/31/1995	46	1.66	
SC0022080	001	8/31/1995	59	2.12	
SC0022080	001	9/30/1995	78	2.38	
SC0022080	001	10/31/1995	40	2.56	
SC0022080	001	11/30/1995	43	2.77	
SC0022080	001	12/31/1995	38	2.79	
SC0022080	001	1/31/1996	54	3.4	
SC0022080	001	2/29/1996	51	3.08	
SC0022080	001	3/31/1996	59	3.07	
SC0022080	001	4/30/1996	68	2.98	
SC0022080	001	5/31/1996	49	2.71	

*Facility ceased discharging to the Cane Creek Watershed in August 1996.

Appendix B

Hydrology Calibration and Validation

The following pages present graphs depicting model runs versus observed flow data for the calibration period (October 1, 1997 to September 30, 1998). Additional tables are provided as validation of the model calibration. The hydrology was validated for the longer time period of October 1, 1990 to September 30, 2000.

Although the nearest weather station (SC4918) was selected for modeling, localized rainfall events were not always reflected in actual rainfall recorded data. This resulted in discrepancies between modeled and observed flow for various storms throughout the calibration and validation time period (e.g. July, 1999 through February 2000).

It is also apparent from the flow duration curves that the model slightly overpredicts baseflow in the stream. Due to the fact that the critical contributions for elevated bacteria concentrations were generally during storm events, the calibration focused more on storm flow prediction. The overprediction of baseflow did not have a significant effect on the allocation process and TMDL development.

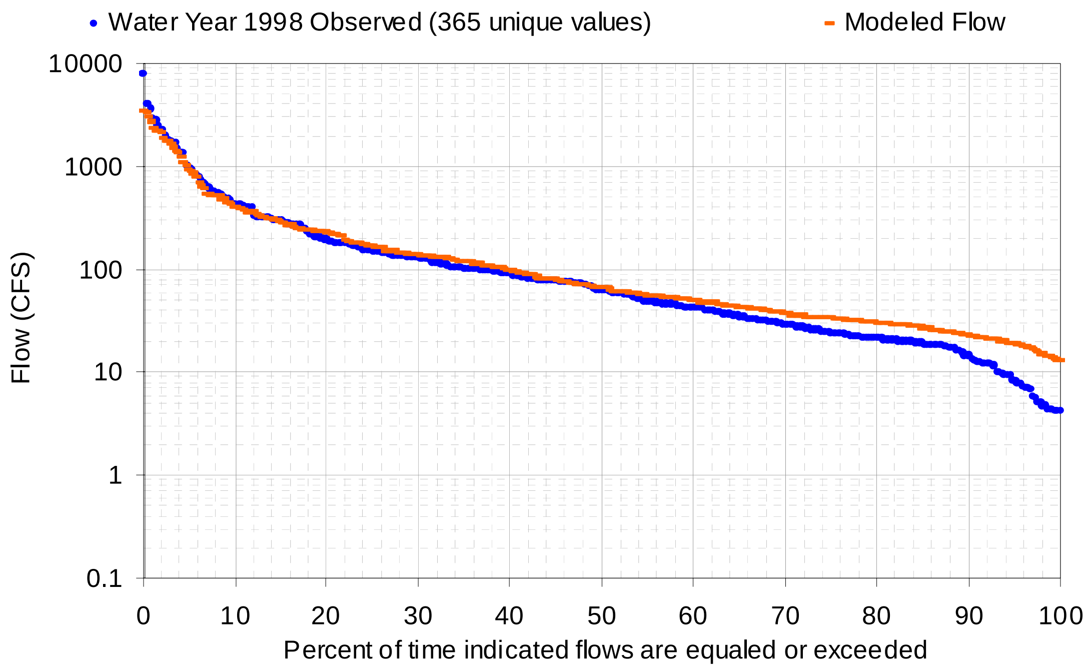


Figure B-1. Flow Duration Analysis for Water Year 1998 at Flow Estimation Location

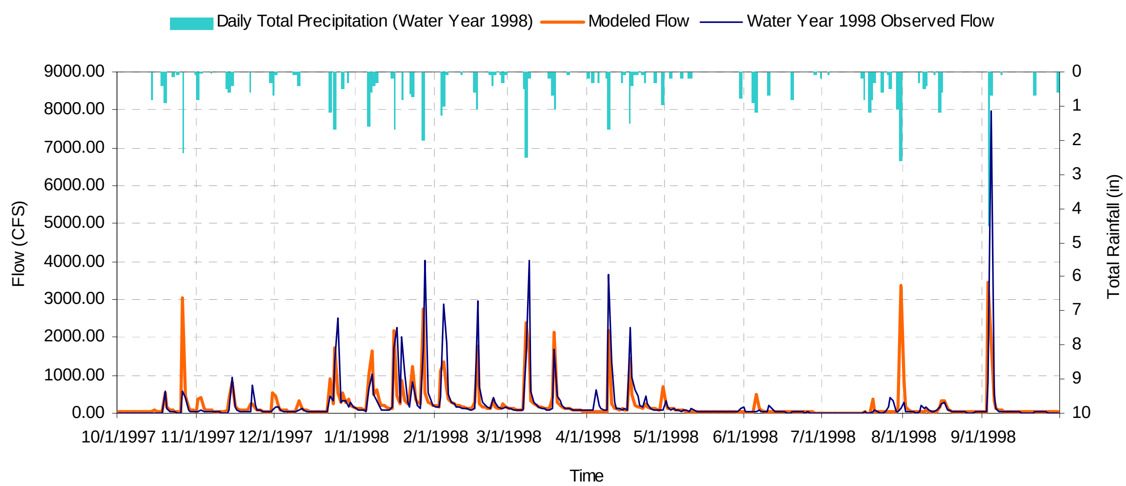


Figure B-2. Hydrology Calibration for Water Year 1998 at Flow Estimation Location

Table B-1. Statistical Hydrology Analysis at Flow Estimation Location for Water Year 1998

Simulation Name:	Cane Creek	**Simulation Period:**	
		Watershed Area (ac):	104267.60
998.00	**1998**		
Type of Year (1=Calendar, 2=Water Year)	**2**	**Baseflow PERCENTILE:**	2.5
Water Year 1998:		*Usually 1%-5%*	
10/1/1997 to 9/30/1998			
Total Simulated In-stream Flow:	**17.90**	Total Observed In-stream Flow:	**20.01**
Total of highest 10% flows:	**10.85**	Total of Observed highest 10% flows:	**13.52**
Total of lowest 50% flows:	**1.50**	Total of Observed Lowest 50% flows:	**1.17**
Simulated Summer Flow Volume (months 7-9):	**3.24**	Observed Summer Flow Volume (7-9):	**3.19**
Simulated Fall Flow Volume (months 10-12):	**4.02**	Observed Fall Flow Volume (10-12):	**2.95**
Simulated Winter Flow Volume (months 1-3):	**8.21**	Observed Winter Flow Volume (1-3):	**10.14**
Simulated Spring Flow Volume (months 4-6):	**2.44**	Observed Spring Flow Volume (4-6):	**3.74**
Total Simulated Storm Volume:	**16.59**	Total Observed Storm Volume:	**19.58**
Simulated Summer Storm Volume (7-9):	**2.91**	Observed Summer Storm Volume (7-9):	**3.08**
Errors (Simulated-Observed)		*Recommended Criteria*	
Error in total volume:	**-11.79**	10	
Error in 50% lowest flows:	**22.27**	10	
Error in 10% highest flows:	**-24.60**	15	
Seasonal volume error - Summer:	**1.75**	30	
Seasonal volume error - Fall:	**26.63**	30	
Seasonal volume error - Winter:	**-23.52**	30	
Seasonal volume error - Spring:	**-53.56**	30	
Error in storm volumes:	**-18.02**	20	
Error in summer storm volumes:	**-5.56**	50	

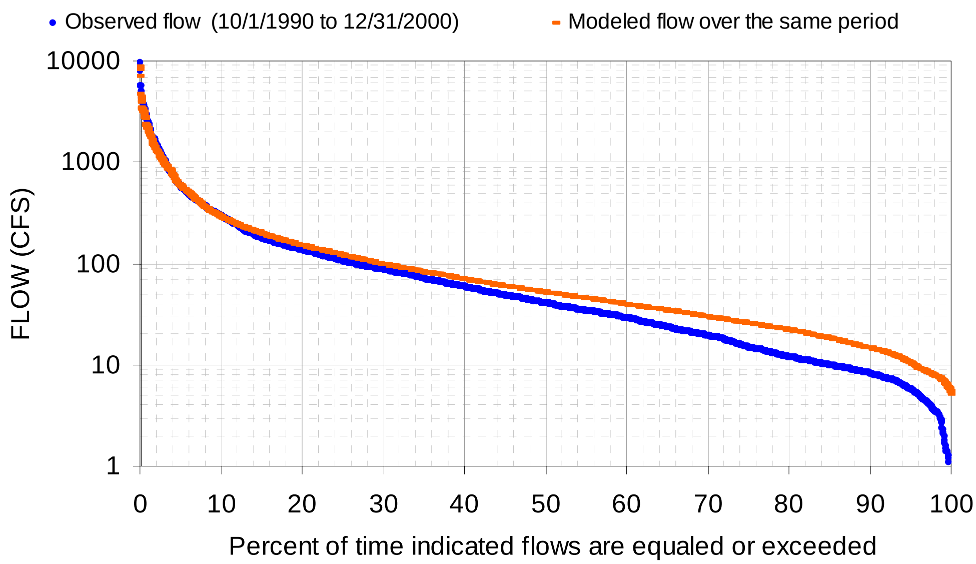


Figure B-3. Hydrology Validation: Flow Duration Analysis for Water Years 1990 to 2000 at Flow Estimation Location

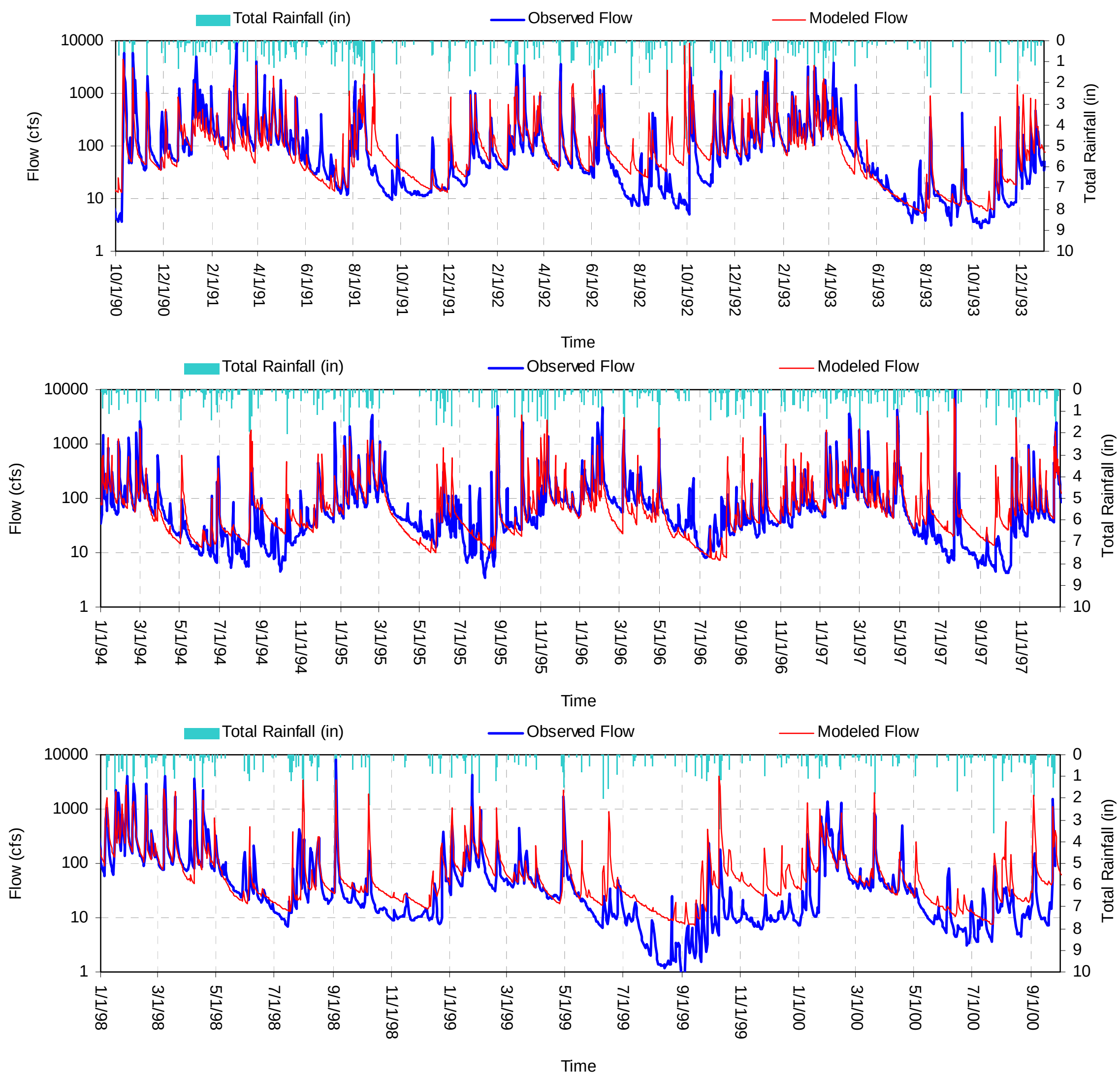


Figure B-4. Hydrology Validation at Flow Estimation Location for Water Years 1990 to 2000

Table B-2. Statistical hydrology analysis at flow estimation location for water year 1990 to 2000

Simulation Name:	Cane Creek	**Simulation Period:**	
		Watershed Area (ac):	104267.60
Period for Flow Analysis			
Begin Date:	**10/01/90**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/00**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**133.28**	Total Observed In-stream Flow:	**134.19**
Total of highest 10% flows:	**81.11**	Total of Observed highest 10% flows:	**90.55**
Total of lowest 50% flows:	**12.05**	Total of Observed Lowest 50% flows:	**8.13**
Simulated Summer Flow Volume (months 7-9):	**23.53**	Observed Summer Flow Volume (7-9):	**14.99**
Simulated Fall Flow Volume (months 10-12):	**34.56**	Observed Fall Flow Volume (10-12):	**25.85**
Simulated Winter Flow Volume (months 1-3):	**51.99**	Observed Winter Flow Volume (1-3):	**70.07**
Simulated Spring Flow Volume (months 4-6):	**23.19**	Observed Spring Flow Volume (4-6):	**23.27**
Total Simulated Storm Volume:	**125.97**	Total Observed Storm Volume:	**130.80**
Simulated Summer Storm Volume (7-9):	**21.70**	Observed Summer Storm Volume (7-9):	**14.16**
Errors (Simulated-Observed)		*Recommended Criteria*	
Error in total volume:	**-0.68**	10	
Error in 50% lowest flows:	**32.52**	10	
Error in 10% highest flows:	**-11.64**	15	
Seasonal volume error - Summer:	**36.28**	30	
Seasonal volume error - Fall:	**25.21**	30	
Seasonal volume error - Winter:	**-34.78**	30	
Seasonal volume error - Spring:	**-0.32**	30	
Error in storm volumes:	**-3.83**	20	
Error in summer storm volumes:	**34.76**	50	

Appendix C

Water Quality Data Used for Water Quality Calibration

Table C-1. Fecal coliform bacteria data at water quality station CW-017 (Cane Creek)

Agency*	Station ID	Date	Parameter Name	Value (FC counts/100 mL)
SCDHEC	CW-017	5/25/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	71
SCDHEC	CW-017	6/28/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	58
SCDHEC	CW-017	7/12/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	7
SCDHEC	CW-017	8/20/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	96
SCDHEC	CW-017	9/6/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	57
SCDHEC	CW-017	10/8/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	77
SCDHEC	CW-017	5/22/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	200
SCDHEC	CW-017	6/4/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	200
SCDHEC	CW-017	7/1/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	58
SCDHEC	CW-017	8/5/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	200
SCDHEC	CW-017	9/9/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	130
SCDHEC	CW-017	10/7/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	87
SCDHEC	CW-017	5/27/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	640
SCDHEC	CW-017	6/16/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	3300
SCDHEC	CW-017	7/9/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	124
SCDHEC	CW-017	8/11/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	290
SCDHEC	CW-017	9/24/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	350
SCDHEC	CW-017	10/27/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	380
SCDHEC	CW-017	11/10/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	190
SCDHEC	CW-017	12/15/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	350
SCDHEC	CW-017	1/5/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	3300
SCDHEC	CW-017	2/2/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	680
SCDHEC	CW-017	3/24/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	940
SCDHEC	CW-017	4/28/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	4000
SCDHEC	CW-017	5/5/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	13000
SCDHEC	CW-017	6/1/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	50
SCDHEC	CW-017	7/28/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	520
SCDHEC	CW-017	8/26/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	20
SCDHEC	CW-017	9/30/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	140
SCDHEC	CW-017	10/28/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	6000
SCDHEC	CW-017	5/17/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	420
SCDHEC	CW-017	6/22/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	100
SCDHEC	CW-017	7/13/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	360
SCDHEC	CW-017	8/16/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	6000
SCDHEC	CW-017	9/8/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	420
SCDHEC	CW-017	10/19/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	660
SCDHEC	CW-017	5/30/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	420
SCDHEC	CW-017	6/7/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	14000
SCDHEC	CW-017	7/19/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1900
SCDHEC	CW-017	8/2/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	4300
SCDHEC	CW-017	9/19/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	440
SCDHEC	CW-017	10/24/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	900
SCDHEC	CW-017	5/16/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	120

Agency*	Station ID	Date	Parameter Name	Value (FC counts/100 mL)
SCDHEC	CW-017	6/10/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	400
SCDHEC	CW-017	7/18/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	100
SCDHEC	CW-017	8/6/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1500
SCDHEC	CW-017	10/2/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	10000
SCDHEC	CW-017	5/1/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	980
SCDHEC	CW-017	6/25/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	20
SCDHEC	CW-017	7/8/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	20
SCDHEC	CW-017	8/18/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	40
SCDHEC	CW-017	9/16/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	20
SCDHEC	CW-017	10/14/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	22
SCDHEC	CW-017	3/2/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	500
SCDHEC	CW-017	4/2/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	460
SCDHEC	CW-017	5/12/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	170
SCDHEC	CW-017	6/2/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	45
SCDHEC	CW-017	7/7/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	10
SCDHEC	CW-017	8/10/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	6600
SCDHEC	CW-017	9/15/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	110
SCDHEC	CW-017	10/27/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	16
SCDHEC	CW-017	8/3/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	4
SCDHEC	CW-017	9/23/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1500
SCDHEC	CW-017	10/28/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	40
SCDHEC	CW-017	5/8/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	30
SCDHEC	CW-017	6/14/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	5
SCDHEC	CW-017	7/18/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	20
SCDHEC	CW-017	8/16/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	10
SCDHEC	CW-017	9/6/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	300
SCDHEC	CW-017	10/10/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1500

*SCDHEC = South Carolina Department of Health and Environmental Control

Table C-2. Fecal coliform bacteria data at water quality station CL-131 (Bear Creek)

*SCDHEC = South Carolina Department of Health and Environmental Control

Agency*	Station ID	Date	Parameter Name	Value (FC counts/100 mL)
SCDHEC	CW-131	5/22/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2100
SCDHEC	CW-131	6/26/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	500
SCDHEC	CW-131	7/17/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	60
SCDHEC	CW-131	8/22/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2000
SCDHEC	CW-131	9/26/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	340
SCDHEC	CW-131	10/18/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1000
SCDHEC	CW-131	5/29/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2600
SCDHEC	CW-131	6/25/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	590
SCDHEC	CW-131	7/29/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	9400
SCDHEC	CW-131	8/19/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	20000
SCDHEC	CW-131	9/5/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	300

Agency*	Station ID	Date	Parameter Name	Value (FC counts/100 mL)
SCDHEC	CW-131	10/8/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	260
SCDHEC	CW-131	5/20/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	540
SCDHEC	CW-131	6/10/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1140
SCDHEC	CW-131	7/23/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	10000
SCDHEC	CW-131	8/11/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	200
SCDHEC	CW-131	9/10/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	580
SCDHEC	CW-131	10/6/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2000
SCDHEC	CW-131	5/5/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	10000
SCDHEC	CW-131	6/17/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	300
SCDHEC	CW-131	7/28/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	580
SCDHEC	CW-131	8/26/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1480
SCDHEC	CW-131	9/30/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	280
SCDHEC	CW-131	10/28/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	300
SCDHEC	CW-131	5/17/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	7100
SCDHEC	CW-131	6/22/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2800
SCDHEC	CW-131	7/13/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	560
SCDHEC	CW-131	8/16/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	9400
SCDHEC	CW-131	9/8/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	220
SCDHEC	CW-131	10/19/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	7900
SCDHEC	CW-131	5/30/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	20000
SCDHEC	CW-131	6/7/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	10000
SCDHEC	CW-131	7/19/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1000000
SCDHEC	CW-131	8/2/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	3800
SCDHEC	CW-131	9/19/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1000
SCDHEC	CW-131	10/24/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2200
SCDHEC	CW-131	5/16/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	10000
SCDHEC	CW-131	6/10/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1500
SCDHEC	CW-131	7/18/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1100
SCDHEC	CW-131	10/2/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	3300
SCDHEC	CW-131	5/1/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	5200
SCDHEC	CW-131	6/25/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	310
SCDHEC	CW-131	7/8/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	6000
SCDHEC	CW-131	8/19/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1100
SCDHEC	CW-131	9/16/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	460
SCDHEC	CW-131	10/14/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	90
SCDHEC	CW-131	5/12/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	460
SCDHEC	CW-131	6/2/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	740
SCDHEC	CW-131	8/10/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	6600
SCDHEC	CW-131	9/15/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	350
SCDHEC	CW-131	10/27/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	90
SCDHEC	CW-131	8/19/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	920
SCDHEC	CW-131	9/27/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	10000
SCDHEC	CW-131	10/28/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	240
SCDHEC	CW-131	5/8/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	550
SCDHEC	CW-131	6/14/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1800

Agency*	Station ID	Date	Parameter Name	Value (FC counts/100 mL)
SCDHEC	CW-131	7/18/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	90
SCDHEC	CW-131	8/16/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	510
SCDHEC	CW-131	9/6/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	390
SCDHEC	CW-131	10/10/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2000

Table C-3. Fecal coliform bacteria data at water quality station CW-047 (Gills Creek)

Agency*	Station ID	Date	Parameter Name	Value (FC counts/100 mL)
SCDHEC	CW-047	5/22/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	640
SCDHEC	CW-047	6/26/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	120
SCDHEC	CW-047	7/17/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	610
SCDHEC	CW-047	8/22/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2000
SCDHEC	CW-047	9/26/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	220
SCDHEC	CW-047	10/18/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	190
SCDHEC	CW-047	5/29/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	510
SCDHEC	CW-047	6/25/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	590
SCDHEC	CW-047	7/29/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2100
SCDHEC	CW-047	8/19/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	700
SCDHEC	CW-047	9/5/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	100
SCDHEC	CW-047	10/8/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	180
SCDHEC	CW-047	5/20/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2200
SCDHEC	CW-047	6/10/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	980
SCDHEC	CW-047	7/23/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	100000
SCDHEC	CW-047	8/11/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	740
SCDHEC	CW-047	9/10/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1600
SCDHEC	CW-047	10/6/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2000
SCDHEC	CW-047	5/5/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	9700
SCDHEC	CW-047	6/17/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1100
SCDHEC	CW-047	7/28/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1300
SCDHEC	CW-047	8/26/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	740
SCDHEC	CW-047	9/30/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	460
SCDHEC	CW-047	10/28/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	40
SCDHEC	CW-047	5/17/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	340
SCDHEC	CW-047	6/22/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	260
SCDHEC	CW-047	7/13/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	15000
SCDHEC	CW-047	8/16/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	5800
SCDHEC	CW-047	9/8/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	990
SCDHEC	CW-047	10/19/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	180
SCDHEC	CW-047	5/30/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	880
SCDHEC	CW-047	6/7/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1400
SCDHEC	CW-047	7/19/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	470
SCDHEC	CW-047	8/2/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	820
SCDHEC	CW-047	9/19/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	540

Agency*	Station ID	Date	Parameter Name	Value (FC counts/100 mL)
SCDHEC	CW-047	10/24/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	620
SCDHEC	CW-047	5/29/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	3300
SCDHEC	CW-047	6/10/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1700
SCDHEC	CW-047	7/18/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2900
SCDHEC	CW-047	8/6/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	8800
SCDHEC	CW-047	10/2/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1100
SCDHEC	CW-047	5/1/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	110
SCDHEC	CW-047	6/25/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	3200
SCDHEC	CW-047	7/8/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	430
SCDHEC	CW-047	8/18/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	70
SCDHEC	CW-047	9/16/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2000
SCDHEC	CW-047	10/14/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2200
SCDHEC	CW-047	5/12/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	130
SCDHEC	CW-047	6/2/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	990
SCDHEC	CW-047	7/7/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	390
SCDHEC	CW-047	9/15/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	350
SCDHEC	CW-047	10/27/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	80
SCDHEC	CW-047	8/19/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1100
SCDHEC	CW-047	9/27/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	16000
SCDHEC	CW-047	10/28/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	420
SCDHEC	CW-047	5/8/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	210
SCDHEC	CW-047	6/14/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	3300
SCDHEC	CW-047	7/18/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1100
SCDHEC	CW-047	8/16/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	260
SCDHEC	CW-047	9/6/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1300
SCDHEC	CW-047	10/10/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	540

*SCDHEC = South Carolina Department of Health and Environmental Control

Table C-4. Fecal coliform bacteria data at water quality station CW-151 (Upper Bear Creek)

Agency*	Station ID	Date	Parameter Name	Value (FC counts/100 mL)
SCDHEC	CW-151	5/22/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	520
SCDHEC	CW-151	6/26/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	30
SCDHEC	CW-151	7/17/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	60
SCDHEC	CW-151	8/22/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	3300
SCDHEC	CW-151	9/26/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	100
SCDHEC	CW-151	10/18/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	260
SCDHEC	CW-151	5/29/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	170
SCDHEC	CW-151	6/25/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	170
SCDHEC	CW-151	7/29/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	570
SCDHEC	CW-151	8/19/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	520

Agency*	Station ID	Date	Parameter Name	Value (FC counts/100 mL)
SCDHEC	CW-151	9/5/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	340
SCDHEC	CW-151	10/8/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	100
SCDHEC	CW-151	5/20/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	180
SCDHEC	CW-151	6/10/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	220
SCDHEC	CW-151	7/23/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	200
SCDHEC	CW-151	8/11/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	120
SCDHEC	CW-151	9/10/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	60
SCDHEC	CW-151	10/6/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2000
SCDHEC	CW-151	5/5/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1800
SCDHEC	CW-151	6/17/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	5300
SCDHEC	CW-151	7/28/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	220
SCDHEC	CW-151	8/26/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	70
SCDHEC	CW-151	9/30/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	70
SCDHEC	CW-151	10/28/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	310
SCDHEC	CW-151	11/9/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	10
SCDHEC	CW-151	12/2/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	140
SCDHEC	CW-151	5/17/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	80
SCDHEC	CW-151	6/22/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	240
SCDHEC	CW-151	7/13/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	10000
SCDHEC	CW-151	8/16/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1000
SCDHEC	CW-151	9/8/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	840
SCDHEC	CW-151	10/19/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	480
SCDHEC	CW-151	5/30/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	420
SCDHEC	CW-151	6/7/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	740
SCDHEC	CW-151	7/19/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	80
SCDHEC	CW-151	8/2/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1320
SCDHEC	CW-151	9/19/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	200
SCDHEC	CW-151	10/24/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	680
SCDHEC	CW-151	5/29/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	160
SCDHEC	CW-151	6/10/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	620
SCDHEC	CW-151	7/18/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	100
SCDHEC	CW-151	8/6/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	120
SCDHEC	CW-151	10/2/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	530
SCDHEC	CW-151	6/25/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	30
SCDHEC	CW-151	7/8/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	64
SCDHEC	CW-151	8/19/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	240
SCDHEC	CW-151	9/16/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	12
SCDHEC	CW-151	10/14/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	3
SCDHEC	CW-151	5/13/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	130
SCDHEC	CW-151	6/2/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	260
SCDHEC	CW-151	7/7/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	130
SCDHEC	CW-151	8/18/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	290
SCDHEC	CW-151	9/15/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	280
SCDHEC	CW-151	10/26/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	13
SCDHEC	CW-151	8/19/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	86

Agency*	Station ID	Date	Parameter Name	Value (FC counts/100 mL)
SCDHEC	CW-151	9/28/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	0
SCDHEC	CW-151	10/28/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	400
SCDHEC	CW-151	5/8/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	290
SCDHEC	CW-151	7/18/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	20
SCDHEC	CW-151	8/16/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	25
SCDHEC	CW-151	9/6/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	410
SCDHEC	CW-151	10/10/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	570

*SCDHEC = South Carolina Department of Health and Environmental Control

Table C-5. Fecal coliform bacteria data at water quality station CW-185 (Upper Cane Creek)

Agency*	Station ID	Date	Parameter Name	Value (FC counts/100 mL)
SCDHEC	CW-185	5/22/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	4100
SCDHEC	CW-185	6/26/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	80
SCDHEC	CW-185	7/16/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	400
SCDHEC	CW-185	8/22/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	2000
SCDHEC	CW-185	9/26/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	25
SCDHEC	CW-185	10/18/1990	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	140
SCDHEC	CW-185	5/29/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	60
SCDHEC	CW-185	6/25/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	90
SCDHEC	CW-185	7/29/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	100
SCDHEC	CW-185	8/19/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	20
SCDHEC	CW-185	9/5/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	50
SCDHEC	CW-185	10/8/1991	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	460
SCDHEC	CW-185	5/20/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	210
SCDHEC	CW-185	6/10/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	350
SCDHEC	CW-185	7/23/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	3300
SCDHEC	CW-185	8/11/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	100
SCDHEC	CW-185	9/10/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	110
SCDHEC	CW-185	10/6/1992	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	790
SCDHEC	CW-185	5/5/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	7400
SCDHEC	CW-185	6/17/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1700
SCDHEC	CW-185	7/28/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	20
SCDHEC	CW-185	8/26/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	30
SCDHEC	CW-185	9/30/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	290
SCDHEC	CW-185	10/28/1993	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	30
SCDHEC	CW-185	5/17/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	120
SCDHEC	CW-185	6/22/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	250
SCDHEC	CW-185	7/13/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	340
SCDHEC	CW-185	8/16/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	640
SCDHEC	CW-185	9/8/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	200
SCDHEC	CW-185	10/19/1994	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	240

Agency*	Station ID	Date	Parameter Name	Value (FC counts/100 mL)
SCDHEC	CW-185	5/30/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	430
SCDHEC	CW-185	6/7/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1200
SCDHEC	CW-185	7/19/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	340
SCDHEC	CW-185	8/2/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	160
SCDHEC	CW-185	9/19/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	190
SCDHEC	CW-185	10/24/1995	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	400
SCDHEC	CW-185	5/16/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	280
SCDHEC	CW-185	6/10/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	220
SCDHEC	CW-185	7/18/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	160
SCDHEC	CW-185	8/6/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	50
SCDHEC	CW-185	10/2/1996	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	1100
SCDHEC	CW-185	5/1/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	480
SCDHEC	CW-185	6/25/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	180
SCDHEC	CW-185	7/8/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	400
SCDHEC	CW-185	8/19/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	880
SCDHEC	CW-185	9/16/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	90
SCDHEC	CW-185	10/14/1997	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	10
SCDHEC	CW-185	5/12/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	45
SCDHEC	CW-185	6/2/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	230
SCDHEC	CW-185	7/7/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	58
SCDHEC	CW-185	8/10/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	280
SCDHEC	CW-185	9/16/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	120
SCDHEC	CW-185	10/27/1998	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	90
SCDHEC	CW-185	8/19/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	80
SCDHEC	CW-185	9/23/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	580
SCDHEC	CW-185	10/28/1999	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	80
SCDHEC	CW-185	5/8/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	95
SCDHEC	CW-185	6/14/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	310
SCDHEC	CW-185	7/18/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	10
SCDHEC	CW-185	8/16/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	10
SCDHEC	CW-185	10/11/2000	FECAL COLIFORM,MEMBR FILTER,M-FC BROTH,44.5 C	120

Appendix D

Water Quality Calibration

The following pages present water quality simulation graphs depicting model runs versus observed water quality data for impaired stations in the Cane Creek Watershed. The water quality calibration was performed for the period 1995 to 1997. The validation period was from 1998 to 2000.

Missing simulated concentration peaks during August 1999 and October 2000 at water quality stations are likely attributed to missing rainfall data. In some cases the model failed to simulate observed concentrations during low flow conditions. This is likely due to the limitations associated with simulating time variable loadings (i.e., animals in stream or failing septic systems) as constant loadings.

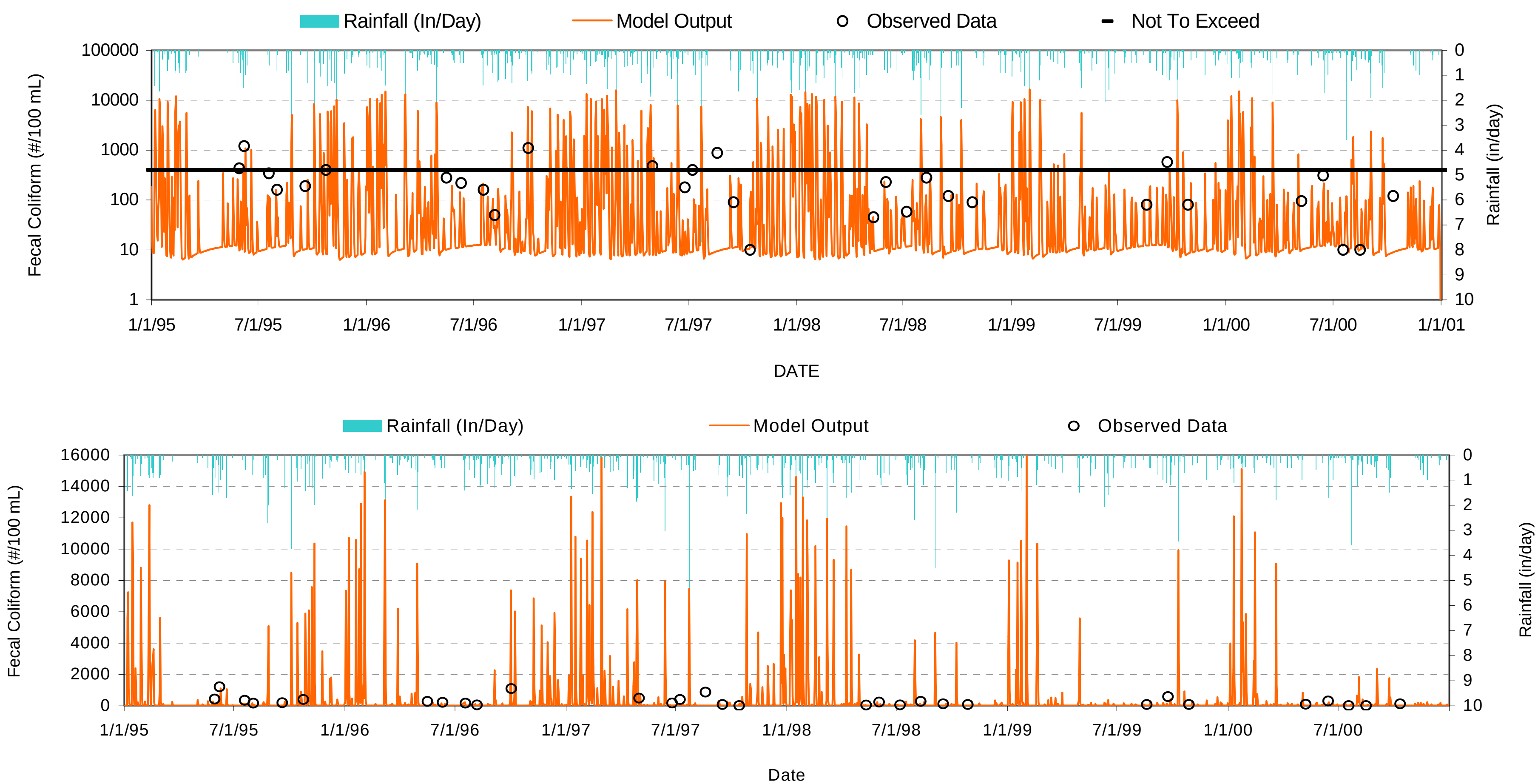
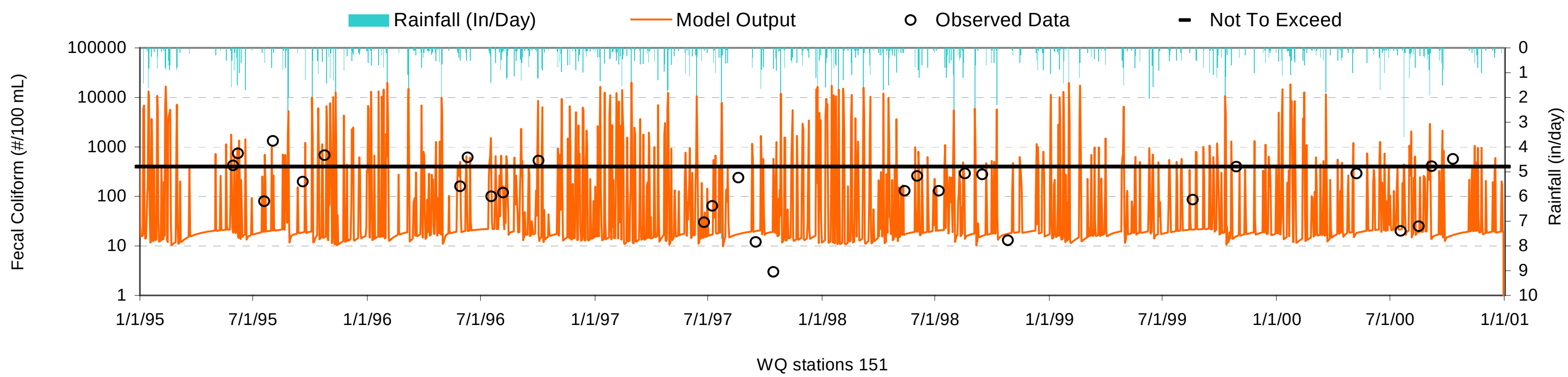


Figure D-1. Fecal coliform bacteria calibration at water quality station CW-185 (Upper Cane Creek) for January 1995 through January 2001



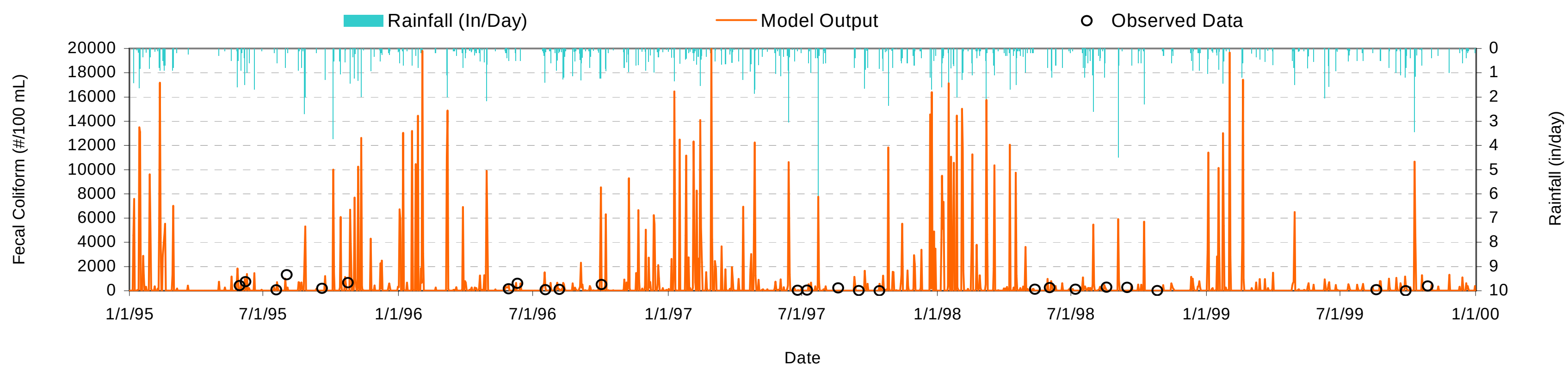


Figure D-2. Fecal coliform bacteria calibration at water quality station CW-151 (Upper Bear Creek) for January 1995 through January 2001

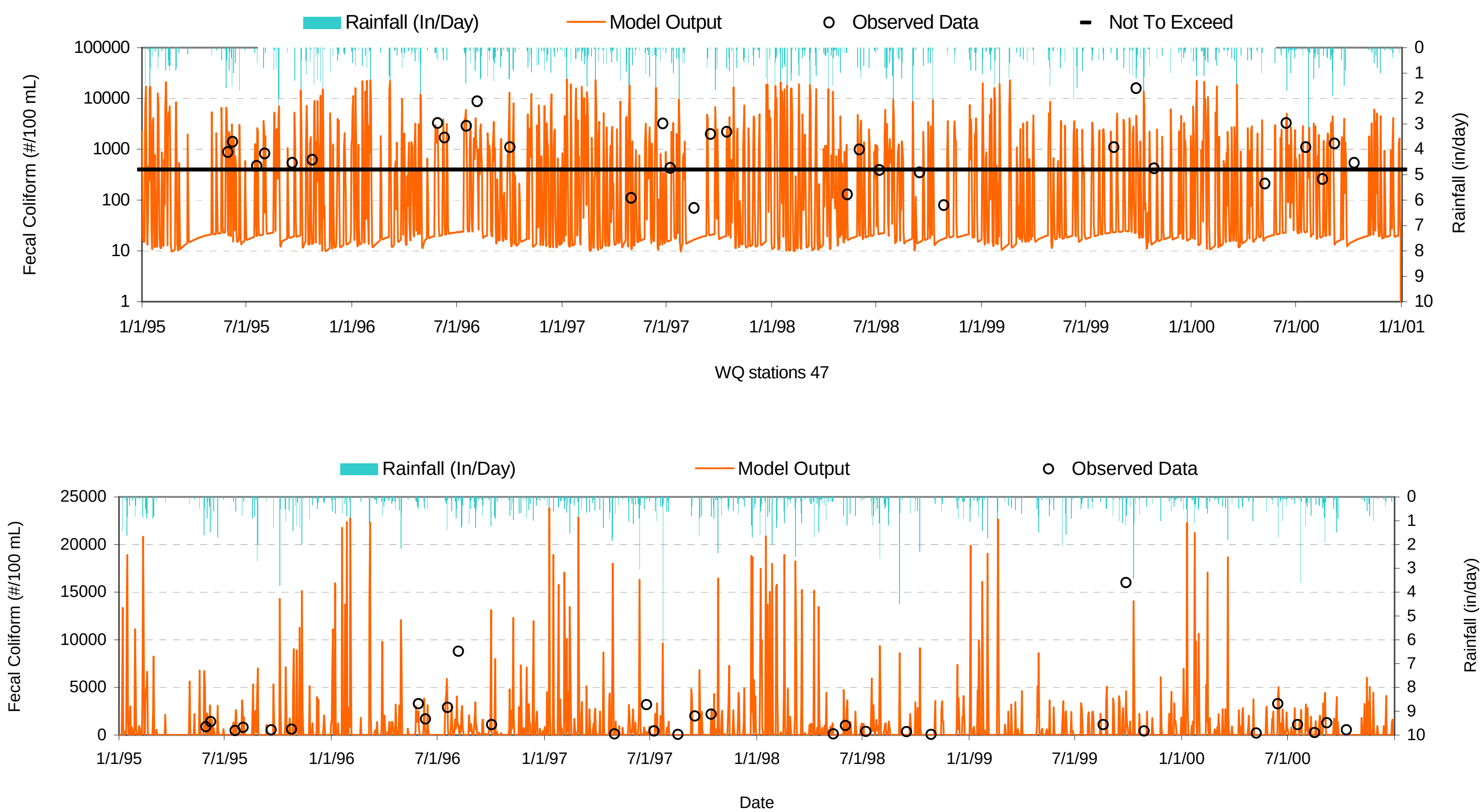
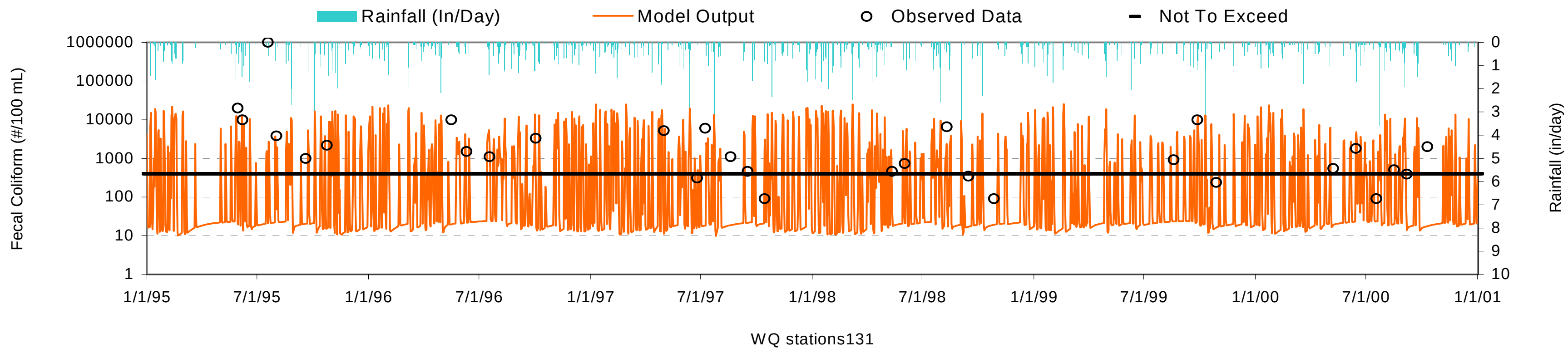


Figure D-3. **Fecal coliform bacteria calibration at water quality station CW-047 (Gills Creek) for January 1995 through January 2001**



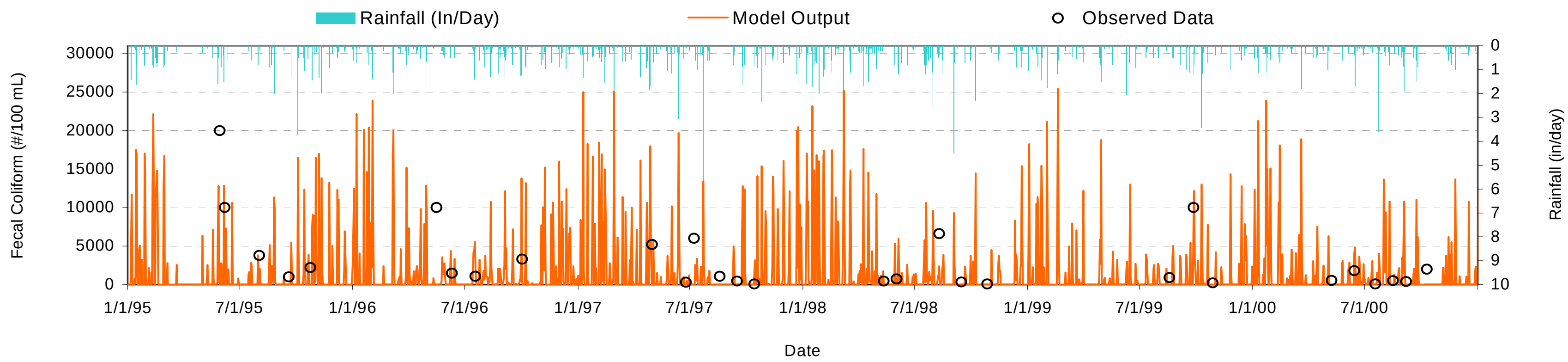
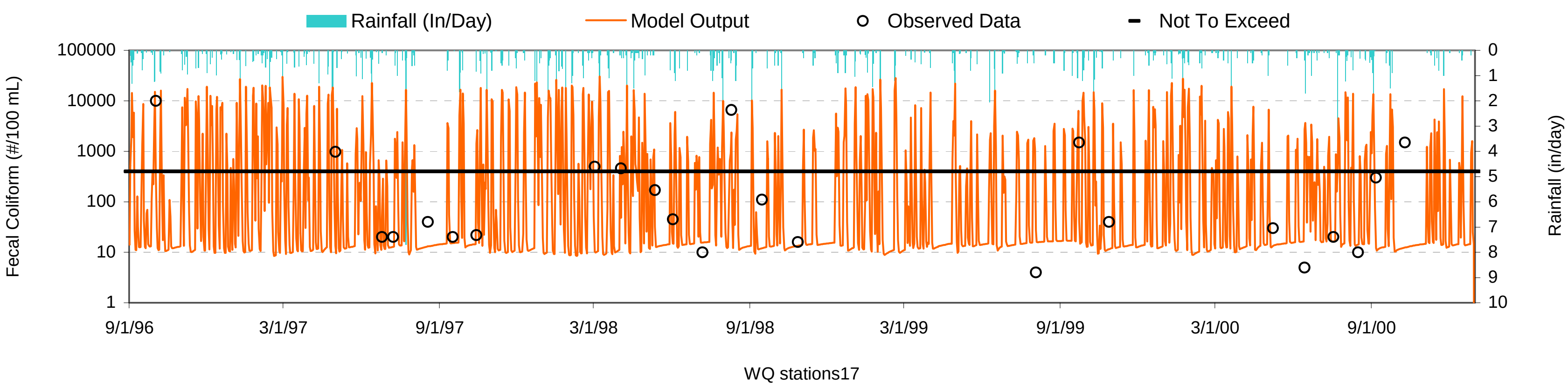


Figure D-4. Fecal coliform bacteria calibration at water quality station CW-131 (Bear Creek) for January 1995 through January 2001



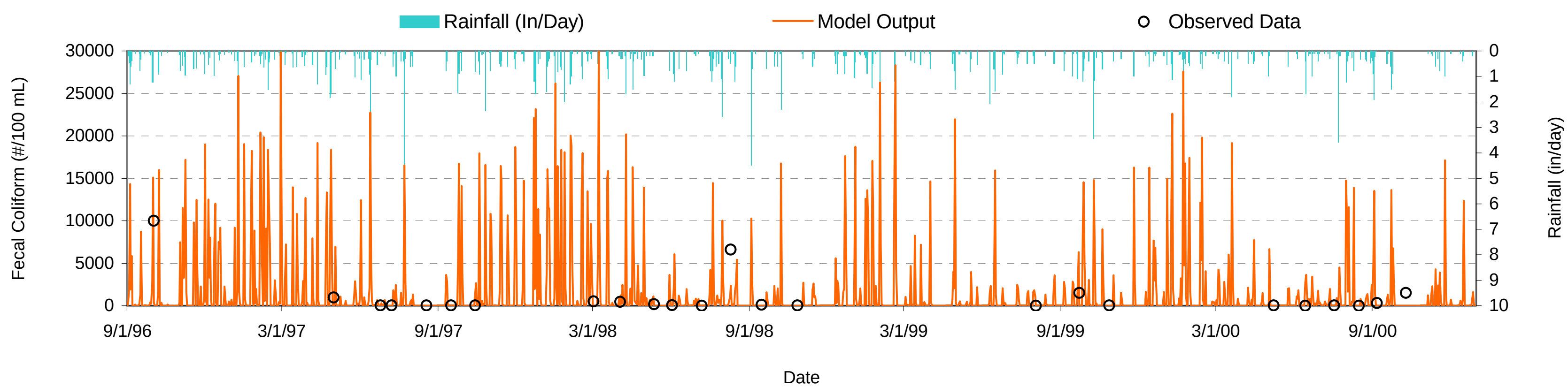


Figure D-5. Fecal coliform bacteria calibration at water quality station CW-017 (Cane Creek) for January 1996 through January 2001

Appendix E

TMDL Allocation Plots at Impaired Water Quality Stations

The figures in Appendix E present the allocation analysis for the geometric mean criteria at each water quality station in the Cane Creek watershed. Each of these plots shows 30-day geometric mean model results for existing and allocation conditions. A text box on each of these plots denotes the last day of the 30-day critical period. These plots display the entire time period used to identify the geometric mean critical period. The concentration that occurred during the identified critical date is not necessarily the highest exceedence for the given subbasin. This is due to the exclusion of exceedences that may have occurred during the highest and lowest ten percent of flows.

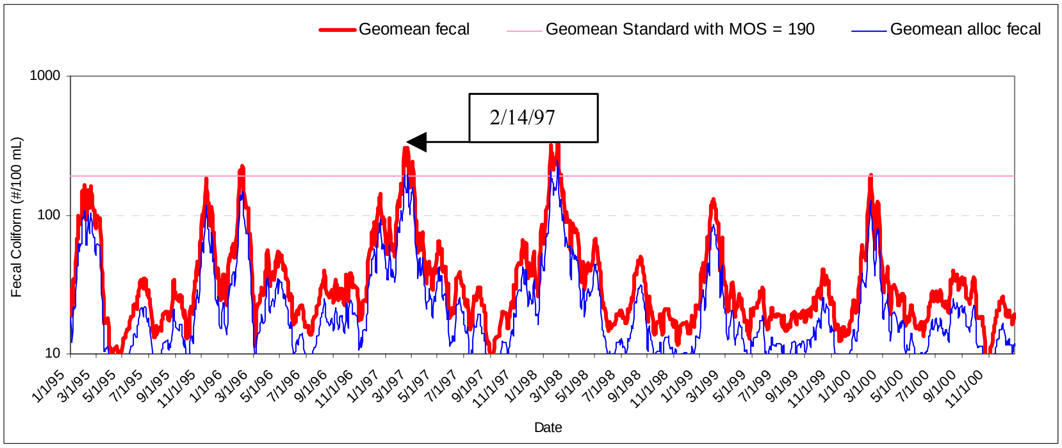


Figure E-1. Existing and allocated geometric mean fecal coliform bacteria concentrations at water quality station CW-185

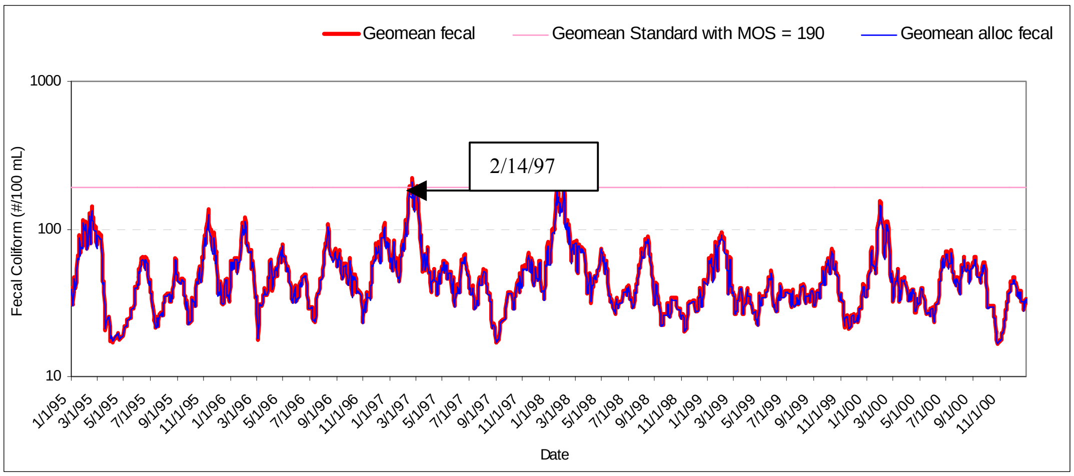


Figure E-2. Existing and allocated geometric mean fecal coliform bacteria concentrations at water quality station CW-151

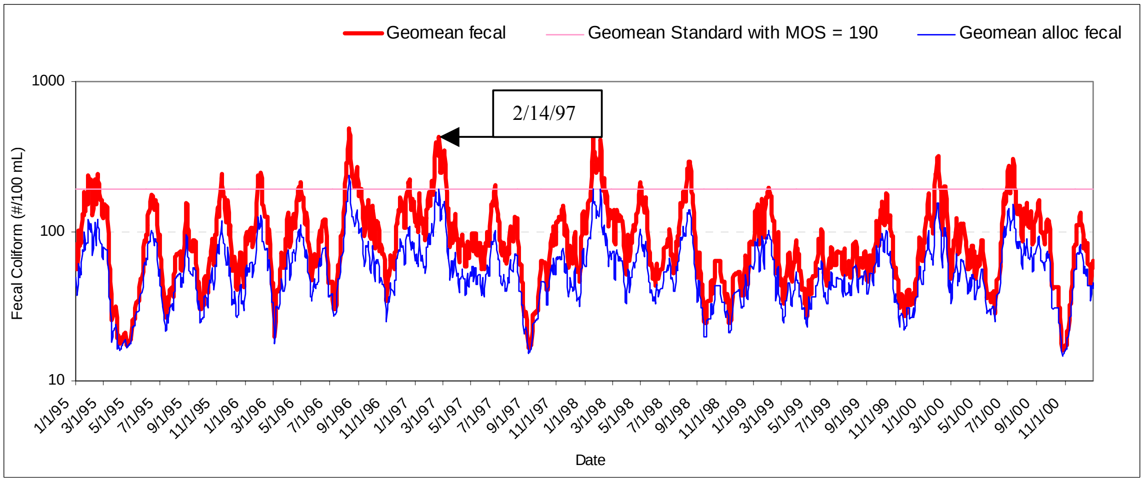


Figure E-3. Existing and allocated geometric mean fecal coliform bacteria concentrations at water quality station CW-047

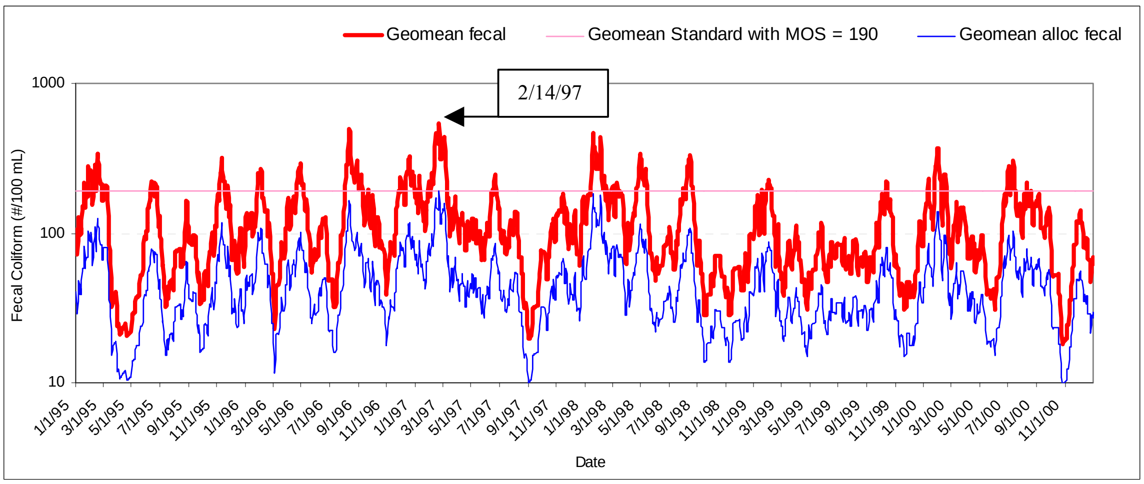


Figure E-4. Existing and allocated geometric mean fecal coliform bacteria concentrations at water quality station CW-131

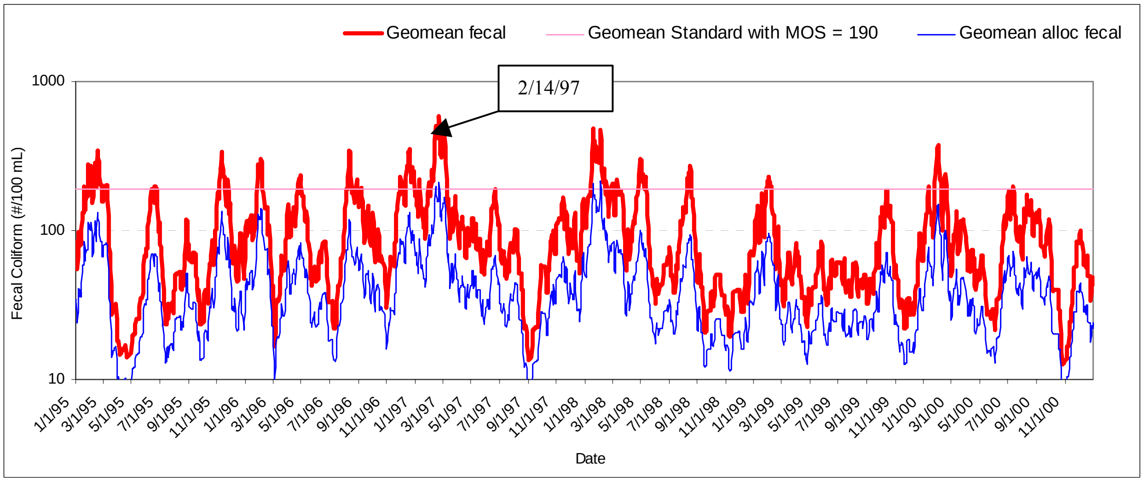


Figure E-5. Existing and allocated geometric mean fecal coliform bacteria concentrations at water quality station CW-017

Appendix F

Public Participation

The following public notice was published in *The State* newspaper on May 28, 2003 and e-mailed to a list of interested persons. The Cane Creek TMDL document was placed on the South Carolina Department of Health and Environmental Control web site from May 28 through June 30, 2003.

PUBLIC NOTICE

AVAILABILTY OF PROPOSED TOTAL MAXIMUM DAILY LOADS FOR WATERS AND POLLUTANTS OF CONCERN IN THE STATE OF SOUTH CAROLINA

Cane Creek and tributaries, Lancaster County, SC and Union County, NC

Four Hole Swamp and tributaries, Orangeburg, Calhoun, Dorchester and Berkeley Counties

Section 303(d)(1) of the Clean Water Act (CWA), 33 U.S.C. §1313(d)(1)(C), and the implementing regulation of the US Environmental Protection Agency (EPA, 40 C.F.R. § 130.7(c)(1), require the establishment of total maximum daily loads (TMDLs) for waters identified as impaired pursuant to § 303(d)(1)(A) of the CWA. Each of these TMDLs is to be established at a level necessary to implement applicable water quality standards with seasonal variations and a margin of safety. The South Carolina Department of Health and Environmental Control (DHEC) has developed proposed fecal coliform bacteria TMDLs for the § 303(d)(1)(A) waters: Cane Creek and tributaries; Four Hole Swamp and tributaries. Upon review of public comment and revision, if necessary, the Department will submit these TMDLs to EPA for approval as final. Persons wishing to comment on the proposed TMDLs or to offer new data are invited to submit the same in writing no later than June 30, 2003, to:

DHEC Bureau of Water
2600 Bull St.
Columbia, S.C. 29201
Attn: Matthew Carswell

or to carsweme@dhec.sc.gov. Persons may also contact Kathy Stecker at 803-898-4011. Copies of TMDLs can be obtained from the Bureau web site: http://www.scdhec.net/water/ or by writing or e-mailing Mr. Carswell. The administrative record supporting proposed TMDLs is available for review. Requests to review this information must be submitted in writing to DHEC's Freedom of Information Office at 2600 Bull Street, Columbia, SC 29201 or faxed to 803-898-3816. Reproduction of documents is available for $0.25 per page.