PROPOSED
TOTAL MAXIMUM DAILY LOAD (TMDL)

for

E. Coli

in the

Lower Tennessee River Watershed (HUC 06020001)

Bledsoe, Bradley, Hamilton, Loudon, Marion, McMinn, Meigs,

Rhea, Roane, and Sequatchie Counties, Tennessee

FINAL

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TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF FIGURES (cont'd)

LIST OF TABLES

LIST OF TABLES (cont'd)

LIST OF ABBREVIATIONS

ADB	Assessment Database
AFO	Animal Feeding Operation
BMP	Best Management Practices
BST	Bacteria Source Tracking
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CFU	Colony Forming Units
DEM	Digital Elevation Model
DWPC	Division of Water Pollution Control
E. coli	Escherichia coli
EPA	Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrological Simulation Program - Fortran
HUC	Hydrologic Unit Code
LA	Load Allocation
LDC	Load Duration Curve
LSPC	Loading Simulation Program in C^{++}
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NHD	National Hydrography Dataset
NMP	Nutrient Management Plan
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PCR	Polymerase Chain Reaction
PDFE	Percent of Days Flow Exceeded
PFGE	Pulsed Field Gel Electrophoresis
Rf3	Reach File v.3
RM	River Mile
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
SWMP	Storm Water Management Program
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment & Conservation
TDOT	Tennessee Department of Transportation
TMDL	Total Maximum Daily Load
TWRA	Tennessee Wildlife Resources Agency
USGS	United States Geological Survey
UCF	Unit Conversion Factor
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Total Maximum Daily Load for E. coli in Lower Tennessee River Watershed (HUC 06020001)

Impaired Waterbody Information

State: Tennessee
Counties: Hamilton
Watershed: Lower Tennessee River (HUC 06020001)
Constituents of Concern: E. coli

Impaired Waterbodies Addressed in This Document:

Waterbody ID	Waterbody	Miles Impaired
TN06020001001T – 0200	NORTH MARKET STREET BRANCH	2.5
TN06020001007 – 0100	FRIAR BRANCH	26.9
TN06020001007 – 0200	UNNAMED TRIB TO SOUTH CHICKAMAUGA CREEK[a]	1.1
TN06020001007 – 0510	SPRING CREEK	9.6
TN06020001007 – 1000	SOUTH CHICKAMAUGA CREEK[b]	17.6
TN06020001029 – 0300	LEWIS BRANCH	1.5
TN060200011240 – 0100	UNNAMED TRIB TO CITICO CREEK	1.2
TN060200011240 – 1000	CITICO CREEK	6.1
TN060200011244 – 0100	DOBBS BRANCH	5.3
TN060200011244 – 0200	UNNAMED TRIB TO CHATTANOOGA CREEK	1.4
TN060200011244 – 0300	MCFARLAND SPRINGS BRANCH[b]	1.2
TN060200011244 – 0400	GILLESPIE SPRINGS BRANCH[a]	1.9
TN060200011244 – 1000 & 2000	CHATTANOOGA CREEK[b]	8.4
TN06020001426 – 0100	STRINGERS BRANCH	5.8

[a] A TMDL could not be developed for these waterbodies. Insufficient monitoring data was available. Additional monitoring is recommended to allow for either development of a TMDL or delisting.
[b] Portions of these waterbodies lie in another state. A TMDL for Fecal Coliform has been developed by the State of Georgia for those portions of the waterbodies lying within their jurisdiction.

Designated Uses:

The designated use classifications for waterbodies in the Lower Tennessee River Watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation.

Water Quality Targets:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January, 2004* for recreation use classification (most stringent):

> The concentration of the E. coli group shall not exceed 126 colony forming units per 100 mL, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 mL shall be considered as having a concentration of 1 per 100 mL. In addition, the concentration of the E. coli group in any individual sample taken from a lake, reservoir, State Scenic River, or Tier II or III stream (1200-4-3-.06) shall not exceed 487 colony forming units per 100 mL. The concentration of the E. coli group in any individual sample taken from any other waterbody shall not exceed 941 colony forming units per 100 mL.

TMDL Scope:

Waterbodies identified on the Final 2004 303(d) list as impaired due to E. coli. TMDLs were developed for impaired waterbodies on a HUC-12 subwatershed or waterbody drainage area basis.

A TMDL could not be developed for Gillespie Springs Branch and the unnamed tributary to South Chickamauga Creek due to insufficient monitoring data. Additional monitoring is recommended to allow for either development of a TMDL or delisting.

Analysis/Methodology:

The TMDLs for impaired waterbodies in the Lower Tennessee River Watershed were developed using a load duration curve methodology to assure compliance with the E. Coli 126 CFU/100 mL geometric mean and the 487 CFU/100 mL maximum water quality criteria for Tier II waterbodies and 941 CFU/100 mL maximum water quality criteria for non-Tier II waterbodies. A duration curve is a cumulative frequency graph that represents the percentage of time during which the value of a given parameter is equaled or exceeded. Load duration curves are developed from flow duration curves and can illustrate existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the region of the waterbody flow regime represented by these existing loads. Load duration curves were used to determine the load reductions required to meet desired maximum concentrations for E. coli. When sufficient data were available, load reductions were also determined based on geometric mean criteria.

Critical Conditions:

Water quality data collected over a period of 10 years for load duration curve analysis were used to assess the water quality standards representing a range of hydrologic and meteorological conditions.

Seasonal Variation:

The 10-year period used for LSPC model simulation period for development of load duration curve analysis included all seasons and a full range of flow and meteorological conditions.

Margin of Safety (MOS):

Explicit MOS = 10% of the E. coli water quality criteria for each impaired subwatershed or drainage area.

Summary of TMDLs, WLAs, & LAs for Impaired Waterbodies

HUC-12 Subwatershed (06020001__) or Drainage Area	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs[a,b]		LAs[e]
				Leaking Collection Systems[c]	MS4s [d]	
			[% Red.]	[CFU/day]	[% Red.]	[% Red.]
0502 (DA)	North Market Street Branch	TN06020001001T – 0200	91.4	0	92.7	92.7
0502 (DA)	Stringers Branch	TN06020001426 – 0100	28.7	0	35.8	35.8
0502 (DA)	Unnamed Trib to Citico Creek	TN060200011240 – 0100	>90.0	0	>91.0	>91.0
	Citico Creek	TN060200011240 – 1000	32.3	0	39.1	39.1
0503	Dobbs Branch	TN060200011244 – 0100	94.1	0	94.7	94.7
	Unnamed Trib to Chattanooga Creek	TN060200011244 – 0200	92.7	0	93.4	93.4
	McFarland Springs Branch[f]	TN060200011244 – 0300	52.6	0	57.4	57.4
	Chattanooga Creek[f]	TN060200011244 –1000 & 2000	>60.8	0	>64.7	>64.7
0602 (DA)	Lewis Branch	TN06020001029 - 0300	98.2	NA	98.4	98.4
0803 (DA)	Spring Creek	TN06020001007 – 0510	86.6	0	88.0	88.0

Summary of TMDLs, WLAs, & LAs for Impaired Waterbodies (cont'd)

HUC-12 Subwatershed (06020001__) or Drainage Area	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs[a,b]		LAs[e]
				Leaking Collection Systems[c]	MS4s [d]	
			[% Red.]	[CFU/day]	[% Red.]	[% Red.]
0804	Friar Branch	TN06020001007 – 0100	73.4	0	76.1	76.1
	South Chickamauga Creek[f]	TN06020001007 – 1000	84.8	0	86.3	86.3

Notes: NA = Not Applicable.

a. There are no CAFOs in the Lower Tennessee River Watershed. Future CAFOs will be assigned a waste load allocation (WLA) of zero.

b. WLAs for WWTFs are expressed as E. coli loads (CFU/day). Future WWTFs must meet instream water quality standards at the point of discharge as specified in their NPDES permit.

c. Pathogen loading due to collection system failure is considered to be unpermitted point source loading from the municipal WWTF. With respect to pathogen loading from leaking collection systems, a WLA of zero is assigned. It is recognized, however, that a WLA of 0 CFU/day may not be practical. For these unpermitted sources, the WLA is interpreted to mean a reduction in pathogen loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

d. Applies to any MS4 discharge loading in the subwatershed or drainage area.

e. The load allocations (LAs) listed apply to precipitation induced nonpoint sources only. The objective for all other nonpoint sources (leaking septic systems, illicit discharges, and animals access to streams) is a LA of zero. It is recognized, however, that for leaking septic systems a LA of 0 CFU/day may not be practical. For these sources, the LA is interpreted to mean a reduction in E. coli loading to the maximum extent feasible, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

f. Portions of these waterbodies lie in another state. A TMDL for Fecal Coliform has been developed by the State of Georgia for those portions of the waterbodies lying within their jurisdiction. The required load reduction is for the Tennessee portion of the waterbodies.

PROPOSED E. COLI TOTAL MAXIMUM DAILY LOAD (TMDL) LOWER TENNESSEE RIVER WATERSHED (HUC 06020001)

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those waterbodies that are not attaining water quality standards. State water quality standards consist of designated uses for individual waterbodies, appropriate numeric and narrative water quality criteria protective of the designated uses, and an antidegradation statement. The TMDL process establishes the maximum allowable loadings of pollutants for a waterbody that will allow the waterbody to maintain water quality standards. The TMDL may then be used to develop controls for reducing pollution from both point and nonpoint sources in order to restore and maintain the quality of water resources (USEPA, 1991).

2.0 SCOPE OF DOCUMENT

This document presents details of TMDL development for waterbodies in the Middle Tennessee-Chickamauga Watershed, identified on the Final 2004 303(d) list as not supporting designated uses due to E. coli. The Middle Tennessee-Chickamauga Watershed is also known as the Lower Tennessee River Watershed. Portions of the Lower Tennessee River Watershed lie in Tennessee, Alabama, and Georgia. This document addresses only impaired waterbodies in Tennessee. TMDL analyses were performed primarily on a 12-digit hydrologic unit area (HUC-12) basis. In some cases, where appropriate, TMDLs were developed for an impaired waterbody drainage area only.

A TMDL could not be developed for Gillespie Springs Branch and the unnamed tributary to South Chickamauga Creek due to insufficient monitoring data. Additional monitoring is recommended to allow for either development of a TMDL or delisting.

3.0 WATERSHED DESCRIPTION

The Lower Tennessee River Watershed (HUC 06020001) is located in Eastern Tennessee (Figure 1), primarily in Hamilton, Rhea, and Meigs Counties. The Lower Tennessee River Watershed lies within two Level III ecoregions (Ridge and Valley, Southwestern Appalachians) and contains eight Level IV ecoregions as shown in Figure 2 (USEPA, 1997):

- **The Southern Limestone/Dolomite Valleys and Low Rolling Hills (67f)** form a heterogeneous region composed predominantly of limestone and cherty dolomite. Landforms are mostly low rolling ridges and valleys, and the solids vary in their productivity. Landcover includes intensive agriculture, urban and industrial, or areas of thick forest. White oak forests, bottomland oak forests, and sycamore-ash-elm riparian forests are the common forest types, and grassland barrens intermixed with cedar-pine glades also occur here.

- **The Southern Shale Valleys (67g)** consist of lowlands, rolling valleys, and slopes and hilly areas that are dominated by shale materials. The northern areas are associated with Ordovician-age calcareous shale, and the well-drained soils are often slightly acid to neutral. In the south, the shale valleys are associated with Cambrian-age shales that contain some narrow bands of limestone, but the soils tend to be strongly acid. Small farms and rural residences subdivide the land. The steeper slopes are used for pasture or have reverted to brush and forested land, while small fields of hay, corn , tobacco, and garden crops are grown on the foot slopes and bottomland.

- **The Southern Sandstone Ridges (67h)** ecoregion encompasses the major sandstone ridges, but these ridges also have areas of shale and siltstone. The steep, forested chemistry of streams flowing down the ridges can vary greatly depending on the geologic material. The higher elevation ridges are in the north, including Wallen Ridge, Powell Mountain, Clinch Mountain, and Bays Mountain. White Oak Mountain in the south has some sandstone on the west side, but abundant shale and limestone as well. Grindstone Mountain, capped by the Gizzard Group sandstone, is the only remnant of Pennsylvanian-age strata in the Ridge and Valley of Tennessee.

- **The Southern Dissected Ridges and Knobs (67i)** contain more crenulated, broken, or hummocky ridges, compared to smoother, more sharply pointed sandstone ridges. Although shale is common, there is a mixture and interbedding of geologic materials. The ridges on the east side of Tennessee's Ridge and Valley tend to be associated with the Ordovician-age Sevier shale, Athens shale, and Holston and Lenoir limestones. These can include calcareous shale, limestone, siltstone, sandstone, and conglomerate. In the central and western part of the ecoregion, the shale ridges are associated with the Cambrian-age Rome Formation: shale and siltstone with beds of sandstone. Chestnut oak forests and pine forests are typical for the higher elevations of the ridges, with areas of white oak, mixed mesophytic forest, and tulip poplar on the lower slopes, knobs, and draws.

- **Cumberland Plateau (68a)** tablelands and open low mountains are about 1000 feet higher than the Eastern Highland Rim (71g) to the west, and receive slightly more precipitation with cooler annual temperatures than the surrounding lower-elevation ecoregions. The plateau surface is less dissected with lower relief compared to the Cumberland Mountains (69d) or the Plateau Escarpment (68c). Elevations are generally 1200-2000 feet, with the Crab Orchard Mountains reaching over 3000 feet. Pennsylvanian-age conglomerate, sandstone, siltstone, and shale is covered by well-drained, acid soils of low fertility. Bituminous coal that has been extensively surface and underground mined underlies the region. Acidification of first and second order streams is common. Stream siltation and mine spoil bedload deposits continue as long-term problems in these headwater systems. Pockets of severe acid mine drainage persist.

  - **Sequatchie Valley (68b)** is structurally associated with an anticline, where erosion of broken rock to the south of the Crab Orchard Mountains scooped out the linear valley. The open, rolling, valley floor, 600-1000 feet in elevation, is generally 1000 feet below the top of the Cumberland Plateau. A low, central, cherty ridge separates the west and east valleys of Mississippian to Ordovician-age limestones, dolomites, and shales. Similar to parts of the Ridge and Valley (67f), this is an agriculturally productive region, with areas of pasture, hay, soybeans, small grain, corn, and tobacco.

- **Plateau Escarpment (68c)** is characterized by steep, forested slopes and high velocity, high gradient streams. Local relief is often 1000 feet or more. The geologic strata include Mississippian-age limestone, sandstone, shale, and siltstone, and Pennsylvanian-age shale, siltstone, sandstone, and conglomerate. Streams have cut down into the limestone, but the gorge talus slopes are composed of colluvium with huge angular, slabby blocks of sandstone. Vegetation community types in the ravines and gorges include mixed oak and chestnut oak on the upper slopes, mesic forests on the middle and lower slopes (beech-tulip poplar, sugar maple-basswood-ash-buckeye), with hemlock along rocky streamsides and river birch along floodplain terraces.

- **The Southern Table Plateaus (68d)** include Sand Mountain and Lookout Mountain in northwest Georgia. While it has some similarities to the Cumberland Plateau (68a) in Tennessee with its Pennsylvanian-age sandstone caprock, shale layers, and coal-bearing strata, this ecoregion is lower in elevation, has a slightly warmer climate, and has more agriculture. Although the Georgia portion is mostly forested, primarily with mixed oak and oak-hickory communities, elevations decrease to the southwest in Alabama and there is more cropland and pasture. The plateau surface is less dissected with lower relief compared to the Plateau Escarpment (68c), and it is slightly cooler with more precipitation than in the nearby lower elevations of 67f.

The Lower Tennessee River Watershed, located in Bledsoe, Bradley, Hamilton, Loudon, Marion, McMinn, Meigs, Rhea, Roane, and Sequatchie Counties, Tennessee, has a drainage area of approximately 1200 square miles (mi^2). The entire watershed, including Tennessee, Alabama, and Georgia, drains approximately 1,870 square miles. Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Although changes in the land use of the Lower Tennessee River Watershed have occurred since 1993 as a result of development, this is the most current land use data available. Land use for the Lower Tennessee River Watershed is summarized in Table 1 and shown in Figure 3. Predominant land use in the Lower Tennessee River Watershed is forest (72%) followed by pasture (10%). Urban areas represent approximately 6% of the total drainage area of the watershed. Details of land use distribution of impaired subwatersheds in the Lower Tennessee River Watershed are presented in Appendix A.

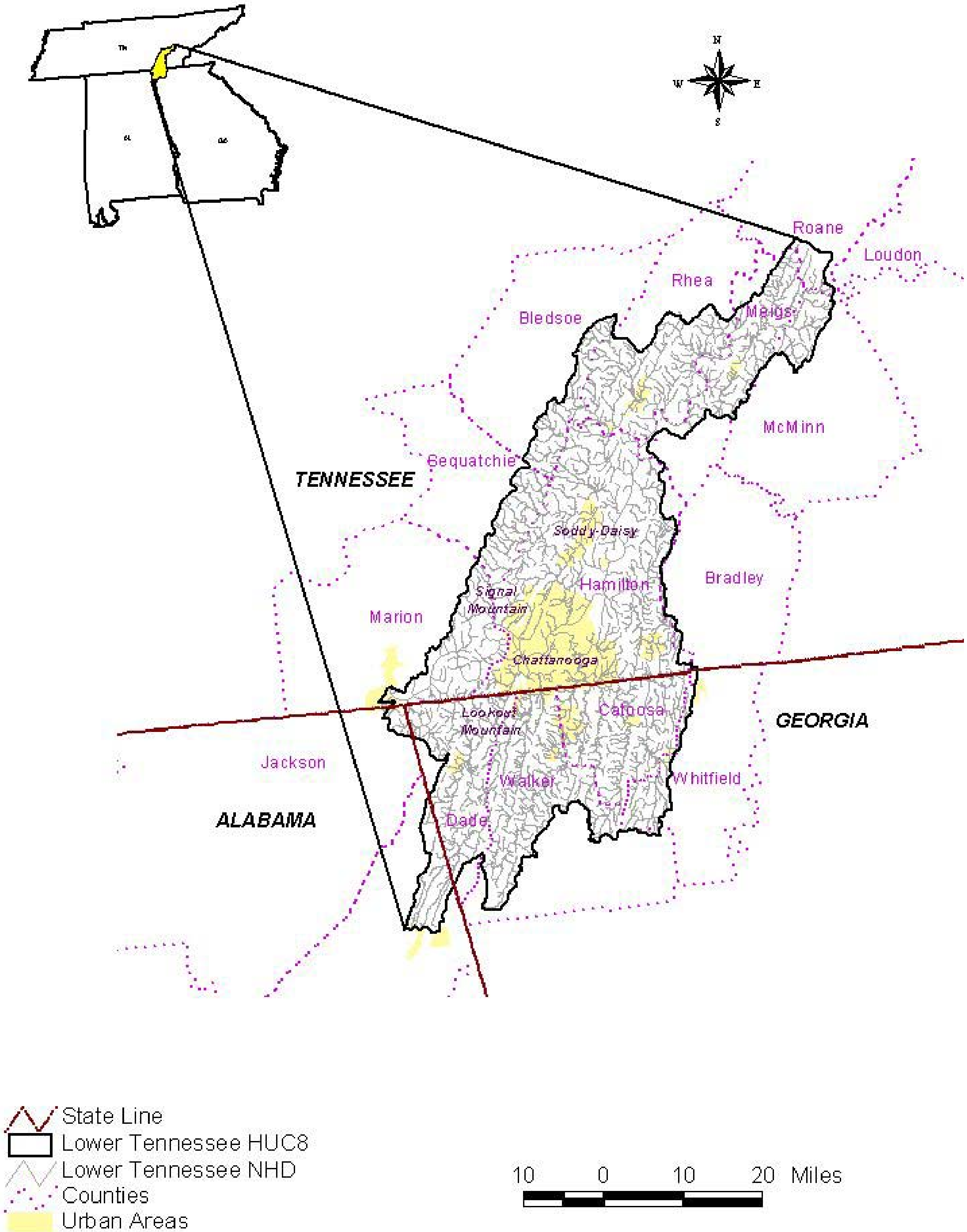

Figure 1. Location of the Lower Tennessee River Watershed.

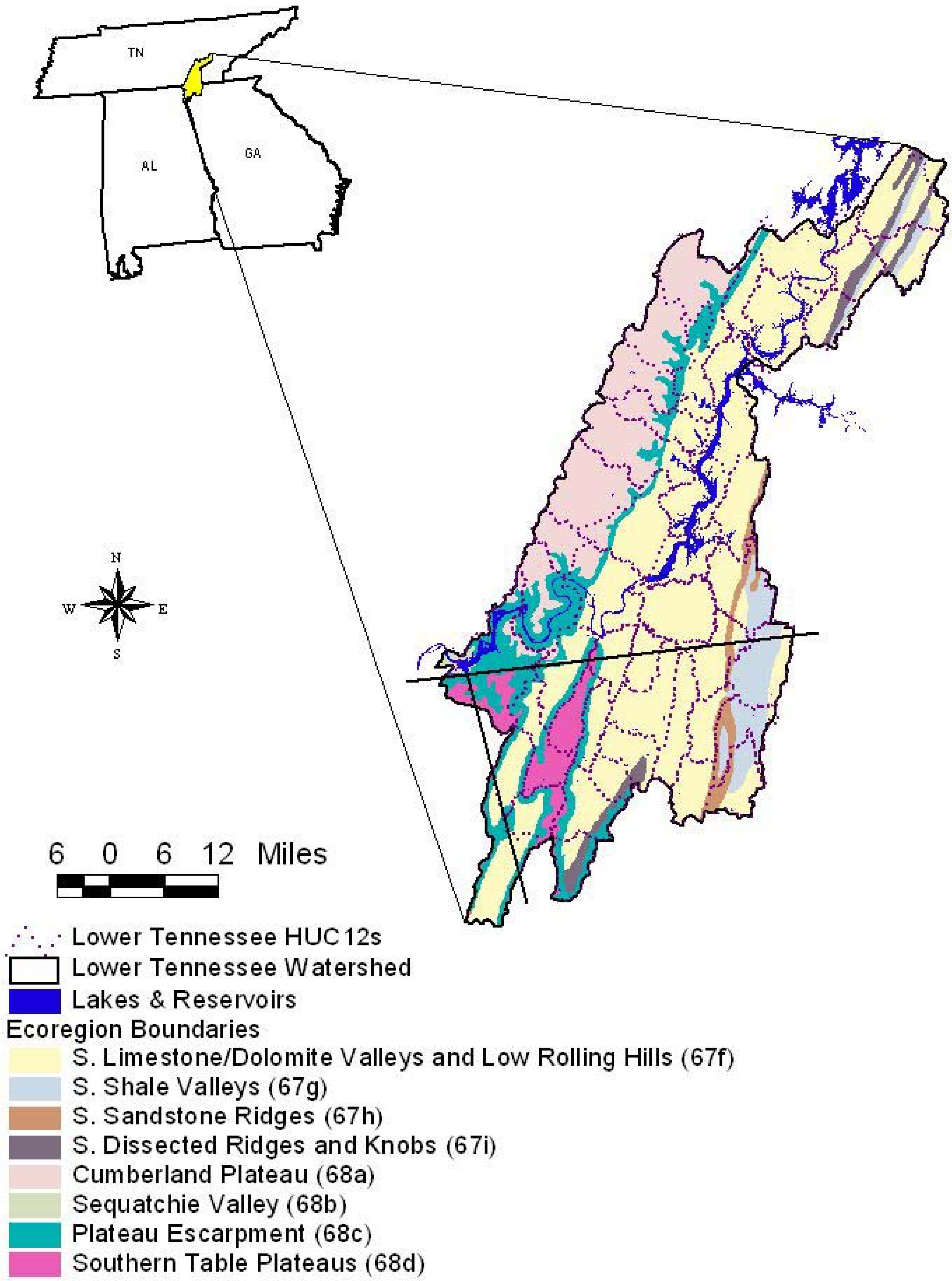

Figure 2. Level IV Ecoregions in the Lower Tennessee River Watershed.

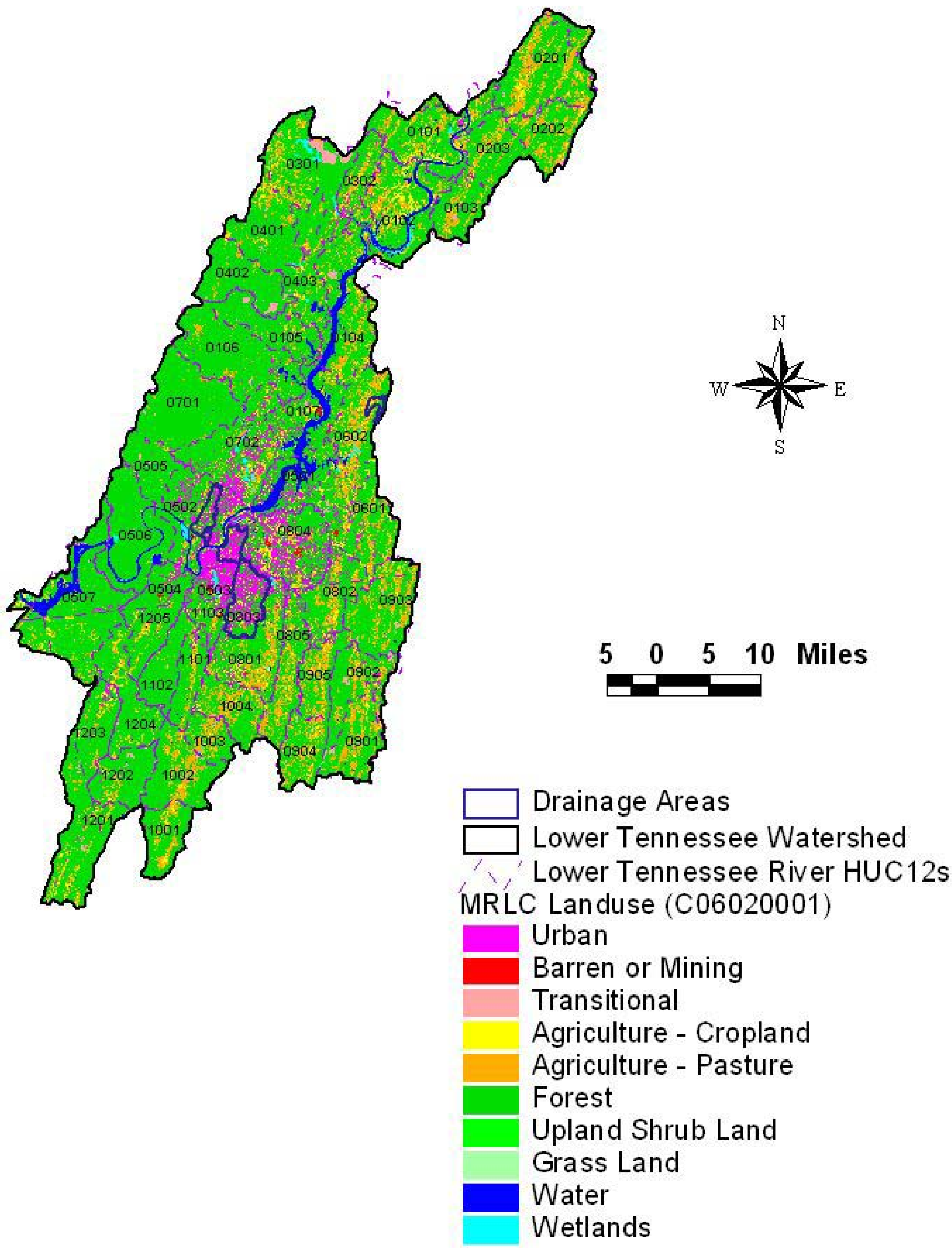

Figure 3. Land Use Characteristics of the Lower Tennessee River Watershed.

Table 1. MRLC Land Use Distribution – Lower Tennessee River Watershed

Land Use	Area – Entire HUC8		Area – Tennessee only	
	[acres]	%]	[acres]	[%]
Bare Rock/Sand/Clay	41	0.0	41	0.0
Deciduous Forest	475,555	39.7	318,445	41.0
Emergent Herbaceous Wetlands	1,329	0.1	1,574	0.2
Evergreen Forest	151,404	12.6	97,287	12.5
High Intensity Commercial/Industrial/ Transportation	15,710	1.3	12,797	1.6
High Intensity Residential	6,407	0.5	5,446	0.7
Low Intensity Residential	37,949	3.2	30,909	4.0
Mixed Forest	254,057	21.2	145,860	18.8
Open Water	34,967	2.9	34,640	4.5
Other Grasses (Urban/recreational)	12,242	1.0	9,403	1.2
Pasture/Hay	147,402	12.3	79,958	10.3
Quarries/Strip Mines/ Gravel Pits	1,321	0.1	1,172	0.2
Row Crops	41,952	3.5	26,435	3.4
Transitional	11,326	0.9	7,464	1.0
Woody Wetlands	5,303	0.4	5,068	0.7
Total	**1,196,966**	**100.0**	**776,499**	**100.0**

4.0 PROBLEM DEFINITION

The State of Tennessee's final 2004 303(d) list (TDEC, 2005) was approved by the U.S. Environmental Protection Agency (EPA), Region IV in August of 2005. This list identified portions of eleven waterbodies in the Lower Tennessee River Watershed as not supporting designated use classifications due, in part, to E. coli (see Table 2 & Figure 4). The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. South Chickamauga Creek and Chattanooga Creek are also designated for industrial water supply.

When used in the context of waterbody assessments, the term pathogens is defined as disease-causing organisms such as bacteria or viruses that can pose an immediate and serious health threat if ingested or introduced into the body. The primary sources for pathogens are untreated or inadequately treated human or animal fecal matter. The E. coli and fecal coliform groups are indicators of the presence of pathogens in a stream.

5.0 WATER QUALITY CRITERIA & TMDL TARGET

As previously stated, the designated use classifications for the Lower Tennessee River waterbodies include fish & aquatic life, recreation, irrigation, and livestock watering & wildlife. Of the use classifications with numeric criteria for pathogens, the recreation use classification is the most stringent and will be used to establish target levels for TMDL development. The coliform water quality criteria, for protection of the recreation use classification, is established by *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January 2004* (TDEC, 2004). Section 1200-4-3-.03 (4) (f) states:

> The concentration of the E. coli group shall not exceed 126 colony forming units per 100 mL, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 mL shall be considered as having a concentration of 1 per 100 mL.
>
> Additionally, the concentration of the E. coli group in any individual sample taken from a lake, reservoir, State Scenic River, or Tier II or III stream (1200-4-3-.06) shall not exceed 487 colony forming units per 100 mL. The concentration of the E. coli group in any individual sample taken from any other waterbody shall not exceed 941 colony forming units per 100 mL.

Portions of Friar Branch, Spring Creek, and South Chickamauga Creek have been classified as Tier II streams. As of February 2, 2006, none of the other E. coli impaired waterbodies in the Lower Tennessee River Watershed have been classified as either Tier II or Tier III streams.

The geometric mean standard for the E. coli group of 126 colony forming units per 100 ml (CFU/100 ml) and the sample maximum of 487 CFU/100 ml have been selected as the appropriate numerical targets for TMDL development for impaired waterbodies classified as Tier II streams. The geometric mean standard for the E. coli group of 126 colony forming units per 100 ml (CFU/100 ml) and the sample maximum of 941 CFU/100 ml have been selected as the appropriate numerical targets for TMDL development for the other impaired waterbodies.

Table 2 Final 2004 303(d) List for E. coli Impaired Waterbodies – Lower Tennessee River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN06020001001T – 0200	NORTH MARKET STREET BRANCH	2.5	Escherichia coli	Collection System Failure
TN06020001007 – 0100	FRIAR BRANCH	26.9	Loss of biological integrity due to siltation Nutrients Habitat loss due to alteration in stream-side or littoral vegetative cover Escherichia coli	Land Development Discharges from MS4 area
TN06020001007 – 0200	UNNAMED TRIB TO SOUTH CHICKAMAUGA CREEK (runs thru airport)	1.1	Nutrients Escherichia coli	Collection System Failure Discharges from MS4 area Hydromodification
TN06020001007 – 0510	SPRING CREEK	9.6	Escherichia coli	Collection System Failure
TN06020001007 – 1000	SOUTH CHICKAMAUGA CREEK (from Nickajack Reservoir to Ga. state line)	17.6	Phosphorus Physical Substrate Habitat Alterations Escherichia coli Loss of biological integrity due to siltation	Land Development Discharges from MS4 area Channelization Sources Outside of State
TN06020001029 – 0300	LEWIS BRANCH	1.5	Habitat loss due to alteration in stream-side or littoral vegetative cover Escherichia coli	Confined Animal Feeding Operations (Nonpoint)
TN060200011240 – 0100	UNNAMED TRIB TO CITICO CREEK	1.2	Phosphorus Thermal Modifications Escherichia coli Habitat loss due to alteration in stream-side or littoral vegetative cover	Collection System Failure Discharges from MS4 area Hydromodification
TN060200011240 – 1000	CITICO CREEK	6.1	Nutrients Low dissolved oxygen Escherichia coli Habitat loss due to alteration in stream-side or littoral vegetative cover	Collection System Failure Hydromodification

Table 2 (cont'd). Final 2004 303(d) List for E. coli Impaired Waterbodies – Lower Tennessee River Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN060200011244 – 0100	DOBBS BRANCH	5.3	Low dissolved oxygen Escherichia coli Habitat loss due to alteration in stream-side or littoral vegetative cover	Collection System Failure Hydromodification
TN060200011244 – 0200	UNNAMED TRIB TO CHATTANOOGA CREEK (near Cedar Hill School)	1.4	Escherichia coli Habitat loss due to alteration in stream-side or littoral vegetative cover	Combined Sewer Overflow Hydromodification
TN060200011244 – 0300	MCFARLAND SPRINGS BRANCH (from Chattanooga Creek to Ga. state line)	1.2	Escherichia coli	Source in Other State
TN060200011244 – 0400	GILLESPIE SPRINGS BRANCH (flows off Lookout Mtn. thru St. Elmo)	1.9	Escherichia coli Habitat loss due to alteration in stream-side or littoral vegetative cover	Discharges from MS4 area Hydromodification
TN060200011244 – 1000	CHATTANOOGA CREEK (from Nickajack Reservoir to Hooker Rd.)	8.4	PCBs Dioxins Low dissolved oxygen Escherichia coli Habitat loss due to alteration in stream-side or littoral vegetative cover Oil and Grease	Combined Sewer Overflow Discharges from MS4 area Non-Industrial Permitted Hydromodification Spills Contaminated Sediment
TN060200011244 – 2000	CHATTANOOGA CREEK (from Hooker Rd. to Ga. state line)	3.5	Escherichia coli	Source in Other State
TN06020001426 – 0100	STRINGERS BRANCH	5.8	Escherichia coli Habitat loss due to alteration in stream-side or littoral vegetative cover	Collection System Failure Discharges from MS4 area Hydromodification

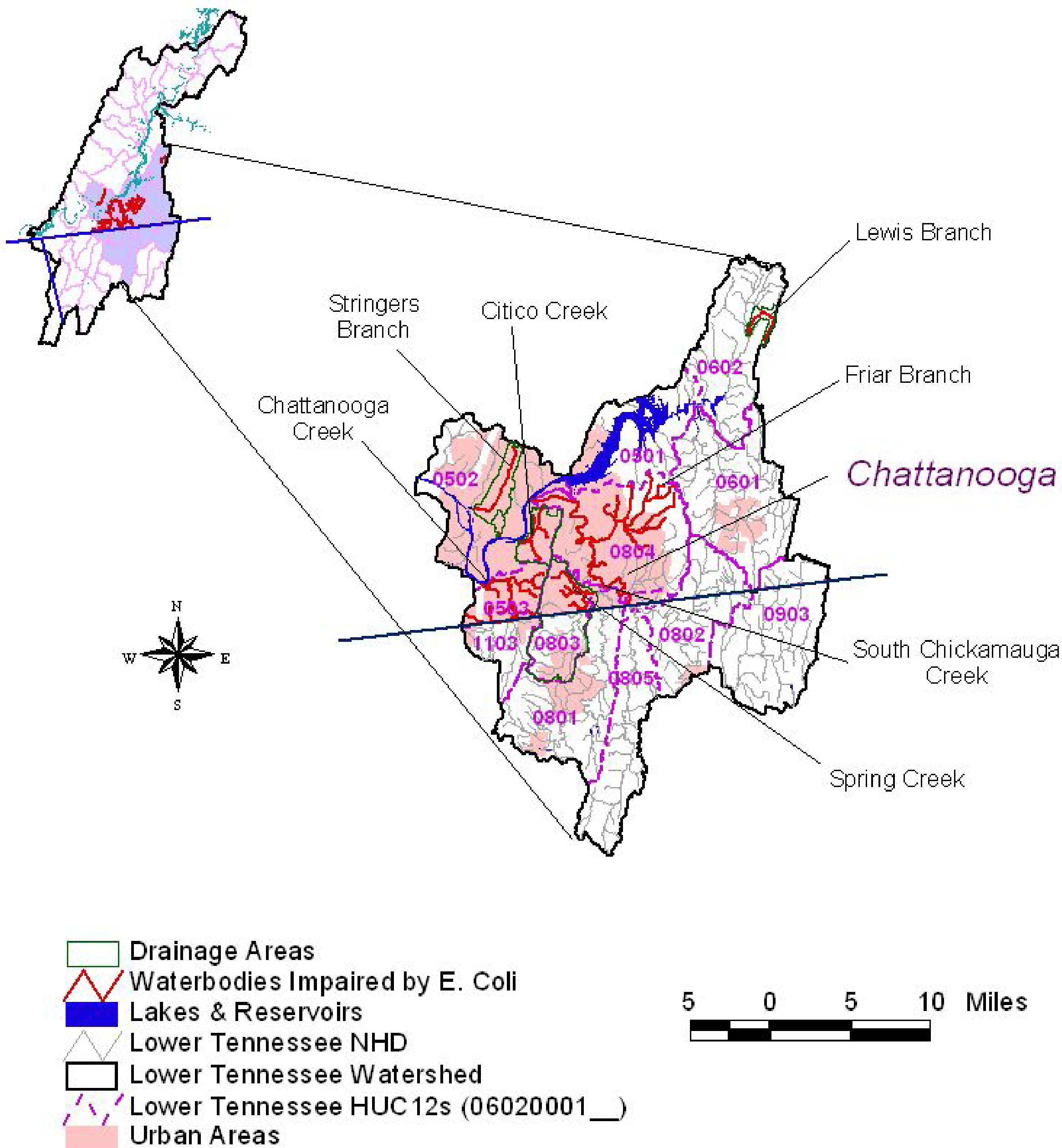

Figure 4. Waterbodies Impaired by E. Coli (as Documented on the Final 2004 303(d) List). (Figure includes only portion of Lower Tennessee Watershed containing E. Coli impaired waterbodies. Major impaired waterbodies are labeled as a point of reference.)

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM TARGET

There are numerous water quality monitoring stations that provide data for waterbodies identified as impaired for E. coli in the Lower Tennessee River Watershed. Monitoring stations located on Tier II waterbodies have been italicized:

- CHATT000.9HM – Chattanooga Creek, at railroad bridge at rendering plant
- CHATT1T0.1HM – Trib to Chattanooga Creek, at junk yard off Hooker
- CITIC000.3HM – Citico Creek, off Riverside Dr. at TN American Water Co., above water supply intake
- CITIC001.0HM – Citico Creek, at corner of Wilcox Blvd. And Amnicola Hwy.
- CITIC1T0.3HM – Trib to Citico Creek, corner of North Holly and Citico Ave., at bridge, just below Carver Rec. Center
- CITIC1T0.8HM – Trib to Citico Creek, at 3rd St. and Orchard Knob Ave., just d/s Orchard Knob Elem. School
- CITIC1T0.9HM – Trib to Citico Creek, at corner of Willow and 5th St., just u/s Orchard Knob Elem. School
- CITIC1T1.2HM – Trib to Citico Creek, at Parkridge Hospital back parking lot
- CITIC2T0.0HM – Trib to Citico Creek, at McConnell and Ivy St., across from Parkridge Hospital
- CITIC3T0.1HM – Trib to Citico Creek, at Willow and 3rd St., just u/s of Orchard Knob Elem. School, d/s of Pruett's
- CITIC3T0.7HM – Trib to Citico Creek, in Orange Grove Center Park (locked area)
- CITIC4T0.5HM – Trib to Citico Creek, at Orange Grove and Derby St., just u/s of Orange Grove Park, d/s of Memorial Hospital
- CITIC5T0.1HM – Trib to Citico Creek, at Cleveland and Carver, u/s of Carver Rec. Center
- CITIC6T0.1HM – Trib to Citico Creek, at Cleveland and Orchard Knob, just above Carver Rec. Center
- DOBBS000.3HM – Dobbs Branch, on Cannon St., at corner of Burnette St., just before Hys' Park, on other side of overpass
- *FRIAR000.8HM – Friar Branch, at Polymer Dr. next to Mayfield*
- *FRIAR002.7HM – Friar Branch, at Hickory Valley Rd.*
- LEWIS000.3HM – Lewis Branch, off Ooltewah-Georgetown Rd., near confluence with Savannah Creek
- MCFAR000.2HM – McFarland Springs Branch, at Stateline Rd.
- NMSTR000.3HM – North Market Street Branch, at Market Street bridge and Frazier Ave., on Roper property behind Suntrust Bank

- *SCHIC000.4HM – South Chickamauga Creek, at Amnicola Hwy.*
- *SCHIC004.9HM – South Chickamauga Creek, at Lightfoot Rd. bridge*
- *SCHIC015.8HM – South Chickamauga Creek, at swinging foot bridge at Audobon Acres*
- *SPRIN000.7HM – Spring Creek, on Spring Creek Rd., past K-Mart at bridge*
- STRIN000.6HM – Stringers Branch, behind Austin's Garden Center, on Signal Mountain Blvd., across from Baylor entrance
- WCHIC001.7HM – West Chickamauga Creek, at Fred Pruett Parkway bridge

The location of these monitoring stations is shown in Figures 5 and 6. Water quality monitoring results for these stations are tabulated in Appendix B. Examination of the data shows exceedances of the 487 CFU/100 mL (Tier II) and 941 CFU/100 mL (non-Tier II) maximum E. coli standard at many monitoring stations. Water quality monitoring results for those stations with 10% or more of samples exceeding water quality maximum criteria are summarized in Table 3.

There were not enough data to calculate the geometric mean at each monitoring station. Whenever a minimum of 5 samples was collected at a given monitoring station over a period of not more than 30 consecutive days, the geometric mean was calculated.

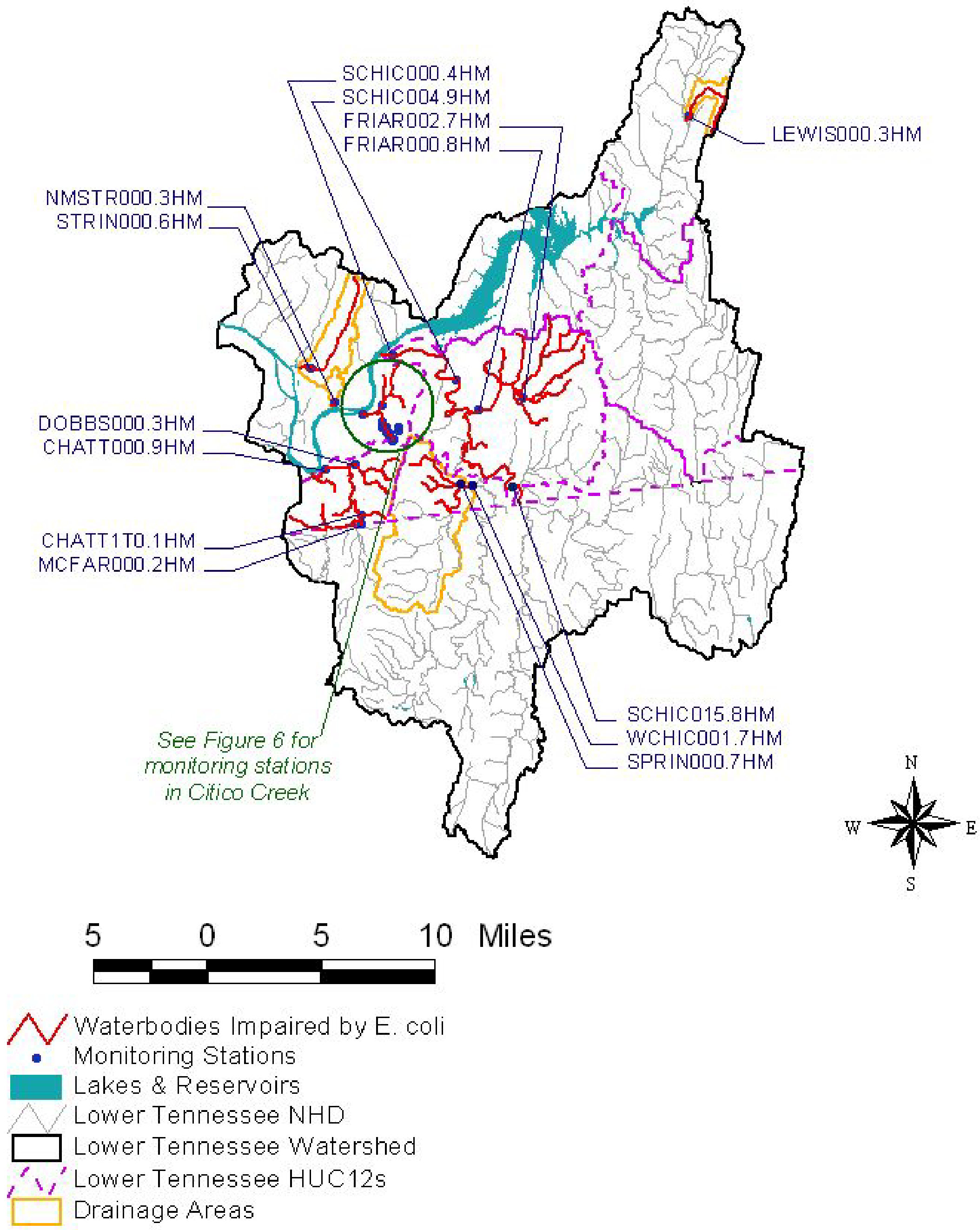

Figure 5. Water Quality Monitoring Stations in the Lower Tennessee River Watershed

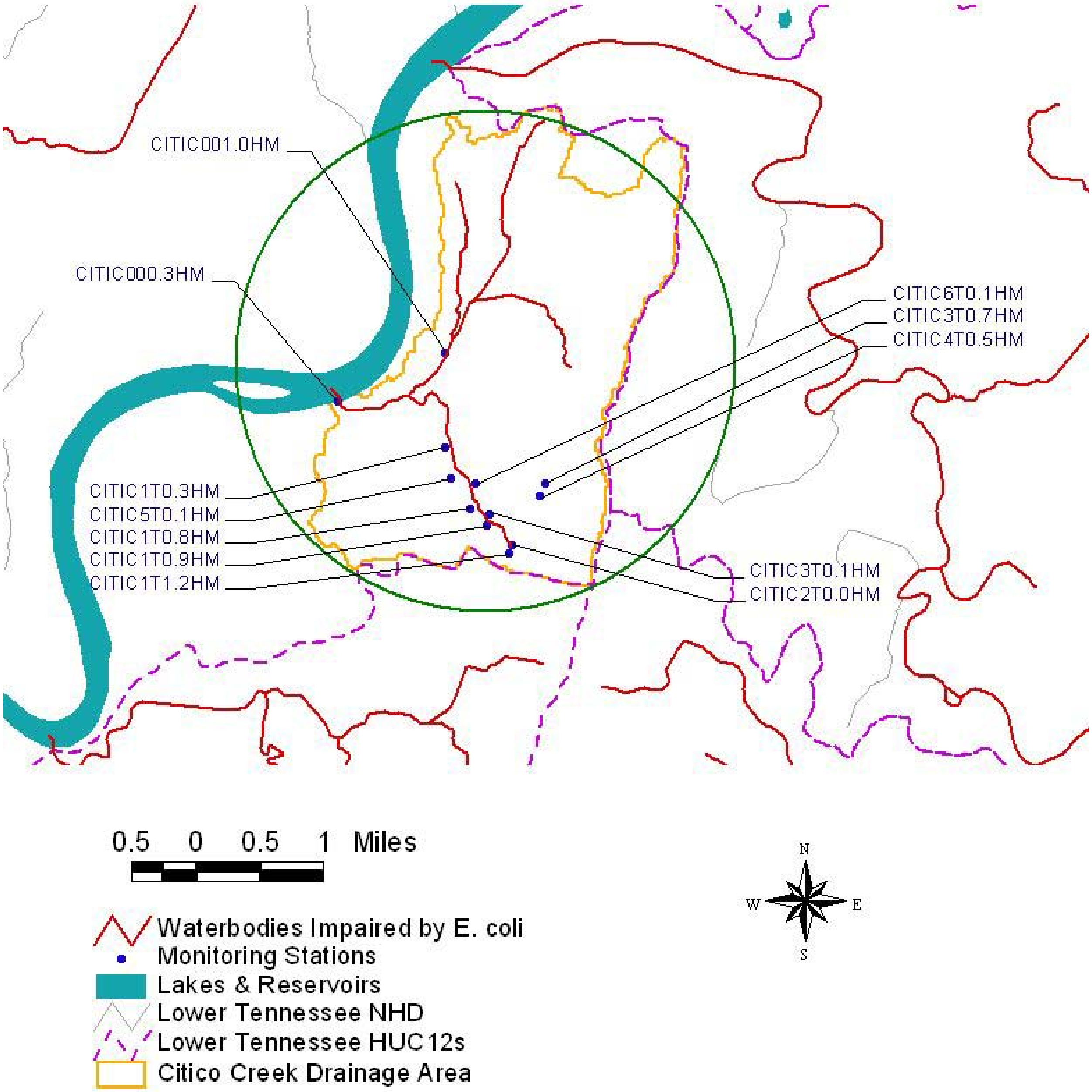

Figure 6. Water Quality Monitoring Stations in the Citico Creek Subwatershed

Table 3 Summary of TDEC Water Quality Monitoring Data

Monitoring Station	Date Range	E. Coli (Max WQ Target = 941 Counts/100 mL)**				
		Data Pts.	Min. [CFU/100 ml]	Avg. [CFU/100 ml]	Max. [CFU/100 ml]	No. Exceed. WQ Max. Target
CHATT000.9HM	1998 – 2005	41	47	904	>2,400	14
CHATT1T0.1HM	2004 – 2005	11	112	3303	17,260	3
CITIC000.3HM	1999 – 2005	8	130	748	1,600	2
CITIC1T0.3HM	2000 – 2005	15	365	4,867	41,060	10
CITIC1T0.8HM	2000 – 2002	3	2,000	2,267	>2,400	3
CITIC1T0.9HM	2000 – 2002	3	32	1,177	>2,400	2
CITIC3T0.1HM	2000 – 2002	3	13	1,238	>2,400	2
CITIC3T0.7HM	2000 – 2002	2	130	715	1,300	1
CITIC4T0.5HM	2000 – 2002	3	170	1,013	2,000	1
CITIC5T0.1HM	2000 – 2002	3	130	1,643	>2,400	2
CITIC6T0.1HM	2000 – 2002	3	300	1,875	>2,400	2
DOBBS000.3HM	2004 – 2005	11	79	4,025	17,850	4
FRIAR002.7HM	*2004 – 2005*	*11*	*163*	*745*	*2,750*	*5*
LEWIS000.3HM	2003 – 2004	9	770	28,414	241,900	7
MCFAR000.2HM	2004 – 2005	11	12	806	4,560	2
NMSTR000.3HM	2004 – 2005	11	105	3,512	15,150	4
SCHIC000.4HM	*1999 – 2005*	*13*	*1*	*841*	*>2,400*	*5*
SCHIC004.9HM	*2004 – 2005*	*11*	*38*	*834*	*4,040*	*2*
SCHIC015.8HM	*2000 – 2005*	*17*	*1*	*288*	*1,450*	*2*
SPRIN000.7HM	*2004 – 2005*	*11*	*53*	*1,307*	*5,830*	*4*
STRIN000.6HM	2004 – 2005	11	63	505	2,500	2

** Maximum water quality target is 487 CFU/100 mL for Tier II waterbodies and 941 CFU/100 mL for other waterbodies. Tier II waterbodies are italicized.

7.0 SOURCE ASSESSMENT

An important part of TMDL analysis is the identification of individual sources, or source categories of pollutants in the watershed that affect pathogen loading and the amount of loading contributed by each of these sources.

Under the Clean Water Act, sources are classified as either point or nonpoint sources. Under 40 CFR §122.2, a point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program regulates point source discharges. Point sources can be described by three broad categories: 1) NPDES regulated municipal and industrial wastewater treatment facilities (WWTFs); 2) NPDES regulated industrial and municipal storm water discharges; and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs). A TMDL must provide Waste Load Allocations (WLAs) for all NPDES regulated point sources. Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a Load Allocation (LA) for these sources.

7.1 Point Sources

7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain coliform bacteria. There are 7 WWTFs in the Lower Tennessee River Watershed that have NPDES permits authorizing the discharge of treated sanitary wastewater. One of these facilities is located in an impaired subwatershed or drainage area (see Table 4 & Figure 7). The permit limits for discharges from this WWTF are in accordance with the coliform criteria specified in Tennessee Water Quality Standards for the protection of the recreation use classification.

> *Note: As stated in Section 5.0, the current coliform criteria are expressed in terms of E. coli concentration, whereas previous criteria were expressed in terms of fecal coliform and E. coli concentration. Due to differences in permit issuance dates, some permits still have fecal coliform limits instead of E. coli. As permits are reissued, limits for fecal coliform will be replaced by E. coli limits.*

A summary of effluent monitoring data, submitted on Discharge Monitoring Reports (DMRs) for the period from February 2004 to November 2005, for facilities that are located in HUC-12 subwatersheds or drainage areas containing waterbodies impaired for pathogens is presented in Table 5. Fecal coliform data are presented for informational purposes only.

All treatment processes were in operation at the Moccasin Bend STP at the time of a Compliance Evaluation Inspection in June 2002. A preventive and predictive maintenance program is followed at the plant. Sludge handling was marginal with equipment out of service for repairs. Plans are underway to upgrade solids handling equipment. Sanitary sewer overflows still occurred in several areas of the collection system. The plant is operating under Agreed Order 86-3093, which required all combined sewer overflow structures to be completed by July 1, 2001. This date was not met. Two structures were not yet complete and the 19th Street structure had not been accepted due to sampling and instrumentation problems.

Table 4 NPDES Permitted WWTFs in Impaired Subwatersheds or Drainage Areas

NPDES Permit No.	Facility	Design Flow [MGD]	Receiving Stream
TN0024210	Moccasin Bend WWTP & Combined Sewer System	140	Tennessee River (Miles 457.8, 461.6, 462.5, 463.3[2], 464.0, and 465.2) and Chattanooga Creek (Miles 1.4 and 2.0)

Table 5 Summary of DMRs for NPDES Permitted WWTFs in Impaired Subwatersheds or Drainage Areas

NPDES Permit No.	E. Coli (Permit Limit = 126 CFU/100 mL Avg.)					Fecal Coliform (Permit Limit = 200 CFU/100 mL Avg.)					Fecal Coliform (Permit Limit = 1000 CFU/100 mL Max.)					No. Bypass/ Overflow Events
	Data Pts.	Min. (CFU/100 mL)	Avg. (CFU/100 mL)	Max. (CFU/100 mL)	No. Exceed.	Data Pts.	Min. (CFU/100 mL)	Avg. (CFU/100 mL)	Max. (CFU/100 mL)	No. Exceed.	Data Pts.	Min. (CFU/100 mL)	Avg. (CFU/100 mL)	Max. (CFU/100 mL)	No. Exceed.	
TN0024210	22	1	4	15	0	22	2	6	12	0	22	16	407	1200	3	128

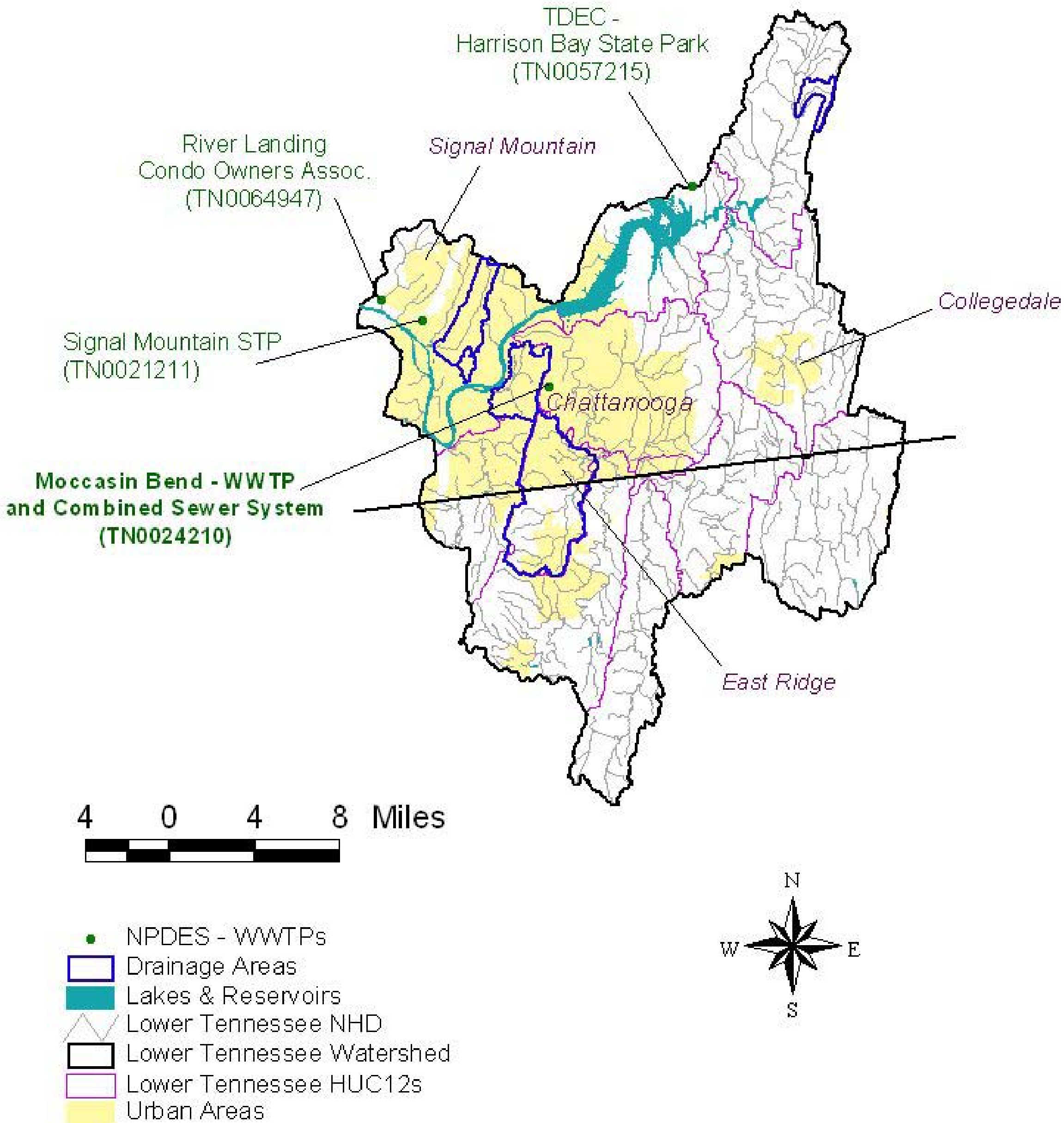

Figure 7. NPDES Regulated Point Sources in and near Impaired Subwatersheds and Drainage Areas of the Lower Tennessee River Watershed.

7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of E. coli. Discharges from MS4s occur in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. Phase I of the EPA storm water program requires large and medium MS4s to obtain NPDES storm water permits. Large and medium MS4s are those located in incorporated places or counties serving populations greater than 100,000 people. At present, Chattanooga is the only large or medium (Phase I) MS4 in the Lower Tennessee River Watershed.

As of March 2003, regulated small MS4s in Tennessee must also obtain NPDES permits in accordance with the Phase II storm water program. A small MS4 is designated as regulated if: a) it is located within the boundaries of a defined urbanized area that has a residential population of at least 50,000 people and an overall population density of 1,000 people per square mile; b) it is located outside of an urbanized area but within a jurisdiction with a population of at least 10,000 people, a population density of 1,000 people per square mile, and has the potential to cause an adverse impact on water quality; or c) it is located outside of an urbanized area but contributes substantially to the pollutant loadings of a physically interconnected MS4 regulated by the NPDES storm water program. Most regulated small MS4s in Tennessee obtain coverage under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003). Signal Mountain, Walden, and Hamilton County Small MS4s are covered under Phase II of the NPDES Storm Water Program. Chattanooga State Technical Community College and University of Tennessee at Chattanooga have applications pending for coverage under Phase II of the NPDES Storm Water Program.

The Tennessee Department of Transportation (TDOT) has been issued an individual MS4 permit that authorizes discharges of storm water runoff from State roads and interstate highway right-of-ways that TDOT owns or maintains, discharges of storm water runoff from TDOT owned or operated facilities, and certain specified non-storm water discharges. This permit covers all eligible TDOT discharges statewide, including those located outside of urbanized areas.

Information regarding storm water permitting in Tennessee may be obtained from the Tennessee Department of Environment and Conservation (TDEC) website at:

http://www.state.tn.us/environment/wpc/stormh2o/.

7.1.3 NPDES Concentrated Animal Feeding Operations (CAFOs)

Animal feeding operations (AFOs) are agricultural enterprises where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland (USEPA, 2002a). Concentrated Animal Feeding Operations (CAFOs) are AFOs that meet certain criteria with respect to animal type, number of animals, and type of manure management system. CAFOs are considered to be potential point sources of pathogen loading and are required to obtain an NPDES permit. Most CAFOs in Tennessee obtain coverage under TNA000000, *Class II Concentrated Animal Feeding Operation General Permit*, while larger, Class I CAFOs are required to obtain an individual NPDES permit.

As of May 11, 2005, there are no Class II CAFOs in the Lower Tennessee River watershed with coverage under the general NPDES permit. There are also no Class I CAFOs with individual permits located in the watershed.

7.2 Nonpoint Sources

Nonpoint sources of coliform bacteria are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources generally, but not always, involve accumulation of coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of E. coli loading are primarily associated with agricultural and urban land uses. The majority of waterbodies identified on the Final 2004 303(d) list as impaired due to E. coli are attributed to nonpoint agricultural or urban sources.

7.2.1 Wildlife

Wildlife deposit coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile.

7.2.2 Agricultural Animals

Agricultural activities can be a significant source of coliform bacteria loading to surface waters. The activities of greatest concern are typically those associated with livestock operations:

- Agricultural livestock grazing in pastures deposit manure containing coliform bacteria onto land surfaces. This material accumulates during periods of dry weather and is available for washoff and transport to surface waters during storm events. The number of animals in pasture and the time spent grazing are important factors in determining the loading contribution.
- Processed agricultural manure from confined feeding operations is often applied to land surfaces and can provide a significant source of coliform bacteria loading. Guidance for issues relating to manure application is available through the University of Tennessee Agricultural Extension Service and the Natural Resources Conservation Service (NRCS).
- Agricultural livestock and other unconfined animals often have direct access to waterbodies and can provide a concentrated source of coliform bacteria loading directly to a stream.

Data sources related to livestock operations include the 2002 Census of Agriculture. Livestock data for counties containing E. coli-impaired watersheds are summarized in Table 6.

7.2.3 Failing Septic Systems

Some coliform loading in the Lower Tennessee River Watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. Estimates from 1997 county census data of people in the Lower Tennessee River Watershed utilizing septic systems were compiled using the WCS and are summarized in Table 7. WCS is an Arcview geographic information system (GIS) based program developed by USEPA Region IV to facilitate watershed characterization and TMDL development. In middle and eastern Tennessee, it is estimated that there are approximately 2.37 people per household on septic systems, some of which can be reasonably assumed to be failing. As with livestock in streams, discharges of raw sewage provide a concentrated source of coliform bacteria directly to waterbodies.

Table 6 Livestock Distribution in the Lower Tennessee River Watershed

County	Livestock Population (2002 Census of Agriculture)					
	Beef Cow	Milk Cow	Poultry	Hogs	Sheep	Horse
Hamilton	6,314	360	D*	138	394	1,496

* In keeping with the provisions of Title 7 of the United States Code, no data are published in the 2002 Census of Agriculture that would disclose information about the operations of an individual farm or ranch. Any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2004).

Table 7 Population on Septic Systems in the Lower Tennessee River Watershed

HUC-12 Subwatershed (06020001__) or Drainage Area	Population on Septic Systems
North Market Street Branch DA	139
Stringers Branch DA	2,270
Citico Creek DA	916
0503 (Chattanooga Ck)	2,011
Lewis Branch DA	437
Spring Creek DA	693
0804 (South Chickamauga Ck)	8,643

7.2.4 Urban Development

Nonpoint source loading of coliform bacteria from urban land use areas is attributable to multiple sources. These include: stormwater runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Impervious surfaces in urban areas allow runoff to be conveyed to streams quickly, without interaction with soils and groundwater. Urban land use area in impaired subwatersheds in the Lower Tennessee River Watershed ranges from 0.8% to 48.2%. Land use for the Lower Tennessee River impaired drainage areas is summarized in Figures 8 thru 11 and tabulated in Appendix A.

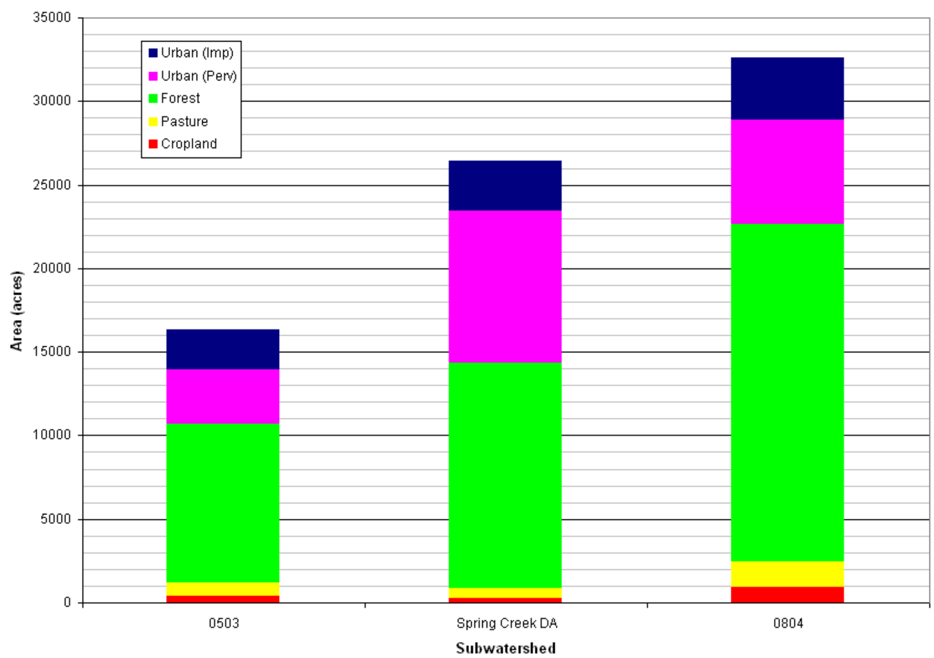

Figure 8. Land Use Area of Lower Tennessee River Pathogen-Impaired Subwatersheds – Drainage Areas Greater Than 10,000 Acres.

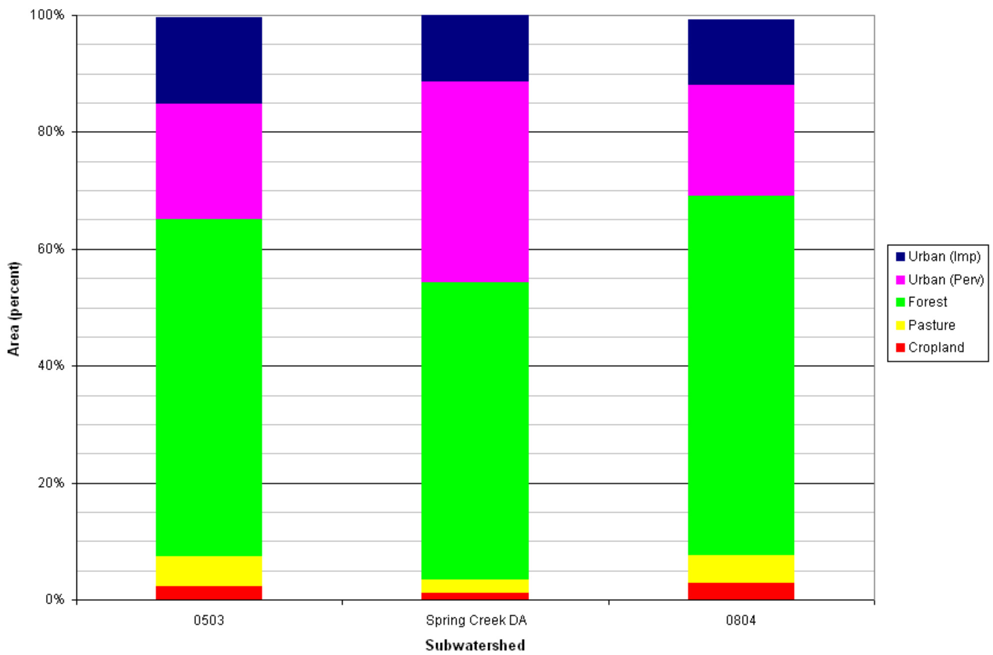

Figure 9. Land Use Percent of the Lower Tennessee River Pathogen-Impaired Subwatersheds – Drainage Areas Greater Than 10,000 Acres.

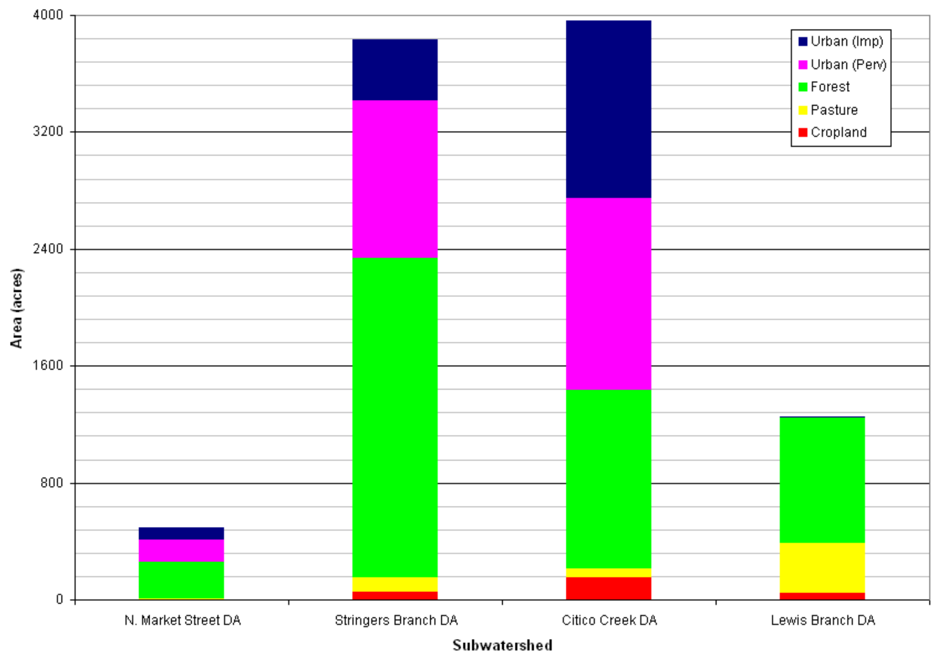

Figure 10. **Land Use Area of Lower Tennessee River Pathogen-Impaired Subwatersheds – Drainage Areas Less Than 5,000 Acres.**

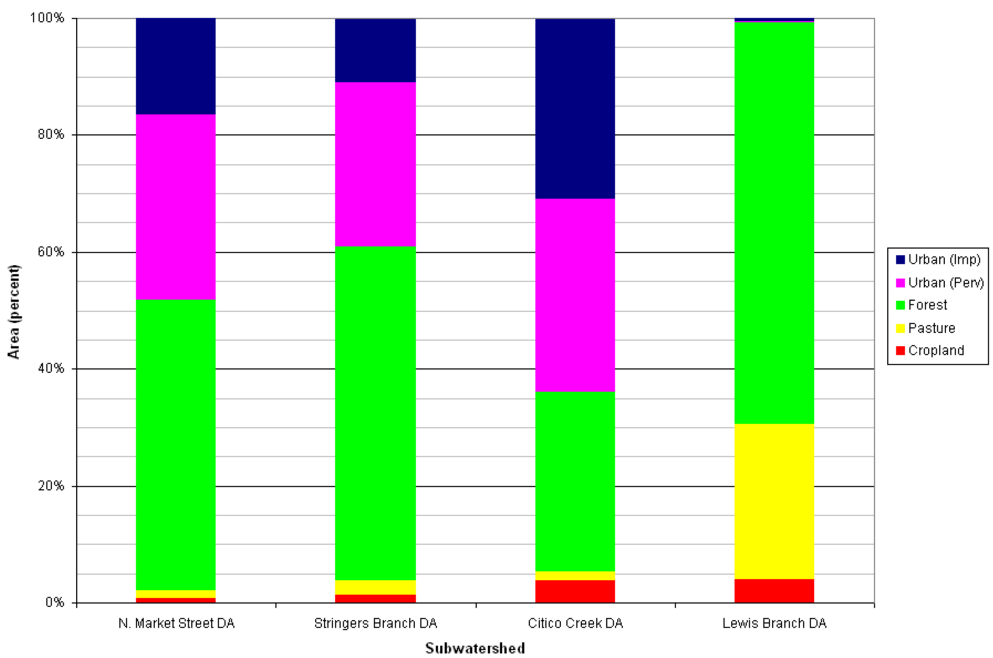

Figure 11. **Land Use Percent of the Lower Tennessee River Pathogen-Impaired Subwatersheds – Drainage Areas Less Than 5,000 Acres.**

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOADS

The Total Maximum Daily Load (TMDL) process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), non-point source loads (Load Allocations), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

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

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

This document describes TMDL, Waste Load Allocation (WLA), and Load Allocation (LA) development for waterbodies identified as impaired due to E. coli on the Final 2004 303(d) list.

8.1 Expression of TMDLs, WLAs, & LAs

In this document, TMDLs are expressed as the percent reduction in instream loading required to decrease existing E. coli concentrations to desired target levels. WLAs & LAs for precipitation-induced loading sources are also expressed as required percent reductions in E. coli loading. Allocations for loading that is independent of precipitation (WLAs for WWTFs and LAs for “other direct sources”) are expressed as CFU/day.

8.2 Area Basis for TMDL Analysis

The primary area unit of analysis for TMDL development was the HUC-12 subwatershed containing one or more waterbodies assessed as impaired due to E. coli (as documented on the 2004 303(d) List). In some cases, however, TMDLs were developed for an impaired waterbody drainage area only. Determination of the appropriate area to use for analysis (see Table 8) was based on a careful consideration of a number of relevant factors, including: 1) location of impaired waterbodies in the HUC-12 subwatershed; 2) land use type and distribution; 3) water quality monitoring data; and 4) the assessment status of other waterbodies in the HUC-12 subwatershed.

Table 8 Determination of Analysis Areas for TMDL Development

HUC-12 Subwatershed (06020001____)	Impaired Waterbody	Area
0502	North Market Street Branch	DA
	Stringers Branch	DA
	UT to Citico Creek	DA
	Citico Creek	
0503	Dobbs Branch McFarland Springs Branch Gillespie Springs Branch UT to Chattanooga Creek Chattanooga Creek	HUC-12
0602	Lewis Branch	DA
0803	Spring Creek	DA
0804	Friar Branch South Chickamauga Creek	HUC-12

Note: HUC-12 = HUC-12 Subwatershed
DA = Waterbody Drainage Area

8.3 TMDL Analysis Methodology

TMDLs for the Lower Tennessee River Watershed were developed using load duration curves for analysis of impaired HUC-12 subwatersheds or specific waterbody drainage areas. A load duration curve (LDC) is a cumulative frequency graph that illustrates existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the portion of the waterbody flow regime represented by these existing loads. Load duration curves are considered to be well suited for analysis of periodic monitoring data collected by grab sample. LDCs were developed at monitoring site locations in impaired waterbodies and an overall load reduction calculated to meet E. coli targets according to the methods described in Appendix C.

8.4 Critical Conditions and Seasonal Variation

The critical condition for non-point source E. coli loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, E. coli bacteria builds up on the land surface, and is washed off by rainfall. The critical condition for point source loading occurs during periods of low streamflow when dilution is minimized. Both conditions are represented in the TMDL analysis.

The ten-year period from October 1, 1995 to September 30, 2005 was used to simulate flow. This 10-year period contained a range of hydrologic conditions that included both low and high streamflows. Critical conditions are accounted for in the load duration curve analysis by using the entire period of flow and water quality data available for the impaired waterbodies. In all subwatersheds, water quality data have been collected during most flow ranges. Based on the location of the water quality exceedances on the load duration curves, no one delivery mode for E. oli appears to be dominant (see Section 9.3 and Table 9).

Seasonal variation was incorporated in the load duration curves by using the entire simulation period and all water quality data collected at the monitoring stations. The water quality data were not collected during all seasons.

8.5 Margin of Safety

There are two methods for incorporating MOS in TMDL analysis: a) implicitly incorporate the MOS using conservative model assumptions; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. For development of pathogen TMDLs in the Lower Tennessee River Watershed, an explicit MOS, equal to 10% of the E. coli water quality targets (ref.: Section 5.0), was utilized for determination of WLAs and LAs:

Instantaneous Maximum (Tier II):	MOS = 49 CFU/100 ml
Instantaneous Maximum (non-Tier II):	MOS = 94 CFU/100 ml
30-Day Geometric Mean:	MOS = 13 CFU/100 ml

8.6 Determination of TMDLs

E. coli load reductions were calculated for impaired segments in the Lower Tennessee Watershed using Load Duration Curves to evaluate compliance with the maximum target concentrations according to the procedure in Appendix C. When sufficient data were available, load reductions were also developed to achieve compliance with the 30-day geometric mean target concentrations. Both instream load reductions (where applicable) for a particular waterbody were compared and the largest required load reduction was selected as the TMDL. These TMDL load reductions for impaired segments are shown in Table 9 and are applied according to the areas specified in Table 8. In cases where the geometric mean could not be developed, it is assumed that achieving the load reduction based on the maximum target concentrations should result in attainment of the geometric mean criteria.

8.7 Determination of WLAs & LAs

WLAs for MS4s and LAs for precipitation induced sources of E. coli loading were determined according to the procedures in Appendix C. These allocations represent the higher load reductions necessary to achieve instream targets <u>after application of the explicit MOS</u>. WLAs for existing WWTFs are equal to their existing NPDES permit limits. Since WWTF permit limits require that E. coli concentrations must comply with water quality criteria (TMDL targets) at the point of discharge and recognition that loading from these facilities are generally small in comparison to other loading sources, further reductions were not considered to be warranted. WLAs for CAFOs and LAs for "other direct sources" (non-precipitation induced) are equal to zero. WLAs, & LAs are summarized in Table 9.

Table 9 TMDLs, WLAs, & LAs for Impaired Subwatersheds and Drainage Areas in the Lower Tennessee River Watershed

HUC-12 Subwatershed (06020001__) or Drainage Area	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs[a,b]		LAs[e]
				Leaking Collection Systems[c]	MS4s [d]	
			[% Red.]	[CFU/day]	[% Red.]	[% Red.]
0502 (DA)	North Market Street Branch	TN06020001001T – 0200	91.4	0	92.7	92.7
0502 (DA)	Stringers Branch	TN06020001426 – 0100	28.7	0	35.8	35.8
0502 (DA)	Unnamed Trib to Citico Creek	TN060200011240 – 0100	>90.0	0	>91.0	>91.0
	Citico Creek	TN060200011240 – 1000	32.3	0	39.1	39.1
0503	Dobbs Branch	TN060200011244 – 0100	94.1	0	94.7	94.7
	Unnamed Trib to Chattanooga Creek	TN060200011244 – 0200	92.7	0	93.4	93.4
	McFarland Springs Branch[f]	TN060200011244 – 0300	52.6	0	57.4	57.4
	Chattanooga Creek[f]	TN060200011244 –1000 & 2000	>60.8	0	>64.7	>64.7
0602 (DA)	Lewis Branch	TN06020001029 - 0300	98.2	NA	98.4	98.4
0803 (DA)	Spring Creek	TN06020001007 – 0510	86.6	0	88.0	88.0

Table 9 (cont'd) TMDLs, WLAs, & LAs for Impaired Subwatersheds and Drainage Areas in the Lower Tennessee River Watershed

HUC-12 Subwatershed (06020001__) or Drainage Area	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs[a,b]		LAs[e]
				Leaking Collection Systems[c]	MS4s [d]	
			[% Red.]	[CFU/day]	[% Red.]	[% Red.]
0804	Friar Branch	TN06020001007 – 0100	73.4	0	76.1	76.1
	South Chickamauga Creek[f]	TN06020001007 – 1000	84.8	0	86.3	86.3

Notes: NA = Not Applicable.

a. There are no CAFOs in the Lower Tennessee River Watershed. Future CAFOs will be assigned a waste load allocation (WLA) of zero.

b. WLAs for WWTFs are expressed as E. coli loads (CFU/day). Future WWTFs must meet instream water quality standards at the point of discharge as specified in their NPDES permit.

c. Pathogen loading due to collection system failure is considered to be unpermitted point source loading from the municipal WWTF. With respect to pathogen loading from leaking collection systems, a WLA of zero is assigned. It is recognized, however, that a WLA of 0 CFU/day may not be practical. For these unpermitted sources, the WLA is interpreted to mean a reduction in pathogen loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

d. Applies to any MS4 discharge loading in the subwatershed or drainage area.

e. The load allocations (LAs) listed apply to precipitation induced nonpoint sources only. The objective for all other nonpoint sources (leaking septic systems, illicit discharges, and animals access to streams) is a LA of zero. It is recognized, however, that for leaking septic systems a LA of 0 CFU/day may not be practical. For these sources, the LA is interpreted to mean a reduction in E. coli loading to the maximum extent feasible, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

f. Portions of these waterbodies lie in another state. A TMDL for Fecal Coliform has been developed by the State of Georgia for those portions of the waterbodies lying within their jurisdiction. The required load reduction is for the Tennessee portion of the waterbodies.

9.0 IMPLEMENTATION PLAN

The TMDLs, WLAs, and LAs developed in Section 8 are intended to be the first phase of a long-term effort to restore the water quality of impaired waterbodies in the Lower Tennessee River Watershed through reduction of excessive pathogen loading. Adaptive management methods, within the context of the State's rotating watershed management approach, will be used to modify TMDLs, WLAs, and LAs as required to meet water quality goals.

9.1 Point Sources

9.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

All present and future discharges from industrial and municipal wastewater treatment facilities are required to be in compliance with the conditions of their NPDES permits at all times, including elimination of bypasses and overflows. In Tennessee, permit limits for treated sanitary wastewater require compliance with coliform water quality standards (ref: Section 5.0) prior to discharge. No additional reduction is required. WLAs for WWTFs are derived from facility design flows and permitted E. coli limits and are expressed as average loads in CFU per day.

9.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For existing and future regulated discharges from municipal separate storm sewer systems, WLAs will be implemented through Phase I & II MS4 permits. These permits will require the development and implementation of a Storm Water Management Program (SWMP) that will reduce the discharge of pollutants to the "maximum extent practicable" and not cause or contribute to violations of State water quality standards. The *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003) and the TDOT individual MS4 permit (TNS077585) require SWMPs to include six minimum control measures:

- Public education and outreach on storm water impacts
- Public involvement/participation
- Illicit discharge detection and elimination
- Construction site storm water runoff control
- Post-construction storm water management in new development and re-development
- Pollution prevention/good housekeeping for municipal operations

The permits also contain requirements regarding control of discharges of pollutants of concern into impaired waterbodies, implementation of provisions of approved TMDLs, and descriptions of methods to evaluate whether storm water controls are adequate to meet the requirements of approved TMDLs.

In order to evaluate SWMP effectiveness and demonstrate compliance with specified WLAs, MS4s must develop and implement appropriate monitoring programs. An effective monitoring program could include:

- Effluent monitoring at selected outfalls that are representative of particular land uses or geographical areas that contribute to pollutant loading before and after implementation of pollutant control measures.
- Analytical monitoring of pollutants of concern in receiving waterbodies, both upstream and downstream of MS4 discharges, over an extended period of time.
- Instream biological monitoring at appropriate locations to demonstrate recovery of biological communities after implementation of storm water control measures.

The Division of Water Pollution Control Chattanooga Field Office should be consulted for assistance in the determination of monitoring strategies, locations, frequency, and methods within 12 months after the approval date of this TMDL. Details of the monitoring plan and monitoring data should be included in the annual report required by the MS4 permit.

9.1.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

As of May 11, 2005, there are no Class I or Class II CAFOs in the Lower Tennessee River watershed with coverage under the general NPDES permit. WLAs and implementation requirements are provided for any future facilities.

WLAs provided to CAFOs will be implemented through NPDES Permit No. TNA000000, General NPDES Permit for *Class II Concentrated Animal Feeding Operation* or the facility's individual permit. Among the provisions of the general permit are:

- Development and implementation of a site-specific Nutrient Management Plan (NMP) that:
  - Includes best management practices (BMPs) and procedures necessary to implement applicable limitations and standards;
  - Ensures adequate storage of manure, litter, and process wastewater including provisions to ensure proper operation and maintenance of the storage facilities.
  - Ensures proper management of mortalities (dead animals);
  - Ensures diversion of clean water, where appropriate, from production areas;
  - Identifies protocols for manure, litter, wastewater and soil testing;
  - Establishes protocols for land application of manure, litter, and wastewater;
  - Identifies required records and record maintenance procedures.

  The NMP must submitted to the State for approval and a copy kept on-site.

- Requirements regarding manure, litter, and wastewater land application BMPs.
- Requirements for the design, construction, operation, and maintenance of CAFO liquid waste management systems that are constructed, modified, repaired, or placed into operation after April 13, 2006. The final design plans and specifications for these systems must meet or exceed standards in the NRCS Field Office Technical Guide and other guidelines as accepted by the Departments of Environment and Conservation, or Agriculture.

Provisions of individual CAFO permits are similar. NPDES Permit No. TNA000000, *Class II Concentrated Animal Feeding Operation General Permit* is available on the TDEC website at http://www.state.tn.us/environment/wpc/programs/cafo/ .

9.2 Nonpoint Sources

The Tennessee Department of Environment & Conservation (TDEC) has no direct regulatory authority over most nonpoint source discharges. Reductions of pathogen loading from nonpoint sources (NPS) will be achieved using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. There are links to a number of publications and information resources on EPA's Nonpoint Source Pollution web page (http://www.epa.gov/owow/nps/pubs.html) relating to the implementation and evaluation of nonpoint source pollution control measures.

TMDL implementation activities will be accomplished within the framework of Tennessee's Watershed Approach (ref: http://www.state.tn.us/environment/wpc/watershed/). The Watershed Approach is based on a five-year cycle and encompasses planning, monitoring, assessment, TMDLs, WLAs/LAs, and permit issuance. It relies on participation at the federal, state, local and nongovernmental levels to be successful.

An excellent example of stakeholder involvement and action for the implementation of the nonpoint source load allocations (LAs) specified in an approved TMDL is described in *Guidance for Development of a Total Maximum Daily Load Implementation Plan for Fecal Coliform Reduction* (SCWA, 2004), prepared by the Sinking Creek Watershed Alliance. This document details the cooperative effort of a number of stakeholders and governmental entities to develop an implementation plan for the restoration of water quality in Sinking Creek, near Johnson City, Tennessee. Plan development was funded, in part, through a TDEC 604(b) grant and a Tennessee Department of Agriculture (TDA) Nonpoint source Program 319 grant. The plan is based on land use and pollutant source identification surveys and considers public education & participation, funding resources, in-stream monitoring, best management practices (BMPs), and stakeholder responsibilities. Recommendations for future activities include verification of chemical/biological findings through Bacteria Source Tracking (BST) research, implementation of appropriate BMPs, post implementation monitoring to verify reduction of pollutant loading.

BMPs have been utilized in the Lower Tennessee River Watershed to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. These BMPs (e.g., animal waste management systems, waste utilization, stream stabilization, fencing, heavy use area treatment, livestock exclusion, etc.) may have contributed to reductions in in-stream concentrations of coliform bacteria in the Lower Tennessee River Watershed during the TMDL evaluation period. The TDA keeps a database of BMPs implemented in Tennessee. Those listed in the Lower Tennessee River Watershed are shown in Figure 12. It is recommended that additional information (e.g., livestock access to streams, manure application practices, etc.) be provided and evaluated to better identify and quantify agricultural sources of coliform bacteria loading in order to minimize uncertainty in future modeling efforts.

It is further recommended that BMPs be utilized to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. Demonstration sites for various types of BMPs should be established, maintained, and evaluated (performance in source reduction) over a period of at least two years prior to recommendations for utilization for subsequent implementation. E. coli sampling and monitoring are recommended during low-flow (baseflow) and storm periods at sites with and without BMPs and/or before and after implementation of BMPs.

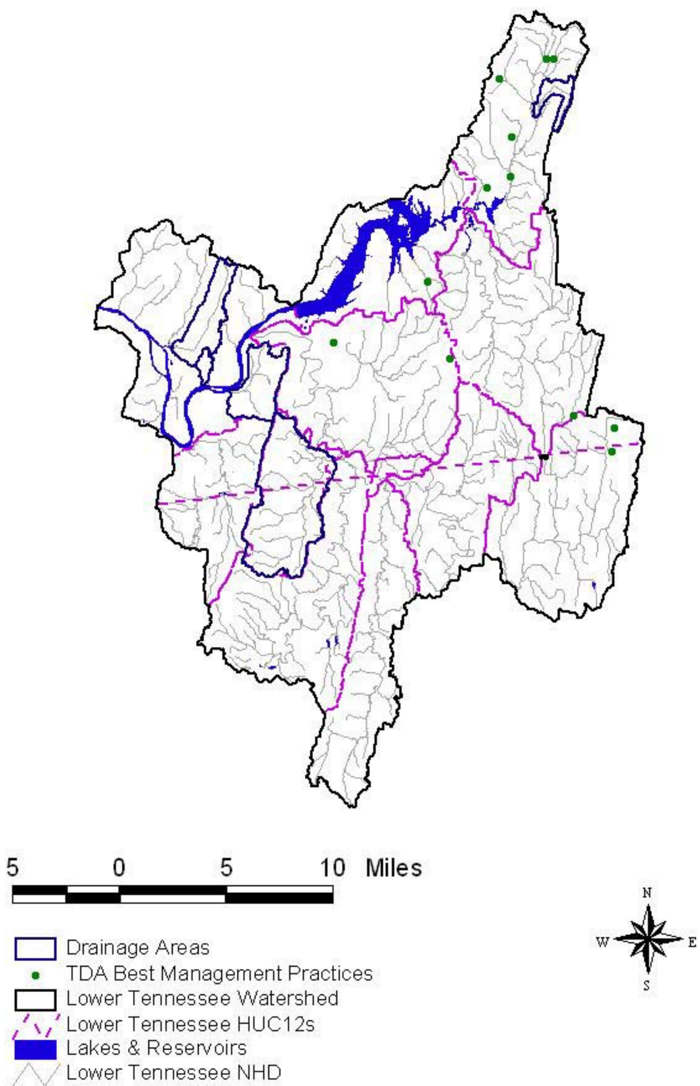

Figure 12. Tennessee Department of Agriculture Best Management Practices located in the Lower Tennessee River Watershed.

9.3 Application of Load Duration Curves for Implementation Planning

The Load Duration Curve methodology (Appendix C) is a form of water quality analysis and presentation of data that aids in guiding implementation by targeting strategies to appropriate flow conditions. One of the strengths of this method is that it can be used to interpret possible delivery mechanisms of pathogens by differentiating between point and nonpoint problems. The E. coli load duration analysis was utilized for implementation planning. The E. coli load duration curve for each pathogen-impaired subwatershed (Figures C-2 through C-15) was analyzed to determine the frequency with which water quality monitoring data exceed the E. coli target maximum concentration of 941 CFU/100 mL under five flow conditions (low, dry, mid- range, moist, and high). A sample E. coli load duration curve is presented in Figure 13.

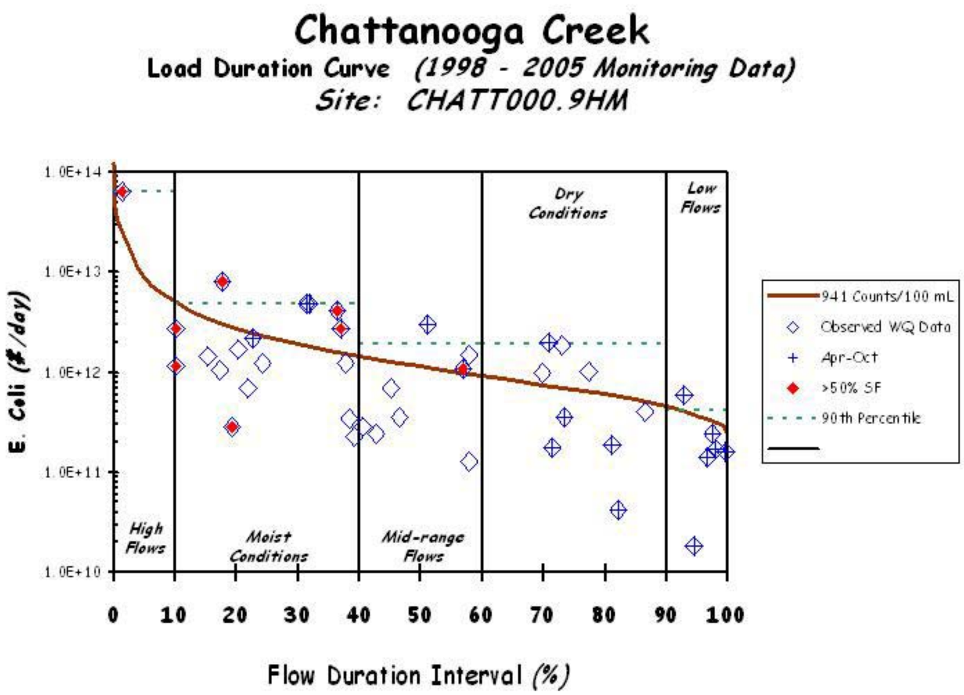

Figure 13. Sample E. Coli Load Duration Curve (Chattanooga Creek at Mile 0.9)

Table 10 presents an example of Load Duration analysis statistics for E. coli. Table 11 presents targeted implementation strategies for each source category covering the entire range of flow (Stiles, 2003). Each implementation strategy addresses a range of flow conditions and targets point sources, nonpoint sources, or a combination of each. Results indicate the implementation strategy for all subwatersheds will require BMPs targeting a variety of sources. The implementation strategies listed in Table 11 are a subset of the categories of BMPs and implementation strategies available for application to the pathogen-impaired Lower Tennessee River Watersheds for reduction of pathogen loading and mitigation of water quality impairment.

See Appendix C for a detailed discussion of the Load Duration Curve Methodology applied to the Lower Tennessee River Watershed.

Table 10 Sample Load Duration Curve Summary (Chattanooga Creek at Mile 0.9)

Flow Condition		High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded		0-10	10-40	40-60	60-90	90-100
Chattanooga Creek at Mile 0.9	% Samples > 941 CFU/100 mL	0.0	31.3	25.0	55.6	33.3
Chattanooga Creek at Mile 0.9	Reduction	0.0	>60.8	>60.8	>60.8	21.6

Table 11 Example Implementation Strategies

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
Municipal NPDES		**L**	**M**	**H**	**H**
Stormwater Management		**H**	**H**	**H**	
SSO Mitigation	**H**	**H**	**M**	**L**	
Collection System Repair		**L**	**M**	**H**	**H**
Septic System Repair		**L**	**M**	**H**	**M**
Livestock Exclusion[1]			**M**	**H**	**H**
Pasture Management/Land Application of Manure[1]	**H**	**H**	**M**	**L**	
Riparian Buffers[1]		**H**	**H**	**H**	
Potential for source area contribution under given hydrologic condition (H: High; M: Medium; L: Low)					

[1] Example Best Management Practices (BMPs) for Agricultural Source reduction. Actual BMPs applied may vary.

9.4 Additional Monitoring

Documenting progress in reducing the quantity of pathogens entering the Lower Tennessee River Watershed is an essential element of the TMDL Implementation Plan. Additional monitoring and assessment activities are recommended to determine whether implementation of TMDLs, WLAs, & LAs in tributaries and upstream reaches will result in achievement of instream water quality targets for E. coli. Future monitoring activities should be representative of all seasons and a full range of flow and meteorological conditions. Monitoring activities should also be adequate to assess water quality using the 30-day geometric mean standard.

Tennessee's watershed management approach specifies a five-year cycle for planning and assessment. Each watershed will be examined (or re-examined) on a rotating basis. Generally, in years two and three of the five-year cycle, water quality data are collected in support of water quality assessment (including TMDL development) and planning activities. Therefore, a watershed TMDL is developed one to two years prior to commencement of the next cycle's monitoring period.

Additional monitoring and assessment activities are recommended for Lewis Branch. Examination of monitoring data indicates that few sampling events have occurred during periods of low flow. Once additional monitoring representing all seasons and a full range of flow and meteorological conditions has been obtained, the required load reductions may be revised.

Additional monitoring and assessment activities also are recommended for Gillespie Springs Branch and the unnamed tributary to South Chickamauga Creek. No monitoring data was available for either waterbody. Once monitoring data representing all seasons and a full range of flow and meteorological conditions has been obtained, the required load reductions may be developed.

9.5 Source Identification

An important aspect of pathogen load reduction activities is the accurate identification of the actual sources of pollution. In cases where the sources of pathogen impairment are not readily apparent, Microbial Source Tracking (MST) is one approach to determining the sources of fecal pollution and pathogens affecting a waterbody. Those methods that use bacteria as target organisms are also known as Bacterial Source Tracking (BST) methods. This technology is recommended for source identification in pathogen impaired waterbodies.

Bacterial Source Tracking is a collective term used for various emerging biochemical, chemical, and molecular methods that have been developed to distinguish sources of human and non-human fecal pollution in environmental samples (Shah, 2004). In general, these methods rely on genotypic (also known as “genetic fingerprinting”), or phenotypic (relating to the physical characteristics of an organism) distinctions between the bacteria of different sources. Three primary genotypic techniques are available for BST: ribotyping, pulsed field gel electrophoresis (PFGE), and polymerase chain reaction (PCR). Phenotypic techniques generally involve an antibiotic resistance analysis (Hyer, 2004).

The USEPA has published a fact sheet that discusses BST methods and presents examples of BST application to TMDL development and implementation (USEPA, 2002b). Various BST projects and descriptions of the application of BST techniques used to guide implementation of effective BMPs to remove or reduce fecal contamination are presented. The fact sheet can be found on the following EPA website: http://www.epa.gov/owm/mtb/bacsortk.pdf.

A multi-disciplinary group of researchers is developing and testing a series of different microbial assay methods based on real-time PCR to detect fecal bacterial concentrations and host sources in water samples (McKay, 2005). The assays have been used in a study of fecal contamination and have proven useful in identification of areas where cattle represent a significant fecal input and in development of BMPs. It is expected that these types of assays could have broad applications in monitoring fecal impacts from Animal Feeding Operations, as well as from wildlife and human sources. Other BST projects have been conducted or are currently in progress throughout the state of Tennessee, as presented in sessions of the Thirteenth Tennessee Water Resources Symposium (Lawrence, 2003) and the Fifteenth Tennessee Water Resources Symposium (Bailey, 2005; Baldwin, 2005; Farmer, 2005).

9.6 Evaluation of TMDL Implementation Effectiveness

The effectiveness of the TMDL will be assessed within the context of the State's rotating watershed management approach. Watershed monitoring and assessment activities will provide information by which the effectiveness of pathogen loading reduction measures can be evaluated. Additional monitoring data, ground-truthing activities, and bacterial source identification actions are recommended to enable implementation of particular types of BMPs to be directed to specific areas in impaired subwatersheds. This will optimize utilization of resources to achieve maximum reductions in pathogen loading. These TMDLs will be re-evaluated during subsequent watershed cycles and revised as required to assure attainment of applicable water quality standards.

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed pathogen TMDLs for the Lower Tennessee River Watershed was placed on Public Notice for a 35-day period and comments solicited. Steps that were taken in this regard include:

1) Notice of the proposed TMDLs was posted on the Tennessee Department of Environment and Conservation website. The announcement invited public and stakeholder comment and provided a link to a downloadable version of the TMDL document.

2) Notice of the availability of the proposed TMDLs (similar to the website announcement) was included in one of the NPDES permit Public Notice mailings which is sent to approximately 90 interested persons or groups who have requested this information.

3) Letters were sent to WWTFs located in E. coli-impaired subwatersheds or drainage areas in the Lower Tennessee River Watershed, permitted to discharge treated effluent containing pathogens, advising them of the proposed TMDLs and their availability on the TDEC website. The letters also stated that a copy of the draft TMDL document would be provided on request. A letter was sent to the following facilities:

   Chattanooga – Moccasin Bend WWTP & Combined Sewer System (TN0024210)

4) A draft copy of the proposed TMDL was sent to those MS4s that are wholly or partially located in pathogen-impaired subwatersheds. A draft copy was sent to the following entities:

   City of Chattanooga MS4, Tennessee (TNS068063)
   Hamilton County Small MS4s, Tennessee (TNS075566)
   Walden, Tennessee (TNS077879)
   Chattanooga State Technical Community College (TNS076058)
   University of Tennessee at Chattanooga (TNS076147)
   Signal Mountain, Tennessee (TNS075761)
   Tennessee Dept. of Transportation (TNS077585)

5) A letter was sent to local stakeholder groups in the Lower Tennessee River Watershed advising them of the proposed E. coli TMDLs and their availability on the TDEC website. The letter also stated that a written copy of the draft TMDL document would be provided upon request. A letter was sent to the following local stakeholder groups:

   Chickamauga Watershed Team
   Friends of the Tennessee River
   Tennessee River Gorge Trust (TRGT)

11.0 FURTHER INFORMATION

Further information concerning Tennessee's TMDL program can be found on the Internet at the Tennessee Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl/

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

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APPENDIX A

Land Use Distribution in the Lower Tennessee River Watershed

Table A-1. MRLC Land Use Distribution of Lower Tennessee River Subwatersheds

Land Use	HUC-12 Subwatershed (06020001__) or Drainage Area					
	North Market Street DA		Stringers Branch DA		Citico Creek DA	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	0.0	0.0	0.0	0.0	0.0	0.0
Deciduous Forest	40.5	8.2	729.0	19.0	387.0	9.7
Emergent Herbaceous Wetlands	0.0	0.0	0.0	0.0	4.7	0.1
Evergreen Forest	87.6	17.7	336.3	8.8	67.2	1.7
High Intensity Commercial/Industrial/Transp.	40.5	8.2	185.0	4.8	933.4	23.5
High Intensity Residential	43.4	8.8	193.7	5.1	441.5	11.1
Low Intensity Residential	154.3	31.2	1116.2	29.1	1156.9	29.1
Mixed Forest	107.2	21.7	945.8	24.7	517.7	13.0
Open Water	0.0	0.0	3.8	0.1	9.3	0.2
Other Grasses (Urban/recreation; e.g. parks)	10.7	2.2	175.7	4.6	213.3	5.4
Pasture/Hay	6.2	1.3	96.1	2.5	59.4	1.5
Quarries/Strip Mines/Gravel Pits	0.0	0.0	0.0	0.0	0.0	0.0
Row Crops	3.8	0.8	52.5	1.4	151.7	3.8
Transitional	0.0	0.0	0.0	0.0	0.0	0.0
Woody Wetlands	0.0	0.0	0.0	0.0	31.6	0.8
Total	494.7	100.0	3,834.1	100.0	3,973.5	100.0

Note: Percent calculations were performed using a spreadsheet. Percentages and totals were rounded off and may differ slightly from values calculated by other means.

Table A-1 (Cont.). MRLC Land Use Distribution of Lower Tennessee River Subwatersheds

Land Use	HUC-12 Subwatershed (06020001__) or Drainage Area					
	0503		Lewis Branch DA		Spring Creek DA	
	[acres]	[%]	[acres]	[%]	[acres]	[%]
Bare Rock/Sand/Clay	0.0	0.0	0.0	0.0	0.0	0.0
Deciduous Forest	2,935.8	17.9	623.6	49.8	2499.7	9.4
Emergent Herbaceous Wetlands	61.2	0.4	0.0	0.0	6.2	0.0
Evergreen Forest	986.1	6.0	89.8	7.2	2162.1	8.2
High Intensity Commercial/Industrial/Transp.	1,694.0	10.3	6.9	0.6	868.7	3.3
High Intensity Residential	951.9	5.8	0.0	0.0	1681.8	6.4
Low Intensity Residential	3,045.7	18.6	2.9	0.2	9538.5	36.1
Mixed Forest	4,084.5	24.9	146.3	11.7	6677.6	25.2
Open Water	53.2	0.3	0.2	0.0	11.1	0.0
Other Grasses (Urban/recreation; e.g. parks)	590.2	3.6	0.0	0.0	1993.1	7.5
Pasture/Hay	830.2	5.1	334.5	26.7	612.0	2.3
Quarries/Strip Mines/Gravel Pits	270.2	1.6	0.0	0.0	0.0	0.0
Row Crops	385.9	2.4	48.9	3.9	276.2	1.0
Transitional	4.7	0.0	0.0	0.0	64.5	0.2
Woody Wetlands	523.1	3.2	0.0	0.0	60.5	0.2
Total	16,416.6	100.0	1,253.2	100.0	26,452.1	100.0

Note: Percent calculations were performed using a spreadsheet. Percentages and totals were rounded off and may differ slightly from values calculated by other means.

Table A-1 (Cont.). MRLC Land Use Distribution of Lower Tennessee River Subwatersheds

Land Use	HUC-12 Subwatershed (06020001__) or Drainage Area	
	0804	
	[acres]	[%]
Bare Rock/Sand/Clay	0.7	0.0
Deciduous Forest	4745.0	14.4
Emergent Herbaceous Wetlands	62.9	0.2
Evergreen Forest	3770.1	11.5
High Intensity Commercial/Industrial/Transp.	2641.2	8.0
High Intensity Residential	1110.2	3.4
Low Intensity Residential	6209.5	18.9
Mixed Forest	8082.1	24.6
Open Water	223.7	0.7
Other Grasses (Urban/recreation; e.g. parks)	2813.5	8.6
Pasture/Hay	1547.0	4.7
Quarries/Strip Mines/Gravel Pits	390.5	1.2
Row Crops	911.6	2.8
Transitional	210.2	0.6
Woody Wetlands	138.8	0.4
Total	32,857.0	100.0

Note: Percent calculations were performed using a spreadsheet. Percentages and totals were rounded off and may differ slightly from values calculated by other means.

APPENDIX B

Water Quality Monitoring Data

There are a number of water quality monitoring stations that provide data for waterbodies identified as impaired for E. coli in the Lower Tennessee River Watershed. The location of these monitoring stations is shown in Figures 5 and 6. Monitoring data recorded by TDEC at these stations are tabulated in Table B-1.

Table B-1. TDEC Water Quality Monitoring Data – Lower Tennessee River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
CHATT000.9HM	11/17/98	1414
	12/15/98	1203
	1/12/99	260
	2/9/99	93
	3/9/99	490
	3/9/99	210
	4/7/99	2400
	5/24/99	2400
	6/8/99	450
	7/15/99	2400
	7/28/99	280
	9/14/99	690
	10/11/99	1000
	11/8/99	730
	12/14/99	1400
	1/10/00	2400
	2/15/00	580
	3/15/00	210
	5/15/00	220
	6/19/00	2400
	7/19/00	490
	8/16/00	380
	9/5/00	1400
	10/9/00	47
	11/14/00	730
	12/4/00	490
	1/16/01	2400
	2/6/01	120
	3/14/01	370
	4/17/01	820
	9/11/01	65

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Lower Tennessee River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
CHATT000.9HM	3/25/02	160
	9/4/02	580
	12/17/02	490
	3/26/03	140
	6/17/03	2400
	9/8/03	2400
	12/2/03	180
	3/9/04	250
	7/7/04	1600
	11/29/04	310
CHATT1T0.1HM	8/16/04	630
	9/13/04	238
	10/12/04	17260
	11/8/04	613
	1/18/05	310
	2/14/05	12910
	3/7/05	112
	3/28/05	3270
	4/18/05	248
	5/2/05	461
	5/23/05	285
CITIC000.3HM	11/8/99	220
	2/15/00	770
	5/15/00	490
	8/16/00	920
	11/14/00	1600
	2/6/01	130
	8/24/04	1300
	11/29/04	550
CITIC001.0HM	8/30/04	1480
	9/27/04	200
	10/4/04	10
	11/1/04	310
	1/10/05	740
	1/31/05	461

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Lower Tennessee River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
CITIC001.0HM (cont'd)	2/28/05	520
	3/14/05	517
	4/11/05	411
	4/25/05	96
	5/9/05	135
CITIC1T0.3HM	6/14/00	2400
	9/18/01	580
	1/23/02	2400
	8/30/04	11450
	9/27/04	970
	10/4/04	365
	11/1/04	4500
	1/10/05	1046
	1/31/05	2990
	2/28/05	41060
	3/14/05	980
	4/11/05	630
	4/25/05	436
	5/9/05	1203
CITIC1T0.8HM	6/14/00	2000
	9/18/01	2400
	1/23/02	2400
CITIC1T0.9HM	6/14/00	1100
	9/18/01	32
	1/23/02	2400
CITIC1T1.2HM	1/23/02	2400
CITIC2T0.0HM	1/23/02	2400
CITIC3T0.1HM	6/14/00	2400
	9/18/01	13
	1/23/02	1300
CITIC3T0.7HM	6/14/00	130
	1/23/02	1300
CITIC4T0.5HM	6/14/00	870
	9/18/01	170
	1/23/02	2000

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Lower Tennessee River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
CITIC5T0.1HM	6/14/00	2400
	9/18/01	130
	1/23/02	2400
CITIC6T0.1HM	6/14/00	2400
	9/18/01	300
	1/23/02	2400
DOBBS000.3HM	8/16/04	281
	9/13/04	1990
	10/12/04	17850
	11/8/04	860
	1/18/05	79
	2/14/05	16070
	3/7/05	104
	3/28/05	5570
	4/18/05	291
	5/2/05	410
	5/23/05	770
FRIAR000.8HM	8/30/04	727
	9/27/04	200
	10/4/04	200
	11/1/04	850
	1/10/05	310
	1/31/05	100
	2/28/05	520
	3/14/05	200
	4/11/05	310
	4/25/05	630
	5/9/05	345
FRIAR002.7HM	8/30/04	770
	9/27/04	548
	10/4/04	310
	11/1/04	1830
	1/10/05	356
	1/31/05	199
	2/28/05	740

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Lower Tennessee River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
FRIAR002.7HM (cont'd)	3/14/05	185
	4/11/05	163
	4/25/05	2750
	5/9/05	345
LEWIS000.3HM	7/30/03	1120
	8/18/03	770
	10/7/03	3900
	11/20/03	1733
	1/6/04	840
	2/11/04	1120
	3/16/04	241900
	4/21/04	3360
	5/25/04	980
MCFAR000.2HM	8/16/04	123
	9/13/04	122
	10/12/04	1986
	11/8/04	200
	1/18/05	200
	2/14/05	4570
	3/7/05	12
	3/28/05	770
	4/18/05	200
	5/2/05	100
	5/23/05	579
NMSTR000.3HM	8/16/04	219
	9/13/04	105
	10/12/04	15150
	11/8/04	1120
	1/18/05	687
	2/14/05	8160
	3/7/05	410
	3/28/05	11530
	4/18/05	740
	5/2/05	248
	5/23/05	261

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Lower Tennessee River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
SCHIC000.4HM	1/12/99	1600
	4/7/99	1400
	7/19/99	1
	10/11/99	370
	1/10/00	2400
	7/19/00	2
	10/9/00	5
	1/16/01	5
	4/17/01	88
	12/1/04	2400
	2/23/05	2400
	5/11/05	260
	7/27/05	3
SCHIC004.9HM	8/30/04	310
	9/27/04	300
	10/4/04	100
	11/1/04	4040
	1/10/05	3200
	1/31/05	410
	2/28/05	310
	3/14/05	38
	4/11/05	200
	4/25/05	210
	5/9/05	54
SCHIC015.8HM	2/22/00	68
	2/23/00	100
	5/1/00	55
	5/2/00	59
	11/6/00	170
	11/7/00	330
	8/30/04	1120
	9/27/04	105
	10/4/04	0
	11/1/04	200
	1/10/05	1450

Table B-1 (Cont.). TDEC Water Quality Monitoring Data – Lower Tennessee River Subwatersheds

Monitoring Station	Date	E. Coli [cts./100 mL]
SCHIC015.8HM (cont'd)	1/31/05	411
	2/28/05	231
	3/14/05	40
	4/11/05	310
	4/25/05	200
	5/9/05	50
SPRIN000.7HM	8/16/04	219
	9/13/04	238
	10/12/04	2720
	11/8/04	310
	1/18/05	100
	2/14/05	3640
	3/7/05	53
	3/28/05	5830
	4/18/05	184
	5/2/05	860
	5/23/05	228
STRIN000.6HM	8/16/04	120
	9/13/04	200
	10/12/04	547
	11/8/04	89
	1/18/05	63
	2/14/05	2500
	3/7/05	410
	3/28/05	1320
	4/18/05	100
	5/2/05	100
	5/23/05	111
WCHIC001.7HM	2/22/00	99
	2/23/00	57
	5/1/00	73
	5/2/00	41
	11/6/00	140
	11/7/00	380

APPENDIX C

Development of TMDLs, WLAs, & LAs

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), nonpoint source loads (Load Allocations), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure.

C.1 Development of TMDLs

E. coli TMDLs, WLAs, and LAs were developed for impaired subwatersheds and drainage areas in the Lower Tennessee River Watershed using Load Duration Curves (LDCs) to determine the reduction in pollutant loading required to decrease existing, instream E. coli concentrations to target levels. TMDLs are expressed as required percent reductions in pollutant loading.

C.1.1 Development of Flow Duration Curves

A flow duration curve is a cumulative frequency graph, constructed from historic flow data at a particular location, that represents the percentage of time a particular flow rate is equaled or exceeded. Flow duration curves are developed for a waterbody from daily discharges of flow over a period of record. In general, there is a higher level of confidence that curves derived from data over a long period of record correctly represent the entire range of flow. The preferred method of flow duration curve computation uses daily mean data from USGS continuous-record stations located on the waterbody of interest. For ungaged streams, alternative methods must be used to estimate daily mean flow. These include: 1) regression equations (using drainage area as the independent variable) developed from continuous record stations in the same ecoregion; 2) drainage area extrapolation of data from a nearby continuous-record station of similar size and topography; and 3) calculation of daily mean flow using a dynamic computer model, such as the Loading Simulation Program C++ (LSPC).

Flow duration curves for impaired waterbodies in the Lower Tennessee River Watershed were derived from LSPC hydrologic simulations based on parameters derived from calibration at USGS Station No. 03567500, located on South Chickamauga Creek near Chickamauga, Tennessee, in the Lower Tennessee River watershed (see Appendix D for details of calibration). For example, a flow-duration curve for Chattanooga Creek at RM 0.9 was constructed using simulated daily mean flow for the period from 10/1/94 through 9/31/04 (RM 0.9 corresponds to the location of monitoring station CHATT000.9HM). This flow duration curve is shown in Figure C-1 and represents the cumulative distribution of daily discharges arranged to show percentage of time specific flows were exceeded during the period of record (the highest daily mean flow during this period is exceeded 0% of the time and the lowest daily mean flow is equaled or exceeded 100% of the time). Flow duration curves for other impaired waterbodies were derived using a similar procedure.

C.1.2 Development of Load Duration Curves and Determination of TMDLs

When a water quality target concentration is applied to the flow duration curve, the resulting load duration curve (LDC) represents the allowable pollutant loading in a waterbody over the entire range of flow. Pollutant monitoring data, plotted on the LDC, provides a visual depiction of stream water quality as well as the frequency and magnitude of any exceedances. Load duration curve intervals can be grouped into several broad categories or zones, in order to provide additional insight about conditions and patterns associated with the impairment. For example, the duration curve could be divided into five zones: high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-60%), dry conditions (60-90%), and low flows (90-100%). Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left on the LDC (representing zones of higher flow) generally reflect potential nonpoint source contributions (Stiles, 2003).

E. coli load duration curves for impaired waterbodies in the Lower Tennessee River Watershed were developed from the flow duration curves developed in Section C.1.1, E. coli target concentrations, and available water quality monitoring data. Load duration curves and required load reductions were developed using the following procedure (Chattanooga Creek is shown as an example):

1. A target load-duration curve (LDC) was generated for Chattanooga Creek by applying the E. coli target concentration of 941 CFU/100 mL to each of the ranked flows used to generate the flow duration curve (ref.: Section D.1) and plotting the results. The E. coli target maximum load corresponding to each ranked daily mean flow is:

   $(\text{Target Load})_{\text{Chattanooga Creek}} = (941\ \text{CFU/100 mL}) \times (Q) \times (\text{UCF})$

   where: Q = daily mean flow
   UCF = the required unit conversion factor

2. Daily loads were calculated for each of the water quality samples collected at monitoring station CHATT000.9HM (ref.: Table B-1) by multiplying the sample concentration by the daily mean flow for the sampling date and the required unit conversion factor. CHATT000.9HM was selected for LDC analysis because it was the monitoring station on Chattanooga Creek with the most exceedances of the target concentration.

   Note: In order to be consistent for all analyses, the derived daily mean flow was used to compute sampling data loads, even if measured ("instantaneous") flow data was available for some sampling dates.

   Example – 9/5/05 sampling event:
   Modelled Flow = 14.98 cfs
   Concentration = 1400 CFU/100 mL
   Daily Load = 5.13×10^{11} CFU/day

3. Using the flow duration curves developed in C.1.1, the "percent of days the flow was exceeded" (PDFE) was determined for each sampling event. Each sample load was then plotted on the load duration curves developed in Step 1 according to the PDFE. The resulting E. coli load duration curve for is shown in Figure C-8.

4. For cases where the existing load exceeded the target maximum load at a particular PDFE, the reduction required to reduce the sample load to the target load was calculated.

   Example – 9/5/00 sampling event:
   Target Concentration = 941 CFU/100 mL
   Measured Concentration = 1400 CFU/100 mL
   Reduction to Target = 32.8%

5. The 90^{th} percentile value for all of the E. coli sampling data at CHATT000.9HM monitoring site was determined. If the 90^{th} percentile value exceeded the target maximum E. coli concentration, the reduction required to reduce the 90^{th} percentile value to the target maximum concentration was calculated (Table C-8).

   Example: Target Concentration = 941 CFU/100 mL
   90^{th} Percentile Concentration = >2400 CFU/100 mL
   Reduction to Target = >60.8%

6. For cases where five or more samples were collected over a period of not more than 30 consecutive days, the geometric mean E. coli concentration was determined and compared to the target geometric mean E. coli concentration of 126 CFU/100 mL. If the sample geometric mean exceeded the target geometric mean concentration, the reduction required to reduce the sample geometric mean value to the target geometric mean concentration was calculated.

   Example: Insufficient monitoring data was available for any monitoring station in the Lower Tennessee River watershed

7. The load reductions required to meet the target maximum (Step 5) and target 30-day geometric mean concentrations (Step 6) of E. coli were compared and the load reduction of the greatest magnitude selected as the TMDL for Chattanooga Creek.

Load duration curves, required load reductions, and TMDLs of other impaired waterbodies were derived in a similar manner and are shown in Figures C-2 through C-15 and Tables C-1 through C-14.

C.2 Development of WLAs & LAs

As previously discussed, a TMDL can be expressed as the sum of all point source loads (WLAs), nonpoint source loads (LAs), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

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

Expanding the terms:

$$\text{TMDL} = [\textstyle\sum \text{WLAs}]_{\text{WWTF}} + [\sum \text{WLAs}]_{\text{MS4}} + [\sum \text{WLAs}]_{\text{CAFO}} + [\sum \text{LAs}]_{\text{DS}} + [\sum \text{LAs}]_{\text{SW}} + \text{MOS}$$

For pathogen TMDLs in each impaired subwatershed or drainage area, WLA terms include:

- $[\sum WLAs]_{WWTF}$ is the allowable load associated with discharges of NPDES permitted WWTFs located in impaired subwatersheds or drainage areas. Since NPDES permits for these facilities specify that treated wastewater must meet instream water quality standards at the point of discharge, no additional load reduction is required. WLAs for WWTFs are calculated from the facility design flow and the Monthly Average permit limit.
- $[\sum WLAs]_{CAFO}$ is the allowable load for all CAFOs in an impaired subwatershed or drainage area. All wastewater discharges from a CAFO to waters of the state of Tennessee are prohibited, except when either chronic or catastrophic rainfall events cause an overflow of process wastewater from a facility properly designed, constructed, maintained, and operated to contain:
  - All process wastewater resulting from the operation of the CAFO (such as wash water, parlor water, watering system overflow, etc.); plus,
  - All runoff from a 25-year, 24-hour rainfall event for the existing CAFO or new dairy or cattle CAFOs; or all runoff from a 100-year, 24-hour rainfall event for a new swine or poultry CAFO.

  Therefore, a WLA of zero has been assigned to this class of facilities.
- $[\sum WLAs]_{MS4}$ is the required load reduction for discharges from MS4s. E. coli loading from MS4s is the result of buildup/wash-off processes associated with storm events.

LA terms include:

- $[\sum LAs]_{DS}$ is the allowable E. coli load from "other direct sources". These sources include leaking septic systems, illicit discharges, and animals access to streams. The LA specified for all sources of this type is zero CFU/day (or to the maximum extent practicable).
- $[\sum LAs]_{SW}$ represents the required reduction in E. coli loading from nonpoint sources indirectly going to surface waters from all land use areas (except areas covered by a MS4 permit) as a result of the buildup/wash-off processes associated with storm events.

Since WWTFs discharges must comply with instream water quality criteria (TMDL target) at the point of discharge, $[\sum WLAs]_{CAFO} = 0$, and $[\sum LAs]_{DS} = 0$, the expression relating TMDLs to precipitation-based point and nonpoint sources may be simplified to:

$$\text{TMDL} - \text{MOS} = [\sum WLAs]_{MS4} + [\sum LAs]_{SW}$$

WLAs for MS4s and LAs for precipitation-based nonpoint sources are equal and expressed as the percent reduction in loading required to decrease instream E. coli concentrations to TMDL target values minus MOS. As stated in Section 8.4, an explicit MOS, equal to 10% of the E. coli water quality targets (ref.: Section 5.0), was utilized for determination of the WLAs and LAs:

Instantaneous Maximum (Tier II):

Target – MOS = (487 CFU/100 ml) – 0.1(487 CFU/100 ml)

Target – MOS = 438 CFU/100 ml

Instantaneous Maximum (non-Tier II):

Target – MOS = (941 CFU/100 ml) – 0.1(941 CFU/100 ml)

Target – MOS = 847 CFU/100 ml

30-Day Geometric Mean: Target – MOS = (126 CFU/100 ml) – 0.1(126 CFU/100 ml)

Target – MOS = 113 CFU/100 ml

C.2.1 Determination of WLAs for MS4s & LAs for Precipitation-Based Nonpoint Sources

WLAs for MS4s and LAs for precipitation-based nonpoint sources were developed using methods similar to those described in C.1.2 (again, using Chattanooga Creek as an example):

8. An allocation LDC was generated for Chattanooga Creek by applying the E. coli "target – MOS" concentration of 847 CFU/100 mL to each of the ranked flows used to generate the flow duration curve (ref.: Section D.1) and plotting the results on the target LDC developed in Step 1. The E. coli target maximum allocated load corresponding to each ranked daily mean flow is:

   $(\text{Target Load - MOS})_{\text{Chattanooga Creek}}$ = (847 CFU/100 mL) x (Q) x (UCF)

   where: Q = daily mean flow
   UCF = the required unit conversion factor

9. For cases where the existing load exceeded the "target maximum load – MOS" at a particular PDFE, the reduction required to reduce the sample load to the "target – MOS" load was calculated.

   Example – 9/5/00 sampling event:
   Target Concentration – MOS = 847 CFU/100 mL
   Measured Concentration = 1400 CFU/100 mL
   Reduction to Target – MOS = 39.5%

10. If the 90th percentile value for all of the E. coli sampling data at CHATT000.9HM monitoring site (calculated in Step 5) exceeded the "target maximum – MOS" E. coli concentration, the reduction required to reduce the 90th percentile value to the "target maximum – MOS" concentration was calculated (Table C-8).

    Example: *Target Concentration – MOS = 847 CFU/100 mL*
    90th Percentile Concentration = >2400 CFU/100 mL
    Reduction to Target – MOS = >64.7%

11. For cases where five or more samples were collected over a period of not more than 30 consecutive days, the geometric mean E. coli concentration was determined and compared to the "target geometric mean E. coli concentration – MOS" of 113 CFU/100 mL. If the sample geometric mean exceeded the "target geometric mean – MOS" concentration, the reduction required to reduce the sample geometric mean value to the "target geometric mean – MOS" concentration was calculated.

    Example: *Insufficient monitoring data was available for any monitoring station in the Lower Tennessee River watershed*

12. The load reductions required to meet the "target maximum – MOS" (Step 10) and "target 30-day geometric mean – MOS" concentrations (Step 11) of E. coli were compared and the load reduction of the greatest magnitude selected as the WLA for MS4s and/or LA for precipitation-based nonpoint sources for Chattanooga Creek.

Load duration curves, required load reductions, WLAs for MS4s, and LAs for precipitation-based nonpoint sources of other impaired waterbodies were derived in a similar manner and are shown in Figures C-2 through C-15 and Tables C-1 through C-14. TMDLs, WLAs, & LAs for impaired subwatersheds and drainage areas in the Lower Tennessee River Watershed are summarized in Table C-15.

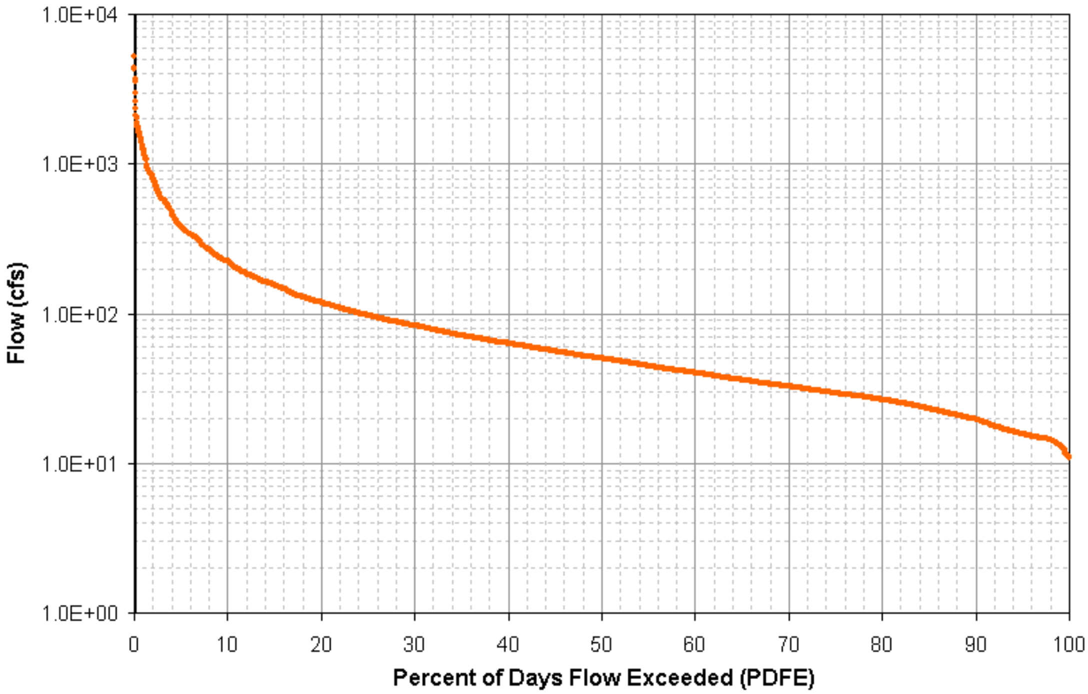

Figure C-1 Flow Duration Curve for Chattanooga Creek at CHATT000.9HM

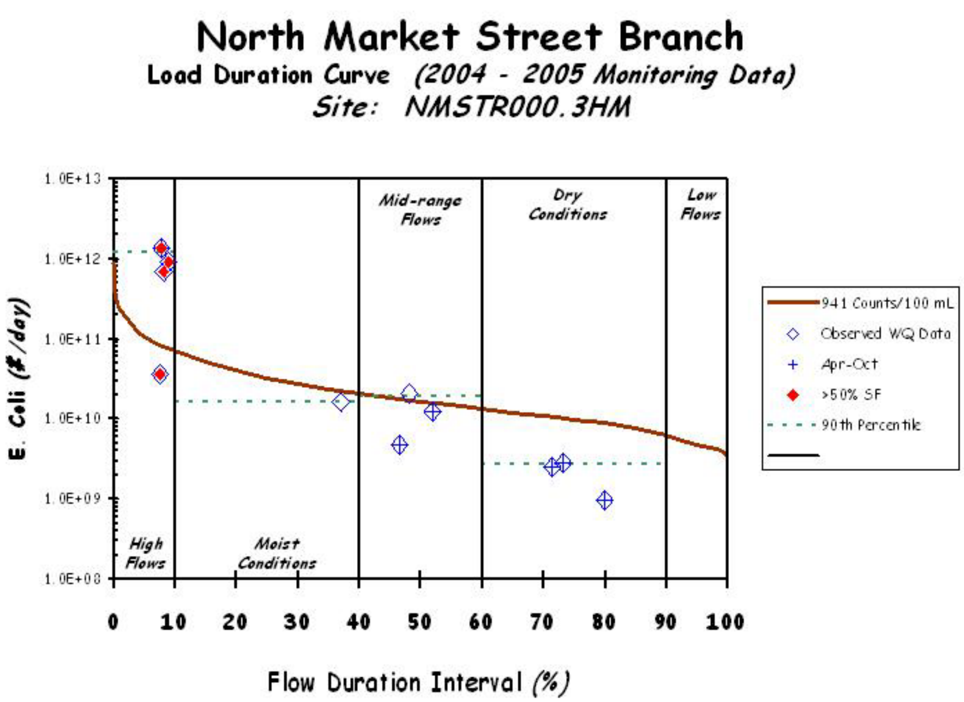

Figure C-2 E. Coli Load Duration Curve for North Market Street Branch

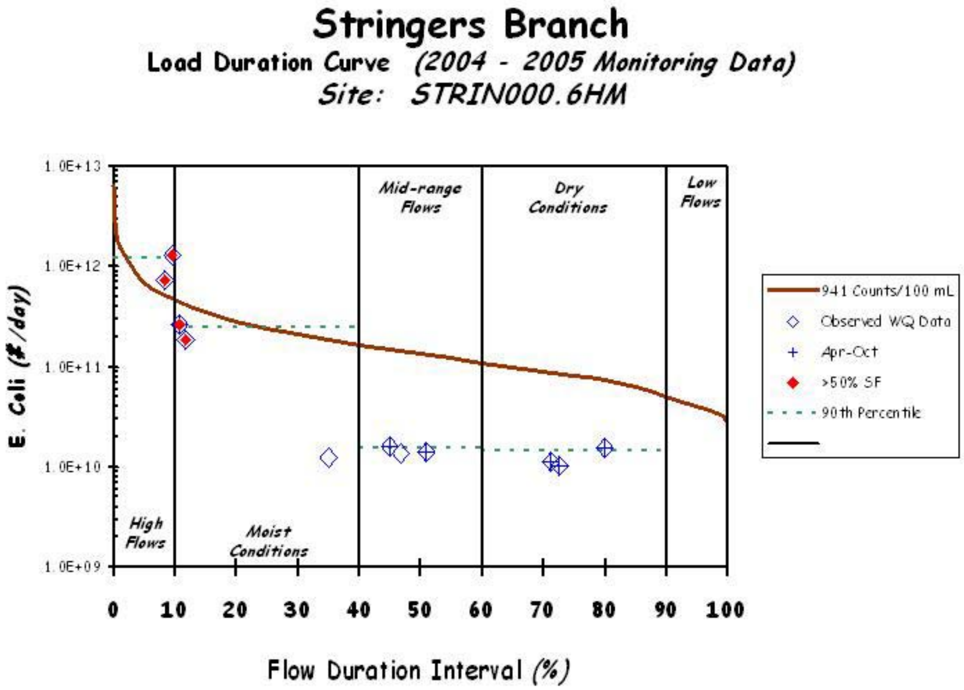

Figure C-3 E. Coli Load Duration Curve for Stringers Branch

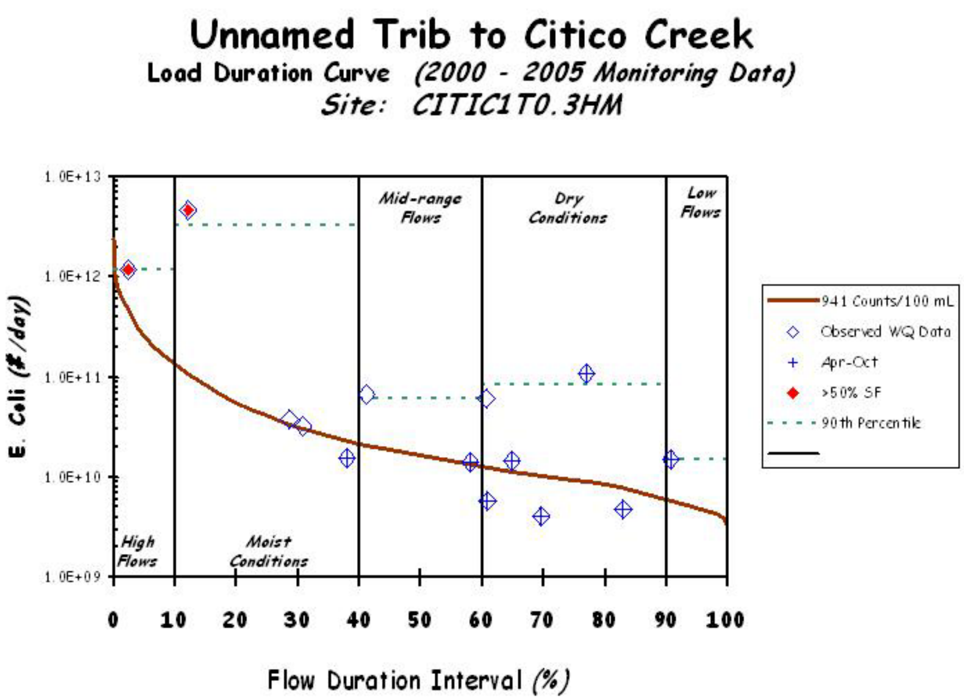

Figure C-4 E. Coli Load Duration Curve for Unnamed Trib to Citico Creek (CITIC1T0.3HM)

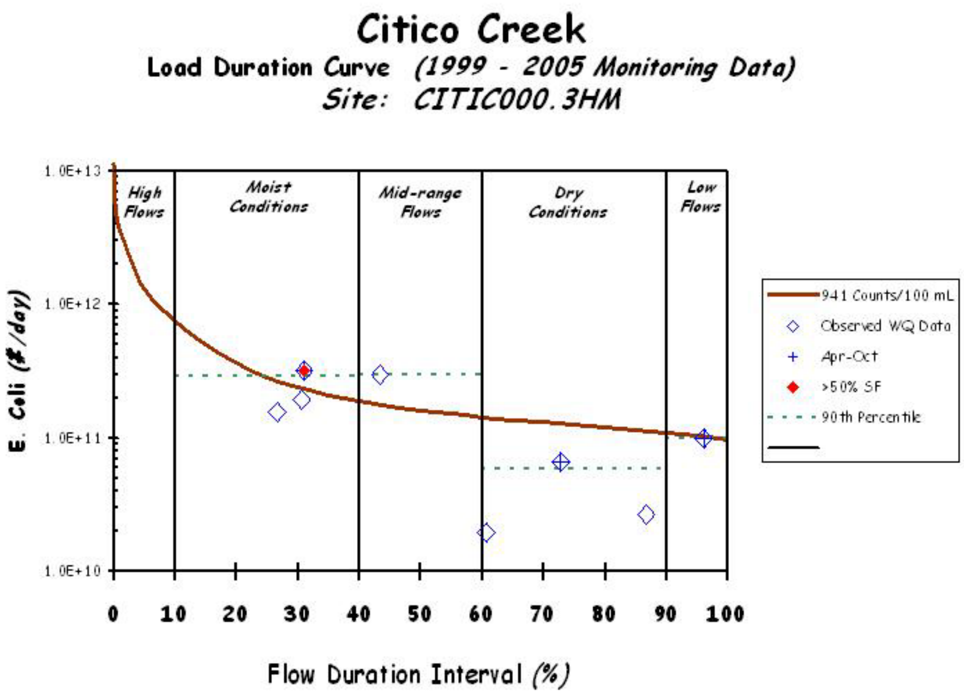

Figure C-5 E. Coli Load Duration Curve for Citico Creek at CITIC000.3HM

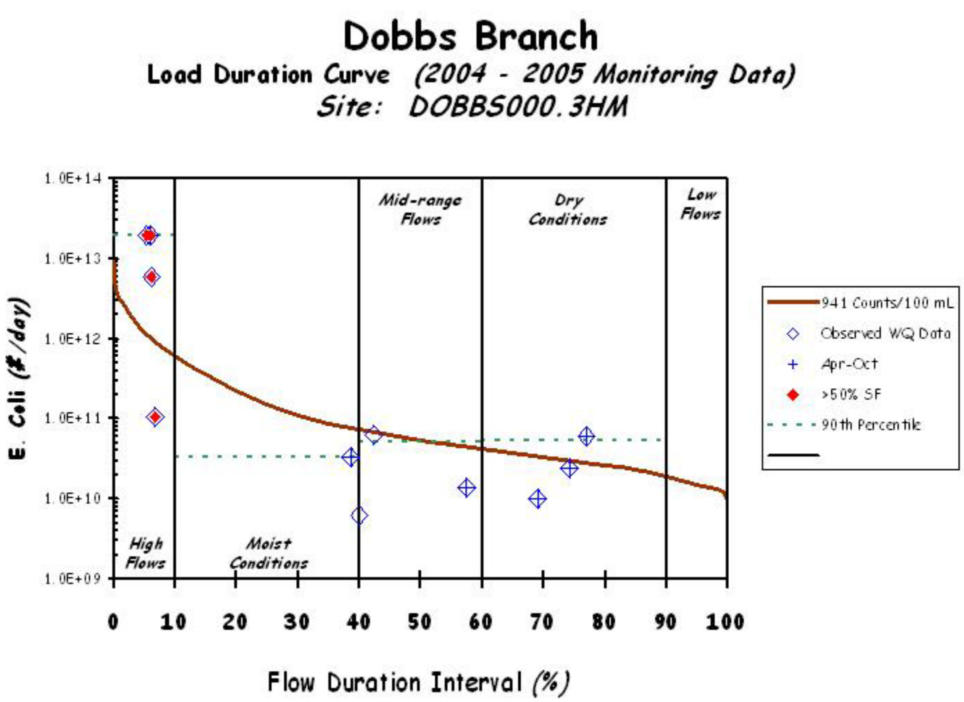

Figure C-6 E. Coli Load Duration Curve for Dobbs Branch

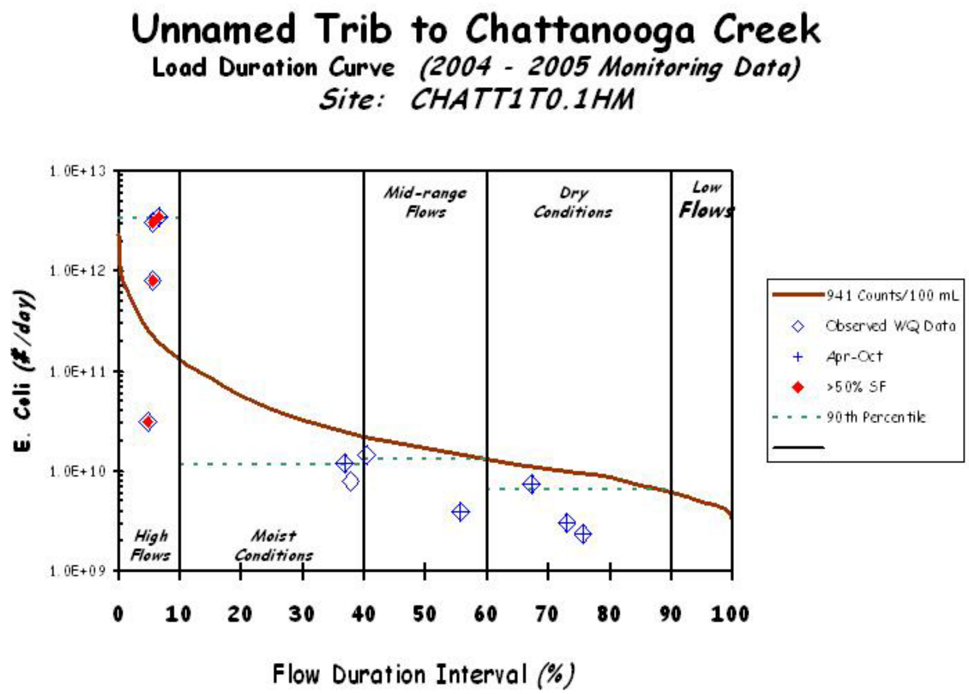

Figure C-7 E. Coli Load Duration Curve for Unnamed trib to Chattanooga Creek

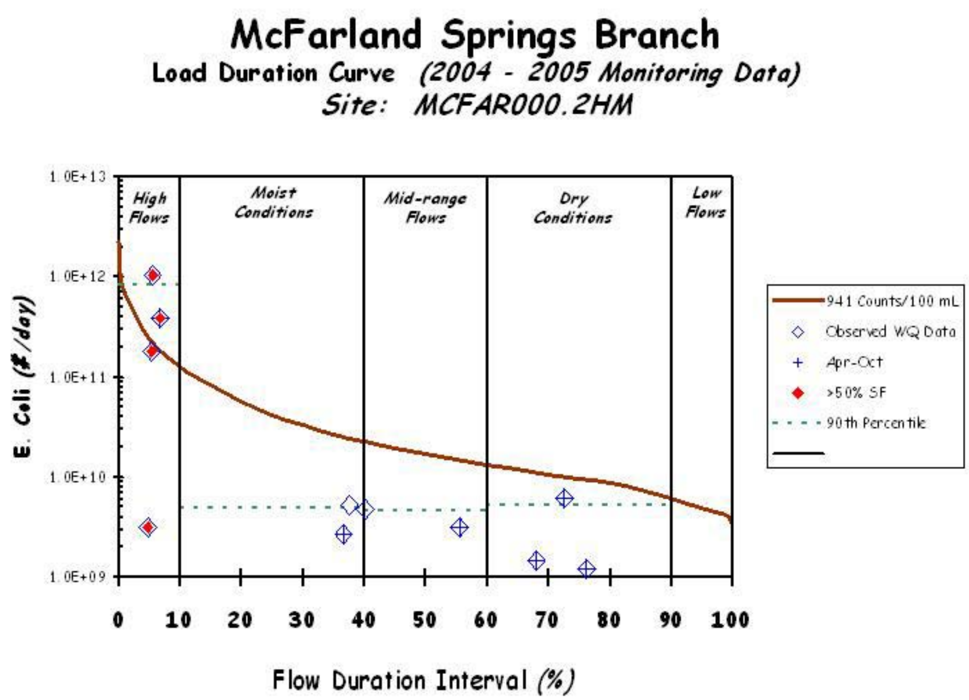

Figure C-8 E. Coli Load Duration Curve for McFarland Springs Branch

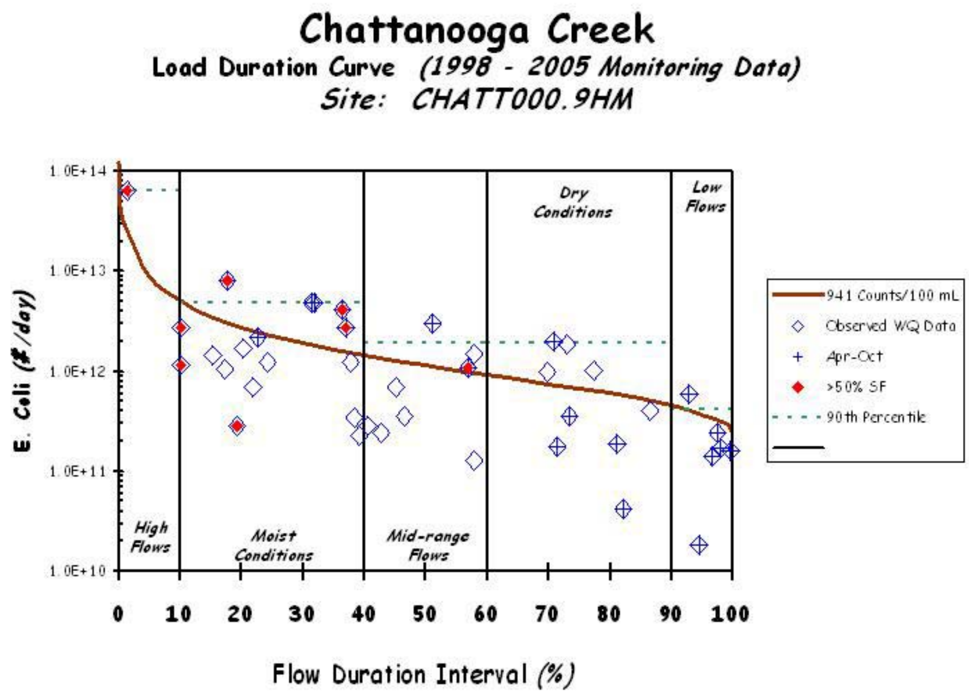

Figure C-9 E. Coli Load Duration Curve for Chattanooga Creek at CHATT000.9HM

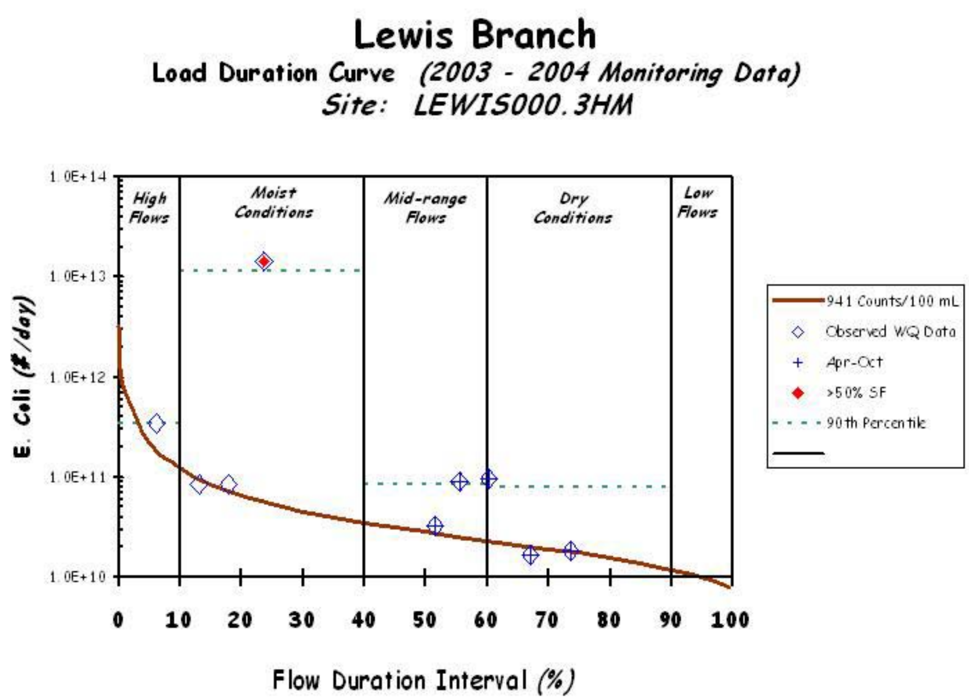

Figure C-10 E. Coli Load Duration Curve for Lewis Branch

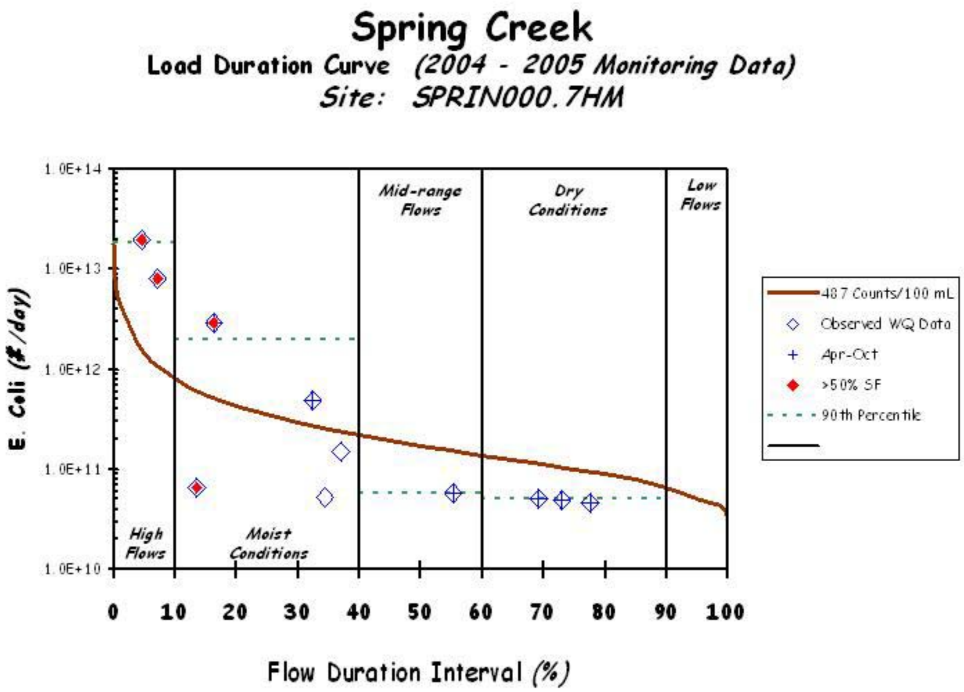

Figure C-11 E. Coli Load Duration Curve for Spring Creek

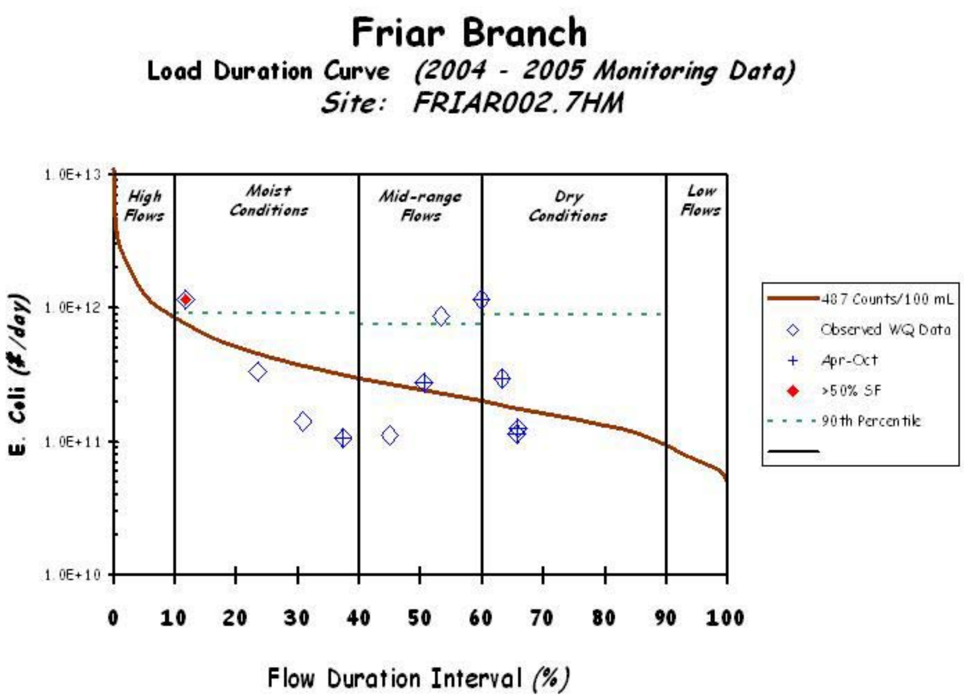

Figure C-12 E. Coli Load Duration Curve for Friar Branch

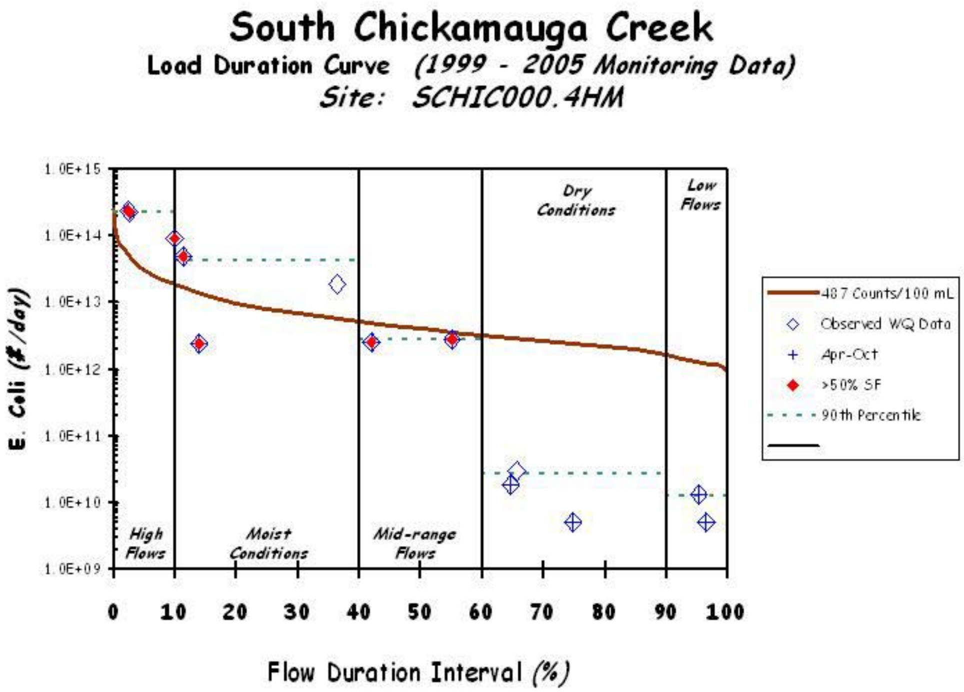

Figure C-13 E. Coli Load Duration Curve for South Chickamauga Creek at SCHIC000.4HM

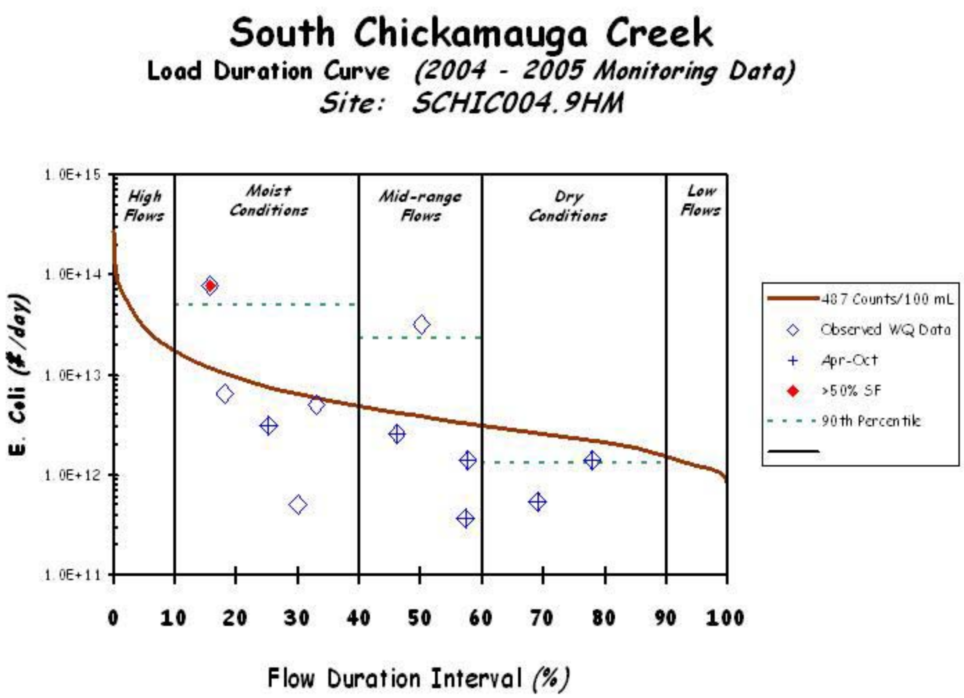

Figure C-14 E. Coli Load Duration Curve for South Chickamauga Creek at SCHIC004.9HM

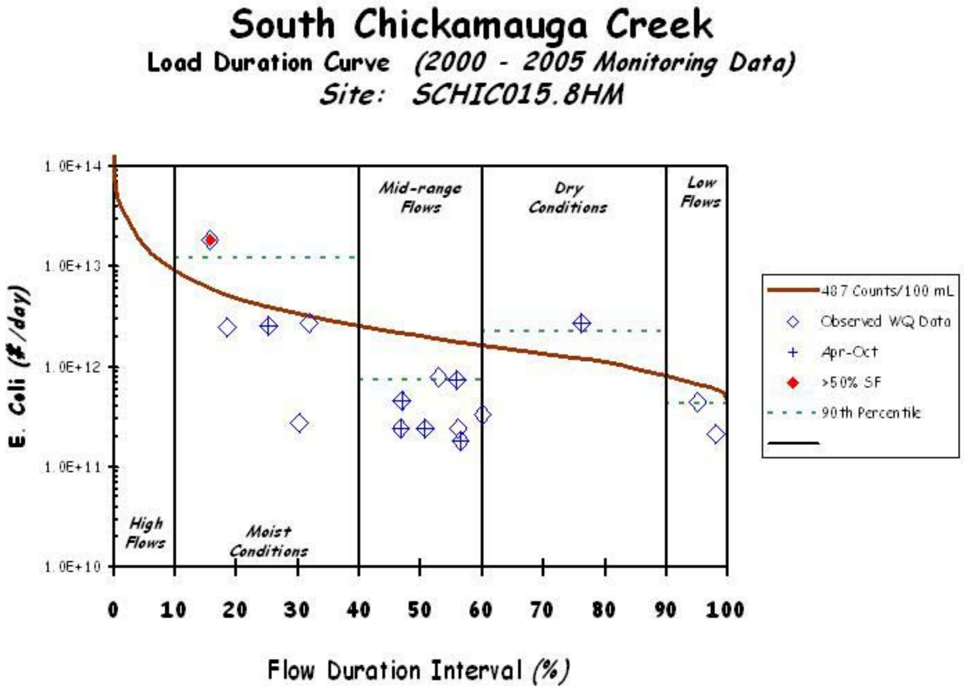

Figure C-15 E. Coli Load Duration Curve for South Chickamauga Creek at SCHIC015.8HM

Table C-1 Required Load Reduction for North Market Street Branch

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target - MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
8/16/04	0.46	71.5	219	NR	NR
9/13/04	0.38	80.1	105	NR	NR
10/12/04	3.61	7.7	15,150	93.8	94.4
11/8/04	0.76	48.2	1,120	16.0	24.4
1/18/05	0.97	37.1	687	NR	NR
2/14/05	3.49	8.1	8,160	88.5	89.6
3/7/05	3.63	7.5	410	NR	NR
3/28/05	3.31	8.9	11,530	91.8	92.7
4/18/05	0.70	52.0	740	NR	NR
5/2/05	0.78	46.6	248	NR	NR
5/23/05	0.45	73.3	261	NR	NR
90th Percentile Concentration			**11,530**	**91.4**	**92.7**

Notes:
1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-2 Required Load Reduction for Stringers Branch

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target - MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
8/16/04	3.81	71.3	120	NR	NR
9/13/04	3.16	80.0	200	NR	NR
10/12/04	19.68	10.7	547	NR	NR
11/8/04	6.26	46.9	89	NR	NR
1/18/05	8.04	35.1	63	NR	NR
2/14/05	21.20	9.6	2,500	62.4	66.1
3/7/05	18.50	11.7	410	NR	NR
3/28/05	22.56	8.4	1,320	28.7	35.8
4/18/05	5.77	50.9	100	NR	NR
5/2/05	6.50	45.0	100	NR	NR
5/23/05	3.70	72.7	111	NR	NR
90th Percentile Concentration			**1,320**	**28.7**	**35.8**

Notes: 1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-3 Required Load Reduction for Unnamed Trib to Citico Creek (CITIC1T0.3HM)

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target - MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
6/14/00	0.25	90.8	>2,400	>60.8	>64.7
9/18/01	0.33	83.0	580	NR	NR
1/23/02	20.52	2.3	>2,400	>60.8	>64.7
8/30/04	0.39	77.1	11,450	91.8	92.6
9/27/04	0.59	58.2	970	3.0	12.7
10/4/04	0.45	69.7	365	NR	NR
11/1/04	0.55	60.8	4,500	79.1	81.2
1/10/05	1.46	28.7	1,046	10.0	19.0
1/31/05	0.91	41.3	2,990	68.5	71.7
2/28/05	4.62	12.2	41,060	97.7	97.9
3/14/05	1.34	30.8	980	4.0	13.6
4/11/05	1.00	38.1	630	NR	NR
4/25/05	0.55	61.0	436	NR	NR
5/9/05	0.50	64.9	1,203	21.8	29.6
90th Percentile Concentration			**>9,365**	**>90.0**	**>91.0**

Notes: 1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-4 Required Load Reduction for Citico Creek at CITIC000.3HM

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target - MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
11/8/99	4.90	86.9	220	NR	NR
2/15/00	10.20	30.6	770	NR	NR
5/15/00	5.54	73.0	490	NR	NR
8/16/00	4.46	96.2	920	NR	NR
11/14/00	7.68	43.5	1,600	41.2	47.1
2/6/01	6.18	60.7	130	NR	NR
8/24/04	10.05	31.1	1,300	27.6	34.8
11/29/04	11.50	26.7	550	NR	NR
90th Percentile Concentration			**1,390**	**32.3**	**39.1**

Notes: 1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-5 Required Load Reduction for Dobbs Branch

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target - MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
8/16/04	1.46	69.2	281	NR	NR
9/13/04	1.23	77.0	1,990	52.7	57.4
10/12/04	44.54	6.0	17,850	94.7	95.3
11/8/04	2.95	42.4	860	NR	1.5
1/18/05	3.19	40.0	79	NR	NR
2/14/05	49.42	5.3	16,070	94.1	94.7
3/7/05	40.68	6.7	104	NR	NR
3/28/05	43.58	6.2	5,570	83.1	84.8
4/18/05	1.93	57.6	291	NR	NR
5/2/05	3.33	38.7	410	NR	NR
5/23/05	1.31	74.4	770	NR	NR
90th Percentile Concentration			**16,070**	**94.1**	**94.7**

Notes: 1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-6 Required Load Reduction for Unnamed Trib to Chattanooga Creek

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target - MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
8/16/04	0.49	67.4	630	NR	NR
9/13/04	0.41	75.7	238	NR	NR
10/12/04	8.38	6.5	17,260	94.5	95.1
11/8/04	0.96	40.4	613	NR	NR
1/18/05	1.05	37.8	310	NR	NR
2/14/05	9.69	5.6	12,910	92.7	93.4
3/7/05	11.44	4.8	112	NR	NR
3/28/05	9.92	5.5	3,270	71.2	74.1
4/18/05	0.64	55.7	248	NR	NR
5/2/05	1.08	36.9	461	NR	NR
5/23/05	0.43	73.2	285	NR	NR
90th Percentile Concentration			**12,910**	**92.7**	**93.4**

Notes: 1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-7 Required Load Reduction for McFarland Springs Branch

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target - MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
8/16/04	0.48	68.2	123	NR	NR
9/13/04	0.41	76.2	122	NR	NR
10/12/04	7.88	6.7	1,986	52.6	57.4
11/8/04	0.97	40.3	200	NR	NR
1/18/05	1.06	37.6	200	NR	NR
2/14/05	9.30	5.6	4,570	79.4	81.5
3/7/05	10.67	4.8	12	NR	NR
3/28/05	9.72	5.4	770	NR	NR
4/18/05	0.65	55.5	200	NR	NR
5/2/05	1.10	36.7	100	NR	NR
5/23/05	0.44	72.7	579	NR	NR
90th Percentile Concentration			**1,986**	**52.6**	**57.4**

Notes: 1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-8 Required Load Reduction for Chattanooga Creek at CHATT000.9HM

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target - MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
11/17/98	29.27	77.5	1,414	33.5	40.1
12/15/98	34.10	69.9	1,203	21.8	29.6
1/12/99	56.11	46.7	260	NR	NR
2/9/99	125.85	19.3	93	NR	NR
3/9/99	225.05	10.2	490	NR	NR
4/7/99	225.05	10.2	>2,400	>60.8	>64.7
5/24/99	135.67	17.7	>2,400	>60.8	>64.7
6/8/99	50.71	51.2	450	NR	NR
7/15/99	31.86	73.5	>2,400	>60.8	>64.7
7/28/99	33.42	70.9	280	NR	NR
9/14/99	27.03	81.2	690	NR	NR
10/11/99	14.59	97.7	1,000	5.9	15.3
11/8/99	44.66	57.0	730	NR	NR
12/14/99	22.77	86.7	1,400	32.8	39.5
1/10/00	43.75	58.0	>2,400	>60.8	>64.7
2/15/00	1100.03	1.4	580	NR	NR
3/15/00	119.93	20.4	210	NR	NR
5/15/00	67.77	38.4	220	NR	NR
6/19/00	33.10	71.6	>2,400	>60.8	>64.7
7/19/00	81.25	31.8	490	NR	NR
8/16/00	14.25	98.3	380	NR	NR
9/5/00	14.98	96.9	1,400	32.8	39.5
10/9/00	17.38	93.1	47	NR	NR
11/14/00	16.15	94.7	730	NR	NR
12/4/00	68.76	37.9	490	NR	NR
1/16/01	57.77	45.3	>2,400	>60.8	>64.7
2/6/01	32.12	73.1	120	NR	NR
3/14/01	43.78	57.9	370	NR	NR
4/17/01	157.11	15.3	820	NR	NR

Table C-8 (cont'd) Required Load Reduction for Chattanooga Creek at CHATT000.9HM

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target - MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
9/11/01	109.22	22.7	65	NR	NR
3/25/02	26.37	82.2	160	NR	NR
9/4/02	61.16	42.8	580	NR	NR
12/17/02	11.23	99.8	490	NR	NR
3/26/03	102.34	24.4	140	NR	NR
6/17/03	66.04	39.3	2,400	60.8	64.7
9/8/03	71.27	36.4	2,400	60.8	64.7
12/2/03	82.17	31.5	180	NR	NR
3/9/04	64.19	40.7	250	NR	NR
7/7/04	112.29	22.0	1,600	41.2	47.1
11/29/04	70.38	37.0	310	NR	NR
90th Percentile Concentration			**>2400**	**>60.8**	**>64.7**

Notes: 1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-9 Required Load Reduction Lewis Branch

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (941 CFU/100 ml)	Sample to Target - MOS (847 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
7/30/03	1.18	51.5	1,120	16.0	24.4
8/18/03	0.88	67.1	770	NR	NR
10/7/03	0.99	60.4	3,900	75.9	78.3
11/20/03	8.18	6.2	1,733	45.7	51.1
1/6/04	4.11	13.2	840	NR	NR
2/11/04	3.10	18.0	1,120	16.0	24.4
3/16/04	2.43	23.7	241,900	99.6	99.6
4/21/04	1.09	55.5	3,360	72.0	74.8
5/25/04	0.77	73.8	980	4.0	13.6
90th Percentile Concentration			**51,500**	**98.2**	**98.4**

Notes: 1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-10 Required Load Reduction for Spring Creek

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (487 CFU/100 ml)	Sample to Target - MOS (438 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
8/16/04	9.40	69.4	219	NR	NR
9/13/04	7.91	77.7	238	NR	NR
10/12/04	44.13	16.4	2,720	82.1	83.9
11/8/04	19.99	37.1	310	NR	NR
1/18/05	21.56	34.5	100	NR	NR
2/14/05	89.33	7.2	3,640	86.6	88.0
3/7/05	51.26	13.6	53	NR	NR
3/28/05	137.74	4.6	5,830	91.6	92.5
4/18/05	12.80	55.4	184	NR	NR
5/2/05	23.01	32.5	860	43.4	49.1
5/23/05	8.73	73.2	228	NR	NR
90th Percentile Concentration			**3,640**	**86.6**	**88.0**

Notes: 1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-11 Required Load Reduction for Friar Branch

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (487 CFU/100 ml)	Sample to Target - MOS (438 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
8/30/04	15.76	63.4	770	36.8	43.1
9/27/04	20.57	50.5	548	11.1	20.1
10/4/04	15.04	65.7	310	NR	NR
11/1/04	19.38	53.4	1,830	73.4	76.1
1/10/05	38.42	23.6	356	NR	NR
1/31/05	22.82	45.1	199	NR	NR
2/28/05	64.27	11.7	740	34.2	40.8
3/14/05	31.27	30.8	185	NR	NR
4/11/05	26.70	37.5	163	NR	NR
4/25/05	17.02	60.0	2,750	82.3	84.1
5/9/05	14.99	66.0	345	NR	NR
90th Percentile Concentration			**1,830**	**73.4**	**76.1**

Notes:
1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-12 Required Load Reduction for South Chickamauga Creek at SCHIC000.4HM

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (487 CFU/100 ml)	Sample to Target - MOS (438 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
1/12/99	473.36	36.5	1,600	69.6	72.6
4/7/99	1412.81	11.3	1,400	65.2	68.7
7/19/99	206.70	75.0	1	NR	NR
10/11/99	302.61	55.2	370	NR	NR
1/10/00	3966.50	2.4	>2,400	>79.7	>81.8
7/19/00	104.54	96.7	2	NR	NR
10/9/00	108.98	95.4	5	NR	NR
1/16/01	245.55	65.7	5	NR	NR
4/17/01	1151.48	13.9	88	NR	NR
12/1/04	1576.31	9.9	>2,400	>79.7	>81.8
2/23/05	3924.54	2.5	>2,400	>79.7	>81.8
5/11/05	409.34	42.1	260	NR	NR
7/27/05	249.92	64.7	3	NR	NR
90th Percentile Concentration			**>2,400**	**>79.7**	**>81.8**

Notes: 1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-13 Required Load Reduction for South Chickamauga Creek at SCHIC004.9HM

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (487 CFU/100 ml)	Sample to Target - MOS (438 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
8/30/04	186.20	78.1	310	NR	NR
9/27/04	350.62	46.3	300	NR	NR
10/4/04	220.50	69.2	100	NR	NR
11/1/04	323.38	50.2	4,040	87.9	89.2
1/10/05	993.49	15.7	3,200	84.8	86.3
1/31/05	500.20	33.0	410	NR	NR
2/28/05	862.47	18.2	310	NR	NR
3/14/05	545.01	30.0	38	NR	NR
4/11/05	640.51	25.3	200	NR	NR
4/25/05	273.53	57.8	210	NR	NR
5/9/05	276.56	57.4	54	NR	NR
90th Percentile Concentration			**3,200**	**84.8**	**86.3**

Notes: 1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-14 Required Load Reduction for South Chickamauga Creek at SCHIC015.8HM

Sample Date	Flow	PDFE	E. Coli Sample Concentration	Required Reduction	
				Sample to Target (487 CFU/100 ml)	Sample to Target - MOS (438 CFU/100 ml)
	[cfs]	[%]	[CFU/100 ml]	[%]	[%]
2/22/00	148.03	56.2	68	NR	NR
2/23/00	136.28	60.2	100	NR	NR
5/1/00	180.78	46.9	55	NR	NR
5/2/00	168.17	50.8	59	NR	NR
11/6/00	50.99	98.2	170	NR	NR
11/7/00	55.56	95.3	330	NR	NR
8/30/04	100.88	76.3	1,120	56.5	60.9
9/27/04	180.70	47.0	105	NR	NR
10/4/04	119.58	67.6	0	NR	NR
11/1/04	159.65	52.9	200	NR	NR
1/10/05	518.58	15.7	1,450	66.4	69.8
1/31/05	267.95	31.8	411	NR	NR
2/28/05	440.10	18.5	231	NR	NR
3/14/05	281.47	30.3	40	NR	NR
4/11/05	334.67	25.2	310	NR	NR
4/25/05	149.18	56.0	200	NR	NR
5/9/05	147.35	56.5	50	NR	NR
90th Percentile Concentration			**695**	**29.9**	**36.9**

Notes: 1. NR = No reduction required.
2. 30-day Geometric Mean could not be calculated due to insufficient data.
3. Reductions for individual samples (shaded area) is included for reference only.

Table C-15 TMDLs, WLAs, & LAs for Lower Tennessee River Watershed

HUC-12 Subwatershed (06020001__) or Drainage Area	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs[a,b]		LAs[e]
				Leaking Collection Systems[c]	MS4s [d]	
			[% Red.]	[CFU/day]	[% Red.]	[% Red.]
0502 (DA)	North Market Street Branch	TN06020001001T – 0200	91.4	0	92.7	92.7
0502 (DA)	Stringers Branch	TN06020001426 – 0100	28.7	0	35.8	35.8
0502 (DA)	Unnamed Trib to Citico Creek	TN060200011240 – 0100	>90.0	0	>91.0	>91.0
	Citico Creek	TN060200011240 – 1000	32.3	0	39.1	39.1
0503	Dobbs Branch	TN060200011244 – 0100	94.1	0	94.7	94.7
	Unnamed Trib to Chattanooga Creek	TN060200011244 – 0200	92.7	0	93.4	93.4
	McFarland Springs Branch[f]	TN060200011244 – 0300	52.6	0	57.4	57.4
	Chattanooga Creek[f]	TN060200011244 –1000 & 2000	>60.8	0	>64.7	>64.7
0602 (DA)	Lewis Branch	TN06020001029 - 0300	98.2	NA	98.4	98.4
0803 (DA)	Spring Creek	TN06020001007 – 0510	86.6	0	88.0	88.0

Table C-15 (cont'd) TMDLs, WLAs, & LAs for Lower Tennessee River Watershed

HUC-12 Subwatershed (06020001__) or Drainage Area	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	WLAs[a,b]		LAs[e]
				Leaking Collection Systems[c]	MS4s [d]	
			[% Red.]	[CFU/day]	[% Red.]	[% Red.]
0804	Friar Branch	TN06020001007 – 0100	73.4	0	76.1	76.1
	South Chickamauga Creek[f]	TN06020001007 – 1000	84.8	0	86.3	86.3

Notes: NA = Not Applicable.

a. There are no CAFOs in the Lower Tennessee River Watershed. Future CAFOs will be assigned a waste load allocation (WLA) of zero.

b. WLAs for WWTFs are expressed as E. coli loads (CFU/day). Future WWTFs must meet instream water quality standards at the point of discharge as specified in their NPDES permit.

c. Pathogen loading due to collection system failure is considered to be unpermitted point source loading from the municipal WWTF. With respect to pathogen loading from leaking collection systems, a WLA of zero is assigned. It is recognized, however, that a WLA of 0 CFU/day may not be practical. For these unpermitted sources, the WLA is interpreted to mean a reduction in pathogen loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

d. Applies to any MS4 discharge loading in the subwatershed.

e. The load allocations (LAs) listed apply to precipitation induced nonpoint sources only. The objective for all other nonpoint sources (leaking septic systems, illicit discharges, and animals access to streams) is a LA of zero. It is recognized, however, that for leaking septic systems a LA of 0 CFU/day may not be practical. For these sources, the LA is interpreted to mean a reduction in E. coli loading to the maximum extent feasible, consistent with the requirement that these sources not contribute to a violation of the water quality standard for E. coli.

f. Portions of these waterbodies lie in another state. A TMDL for Fecal Coliform has been developed by the State of Georgia for those portions of the waterbodies lying within their jurisdiction. The required load reduction is for the Tennessee portion of the waterbodies.

APPENDIX D

Hydrodynamic Modeling Methodology

HYDRODYNAMIC MODELING METHOD

D.1 Model Selection

The Loading Simulation Program C++ (LSPC) was selected for flow simulation of pathogen-impaired waters in the subwatersheds of the Lower Tennessee River Watershed. LSPC is a watershed model capable of performing flow routing through stream reaches. LSPC is a dynamic watershed model based on the Hydrologic Simulation Program - Fortran (HSPF)

D.2 Model Set Up

The Lower Tennessee River Watershed was delineated into subwatersheds in order to facilitate model hydrologic calibration. Boundaries were constructed so that subwatershed "pour points" coincided with HUC-12 delineations, 303(d)-listed waterbodies, and water quality monitoring stations. Watershed delineation was based on the NHD stream coverage and Digital Elevation Model (DEM) data. This discretization facilitates simulation of daily flows at water quality monitoring stations.

Several computer-based tools were utilized to generate input data for the LSPC model. The Watershed Characterization System (WCS), a geographic information system (GIS) tool, was used to display, analyze, and compile available information to support hydrology model simulations for selected subwatersheds. This information includes land use categories, point source dischargers, soil types and characteristics, population data (human and livestock), and stream characteristics.

An important factor influencing model results is the precipitation data contained in the meteorological data files used in these simulations. Weather data from multiple meteorological stations were available for the time period from January 1970 through August 2004. Meteorological data for a selected 11-year period were used for all simulations. The first year of this period was used for model stabilization with simulation data from the subsequent 10-year period (10/1/94 – 9/30/04) used for TMDL analysis.

D.3 Model Calibration

Hydrologic calibration of the watershed model involves comparison of simulated streamflow to historic streamflow data from U. S. Geological Survey (USGS) stream gaging stations for the same period of time. A USGS continuous record station located near the Lower Tennessee River Watershed with a sufficiently long and recent historical record was selected as the basis of the hydrology calibration. The USGS station was selected based on similarity of drainage area, Level IV ecoregion, land use, and topography. The calibration involved comparison of simulated and observed hydrographs until statistical stream volumes and flows were within acceptable ranges as reported in the literature (Lumb, et al., 1994).

Initial values for hydrologic variables were taken from an EPA developed default data set. During the calibration process, model parameters were adjusted within reasonable constraints until acceptable agreement was achieved between simulated and observed streamflow. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge.

The results of the hydrologic calibration for South Chickamauga Creek near Chickamauga, Tennessee, USGS Station 03567500, are shown in Table D-1 and Figures D-1 and D-2.

Table D-1. Hydrologic Calibration Summary: South Chickamauga Creek (USGS 03567500)

			424.61 sq. m
Simulation Name:	3567500	**Simulation Period:**	
	S. Chick nr Chickamauga	**Watershed Area (ac):**	271752.07
Period for Flow Analysis			
Begin Date:	**10/01/88**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/30/94**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**161.68**	Total Observed In-stream Flow:	**166.91**
Total of highest 10% flows:	**80.62**	Total of Observed highest 10% flows:	**85.55**
Total of lowest 50% flows:	**19.90**	Total of Observed Lowest 50% flows:	**20.05**
Simulated Summer Flow Volume (months 7-9):	**22.15**	Observed Summer Flow Volume (7-9):	**17.27**
Simulated Fall Flow Volume (months 10-12):	**29.80**	Observed Fall Flow Volume (10-12):	**30.86**
Simulated Winter Flow Volume (months 1-3):	**75.29**	Observed Winter Flow Volume (1-3):	**86.36**
Simulated Spring Flow Volume (months 4-6):	**34.45**	Observed Spring Flow Volume (4-6):	**32.42**
Total Simulated Storm Volume:	**145.53**	Total Observed Storm Volume:	**146.80**
Simulated Summer Storm Volume (7-9):	**18.09**	Observed Summer Storm Volume (7-9):	**12.20**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-3.13**	10	
Error in 50% lowest flows:	**-0.75**	10	
Error in 10% highest flows:	**-5.76**	15	
Seasonal volume error - Summer:	**28.25**	30	
Seasonal volume error - Fall:	**-3.44**	30	
Seasonal volume error - Winter:	**-12.82**	30	
Seasonal volume error - Spring:	**6.26**	30	
Error in storm volumes:	**-0.87**	20	
Error in summer storm volumes:	**48.35**	50	

Criteria for Median Monthly Flow Comparisons	
Lower Bound (Percentile):	25
Upper Bound (Percentile):	75

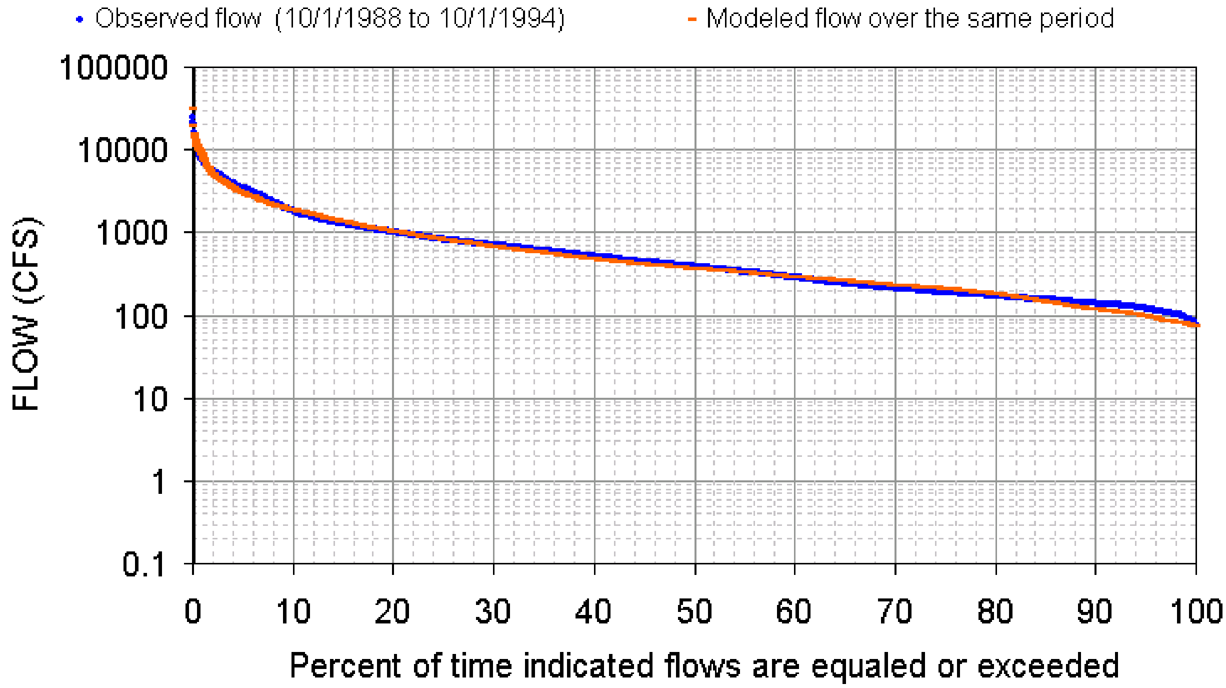

Figure D-1. Hydrologic Calibration: South Chickamauga Creek, USGS 03567500

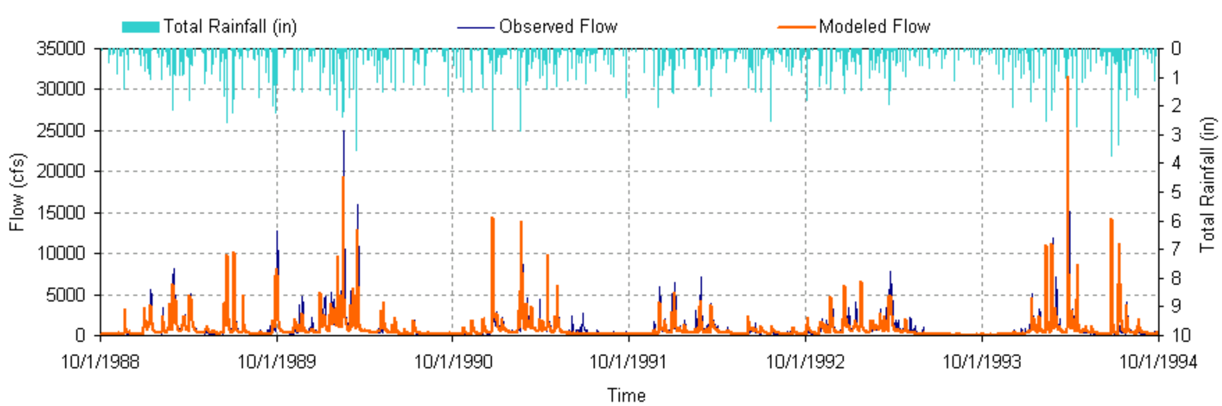

Figure D-2. 6-Year Hydrologic Comparison: South Chickamauga Creek, USGS 03567500

APPENDIX E

Public Notice Announcement

STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF WATER POLLUTION CONTROL

PUBLIC NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR E. COLI IN LOWER TENNESSEE RIVER WATERSHED (HUC 06020001), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Load (TMDL) for E. coli in the Lower Tennessee River watershed, located in eastern Tennessee. Section 303(d) of the Clean Water Act requires states to develop TMDLs for waters on their impaired waters list. TMDLs must determine the allowable pollutant load that the water can assimilate, allocate that load among the various point and nonpoint sources, include a margin of safety, and address seasonality.

A number of waterbodies in the Lower Tennessee River watershed are listed on Tennessee's Final 2004 303(d) list as not supporting designated use classifications due, in part, to discharge of pathogens from collection system failure and MS4 areas. The TMDL utilizes Tennessee's general water quality criteria, continuous flow data from a USGS discharge monitoring station located in proximity to the watershed, site specific water quality monitoring data, a calibrated hydrologic model, load duration curves, and an appropriate Margin of Safety (MOS) to establish allowable loadings of pathogens which will result in the reduced in-stream concentrations and attainment of water quality standards. The TMDL requires reductions of pathogen loading on the order of 28-98% in the listed waterbodies.

The proposed Lower Tennessee River E. coli TMDL may be downloaded from the Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl/

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

Vicki S. Steed, P.E., Watershed Management Section
Telephone: 615-532-0707

Sherry H. Wang, Ph.D., Watershed Management Section
Telephone: 615-532-0656

Persons wishing to comment on the proposed TMDLs are invited to submit their comments in writing no later than June 12, 2006 to:

Division of Water Pollution Control
Watershed Management Section
7th Floor, L & C Annex
401 Church Street
Nashville, TN 37243-1534

All comments received prior to that date will be considered when revising the TMDL for final submittal to the U.S. Environmental Protection Agency.

The TMDL and supporting information are on file at the Division of Water Pollution Control, 6th Floor, L & C Annex, 401 Church Street, Nashville, Tennessee. They may be inspected during normal office hours. Copies of the information on file are available on request.