Total Maximum Daily Load for Fecal Coliform Bacteria in Chicod Creek, North Carolina

[Waterbody ID 28-101]

Final Report
July 2004

Tar-Pamlico River Basin

Prepared by:
NC Department of Environment and Natural Resources
Division of Water Quality
1617 Mail Service Center
Raleigh, NC 27699-1617

With support from:
Tetra Tech, Inc.
Cape Fear Bldg., Suite 105
3200 Chapel Hill-Nelson Highway
PO Box 14409
Research Triangle Park, NC 27709

Table of Contents

List of Tables iii

List of Figures iv

1 Introduction 1

1.1 Problem Definition 1
1.1.1 TMDL Components 1
1.1.2 Chicod Creek Fecal Coliform Impairments 2
1.2 Watershed Description 2
1.2.1 Landuse/Land Cover 3
1.2.2 Population and Onsite Wastewater Disposal 5
1.2.3 Agriculture 7
1.2.4 Swine Operations 7
1.2.5 Other Livestock Operations 13
1.3 Flow Gaging 13
1.4 Water Quality Monitoring 14
1.4.1 Monitoring Sites 14
1.4.2 Primary Chicod Creek Monitoring Site 15
1.4.3 Control Sites in the Creeping Swamp Watershed 17
1.4.4 Reference Sites in Van Swamp and Durham Creek Watersheds 18
1.4.5 Chicod Creek Upstream Site at Boyd's Crossroads 19
1.4.6 Comparison of Fecal Coliform Statistics at Monitoring Stations 21

2 Source Assessment 23

2.1 Point Source Fecal Coliform Contributions 23
2.2 Nonpoint Source Fecal Coliform Contributions 23
2.2.1 Interpretation of Monitoring Data for Nonpoint Sources 23
2.2.2 Agriculture 25
2.2.3 Animal Operations 25
2.2.4 Onsite Wastewater Disposal 25
2.2.5 Impacts of Silviculture 26
2.3 Analysis of Existing Management Measures 27
2.4 Conceptual Model of Fecal Coliform in Chicod Creek 27

3 Technical Approach to TMDL 29

3.1 TMDL Endpoints 29
3.2 Load-Duration Curves for Fecal Coliform 29
3.3 Determination of Existing Fecal Coliform Load and Assimilative Capacity 33
3.3.1 Instantaneous Criterion 34
3.3.2 Geometric Mean Criterion 36

4 TMDL Development 39

4.1 TMDL Definition 39
4.2 TMDL Endpoints 39
4.3 Critical Conditions 39
4.4 Seasonal Variation 40
4.5 Margin of Safety 40
4.6 Wasteload Allocations 40
4.7 Load Allocations 40
4.8 TMDL Summary 41

5 Report Summary 43

6 TMDL Implementation Plan 45

7 Stream Monitoring 47

8 Future Efforts 49

9 Public Participation 51

10 Further Information 53

11 References 55

12 Appendices 57

Appendix A. Fecal Coliform Data for Chicod Creek A1

Appendix B. Assimilative Capacity and Load Reduction Calculations B1

Appendix C. Public Notification of Public Review Draft of Chicod Creek TMDL.....C1

List of Tables

Table 1. Landuse Tabulation for the Chicod Creek Watershed 5
Table 2. Swine Operations Located in the Chicod Creek Watershed 8
Table 3. Daily Average Stream Flow Statistics for USGS Station 02084160 Chicod Creek at SR1760 Near Simpson, NC, Oct. 1975 – Dec. 2003 13
Table 4. Fecal Coliform Monitoring Stations for the Chicod Creek Analysis 15
Table 5. Comparison of Excursions of Fecal Coliform Criteria in the Chicod Creek Watershed and the Reference and Control Sites (period of record) 22
Table 6. Number of Excursions of the Instantaneous Fecal Coliform Criterion of 400 per 100 mL. Classified by Flow Regime 24
Table 7. Fecal Coliform Target Load and Reduction Requirements Calculated using the Load-Duration Curve Approach 36
Table 8. Fecal Coliform Bacteria Load Allocations for Chicod Creek 41
Table 9. TMDL Summary for Fecal Coliform in Chicod Creek 41
Table A-1. Fecal Coliform and Flow Data at the Primary Site in Chicod Creek (USGS 02084160, NC DWQ O6450000) A1
Table A-2. Fecal Coliform Data at the Upstream Site in Chicod Creek (NCDWQ Site ChC1) A5
Table A-3. 30-day Fecal Coliform Geometric Mean Concentrations and Representative Flows at the Primary Site in Chicod Creek (USGS 02084160, NC DWQ O6450000) A5
Table B-1. Regression of Natural Logarithm of Fecal Coliform Load on Flow Frequency, Chicod Creek Fecal Coliform Data, 1997-2003 .... A2

List of Figures

Figure 1. Location of Chicod Creek Watershed in the Tar/Pamlico Basin, NC 3
Figure 2. NLCD Landuse Data for the Chicod Creek Watershed (1992) 4
Figure 3. Septic System Densities by Census Block (2000) in the Chicod Creek Watershed............. 6
Figure 4. Locations of Swine Operations within the Chicod Creek Watershed................................. 10
Figure 5. Growth in Swine Production Capacity in Chicod Creek Watershed 11
Figure 6. Cumulative Daily Average Flow Frequency Histogram for USGS Station 02084160 14
Figure 7. Daily Fecal Coliform Observations in Chicod Creek at State Road 1760.......................... 16
Figure 8. Fecal Coliform Thirty-Day Geometric Means in Chicod Creek at State Road 1760 (based on at least five samples in a 30-day period)... 17
Figure 9. Daily Fecal Coliform Observations in the Creeping Swamp Watershed........................... 18
Figure 10. Daily Fecal Coliform Observations in the Van Swamp and Durham Creek Watersheds... 19
Figure 11. Daily Fecal Coliform Observations at the Upstream Chicod Creek Site............................ 19
Figure 12. Thirty-Day Geometric Means at the Upstream Chicod Creek Site 20
Figure 13. Comparison of Fecal Coliform Observations at the Upstream and Primary Monitoring Sites.. 21
Figure 14. Instantaneous Fecal Coliform Load-Duration Curve (400/100 mL) for Chicod Creek at State Road 1760 Near Simpson, NC.. 30
Figure 15. Geometric-Mean Fecal Coliform Load-Duration Curve for Chicod Creek at State Road 1760 Near Simpson, NC 31
Figure 16. Graphical Method for Determining Baseflow Recession in Chicod Creek........................ 32
Figure 17. Load-Duration Characterization of Post-1997 Instantaneous Fecal Coliform Concentration Data in Chicod Creek... 33
Figure 18. Regression Analysis of the Instantaneous Fecal Coliform Load-Duration Curve, Chicod Creek Data for 1997-2003... 35
Figure B-1. Regression Equations for Fecal Coliform Load versus Flow Frequency, Chicod Creek, 1997-2003 ....B1

SUMMARY SHEET

Total Maximum Daily Load (TMDL)

1. 303(d) Listed Waterbody Information

State: North Carolina

Counties: Pitt, Beaufort

Major River Basin: Tar-Pamlico River Basin

Watershed: Chicod Creek in Tar River Watershed HUC 03020103080010, Waterbody ID 28-101

Impaired Waterbody (2002 303(d) List):

Waterbody Name - (ID)	Water Quality Classification	Impairment	Length (mi)
Chicod Creek (28-101)	Class C (aquatic life, secondary contact recreation), NSW	Fecal Coliform Bacteria	13.0

Constituent(s) of Concern: Fecal Coliform Bacteria

Designated Uses: Biological integrity, propagation of aquatic life, and secondary contact recreation.

Applicable Water Quality Standards for Class C Waters:

Fecal coliforms shall not exceed a geometric mean of 200/100mL (membrane filter count) based upon at least five consecutive samples examined during any 30-day period, nor exceed 400/100 mL in more than 20 percent of the samples examined during such period.

2. TMDL Development

Analysis/Modeling:

Load duration curves for fecal coliform bacteria were based on cumulative frequency distribution of flow conditions in the watershed. A predictive upper confidence limit about the regression line on load versus flow is compared to a criterion limit curve, calculated as the load that would occur at 90 percent of the water quality criterion (thus incorporating a margin of safety). Necessary reductions in load are calculated as the maximum distance between the confidence bound on the regression line and the limit curve.

Critical Conditions:

Critical conditions are accounted for in the load curve analysis by determining the difference between the existing load violation trend line and the allowable load line. This approach was chosen because existing load violations occur at all flow levels. Maximum reduction requirements occur at a flow of approximately 100 cfs, which serves as a critical condition for the development of allocations.

Seasonal Variation:

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

3. Allocation Watershed/Stream Reach

Segment (ID)	Existing Load	WLA[1]	LA	MOS[2]	Reduction Required	TMDL
Chicod Creek (28-101)	1.05×10^{12} CFU/d	0	8.81×10^{11} CFU/d	9.79×10^{10} CFU/d	15.9%	9.79×10^{11} CFU/d

Notes:

Loading rates are estimated at the critical flow of 100 cfs.

WLA = wasteload allocation, LA = load allocation, MOS = margin of safety

[1]WLA = TMDL – LA - MOS; where TMDL is the average allowable load between the 95th and 10th percent flow exceeded.

[2]Margin of safety (MOS) equivalent to 10 percent of the target concentration for fecal coliform and turbidity.

4. Public Notice Date: May 8, 2004

5. Submittal Date: July 20, 2004

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: Nonpoint Source

1 Introduction

1.1 PROBLEM DEFINITION

Section 303(d) of the Clean Water Act (CWA) requires states to develop a list of waters not meeting water quality standards or which have impaired uses. This list, referred to as the 303(d) list, is submitted biennially to the U.S. Environmental Protection Agency (EPA) for review. Development of a TMDL requires an assessment of the assimilative capacity of the stream, assessment of the sources within the watershed contributing to the total instream load, and a recommendation of the reductions required from each source.

1.1.1 TMDL Components

The 303(d) process requires that a TMDL be developed for each of the waters appearing on Part I of the 303(d) list. The objective of a TMDL is to estimate allowable pollutant loads and allocate to known sources so that actions may be taken to restore the water to its intended uses (USEPA, 1991). Generally, the primary components of a TMDL, as identified by EPA (1991, 2000) and the Federal Advisory Committee (FACA, 1998) are as follows:

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

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

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

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

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

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

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

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

1.1.2 Chicod Creek Fecal Coliform Impairments

1.1.2.1 Chicod Creek 303(d) Listing

The Chicod Creek listing of impairment is contained in the *North Carolina Water Quality Assessment and Impaired Waters List (2002 Integrated 305(b) and 303(d) Report).* The segment of Chicod Creek considered impaired due to fecal coliform [Waterbody ID 28-101] extends 13.0 miles from the source to the Tar River. This segment is listed as partially supporting with agriculture as the potential source of the impairment.

Chicod Creek is designated a Class C, Nutrient Sensitive Water. The Class C designation requires protection of aquatic life and secondary contact recreation (NCDENR, 2003). The North Carolina fresh water quality standard for fecal coliform in Class C waters (T15A:02B.0211) states:

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

1.1.2.2 Assessment of Impairment

Monitoring data for Chicod Creek are summarized in Section 1.4. North Carolina bases impairment status on both the instantaneous and geometric mean criteria (Section 1.1.2.1). For comparison to the instantaneous standard, North Carolina assesses use support only when at least five samples are available from a 30-day period, in accordance with the water quality standard. In 1992, sets of five samples from June, July, and August all had more than 20 percent of individual samples well above the 400 colonies per 100 mL criterion. During the 2003 sampling, two samples from a five-sample set collected in September had concentrations in excess of 400 colonies per 100 mL, demonstrating continued impairment. Nine percent of individual samples from 1992 to present are greater than 400 colonies/100 mL; from 1997 to present nine individual samples (7 percent) exceeded the criterion.

In the case of the geometric mean criterion, only sets of data that include at least five samples within a 30-day period can be compared to the criterion (200 colonies/100 mL). For the Chicod Creek analysis, a set was defined as a sample plus all observations occurring in the previous 30 days. All eight geometric means calculated in 1992 were well above the 200 colonies/100mL criterion (Section 1.4.2). No 30-day geometric means greater than 200 colonies/100 mL have been documented since 1992, although geometric means at the end of September through beginning of October 2003 were just below 200. While Chicod Creek was clearly impaired relative to the geometric mean criterion for fecal coliform in the past, this no longer appears to be the case – likely due to the installation of BMPs at animal operations.

1.2 WATERSHED DESCRIPTION

Chicod Creek is located in the lower Tar River basin (NC Subbasin 03-03-05) and flows from Beaufort into Pitt County, joining the Tar River near Grimesland, NC (Figure 1). The watershed drains 40,670 acres of the North Carolina Coastal Plain.

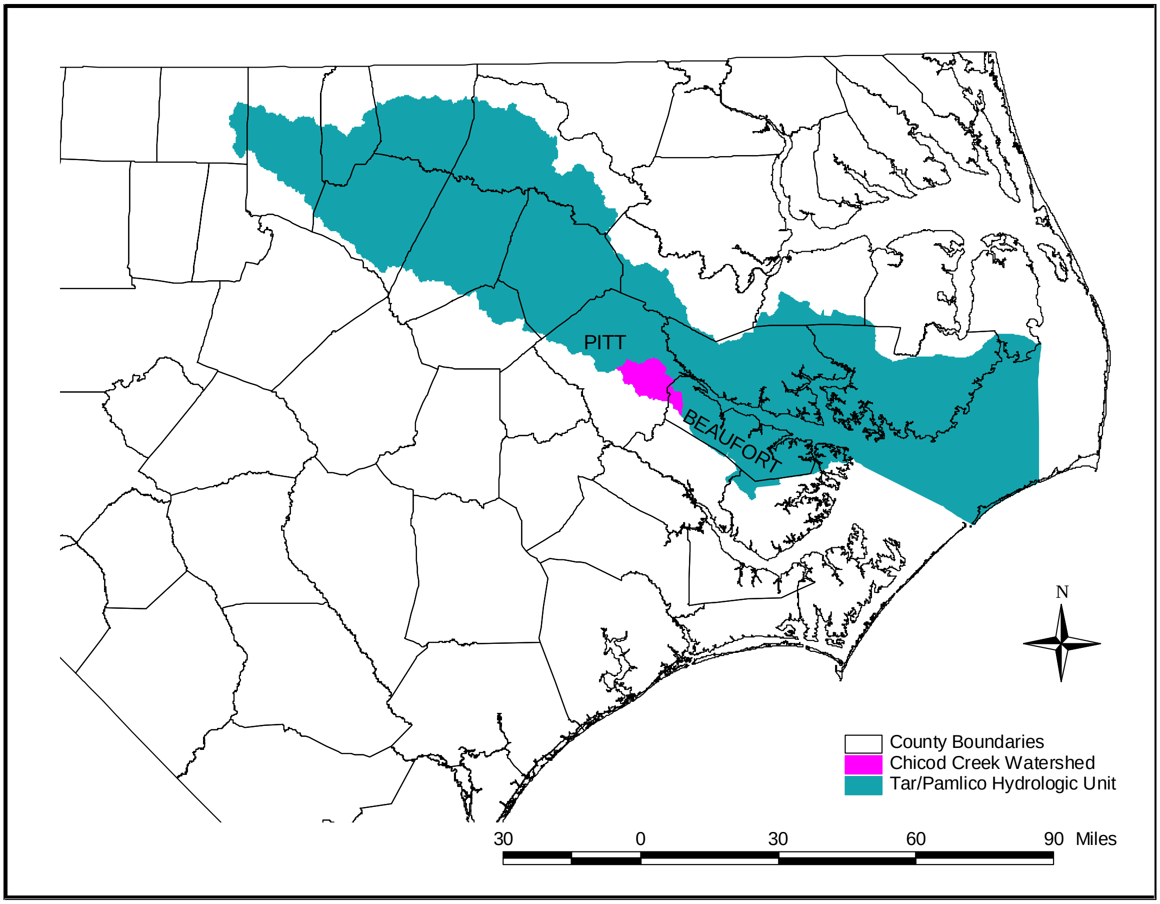
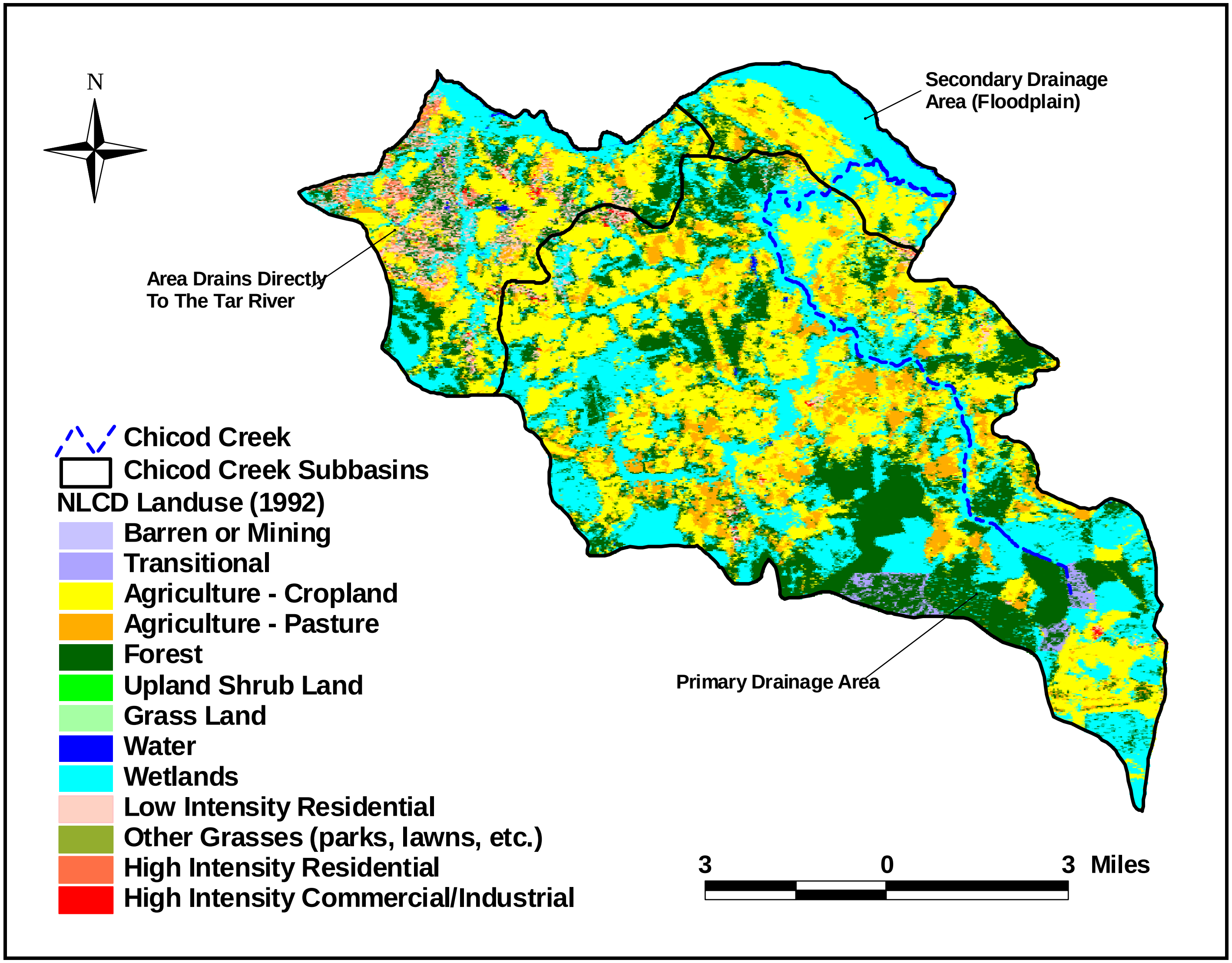


Figure 1. Location of Chicod Creek Watershed in the Tar/Pamlico Basin, NC

1.2.1 Landuse/Land Cover

Landuse data for the Chicod Creek Watershed was tabulated from the USGS National Land Cover Database (NLCD) compiled in 1992. This is the most recent available comprehensive land cover data set for the watershed. Changes since this time are expected to have been small, as the watershed has remained rural and agricultural in nature, with minimal development pressure and no known continuation of wetland drainage.

The primary drainage area is the portion of the watershed upstream of the flow gage and primary water quality monitoring site. An additional area in the Roanoke River floodplain drains to the Roanoke through the lower portion of Chicod Creek (secondary drainage area). The HUC also contains area that drains directly to the Roanoke, not through Chicod Creek. A landuse map of the HUCs containing the Chicod Creek Watershed is presented in Figure 2 and data are tabulated in Table 1 for the Chicod Creek drainage areas only. According to the landuse data, 97.8 percent of the watershed is either forested or agricultural land: 55.8 percent may be classified as forest or forested wetlands; 33.1 percent as row crop agriculture; and 8.6 percent as pasture or grass. In the period since 1992, residential land use has likely increased somewhat, but constitutes only a small portion of the area. The increase in swine operations since 1992 has likely resulted in some conversion of row crop to grassed sprayfields, which would occur in the “Pasture/Grass” classification.



Note: HUCs 03020103080010 and 03020103060030

Figure 2. NLCD Landuse Data for the Chicod Creek Watershed (1992)

Table 1. Landuse Tabulation for the Chicod Creek Watershed

Landuse	Primary Drainage Area (ac)	Primary Drainage Percentage	Secondary Drainage Area (ac)	Secondary Drainage Percentage	Entire Watershed Area (ac)	Entire Watershed Percentage
Residential	400	1.1%	31	0.8%	431	1.1%
Row Crop	11,896	32.5%	1,553	37.9%	13,449	33.1%
Pasture/Grass	3,324	9.1%	193	4.7%	3,517	8.6%
Forest/ Forested Wetlands	20,400	55.8%	2,188	53.5%	22,588	55.5%
Emergent Wetlands/ Water	82	0.2%	128	3.1%	209	0.5%
Other[1]	474	1.3%	1	0.0%	475	1.2%
Total	36,576	100.0%	4,094	100.0%	40,670	100.0%

[1]Other landuses include commercial, industrial, transportation, bare rock, sand, or clay, and transitional areas.

1.2.2 Population and Onsite Wastewater Disposal

Poorly maintained and/or failing septic systems are a common source of fecal coliform contamination in rural watersheds. In coastal plain watersheds, where the water table is relatively high and has a greater chance of intersecting the septic drain field, the frequency of contamination may be much higher. The Chicod Creek Watershed is only served by onsite wastewater disposal, and no sewer service area is planned for the near future.

Septic tanks are generally associated with low flow exceedances of the fecal coliform standard because they represent continuous discharges that may be diluted and have less impact during high-flow events. Other sources of low flow fecal coliform loading are illicit discharges and other direct inputs of raw sewage. However, in low-lying watersheds, septic tanks may contribute excessive loads during moderate to high-flow events as water tables rise and meet septic drain fields. If the recharge path to nearby streams is relatively short, the contaminated groundwater may reach the surface before bacterial die-off has occurred.

A GIS analysis was performed to determine the total population and number of septic systems within the Chicod Creek Watershed as well as the relative distributions. Census blocks provided in the *BasinPro* GIS data package distributed by the N.C. Center for Geographic Information and Analysis (NCCGIA, 2002) were processed in ArcView to isolate blocks within the watershed. Information on household sanitary waste disposal methods is no longer available from census data, but given that no sanitary sewers extend into the Chicod Creek Watershed area from surrounding communities, it was assumed that the number of septic systems within the watershed could be approximated by the number of households. The number of households and total population per census block are attributes available within the *BasinPro* 2000 Census data coverage. All coinciding census blocks that partially intersected the watershed boundaries were clipped to the extent of the watershed and area-weighted average numbers of households and total population were calculated within those blocks.

The GIS analysis indicated that the Chicod Creek Watershed contains approximately 2,400 households and 6,500 residents. The average septic system density across the 57 square mile Chicod Creek Watershed (as defined by the USGS 14-digit hydrologic unit 03020103080010) is approximately 42 septic systems per square mile. However, when the densities are mapped by census block (as shown in Figure 3) it becomes apparent that the systems are by no means distributed evenly throughout the watershed. Many of the census blocks in the most rural, eastern portion of the watershed have densities less than 25 systems per square mile. In the western portion of the watershed, nearer to the City of Greenville, densities exceed 100 systems per square mile and are even higher in small areas within and around the towns of Simpson and Grimesland.

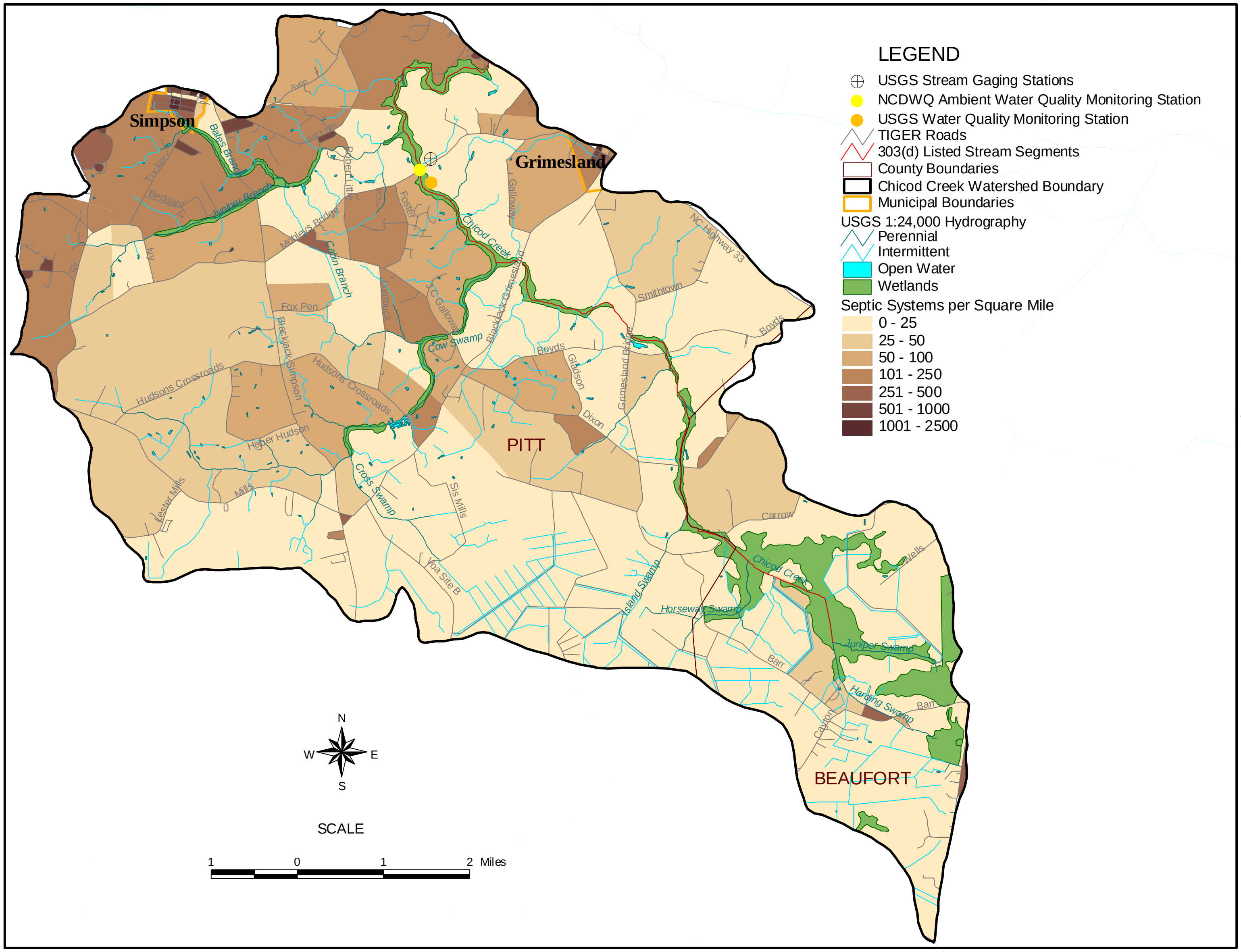


Figure 3. Septic System Densities by Census Block (2000) in the Chicod Creek Watershed

1.2.3 Agriculture

The primary agricultural activities in the Chicod Creek Watershed are row cropping and livestock production. Most of the row cropland within the watershed is cultivated in the corn-wheat-soybean rotation that is prevalent across the North Carolina coastal plain. As indicated in Table 1, cultivated row crops occupy approximately 33 percent of the land area in the primary watershed. Information such as levels of production, farm characteristics, and best management practices are tracked by the local USDA Natural Resource Conservation Service (NRCS) office, but records are typically compiled by county so data is difficult to characterize by watershed. However, in a recent interview, the Pitt County NRCS District Conservationist, Tim Etheridge, estimated that 25-40 percent of the cultivated cropland within the Chicod Creek Watershed is associated with tiled drainage systems. Tiled drain systems use drain pipes buried beneath the surface of fields to convey rainfall away from crops during wet periods and maintain artificially high water table levels during drought periods (Etheridge, 2004).

In terms of BMP applications, Mr. Etheridge estimated that 10-15 acres of grassed field borders and grassed drainage swales have been planted in the Chicod Creek Watershed within the last 10 years. Using the standard 10:1 ratio of affected land area per practice acre installed, only 100-150 acres, or approximately 1 percent of the cropland in the primary watershed, would be affected by such BMPs. It was also estimated that 30 percent of the cropland in the watershed is subject to no-till practices during at least one crop rotation in each annual planting cycle. Application of BMPs to row cropland is limited in the watershed because the local resource conservation agency staff have focused their efforts in recent years on improving management practices and BMP applications at large scale livestock facilities (Etheridge, 2004).

1.2.4 Swine Operations

Most of the livestock production operations in the Chicod Creek Watershed are swine facilities. A detailed review of the permitting and enforcement files for concentrated animal feeding operations (CAFOs) in the Washington Regional Office of NCDENR confirm that there are 17 permitted CAFOs in the Chicod Creek Watershed. The individual swine operations and some of their pertinent characteristics are listed in Table 2 and their locations within the watershed are shown in Figure 4. As shown in Table 2, the total design capacity for all facilities in the watershed is slightly over 68,000. Records indicate that most facilities operate at or above 95 percent of design capacity and that two of the 17 operations are currently inactive. Accounting for these two factors, the standing population of swine in the watershed is likely to be in the range of 60,000 – 65,000 animals.

The growth in swine populations in the Chicod Creek Watershed, as well as in the rest of eastern North Carolina, has been a recent phenomenon. Change over time in design production capacity of swine operations in the watershed is shown in Figure 4. While some semi-large operations (with capacities of 1000-1500 animals) have been present in the watershed for 20 years or more, Figure 5 shows that up until 1990 the swine population was still around 10,000. In the four years from 1992 through 1995 the population, in terms of production capacity, grew by approximately 12,500 animals per year. In contrast to the facilities present prior to 1990, the operations started in the 1992-1995 period tended to be much larger in scale. There have been no increases in capacity since 1995. In 1997, as a direct result of problems with the Neuse River estuary and out of broader concerns over potential water quality impacts, the N.C. Legislature enacted a statewide moratorium on new swine operations with capacities over 250 animals. The moratorium was reauthorized in 2003 for four more years.

Table 2. Swine Operations Located in the Chicod Creek Watershed

Facility ID	Name	Type of Operation	Year Estab.	Design Population (animals)	Steady State Live Weight (pounds)	Number of Lagoons	Spray Acreage (acres)	Required Acreage (acres)	Number of Illicit Discharges*	Status
74a16	Cloverdale Farm	Feeder to Finish	1986	6,000	810,000	1	75.9	75.9		Active
74a18	Rosewood #3	Feeder to Finish	1994	8,640	1,166,400	1	80	75.4	1	Active
74a19	T&R Sow Farm	Farrow to Wean	1985	1,500	649,500	2	30.9	30.9		Active
74a28	Rosewood #2	Feeder to Finish	1990	3,672	495,720	1	47.1	47.1		Active
74a29	Rosewood #1A	Feeder to Finish	1992	3,672	495,720	2	42.9	42.9	1	Active
74a33	Robin Hudson Farm	Feeder to Finish	1986	3,280	442,800	2	42.6	42.6	1	Active
74a39	High Ridge Farms	Farrow to Feeder	1993	2,400	1,252,800	1	58.4	48.6		Active
74a41	Fairwinds	Farrow to Finish	1993	2,400	1,252,800	1	91.4	91.4	2	Active
74a52	Woodcliff Farm	Farrow to Wean	1990	1,600	626,400	1	35	54.4	1	Active
74a57	Peggy Roberson Farm	Feeder to Finish	1981	1,050	141,750	2	74.8	56.8		Active
74a84	Gaskins Pork Producers	Farrow to Wean	1978	980	424,340	1	43	34.6		Inactive
74a106	Phillip Page Farm	Feeder to Finish	1995	3,672	495,720	1	87.8	69		Active
74a111	Southwoods	Farrow to Feeder	1994	3,600	1,879,200	1	119.5	119.5		Active

Facility ID	Name	Type of Operation	Year Estab.	Design Population (animals)	Steady State Live Weight (pounds)	Number of Lagoons	Spray Acreage (acres)	Required Acreage (acres)	Number of Illicit Discharges*	Status
74a118	Rosewood #4	Feeder to Finish	1995	7,920	1,069,200	1	168	53.2	2	Active
74a119	Rosewood #5	Feeder to Finish	1995	5760	777,600	1	50	37.8		Active
74a122	Rosewood #1B	Feeder to Finish	1992	3672	495,720	1	39.5	39.5	2	Inactive
7a2	Mills Farm	Feeder to Finish	1993	8640	1,166,400	2	92.7	39.7	2	Active
Total				***68,458***	***13,642,070***	***22***	***1179.5***	***959.3***	***12***	

* Illicit discharges varied by facility. For the period 1992-2003, instances included a leaking lagoon, spraying to an oversaturated field, spraying to a tile-drained field, and direct routing to a stream.

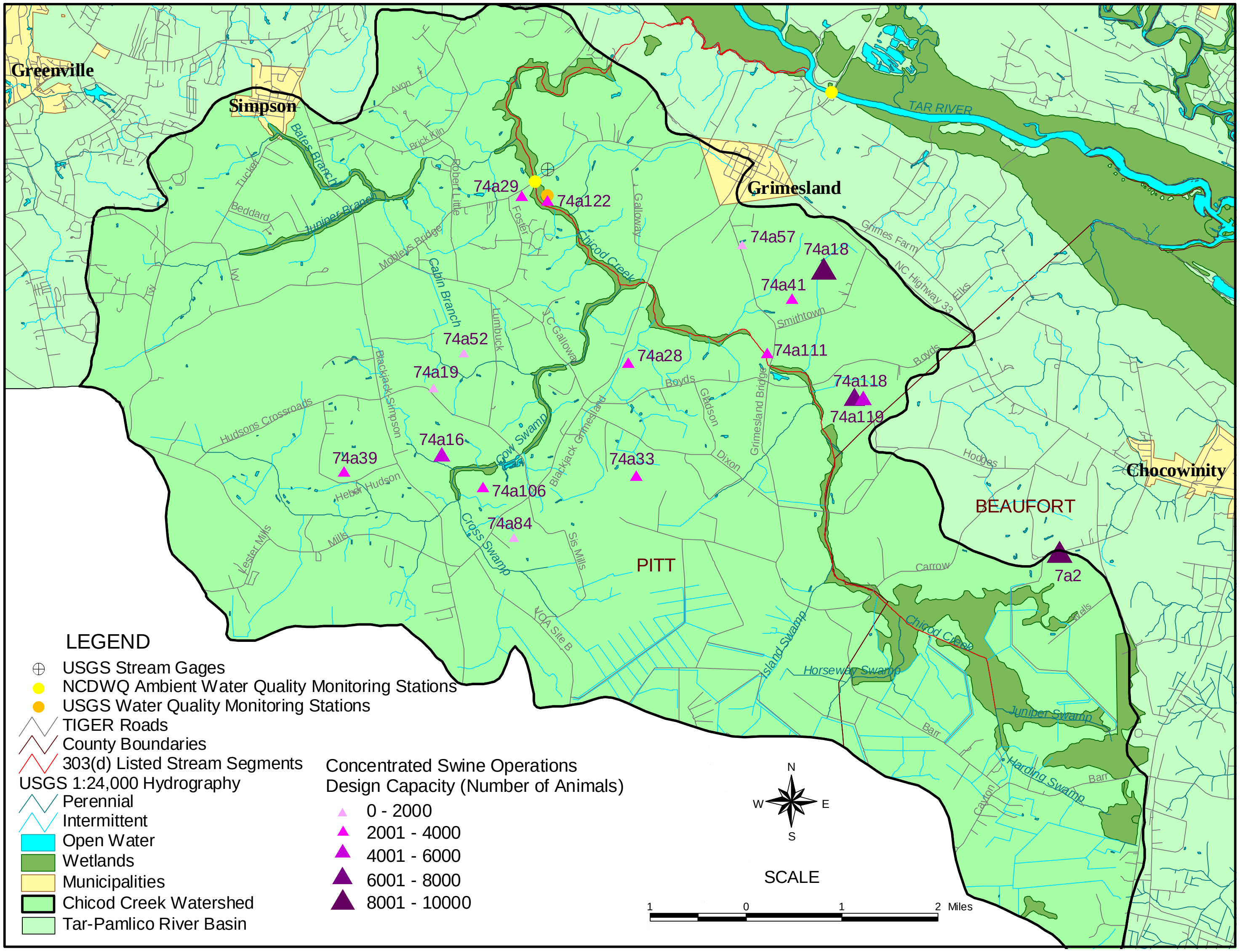
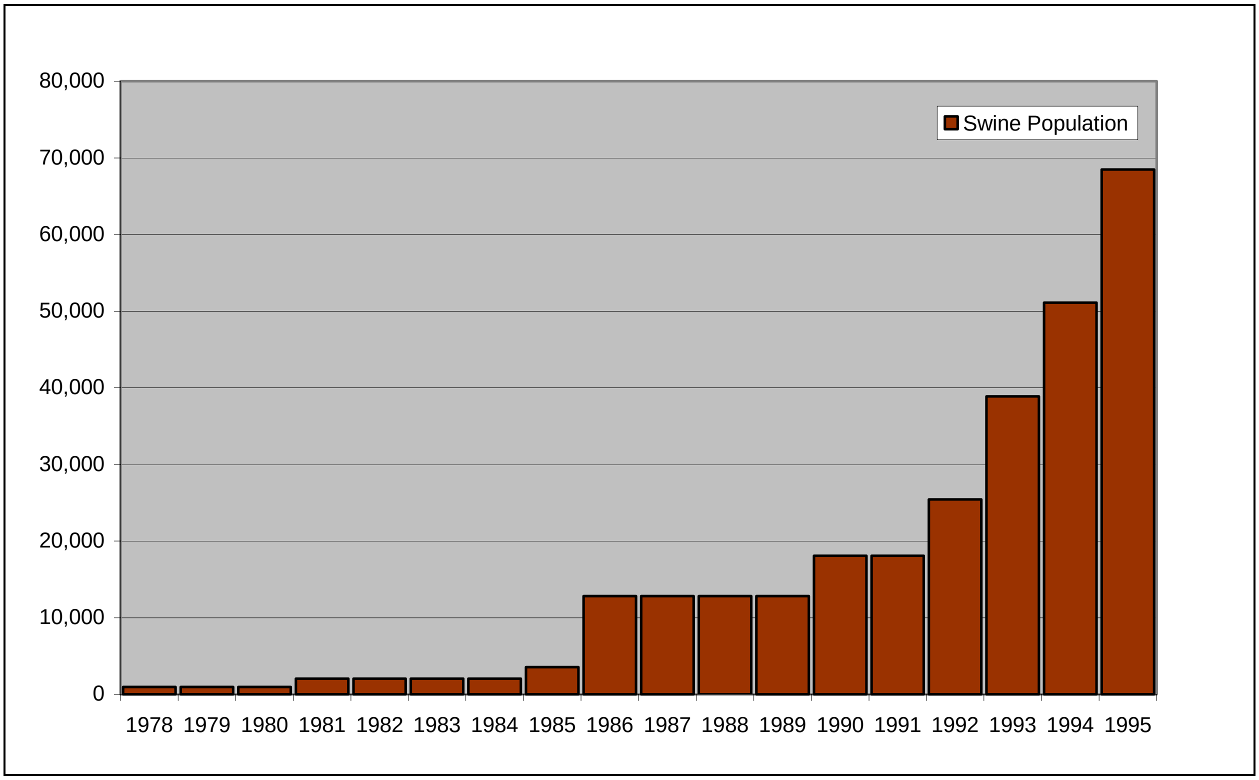


Figure 4. Locations of Swine Operations within the Chicod Creek Watershed



Note: There has been no increase in swine production capacity since 1995.

Figure 5. Growth in Swine Production Capacity in Chicod Creek Watershed

In all of these operations, large numbers of animals are housed in small quarters, and feces are typically washed off through the floor into one or two storage lagoons located outside. After some digestion, wastewater from the lagoons is then sprayed onto grass fields. Each facility is required to develop a waste utilization plan in conjunction with local resource conservation agency staff and have that plan on file with NCDWQ. The plans determine sufficient spray field acreage such that wastes can be applied at agronomic loading rates for nitrogen and phosphorus and liquid will remain on site until removed by evapotranspiration. However, if spraying occurs just before a heavy rainfall, it is possible that runoff from the spray fields may reach nearby streams prior to nutrient uptake and/or fecal coliform die off. As shown in Table 2, the swine operations in the Chicod Creek Watershed utilize 22 waste lagoons and almost 1,200 acres of spray irrigation fields. Collectively, the waste utilization plans for the facilities only call for approximately 950 acres of spray fields, but some facilities have a larger acreage than required to provide a margin of safety.

1.2.4.1 Regulation of Swine Operations and Enforcement Efforts

In 1997, legislation was enacted requiring the formal permitting of CAFOs along with development of waste utilization plans and biannual inspections. Prior to that legislation, few records are available to characterize management efforts at swine operations. Review of the permitting and enforcement files indicated that many operations were seldom or never inspected prior to 1997 unless reports of illicit discharges or other severe problems caused regulators to visit a given facility. Once a discharge or other problem was observed at a facility, that operation was typically designated as a CAFO and a formal letter was transmitted to the owner notifying them of the designation. After designation, facilities appeared to be tracked more closely and inspected on occasion.

In general, the problems reported at swine facilities were more severe in the years prior to the requirement for regular inspections with events such as straight pipes or other direct flows from hog houses or lagoons to nearby streams. After 1997, the most common type of recorded illicit "discharge" resulted from irrigating on saturated spray fields. A comprehensive review of the CAFO files showed that at least 12 illicit discharge events from 1987 through 2002 which resulted in swine waste entering surface waters from facilities in the Chicod Creek Watershed. The NCDWQ enforcement files reflected that all but one or two of these events were referred for enforcement action which resulted in monetary fines paid by the owners.

Lagoon failure may also cause fecal coliform loading by discharging large volumes of waste to the surrounding area. These events can occur during wet or dry conditions and happen less frequently than waste runoff from spray fields. No catastrophic lagoon failures have been reported in the Chicod Creek Watershed.

It is likely that some discharge events go unnoticed by regulatory staff. In many cases, discharges were reported because citizens within the watershed saw waste draining off fields or across roadways. Many of the swine operations within the watershed, and across the eastern portion of the state, are in very remote locations nowhere near housing or public roadways. The legislation passed in 1997 to establish the process for permitting and inspection of CAFOs in North Carolina stipulated that regulatory staff from NCDWQ inspect each facility for compliance once per year and that resource agency staff visit each facility once a year for evaluation and consultation to maintain and improve waste management efforts. While the resource agency staff are not intended to have a regulatory role, they do have the authority to refer problems they encounter to the regulatory agency for follow-up inspection and enforcement. As a result, provided sufficient staff resources are available within the two agencies, each swine operation is visited twice per year. However, it should be noted that during the time of Tetra Tech's review of the permitting and enforcement files, only three staff were assigned to inspecting CAFOs within the Washington Regional Office territory for NCDWQ. That territory consists of 21 northeastern counties, which contain over 500 CAFOs that are almost all swine operations. Considering the administrative demands and travel time associated with carrying out such an effort, the current staffing level may not be sufficient to ensure the desired frequency of inspections of these facilities.

1.2.4.2 Best Management Practices at Swine Operations

Interviews with the Pitt County NRCS District Conservationist, Tim Etheridge, have indicated that no database or tracking system exists that would have a formal record of the BMPs that have been instituted at swine facilities within the Chicod Creek Watershed. However, the interviews also revealed that Mr. Etheridge worked in conjunction with NCDWQ staff and staff from the Division of Soil and Water Conservation during a period from approximately 1991-1994 to identify problem swine facilities and implement best management practices at those facilities. He and field staff from the NCDWQ Regional office systematically visited all swine operations within the watershed and developed a list of high priority facilities exhibiting the greatest levels of operational deficiencies and targeted them for improvement. Operations at each swine facility were reviewed and opportunities for management and structural improvement were identified. Through the use of Clean Water Act Section 319 grant monies, BMPs such as increased vegetated buffers between spray areas and waterways, increased spray acreage to minimize overloading of wastes, and improved cover crops for spray fields were implemented at each facility as necessary (Etheridge, 2004). While no formal report is available from which to quantify these efforts, it should be noted that a significant decrease in the measured levels of fecal coliform in Chicod Creek coincides with this time period (see Section 1.4).

1.2.5 Other Livestock Operations

A 1995 USGS publication evaluating land use and nutrient concentrations in the Albemarle – Pamlico drainage area reported that, as of 1994, poultry growing facilities containing approximately 470,000 birds were located in the Chicod Creek Watershed (Woodside and Simerl, 1995). Interviews with the Pitt County District Conservationist have indicated that, at that time, at least two layer operations and two broiler operations were present in the watershed. The layer operations were depopulated around 1999 to 2001. It should be noted that the layer operations employed wet waste management systems with lagoons and spray fields not unlike swine production facilities. In addition, reduced demand prompted a reduction in the geographic range of suppliers for the primary broiler chicken processing facility in the region, and the two broiler operations in Chicod Creek were depopulated in 2003. As a result, no active poultry growing facilities are present in the Chicod Creek Watershed at this time (Etheridge, 2004). However, the structural facilities to support these operations are still in existence and future increases in poultry demand could cause them to be restarted.

Applications for CAFO permits require that the applicant list all other livestock present on the farm in question other than the subject CAFO. Review of the NCDWQ CAFO permit files indicated that approximately 75 head of beef cattle and 9 goats are kept on farms within the Chicod Creek Watershed. Interviews with the Pitt County District Conservationist confirmed these low numbers of livestock other than swine in the watershed (Etheridge, 2004).

1.3 FLOW GAGING

USGS has monitored stream flow at Station 02084160 (Chicod Creek at SR1760 near Simpson, NC) since 1975, with a gap from 4/15/1987 to 4/30/1992. Data were obtained from the USGS NWIS system, including provisional data updated through February 12, 2004. The station is located in Pitt County at 35°33'47" latitude and 77°13'43" longitude NAD27 and has a reported drainage area of 45 square miles. Summary statistics for this station through December 2003 are listed in Table 3. A cumulative frequency histogram for the monitoring period is presented in Figure 6. Low flows are frequent in this system, with 22 percent of recorded flows at 2 cfs or less.

Table 3. Daily Average Stream Flow Statistics for USGS Station 02084160 Chicod Creek at SR1760 Near Simpson, NC, Oct. 1975 – Dec. 2003

Count (days)	8474
Minimum (cfs)	0
Maximum (cfs)	4560
Average (cfs)	55.1
Median (cfs)	12

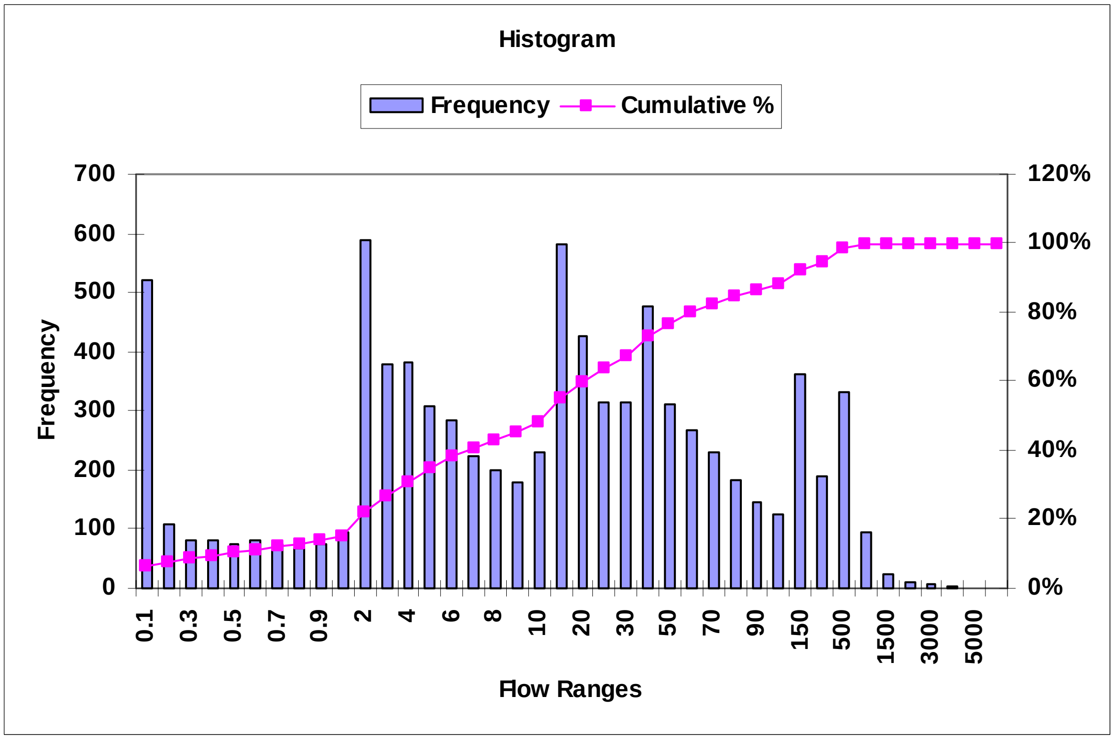


Figure 6. Cumulative Daily Average Flow Frequency Histogram for USGS Station 02084160

1.4 Water Quality Monitoring

1.4.1 Monitoring Sites

Fecal coliform data have been collected in the Chicod Creek Watershed at State Road 1760 by USGS and NC DWQ from November 1977 to the present (USGS Station 02084160; DWQ Station O6450000). This station is part of the USGS Albemarle-Pamlico National Water Quality Assessment (NAWQA) study. The Chicod Creek Watershed underwent drainage modifications from November 1978 to December 1981, and USGS monitored hydrologic conditions and water quality before, during, and after modification as part of their environmental impact assessment (Mason, 1988; Watkins and Simmons, 1984; Mason et al., 1990). The station at SR 1760 is referred to as the "primary site" because it represents the majority of data collected in the watershed and is near the outlet of the listed reach.

USGS also monitored water quality and ground water levels at two sites in the Creeping Swamp Watershed (USGS Stations 02091960 and 02091970), which is just south of the Chicod Creek watershed. The Creeping Swamp stations were used as control sites to compare the impacts of hydrologic modifications in the Chicod Creek Watershed. The Creeping Swamp Watershed has similar soils, stream characteristics, and landuses as the Chicod Creek Watershed. Both contain animal operations, though Chicod Creek has a higher density based on visual interpretation of 1998 1-meter resolution aerial photography. These sites are referred to as "control sites" in this document.

Tetra Tech selected two additional USGS NAWQA sites to compare water quality conditions in Chicod Creek to undisturbed bottomlands with no agriculture or animal operations. These sites are located on Durham Creek near Edward, NC (USGS Station 02084540) and Van Swamp near Hoke, NC (USGS Station 02084557) and are referred to as "reference sites" in this document.

Fecal coliform data were also collected by NCDWQ for a brief time along Chicod Creek at Boyd's Crossroads (NCDWQ Site ChC1). This site is referred to as the "upstream site" because it is upstream of the primary site as well as most of the swine facilities in the watershed. One facility was identified just upstream of Boyd's Crossroads.

Table 4 summarizes the monitoring sites used in this study.

Table 4. Fecal Coliform Monitoring Stations for the Chicod Creek Analysis

Site Number	Site Name	Type	Monitoring Period
02084160	Chicod Creek at SR1760 near Simpson, NC	Primary	Nov-77 to Oct-03
02091960	Creeping Swamp near Calico, NC	Control	Oct-74 to May-75
02091970	Creeping Swamp near Vanceboro, NC	Control	Oct-74 to May-86
02084540	Durham Creek at Edward, NC	Reference	Mar-93 to Aug-93
02084557	Van Swamp near Hoke, NC	Reference	Mar-78 to Feb-94
ChC1	Chicod Creek at Boyd's Crossroads	Upstream	Sep-03 to Oct-03

1.4.2 Primary Chicod Creek Monitoring Site

Fecal coliform data are generally discussed in terms of daily observations or 30-day geometric means of at least five samples. At the primary monitoring site along Chicod Creek, 206 daily observations were collected from November 1977 to October 2003 ranging from 9 to 31,000 colonies/100 mL. Daily observations at this site are shown in Figure 7 along with the instantaneous criterion of 400 colonies/100 mL. The magnitude of concentrations has decreased substantially over the past two decades. Concentrations greater than 30,000 occurred in the 1980s, but concentrations greater than 3,500 have not been observed since 1992. The frequency of excursions of the instantaneous criterion also decreased from 42 percent prior to the end 1992 to 9 percent after 1992.

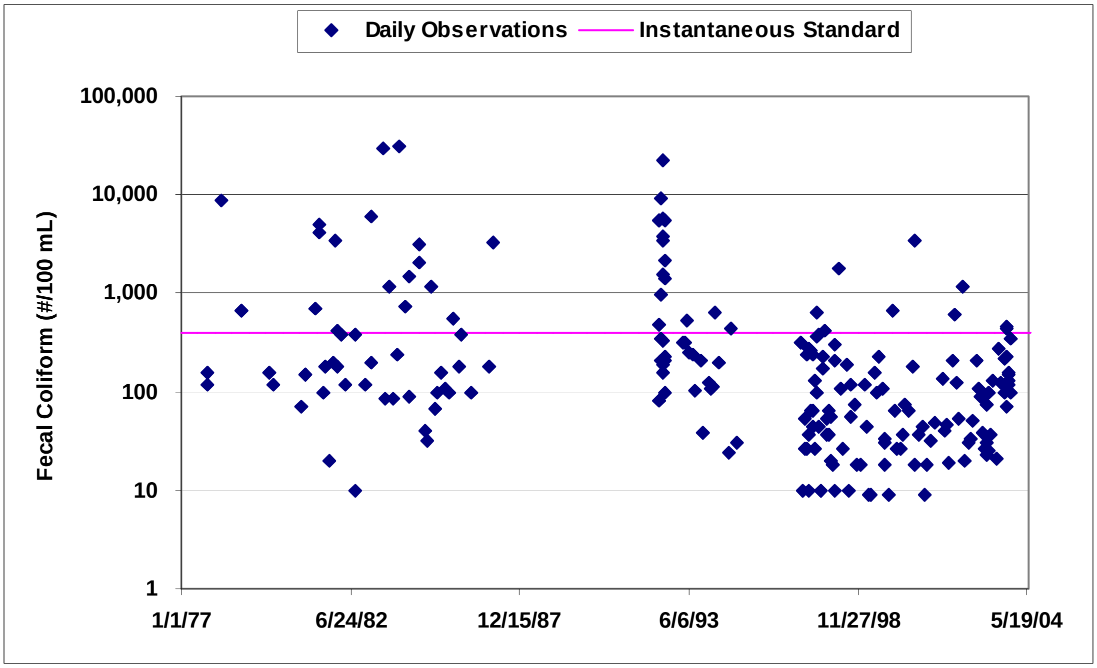


Figure 7. Daily Fecal Coliform Observations in Chicod Creek at State Road 1760

Thirty-day geometric means may be calculated for 19 sets of fecal coliform observations that have at least five samples. Geometric means were calculated for all samples within 30-days of the last sampling date if at least five samples were taken. This translates to a rolling average for the prior 30 days for all applicable samples within the window. Analysis of 30-day windows centered on each sampling point yields similar results. The geometric means are plotted in Figure 8. Eight geometric means are calculated during the summer of 1992 ranging from 763 to 1,401 colonies/100 mL. Two geometric means are calculated during 1997 having values of 32 and 103 colonies/100 mL. Nine geometric means are calculated during 2003 ranging from 42 to 199 colonies/100 mL. All geometric means calculated during 1992 exceeded the geometric mean criterion of 200 colonies/100 mL; none exceeded the criterion after 1992.

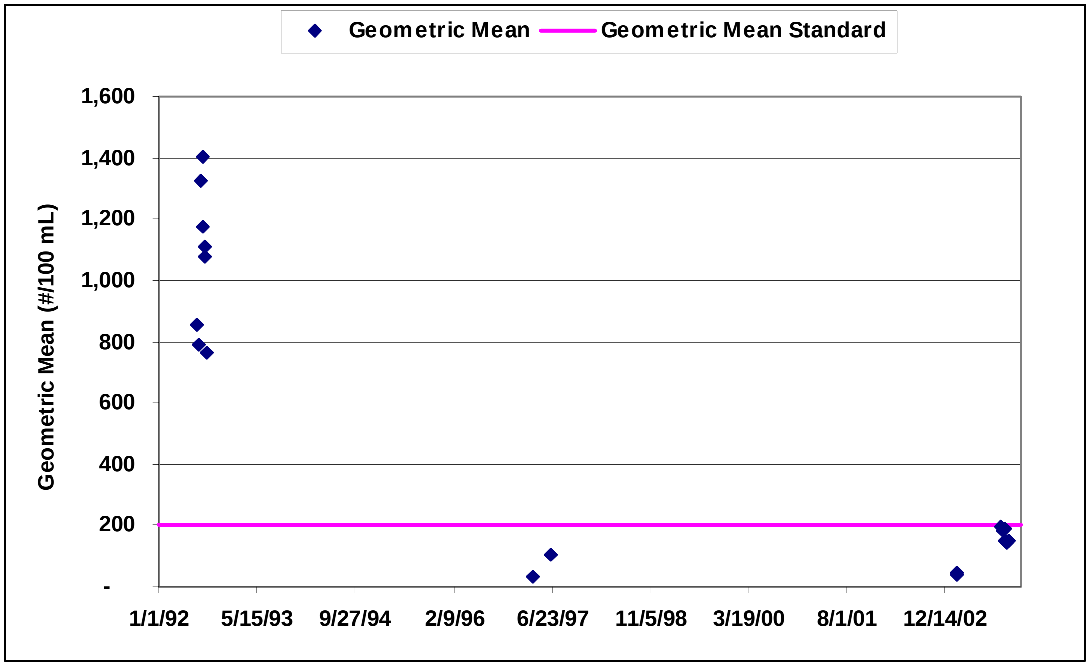


Figure 8. Fecal Coliform Thirty-Day Geometric Means in Chicod Creek at State Road 1760 (based on at least five samples in a 30-day period)

Water quality BMPs funded through Section 104 (b) (3) of the Clean Water Act were installed throughout the Chicod Creek Watershed between 1994 and 1997. Animal waste controls included anaerobic waste lagoons, stormwater management controls, dry manure storage facilities, waste application systems, and the closure of abandoned swine waste lagoons (NCDENR, 1999). It appears that these BMPs were effective in reducing fecal coliform concentrations and geometric means. The frequency of excursions of the instantaneous standard decreased from 42 percent to 9 percent, and the frequency of excursions of the geometric mean standard decreased from 100 percent to 0 percent.

1.4.3 Control Sites in the Creeping Swamp Watershed

Fecal coliform data were collected by USGS at two sites in the Creeping Swamp Watershed. The watershed is 70 percent forest, 25 percent agriculture, and 5 percent rural development (Mason, 1988), and some animal operations are present. Figure 9 shows daily observations at the two Creeping Swamp sites combined. No five-samples occur within a 30-day period to calculate a geometric mean.

Daily observations of fecal coliform are generally lower at Creeping Swamp compared to the primary site on Chicod Creek for the period prior to 1997. No observation exceeds 1,000 colonies/100 mL. Four of twenty-four observations are greater than the instantaneous standard of 400 colonies/100 mL. However, concentrations are in the same range as more recent observations in Chicod Creek. Agriculture and animal operations present in this watershed may elevate fecal coliform concentrations above background concentrations seen in sites without anthropogenic disturbance.

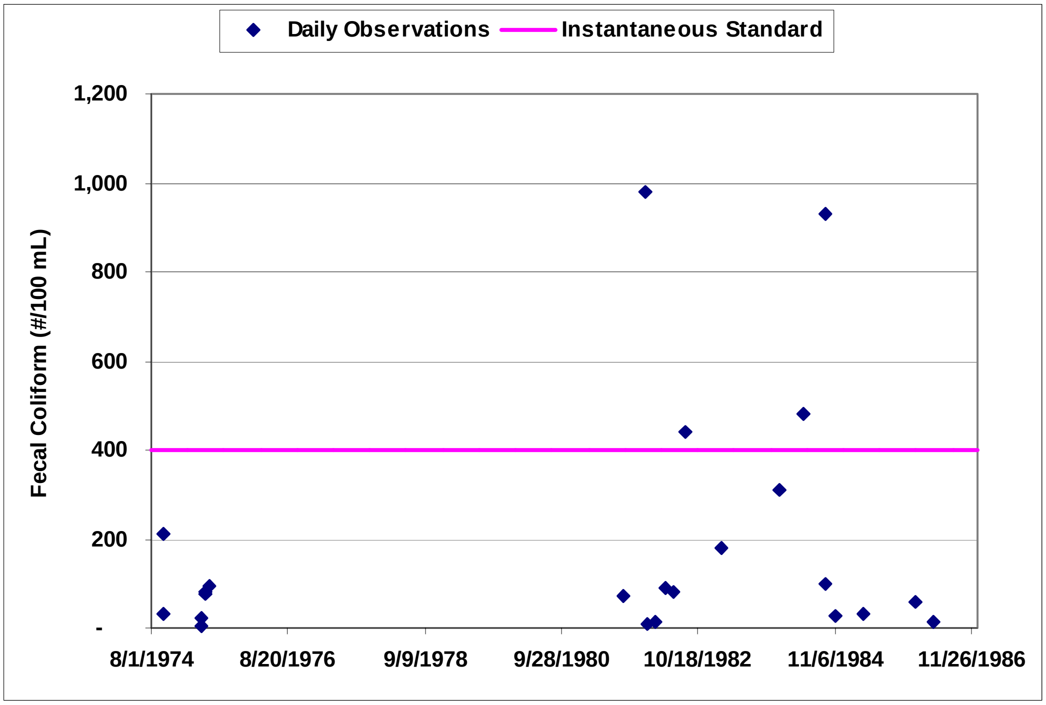


Figure 9. Daily Fecal Coliform Observations in the Creeping Swamp Watershed

1.4.4 Reference Sites in Van Swamp and Durham Creek Watersheds

Fecal coliform data collected at the reference sites at Van Swamp and Durham Creek were combined for comparison to the Chicod Creek data. These sites are located in relatively undisturbed, swampy watersheds with no animal operations and limited agriculture. As expected, fecal coliform concentrations are relatively low. Daily observations are shown in Figure 10; none exceed the instantaneous standard of 400 colonies/100 mL. No five-sample 30-day geometric means can be calculated from the available data at the reference sites.

Results from these sites suggest that the water quality criteria are likely to be achieved in this topography when agriculture, animal operations, and human sources, such as septic tanks, are not present in significant numbers.

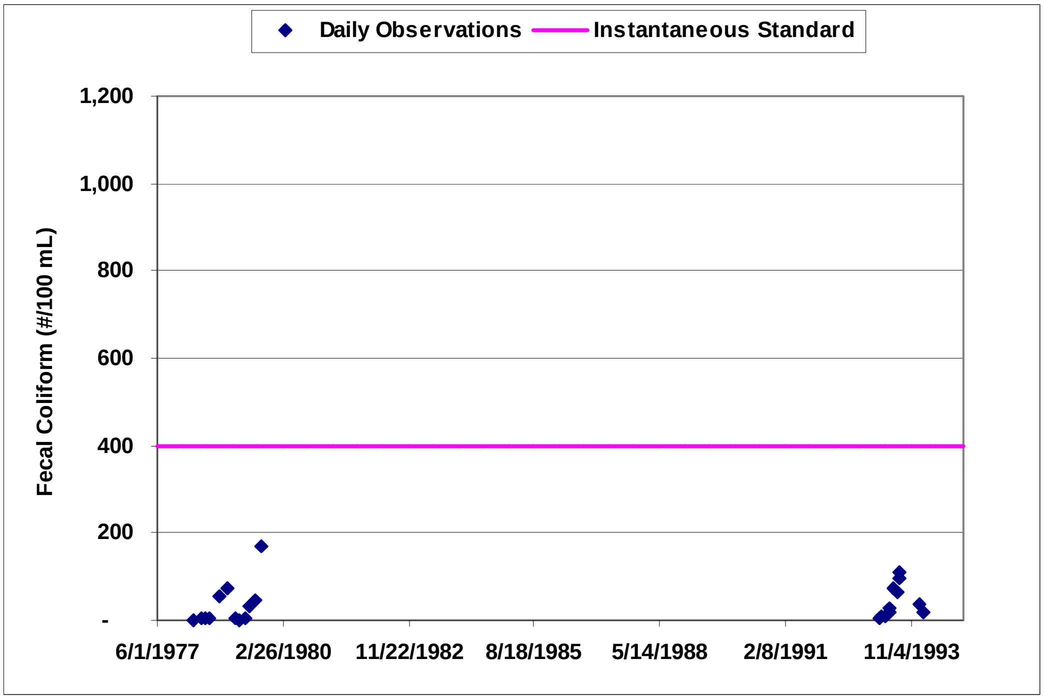


Figure 10. Daily Fecal Coliform Observations in the Van Swamp and Durham Creek Watersheds

1.4.5 Chicod Creek Upstream Site at Boyd's Crossroads

Fecal coliform data were collected at Chicod Creek at Boyd's Crossroads during the late summer/early fall of 2003. Two of eleven samples exceeded the instantaneous fecal coliform standard of 400 colonies/100 mL (Figure 11).

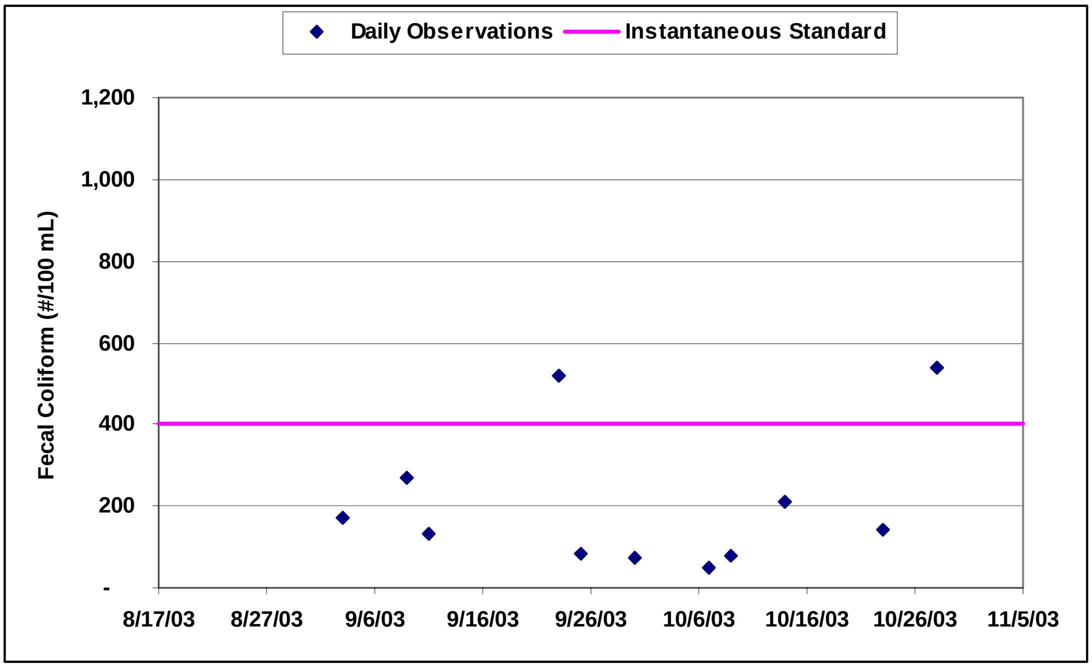


Figure 11. Daily Fecal Coliform Observations at the Upstream Chicod Creek Site

The 11 paired upstream-downstream samples include a wide range of flow conditions, ranging from ~0 cfs (10/9 and 10/28) to 88 and 215 cfs (9/23 and 9/30). The latter two flows fall near the 15^{th} and 5^{th} percentiles of the flow distribution. The majority of the other points are in the range of 35-45^{th} percentile flows.

Seven 30-day geometric means are calculated for the upstream site. None exceed the geometric mean standard of 200 colonies/100 mL (Figure 12).

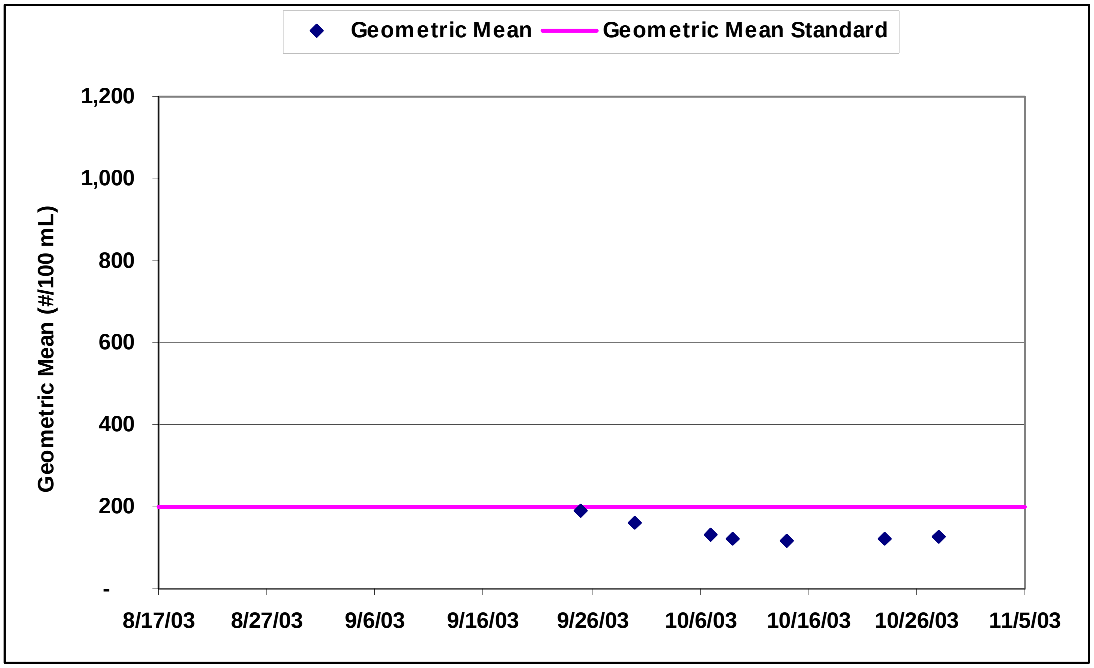


Figure 12. Thirty-Day Geometric Means at the Upstream Chicod Creek Site

It is of interest to compare daily observations at the upstream site to the primary site. Given the number of swine operations draining to creek between the primary site and the upstream site, which has only one swine operation in its drainage area, an increase in concentration would be expected if the swine operations were a significant source of coliform load. The concentrations are quite similar, however, and on some days, the concentration at the upstream site is greater than at the primary site (Figure 13). Each site has two excursions of the instantaneous standard. This suggests that, at least under 2003 conditions, there is little evidence for an increase in loading rate associated with swine operations in the Chicod Creek watershed. Instead, loading rates appear to be fairly consistent across the watershed.

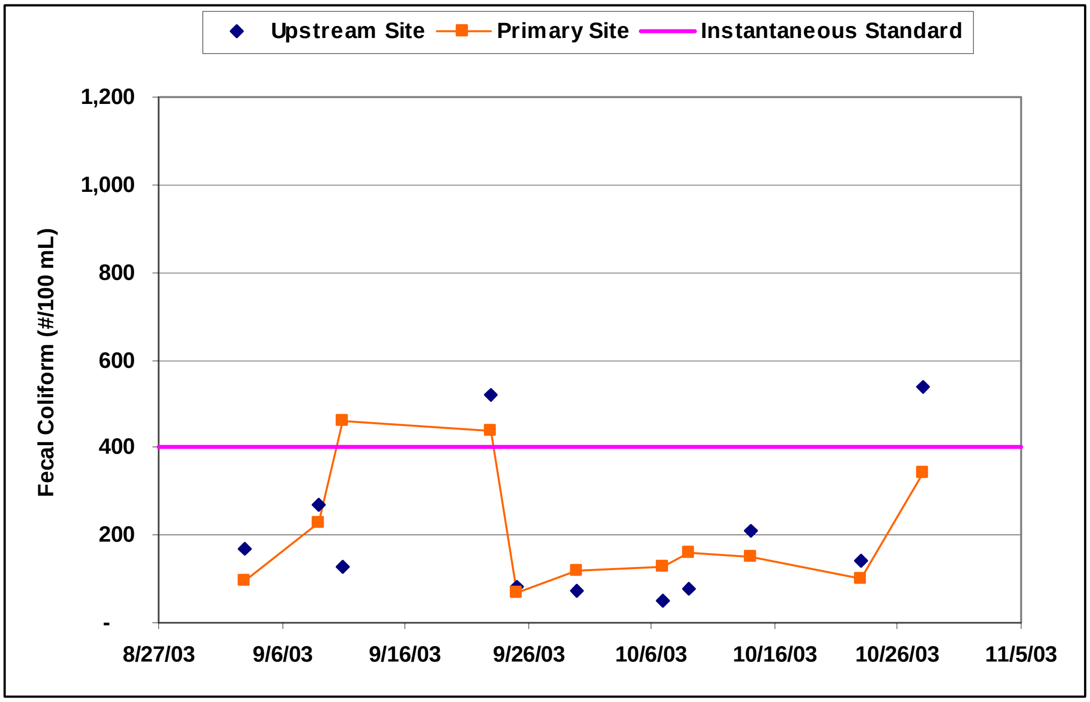


Figure 13. Comparison of Fecal Coliform Observations at the Upstream and Primary Monitoring Sites

1.4.6 Comparison of Fecal Coliform Statistics at Monitoring Stations

Table 5 compares the frequency of excursions of both the instantaneous and geometric mean criteria for each site type. The primary site has the greatest number of excursions of both the instantaneous criterion (21 percent) and the geometric mean criterion (42 percent). This site also drains the greatest area of agricultural land and all of the swine operations in the Chicod Creek Watershed. The upstream site on Chicod Creek has no excursions of the geometric mean criterion, but exceeds the instantaneous criterion in 18 percent of observations. This site drains one known swine operation (Mills Farm, with a design capacity of 8,640 animals (see Table 2), but which has an animal density much less than does the downstream station (436 vs. 1,197 swine/mi^2). The reference site has no excursions of the instantaneous criterion and drains no agricultural land or animal operations; a geometric mean could not be calculated with the available data, but no individual observations exceeded 200 colonies/100 mL. The control sites, which drain less agricultural land and animal operations compared to the primary site, exceed the instantaneous criterion in 17 percent of the observations. Data were not available at the control sites to calculate geometric means.

Table 5. Comparison of Excursions of Fecal Coliform Criteria in the Chicod Creek Watershed and the Reference and Control Sites (period of record)

Sites	Number of Observations	Frequency of Excursions of the Instantaneous Criterion	Frequency of Excursions of the Geometric Mean Criterion
Primary	206	21%	42%
Control	24	17%	na[1]
Reference	23	0%	na[1]
Upstream	11	18%	0%

[1] No 30-day sets of at least five samples were present in the data set.

2 Source Assessment

A critical step in developing a useful and defensible TMDL is the assessment of potential sources. Tetra Tech performed a watershed-wide review of sources that potentially contribute to fecal coliform loading. Geographical information systems and digital orthophotos were used to gain an understanding of the sources within the watershed. Discussion with local jurisdictions and field personnel were also used to identify and quantify potential sources.

Both point and nonpoint sources may contribute fecal coliform to the waterbodies. Potential sources of fecal coliform loading are numerous and often occur in combination. In rural areas, runoff can transport significant loads of fecal coliform from sources such as agricultural activities and wildlife contributions. Septic systems, illicit discharges, broken sewer pipes, and stormwater runoff can be potential sources in urban areas.

Potential sources of fecal coliform loading in the watershed were identified based on an evaluation of current landuse/cover, animal operations, and septic systems. The source assessment was used as the basis of development of the model and ultimate analysis of the TMDL allocations.

2.1 Point Source Fecal Coliform Contributions

There are no permitted point sources in the Chicod Creek Watershed.

2.2 Nonpoint Source Fecal Coliform Contributions

Runoff from landuses in the watershed can contribute significant fecal coliform loading to streams. The Chicod Creek Watershed is primarily rural, so stormwater runoff most likely carries fecal coliform from wildlife, domestic animals, pasture lands, animal operations, and other agricultural lands to nearby streams.

Research was performed to assess the most probable nonpoint sources of fecal coliform. Information on sources was gathered from GIS information, census data, and personal communication with local and state officials. The principal sources investigated were landuse distribution, septic systems, swine and poultry operations, and the populations of wildlife and domestic animals.

Based on the landuse distribution, the flow-duration analysis, and the parameter correlation, it appears that swine operations were the most significant contributor to fecal coliform loading prior to BMP installation. After BMP installation swine operations, agriculture fields, and wildlife are each likely sources of contamination, though the frequency of instantaneous excursions has decreased significantly. Timber harvesting likely exacerbates fecal coliform loading for a few years following harvesting.

2.2.1 Interpretation of Monitoring Data for Nonpoint Sources

A flow-duration curve analysis was performed to identify the flow regimes during which excursions of the water quality criteria occur (see Section 3.1). Excursions that occur only during low-flow events (flows that are frequently exceeded) are likely caused by continuous or point source discharges, which are generally diluted during storm events. Excursions that occur during high-flow events (flows that are not frequently exceeded) are generally driven by storm-event runoff. A mixture of point and nonpoint sources may cause excursions during normal flows.

The flow-duration analysis was presented by monitoring period relative to 1997, which was when most of the water quality BMPs were functioning in the watershed. The majority of excursions of the instantaneous fecal coliform criterion (400 colonies/100 mL), before and after BMP implementation, occurred during higher flows. Only one excursion (observed load 4 percent over standard load) coincided with a flow exceeded 80 percent of the time. Excursions by flow regime are summarized in Table 6. Fifty-six percent of all excursions occur during the highest 20 percent of flows, 42 percent occur during moderate flows, and 2 percent occur during the lowest 20 percent of flows. This distribution suggests that storm event washoff is the likely source of most excursions of the fecal coliform criterion. Storm event loads may include washoff of freshly applied animal waste from sprayfields in this watershed; however, the comparison of upstream and downstream stations in 2003 (Section 1.4.5) suggests that fecal coliform concentrations are not strongly correlated with position in the watershed relative to animal operations.

Table 6. Number of Excursions of the Instantaneous Fecal Coliform Criterion of 400 per 100 mL. Classified by Flow Regime

Flow Regime (Percent of Time Flows Exceeded)	Pre-1/97 Monitoring	Post-1/97 Monitoring	Complete Monitoring Period
0% - 20% (high flows)	19	5	24
20% - 80% (moderate flows)	15	3	18
80% - 100% (low flows)	0	1	1
All flows	34	9	43

To assess the sources of fecal coliform contamination in the Chicod Creek Watershed, a correlation of ammonia, dissolved phosphorus, turbidity, and organic carbon to fecal coliform was performed for the USGS Station at Chicod Creek at SR 1760. A strong correlation between ammonia and dissolved phosphorus with fecal coliform concentration would suggest the swine operations as a major source in the watershed because sprayed lagoon waste contains high concentrations of these dissolved nutrients (Mallin et al., 1997). A strong correlation between ammonia and organic carbon with fecal coliform concentration would suggest malfunctioning septic systems as a potential source. A strong correlation of turbidity with fecal coliform concentration would point to other sources in the watershed such as wildlife whose waste would be washed off during storm events along with upland sediment. High turbidity can also result from lagoon failure, but it is not considered a continuous source of fecal coliform loading and would not result in a correlation with long-term monitoring data.

Parameter correlation was performed for two monitoring periods to assess the impacts of BMPs that were installed in the watershed between 1994 and 1997. Prior to January 1997, the ammonia to fecal coliform correlation was 0.91; after January 1997 it dropped to 0.09. The correlation of dissolved phosphorus to fecal coliform was 0.15 prior to 1997; no dissolved phosphorus measurements were collected after January 1997. Turbidity was not collected prior to January 1997, but correlation to fecal coliform after January 1997 was 0.33. Organic carbon was not collected after January 1997, but has a correlation of 0.29 prior to that date. Together, these results suggest that swine waste was a major source of coliform loading prior to 1997, but has decreased in importance since that time.

Fecal streptococci generally occur in the digestive systems of humans and other warm-blooded animals. In the past, fecal streptococci were monitored together with fecal coliforms and a ratio of fecal coliforms to streptococci was calculated: this ratio was used to determine whether the contamination was of human or nonhuman origin. However, this is no longer recommended as a reliable test (US EPA, 1986).

One common rule of thumb was that fecal coliform to fecal streptococci ratios from human waste would have ratios greater than 4, and from animal waste less than 4. Only 1 of 23 samples at the water quality reference sites had a ratio greater than 4 (4.5); only 1 of 21 samples at the hydraulic control sites had a ratio greater than 4 (4.8); no fecal streptococci data was available at the upstream Chicod site; at the downstream Chicod site, 4 of 92 ratios are greater than 4 with values of 4.3, 5.1, 10.0, and 18.4. Though the method is now considered questionable, it would have suggested that contamination in the Chicod Creek Watershed was due to animal sources rather than human sources.

2.2.2 Agriculture

Fecal coliform loads from agriculture derive from domestic animals, wildlife, and wildfowl. Row crop fields have high runoff volumes compared to most other rural landuses. Concentrated food stores often attract wildlife to fields. Pastureland used for cattle grazing can contribute high concentrations of fecal coliform bacteria, especially if BMPs are not utilized.

According to the 1992 USGS NLCD landuse data, 33.1 percent of the Chicod Creek Watershed is used for row crop agriculture and 8.6 percent is used for pasture land. Row crops are a likely source of past and present fecal coliform loading because (1) row crop fields are known sources of fecal coliform and sediment loading during rainfall/runoff events, (2) most excursions occurred during rainfall events, and (3) fecal coliform was correlated to turbidity (0.33) after BMP implementation (turbidity was not monitored prior to BMP implementation).

Pastureland is not as significant in the Chicod Creek Watershed based on relative area. Although the NLCD landuse/land cover data shows approximately 3,300 acres of pasture in the primary watershed (Table 1), review of the CAFO permitting files has indicated that only 75 head of beef cattle are present in the watershed (Section 1.2.5). Note that some of the land classified as pasture in the satellite-based NLCD data is actually grassed spray irrigation fields associated with swine operations.

2.2.3 Animal Operations

The high correlation between ammonia and fecal coliform prior to January 1997 suggests that liquid wastes, such as swine lagoon effluent or septic system effluent, were a major contributor to fecal coliform loading. Neither dissolved phosphorus nor organic carbon correlate strongly with fecal coliform, but the high number of swine relative to the number of septic systems does suggest that swine operations were a more likely source. The fact that the correlation dropped 10-fold after animal waste BMP implementation also supports this conclusion because the loads from septic systems would not have been affected by the BMPs. The animal waste BMPs appear to be functioning well in this watershed though there may be some room for improvement. However, after 1997, there is no evidence that isolates swine operations as the major source of loading.

2.2.4 Onsite Wastewater Disposal

Failing septic tanks are generally associated with low-flow excursions of the fecal coliform standard because they represent continuous discharges that impact baseflows, but that are often diluted and less apparent during high rainfall periods. Other sources of low flow fecal coliform loading are illicit discharges and other direct inputs of raw sewage. According to the flow duration analysis, only one excursion of the fecal coliform criterion occurred during low flows, suggesting that failing septic systems are not the major source of fecal coliform load in the watershed.

In low-lying watersheds such as Chicod Creek, septic tanks may contribute excessive loads during moderate to high-flow events as water tables rise and meet septic drain fields. If the recharge path to nearby streams is relatively short, the contaminated groundwater may reach the surface before bacterial die-off has occurred.

With a properly functioning septic system, effluent is typically characterized by high nitrate concentrations and low organic carbon concentrations because ammonia and organic carbon are oxidized to nitrate and CO_2, respectively, in the unsaturated drainfield. If the water table rises into the drain field, these processes are less likely to occur and ammonia and organic carbon concentrations remain high. Though ammonia is strongly correlated to fecal coliform concentrations prior to 1997 (0.91), organic carbon is poorly correlated (0.27). Given the other likely sources of ammonia and fecal coliform in the watershed and the small number of septic systems, septic systems are not the likely cause of fecal coliform excursions in the watershed.

2.2.5 Impacts of Silviculture

Much of the forested land in the Chicod Creek Watershed is used for silviculture, though it is not apparent from the NLCD database what fraction of the forest is managed. Fecal coliform loads in forestland derive primarily from wildlife. Timber harvesting has been correlated with elevated fecal coliform loads due to the altered hydrology of the forest system after harvest (Ensign and Mallin, 2001; Mallin et al., 2001). Contaminated runoff that flows through an intact forest is typically infiltrated before reaching a stream. Clearcutting and harvesting practices shorten runoff pathways and reduce infiltration, allowing more runoff to reach the stream more quickly. Clearcutting also reduces evapotranspiration, which results in higher water tables and runoff volumes.

A water quality study in the coastal plains of North Carolina showed that clearcutting resulted in significantly higher concentrations of suspended solids, nutrients, and fecal coliform bacteria. Ensign and Mallin (2001) compared water quality at two adjacent watersheds with similar hydrology, landuse patterns, and density of animal operations. The Goshen Swamp Watershed is 52.5 percent forest, 46.0 percent agriculture, 1.0 percent urban, and has a swine density of 705/km^2. The Six Runs Creek Watershed is 62.6 percent forest, 36.4 percent agriculture, 1.1 percent urban, and has a swine density of 665/km^2. One hundred thirty acres (outside of a 10-m stream buffer) of the Goshen Swamp Watershed were clear-cut during May through September of 1998; Six Runs Creek was used as the control watershed and no clearcutting occurred. All North Carolina best management practices were observed during the study and no violations were found.

Water quality was monitored before, during, and after the clearcutting period in both watersheds. The mean fecal coliform concentration in the Goshen Swamp Watershed increased from 116 colonies/100 mL to 1,993 colonies/100 mL after clearcutting with a maximum concentration of 23,400 colonies/100 mL. Prior to clearcutting, concentrations above 330 were not observed. Fecal coliform concentrations remained elevated well into 1999 (last reported monitoring) with 3,510 colonies/100 mL observed in July.

During the pre- and post-clearcutting monitoring periods at the Six Runs Creek reference site, mean fecal coliform concentrations were 143 and 244 colonies/100 mL, respectively. Though the mean increased by 70 percent, the concentrations remained relatively low compared to Goshen Swamp Creek. During the pre-clearcutting monitoring period, the maximum fecal coliform concentration observed at Six Runs Creek was 1,100 colonies/100 mL; in the period after clearcutting at Goshen Swamp the maximum concentration was 3,020 colonies/100 mL. Again, the magnitude of increase is low relative to that seen in Goshen Swamp.

Both watersheds experienced excursions of the North Carolina instantaneous fecal coliform standard (400 colonies/100 mL) prior to the clearcutting that occurred in the Goshen Swamp watershed. Excursions were likely due to swine operations. Once clearcutting occurred, increases in fecal coliform concentrations in the control watershed were minor compared to the clearcut watershed. Though timber harvesting is not a direct source of fecal coliform loading, altered hydrology does appear to impact water quality and increase fecal coliform loading to streams.

Another study reported the impacts of timber harvesting on a coastal watershed. Mallin et al. (2001) used closure of shell-fish waters to identify fecal coliform impacts. Mallin et al. report that 1,100 acres of harvesting waters in Carteret County were closed for three years following a forest clearcut. The direct sources of fecal coliform were not identified.

Public data on the acreage of managed forest in the Chicod Creek Watershed is not available. In addition, the forest industry is not required to notify the Division of Forest Resources when clearcutting or timber harvesting occur, but the forest service does track reforestation by county (Raval, 2004). Pitt County currently has 208,306 acres of forestland. During the period January 1, 1997 through December 31, 2002, 12,000 acres were reforested (approximately 5.8 percent of total forest).

1998 DOQQs for the Chicod Creek watershed show extensive managed pine plantations, particularly in the southern part of the watershed. On the land use coverage (Table 1) there are a total of 20,400 acres in forest and forested wetland. Assuming that all of this land is in silviculture and is predominantly loblolly pine with a rotation period of 30 years, on average only 680 acres per year would be harvested. Even if increased coliform loads persisted for three years, the average area affected (2,040 acres or less) would be much smaller than the amount of active agricultural land (greater than 15,000 acres).

From available information, we are not able to match timber harvesting with particular water quality excursions in Chicod Creek. It is likely that harvesting has occurred since 1997 and may have led to some increase in fecal coliform concentrations in streams near harvesting sites. However, given the expected rotation period for timber harvest, it appears unlikely that silviculture is a major source of bacterial load above natural background relative to agricultural land uses.

2.3 ANALYSIS OF EXISTING MANAGEMENT MEASURES

As discussed in Section 1.4.2, there was a significant decrease in fecal coliform concentrations in Chicod Creek in the early 1990s. Based on NC DENR's "Final Report on BMP Implementation in the Tar-Pamlico River Basin" (1999), the majority of installed animal waste management BMPs were operational by early 1997. Discussion with local NRCS staff suggests that farmer education was increased and better operating practices were encouraged from 1992 to 1993. The sharp decline in fecal coliform observations after 1992 leads to the conclusion that education, improved operating procedures, and water quality BMPs have significantly improved water quality in the Chicod Creek Watershed. Prior to January 1993, 42 percent of fecal coliform observations exceeded the instantaneous criterion of 400 colonies/100 mL. After January 1993, the frequency decreased to 9 percent. The frequency of exceeding the geometric mean standard decreased from 100 percent in 1992 to 0 percent in 1997 and 2003.

2.4 CONCEPTUAL MODEL OF FECAL COLIFORM IN CHICOD CREEK

Runoff from animal waste management dominated bacteriological conditions in the Chicod Creek watershed in the early 1990s. Installation of BMPs and development of waste management plans in the mid-1990s appears to have drastically reduced the significance of this source. For the period since 1997, fecal coliform concentrations in Chicod Creek have continued to occasionally exceed water quality criteria, but not by a large amount.

Under current conditions, the major source of bacterial load to Chicod Creek appears to be storm washoff from agricultural land (including, but not limited to sprayfields), with some additional input in excess of natural conditions from clearcut forest and other land uses. Loading during washoff events is likely exacerbated by the extensive use of artificial drainage in the watershed and relatively low level of efforts to implement cropland BMPs.

(This page left intentionally blank.)

3 Technical Approach to TMDL

Given the results of the initial data analysis and time and budget constraints, an approach focusing on the magnitude of water quality standard exceedances and potential sources contributing to the stream during the exceedances was used. This approach used a flow-duration curve analysis to determine the flow conditions under which impairment occurs. In addition, the approach was used to identify source types, specify the assimilative capacity of the stream, and estimate the magnitude of load reduction required to meet the water quality standards. The potential sources determined from the load-duration curve were inventoried and assessed for their relative contributions to allocate reductions among sources. The results of this assessment were used to derive the allocations required by the TMDL.

This section describes the process used to specify the endpoints and calculate the existing loading and assimilative capacity. The determination of the TMDL reductions and loads is presented in Section 4.

3.1 TMDL ENDPOINTS

The achievement of the TMDL objectives requires the instream concentrations to meet both the instantaneous standard of 400 CFU/100 mL and the geometric mean standard of 200 CFU/100 mL. Both standards are considered to be the endpoints for the determination of the fecal coliform TMDL for Chicod Creek.

3.2 LOAD-DURATION CURVES FOR FECAL COLIFORM

The analysis of pollutant levels in conjunction with water quality standards and measured flow is a useful tool for assessing critical conditions, as well as existing and target loads. The Load-Duration Curve Method (Stiles, 2001, 2002; Cleland, 2002, 2003) was used to assess fecal coliform impairment. This method plots flow and observed data to analyze the flow conditions under which impairment occurs and water quality deviates from the standard.

A flow-duration curve analysis was performed to identify the flow regimes during which excursions of the water quality criteria occur. This method determines the relative ranking of a given flow based on the percent of time that historic flows exceed that value. Flow data have been collected by USGS at the primary site (USGS Gage 02084160) from October 1, 1975 to the present, as summarized in Section 1.3.

Once the relative rankings were calculated for flow, monitoring data were matched by date to compare observed water quality to the flow regime during which it was collected. This type of analysis can help define the flow regime during which excursions occur and identify the sources of the impairment. Excursions that occur only during low-flow events (flows that are frequently exceeded) are likely caused by continuous or point source discharges, which are generally diluted during storm events. Excursions that occur during high-flow events (flows that are not frequently exceeded) are generally driven by storm-event runoff. A mixture of point and nonpoint sources may cause excursions during normal flows, although there are no point sources in this application.

The fecal coliform assessment uses the Load-Duration Curve approach for determination of the existing load and assimilative capacity. The analysis was performed for both the instantaneous and geometric mean criteria to determine the most conservative measure of impairment. Figure 14 and Figure 15 present the results of the instantaneous and geometric mean load-duration analyses, respectively, based on USGS data collected for Chicod Creek at State Road 1760 near Simpson, NC. Loads, as CFU (colony forming units) per day, are presented by collection period relative to 1997, which was when most of the water quality BMPs were functioning in the watershed. The average of the flow observations corresponding to the fecal coliform sample dates was used as the flow for each geometric mean load.

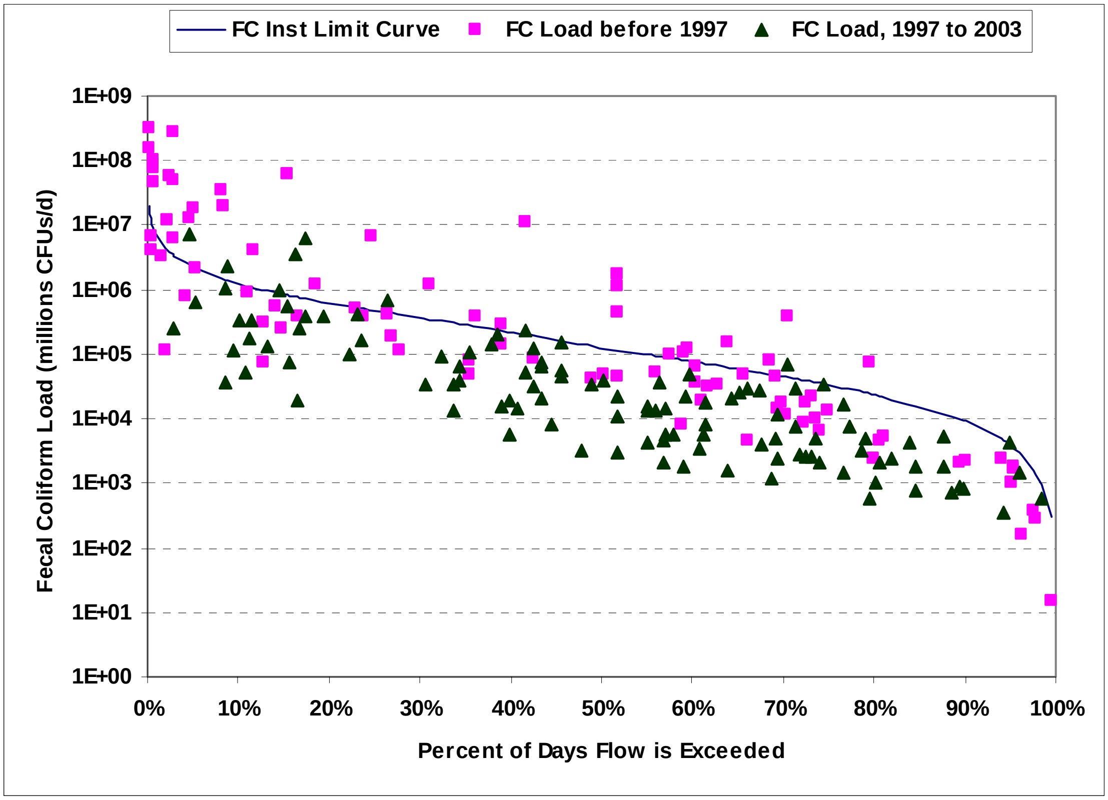


Figure 14. Instantaneous Fecal Coliform Load-Duration Curve (400/100 mL) for Chicod Creek at State Road 1760 Near Simpson, NC

The majority of excursions of the instantaneous criterion from both periods occurred during higher flows (toward the left side of Figure 14). Only one excursion (observed load 4 percent over standard load) coincided with a flow exceeded 80 percent or more of the time. Prior to 1997, 38 percent of observed daily fecal coliform loads exceeded the instantaneous-target load based on the criterion of 400/100 mL. After 1997, 8 percent of daily loads exceeded the target.

Comparison to the geometric mean standard requires at least five samples within a 30-day period. Geometric means were calculated for all trailing 30-day windows (30-days prior to a given sample) with at least five observations. A total of 19 valid geometric mean samples can be calculated, including overlapping sets. Eight of these are from 1992, one from 1997, and ten from 2003. The geometric mean load-duration curve is shown in Figure 15.

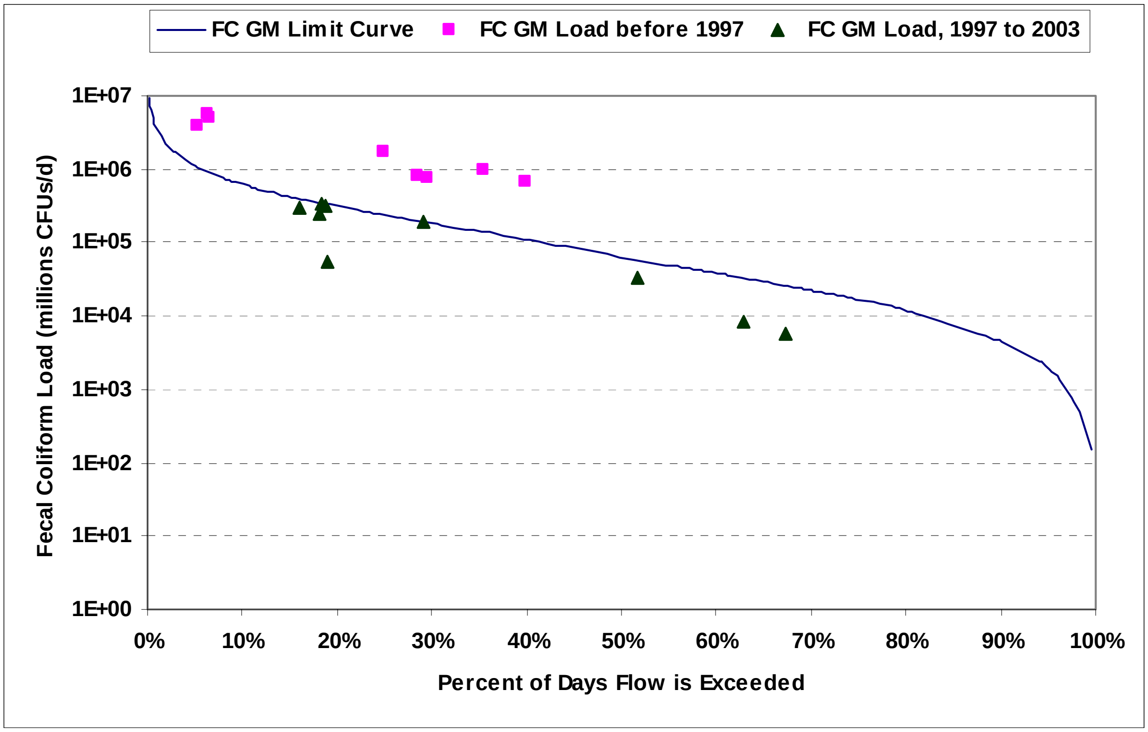


Figure 15. Geometric-Mean Fecal Coliform Load-Duration Curve for Chicod Creek at State Road 1760 Near Simpson, NC

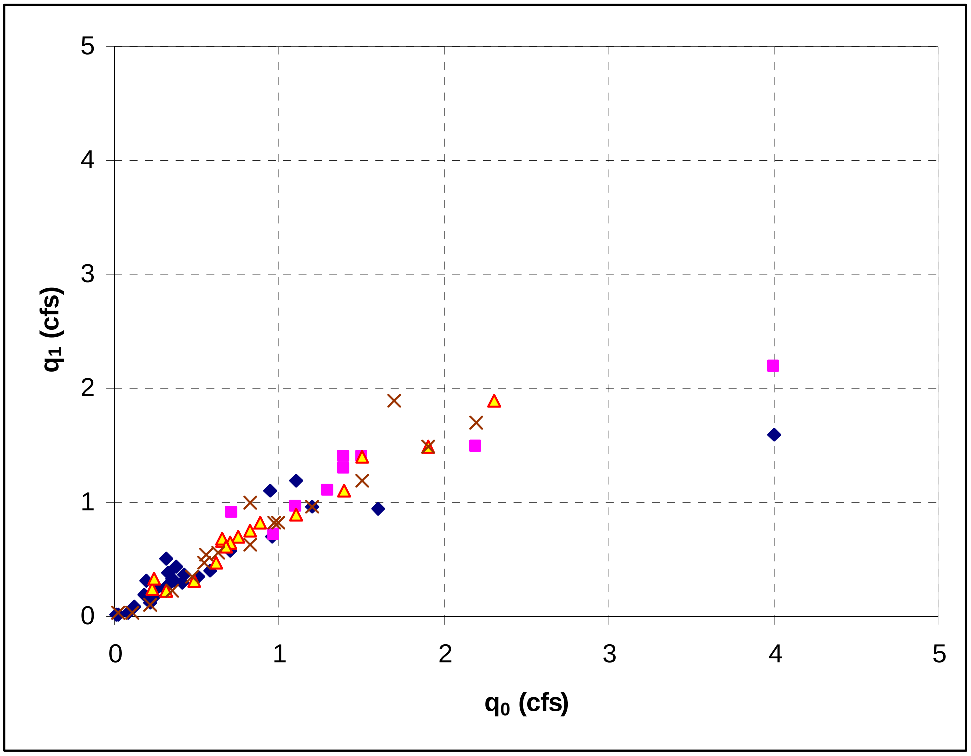
One hundred percent of the geometric mean loads calculated prior to 1997 exceed the geometric mean criterion of 200 colonies/100 mL. In order to meet the criterion, reductions of 74 to 86 percent would be required. After 1997, no geometric mean loads exceed the criterion, although several fall close to the criterion limit. Because no excursions of the geometric mean criterion are documented within the most recent 5-year assessment period, direct reductions in the geometric mean are not required as a part of this TMDL. However, reductions in instantaneous concentrations will be required, which should in turn result in a decrease in the geometric mean concentration.

It is difficult to assign flow patterns to excursions of the geometric mean criterion with this data set because no geometric means can be calculated during dry weather conditions. All of the geometric means calculated prior to 1997 exceed the criterion, but they were all observed during flows exceeded less than 40 percent of the time.

The load-duration curves developed in this section provide guidance in the determination of the pollutant sources that are likely to be the primary contributors to elevated levels of fecal coliform. Because most excursions (of the instantaneous standard) occurred during high flows, it is likely that nonpoint sources are the major contributor to fecal coliform loading in this watershed.

Further advances in the application of load-duration curve techniques are provided in Cleland (2003). This approach involves separating the load duration results into different intervals characteristic of flow-regimes. In addition, samples are marked to distinguish baseflow from surface flow conditions.

To apply this method in full, it is first necessary to distinguish surface from baseflow conditions. The TSPROC utility (Watermark Computing, 2002) performs automated baseflow separation using a digital filter after specification of the baseflow decay rate or recession coefficient. The recession coefficient can be estimated by plotting flow on a given day (q_1) versus flow on the preceding day (q_0). Flows representative of true baseflow conditions should exhibit a linear relationship with slope equal to the recession coefficient and fall just below the 1:1 line on such a plot, while flows influenced by surface runoff will diverge non-linearly further to the right. 0 shows candidate baseflow recession data from dry weather periods in the summers of 2001 and 2002. From the plot it is evident that flows below about 2 cfs exhibit baseflow behavior. The recession coefficient calculated through these points is 0.86, which is lower than the typical range of 0.90 – 0.95, reflecting the significant role of artificial drainage in the watershed.

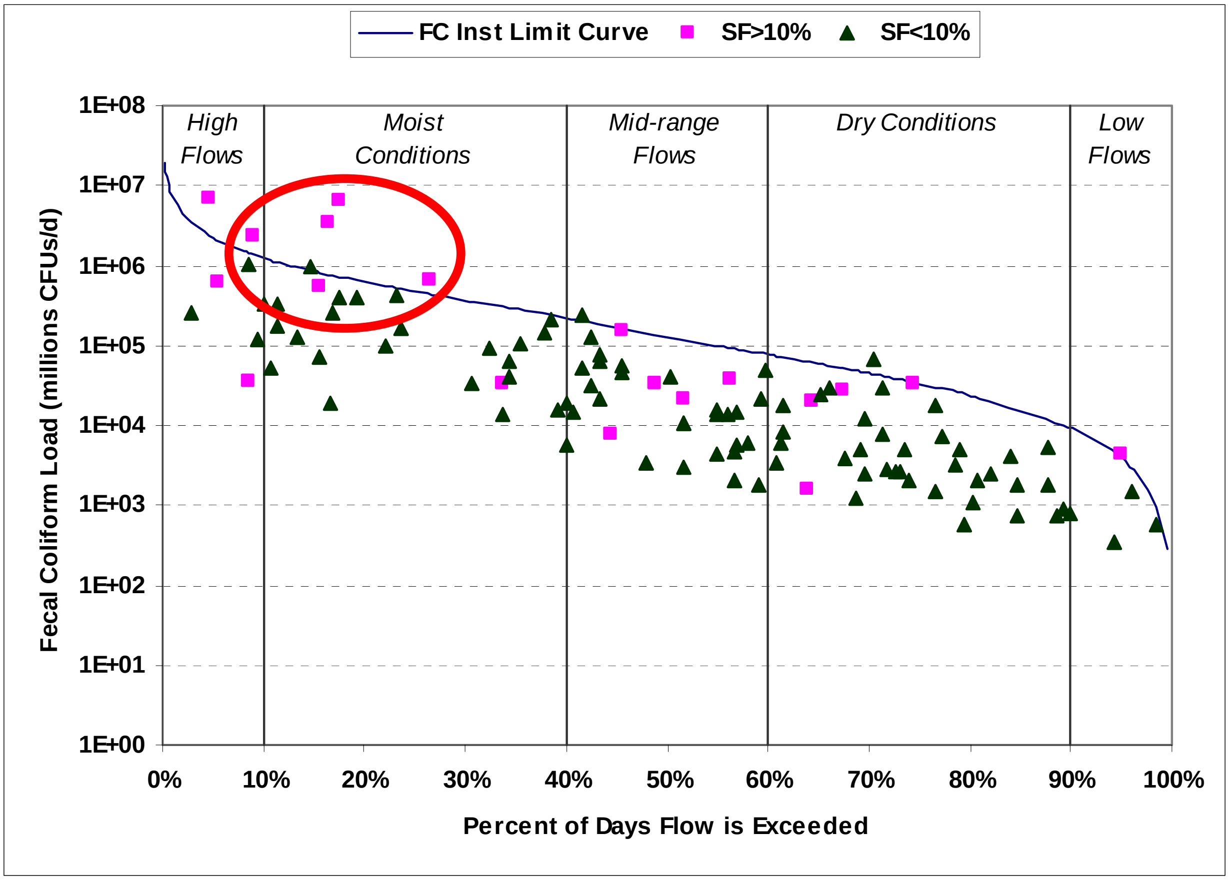


Note: Symbols distinguish different dry weather recession periods.

Figure 16. Graphical Method for Determining Baseflow Recession in Chicod Creek

Due to the artificial drainage and fast recession of flows in Chicod Creek, hydrograph peaks are brief, and few observations coincide with conditions that are dominated by surface runoff. Rather than use the criterion of surface flows (SF) greater than 50 percent recommended by Cleland (2003) to distinguish surface versus non-surface washoff loading, a criterion of 10 percent SF was adopted. Because surface washoff concentrations are typically an order of magnitude or more greater than groundwater concentrations, this low cutoff should still provide useful information on the dominance of observed concentrations by surface loading pathways.

Figure 17 provides a load-duration characterization of the post-1997 instantaneous coliform data, using the methods recommended by Cleland (2003). Observations above the criterion line occur primarily in the high flow and moist condition sections of the plot, with the area of greatest concern denoted by the red circle. A number of the observations at lower flows that fall on or near the criterion line are also associated with surface washoff events (SF > 10 percent). This further suggests that remaining bacteriological problems in Chicod Creek are mostly associated with surface washoff events. Three observations that fall just above the criterion line are associated with a lower fraction of surface runoff and could reflect a non-precipitation driven source, such as a lagoon spill or improper spray application.



Notes: SF = Surface runoff fraction. Circle indicates conditions at which the criterion is most likely to be exceeded.

Figure 17. Load-Duration Characterization of Post-1997 Instantaneous Fecal Coliform Concentration Data in Chicod Creek

The nine observations that fall above the criterion line occur throughout the year (two in January, two in April, one in July, three in September, and one in October). Therefore, there does not appear to be a seasonal pattern to criterion excursions.

3.3 Determination of Existing Fecal Coliform Load and Assimilative Capacity

NC DWQ's 305(b) assessment methodology relies on data collected during the previous seven years. Significant work on installing BMPs in the watershed was completed in 1997, leading to a change in observed fecal coliform concentrations. Therefore, only the data since 1997 are relevant to estimating load reductions.

In the recent data, there are no documented excursions of the geometric mean criterion, and no reductions are required to achieve water quality standards. However, there are a limited number of excursions of the instantaneous criterion (Figure 14) indicating the need for an incremental amount of further reductions.

3.3.1 Instantaneous Criterion

The load-duration curve for instantaneous fecal coliform concentrations presented in Figure 17 for post-1997 data is used as the basis for estimating the TMDL.

The water quality criterion for instantaneous fecal coliform concentrations allows up to 20 percent of samples within a 30-day period to exceed the target. The regulations clearly recognize that some excursions of the 200 CFU/100 mL target are expected to occur during washoff events. This frequency component needs to be taken into account when determining the assimilative capacity.

In some past applications, NC DWQ has used an ad hoc approach to the analysis of the difference between existing load and assimilative capacity. This approach involved fitting a regression line through those observations that were above the criterion limit curve and associated with the 10^{th} through 95^{th} percentile of the flow distribution. Based on guidance from EPA Region 4 and NCDENR, data collected during extreme drought conditions (> 95^{th} percentile) and floods (< 10^{th} percentile) were excluded from the reduction analysis. Then, the natural log of the coliform loads exceeding the criterion was regressed on the natural log of the flow interval, and this regression curve was used to estimate the existing loading at every 5^{th} percentile flow recurrence. The existing loading was then compared to the allowable loading (with a margin of safety), and the difference used to establish needed reductions. Because the regression line goes through the center of the distribution of points above the criterion limit curve, it allows a fraction of the observations to exceed the criterion; however, this fraction is not explicitly tied to the 20 percent frequency of allowable excursions specified in the criterion.

For this TMDL, a more rigorous quantitative approach is used. The essence of this approach is follows:

- Establish a regression model to predict existing load as a function of flow percentage.
- Develop a prediction confidence interval on the regression line, with the confidence interval set at a level that reflects the allowed 20 percent frequency of excursions.
- Calculate a reduced criterion limit curve at 90 percent of the criterion concentration, thus incorporating a 10 percent margin of safety.
- Evaluate needed reductions based on the maximum difference between the prediction confidence interval and the reduced criterion limit curve, incorporating a margin of safety, between the 10^{th} and 95^{th} percentile flows.

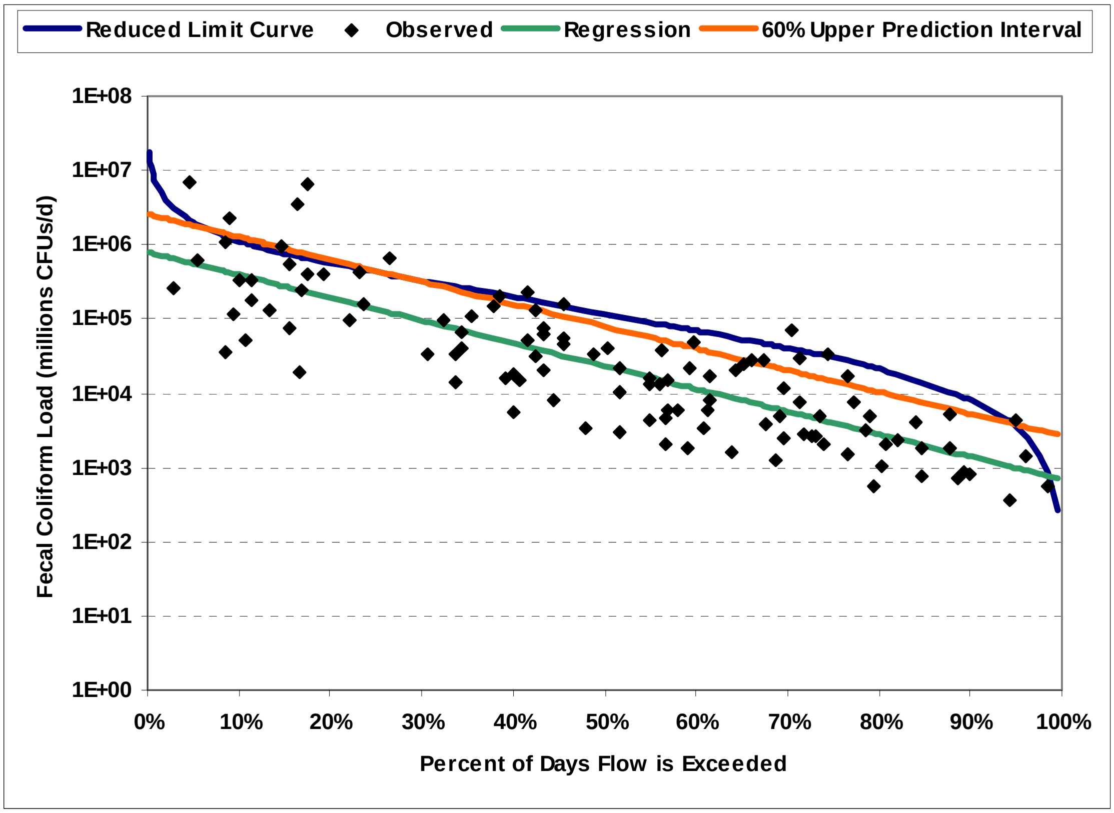
The confidence interval is based on the point prediction interval about the regression line. That is, it reflects the range of expected values for individual observations at a given flow frequency, and incorporates both the uncertainty in the regression line and the natural variability of individual points about the regression line. In theory, the upper 60^{th} percentile confidence interval is just sufficient to meet the criterion (20 percent of observations are expected to fall in both the high and low tails of the distribution). However, the TMDL also requires a Margin of Safety. This is achieved by evaluating needed reductions in relation to the criterion limit curve reduced by 10 percent (that is, evaluated at 360 rather than 400 CFU/100 mL). The Margin of Safety is thus assigned explicitly through a 10 percent reduction in the criterion.

Complete details of the methodology for establishing the regression line and prediction confidence interval are presented in Appendix B. A comparison of regression methods showed that the best fit was obtained with a log-linear regression (adjusted R^2 = 70 percent), yielding a model of the following form:

$$Ln\left(Coliform\ Load\ in\ 10^6\ CFU/d\right) = 13.57 - 7.123 \cdot Flow\ Fraction,$$

where flow fraction is the percentile of the flow expressed as a fraction.

Application of the regression equation and its upper 60^{th} percentile prediction interval (see Appendix B) is shown in Figure 18. As expected, the majority, but not all of the observed data fall below the upper prediction interval. For instance, in the 10-40 percent flow frequency range, 3 points or 10 percent of the observations fall above the line, consistent with the water quality criterion that allows up to 20 percent of observations within a 30-day period to exceed the target concentration.



Note: Reduced limit curve represents allowed load at 90 percent of the water quality criterion of 400 CFU/100 mL.

Figure 18. Regression Analysis of the Instantaneous Fecal Coliform Load-Duration Curve, Chicod Creek Data for 1997-2003

The upper 60 $^{\%le}$ Prediction Interval lies above the reduced instantaneous Limit Curve in two areas of the graph – between flow frequencies of 5 and 32 percent, and for flow frequencies above 95 percent. These are the two areas in which reductions may be needed. The amount of these reductions, based on the maximum difference between the 90 percent Prediction Interval and the Limit Curve for each of the flow intervals as defined by Cleland (2003), but omitting flows with greater than 95 percent is summarized in Table 7. Reductions of about 16 percent (including the Margin of Safety incorporated through use of the reduced limit curve) are required for the moist condition regime. High flows (0-10 percent frequency of excursion) are usually not addressed in North Carolina fecal coliform TMDLs; but do not require any greater reduction than is needed for the "moist" conditions and are included in the table for information purposes. These reductions are consistent with the existing data, as most reported excursions of the water quality criterion (since 1997) have occurred in these flow ranges. The regression model also predicts a potential need for a small (< 1 percent) load reduction in the low flow range (90-95 percent flow frequency). However, the linear nature of the model fit may be suspect in this tail range.

Table 7. Fecal Coliform Target Load and Reduction Requirements Calculated using the Load-Duration Curve Approach

Flow Range	Critical Percentile	Flow (cfs)	Target Load (CFU/d)	60^{le} Prediction Limit (CFU/d)	Reduction Required
0-10% (High Flows)	9.38%	134	1.18×10^{12}	1.33×10^{12}	11.0%
10-40% (Moist Conditions)	12.73%	100	8.81×10^{11}	1.05×10^{12}	15.9%
40-60% (Mid-Range Flows)	40.40%	22	1.94×10^{11}	1.53×10^{11}	NA
60-90% (Dry Conditions)	89.24%	1	8.81×10^{9}	5.56×10^{9}	NA
90-95% (Low Flows)	94.83%	0.43	3.79×10^{9}	3.82×10^{9}	0.9%

Notes:

Critical Percentiles are the values within the flow range at which the ratio of the 6^{th} percentile prediction limit to target load is greatest. These are evaluated from the set of flows on all days on which fecal coliform data were collected, excluding days with zero flow.

Flow column gives the flow corresponding to the critical percentile.

Target Load is the value of 90 percent of the instantaneous criterion limit curve at the specified flow and percentile, thus incorporating a 10 percent Margin of Safety.

60^{le} Prediction Limit is the upper prediction interval about the regression line at the 60 percent confidence level.

Reduction Required is calculated as (60^{le} Prediction Limit – Target Load)/(60^{le} Prediction Limit)

3.3.2 Geometric Mean Criterion

As noted above, no reductions are required in the geometric mean concentration to achieve water quality standards, based on monitoring from 1997 to present. However, reductions in the geometric mean can reasonably be expected to occur as a result of required reductions in the instantaneous concentration.

The 5-day geometric mean is calculated as

$$GM = \left[\prod_{i=1}^{5} x_i \right]^{1/5},$$

where the x_i are the individual observations. If each of the individual x_i are reduced by a factor β, then the new geometric mean, GM_{new}, would also be reduced:

$$GM_{new} = \left[\prod_{i=1}^{5} \beta\, x_i \right]^{1/5} = \left(\beta^5\right)^{1/5} \cdot \left[\prod_{i=1}^{5} x_i \right]^{1/5} = \beta \cdot GM \, .$$

The actual reduction in the geometric mean depends on whether reductions apply to all or some of the individual observations. For instance, if only the highest concentration in a set of five is reduced (for instance, because implementation measures address large event runoff only), then the change would be equivalent to $\beta^{1/5}$.

The Chicod Creek coliform TMDL proposes a reduction of 16 percent in instantaneous concentrations, specifically targeted toward flow with a recurrence interval of 40 percent or less. If the reduction applied to all fecal coliform concentrations, then the geometric mean would also be expected to decline, on average, by 16 percent (to 84 percent of the existing value). If, however, the reduction applies only to the upper 40 percent of the flow distribution, the geometric mean would decline by 6.7 percent (to 93.3 percent of the existing geometric mean). While no reduction is required in the observed geometric mean concentration, this expected reduction will provide a further margin of safety relative to existing conditions.

(This page left intentionally blank.)

4 TMDL Development

Sections 1 through 3 described the processes and rationale required to identify the endpoints, critical conditions, potential sources, and target loadings for each pollutant. These efforts formed the basis for the TMDL process. This section describes the key components required by the TMDL guidelines and synthesizes the project efforts to set the final TMDL allocations.

4.1 TMDL Definition

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality criteria (in this case a target for warm water aquatic habitat). TMDLs can be expressed in terms of mass per time or by other appropriate measures such as concentration. TMDLs are comprised of the sum of individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation:

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

The TMDL is equivalent to the assimilative capacity or loading capacity of the waterbody, which varies according to flow, as shown in Section 3.3.

4.2 TMDL Endpoints

TMDL endpoints represent the instream water quality targets used in quantifying TMDLs and their individual components. As discussed in Section 3, there are two endpoints that can be used to determine the fecal coliform TMDL, as specified in the North Carolina water quality standards. Both the instantaneous limit of 400 CFU/100 mL and the geometric mean of 200 CFU/100 mL were considered. However, based on analysis of monitoring data since 1997, the existing documented impairment is based only on excursions of the instantaneous criterion. Therefore, the instantaneous criterion serves as the endpoint for this TMDL. However, as noted in Section 3.3.2, implementing reductions to meet the instantaneous criterion will also result in a reduction in geometric mean concentrations.

4.3 Critical Conditions

The Load-Duration-Curve approach addresses the load reductions required during all flow regimes. Unlike a steady state analysis, it does not depend on the identification of critical conditions to determine allocations. The load-duration analysis in Section 3.2, however, indicates that excursions of the criterion are primarily associated with higher flows with significant surface runoff. Therefore, implementation of the TMDL should focus on storm washoff events as a critical condition.

As shown in Table 7 in Section 3.3.1, the maximum reduction in existing loads is required at a flow of 100 cfs. At a flow of 100 cfs, the assimilative capacity (the maximum load that just meets the instantaneous limit of 400 CFU/100 mL) is 4.79×10^{11} CFU/d.

4.4 Seasonal Variation

The load-duration approach automatically accounts for seasonal variations in flows. No seasonal pattern was detected in excursions of the criterion (Section 3.2), which occur throughout the year. Thus, no additional seasonal component is needed in the TMDL, and the reductions should be sought over all seasons.

4.5 Margin of Safety

There are two methods for incorporating a MOS in the analysis: 1) by implicitly incorporating the MOS using conservative model assumptions to develop allocations; or 2) by explicitly specifying a portion of the TMDLs as the MOS and using the remainder for allocations. For the purposes of this TMDL analysis, an explicit 10 percent margin of safety was specified by calculating reductions relative to the load limit curve estimated at 90 percent of the instantaneous criterion.

At the critical flow condition of 100 cfs, the assimilative capacity is 9.79×10^{11} CFU/d, while the target load is 8.81×10^{11} CFU/d – a 10 percent reduction. Therefore, the explicit MOS is 9.79×10^{10} CFU/d at the critical flow of 100 cfs.

An additional implicit margin of safety is provided because the proposed reductions are also likely to result in achieving standards during those high flow conditions (flow recurrence less than 10 percent), as they are not typically addressed in North Carolina coliform TMDLs.

4.6 Wasteload Allocations

There are no permitted point sources in the watershed. Therefore, no wasteload allocations are required.

4.7 Load Allocations

Load allocations account for the portion of the TMDL assigned to nonpoint sources. Federal regulations at 40 CFR § 130.2(g) state that "Load allocations are best estimates of the loading, which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished."

As there are no wasteload allocations, the total load allocations for Chicod Creek are equivalent to the target load at critical conditions of 100 cfs flow, or 8.81×10^{11} CFU/d (Table 7).

Quantitative estimates of coliform loading rates from individual land uses have not been established for the Chicod Creek watershed. However, "gross allotment" load allocations may be estimated for individual land uses, based on the following assumptions:

- Natural background loading rates are applied equally to all land areas and are assigned based on the percentage of land in the watershed in each land use.
- The natural background loading may be estimated from the ratio of the long-term geometric mean loading observed at the reference sites of Durham Creek and Van Swamp to the 1997-2002 long-term geometric mean loading observed in Chicod Creek (where the long-term geometric mean refers to the geometric mean of all individual observations), or 19/70.
- The remainder of the load allocation is assigned to those land uses that are likely to contribute fecal coliform load at rates above natural background, specifically cropland,

pasture, residential land, and the fraction of forest that has been cut within the last two years, estimated at 1360 acres (on average), or 6.7 percent of the total forest area.

- The portion of the load allocation in excess of natural background is allocated to individual land uses according to their proportion of the total area of land expected to generate load in excess of natural background.

Using these assumptions, the Load Allocations may be partitioned as summarized in Table 8.

Table 8. Fecal Coliform Bacteria Load Allocations for Chicod Creek

Source Area	Percent of Land Area	Percent of Area with Loads above Background	Load Allocations (CFU/d at 100 cfs flow)		
			Natural Background	Additional Allocation	Total
Agriculture	41.60%	89.63%	1.19×10^{11}	5.34×10^{11}	6.53×10^{11}
Forest	55.80%	8.01%	1.59×10^{11}	4.77×10^{10}	2.07×10^{11}
Residential	1.50%	2.36%	4.28×10^{9}	1.40×10^{10}	1.83×10^{10}
Other	1.10%	0.00%	3.14×10^{9}	0	3.14×10^{9}
Total	***100.0%***	***100.0%***	$\boldsymbol{2.85 \times 10^{11}}$	$\boldsymbol{5.96 \times 10^{11}}$	$\boldsymbol{8.81 \times 10^{11}}$

4.8 TMDL SUMMARY

The load-duration curves for the existing and target conditions were evaluated to determine the reductions needed to meet the TMDL endpoints. To achieve the specified TMDL targets, a reduction of about 16 percent from nonpoint runoff sources will be required, and is specified in the Load Allocations. The components of the TMDL are summarized in Table 9.

Table 9. TMDL Summary for Fecal Coliform in Chicod Creek

Criterion	Instantaneous concentration shall not exceed 400 CFU/100 mL in more than 20 percent of samples in a 30-day period
Criterion Load (TMDL; at 100 cfs)	9.79×10^{11} CFU/d
Existing Load	1.05×10^{12} CFU/d
Wasteload Allocation	0
Load Allocations	8.81×10^{11} CFU/d
Margin of Safety	9.79×10^{10} CFU/d
Reduction Required	15.9 %

Note: All loading rates are calculated at the critical flow of 100 cfs.

(This page left intentionally blank.)

5 Report Summary

This report presents the development of Total Maximum Daily Loads (TMDLs) for fecal coliform impairment of Chicod Creek, a tributary to the Tar River, in Pitt and Beaufort Counties, North Carolina. This waterbody was placed on the North Carolina 2002 list of impaired waters (the 303(d) list) for fecal coliform bacteria. Available water quality data were reviewed to determine the frequency of excursions. The load-duration curve method was applied to determine the critical periods and the sources that lead to criteria excursions, along with the reductions needed to achieve water quality standards.

While the watershed has many swine and poultry operations, extensive efforts to improve animal waste management appear to have largely mitigated confined animal operations as a source of bacterial loading. Since the mid-1990s, fecal coliform loading has been greatly reduced; however, the remaining loading is sufficient to result in an unacceptably high rate of excursions of the instantaneous standard of 400 CFU/100 mL. There are no point sources in the watershed. Continued excess loading appears to be due primarily to stormwater washoff from agriculture lands and, potentially, clearcut forest lands.

The TMDL analysis, which uses a load-duration curve approach, indicates that a reduction of about 16 percent in the wet-weather loading of fecal coliform bacteria to Chicod Creek is needed to achieve water quality standards. These reductions can be achieved through additional efforts to install BMPs that limit surface transport of pollutants from agricultural and forest lands, such as the use of vegetative filter strips and enhanced riparian buffers. In addition, inspection and enforcement activities should be continued to ensure that confined animal feeding operations are in compliance with their waste management plans.

(This page left intentionally blank.)

6 TMDL Implementation Plan

The TMDL analysis was performed using the best data available to specify the fecal coliform reductions necessary to achieve water quality criteria. The intent of meeting the criteria is to support the designated use classifications in the watershed. A detailed implementation plan is not included in this TMDL. The involvement of local land owners and agencies will be needed in order to develop an implementation plan.

In general, reductions in fecal coliform loads should be sought through identification and installation of additional agricultural and post-cutting silvicultural BMPs to reduce loads during runoff events. Implementation should also ensure proper operation of animal waste sprayfields in accordance with waste management plans. Additional information on potential next steps is included in Section 8.

(This page left intentionally blank.)

7 Stream Monitoring

Monitoring will continue on a monthly interval at the ambient monitoring site on Chicod Creek. The continued monitoring of fecal coliform will allow for the evaluation of progress towards the goal of achieving water quality standards and intended best uses.

(This page left intentionally blank.)

8 Future Efforts

Bacteriological water quality in Chicod Creek appears to have improved significantly over the last decade. This improvement appears to have been the result of improved adoption of agricultural BMPs, particularly those related to hog waste sprayfield applications. The TMDL estimates, however, that a further incremental reduction in fecal coliform loading is needed.

The most important current sources of fecal coliform loading appear to be stormwater runoff from agricultural and, perhaps, cut-over silvicultural land. Addressing these sources will require further voluntary adoption of BMPs, facilitated by existing cost-share programs and educational efforts. Improper operation of sprayfields may also be an occasional source of coliform excursions. If present, such sources are in violation of the no-discharge general permit and should be addressed through enforcement.

As described in Section 1.2.4.2 extensive efforts were conducted in the early 1990s to implement BMPs at targeted swine operations in order to improve the operation and performance of lagoon-spray irrigation waste systems. Much room for improvement existed at swine operations during that time period because such facilities were not subject to regular inspections or regulatory requirements. After the N.C. General Assembly enacted legislation in 1997 requiring regular inspections of swine operations and development and implementation of waste utilization plans, most of the BMPs applied to targeted facilities in previous years were subsequently applied at most, if not all, facilities through the implementation of the waste plans. As a result, little opportunity now exists for achieving further reductions in fecal coliform loading through the application of structural BMPs at swine operations.

As discussed in Section 1.2.4.1, after the enactment of legislation regulating concentrated animal feeding operations (CAFOs), the most common type of recorded illicit “discharge” at swine operations in the Chicod Creek watershed resulted from irrigating on saturated spray fields. Occurrences of this nature are most likely prevented or reduced through increased enforcement efforts. At the time of Tetra Tech’s review of the CAFO permitting and enforcement files, only three NCDWQ staff members were assigned to inspecting operations within the Washington Regional Office territory for NCDWQ. That territory consists of 21 northeastern counties, which contain over 500 CAFOs that are almost all swine operations. Considering the administrative demands and travel time associated with carrying out such an effort, the current staffing level may not be sufficient to ensure the desired frequency of inspections of these facilities. An increase in the level of program resources devoted to inspection and enforcement may result in a reduction in the occurrence of episodic illicit discharges from spray irrigation systems at swine operations. Review of the permitting and enforcement files also indicated that some of the enforcement cases related to illicit discharges originated with citizen complaints. Increased enforcement efforts to address these problems could be augmented by efforts to better educate citizens in the area on how to recognize and report illicit discharges. Establishment and promotion of a dedicated phone “hotline” for such citizen reports, such as the Sediment Hotline operated by the N.C. Division of Soil and Water Conservation, might also increase the effectiveness of enforcement efforts.

The future effort offering the largest opportunity for reduction in fecal coliform loads is that of application of BMPs to row crop agricultural lands. As discussed in Section 1.2.3, estimates are that only 100 – 150 acres, or approximately one percent of the row cropland within the Chicod Creek watershed use grassed field borders and drainage swales. A concerted effort to increase the application of such BMPs could result in significant reductions in coliform loads stemming from wildlife attracted to row crops as a food source. BMPs of this type would also help achieve reductions in nutrient export to Pamlico Sound.

(This page left intentionally blank.)

9 Public Participation

A draft of the TMDL will be publicly noticed through various means, including notification in the local newspapers. DWQ will electronically distribute the draft TMDL and public comment information to known interested parties. The TMDL will also be available from the Division of Water Quality's website at http://h2o.enr.state.nc.us/tmdl/ during the comment period. A public meeting will be held in mid-2004 to present the TMDL and answer questions. The public comment period will last for a minimum of 30-days.

(This page left intentionally blank.)

10 Further Information

Further information concerning North Carolina's TMDL program can be found on the Internet at the Division of Water Quality website**:**

http://h2o.enr.state.nc.us/tmdl/

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

Brian Jacobson, Modeler
e-mail: Brian.Jacobson@ncmail.net

Michelle Woolfolk, Supervisor
e-mail: Michelle.Woolfolk@ncmail.net

(This page left intentionally blank.)

11 References

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

Cleland, B.R. 2003. TMDL development from the "bottom up" – Part III: Duration curves and wet-weather assessments. America's Clean Water Foundation, Washington, DC. Available online at http://www.tmdls.com/tipstools/docs/TMDLsCleland.pdf (accessed 2/11/04).

Ensign, S.H. and M.A. Mallin. 2001. Stream water quality changes following timber harvest in a coastal plain swamp forest, *Wat. Res.* Vol. 35, No. 14, pp. 3381-3390.

Etheridge, Tim. 2004. Personal Communication by phone interview, January 10, 2004 and February 2, 2004. District Conservationist, USDA – Natural Resources Conservation Service, Pitt County, N.C.

FACA. 1998. Federal Advisory Committee (FACA). Draft final TMDL Federal Advisory Committee Report.

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold, New York.

Mallin, M.A., J.M. Burkholder, M.R. McIver, G.C. Shank, H.B. Glasgow, Jr., B.W. Touchette, J. Springer. 1997. Comparative effects of poultry and swine waste lagoon spills on the quality of receiving streamwaters, *Journal of Environmental Quality* 26:1622-1631.

Mallin, M.A., S.H. Ensign, M.R. McIver, G.C. Shank, P.K. Fowler. 2001. Demographic, landscape, and meteorological factors controlling the microbial pollution of coastal waters, *Hydrobiologia* 460: 185-193.

Mason, R.R., Jr. 1988. Ground-water and surface-water conditions in the Chicod Creek Basin, North Carolina, before, during, and after channel modifications. Proceedings of the AWRA Symposium on Coastal Water Resources, Wilmington, NC, May 22-25, 1988, American Water Resources Association, p. 419-427.

Mason, R.R, Jr., C.E. Simmons, S.A. Watkins. 1990. Effects of Channel Modifications on the Hydrology of Chicod Creek Basin, North Carolina, 1975-87. U.S. Geological Survey Water-Resources Investigations Report 90-4031, 83 p.

NCCGIA. 2002. *BasinPro* GIS data system Version 2.1. N.C. Center for Geographic Information and Analysis. Raleigh, N.C. 4 CD set.

NCDENR. 1999. Final Report on BMP Implementation in the Tar-Pamlico River Basin: Results of a Cooperative Agreement Funded Through Section 104 (b) (3) of the Clean Water Act. Prepared by J. Todd Kennedy, Division of Soil and Water Conservation, December 1999.

NCDENR. 2003. North Carolina Water Quality Assessment and Impaired Waters List (2002 Integrated 305(b) and 303(d) Report) Final, February 2003. Prepared by the North Carolina Department of Environment and Natural Resources, Division of Water Quality.

Raval, Chardul. 2004. Personal communication via phone on January 21, 2004 concerning managed forests in Pitt County, North Carolina.

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

Stiles, T.C. 2001. A simple method to define bacteria TMDLs in Kansas. ASIWPCA/ACWR/WEF TMDL Science Issues Confrence: On-site Program, St. Louis, MO, pp. 375-378.

USEPA 2000. Revisions to the Water Quality Planning and Management Regulation and Revisions to the National Pollutant Discharge Elimination System Program in Support of Revisions to the Water Quality Planning and management Regulation; Final Rule. *Federal Register,* 65:43586-43670.

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

USEPA. 1986. Bacteriological Ambient Water Quality Criteria for Marine and Fresh Recreational Waters. EPA 440/5-84-002. U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH.

Watermark Computing. 2002. PEST Surface Water Utilities. Watermark Numerical Computing, Brisbane, Australia.

Watkins, S.A. and C.E. Simmons. 1984. Hydrologic Conditions in the Chicod Creek Basin, North Carolina, Before and During Channel Modification, 1975-81. Water-Resources Investigations Report 84-4025. U.S. Geological Survey, Raleigh, NC.

Woodside, Michael D. and Simerl, Benjamin R., 1995, Land use and nutrient concentrations and yields in selected streams in the Albemarle-Pamlico Drainage Basin, North Carolina and Virginia. Open-File Report 95-457. U.S. Geological Survey, Raleigh, NC.

12 Appendices

(This page left intentionally blank.)

Appendix A. Fecal Coliform Data for Chicod Creek

Fecal coliform data were collected at two sites in Chicod Creek. The primary site used for TMDL allocations is coincident with USGS Station 02084160 at State Road 1760 near Simpson, NC and is equivalent to NC DWQ site O6450000. This station is referred to as the "primary site" because it represents the majority of data collected in the watershed and is near the outlet of the listed reach. USGS flow gaging is also available at this station.

Fecal coliform data were also collected by NC DWQ for a brief time as part of a special study from Chicod Creek at Boyd's Crossroads (NCDWQ Site ChC1). This site is referred to as the "upstream site" because it is upstream of the primary site as well as most of the swine facilities in the watershed. No flow gage is present at this site.

Table A-1 lists fecal coliform and flow data at the primary site. Table A-2 lists fecal coliform data collected at the upstream site. Table A-3 lists the valid 30-day geometric mean fecal coliform concentrations and representative flows at the primary site.

Table A-1. Fecal Coliform and Flow Data at the Primary Site in Chicod Creek (USGS 02084160, NC DWQ O6450000)

Date	Flow (cfs)	FC Observation (#/100 mL)
11/8/77	1020	160
11/10/77	268	120
4/27/78	1480	8600
11/29/78	5.1	660
11/5/79	3.5	160
1/2/80	14	120
11/17/80	3.7	72
1/12/81	13	150
1/13/81	12	150
5/12/81	70	700
6/7/81	854	4200
6/7/81	854	4900
8/5/81	0.16	96
8/31/81	7.3	180
10/13/81	0.03	20
12/1/81	0.36	196
1/4/82	227	3400
1/5/82	215	410
1/18/82	20	180
2/24/82	45	380
4/20/82	4.8	120
8/12/82	456	10
8/23/82	4.9	390
12/21/82	87	120
2/22/83	78	200
3/1/83	394	6100
7/5/83	85	30000
8/15/83	0.14	84
9/19/83	2.6	1200
11/14/83	1	84
1/3/84	24	240
1/11/84	353	31000
3/26/84	345	720
5/8/84	109	1500
5/21/84	4.1	88

Date	Flow (cfs)	FC Observation (#/100 mL)
9/13/84	927	2100
9/14/84	1980	3200
11/14/84	2.5	40
12/17/84	5.7	32
2/6/85	416	1200
3/26/85	29	68
4/12/85	4.6	100
5/29/85	0	160
7/15/85	3.8	110
9/4/85	2.2	96
10/23/85	28	560
12/18/85	44	180
1/29/86	55	390
5/8/86	0.94	96
12/17/86	4	180
1/23/87	942	3320
6/8/92	2.3	80
6/10/92	150	5400
6/12/92	50	5400
6/24/92	24	490
7/2/92	6.5	960
7/8/92	7.8	350
7/17/92	0.36	210
7/20/92	154	9000
7/27/92	5.9	330
7/28/92	21	22000
7/29/92	12	1570
8/3/92	12	5800
8/3/92	12	3770
8/5/92	7.8	190
8/7/92	4.7	160
8/10/92	4.5	3400
8/12/92	9.9	210
8/14/92	355	5600
8/17/92	1320	210
8/19/92	572	230
8/21/92	243	2160
8/26/92	35	1400
9/2/92	7.6	100
3/30/93	116	317
4/15/93	52	310
5/18/93	8.4	527
6/15/93	91	250
7/21/93	3.9	240
8/11/93	0.39	105
10/19/93	6.9	207
11/17/93	8.5	38
1/20/94	100	126
2/16/94	42	108
3/25/94	29	113
4/13/94	8.2	628
5/17/94	0.5	200
9/20/94	0.28	24
10/20/94	9.1	430
12/14/94	101	31
1/8/97	54	315
2/17/97	146	10

Date	Flow (cfs)	FC Observation (#/100 mL)
2/19/97	78	10
3/5/97	30	54
3/11/97	22	27
3/19/97	67	240
4/2/97	24	27
4/10/97	12	36
4/16/97	12	10
5/1/97	84	270
5/14/97	20	63
5/15/97	20	260
5/29/97	9.4	64
6/10/97	8.1	240
6/11/97	7.4	45
6/25/97	3.9	27
7/7/97	6.3	130
7/17/97	4.5	630
7/21/97	17	370
8/4/97	3	100
8/18/97	1.6	45
8/19/97	3.6	380
9/2/97	5	10
9/16/97	6.5	10
9/29/97	6	170
10/6/97	0.1	230
10/27/97	0.43	420
11/17/97	3.8	54
11/24/97	2.3	36
12/8/97	10	64
12/9/97	12	36
1/5/98	9.5	20
1/7/98	9.9	55
2/9/98	119	18
2/12/98	145	300
2/26/98	23	10
3/5/98	5.7	205
4/2/98	79	1799
5/12/98	17	109
6/3/98	4	27
7/7/98	0.31	190
8/3/98	0	10
8/31/98	112	120
9/3/98	10	55
10/6/98	12	73
11/2/98	7.7	18
1/6/99	31	18
2/1/99	33	118
3/3/99	31	45
4/6/99	15	9
5/4/99	2.6	9
6/15/99	9.7	155
7/7/99	1.7	100
8/5/99	3.1	227
9/9/99	126	109
9/27/99	350	30
10/4/99	23	33
10/12/99	10	18
11/15/99	8.4	9

Date	Flow (cfs)	FC Observation (#/100 mL)
1/11/00	142	672
2/3/00	113	64
3/7/00	1.1	27
4/4/00	4.2	27
5/2/00	134	36
6/8/00	2.7	73
7/10/00	1.2	63
8/22/00	1.2	182
9/19/00	74	3500
10/3/00	2.4	18
11/2/00	1	36
12/21/00	19	45
1/9/01	9.5	9
2/7/01	18	18
4/11/01	7.5	32
5/17/01	2	49
8/20/01	19	137
9/19/01	4.9	41
10/17/01	2.8	47
11/8/01	1.6	19
12/12/01	5.4	210
1/8/02	45	600
2/11/02	53	125
3/6/02	98	54
4/4/02	244	1200
5/9/02	3.1	20
6/25/02	0.48	30
7/9/02	0.97	34
8/8/02	0	50
9/19/02	0	210
10/15/02	8.3	108
11/21/02	30	88
12/12/02	36	39
1/7/03	8.9	27
1/16/03	5.3	30
1/28/03	3.7	23
1/30/03	4.3	73
2/6/03	4.8	100
2/12/03	14	100
2/13/03	9.4	25
3/10/03	83	36
4/14/03	77	132
5/13/03	4.8	21
6/23/03	4.3	280
7/14/03	13	124
8/19/03	74	220
9/3/03	7.4	96
9/9/03	26	230
9/11/03	21	460
9/23/03	88	440
9/25/03	57	70
9/30/03	215	120
10/7/03	17	130
10/9/03	19	160
10/14/03	29	150
10/22/03	21	100
10/28/03	25	340

Table A-2. Fecal Coliform Data at the Upstream Site in Chicod Creek (NCDWQ Site ChC1)

Date	FC Observation (#/100 mL)
9/3/03	170
9/9/03	270
9/11/03	130
9/23/03	520
9/25/03	83
9/30/03	73
10/7/03	51
10/9/03	76
10/14/03	210
10/23/03	140
10/28/03	540

Table A-3. 30-day Fecal Coliform Geometric Mean Concentrations and Representative Flows at the Primary Site in Chicod Creek (USGS 02084160, NC DWQ O6450000)

End Date	Representative Flow (cfs)	Fecal Coliform Geometric Mean (#/100 mL)
7/8/92	40.1	853
7/20/92	38.5	792
7/29/92	29.7	1327
8/7/92	23.8	1175
8/14/92	49.9	1401
8/19/92	191.6	1219
8/26/92	186.8	1112
9/2/92	215.3	763
3/19/97	68.6	32
6/11/97	13.0	103
2/6/03	5.4	42
2/13/03	6.9	48
9/25/03	39.9	199
9/30/03	69.1	183
10/7/03	70.7	192
10/9/03	70.7	187
10/14/03	81.2	150
10/22/03	71.2	142
10/28/03	70.5	153

Note: Valid 30-day geometric means require at least 5 samples within a 30-day period. Results are reported for every 30-day period, by end date, with 5 or more samples. “Representative flows” are the averages of the flows associated with each of the individual observations within the 30-day period.

(This page left intentionally blank.)

Appendix B. Assimilative Capacity and Load Reduction Calculations

B.1 Development of Regression Equation

Regression equations were developed to predict fecal coliform load in Chicod Creek (CFU/d) as a function of flow frequency. The two regression relationships considered were a log-linear relationship (natural log of load as a function of flow frequency) and a log-log relationship (natural log of load as a function of the natural log of flow frequency). Based on visual inspection (Figure B-1), the log-linear regression is appropriate for the analysis, exhibiting a linear relationship with an approximately constant distribution of residuals.

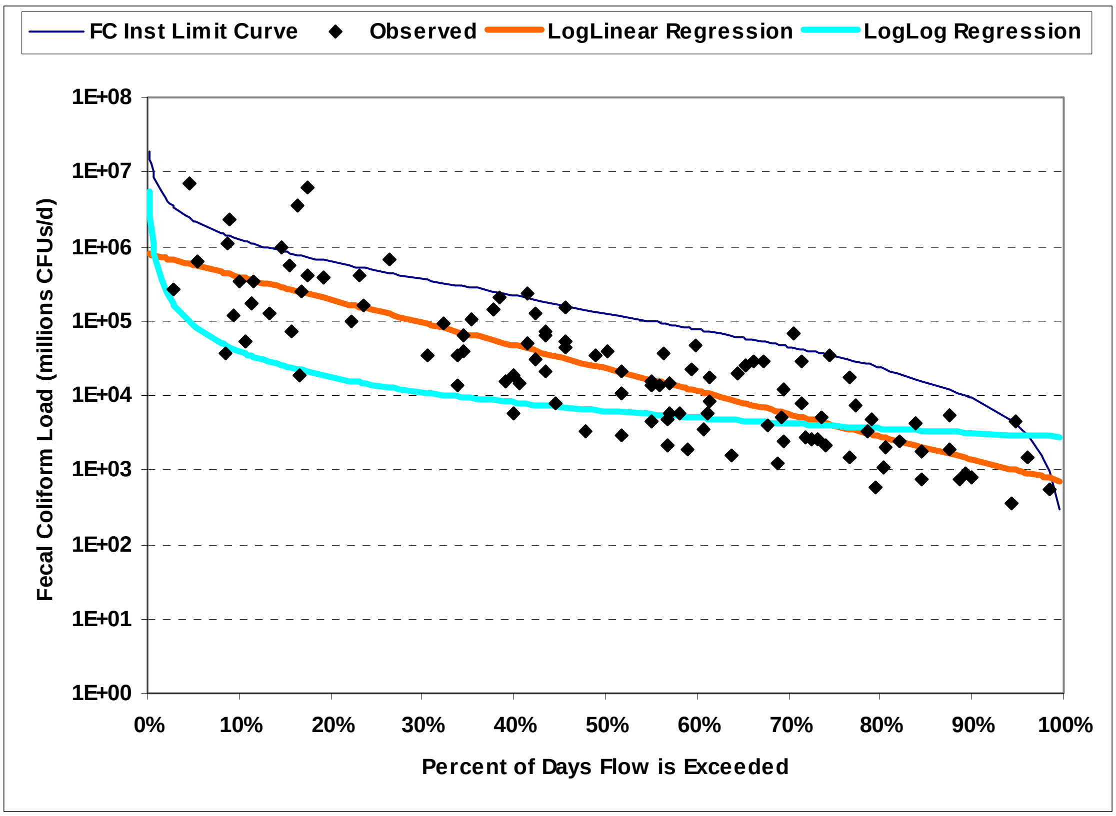


Figure B-1. Regression Equations for Fecal Coliform Load versus Flow Frequency, Chicod Creek, 1997-2003

Results of the regression analysis are summarized in Table B-1.

Table B-1. Regression of Natural Logarithm of Fecal Coliform Load on Flow Frequency, Chicod Creek Fecal Coliform Data, 1997-2003

Regression Statistics	
Multiple R	0.839171
R Square	0.704208
Adjusted R Square	0.701543
Standard Error	1.175686
Observations	113

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	365.2746	365.2746	264.2631	3.91E-31
Residual	111	153.4285	1.382239		
Total	112	518.7031			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*
Intercept	13.57047	0.249015	54.49662	6.03E-82	13.07703	14.0639	13.07703
Flow %le	-7.12253	0.438143	-16.2562	3.91E-31	-7.99074	-6.25432	-7.99074

B.2 ESTIMATION OF PREDICTION INTERVALS

The method requires the estimation of a prediction interval about the regression line. In addition, because the regression is in log space, the bias inherent in conversion from log space to arithmetic space must be addressed.

The regression equation yields a minimum variance unbiased estimate of the local mean value, μ_0 of the natural logarithms of load, conditional on a corresponding value of the independent variable, x_0, (expressed as the deviation from the mean of all observed x values), in this case representing the flow fraction:

$$\mu_0 = \beta_0 + \beta_1 \cdot x_0 + \varepsilon \,,$$

where ε is a random disturbance term. The desired confidence limit (in log space) is given by the prediction interval estimate for an individual realization y_0 with mean μ_0. This interval addresses both the uncertainty in estimating the mean and the variability of individual observations about the mean and is given by

$$y_0 = \mu_0 \pm t_{\alpha,n-2} \cdot s_y \cdot \sqrt{\frac{1}{n} + \frac{{x_0}^2}{\sum {x_i}^2} + 1} \,,$$

where s_y is the sample standard deviation of the y values, and $t_{\alpha,\, n\text{-}2}$ is the Student's t statistic with tail area α and n-2 degrees of freedom. For a two-tailed 90 percent confidence interval, $\alpha = 0.05$.

Conversion from logarithmic to arithmetic space introduces a bias, as the transform is not symmetrical. The exact minimum variance unbiased estimator of the arithmetic mean from the logarithmic mean does not have a closed-form solution, but, for large samples, is closely approximated by (Gilbert, 1987):

$$w_0 = e^{\left(y_0 + {s_{y0}}^2 / 2 \right)},$$

where w_0 is the estimator in arithmetic space and ${s_{y0}}^2$ is the local variance about the mean line, or

$$s_{y0} = s_y \cdot \sqrt{\frac{1}{n} + \frac{{x_0}^2}{\sum {x_i}^2}}\ .$$

(This page left intentionally blank.)

Appendix C. Public Notification of Public Review Draft of Chicod Creek TMDL.

Chicod Creek, Tar-Pamlico River Basin

Now Available Upon Request

Chicod Creek Fecal Coliform Total Maximum Daily Load
Public Review Draft – May 2004

Is now available upon request from the North Carolina Division of Water Quality. This TMDL study was prepared as a requirement of the Federal Water Pollution Control Act, Section 303(d). The study identifies the sources of pollution, determines allowable loads to the surface waters, and suggests allocations.

TO OBTAIN A FREE COPY OF THE TMDL REPORT:

Please contact Mr. Brian Jacobson (919) 733-5083, extension 552 or write to:

Mr. Brian Jacobson
Water Quality Planning Branch
NC Division of Water Quality
1617 Mail Service Center
Raleigh, NC 27699-1617

The draft TMDL is also located on the following website: http://h2o.enr.state.nc.us/tmdl. Interested parties are invited to comment on the draft TMDL study by **June 30, 2004**. Comments concerning the report should be directed to Mr. Brian Jacobson at the above address.

Public Meetings Notice

A public meeting to discuss the Chicod Creek Fecal Coliform TMDL will be held on **Monday, June 14th** at 10:00am at the following address:

Pitt County Agricultural Center
403 Government Circle
Greenville, NC 27834
Phone: (252) 752-2720

PUBLISHER'S AFFIDAVIT

NORTH CAROLINA
PITT COUNTY:

Allison Hennasey affirms that she is clerk of The Daily Reflector, a newspaper published daily at Greenville, Pitt County, North Carolina, and that the advertisement, a true copy of which is herreto attached, entitled

Public Notice
Chicod Creek

was published in said The Daily Reflector on the following dates:

May 8, 2004

and that the said newspaper in which such notice, paper, document or legal advertisement was published, was at the time of each and every publication, a newspaper meeting all of the requirements and qualifications of Chapter 1, Section 597 of the General Statutes of North Carolina and was a qualified newspaper within the meaning of Chapter 1, Section 597 of the General Statutes of North Carolina.

Allison Hennasey

Affirmed and subscribed before me this 14th **day**

of July, 2004

Anita C. House
(Notary Public)

My commission expires 11/17/06

ANITA C. HOUSE NOTARY PUBLIC PITT COUNTY, N.C.

PUBLIC NOTICE
State of North Carolina
Division of Water Quality

Availability of the Chicod Creek Fecal Coliform Total Maximum Daily Load (TMDL).

Copies of the TMDL may be obtained by calling Mr. Brian Jacobson at (919) 733-5083, extension 552 or on the internet at http://h2o.enr.state.nc.us/tmdl.

A public meeting will be held at 10:00 AM, June 14, 2004 at the Pitt County Agricultural Center, 403 Government Circle in Greenville, NC 27834. Written comments regarding the TMDL will be accepted until June 30, 2004. Please mail comments to Mr. Brian Jacobson, Water Quality Planning Branch, NC Division of Water Quality, 1617 Mail Service Center, Raleigh, NC 27699-1617.

May 8, 2004.

(This page left intentionally blank.)