TOTAL MAXIMUM DAILY LOAD (TMDL)

for

Fecal Coliform

in the

Upper Duck River Watershed (HUC 06040002)

Bedford, Coffee, Marshall, & Maury Counties, Tennessee

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LIST OF ABBREVIATIONS

ADB	Assessment Database
AFO	Animal Feeding Operation
BMP	Best Management Practices
BPJ	Best Professional Judgment
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
DWPC	Division of Water Pollution Control
EPA	Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrological Simulation Program - Fortran
HUC	Hydrologic Unit Code
LA	Load Allocation
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
MWS	Metro Water Services
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
OAP	Overflow Abatement Program
PCS	Permit Compliance System
Rf3	Reach File v.3
RM	River Mile
STP	Sewage Treatment Plant
SWMP	Storm Water Management Plan
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment & Conservation
TDOT	Tennessee Department of Transportation
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Total Maximum Daily Loads for Fecal Coliform in Upper Duck River Watershed (HUC 06040002)

Impaired Waterbody Information

State: Tennessee
Counties: Bedford, Coffee, Marshall, & Maury
Watershed: Upper Duck River (HUC 06040002)
Constituents of Concern: Fecal Coliform

Impaired Waterbodies:

	Waterbody ID	Waterbody	RM
1998 303(d) List	TN06040002027	DUCK RIVER – Flat Creek to Garrison Fork	81.3
	TN06040002032	DUCK RIVER	4.0
	TN06040002LITTLEDUCKR	LITTLE DUCK RIVER	19.3
	TN06040002033	WARTRACE CREEK (Bell Buckle Ck)	11.1
	TN06040002038	FALL CREEK	61
	TN06040002039	NORTH FORK CR. INCL ALEXANDER, WEAKLEY, & CLEM CR	98.4
2002 303(d) List	TN06040002002 - 3000	FOUNTAIN CREEK (South Fork to headwaters)	7.9
	TN06040002027 – 1000	DUCK RIVER (Flat Creek to Highway 231)	1.6
	TN06040002032 – 0300	CLEAR BRANCH	7.3
	TN06040002032 – 2000	DUCK RIVER (Little Duck River to Morton Lake)	2.0
	TN06040002033 – 0300	BELL BUCKLE CREEK	11.1
	TN06040002038 – 0300	HURRICANE CREEK	29.4
	TN06040002038 – 1000	FALL CREEK	11.4
	TN06040002039 – 0100	CLEM CREEK	14.2
	TN06040002039 – 0200	WEAKLEY CREEK (North Fork Creek to unnamed tributary near Highway 41A)	6.2
	TN06040002039 – 0250	WEAKLEY CREEK (Unnamed tributary near Highway 41A to headwaters)	13.1
	TN06040002039 – 0300	ALEXANDER CREEK	21.1
	TN06040002039 – 3000	NORTH FORK CREEK (Alexander Ck. to headwaters)	9.2
	TN06040002046 – 1000	WILSON CREEK	19.5
	TN06040002047 – 0300	LICK CREEK	8.8
	TN06040002047 – 1000	SPRING CREEK	13.2
	TN06040002048 – 0100	THICK CREEK	13.4
	TN06040002049 – 0400	WALACE BRANCH	3.8
	TN06040002502 – 1000	LITTLE DUCK RIVER	10.6

Designated Uses: The designated use classifications for the Upper Duck River and its tributaries include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Some waterbodies in the watershed are also classified for industrial water supply, domestic water supply, and/or navigation (Normandy Lake). The Duck River, from River Mile (RM) 244.0 to 266.5 is designated as a trout stream.

Water Quality Goal:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, October, 1999* for recreation use classification (most stringent):

> The concentration of the fecal coliform group shall not exceed 200 per 100 ml as a geometric mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 days with individual samples being collected at intervals of not less than 12 hours. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 1,000 per 100 ml.

TMDL Scope:

Waterbodies identified on either the 1998, or 2002, 303(d) list as impaired due to pathogens. TMDLs were generally developed for impaired waterbodies on a HUC-12 basis. In cases where impaired waterbody drainage areas were small with respect to the HUC-12 subwatershed (Wallace Branch, Thick Creek, Bell Buckle Creek, and Clear Branch), TMDLs were based on the drainage area of the impaired waterbody. TMDLs for pathogen impaired waterbodies not listed in the table above will be addressed in a separate document.

Analysis/Methodology:

TMDLs for impaired waterbodies in the Upper Duck River watershed were developed using two different methodologies to assure compliance with both the 200 counts/100 ml geometric mean standard and the 1,000 counts/100 ml maximum standards.

Dynamic Loading Model Method

In order to demonstrate compliance with the 200 counts/100 ml geometric mean standard, the Loading Simulation Program C++ (LSPC) was used to simulate the buildup and washoff of fecal coliform bacteria from land surfaces, loading from point sources, and compute the resulting water quality response. From model output, instream 30-day geometric mean concentrations were computed, critical conditions identified, existing loads determined, and reductions required to meet the target concentrations (standard + MOS) calculated for impaired subwatersheds.

Load Duration Curve Method

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 portion of the waterbody flow regime represented by these existing loads. Load duration curves were used to determine the load reductions required to meet the target maximum concentration (standard + MOS).

The required load reductions that were determined using each method were compared and the largest load reduction specified as the TMDL for impaired subwatersheds.

Seasonal Variation:

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

Margin of Safety (MOS): Implicit – Conservative modeling assumptions.
Explicit – 10% of the water quality standard for each impaired subwatershed.

TMDLs, WLAs, & LAs

Summary of TMDLs, WLAs, & LAs for Impaired Waterbodies

Impaired Waterbody	HUC-12 Subwatershed (06040002____)	TMDL	WLAs				LAs	
			WWTFs		CAFO	MS4s [a]	Precipitation Induced Nonpoint Sources	Other Direct Sources [b]
			Monthly Avg.	Daily Max.				
		[% Red.]	[cts./day]	[cts./day]	[cts./day]	[% Red.]	[% Red.]	[cts./day]
Clear Branch	DA	89.3	NA	NA	NA	89.3	89.3	0
Duck River	0101	20.4	NA	NA	NA	20.4	20.4	0
Little Duck River	0102	NR	2.572×10^{11}	1.286×10^{12}	NA	NR	NR	0
Bell Buckle Creek	DA	74.6	2.118×10^{10}	1.059×10^{11}	0	74.6	74.6	0
Duck River	0301	27.0	4.895×10^{11}	2.448×10^{12}	0	27.0	27.0	0
Duck River Tribs.	0303	27.0	NA	NA	NA	27.0	27.0	0
Fall Creek Hurricane Creek	0308	86.2	NA	NA	0	86.2	86.2	0
North Fork Creek	0401	87.9	NA	NA	0	87.9	87.9	0
Alexander Creek	0402	87.3	NA	NA	NA	87.3	87.3	0
Weakley Creek	0404	87.1	NA	NA	NA	87.1	87.1	0
Clem Creek	0405	NR	NA	NA	NA	89.9	89.9	0
Wilson Creek	0502	89.3	NA	NA	NA	89.3	89.3	0
Spring Creek Lick Creek	0503	85.9	NA	NA	NA	85.9	85.9	0
Thick Creek	DA	96.5	NA	NA	NA	96.5	96.5	0
Wallace Branch	DA	86.3	NA	NA	NA	86.3	86.3	0
Fountain Creek	0702	75.9	NA	NA	NA	75.9	75.9	0

Note: DA = Drainage Area; NA = Not applicable; NR = No reduction required.

a. Applies to any MS4 discharge loading in the HUC-12 subwatershed or drainage area.

b. The objective for all “other direct sources” is a load allocation of zero. It is recognized, however, that for leaking septic systems, a LA of 0 counts/day may not be practical. For these sources, the LA is interpreted to mean a reduction in fecal coliform loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for pathogens.

PROPOSED FECAL COLIFORM TOTAL MAXIMUM DAILY LOAD (TMDL) UPPER DUCK RIVER WATERSHED (HUC 06040002)

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 water bodies that are not attaining water quality standards. State water quality standards consist of designated use(s) 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 a number of waterbodies in the Upper Duck River Watershed identified on the 1998 and/or 2002 303(d) list as not supporting designated uses due to pathogens. These waterbodies are identified in Section 4.0. TMDL development for other pathogen-impaired waterbodies in the Upper Duck River watershed will be addressed in a separate document.

3.0 GENERAL DESCRIPTION – UPPER DUCK RIVER WATERSHED

The Upper Duck River watershed (HUC 06040002) is located in Middle Tennessee (Figure 1) and is primarily located in Bedford, Coffee, Marshall, and Maury Counties. The watershed lies within the Level III Interior Plateau (71) ecoregion and contains three Level IV ecoregions (a very small area in the southwestern tip of the watershed is in a fourth Level IV ecoregion) as shown in Figure 2 (USEPA, 1997):

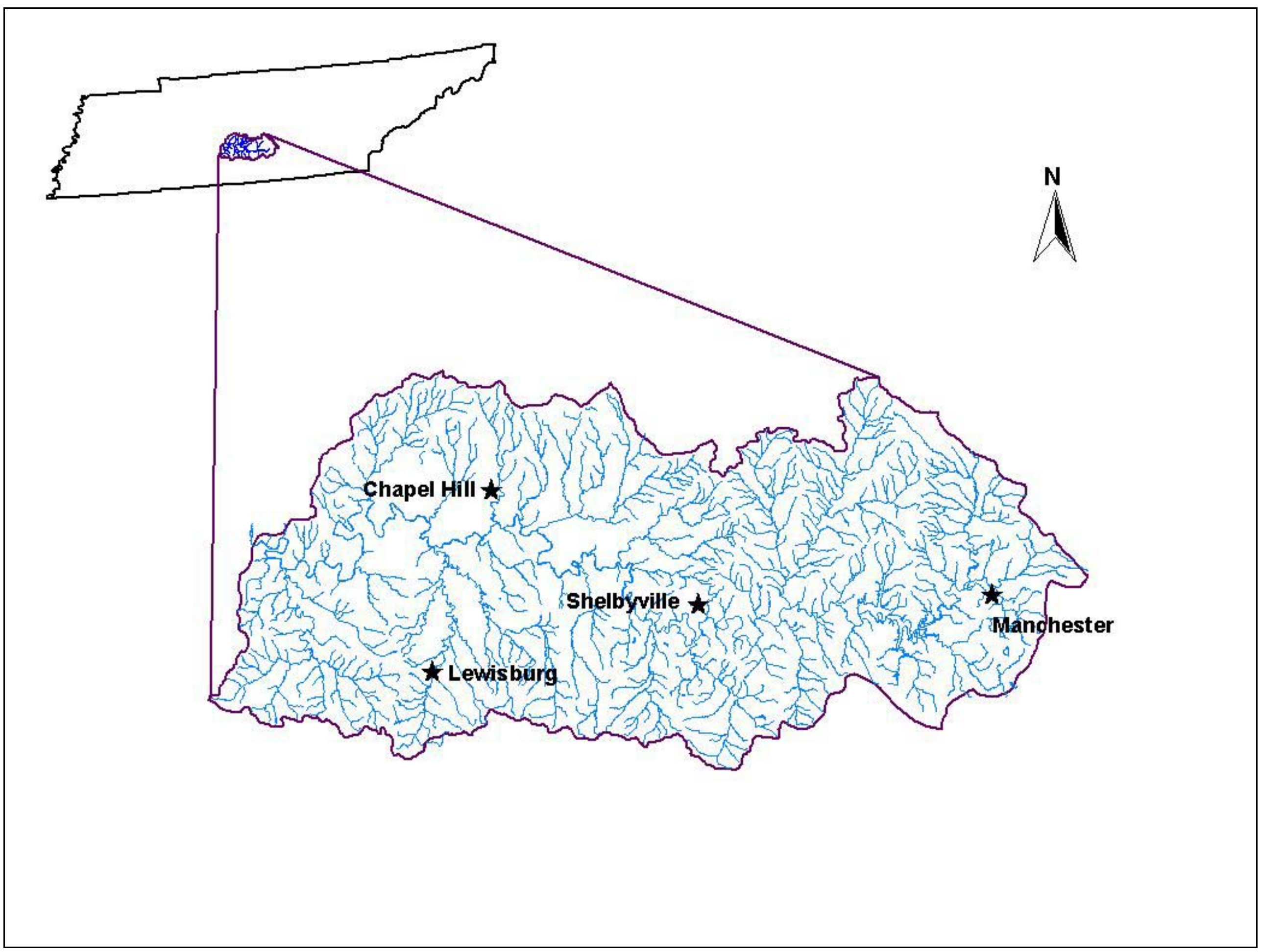
- The Eastern Highland Rim (71g) has level terrain, with landforms characterized as tablelands of moderate relief and irregular plains. Mississippian-age limestone, chert, shale, and dolomite predominate, and karst terrain sinkholes and depressions are especially noticeable between Sparta and McMinnville. Numerous springs and spring-associated fish fauna also typify the region. Natural vegetation for the region is transitional between the oak-hickory type to the west and the mixed mesophytic forests of the Appalachian ecoregions (68, 69) to the east. Bottomland hardwood forest has been inundated by several large impoundments. Barrens and former prairie areas are now mostly oak thickets or pasture and cropland.

- Outer Nashville Basin (71h) is a more heterogeneous region than the Inner Nashville Basin, with more rolling and hilly topography and slightly higher elevations. The region encompasses most all of the outer areas of the generally non-cherty Ordovician limestone bedrock. The higher hills and knobs are capped by the more cherty

Mississippian-age formations, and some Devonian-age Chattanooga shale, remnants of the Highland Rim. The region's limestone rocks and soils are high in phosphorus, and commercial phosphate is mined. Deciduous forests with pasture and cropland are the dominant land covers. Streams are low to moderate gradient, with productive nutrient-rich waters, resulting in algae, rooted vegetation, and occasionally high densities of fish. The Nashville Basin as a whole has a distinctive fish fauna, notable for fish that avoid the region, as well as those that are present.

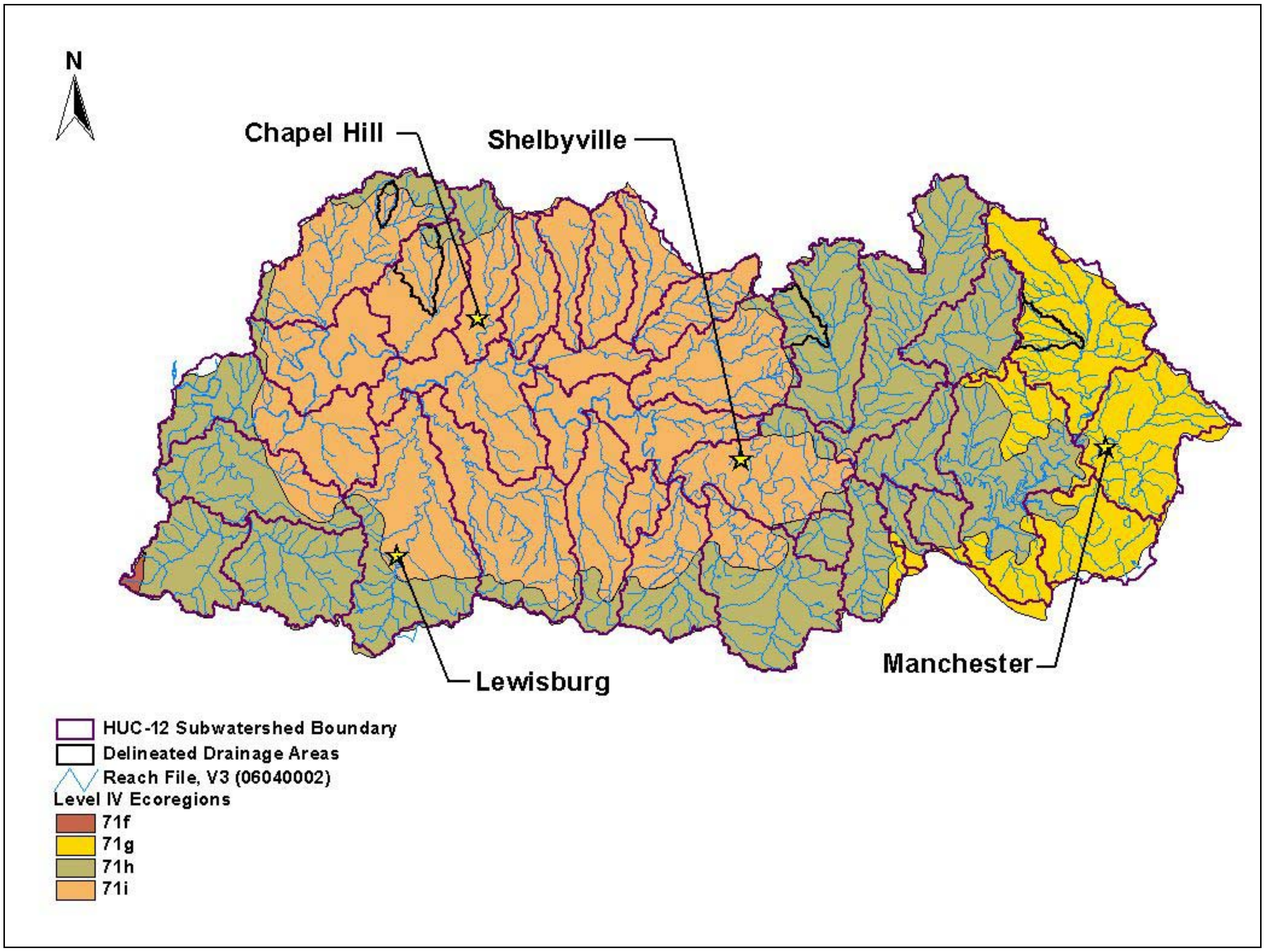
- Inner Nashville Basin (71i) is less hilly and lower than the Outer Nashville Basin. Outcrops of the Ordovician-age limestone are common, and the generally shallow soils are redder and lower in phosphorus than those of the Outer Basin. Streams are lower gradient than surrounding regions, often flowing over large expanses of limestone bedrock. The most characteristic hardwoods within the Inner Basin are a maple-oak-hickory-ash association. The limestone cedar glades of Tennessee, a unique mixed grassland/forest/cedar glades vegetation type with many endemic species, are located primarily on the limestone of the Inner Nashville Basin. The more xeric, open characteristics and shallow soils of the cedar glades also result in a distinct distribution of amphibian and reptile species.

Figure 1 Location of the Upper Duck River Watershed



The Upper Duck River watershed has approximately 1,795 miles of streams (Rf3) and drains a total area of 1,181 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. Land use for the entire Upper Duck River watershed is summarized in Table 1 and shown in Figure 3. Land use for pathogen impaired Huc-12 watersheds and drainage areas are tabulated in Appendix A.

Figure 2 Level IV Ecoregions in the Upper Duck River Watershed



Note: HUC-12 subwatershed boundaries and delineated drainage areas are shown in figures for reference.

Figure 3 MRLC Land Use Distribution in the Upper Duck River Watershed

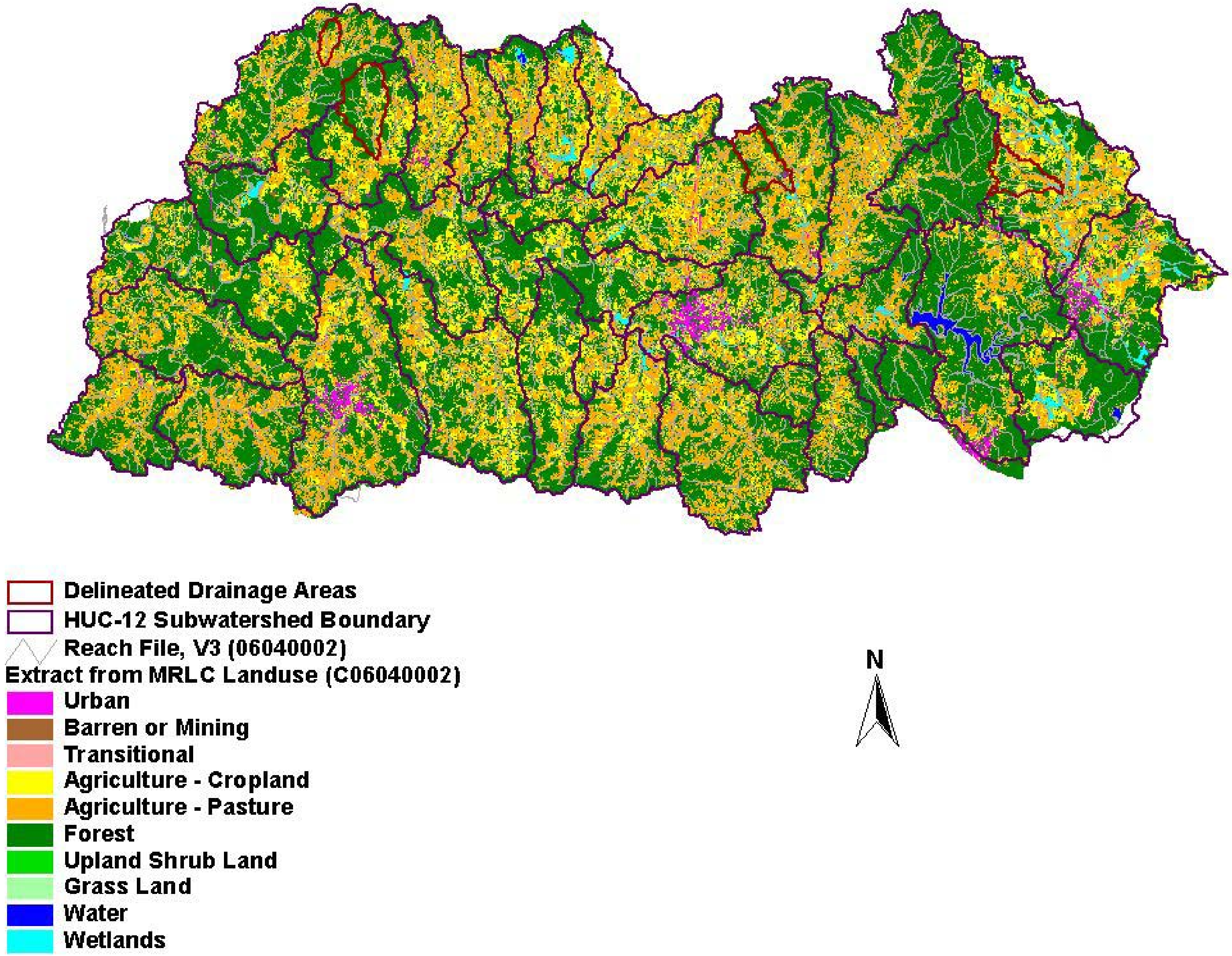


Table 1 MRLC Land Use Distribution – Upper Duck River Watershed

Land Use	Area - Upper Duck River Watershed	
	[acres]	[%]
Bare Rock/Sand/Clay	3	0.0
Deciduous Forest	296,264	39.2
Emergent Herbaceous Wetlands	420	0.1
Evergreen Forest	27,511	3.6
High Intensity Commercial/Industrial/ Transportation	5,076	0.7
High Intensity Residential	1,190	0.2
Low Intensity Residential	5,806	0.8
Mixed Forest	85,377	11.3
Open Water	4,777	0.6
Other Grasses (Urban/recreational)	3,205	0.4
Pasture/Hay	208,807	27.6
Quarries/Strip Mines/ Gravel Pits	419	0.1
Row Crops	106,937	14.1
Transitional	652	0.1
Woody Wetlands	9,428	1.2
Total	**755,871**	**100.0**

4.0 PROBLEM DEFINITION

The State of Tennessee's final 1998 303(d) list (TDEC, 1998) was approved by the U.S. Environmental Protection Agency (EPA), Region IV on September 17, 1998. The list identified a number of waterbodies in the Upper Duck River watershed as not fully supporting designated use classifications due to pathogens (see Table 2). The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Some waterbodies are also classified for industrial water supply, and/or domestic 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 main source for pathogens are untreated or inadequately treated human or animal fecal matter. The fecal coliform group is an indicator of the presence of pathogens in a stream.

Waterbodies in the Upper Duck River watershed were reassessed by the State in 2000 using more recent data and a revised waterbody identification system. The results of this reassessment are the best professional judgment (BPJ) of the Division of Water Pollution Control (DWPC) and were incorporated into the 2002 303(d) List (see Table 3), approved by EPA in January, 2004 (TDEC, 2004). The waterbody listings in Table 3 represent more precisely defined waterbody assessments than those listed in the 1998 303(d) list (ref: Table 2). The last column in Table 3 provides the link between the 2002 assessment and the 1998 303(d) list. Waterbodies identified as impaired for pathogens on the 1998 or 2002 303(d) list are shown in Figure 4.

A description of the stream assessment process in Tennessee can be found in *2002 305(b) Report, The Status of Water Quality in Tennessee* (TDEC, 2002). The waterbody segments listed in Table 3 were assessed as impaired based on sampling data and/or biological surveys. The results of these assessment surveys are summarized in Table 4. The assessment information presented is excerpted from the EPA/TDEC Assessment Database (ADB) and is referenced to the waterbody IDs in Table 3. ADB information may be accessed at:

http://gwidc.gwi.memphis.edu/website/wpc_arcmap

Table 2 1998 303(d) List for Pathogens – Upper Duck River Watershed

Waterbody ID	Impacted Waterbody	RM Partially Supporting	RM Not Supporting	CAUSE (Pollutant)	Pollutant Source
TN06040002027	DUCK RIVER - From confluence of Flat Ck. to confluence of Garrison Fork Creek	81.3		Pathogens Siltation	Agriculture
TN06040002032	DUCK RIVER		4.0	Pathogens	Municipal Point Source
TN06040002LITTLEDUCKR	LITTLE DUCK RIVER		19.3	Pathogens	Municipal Point Source
TN06040002033	WARTRACE CREEK (Bell Buckle Creek)	11.1		Pathogens	Municipal Point Source Pastureland
TN06040002038	FALL CREEK	61		Pathogens Nutrients	Agriculture
TN06040002039	NORTH FORK CR. INCL ALEXANDER, WEAKLEY, & CLEM CR	98.4		Pathogens Nutrients	Agriculture

Table 3 2002 303(d) List for Pathogens - Upper Duck River Watershed

Waterbody ID	Impacted Waterbody	RM Partially Supporting	RM Not Supporting	CAUSE (Pollutant)	Pollutant Source	Reference to 1998 303(d) List Waterbody ID
TN06040002002 - 3000	FOUNTAIN CREEK [a]	7.9		Pathogens	Livestock in Stream	
TN06040002027 – 1000	DUCK RIVER [b]	1.6		Pathogens Siltation	Collection System Failure Urban Runoff/Storm Sewers	TN06040002027
TN06040002032 – 0300	CLEAR BRANCH		7.3	Organic Enrichment/Low DO Pathogens	Agriculture	
TN06040002032 – 2000	DUCK RIVER [c]		2.0	Pathogens	Collection System Failure	TN06040002032
TN06040002033 – 0300	BELL BUCKLE CREEK		11.1	Siltation Other Habitat Alterations Pathogens	Minor Municipal Point Source Livestock in Stream	TN06040002033
TN06040002038 – 0300	HURRICANE CREEK	29.4		Pathogens Nutrients Siltation Other Habitat Alterations	Pasture Grazing	TN06040002038
TN06040002038 – 1000	FALL CREEK	11.4		Pathogens Nutrients Siltation Other Habitat Alterations	Pasture Grazing	TN06040002038
TN06040002039 – 0100	CLEM CREEK	14.2		Nutrients Pathogens	Pasture Grazing	TN06040002039
TN06040002039 – 0200	WEAKLEY CREEK [d]	6.2		Pathogens	Agriculture	TN06040002039
TN06040002039 – 0250	WEAKLEY CREEK [e]	13.1		Siltation Pathogens	Agriculture	TN06040002039
TN06040002039 – 0300	ALEXANDER CREEK	21.1		Siltation Pathogens	Pasture Grazing	TN06040002039

Table 3 2002 303(d) List for Pathogens - Upper Duck River Watershed (Continued)

Waterbody ID	Impacted Waterbody	RM Partially Supporting	RM Not Supporting	CAUSE (Pollutant)	Pollutant Source	Reference to 1998 303(d) List Waterbody ID
TN06040002039 – 3000	NORTH FORK CREEK [f]	9.2		Siltation Pathogens	Agriculture	TN06040002039
TN06040002046 – 1000	WILSON CREEK	19.5		Pathogens Nitrate Other Habitat Alterations	Pasture Grazing	
TN06040002047 – 0300	LICK CREEK	8.8		Pathogens Other Habitat Alterations	Livestock in Stream	
TN06040002047 – 1000	SPRING CREEK	13.2		Pathogens Other Habitat Alterations	Livestock in Stream	
TN06040002048 – 0100	THICK CREEK	13.4		Pathogens Other Habitat Alterations	Livestock in Stream	
TN06040002049 – 0400	WALLACE BRANCH	3.8		Pathogens	Pasture Grazing	
TN06040002502 – 1000	LITTLE DUCK RIVER		10.6	Pathogens	Collection System Failure	

Notes:
a. Upper Fountain Creek – South Fork to headwaters.
b. Flat Creek to Highway 231.
c. Little Duck River to Morton Lake.
d. North Fork Creek to unnamed tributary near Highway 41A.
e. Unnamed tributary near Highway 41A to headwaters.
f. Alexander Creek to headwaters.

Figure 4 Selected Waterbodies on 1998 or 2002 303(d) List – Pathogens

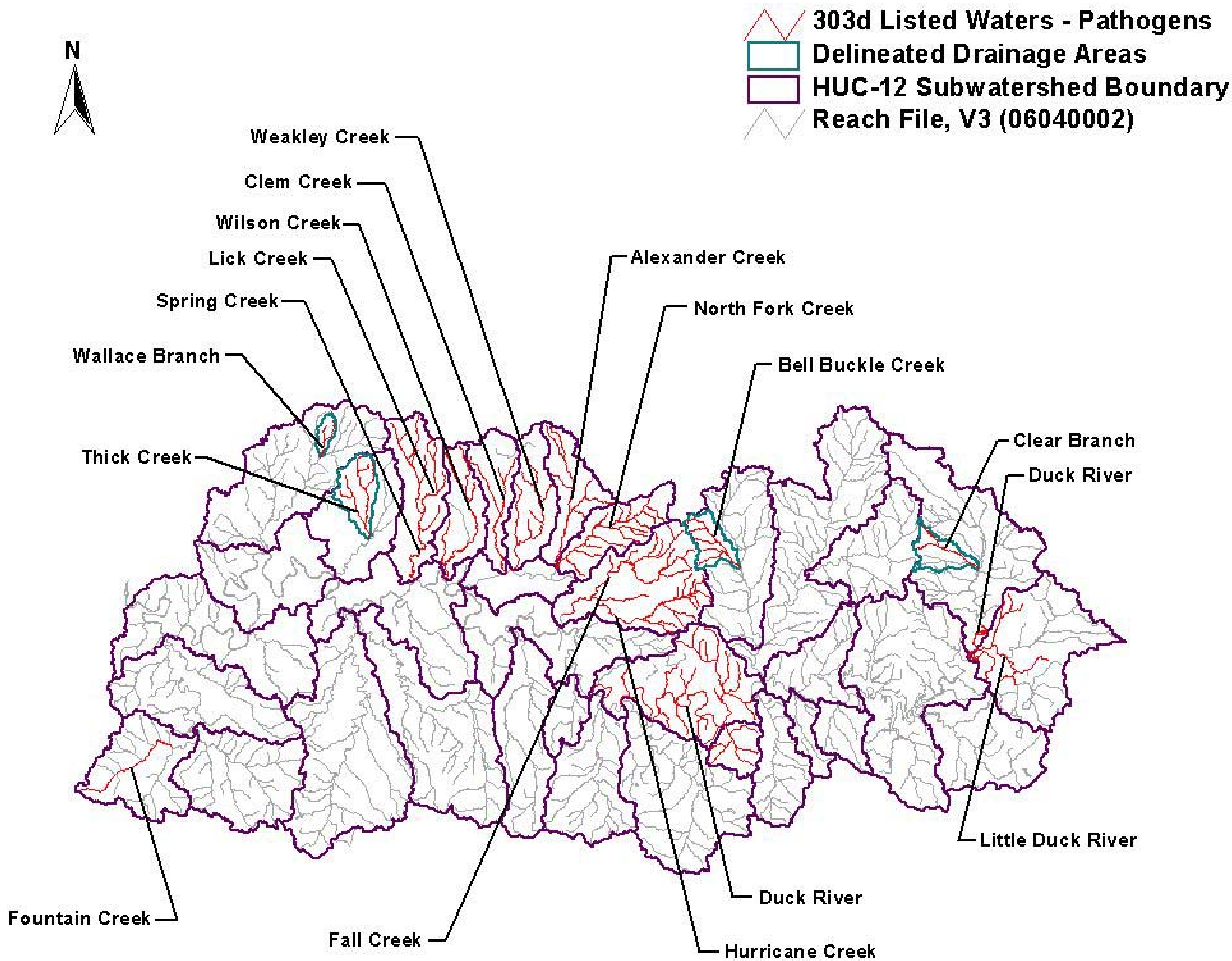


Table 4 Water Quality Assessment of Waterbodies Impaired Due to Pathogens – Upper Duck River Watershed

Waterbody ID	Segment Name	Cause	Sources	Comments
TN06040002002 - 3000	FOUNTAIN CREEK	Pathogens	Livestock in Stream	TVA has chemical stations at miles 14.5 and 17.1. Fecal coliform standards violated.
TN06040002027 – 1000	DUCK RIVER	Pathogens Siltation	Collection System Failure Urban Runoff/Storm Sewers	TDEC stream survey by canoe.
TN06040002032 – 0300	CLEAR BRANCH	Organic Enrichment/Low DO Pathogens	Agriculture	1999 TDEC biological station at mile 1.1 (Dawson Road). Zero EPT families, 6 total families. Habitat score = 117.
TN06040002032 – 2000	DUCK RIVER	Pathogens	Collection System Failure	Water contact advisory. TDEC biological station at mile 268.6 (Old Stone Fort Park). 10 EPT families, 27 total families. Habitat score = 154. Pretreatment station at 268.5.
TN06040002033 – 0300	BELL BUCKLE CREEK	Siltation Other Habitat Alterations Pathogens	Minor Municipal Point Source Livestock in Stream	1999 TDEC biological station at mile 1.0 (downstream STP). 0 EPT families, 16 total families. Habitat score = 95.
TN06040002038 – 0300	HURRICANE CREEK	Pathogens Nutrients Siltation Other Habitat Alterations	Pasture Grazing	TDEC 2000 probabilistic monitoring station at mile 4.2 at Midland Road. Violated proposed biocriteria for 71i. Elevated fecal. 1999 TDEC biological station at mile 1.8 (Burns Road). 5 EPT families, 23 total families. Habitat score = 94.
TN06040002038 – 1000	FALL CREEK	Pathogens Nutrients Siltation Other Habitat Alterations	Pasture Grazing	TDEC 2000 probabilistic monitoring station at mile 3.0 at Gregory Mill Rd. Violated proposed biocriteria for 71i. 1999 TDEC biological and 319 site at mile 1.2 (Old Unionville Rd). 5 EPT, 24 total families. Habitat = 103. Pathogens elevated.
TN06040002039 – 0100	CLEM CREEK	Nutrients Pathogens	Pasture Grazing	TDEC 2000 probabilistic monitoring station at mile 0.4 at Old Pencil Mill Road. Violated proposed biocriteria for 71i. Goes dry from time to time.
TN06040002039 – 0200	WEAKLEY CREEK	Pathogens	Agriculture	Three 319 stations in this watershed. Pathogens elevated. 1999 TDEC biological station at mile 0.2 (Halls Mill Road). 7 EPT families. Habitat score = 115.

Table 4 Water Quality Assessment of Waterbodies Impaired Due to Pathogens – Upper Duck River Watershed (Continued)

Waterbody ID	Segment Name	Cause	Sources	Comments
TN06040002039 – 0250	WEAKLEY CREEK	Siltation Pathogens	Agriculture	TDEC 2000 probabilistic monitoring station at mile 5.2 at Coopertown Road. Violated proposed biocriteria for 71i. Three 319 stations in this watershed. Pathogens elevated.
TN06040002039 – 0300	ALEXANDER CREEK	Siltation Pathogens	Pasture Grazing	TDEC 2000 probabilistic monitoring station at mile 4.0 u/s of Pepper Hill Road. Violated proposed biocriteria for 71i. E. coli also elevated. Dry when observed in August, 1999.
TN06040002039 – 3000	NORTH FORK CREEK	Siltation Pathogens	Agriculture	TDEC 2000 probabilistic monitoring station at mile 16.4 d/s of Squire Hall Road. Violated proposed biocriteria for 71i.
TN06040002046 – 1000	WILSON CREEK	Pathogens Nitrate Other Habitat Alterations	Pasture Grazing	2000 TDEC probabilistic station at mile 5.2 at Chapel Hill to Unionville Road. Site did not meet proposed biocriteria for 71i. Elevated E. coli levels. 2000 TDEC biological survey at mile 2.8 (Wright Rd). 4 EPT, 14 total families, habitat=144.
TN06040002047 – 0300	LICK CREEK	Pathogens Other Habitat Alterations	Livestock in Stream	TDEC chemical station mile 1.6 (Mt Vernon Road). Coliforms elevated.

Table 4 Water Quality Assessment of Waterbodies Impaired Due to Pathogens – Upper Duck River Watershed (Continued)

Waterbody ID	Segment Name	Cause	Sources	Comments
TN06040002047 – 1000	SPRING CREEK	Pathogens Other Habitat Alterations	Livestock in Stream	TDEC biological station at miles 5.6 (1995) and at 3.2 (1999). 8 EPT families and 27 total families in 1999. Habitat score = 123. Chemical station at mile 3.2. Pathogens elevated.
TN06040002048 – 0100	THICK CREEK	Pathogens Other Habitat Alterations	Livestock in Stream	2000 TDEC probabilistic station at river mile 2.0 off Pyles Road. Site did not meet proposed biocriteria for 71i. (1 EPT genus, 14 total genera, habitat score=131, NCBI=7.59). Dominated by isopods. Fecal coliforms elevated.
TN06040002049 – 0400	WALLACE BRANCH	Pathogens	Pasture Grazing	2000 TDEC probabilistic station at river mile 0.8 at Flat Creek Road. Site met proposed biocriteria for 71i, but fecal elevated. (8 EPT genera, 23 total genera, habitat score=120, NCBI=5.44)
TN06040002502 – 1000	LITTLE DUCK RIVER	Pathogens	Collection System Failure	Water contact advisory. 1999 USGS RBPIII at mile 1.3 near Manchester. 15 EPT genera, 48 total. Failed biocriteria.1999 TDEC biorecons at miles 0.1 & 4.2. 8 EPT families, 26 total, habitat=150 at mile 0.1. 9 EPTs, 20 total, habitat=147 at mile 4.2.

5.0 WATER QUALITY GOAL

As previously stated, the designated use classifications for waterbodies in the Upper Duck River watershed include fish & aquatic life, recreation, irrigation, livestock watering & wildlife, industrial water supply, and domestic water supply. Of the use classifications with numeric criteria for fecal coliform bacteria, the recreation use classification is the most stringent and will be used as the target level for TMDL development. The fecal 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, October, 1999* (TDEC, 1999). Section 1200-4-3-.03 (4) (f) states:

> The concentration of a fecal coliform group shall not exceed 200 per 100 mL, nor shall the concentration of the *E. coli* group exceed 126 per 100 mL, as a geometric mean based on a minimum of 10 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 a fecal coliform group or *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 fecal coliform group in any individual sample shall not exceed 1,000 per 100 mL.

The geometric mean standard for fecal coliform of 200 counts/100 ml and the sample maximum of 1,000 counts/100 ml have been selected as the primary instream goals for TMDL development. It is believed that TMDLs developed to achieve fecal coliform water quality goals will also be in compliance with the *E. coli* water quality standard.

Note: In this document, the water quality standard is the instream goal. The term "target concentration" reflects the application of an explicit Margin of Safety (MOS) to the water quality standard. See Section 8.3 for an explanation of MOS.

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM GOAL

There are a number of water quality monitoring stations that provide data for waterbodies identified as impaired for pathogens in the Upper Duck River watershed:

- ALEXA004.0BE – Alexander Creek, ¼ mile upstream from Pepper Hill Road (~RM 4.0).
- BBUCK001.0BE – Bell Buckle Creek at Bell Buckle Road upstream of STP (~RM 1.0).
- BBUCK001.3BE – Bell Buckle Creek at Highway 82 upstream of STP (~RM 1.3).
- CLEAR001.1CE – Clear Creek, 100 feet downstream of Dawson Road (~RM 1.1).
- CLEAR001.8CE – Clear Creek, Eldon Road (~RM 1.8).
- CLEM000.4BE – Clem Creek, 200 yards downstream of Old Pencil Mill Road (~RM 0.4).
- DUCK216.2BE - Duck River at Sims Road, downstream of Flat Creek (~RM 216.2).
- DUCK219.7BE - Duck River at River Road, upstream of Flat Creek (~RM 219.7).
- DUCK235.6BE – Duck River at Highway 41/16, upstream of Shelbyville (~RM 235.6).

- DUCK237.0BE – Duck River at Highway 41/16, downstream of Garrison Fork (~RM 237.0).
- DUCK269.6CE - Duck River at Old Stone Fort (~RM 269.6).
- FALL001.2BE – Fall Creek at Highway 41A (~RM 1.2).
- FALL003.0BE – Fall Creek downstream of Gregory Mill Road (~RM 3.0).
- FALL006.1BE – Fall Creek at Pinkston/Milligan Road (~RM 6.1).
- HURRI001.0BE – Hurricane Creek at Frank Martin Road (~RM 1.0).
- HURRI004.2BE – Hurricane Creek, 200 yards upstream of Midland Road (~RM 4.2).
- LDUCK001.3CE – Little Duck River Falls at Old Stone Fort (~RM 1.3).
- LICK001.8ML – Lick Creek at Mt. Vernon Road (~RM 1.8).
- NFORK007.7BE – North Fork Creek, 100 yards upstream of Highway 41A (~RM 7.7).
- NFORK016.4BE – North Fork Creek, ¼ mile downstream of Squire Hall Road (~RM 16.4).
- SPRIN003.2ML – Spring Creek at Hurt Road near Chapel Hill (~RM 3.2).
- THICK002.0ML – Thick Creek, 100 yards upstream of Pyles Road(~RM 2.0).
- TVA Station (14.5) – Fountain Creek at Campbells Station Road (~RM 14.5).
- TVA Station (17.1) – Fountain Creek at ~RM 14.5.
- WALLA000.8WI – Wallace Branch, 200 yards upstream of Flat Creek Road (~RM 0.8).
- WEAKL001.7BE – Weakley Creek at Highway 41A (~RM 1.7).
- WEAKL005.2BE – Weakley Creek, 150 yards upstream of Coopertown Road (~RM 5.2).
- WILSO000.7ML – Wilson Creek at Highway 270 (~RM 0.7).
- WILSO002.9BE – Wilson Creek at Wright Road (~RM 2.9).
- WILSO005.2BE – Wilson Creek at Old Columbia Road (~RM 5.2).

The location of these monitoring stations is shown in Figure 5. Water quality monitoring results for all stations are tabulated in Appendix B and summarized in Table 5. Examination of this data shows violation of the 1,000 counts/100 ml maximum fecal coliform standard in 16 of the 32 monitoring stations. There was not enough data to determine compliance with the geometric mean standards for fecal coliform or *E. coli*.

Figure 5 Selected Water Quality Monitoring Stations in the Upper Duck River Watershed

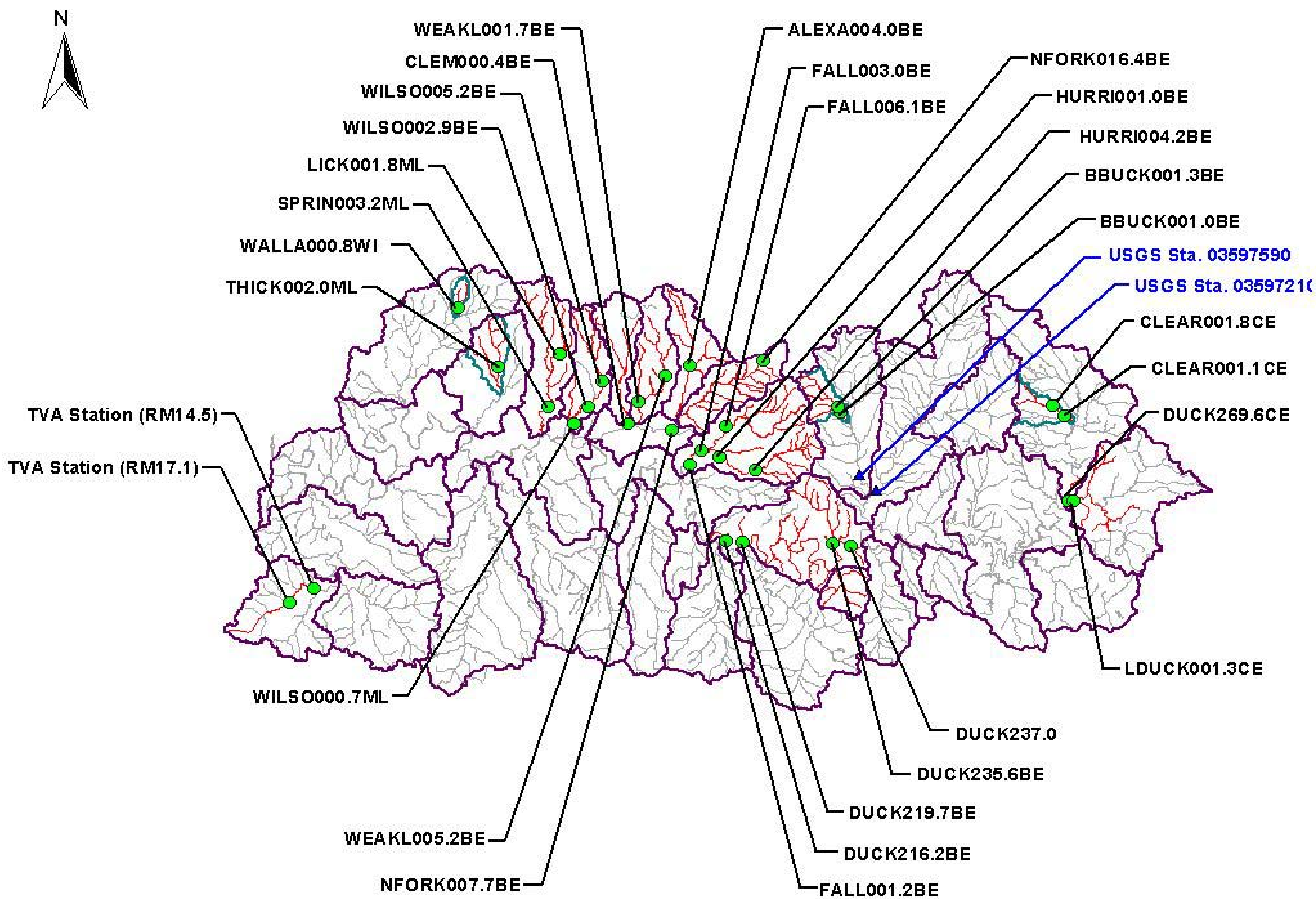


Table 5 Summary of Water Quality Monitoring Data

Monitoring Station	Fecal Coliform					E. Coli			
	Data Pts.	Min. [mg/l]	Avg. [mg/l]	Max. [mg/l]	No. Viol. WQ Std. *	Data Pts.	Min. [mg/l]	Avg. [mg/l]	Max. [mg/l]
ALEXA004.0BE	3	340	770	1,600	1	3	410	817	1,600
BBUCK001.0BE	8	46	513	2,400	1	8	20	547	2,400
BBUCK001.3BE	1	—	390	—	0	1	—	310	—
CLEAR001.1CE	6	5,400	10,583	20,000	6	6	50	1,892	2,400
CLEAR001.8CE	1	—	58,000	—	1	0			
CLEM000.4BE	3	1	74	170	0	3	1	146	410
DUCK216.2BE	7	150	563	1,500	2	6	66	494	1,300
DUCK219.7BE	1	—	380	—	0	1	—	310	—
DUCK235.6BE	6	50	272	630	0	6	8	305	870
DUCK237.0BE	1	—	340	—	0	1	—	380	—
DUCK269.6CE	6	2	37	140	0	6	1	9	19
FALL001.2BE	1	—	110	—	0	1	—	100	—
FALL003.0BE	5	5	377	1,000	0	5	4	381	1,100
FALL006.1BE	1	—	20,000	—	1	1	—	2,400	—
HURRI001.0BE	1	—	140	—	0	1	—	120	—
HURRI004.2BE	5	87	787	2,300	1	5	47	909	2,400
LDUCK001.3CE	6	15	51	83	0	6	15	50	130
LICK001.8ML	10	120	3,722	15,000	7	10	130	1,325	2,400
NFORK007.7BE	4	90	1,018	3,700	1	4	67	687	2,400
NFORK016.4BE	3	240	370	530	0	3	310	510	730
SPRIN003.2ML	9	240	2,680	13,000	4	9	340	1,189	2,400
THICK002.0ML	5	4	789	2,800	1	9	2	690	2,000
TVA Sta. (14.5)	4	1	1,598	3,210	3	—	—	—	—
TVA Sta. (17.1)	4	1	2,058	5,260	3	—	—	—	—
WALLA000.8WI	4	27	6,062	20,000	2	4	55	1,246	2,400
WEAKL001.7BE	1	—	500	—	0	1	—	550	—
WEAKL005.2BE	3	300	1,057	2,100	1	3	260	1,153	2,400
WILSO000.7ML	3	36	1,389	3,700	1	3	31	994	2,400
WILSO002.9BE	5	1	2,578	12,000	1	5	130	724	2,400
WILSO005.2BE	7	1	4,916	18,000	4	6	1	1,702	2,400

* Number of violations of the 1,000 cts./100 ml maximum water quality standard.

Note: In cases where multiple samples were collected in a single day, only the sample with the highest fecal coliform concentration was used to compute minimum, maximum, and average values.

7.0 SOURCE ASSESSMENT

An important part of TMDL analysis is the identification of individual sources, or source subcategories 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 subcategories: 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 fecal coliform bacteria. There are eight NPDES permitted WWTFs in the Upper Duck River watershed that are authorized to discharge treated sanitary wastewater. These facilities are tabulated in Table 6 and the location shown in Figure 6. It should be noted that only five of these WWTFs are authorized to discharge to waterbodies identified on the 1998 or 2002 303(d) as impaired due to pathogens. The fecal coliform and *E. coli* permit limits for discharges from all of these WWTFs are in accordance with the criteria specified in State water quality standards (ref.: Section 5.0). A summary of effluent monitoring data, submitted on Discharge Monitoring Reports(DMRs) for the period from January, 1998 to February, 2003, for facilities that are located in HUC-12 subwatersheds or drainage areas containing waterbodies impaired for pathogens is presented in Table 7.

Figure 6 NPDES Permitted Wastewater Treatment Facilities Discharging Treated Sanitary Wastewater

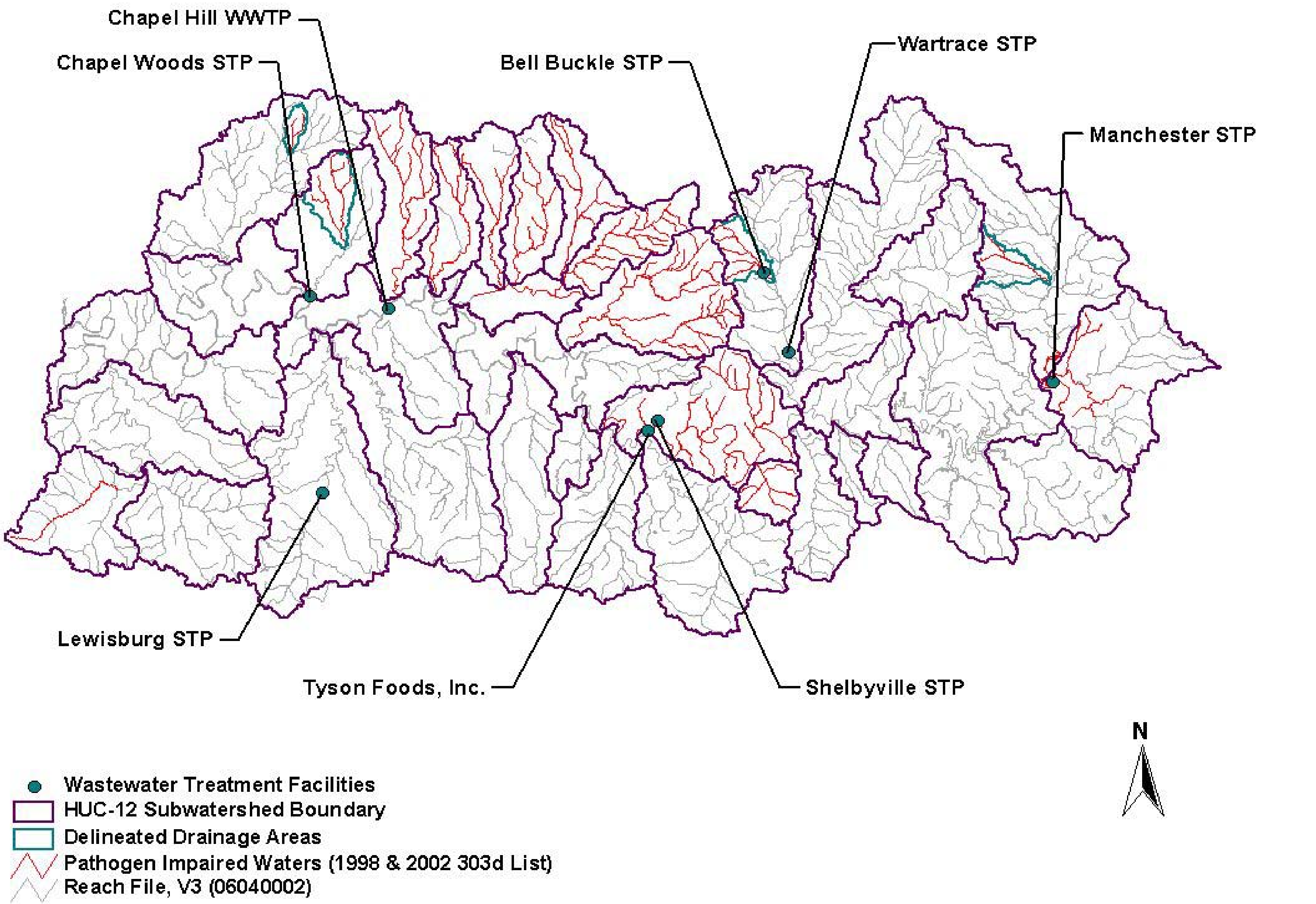


Table 6 WWTFs Permitted to Discharge Treated Sanitary Wastewater in the Upper Duck River Watershed

NPDES Permit No.	Facility	Design Flow [MGD]	Receiving Stream
TN0002135	Tyson Foods, Inc.	1.572 *	Duck River at RM 220.2
TN0020443	Wartrace STP	0.13	Wartrace Creek at RM 2.1
TN0020591	Bell Buckle STP	0.15	Bell Buckle Creek at RM 0.8
TN0022888	Lewisburg STP	3.024	Big Rock Creek at RM 16.8
TN0024180	Shelbyville STP	4.9	Duck River at RM 221.3
TN0025038	Manchester STP	3.4	Duck River at RM 268.5
TN0062073	Chapel Woods STP	0.05	Duck River at RM 177.5
TN0064670	Chapel Hill WWTP	0.17	Duck River at RM 185.5

* Long term average flow is used for industrial facilities.

Table 7 Summary of Discharge Monitoring Reports (1/98 – 2/03)

Permit No.	Facility	Description	DMR Category	
			Monthly Average [counts/100 ml]	Daily Maximum [counts/100 ml]
TN0002135	Tyson Foods, Inc.	Minimum	1	1
		Average	24	67
		Maximum	660	760
		POC *	2	0
TN0020443	Wartrace STP	Minimum	10	10
		Average	31	32
		Maximum	172	172
		POC *	0	0
TN0020591	Bell Buckle STP	Minimum	<1	1
		Average	3	30
		Maximum	63	450
		POC *	0	0
TN0024180	Shelbyville STP	Minimum	5	31
		Average	45	356
		Maximum	185	2,228
		POC *	0	2
TN0025038	Manchester STP	Minimum	1	1
		Average	3	85
		Maximum	13	>1,000
		POC *	0	1

* Number of months with at least one effluent measurement out of compliance with permit limit.

7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of pathogens. Discharges from MS4s occur in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. Large and medium MS4s serving populations greater than 100,000 people are required to obtain an NPDES storm water permit. At present, there are no MS4s of this size in the Upper Duck River watershed. As of March 2003, small MS4s serving urbanized areas, or having the potential to exceed instream water quality standards, are required to obtain a permit under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2002a). An urbanized area is defined as an entity with a residential population of at least 50,000 people and an overall population density of at 1,000 people per square mile. Lewisburg, Shelbyville, and Tullahoma are covered under Phase II of the NPDES Storm Water Program. The Tennessee Department of Transportation (TDOT) is also being issued MS4 permits for State roads in urban areas. Information regarding storm water permitting in Tennessee may be obtained from the 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, 2002). 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* (included as Appendix C), while larger, Class I CAFOs are required to obtain an individual NPDES permit. Requirements of both the general and individual CAFO permits include:

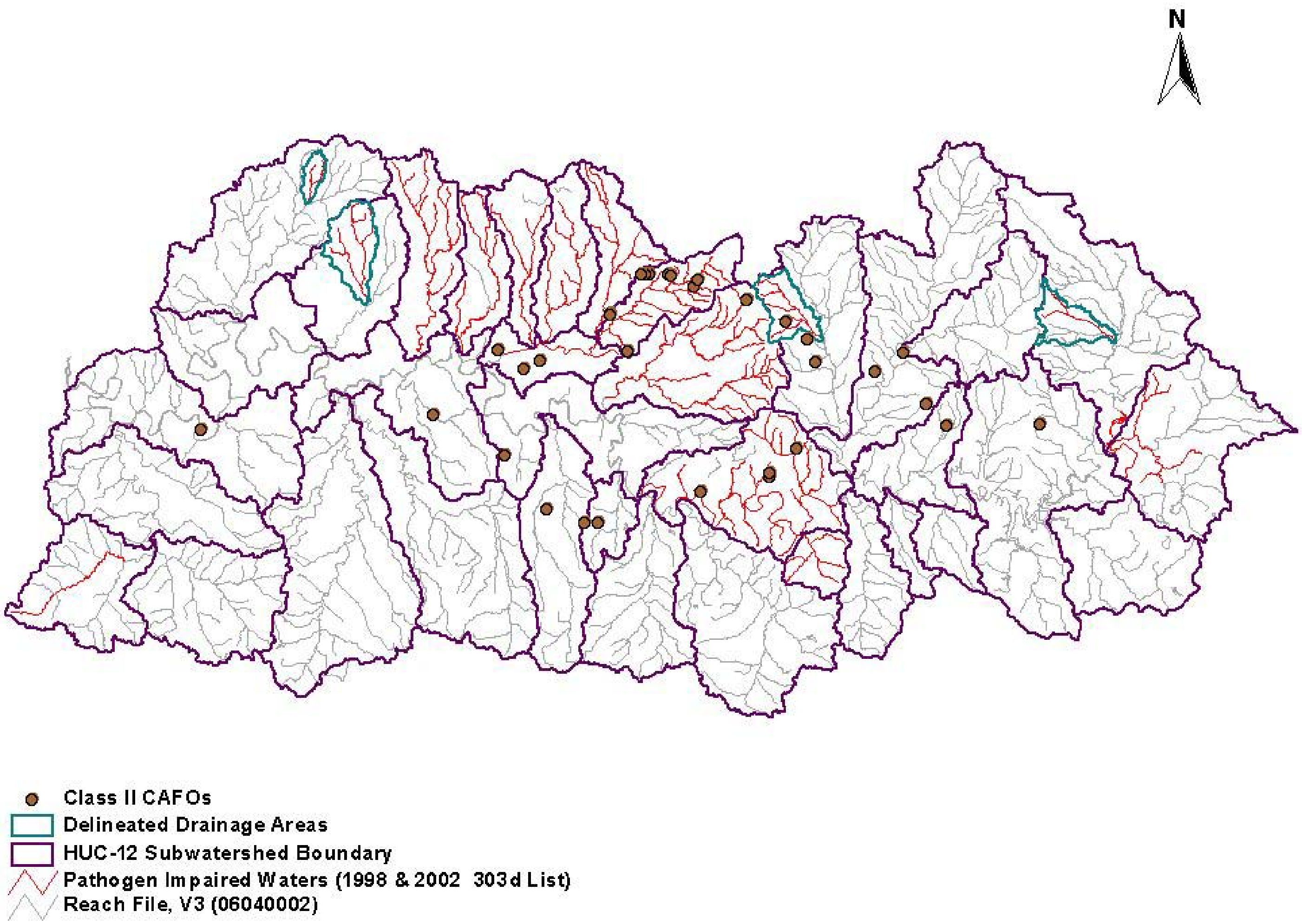
- Development of a Nutrient Management Plan (NMP), and approval of the NMP by the Tennessee Department of Agriculture (TDA).

- Liquid waste handling systems, if utilized, be designed, constructed, and operated to contain all process generated waste waters plus the runoff from a 25-year, 24-hour rainfall event. A discharge from a liquid waste handling facility to waters of the state during a chronic or catastrophic rainfall event, or as a result of an unpermitted discharge, upset, or bypass of the system, shall not cause or contribute to an exceedance of Tennessee water quality standards.

- Other Best Management Practices (BMPs).

As of May 19, 2003, there are 35 Class II CAFOs in the Upper Duck River watershed with coverage under the general NPDES permit. The location of these facilities is shown in Figure 7. There are no CAFOs with individual permits located in the watershed. It should be noted that facilities are located both in subwatersheds containing impaired waterbodies and subwatersheds that do not contain impaired waterbodies.

Figure 7 Location of CAFOs in the Upper Duck River Watershed



7.2 Nonpoint Sources

Nonpoint sources of fecal 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 fecal coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of pathogen loading are primarily associated with agricultural and urban land uses. The vast majority of waterbodies identified on the 1998 or 2002 303(d) lists as impaired due to pathogens are attributed to nonpoint agricultural or urban sources.

7.2.1 Wildlife

Wildlife deposit fecal 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. In order to account for higher density areas and loading due to other species, a conservative density of 45 animals per square mile was used for modeling purposes. Fecal coliform loads due to deer are estimated by EPA to be 5.0×10^8 counts/animal/day.

7.2.2 Agricultural Animals

Agricultural activities can be a significant source of fecal 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 fecal 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 fecal 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 (i.e., deer and other wildlife) often have direct access to waterbodies and can provide a concentrated source of fecal loading directly to a stream.

Livestock data for pathogen-impaired subwatersheds were compiled from the 1997 Census of Agriculture utilizing the Watershed Characterization System (WCS) and summarized in Table 8. WCS is an Arcview geographic information system (GIS) based program developed by USEPA Region IV to facilitate watershed characterization and TMDL development.

Table 8 Livestock Distribution in the Upper Duck River Watershed

HUC-12 Subwatershed (06040002__)	Impaired Waterbody	Livestock Population (1997 Census of Agriculture)					
		Beef Cow	Cattle	Milk Cow	Poultry	Hogs	Sheeps
DA	Clear Branch	207	538	49	56,463	49	4
0101	Duck River Clear branch	1,944	5,042	462	528,949	458	38
0102	Little Duck River	1,082	2,802	257	294,407	255	21
DA	Bell Buckle Creek	464	961	64	419,291	64	7
0301	Duck River	1,703	3,523	234	1,680,834	250	25
0303	Duck River	339	702	47	334,813	50	5
0308	Fall Creek Hurricane Creek	2,297	4,753	316	2,268,069	337	33
0401	North Fork Creek	1,194	2,472	164	1,112,619	169	18
0402	Alexander Creek	1,263	2,618	172	1,018,885	163	20
0404	Weakley Creek	1,037	2,146	143	1,002,857	150	15
0405	Clem Creek	883	1,828	122	869,960	129	13
0502	Wilson Creek	1,131	2,462	223	497,339	201	15
0503	Lick Creek Spring Creek	2,004	4,421	427	6	344	30
DA	Thick Creek	228	518	57	1	48	3
DA	Wallace Branch	372	723	33	1	42	10
0702	Fountain Creek	2,785	5,835	273	8	242	32

DA = Drainage Area

It can be seen from Table 8 that each of the pathogen-impaired subwatersheds contains a significant number of agricultural animals. The percentage of subwatershed land use area classified as agricultural ranges from 32.9% to 69.4% (see Tables A-1 & A-2 and Figures 8 & 9).

Figure 8 Land Use Area of Impaired Subwatersheds & Drainage areas

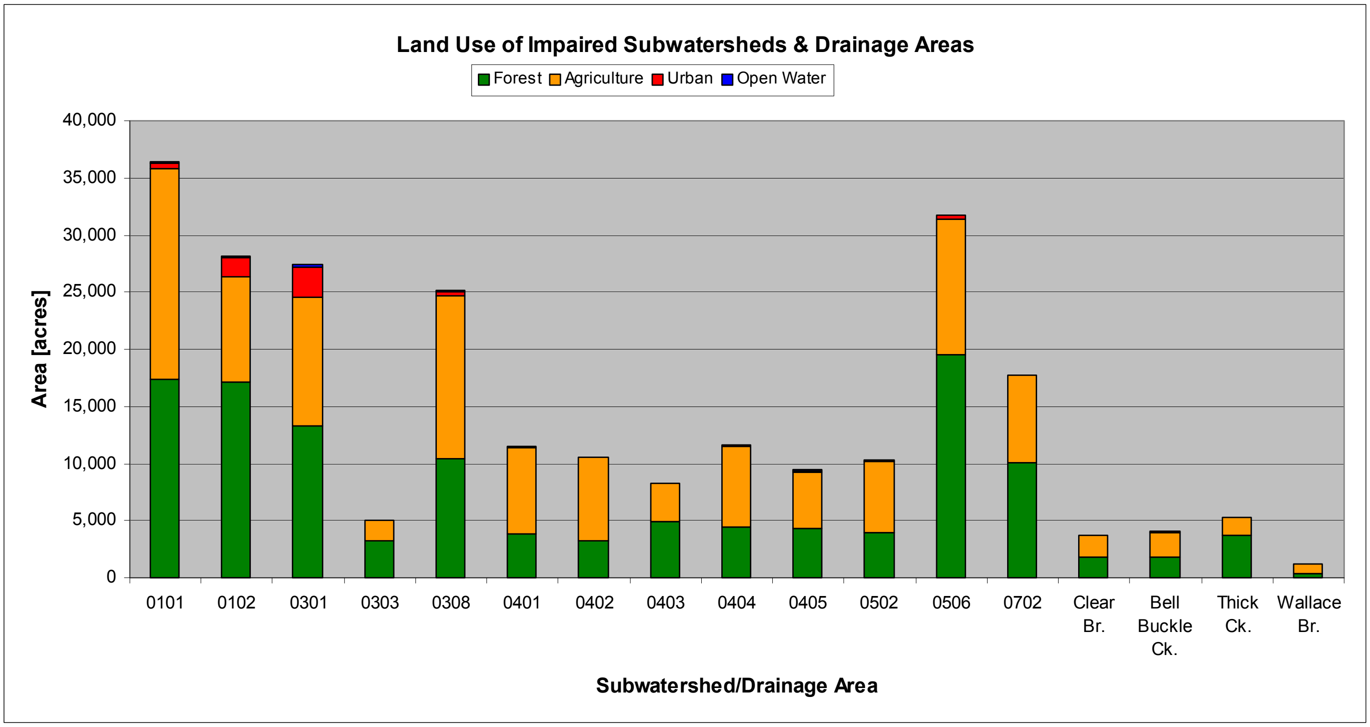
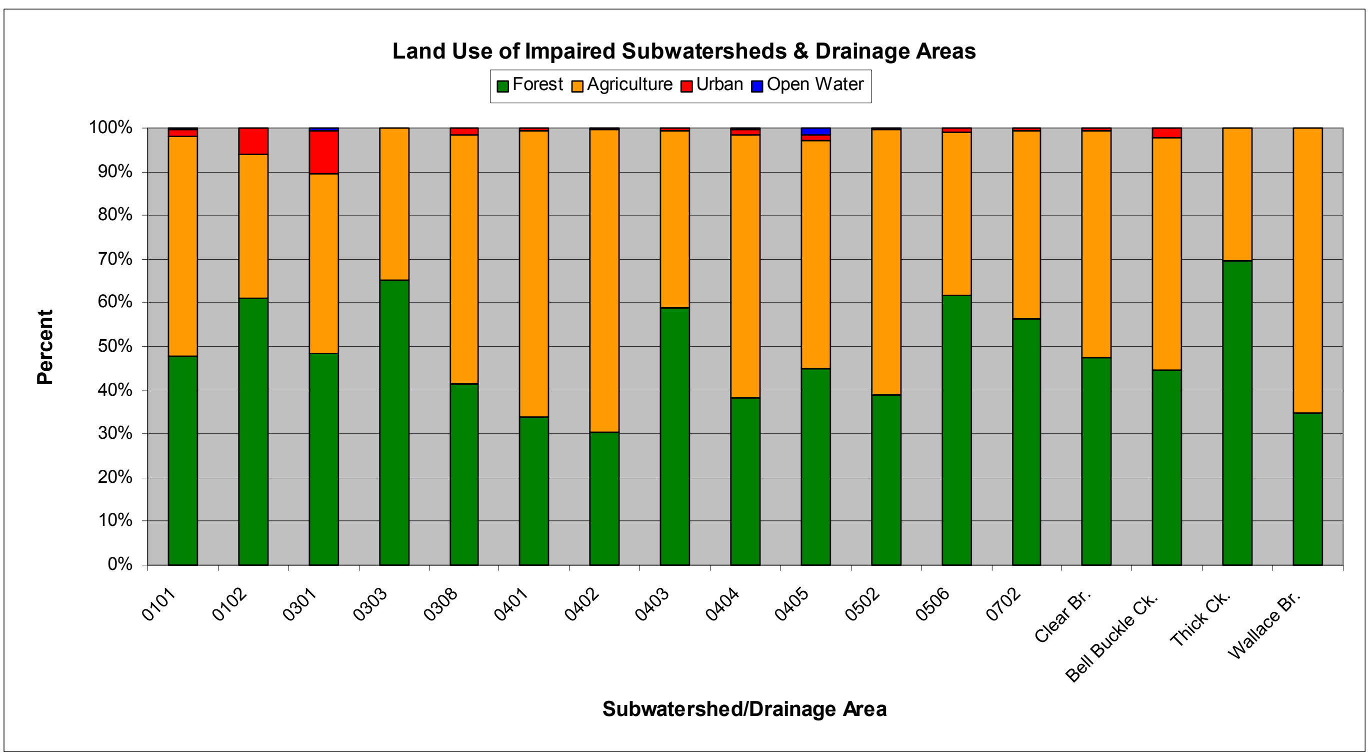


Figure 9 Land Use Percentage of Impaired Subwatersheds & Drainage Areas



7.2.3 Failing Septic Systems

Some fecal coliform loading in the Upper Duck 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 pathogen-impaired subwatersheds utilizing septic systems were compiled using WCS and are summarized in Table 9. In middle 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 fecal bacteria directly to waterbodies.

Table 9 Population on Septic Systems in the Upper Duck River Watershed

HUC-12 Subwatershed (06040002__)	Impaired Waterbody	Population On Septic Systems
DA	Clear Branch	262
0101	Duck River Clear Branch	2,597
0102	Little Duck River	2,289
DA	Bell Buckle Creek	236
0301	Duck River	1,596
0303	Duck River	263
0308	Fall Creek Hurricane Creek	1,318
0401	North Fork Creek	727
0402	Alexander Creek	870
0404	Weakley Creek	687
0405	Clem Creek	568
0502	Wilson Creek	621
0503	Lick Creek Spring Creek	1,346
DA	252	900
DA	Wallace Branch	244
0702	Fountain Creek	1,233

DA = Drainage Area

7.2.4 Urban Development

Nonpoint source loading of fecal bacteria from urban land use areas is attributable to multiple sources. These include: storm water 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 infiltration through soils and interaction with groundwater. The percentage of subwatershed land use area classified as urban ranges from 0.1% to 9.7% (see Tables A-1 & A-2 and Figures 8 & 9). Subwatersheds 0102 & 0301 have the largest area and percentage of urban land use.

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

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) which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

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

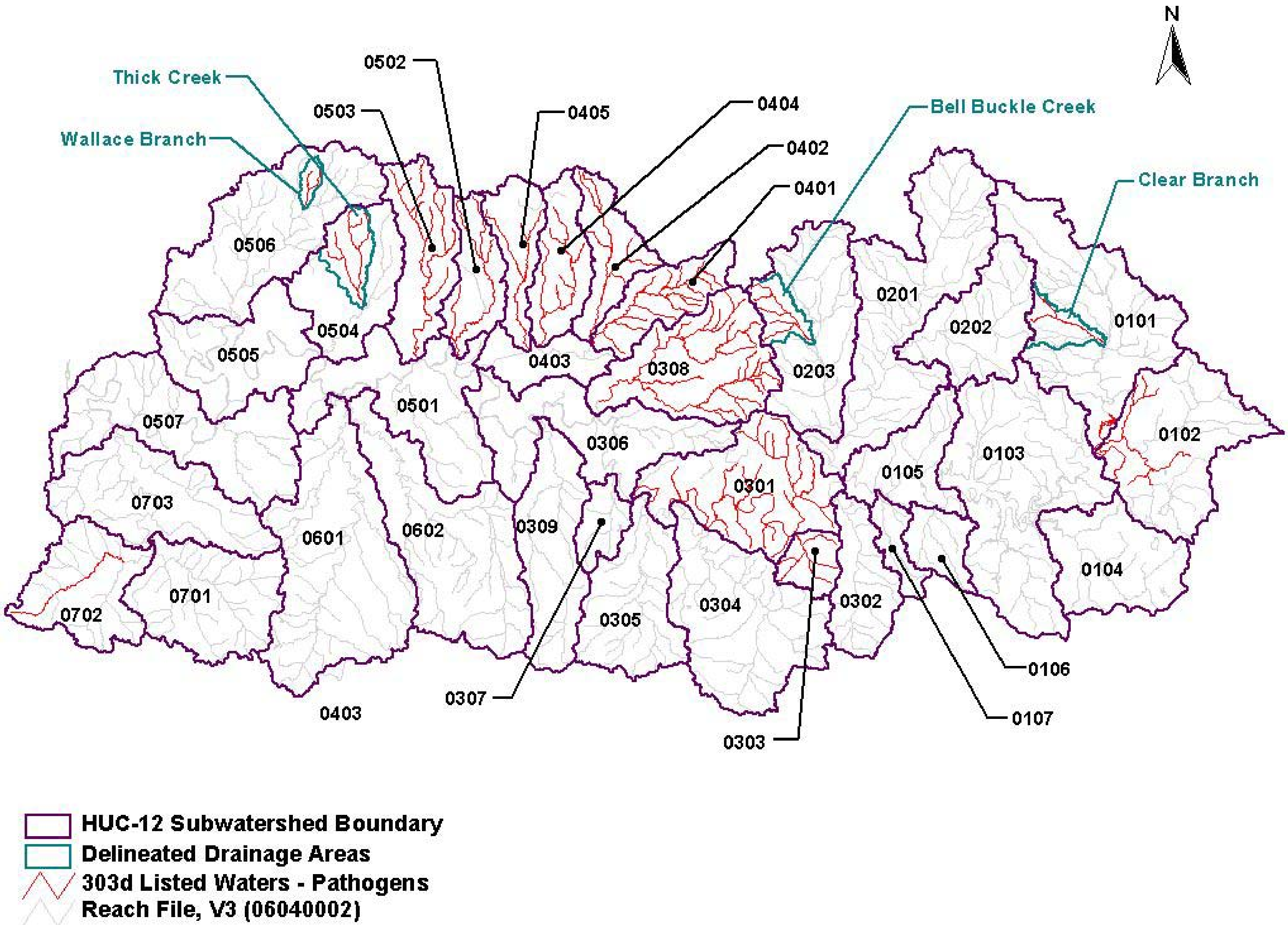
An important objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time, toxicity,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

This document describes fecal coliform TMDL, Waste Load Allocation (WLA), and Load Allocation (LA) development for waterbodies identified as impaired due to pathogens on the 1998 303(d) list or 2002 303(d) list. Since the drainage area of most impaired waterbodies corresponded to HUC-12 subwatershed drainage areas, analyses were performed on a HUC-12 basis. In cases where impaired waterbody drainage areas were small with respect to the HUC-12 subwatershed (Wallace Branch, Thick Creek, Bell Buckle Creek, and Clear Branch), analyses were based on the drainage area of the impaired waterbody. HUC-12 subwatersheds and delineated drainage areas are shown in Figure 10.

8.1 TMDL Analysis Methodology

Establishing the relationship between in-stream water quality and source loading is an important component of TMDL development. It allows the determination of the relative contribution of sources to total pollutant loading and the evaluation of potential changes to water quality resulting from implementation of various management options. This relationship can be developed using a variety of techniques ranging from qualitative assumptions based on scientific principles to numerical computer modeling. TMDLs for impaired waterbodies in the Upper Duck River watershed were developed using two different methodologies to assure compliance with both the 200 counts/100 ml geometric mean standard and the 1,000 counts/100 ml maximum standards (ref.: Section 5.0).

Figure 10 HUC-12 Subwatershed Boundaries & Delineated Drainage Areas in the Upper Duck River Watershed



8.1.1 Dynamic Loading Model Method

In order to demonstrate compliance with the 200 counts/100 ml geometric mean water quality standard, a dynamic loading model was chosen to: a) continuously simulate fecal coliform bacteria deposition on land surfaces and pollutant transport to receiving waters in response to storm events; b) incorporate seasonal effects on the production and fate of fecal coliform bacteria; and c) simulate continuous fecal coliform concentration in surface waters.

The Loading Simulation Program C++ (LSPC) is a dynamic watershed model based on the Hydrologic Simulation Program - Fortran (HSPF) and was selected for TMDL analyses of pathogen impaired waters in the Upper Duck River watershed. LSPC was used to simulate the deposition and transport of fecal coliform bacteria from land surfaces, point source loading, and compute the resulting water quality response. From model output, instream 30-day geometric mean concentrations were computed, critical conditions identified, existing loads determined, and reductions required to meet the target concentrations (standard + MOS) calculated. Details of model development, calibration and TMDL analyses are presented in Appendix C.

8.1.2 Load Duration Curve Method

A load duration curve 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 were considered to be well suited for analysis of periodic monitoring data collected by grab sample and determination of the load reductions required to meet the target maximum concentration (standard - MOS). Details of load duration curve development for impaired waterbodies in the Upper Duck River watershed are presented in Appendix D.

Due to the uncertainties associated with a large drainage area (~ 434 mi^2), the vast majority of which is not impaired for pathogens, and the effects of Normandy Dam, no loading model was constructed for impaired waterbodies in HUC-12 subwatersheds 0301 & 0303. TMDLs were developed for these waterbodies using the load duration curve method only.

8.2 Margin of Safety

There are two methods for incorporating an MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions to develop allocations; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. In these TMDLs, both and explicit and implicit MOS were utilized.

<u>Dynamic Loading Model Analysis</u>
An explicit MOS, equal to 10% of the geometric mean fecal coliform standard (200 counts/100 ml), was utilized for TMDL modeling analyses. Application of this explicit MOS of 20 counts/100 ml results in an effective 30-day geometric mean target concentration of 180 counts/100 ml.

Implicit MOS includes the use of conservative modeling assumptions and a 10-year continuous simulation that incorporates a range of meteorological events. Conservative modeling assumptions used include: septic systems discharging directly into the streams; development of the TMDL using loads based on the design flow and fecal coliform permit limits of NPDES facilities; all land uses connected directly to streams; fecal coliform applied to land surfaces was not subjected to die-off or absorption rates ;and a conservative value was used to estimate the in-stream decay of fecal coliform in the waterbodies.

Load Duration Curve Analysis
An explicit MOS, equal to 10% of the maximum fecal coliform standard (1,000 counts/100 ml), was utilized for TMDL analyses. Application of this explicit MOS of 100 counts/100 ml results in an effective maximum target concentration of 900 counts/100 ml.

Note: In this document, the water quality standard is the instream goal. The term “target concentration” reflects the application of an explicit Margin of Safety (MOS) to the water quality standard. See Section 5.0.

8.3 Expression of TMDL, WLAs, & LAs

In this document, fecal coliform TMDLs are expressed as the percent reduction in instream loading required to decrease: a) the existing 30-day geometric mean concentration to the target of 180 counts/100 ml; and b) the existing maximum concentration to the target of 900 counts/100 ml. WLAs & LAs for precipitation-induced loading sources are also expressed as required percent reductions in fecal coliform loading. Allocations for loading that are independent of precipitation (WLAS for WWTFs, WLAs for CAFOs, and LAs for “other direct sources”) are expressed as counts per day.

8.4 Determination of TMDL

Load reductions for impaired waterbodies were developed using the Dynamic Loading Model to achieve compliance with the 30-day geometric mean target concentration (Appendix C). Load reductions were also developed for these waterbodies using Load Duration Curves to achieve compliance with the maximum target concentration (Appendix D). The instream load reductions determined by these two methodologies were compared and the largest required load reduction was selected as the TMDL for each impaired subwatershed. TMDLs for impaired subwatersheds are shown in Table 10.

8.5 Determination of WLAs & LAs

WLAs & LAs are developed in Appendix E for point sources and nonpoint sources respectively. TMDLs, WLAs, & LAs for impaired subwatersheds are summarized in Table 11.

Table 10 Determination of TMDLs for Impaired Waterbodies

Impaired Waterbody	HUC-12 Subwatershed (06040002____)	Required Load Reduction		
		Dynamic Loading Model [a]	Load Duration Curve [b]	TMDL
		[%]	[%]	[%]
Clear Branch	DA	NR	89.3	89.3
Duck River	0101	20.4	NR	20.4
Little Duck River	0102	NR	NR	NR
Bell Buckle Creek	DA	74.6	62.5	74.6
Duck River	0301	NA	27.0	27.0
Duck River Tribs.	0303	NA	27.0	27.0
Fall Creek Hurricane Creek	0308	86.2	10.0	86.2
North Fork Creek	0401	87.9	75.7	87.9
Alexander Creek	0402	87.3	43.8	87.3
Weakley Creek	0404	87.1	57.1	87.1
Clem Creek	0405	89.9	NR	89.9
Wilson Creek	0502	89.3	75.7	89.3
Spring Creek Lick Creek	0503	85.9	41.8	85.9
Thick Creek	DA	96.5	67.9	96.5
Wallace Branch	DA	77.9	86.3	86.3
Fountain Creek	0702	75.9	51.1	75.9

Notes: DA = Drainage area; NR = No reduction required; NA = No analysis performed

a. Required load reduction to comply with 30-day geometric mean target of 180 cts./100 ml (Standard – MOS).
b. Required load reduction to comply with maximum target of 900 cts./100 ml (Standard – MOS).

Table 11 WLAs & LAs for Impaired Waterbodies

Impaired Waterbody	HUC-12 Subwatershed (06040002____)	WLAs				LAs	
		WWTFs		CAFO	MS4s [a]	Precipitation Induced Nonpoint Sources	Other Direct Sources [b]
		Monthly Avg.	Daily Max.				
		[cts./day]	[cts./day]	[cts./day]	[% Red.]	[% Red.]	[cts./day]
Clear Branch	DA	NA	NA	NA	89.3	89.3	0
Duck River	0101	NA	NA	NA	20.4	20.4	0
Little Duck River	0102	2.572×10^{11}	1.286×10^{12}	NA	NR	NR	0
Bell Buckle Creek	DA	2.118×10^{10}	1.059×10^{11}	0	74.6	74.6	0
Duck River	0301	4.895×10^{11}	2.448×10^{12}	0	27.0	27.0	0
Duck River Tribs.	0303	NA	NA	NA	27.0	27.0	0
Fall Creek Hurricane Creek	0308	NA	NA	0	86.2	86.2	0
North Fork Creek	0401	NA	NA	0	87.9	87.9	0
Alexander Creek	0402	NA	NA	NA	87.3	87.3	0
Weakley Creek	0404	NA	NA	NA	87.1	87.1	0
Clem Creek	0405	NA	NA	NA	89.9	89.9	0
Wilson Creek	0502	NA	NA	NA	89.3	89.3	0
Spring Creek Lick Creek	0503	NA	NA	NA	85.9	85.9	0
Thick Creek	DA	NA	NA	NA	96.5	96.5	0
Wallace Branch	DA	NA	NA	NA	86.3	86.3	0
Fountain Creek	0702	NA	NA	NA	75.9	75.9	0

Note: DA = Drainage Area; NA = Not applicable; NR = No reduction required.

a. Applies to any MS4 discharge loading in the HUC-12 subwatershed or drainage area.

b. The objective for all "other direct sources" is a load allocation of zero. It is recognized, however, that for leaking septic systems, a LA of 0 counts/day may not be practical. For these sources, the LA is interpreted to mean a reduction in fecal coliform loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for pathogens.

9.0 IMPLEMENTATION PLAN

The TMDLs, WLAs, and LAs developed in Section 7 are intended to be the first phase of a long-term effort to restore the water quality of impaired waters in the Upper Duck River watershed through reduction of excessive pathogen loading. An adaptive management approach, within the context of the State's rotating watershed management approach, will be used to refine TMDLs, WLAs, and LAs as required to meet water quality goals.

TMDLs, WLAs, & LAs for most impaired waterbodies in the Upper Duck River watershed are implemented for the entire HUC-12 subwatershed in which impaired segments are located. TMDLs, WLAs, & LAs for Clear Branch, Bell Buckle Creek, Thick Creek, and Wallace Branch, however, are applied only to the drainage areas of these waterbodies (see Figure 10).

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 permit at all times. 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 expressed as both maximum and average loads in counts per day. WLAs are derived from facility design flows and permitted fecal coliform limits.

9.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For 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, 2002a) was issued on February 27, 2003 and requires 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

For discharges into impaired waters, the Small MS4 General Permit (ref: http://www.state.tn.us/environment/wpc/stormh2o/MS4II.php) requires that SWMPs include a section describing how discharges of pollutants of concern will be controlled to ensure that they do not cause or contribute to instream exceedances of water quality standards. Specific measures and BMPs to control pollutants of concern must also be identified. In addition, MS4s must implement the WLA provisions of an applicable TMDL and describe methods to evaluate whether storm water controls are adequate to meet the WLA.

Implementation of the fecal coliform WLAs for MS4s in this TMDL document will require effluent or instream monitoring to evaluate SWMP effectiveness with respect to reduction of pathogen loading.

9.1.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

Existing or future CAFOs that are located in impaired subwatersheds will be required to comply with the WLAs in Table 11. These WLAs will be implemented through the Nutrient Management Plan (NMP), liquid waste handling system, and Best Management Practices (BMP) provisions of NPDES Permit No. TNA000000, *Class II Concentrated Animal Feeding Operation General Permit*. All discharges, except during a catastrophic or chronic rainfall event are not authorized by this permit. Any discharge shall not cause an exceedance of Tennessee water quality standards.

9.2 Load Allocations for 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. Local citizen-led and implemented management measures offer the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. 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 is described in the *Big Rock Creek Watershed Final Management Plan, March 2003* (NCDRP, 2003), prepared by the Center for Watershed Protection for The Nature Conservancy, Duck River Project. This development of this plan was funded, in part, under an agreement with the Tennessee Department of Agriculture, Nonpoint Source Program and a U.S. Environmental Protection Agency Assistance Agreement (#C9994674-01-0). This plan was based on an extensive evaluation of stream conditions, various investigations and analyses, and usage surveys of conservation practices in the Big Rock Creek subwatershed. The plan establishes subwatershed goals and recommendations to meet these goals. A number of restoration projects are identified and prioritized and plan implementation is divided into three phases for implementation. The plan may be accessed at:

http://www.cwp.org/watershed_services/Big_Rock_es.pdf

The Tennessee Department of Environment & Conservation (TDEC) will coordinate with the Tennessee Department of Agriculture (TDA) and the Natural Resources Conservation Service (NRCS) to address issues concerning fecal coliform loading from agricultural land uses in the Upper Duck River watershed. It is recommended that additional information (such as livestock populations by subwatershed, animal access to streams, manure application practices, etc.) be evaluated to better identify and quantify agricultural sources of fecal coliform loading in order to minimize uncertainty in future modeling efforts. It is further recommended that BMPs be utilized to reduce the amount of fecal coliform bacteria transported to surface waters from agricultural sources to the maximum extent practicable.

9.3 Additional Monitoring

Additional monitoring and assessment activities are recommended for the Little Duck River (HUC-12 subwatershed 0102) to verify the assessment status of the stream reaches identified on the 1998 and 2002 303(d) lists as impaired due to pathogens. If it is determined that these stream reaches are still not fully supporting designated uses, then sufficient data to enable development of a TMDL must be acquired.

9.4 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 fecal coliform impairment are not readily apparent, utilization of Bacteria Source Tracking (BST) technologies are recommended.

9.5 Evaluation of TMDL 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 fecal coliform TMDLs for the Upper Duck 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. The Public Notice Announcement is included as Appendix F.

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) A letter was sent to WWTFs located impaired subwatersheds in the Upper Duck River watershed that are permitted to discharge treated sanitary wastewater advising them of the proposed TMDLs and their availability on the TDEC website. The letter also stated that a written copy of the draft TMDL document would be provided on request. Letters were sent to the following facilities:

   Tyson Foods, Inc (TN0002135)
   Wartrace STP (TN0020443)
   Bell Buckle STP (TN0020591)
   Shelbyville STP (TN0024180)
   Manchester STP (TN0025038)

4) A draft copy of the proposed TMDLs was sent to the City of Shelbyville and Tennessee Department of Transportation. These MS4s are wholly or partially located in pathogen-impaired subwatersheds. Letters were sent to the City of Tullahoma and City of Lewisburg advising them of the proposed TMDLs and their availability on the TDEC website.

No written comments were received during the Public Notice period.

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 of Impaired Subwatersheds & Drainage Areas

Table A-1 MRLC Land Use Distribution of Pathogen Impaired HUC-12 Subwatersheds

Land Use	HUC-12 Subwatershed (06040002__)							
	0101		0102		0301		0303	
	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]
Open Water	157	0.43	22	0.08	213	0.78	1	0.02
Low Intensity Residential	205	0.56	734	2.61	1,263	4.62	4	0.08
High Intensity Residential	26	0.07	245	0.87	516	1.89	0	0.00
High Intensity Commercial /Industrial/Transportation	147	0.40	666	2.37	867	3.17	0	0.00
Bare Rock/Sand/Clay	2	0.01	0	0.00	0	0.00	0	0.00
Transitional	139	0.38	57	0.20	4	0.01	0	0.00
Deciduous Forest	14,147	38.80	13,871	49.38	8,572	31.32	2,313	46.12
Evergreen Forest	132	0.36	291	1.04	685	2.50	222	4.43
Mixed Forest	729	2.00	820	2.92	2,586	9.45	736	14.68
Pasture/Hay	10,056	27.58	5,599	19.93	6,625	24.21	1,319	26.30
Row Crops	8,325	22.83	3,637	12.95	4,621	16.89	420	8.37
Other Grasses (Urban/Recreational)	63	0.17	474	1.69	788	2.88	0	0.00
Woody Wetlands	2,280	6.25	1,591	5.66	502	1.83	0	0.00
Emergent Herbaceous Wetlands	53	0.15	82	0.29	50	0.18	0	0.00
Quarries/Strip Mines/Gravel Pits	0	0.00	0	0.00	74	0.27	0	0.00
Subtotal – Urban	517	1.42	1,702	6.06	2,650	9.68	4	0.08
Subtotal - Agriculture	18,381	50.41	9,236	32.88	11,246	41.09	1,739	34.68
Subtotal - Forest	17,406	47.74	17,129	60.98	13,257	48.44	3,271	65.22
Total	**36,461**	**100.00**	**28,089**	**100.00**	**27,366**	**100.00**	**5,015**	**100.00**

Table A-1 MRLC Land Use Distribution of Pathogen Impaired HUC-12 Subwatersheds (Continued)

Land Use	HUC-12 Subwatershed (06040002__)							
	0308		0401		0402		0404	
	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]
Open Water	19	0.08	4	0.03	1	0.01	38	0.33
Low Intensity Residential	115	0.46	32	0.28	15	0.14	66	0.57
High Intensity Residential	0	0.00	0	0.00	0	0.00	6	0.05
High Intensity Commercial /Industrial/Transportation	244	0.97	46	0.40	3	0.03	76	0.65
Bare Rock/Sand/Clay	0	0.00	0	0.00	0	0.00	0	0.00
Transitional	7	0.03	0	0.00	0	0.00	0	0.00
Deciduous Forest	6,917	27.56	2,604	22.75	2,034	19.25	2,325	19.94
Evergreen Forest	826	3.29	206	1.80	197	1.86	374	3.21
Mixed Forest	2,285	9.10	778	6.80	700	6.62	981	8.41
Pasture/Hay	8,941	35.63	4,507	39.38	4,454	42.15	3,990	34.23
Row Crops	5,337	21.27	2,973	25.97	2,880	27.25	3,020	25.90
Other Grasses (Urban/Recreational)	129	0.51	0	0.00	18	0.17	5	0.04
Woody Wetlands	272	1.08	279	2.44	252	2.38	678	5.82
Emergent Herbaceous Wetlands	5	0.02	17	0.15	14	0.13	99	0.85
Quarries/Strip Mines/Gravel Pits	0	0.00	0	0.00	0	0.00	0	0.00
Subtotal – Urban	366	1.46	78	0.68	18	0.17	148	1.27
Subtotal - Agriculture	14,278	56.89	7,480	65.35	7,334	69.40	7,010	60.13
Subtotal - Forest	10,434	41.57	3,884	33.93	3,215	30.42	4,462	38.27
Total	**25,097**	**100.00**	**11,446**	**100.00**	**10,568**	**100.00**	**11,658**	**100.00**

Table A-1 MRLC Land Use Distribution of Pathogen Impaired HUC-12 Subwatersheds (Continued)

Land Use	HUC-12 Subwatershed (06040002__)							
	0405		0502		0503		0702	
	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]
Open Water	146	1.54	4	0.04	7	0.04	2	0.01
Low Intensity Residential	30	0.32	13	0.13	162	1.00	65	0.37
High Intensity Residential	2	0.02	0	0.00	17	0.11	7	0.04
High Intensity Commercial /Industrial/Transportation	80	0.84	11	0.11	164	1.01	24	0.13
Bare Rock/Sand/Clay	0	0.00	0	0.00	0	0.00	0	0.00
Transitional	0	0.00	0	0.00	0	0.00	0	0.00
Deciduous Forest	2,338	24.62	2,417	23.59	3,347	20.71	7,542	42.42
Evergreen Forest	611	6.43	486	4.74	854	5.28	312	1.75
Mixed Forest	1,215	12.79	1,093	10.67	2,111	13.06	2,168	12.19
Pasture/Hay	3,432	36.14	4,362	42.56	6,641	41.09	6,526	36.70
Row Crops	1,532	16.13	1,862	18.17	2,804	17.35	1,132	6.37
Other Grasses (Urban/Recreational)	1	0.01	0	0.00	56	0.35	3	0.02
Woody Wetlands	101	1.06	0	0.00	0	0.00	0	0.00
Emergent Herbaceous Wetlands	8	0.08	0	0.00	0	0.00	0	0.00
Quarries/Strip Mines/Gravel Pits	0	0.00	0	0.00	0	0.00	0	0.00
Subtotal – Urban	112	1.18	24	0.23	343	2.12	96	0.54
Subtotal - Agriculture	4,964	52.27	6,224	60.73	9,445	58.44	7,658	43.07
Subtotal - Forest	4,274	45.01	3,996	38.99	6,368	39.40	10,025	56.38
Total	**9,496**	**100.00**	**10,248**	**100.00**	**16,163**	**100.00**	**17,781**	**100.00**

Table A-2 MRLC Land Use Distribution of Pathogen Impaired Drainage Areas

Land Use	Drainage Area							
	Clear Branch		Bell Buckle Creek		Thick Creek		Wallace Branch	
	[acres]	[%]	[acres]	[%]	[acres]	[%]	[acres]	[%]
Open Water	0	0.00	3	0.07	0	0.00	0	0.00
Low Intensity Residential	10	0.27	74	1.83	6	0.11	1	0.09
High Intensity Residential	0	0.00	8	0.20	0	0.00	0	0.00
High Intensity Commercial /Industrial/Transportation	2	0.05	11	0.27	2	0.04	0	0.00
Bare Rock/Sand/Clay	0	0.00	0	0.00	0	0.00	0	0.00
Transitional	7	0.19	0	0.00	0	0.00	0	0.00
Deciduous Forest	1,575	42.52	1,010	24.98	2,610	49.25	246	21.10
Evergreen Forest	12	0.32	200	4.95	260	4.91	40	3.43
Mixed Forest	82	2.21	539	13.33	812	15.32	113	9.69
Pasture/Hay	1,074	2900	1,727	42.71	889	16.78	552	47.34
Row Crops	849	22.92	419	10.36	720	13.59	206	17.67
Other Grasses (Urban/Recreational)	0	0.00	22	0.54	0	0.00	8	0.69
Woody Wetlands	93	2.51	30	0.74	0	0.00	0	0.00
Emergent Herbaceous Wetlands	0	0.00	1	0.02	0	0.00	0	0.00
Quarries/Strip Mines/Gravel Pits	0	0.00	0	0.00	0	0.00	0	0.00
Subtotal – Urban	19	0.51	93	2.30	8	0.15	1	0.09
Subtotal - Agriculture	1,923	51.92	2,146	53.07	1,609	30.36	758	65.01
Subtotal - Forest	1,762	47.57	1,802	44.56	3,682	69.48	407	34.91
Total	**3,704**	**100.00**	**4,044**	**100.00**	**5,299**	**100.00**	**1,166**	**100.00**

APPENDIX B

Water Quality Monitoring Data

There are a number of water quality monitoring stations that provide data for waterbodies identified as impaired for pathogens in the Upper Duck River watershed. The location of these monitoring stations is shown in Figure 5. Monitoring data recorded at these stations for fecal coliform or *E. coli* are tabulated in Table B-1.

Table B-1 Water Quality Monitoring Data – Upper Duck River Watershed

Monitoring Station	Date	Time	E. Coli	Fecal Coliform	Flow
			[cts./100 ml]	[cts./100 ml]	[cfs]
ALEXA004.0BE	1/10/00	0950	1,600	1,600	14.46
	4/13/00	1248	410	340	37.2
	7/24/00	1030	440	370	
BBUCK001.0BE	12/8/99	0845	20	46	
	1/25/00	1100	460	250	2.77
	2/17/00	1155	120	120	4.41
	3/15/00	1320	160	100	4.07
	4/27/00	1120	410	270	11.02
	5/25/00	1045	>2,400	2,400	0.55
	6/21/00	1200	370	450	
	8/6/01	1100	440	470	
BBUCK001.3BE	8/6/01	1130	310	390	23.8
CLEAR001.1CE	12/16/99	1130	>2,400	15,000	0.45
	1/26/00	1215	>2,400	9,700 *	1.01
	2/9/00	1127	2,400	7,400 *	0.96
	3/13/00	1045	50	6,000	8.15
	5/11/00	0950	>2,400	>20,000	1.80
	6/1/00	1100	1,700	5,400	0.83
CLEAR001.8BE	9/20/01	1156		58,000	19.92
CLEM000.4BE	2/8/00	1015	<1	1 *	14.7
	4/17/00	0723	410	170	
	5/10/01	1000	28	52	
DUCK216.2BE	12/7/99	0930	88	140	178.7
	12/7/99	0935	66	150	
	1/24/00	0930	180	150	249.3
	2/16/00	0950	1,300	1,500	
	3/15/00	1030	140	170	
	4/26/00	1040	870	1,100	
	6/15/00	0905		200	
	9/27/01	1031	410	670	
DUCK219.7BE	9/26/01	1230	310	380	

Table B-1 Water Quality Monitoring Data – Upper Duck River Watershed (Continued)

Monitoring Station	Date	Time	E. Coli	Fecal Coliform	Flow
			[cts./100 ml]	[cts./100 ml]	[cfs]
DUCK235.6BE	12/7/99	1245	8	50	174.0
	1/24/00	1130	870	630 *	
	2/17/00	0925	160	130	246.6
	3/14/00	1235	190	150	
	4/27/00	0942	110	180	
	6/21/00	1000	490	490	
DUCK237.0BE	9/26/01	1003	340	380	
DUCK269.6CE	12/20/99	1300	12	11 *	
	1/27/00	1100	5	4 *	21.04
	2/9/00	1318	1 *	2 *	21.58
	3/14/00	1035	19	140	72.9
	5/11/00	1130	14	52	44.14
	6/8/00	1215	2	14 *	27.91
FALL001.2BE	9/11/01	1050	100	110	
FALL003.0BE	1/12/00	0935	120	100	12.11
	4/13/00	1103	1,100	1,000	156.2
	7/24/00	0600	<1	<1	
	7/24/00	0910	46	1	
	7/24/00	0920	190	270	
	7/24/00	0930	<1	<1	
	10/16/00	1115	4	5	
	5/8/01	1100	490	510	3.86
FALL006.1BE	9/10/01	0920	>2,400	>20,000	
HURRI001.0BE	9/11/01	1235	120	140	
HURRI004.2BE	1/12/00	1100	>2,400	2,300	3.16
	4/19/00	0910	350	280	8.33
	7/25/00	0900	47	87	
	10/17/00	1100	1,200	1,000	
	5/10/01	1230	550	270	
LDUCK001.3CE	1/20/99	1340	55	67 *	
	1/31/00	1000	130	15	16.44
	2/8/00	1245	15	20	18.72
	3/14/00	1010	41	83	69.35
	5/11/00	1100	35	60	23.43
	6/8/00	1140	23	60 *	16.68

Table B-1 Water Quality Monitoring Data – Upper Duck River Watershed (Continued)

Monitoring Station	Date	Time	E. Coli	Fecal Coliform	Flow
			[cts./100 ml]	[cts./100 ml]	[cfs]
LICK001.8ML	10/6/99	1000	170	770	0.01
	10/6/99	1015	580	1,300	
	11/9/99	0950	1,300	1,200	0.01
	11/9/99	0951	820	1,700	
	12/2/99	0935	690	530	0.05
	12/2/99	0937	1,000	670	
	1/6/00	1000	>2,400	9,800 *	2.41
	1/6/00	1015	>2,400	7,600 *	
	2/8/00	0955	1,000	430	1.39
	2/8/00	0958	1,600	420	
	3/8/00	1015	>2,400	5,200	4.81
	4/6/00	0940	1,300	1,300	
	4/6/00	0945	1,600	1,300 *	
	5/4/00	1020	>2,400	14,000 *	4.8
	5/4/00	1021	>2,400	15,000 *	
	6/20/00	0950	920	1,700	0.06
	9/17/01	1030	130	120	
NFORK003.5BE	9/10/01	1145	75	80	
NFORK004.7BE	9/11/01	0620	<1	<1	
	9/11/01	0950	550	360	
	9/11/01	1000	230	250	
	9/11/01	1020	<1	<1	
NFORK007.7BE	2/1/00	0915	160	190	28.5
	4/17/00	1025	120	93	58.5
	7/24/00	0950	67	90	
	5/8/01	0945	<1	<1	
	5/8/01	1200	<1	1 *	
	5/8/01	1205	2,400	3,700	
	5/8/01	1210	>2,400	3,600	2.41
NFORK016.4BE	1/11/00	0930	730	530	0.71
	4/19/00	0945	490	340	0.89
	5/10/01	1315	310	240	0.024

Table B-1 Water Quality Monitoring Data – Upper Duck River Watershed (Continued)

Monitoring Station	Date	Time	E. Coli	Fecal Coliform	Flow
			[cts./100 ml]	[cts./100 ml]	[cfs]
SPRIN003.2ML	10/16/99	1045	1,700	1,300	0.01
	11/9/99	1035	550	730	0.01
	12/2/99	1047	770	540	0.05
	1/6/00	1045	>2,400	4,800	17.62
	2/8/00	1034	340	240	6.26
	3/8/00	1100	690	510	25.68
	3/8/00	1101	290	400	
	4/5/00	1015	980	1,000	
	5/4/00	1050	>2,400	13,000 *	34.88
	6/20/00	1025	870	2,000	0.76
THICK002.0ML	1/24/00	0815	230	230	1.87
	4/12/00	0830	2,000	2,800	13.46
	7/12/00	0915	1,100	730	
	7/12/00	0953	<1	<1	
	7/12/00	0710	<1	<1	
	10/30/00	1238	2	4 *	
	5/29/01	1015	120	180	
TVA Sta. (RM 14.5)	8/26/98	0915		1,490	6.94
	9/29/98	1015		1,690	3.7
	10/20/98	0950		<1	2.74
	11/17/98	1440		3,210 *	2.29
TVA Sta. (RM 17.1)	8/26/98	0800		1,220	2.74
	9/29/98	0925		1,750	1.25
	10/20/98	0922		5,260	1.76
	11/17/98	1400		<1	1.38

Table B-1 Water Quality Monitoring Data – Upper Duck River Watershed (Continued)

Monitoring Station	Date	Time	E. Coli	Fecal Coliform	Flow
			[cts./100 ml]	[cts./100 ml]	[cfs]
WALLA000.8WI	2/8/00	1145	55	27	0.17
	4/12/00	1130	2,400	4,100	4.68
	7/12/00	1130	>2,400	>20,000	
	5/30/00	1030	130	120	
WEAKL001.7BE	9/10/01	1005	550	500	
WEAKL005.2BE	1/10/00	1020	2,400	2,100 *	12.45
	4/17/00	1130	260	300	9.28
	5/8/01	1330	800	770	0.04
WILSO000.7ML	11/9/99	1105	550	430	0.01
	12/2/99	1040	31	36	0.12
	1/6/00	1130	>2,400	3,700	
WILSO002.9BE	2/9/00	1104	130	1 *	4.29
	3/8/00	1145	610	300	8.63
	4/6/00	1055	230	360	
	5/4/00	1155	>2,400	12,000 *	30.78
	6/20/00	1055	250	230	0.51
WILSO005.2BE	5/20/96	1300		1,100	21.86
	1/10/00	1200	>2,400	4,000	8.66
	4/17/00	0850	610	410	16.22
	7/25/00	1150	>2,400	>7,800	
	10/16/00	0645	<1	<1	
	10/16/00	0930	<1	<1	
	10/16/00	0945	>2,400	18,000 *	0.03
	10/16/00	0940	>2,400	17,000 *	
	5/10/01	0930	>2,400	3,100	1.185
	5/10/01	0645	<1	<1	

* Estimate

APPENDIX C

Dynamic Loading Model Methodology

DYNAMIC LOADING MODEL METHOD

C.1 Model Selection

The Loading Simulation Program C++ (LSPC) was selected for TMDL analyses of pathogen impaired waters in the Upper Duck River watershed. LSPC is a dynamic watershed model based on the Hydrologic Simulation Program - Fortran (HSPF) and is well suited to demonstrate compliance with the 200 counts/100 ml geometric mean standard. LSPC was used to simulate the buildup and washoff of fecal coliform bacteria from land surfaces in response to storm events, loading from point sources, and compute the resulting water quality response. From model output, instream 30-day geometric mean concentrations were computed, critical conditions identified, existing loads determined, and reductions required to meet target concentrations (standard - MOS) calculated.

C.2 Model Set Up

The Upper Duck River watershed was delineated into subwatersheds in order to facilitate model hydrologic and water quality calibration; and to characterize relative fecal coliform contributions from significant contributing drainage areas. Boundaries were constructed so that subwatershed “pour points” coincided, when possible, with USGS continuous stream gages and water quality monitoring stations. Watershed delineation was based on the Rf3 stream coverage and Digital Elevation Model (DEM) data. This discretization allows management and load reduction alternatives to be varied by subwatershed.

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 water quality 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. Results of WCS subwatershed characterizations were input into the Fecal Coliform Loading Estimation Spreadsheet (FCLES), developed by Tetra Tech, Inc., to estimate LSPC input parameters associated with fecal coliform buildup (loading rates) and subsequent washoff from land surfaces. In addition, FCLES was used to estimate direct sources of fecal coliform loading to water bodies from leaking septic systems and animals having access to streams. Information from the WCS and FCLES utilities were used as initial input for variables in the LSPC model.

An important factor influencing model results is the precipitation data contained in the meteorological data files used in these simulations. The pattern and intensity of rainfall affects the buildup and washoff of fecal coliform bacteria from the land into the streams, as well as the dilution potential of the stream. Weather data from the multiple meteorological stations were available for the time period from January 1970 through December 2001. 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 (10/1/91 – 9/30/01) used for TMDL analysis.

C.3 Model Calibration

The calibration of the LSPC watershed model involves both hydrology and water quality components. The model must be first calibrated to appropriately represent hydrologic response to meteorological conditions before water quality calibration and subsequent simulations can be performed. Due to the lack of comprehensive data sets at the mouths of the listed waterbodies, data collected at the nearest locations were used to calibrate the subwatershed models.

C.3.1 Hydrologic Calibration

Hydrologic calibration of the watershed model involves comparison of simulated stream flow to historic stream flow data from USGS stream gaging stations for the same period of time. The USGS continuous record stations located in Wartrace Creek (USGS 03597590) and Garrison Fork (USGS 03597210) were selected for hydrology calibration. 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 stream flow. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge.

Each 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). Statistical stream volumes and flows were evaluated over the entire 10-year simulation period . The resulting calibrated models were considered to best represent watershed hydrology over a wide range of meteorological conditions for certain subwatershed areas. The results of the hydrologic calibration for Wartrace Creek at USGS Station 03597590 (ref.: Figure 5) are shown in Table C-1 and Figures C-1 through C-10. This hydrologic calibration was used as the basis for all models except for Clear Branch, upper Duck River, and Little Duck River. The results of the hydrologic calibration for Garrison Fork at USGS Station 03597210 (ref.: Figure 5) are shown in Table C-2 and Figures C-11 through C-20. The Clear Branch, upper Duck River, and Little Duck River models were based on this calibration.

C.3.2 Water Quality Calibration

Water quality calibration involves comparison of simulated instream fecal coliform concentrations to monitoring data concentrations on the same date. An LSPC model, using values for hydrologic variables derived from the hydrologic calibration, was configured for each impaired waterbody so that the model pour point corresponded to the location of the water quality monitoring station. Watershed data, produced with WCS, were processed through the FCLES spreadsheet to generate fecal coliform loading data for use as <u>initial</u> input for model pollutant loading variables. Instream decay of fecal coliform bacteria was conservatively estimated using the values reported in Lombardo (1972). For freshwater streams, decay ranges from 0.008 hr^{-1} to 0.13 hr^{-1}, with a median value of 0.048 hr^{-1}. The median value was used as initial input to model simulations. Derivation of the various loading variables is discussed in the subsections that follow.

Model variables were adjusted, as necessary, within reasonable limits until acceptable agreement was achieved between simulated and instream observed data was achieved. Model variables adjusted include:

- Rate of fecal coliform bacteria accumulation
- Maximum storage of fecal coliform bacteria
- Rate of surface runoff that will remove 90% of stored fecal coliform bacteria
- Concentration of fecal coliform bacteria in interflow
- Concentration of fecal coliform bacteria in groundwater
- Concentration of fecal coliform bacteria and rate of flow of “other direct sources”.
- In-stream fecal coliform decay (die-off) rate.

C.3.2.1 Point Sources

For existing conditions, NPDES facilities located in modeled watersheds are represented as point sources of average (constant) flow and concentration based on the facility’s flow and effluent fecal coliform concentration as reported on Discharge Monitoring Reports (DMRs).

C.3.2.2 Nonpoint Sources

A number of nonpoint source categories are not associated with land loading processes and are represented as direct, instream source contributions in the model. These may include, but are not limited to, failing septic systems, animals in streams, illicit connections, direct discharge of raw sewage, and undefined sources. All other nonpoint sources involve land loading of fecal coliform bacteria and washoff as a result of storm events. Only a portion of the load from these sources is actually delivered to streams due to the mechanisms of washoff (efficiency), decay, and incorporation into soil (adsorption, absorption, filtering) before being transported to the stream. Therefore, land loading nonpoint sources are represented as indirect contributions to the stream. Buildup, washoff, and die-off rates are dependent on seasonal and hydrologic processes.

C.3.2.2.1 Wildlife

Wildlife deposit fecal 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. In order to account for higher density areas and loading due to other species, a conservative density of 45 animals per square mile was used for modeling purposes. Fecal coliform loads due to deer are estimated by EPA to be 5.0×10^8 counts/animal/day. The resulting fecal coliform loading on a unit area basis is 3.52×10^7 counts/acre/day and is considered background.

C.3.2.2.2 Land Application of Agricultural Manure

In the water quality model, livestock populations are distributed to subwatersheds based on information derived from WCS. Fecal coliform loading rates were calculated from livestock populations based on manure application rates, literature values for bacteria concentrations in livestock manure, and the following assumptions:

- Fecal content in manure was adjusted to account for die-off due to known treatment/storage methods.

- Manure application rates from the various animal sources are applied according to application practices throughout the year.

- The fraction of manure available for runoff is dependent on the method of manure application. In the water quality model, the fraction available is estimated based on incorporation into the soil.

Fecal coliform production rates used in the model for beef cattle, dairy cattle, hogs, horses, and chicken are 1.06×10^{11} counts/day/beef cow, 1.04×10^{11} counts/day/dairy cow, 1.24×10^{10} counts/day/hog, 4.18×10^{8} counts/day/horse, and 1.38×10^{8} counts/day/chicken (NCSU, 1994).

C.3.2.2.3 Grazing Animals

Cattle spend time grazing on pastureland and deposit feces onto the land. During storm events, a portion of this material containing fecal coliform bacteria is transported to streams. Beef cattle are assumed to spend all their time in pasture. The percentage of feces deposited during grazing time is used to estimate fecal coliform loading rates from pastureland. Because there is no assumed monthly variation in animal access to pastures in middle Tennessee, the fecal loading rate does not vary significantly throughout the year. Therefore, the loading rate to pastureland is assumed to be relatively constant within each subwatershed. However, this rate varies across subwatersheds depending on livestock population. The approximate loads from grazing cattle vary from 1.09×10^{10} to 5.09×10^{10} counts/acre-day. Contributions of fecal coliform from wildlife (as noted in Section D.3.2.2.1) are also included in these rates.

C.3.2.2.4 Urban Development

Urban land use represented in the MRLC database includes areas classified as: high intensity commercial, industrial, transportation, low intensity residential, high intensity residential, and transitional. Associated with each of these classifications is a percent of the land area that is impervious. A single, area-weighted loading rate from urban areas is used in the model and is based on the percentage of each urban land use type in the watershed and buildup and accumulation rates referenced in Horner (Horner, 1992). In the water quality calibrated model, this rate is 1.0×10^{9} counts/acre-day and is assumed constant throughout the year.

C.3.2.2.5 Other Direct Sources

As previously stated, there are a number of nonpoint sources of fecal coliform bacteria that are not associated with land loading and washoff processes. These include animal access to streams, failing septic systems, illicit discharges, and other undefined sources. In each watershed, these miscellaneous sources have been modeled as point sources of constant flow and fecal coliform concentration and are referred to as "other direct sources" in this document. The initial baseline values of flow and concentration were estimated using the FCLES spreadsheets and the following assumptions:

- The load attributed to animals having access to streams is initially based on the beef cow population in the watershed. The percentage of animals having access to streams is derived from assumptions on animals in operations that are adjacent to streams and seasonal and behavioral assumptions. Literature values were used to estimate the fecal coliform bacteria concentration in beef cow manure.

- The initial baseline loads attributable to leaking septic systems is based on an assumed failure rate of 20 percent.

Flow and concentration variables were adjusted during water quality calibration to best-fit simulated in-stream fecal coliform concentrations during dry weather conditions.

C.3.2.3 Water Quality Calibration Results

Water quality calibration results show that, overall, each waterbody model adequately simulates peaks in fecal coliform bacteria in response to rainfall events and pollutant loading dynamics. In some cases, an observed value is not simulated in the model well due to differences in rainfall at the meteorological station as compared to localized rainfall occurring in the watershed, or is the result of an unknown source that is not included in the model.

Water quality calibrations for the Upper Duck River watershed were performed at three monitoring sites, each located in a different Level IV ecoregion. Model parameters from these calibrations were then used for subwatershed models in the same ecoregion, as shown in Table C-3. Loading parameters for "other direct sources" were adjusted for subwatershed models according to land area. The results of the water calibrations are shown in Figures C-21 through C-23.

C.4 Margin of Safety

There are two methods for incorporating an MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions to develop allocations; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. For TMDL analyses using LSPC, both an explicit and implicit MOS were used. The explicit MOS is 20 counts/100 ml, equal to 10% of the 200 counts/100 ml geometric standard. This results in a target fecal coliform concentration of 180 counts/100 ml. The implicit MOS includes the use of conservative modeling assumptions and a 10-year continuous simulation that incorporates a wide range of meteorological events. Conservative modeling assumptions used include: septic systems discharging directly into the streams; development of the TMDL using loads based on the design flow and fecal coliform permit limits of NPDES facilities; and all land uses connected directly to streams.

Note: In this document, the water quality standard is the instream goal. The term "target concentration" reflects the application of an explicit Margin of Safety (MOS) to the water quality standard. See Section 5.0.

C.5 Determination of Existing Loading

The critical condition for nonpoint source fecal coliform loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, fecal coliform 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 simulated in the water quality model.

For each modeled subwatershed, the 10-year simulation period was used to generate daily mean instream concentrations. These were used to calculate continuous 30-day geometric mean concentrations which were then compared to the target concentration. The 10-year simulation period contained a range of hydrologic conditions that included both low and high streamflows. The 30-day critical period for each subwatershed is the period preceding the highest simulated violation of the geometric mean standard. The magnitude of the highest peak, together with the corresponding simulated flow, represents the existing fecal coliform loading to the waterbody.

For the majority of pathogen impaired waterbodies in the Upper Duck River watershed, the drainage area of the impaired waterbody coincided with a HUC-12 subwatershed or the impaired waterbody segment was at the “pour point” of the HUC-12 subwatershed. Existing loads and required load reductions were determined on a HUC-12 subwatershed basis for these waterbodies. In four cases (Wallace Branch, Thick Creek, Bell Buckle Creek, & Clear Branch), the impaired drainage area was much smaller than the HUC-12 subwatershed and was located in a headwater region. Existing loads and required load reductions for these waterbodies were determined for the drainage area of the impaired waterbody only.

The results of the 10-year simulations used to determine existing conditions for impaired waterbodies are shown in Figures C-24 through C-37.

C.7 Determination of TMDLs

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) which 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 <u>other appropriate measure</u>.

For the purposes of these analyses, fecal coliform TMDLs are expressed as the percent reduction in instream loading required to decrease the existing instream 30-day geometric mean concentration (as defined in Section C.5) to the target of 180 counts/100 ml. The required reduction can be determined directly using the following equation:

$$\text{TMDL} = \text{RILR} = \frac{[(C)\,(Q)\,(\text{Const})]_{\text{Existing}} - [(C)\,(Q)\,(\text{Const})]_{\text{Target}}}{[(C)\,(Q)\,(\text{Const})]_{\text{Existing}}} \times 100$$

where: RILR = Required Instream Load Reduction [%]
C = Instream Concentration [counts/100 ml]
Q = Daily Mean Flow [cfs]
Const = Unit Conversion Constant

Since the stream flow for the existing condition is equal to the stream flow for the target condition:

$$\text{TMDL} = \text{RILR} = \frac{(Q)\,(\text{Const})}{(Q)\,(\text{Const})} \times \frac{[C]_{\text{Existing}} - [C]_{\text{Target}}}{[C]_{\text{Existing}}} \times 100$$

therefore:

$$\text{TMDL} = \text{RILR} = \frac{[C]_{\text{Existing}} - [C]_{\text{Target}}}{[C]_{\text{Existing}}} \times 100$$

As an example, for Subwatershed 0503 (Spring Creek), the simulated 30-day geometric mean concentration for the existing loading condition (ref.: Section C.5) is 1,277 counts/100 ml. The required instream load reduction is calculated by:

$$\text{TMDL} = \text{RILR} = \frac{(1{,}277 \text{ cts/100 ml}) - (180 \text{ cts/100 ml})}{(1{,}277 \text{ cts/100 ml})} \times 100$$

$$\text{TMDL} = \text{RILR} = 85.9\%$$

TMDLs to achieve the 30-day geometric mean target for impaired subwatersheds are summarized in Table C-4. For cases where the highest simulated 30-day geometric mean concentration is below the target concentration of 180 counts/100 ml, no load reduction is required.

Table C-1 Hydrologic Calibration Summary of Wartrace Creek at USGS Station 03597590

Simulation Name:	Wartrace	**Simulation Period:**	
		Watershed Area (ac):	22847.00
Period for Flow Analysis			
Begin Date:	**10/01/91**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/23/01**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**240.83**	Total Observed In-stream Flow:	**248.64**
Total of highest 10% flows:	**170.17**	Total of Observed highest 10% flows:	**172.66**
Total of lowest 50% flows:	**7.70**	Total of Observed Lowest 50% flows:	**8.34**
Simulated Summer Flow Volume (months 7-9):	**14.34**	Observed Summer Flow Volume (7-9):	**22.77**
Simulated Fall Flow Volume (months 10-12):	**60.75**	Observed Fall Flow Volume (10-12):	**59.06**
Simulated Winter Flow Volume (months 1-3):	**109.55**	Observed Winter Flow Volume (1-3):	**118.60**
Simulated Spring Flow Volume (months 4-6):	**56.19**	Observed Spring Flow Volume (4-6):	**48.21**
Total Simulated Storm Volume:	**240.83**	Total Observed Storm Volume:	**248.60**
Simulated Summer Storm Volume (7-9):	**14.34**	Observed Summer Storm Volume (7-9):	**22.76**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-3.14**	10	
Error in 50% lowest flows:	**-7.72**	10	
Error in 10% highest flows:	**-1.44**	15	
*** Seasonal volume error - Summer:	**-37.01**	30	
Seasonal volume error - Fall:	**2.86**	30	
Seasonal volume error - Winter:	**-7.63**	30	
Seasonal volume error - Spring:	**16.54**	30	
Error in storm volumes:	**-3.23**	20	
Error in summer storm volumes:	**-36.99**	50	

Table C-2 Hydrologic Calibration Summary of Garrison Fork at USGS Station 03597210

Simulation Name:	Garrison Fork	**Simulation Period:**	
		Watershed Area (ac):	54719.00
Period for Flow Analysis			
Begin Date:	**10/01/91**	**Baseflow PERCENTILE:**	2.5
End Date:	**09/29/01**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**235.93**	Total Observed In-stream Flow:	**240.06**
Total of highest 10% flows:	**130.83**	Total of Observed highest 10% flows:	**142.04**
Total of lowest 50% flows:	**17.98**	Total of Observed Lowest 50% flows:	**16.63**
Simulated Summer Flow Volume (months 7-9):	**16.32**	Observed Summer Flow Volume (7-9):	**17.59**
Simulated Fall Flow Volume (months 10-12):	**54.13**	Observed Fall Flow Volume (10-12):	**53.81**
Simulated Winter Flow Volume (months 1-3):	**106.83**	Observed Winter Flow Volume (1-3):	**114.66**
Simulated Spring Flow Volume (months 4-6):	**58.64**	Observed Spring Flow Volume (4-6):	**54.00**
Total Simulated Storm Volume:	**229.24**	Total Observed Storm Volume:	**232.65**
Simulated Summer Storm Volume (7-9):	**14.64**	Observed Summer Storm Volume (7-9):	**15.75**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-1.72**	10	
Error in 50% lowest flows:	**8.17**	10	
Error in 10% highest flows:	**-7.89**	15	
Seasonal volume error - Summer:	**-7.19**	30	
Seasonal volume error - Fall:	**0.60**	30	
Seasonal volume error - Winter:	**-6.83**	30	
Seasonal volume error - Spring:	**8.59**	30	
Error in storm volumes:	**-1.48**	20	
Error in summer storm volumes:	**-7.09**	50	

Figure C-1 Hydrologic Calibration of Wartrace Creek at USGS 03597590 (WY 92)

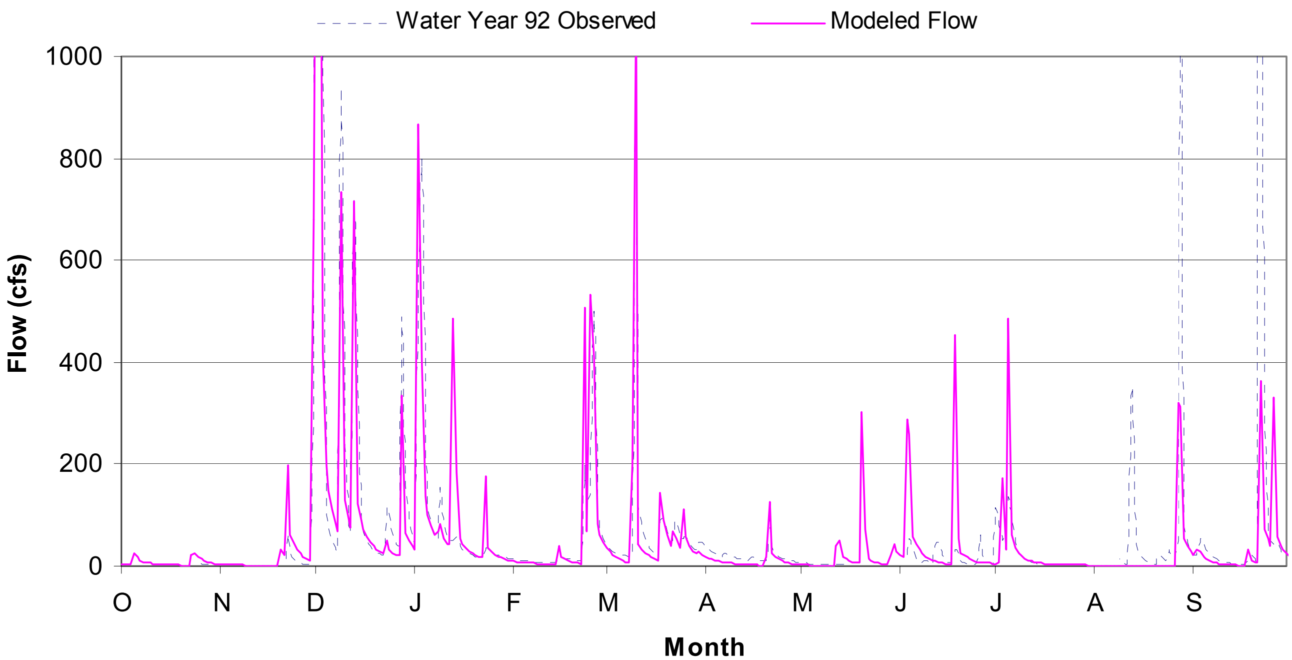


Figure C-2 Hydrologic Calibration of Wartrace Creek at USGS 03597590 (WY 93)

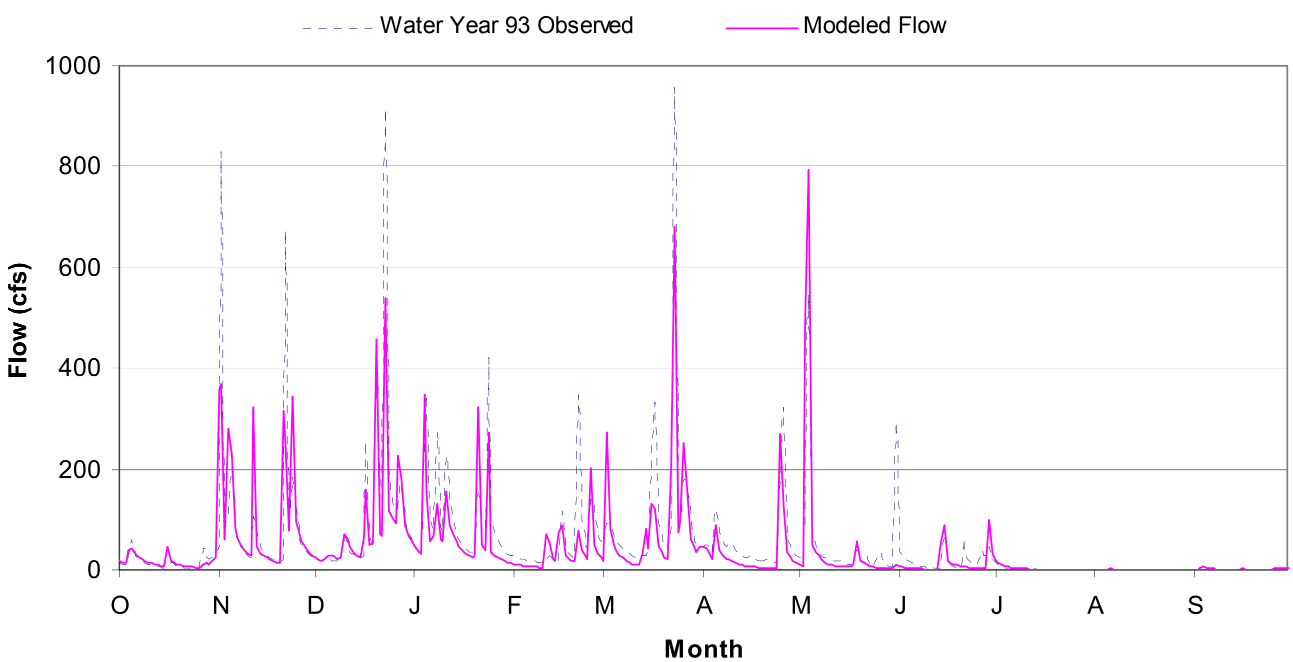


Figure C-3 Hydrologic Calibration of Wartrace Creek at USGS 03597590 (WY 94)

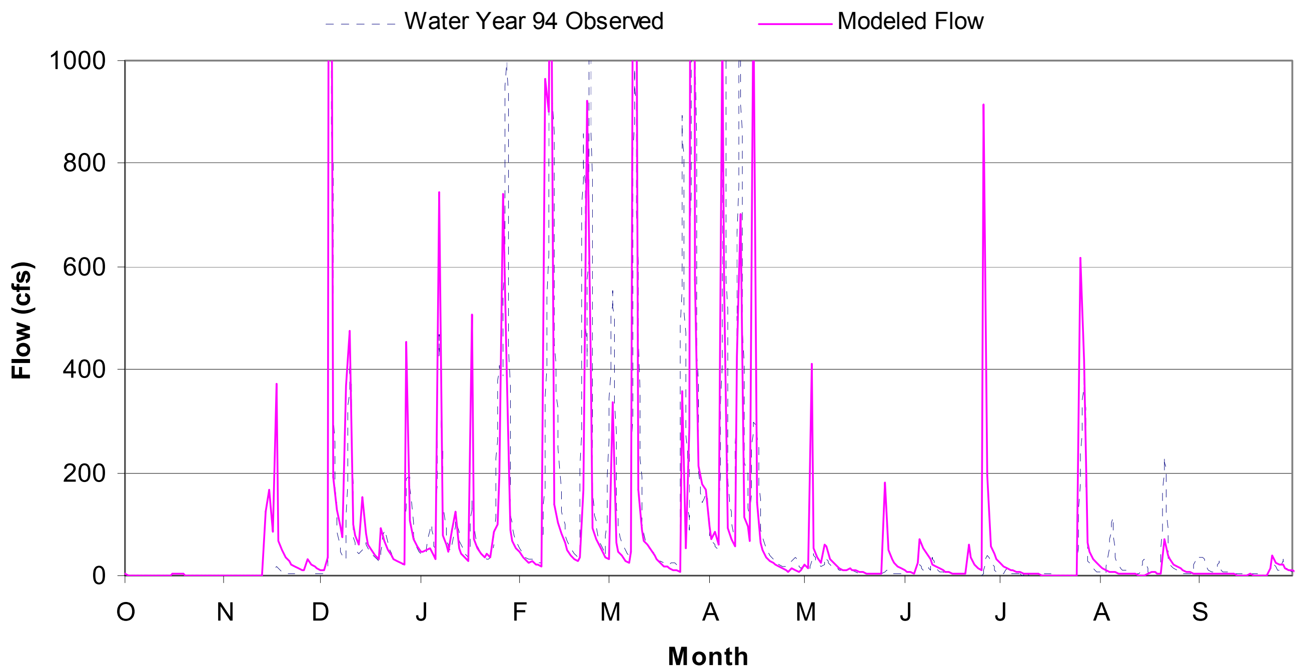


Figure C-4 Hydrologic Calibration of Wartrace Creek at USGS 03597590 (WY 95)

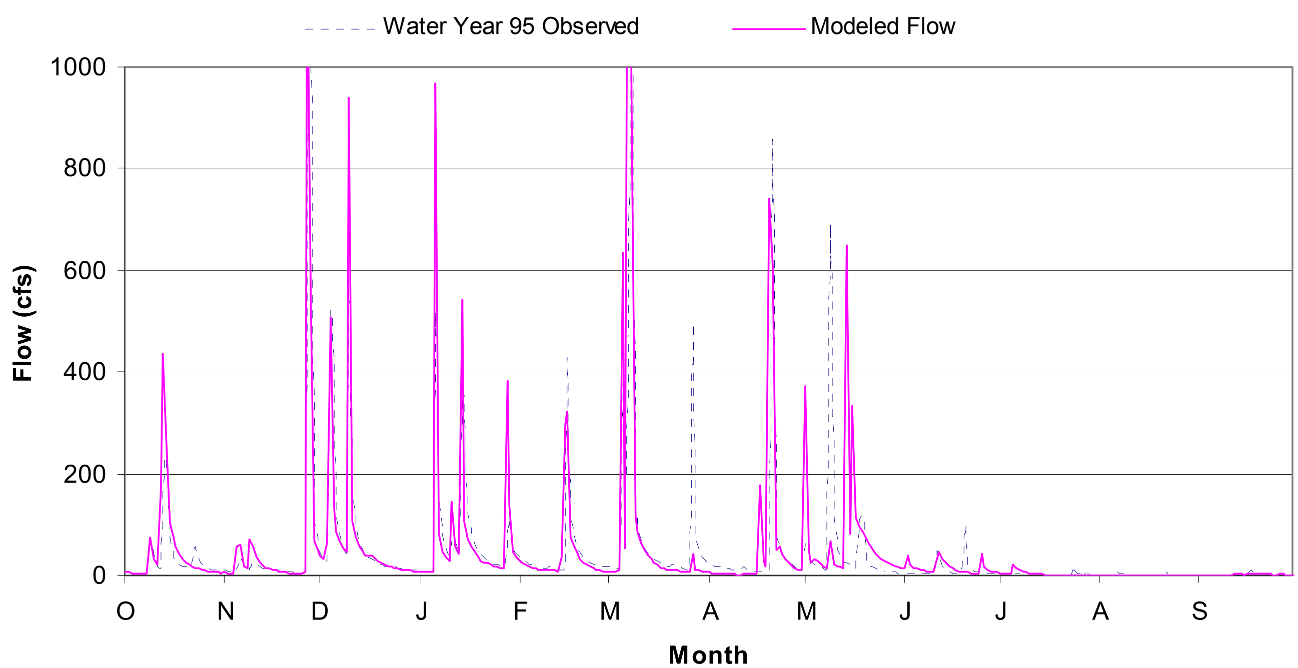


Figure C-5 Hydrologic Calibration of Wartrace Creek at USGS 03597590 (WY 96)

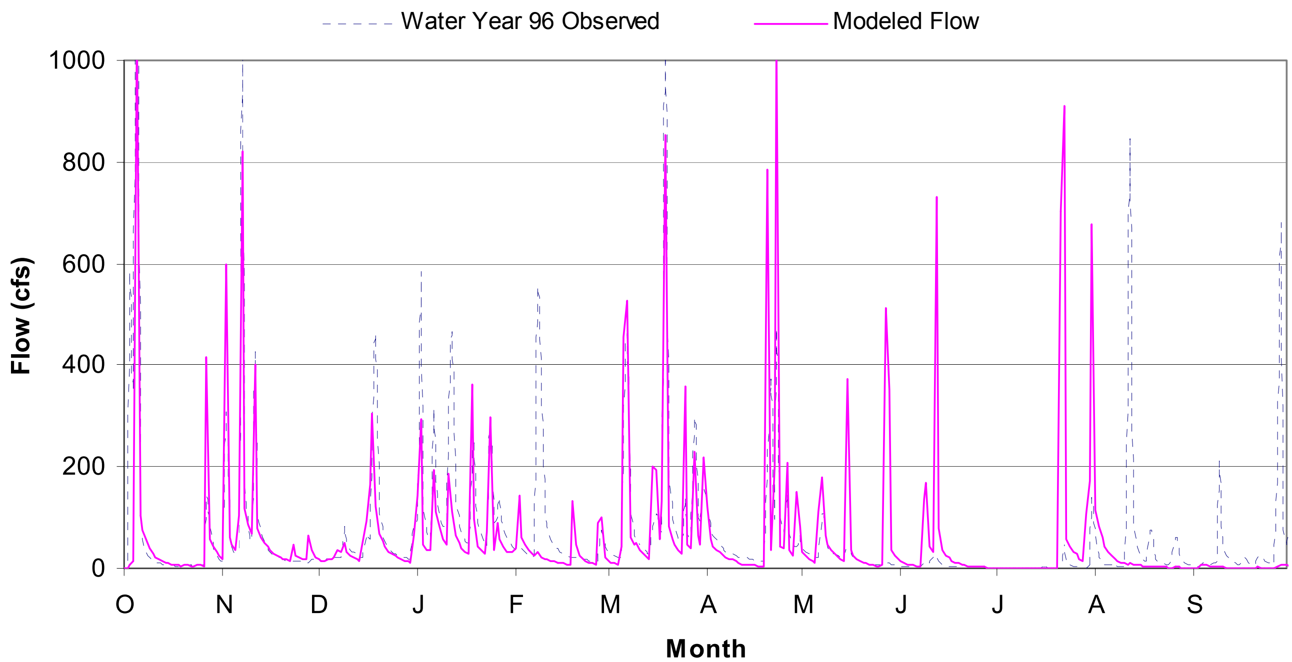


Figure C-6 Hydrologic Calibration of Wartrace Creek at USGS 03597590 (WY 97)

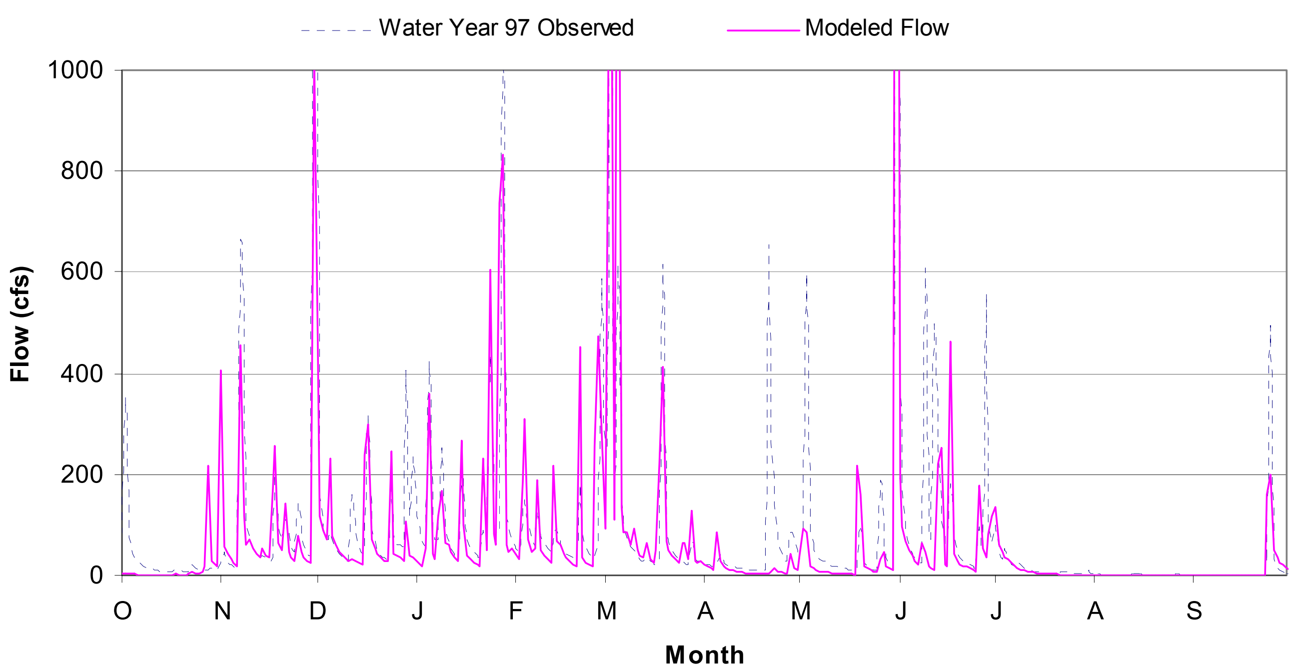


Figure C-7 Hydrologic Calibration of Wartrace Creek at USGS 03597590 (WY 98)

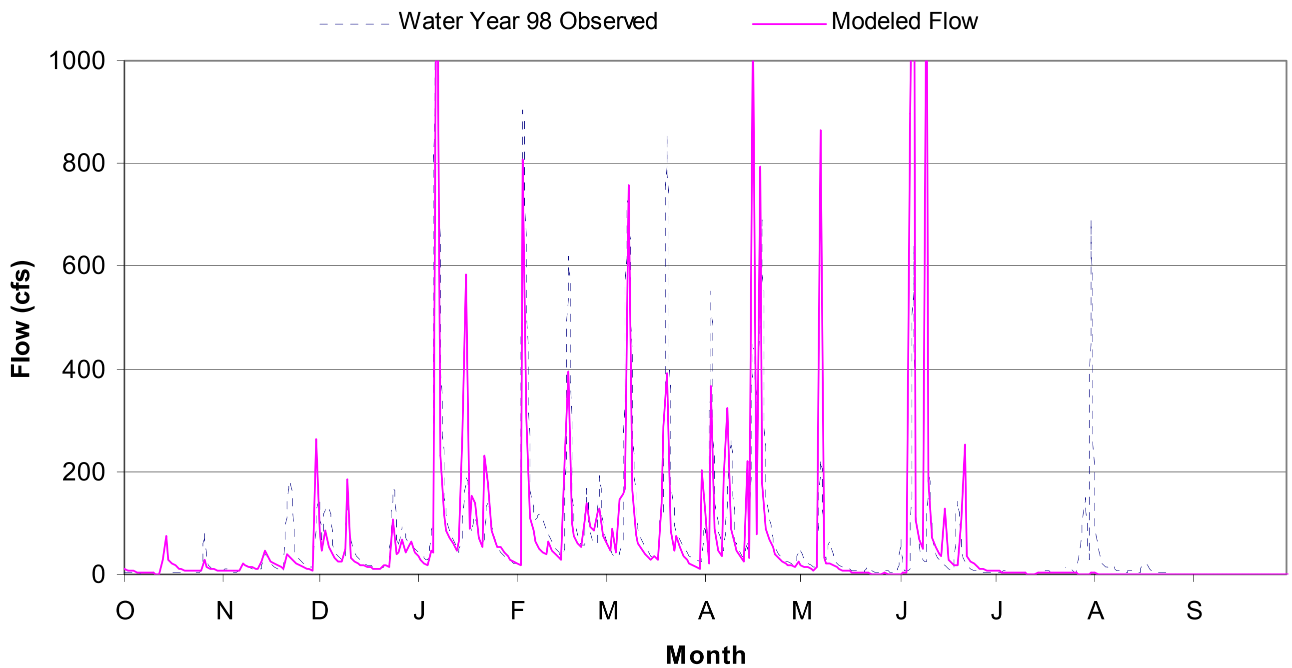


Figure C-8 Hydrologic Calibration of Wartrace Creek at USGS 03597590 (WY 99)

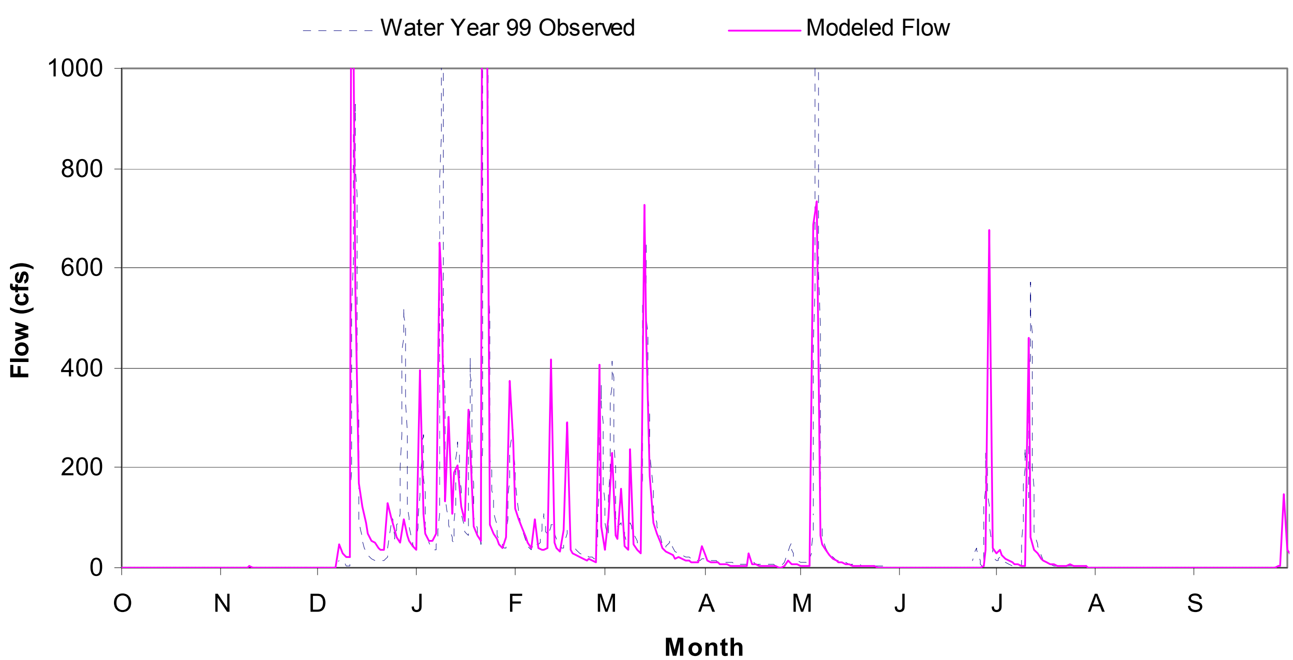


Figure C-9 Hydrologic Calibration of Wartrace Creek at USGS 03597590 (WY 00)

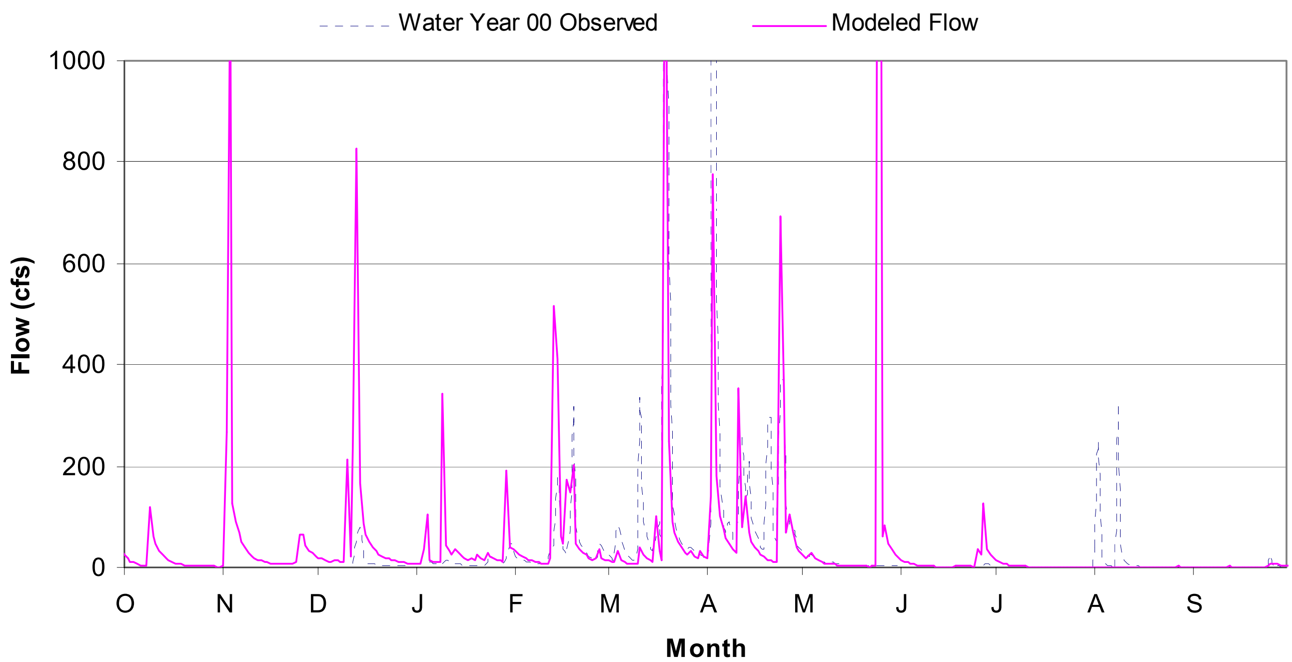


Figure C-10 Hydrologic Calibration of Wartrace Creek at USGS 03597590 (WY 01)

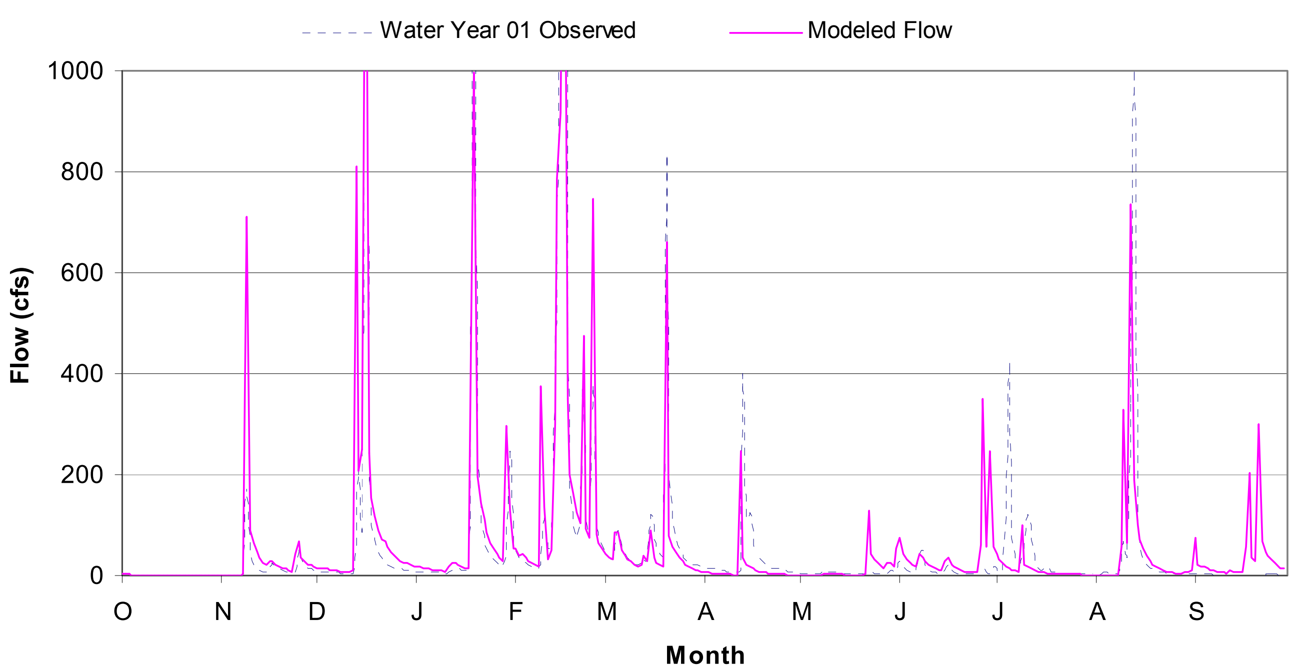


Figure C-11 Hydrologic Calibration of Garrison Fork at USGS 03597210 (WY 92)

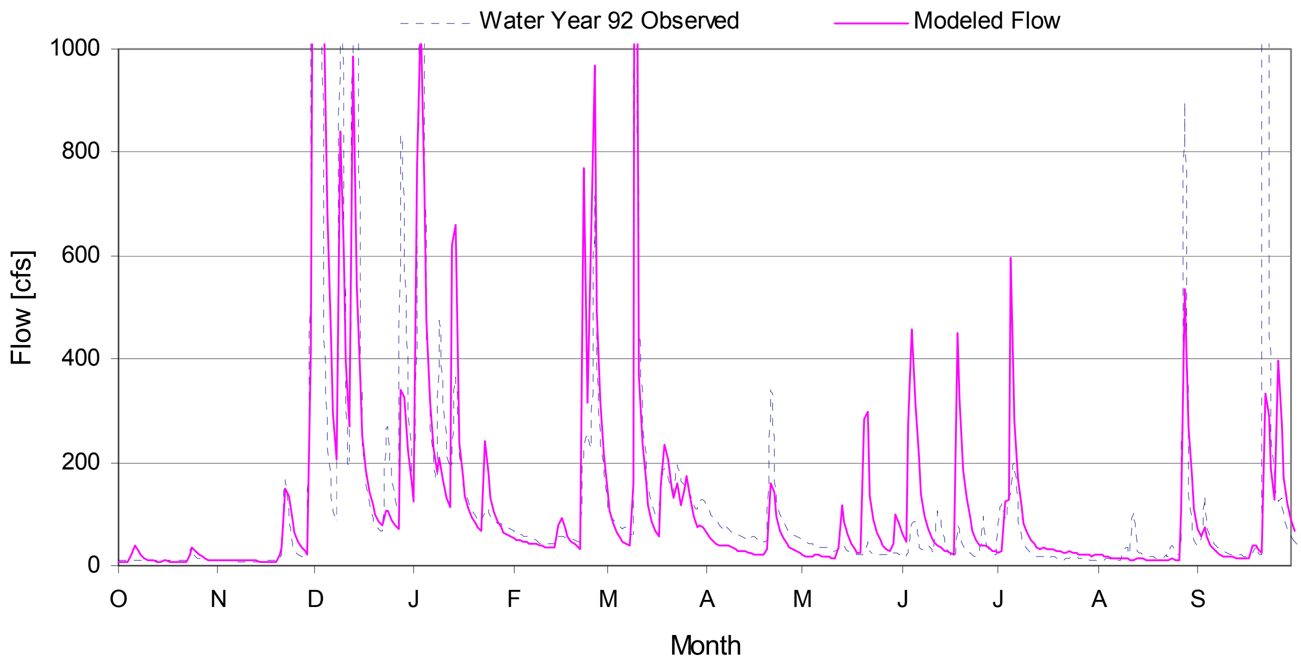


Figure C-12 Hydrologic Calibration of Garrison Fork at USGS 03597210 (WY 93)

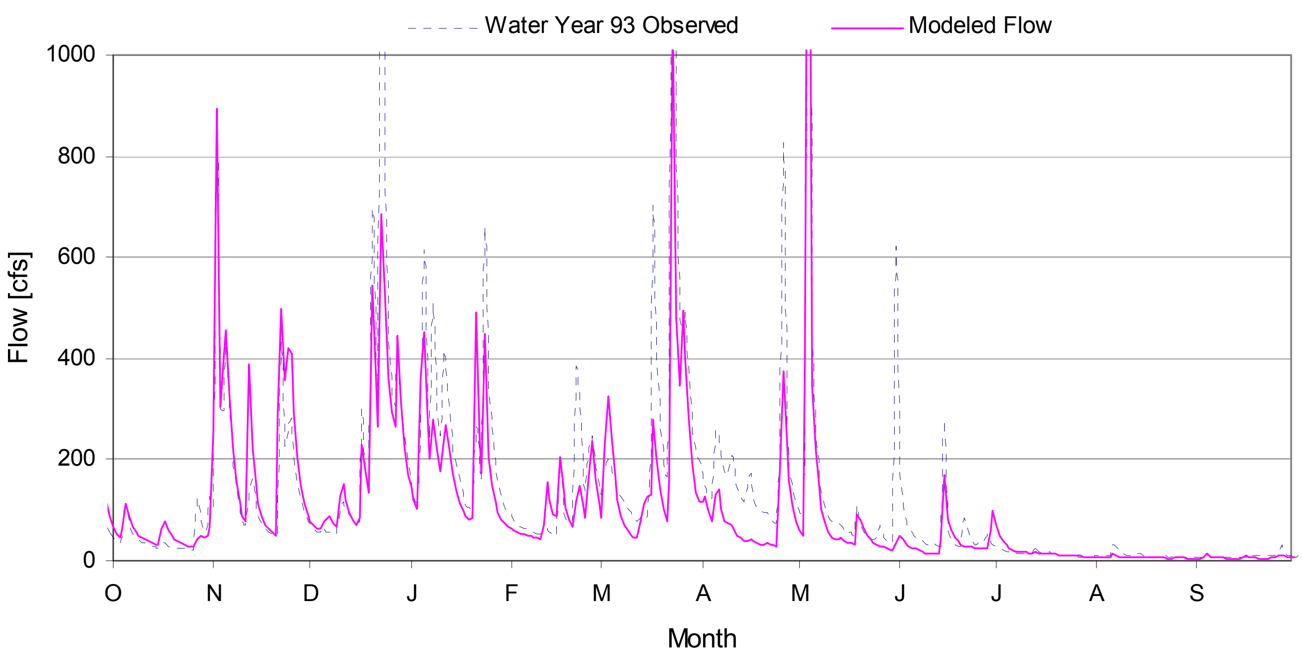


Figure C-13 Hydrologic Calibration of Garrison Fork at USGS 03597210 (WY 94)

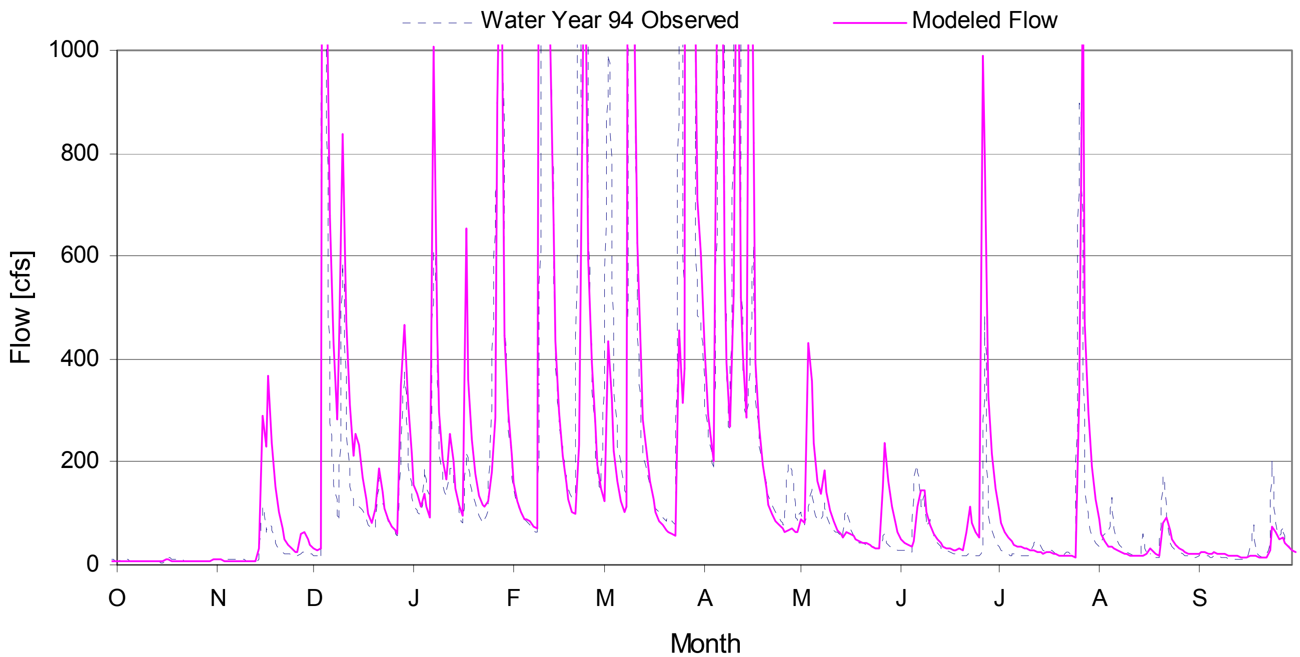


Figure C-14 Hydrologic Calibration of Garrison Fork at USGS 03597210 (WY 95)

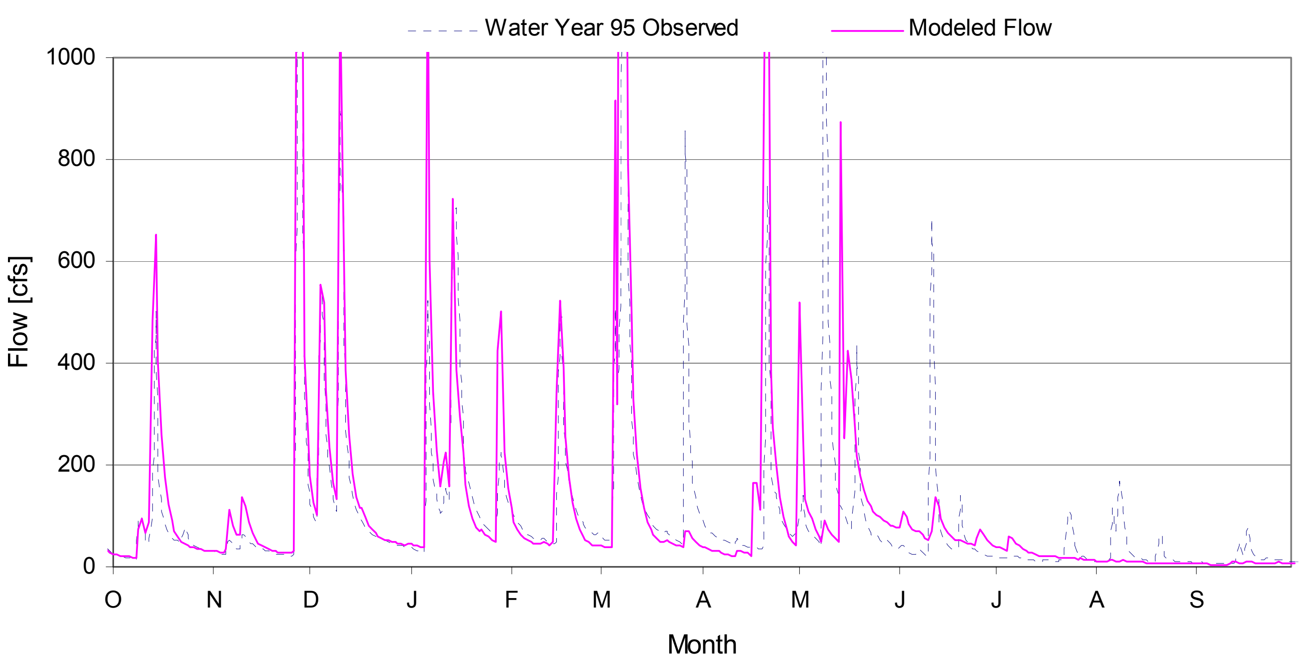


Figure C-15 Hydrologic Calibration of Garrison Fork at USGS 03597210 (WY 96)

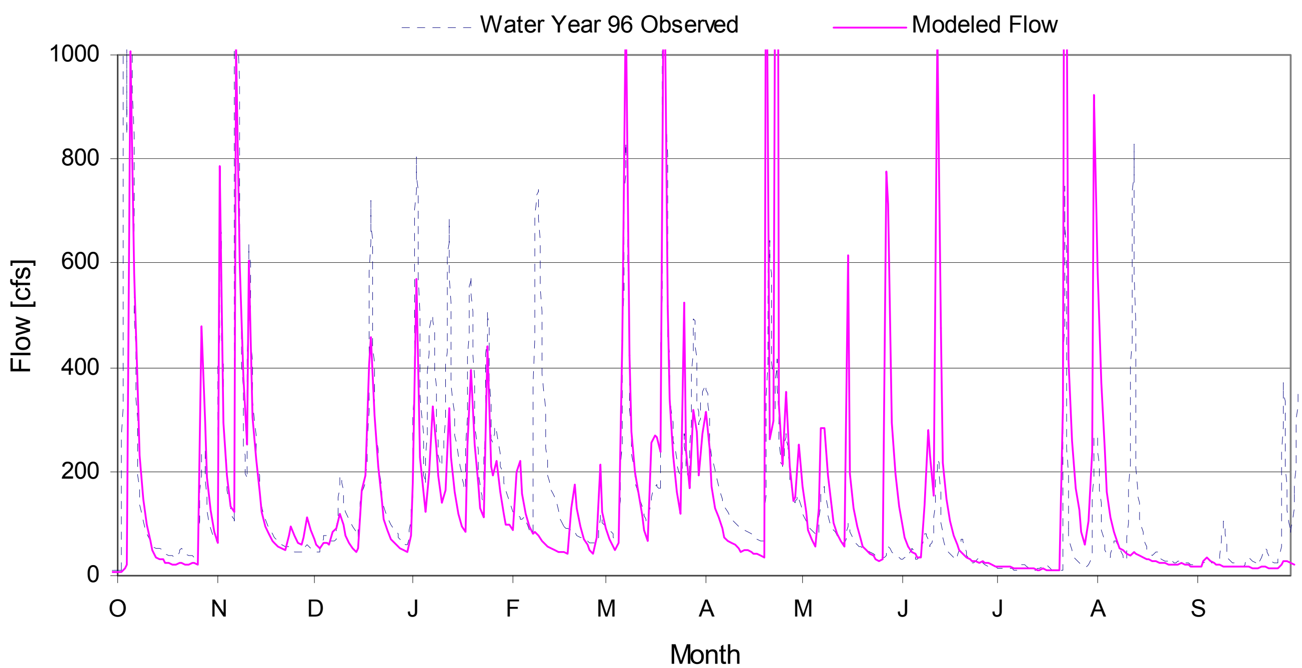


Figure C-16 Hydrologic Calibration of Garrison Fork at USGS 03597210 (WY 97)

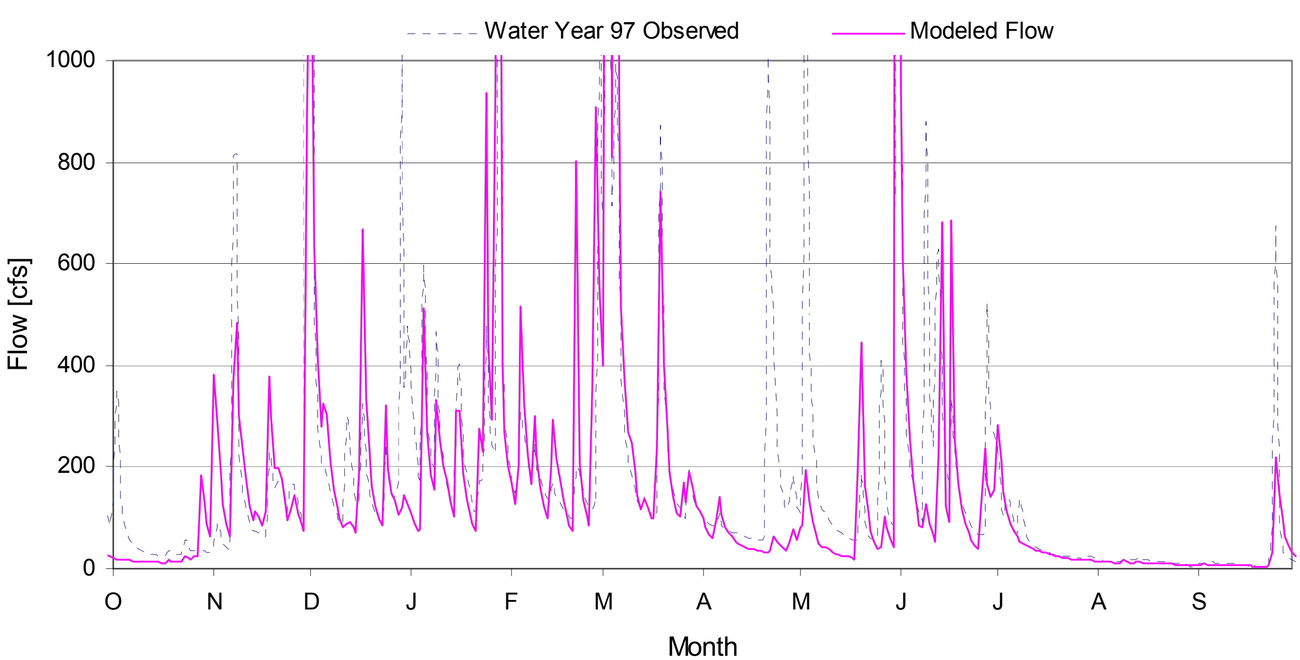


Figure C-17 Hydrologic Calibration of Garrison Fork at USGS 03597210 (WY 98)

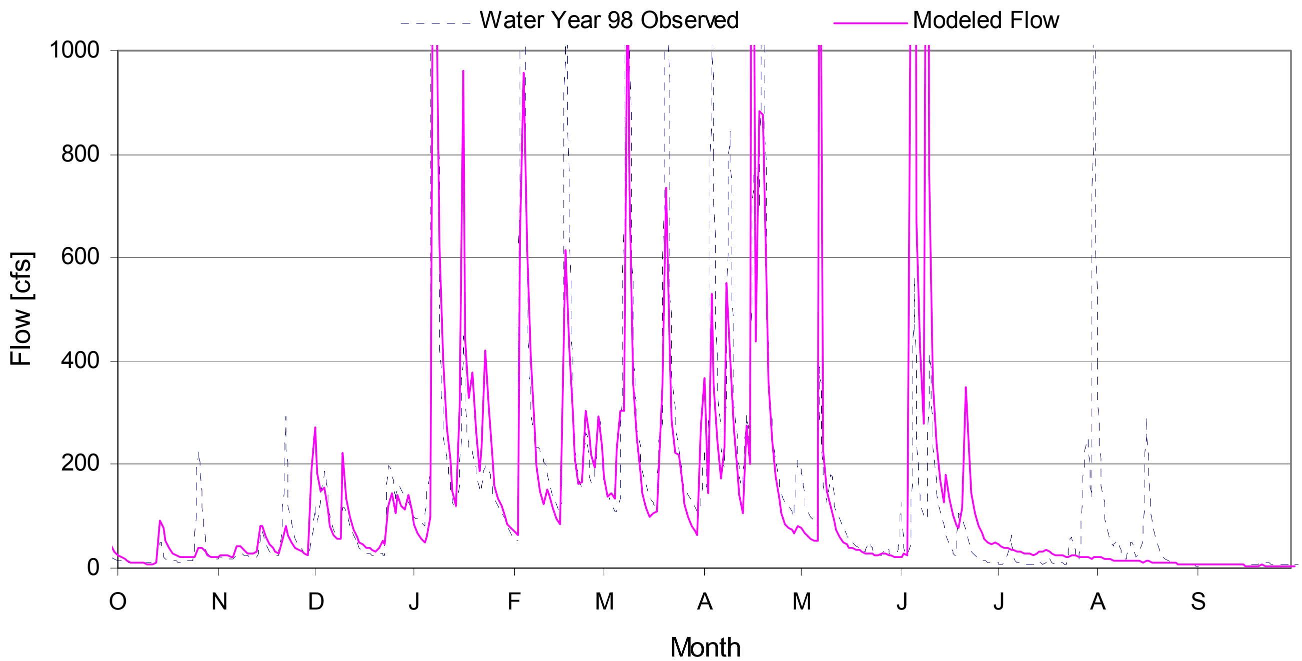


Figure C-18 Hydrologic Calibration of Garrison Fork at USGS 03597210 (WY 99)

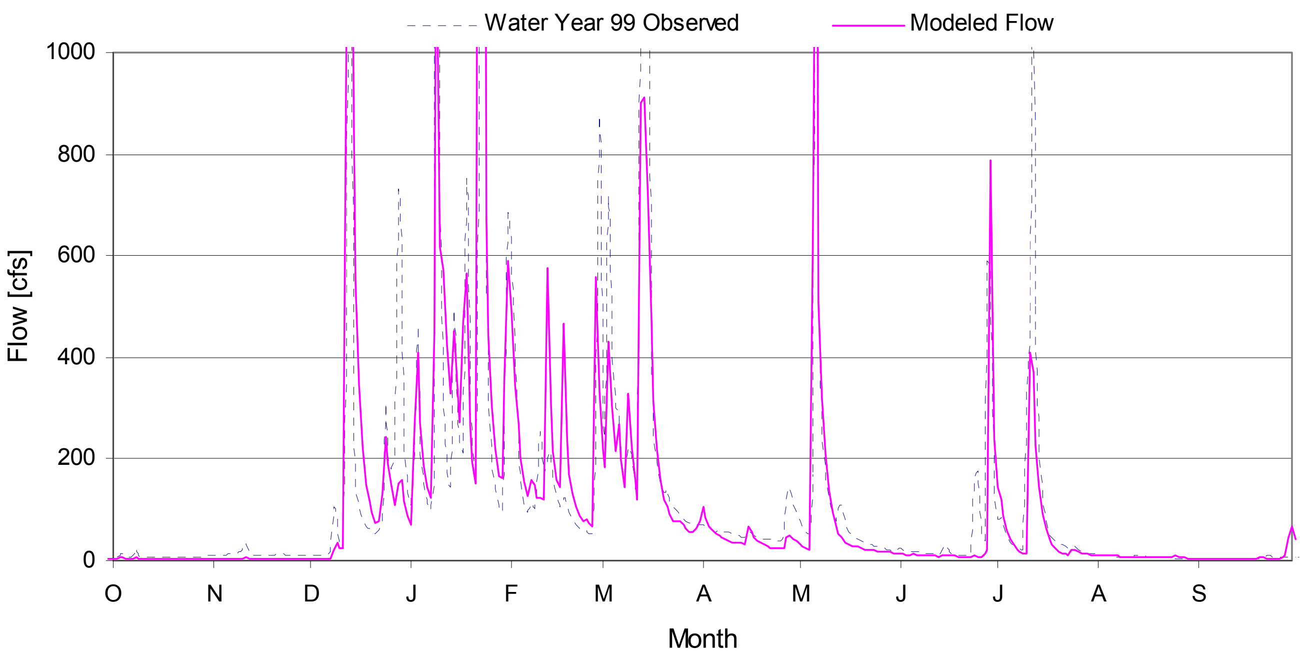


Figure C-19 Hydrologic Calibration of Garrison Fork at USGS 03597210 (WY 00)

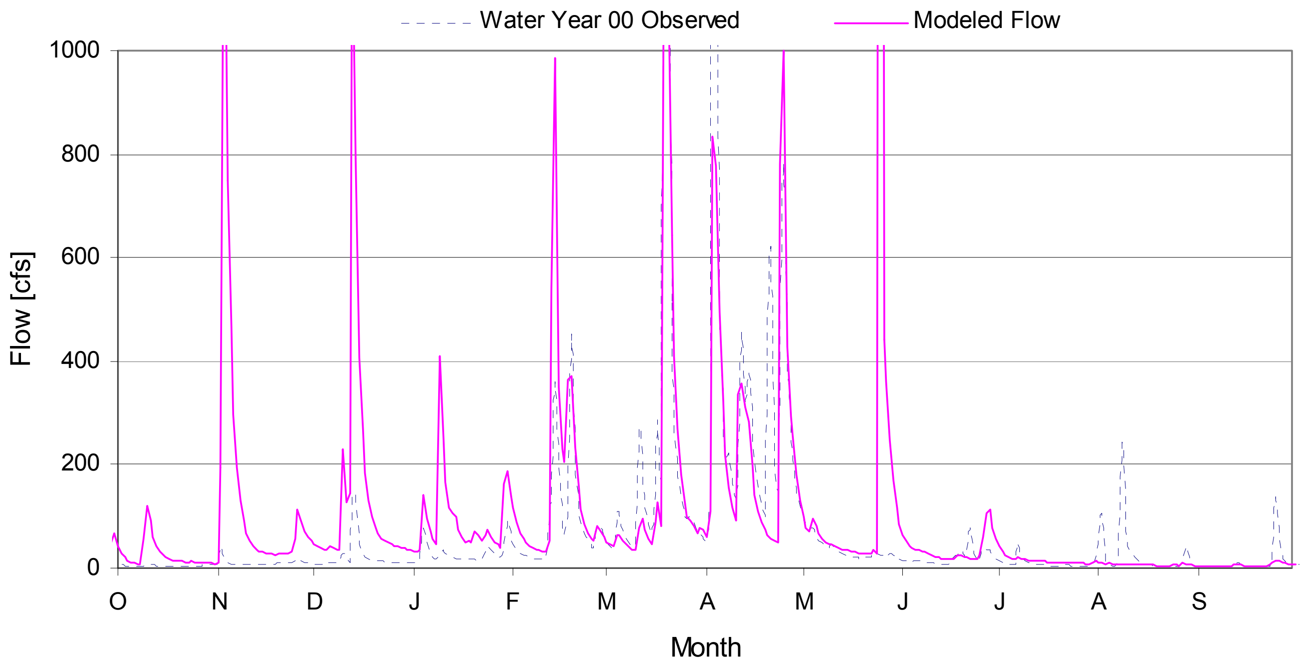


Figure C-20 Hydrologic Calibration of Garrison Fork at USGS 03597210 (WY 01)

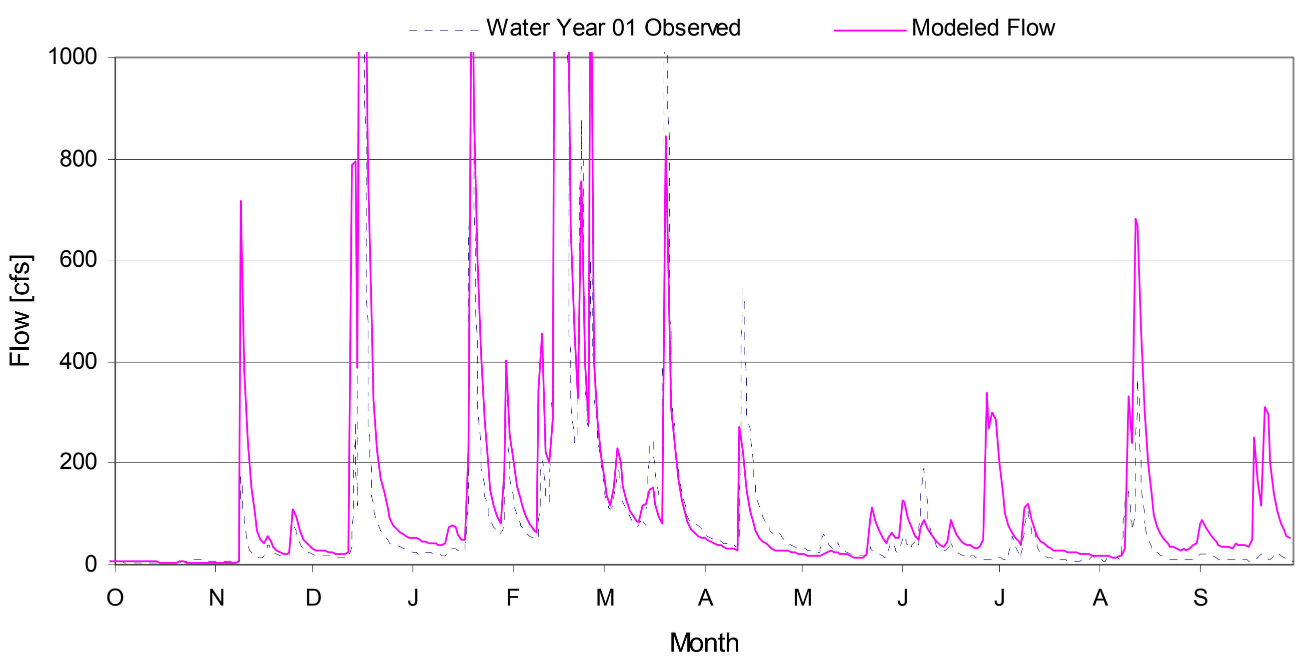


Table C-3 Application of Water Quality Calibrations to Subwatershed Models

Water Quality Calibration			Calibration Application	
Monitoring Site	Waterbody	Level IV Ecoregion	HUC-12 Subwatershed (06040002____)	Impaired Waterbodies
LDUCK001.3CE	Little Duck River	71g	0101	Clear Branch Duck River
			0102	Little Duck River
BBUCK001.0BE	Bell Buckle Creek	71h	0203	Bell Buckle Creek
			0702	Fountain Creek
SPRIN003.2ML	Spring Creek	71i	0308	Fall Creek Hurricane Creek
			0401	North Fork Creek
			0402	Alexander Creek
			0404	Weakley Creek
			0405	Clem Creek
			0502	Wilson creek
			0503	Spring Creek
			0504	Thick Creek
			0506	Wallace Branch

Table C-4 TMDLs for Impaired Subwatersheds – 30-Day Geometric Mean Target

Impaired Waterbody	HUC-12 Subwatershed (06040002____)	Existing Conditions		TMDL - Required Load Reduction
		Date(s) of Max. 30-Day Geom. Mean Concen.	Max. 30-Day Geom. Mean Concentration [cts./100 ml]	[%]
Clear Branch	DA	12/23/01	128.1	NR
Duck River	0101	6/23/97	226.1	20.4
Little Duck River	0102	6/22/97	164.8	NR
Bell Buckle Creek	DA	3/23/98	709.0	74.6
Duck River	0301	NA	NA	NA
Duck River Tribs.	0303	NA	NA	NA
Fall Creek Hurricane Creek	0308	4/10/93	1,300.4	86.2
North Fork Creek	0401	9/20/98	1,488.5	87.9
Alexander Creek	0402	3/23/98	1,418.5	87.3
Weakley Creek	0404	9/5/99 – 9/7/99	1,398.9	87.1
Clem Creek	0405	9/3/99 – 9/7/99	1,780.3	89.9
Wilson Creek	0502	9/3/99 – 9/7/99	1,683.8	89.3
Spring Creek Lick Creek	0503	4/10/93	1,277.1	85.9
Thick Creek	DA	8/29/99 – 9/7/99	5,131.3	96.5
Wallace Branch	DA	1/2/99	816.0	77.9
Fountain Creek	0702	1/19/98	746.6	75.9

Note: NR = No load reduction required
DA = Drainage Area

Figure C-21 Water Quality Calibration of Spring Creek at SPRIN003.2ML

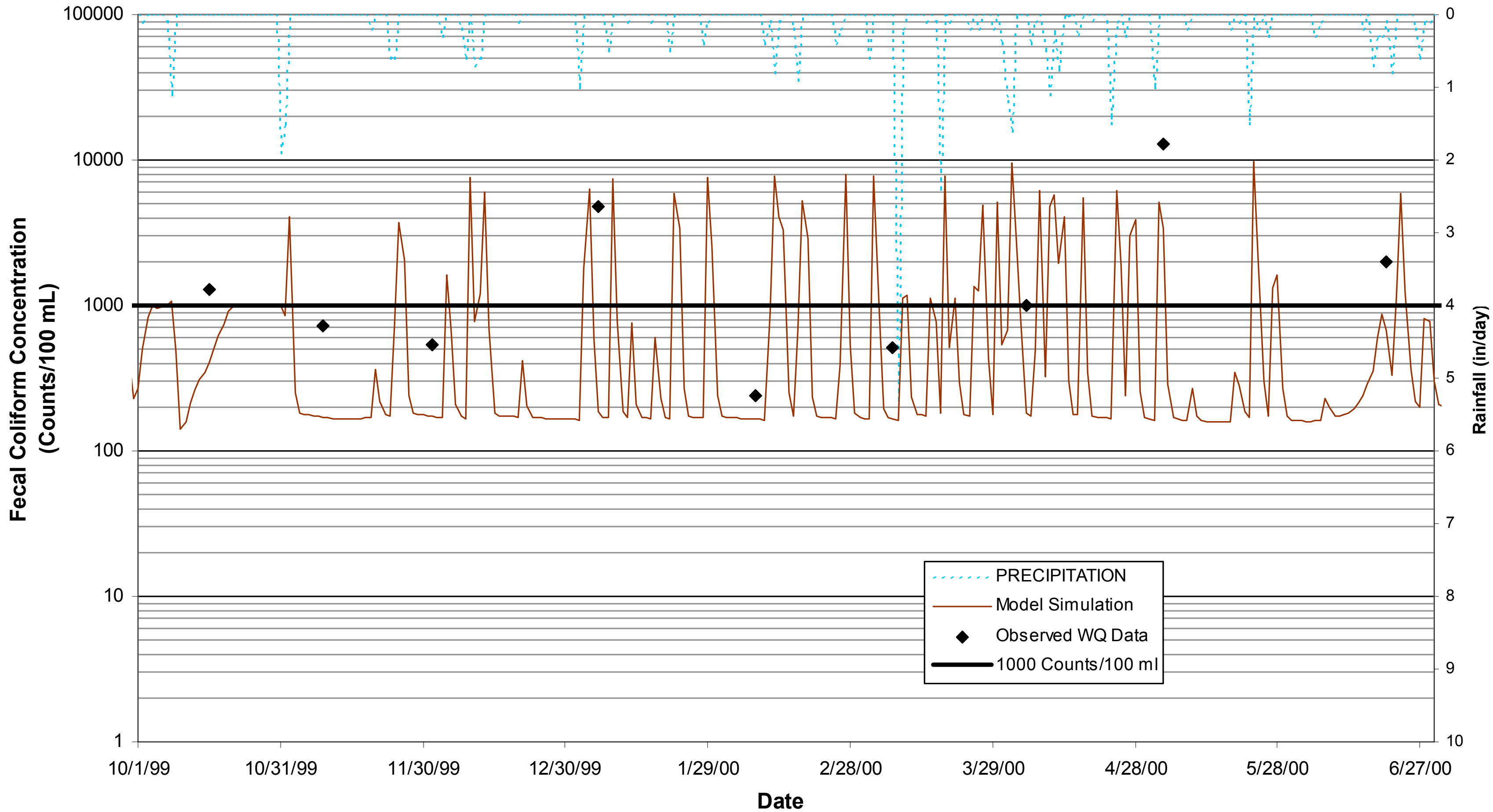


Figure C-22 Water Quality Calibration of Bell Buckle Creek at BBUCK001.0BE

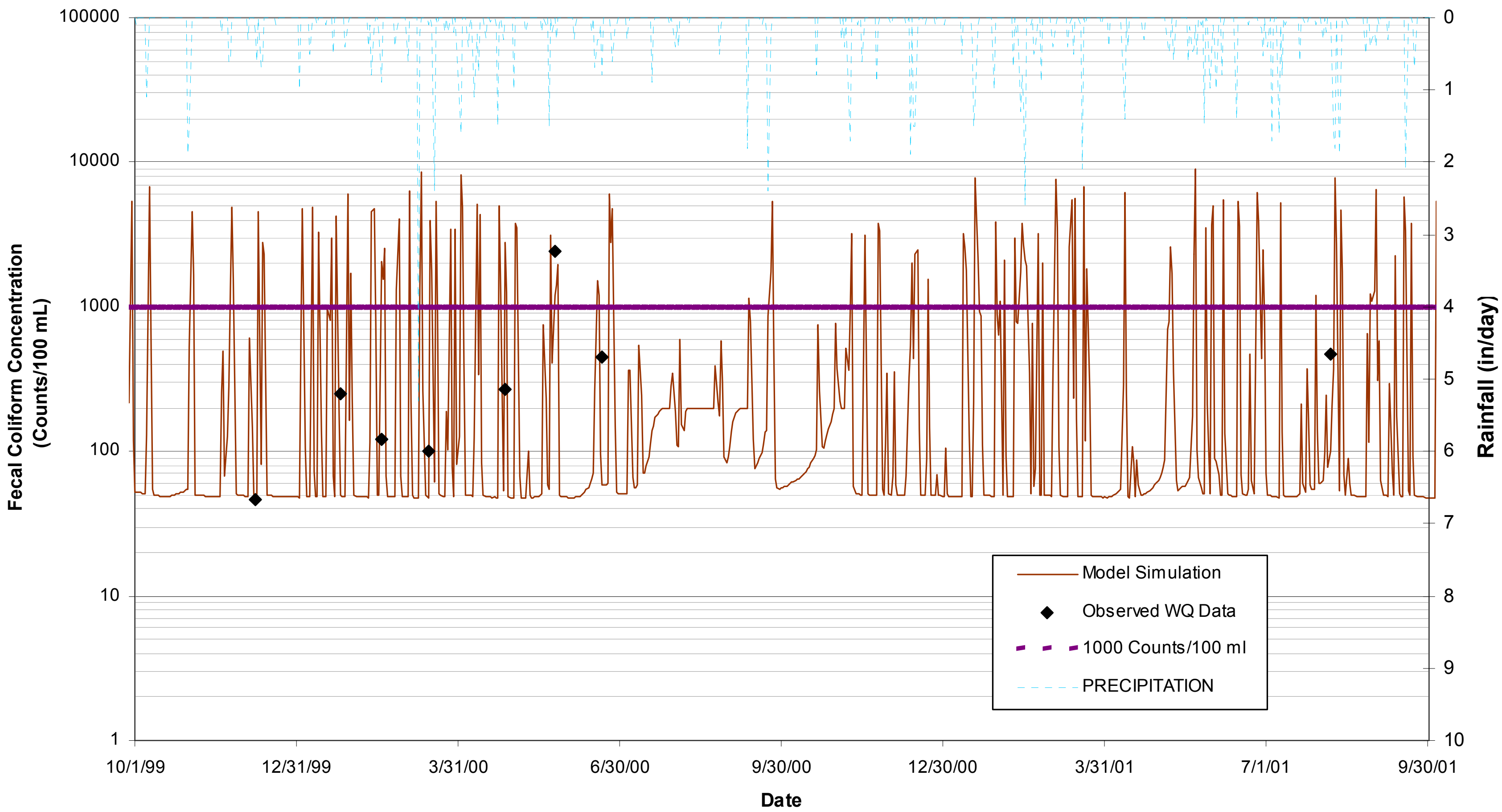


Figure C-23 Water Quality Calibration of Little Duck River at LDUCK001.3CE

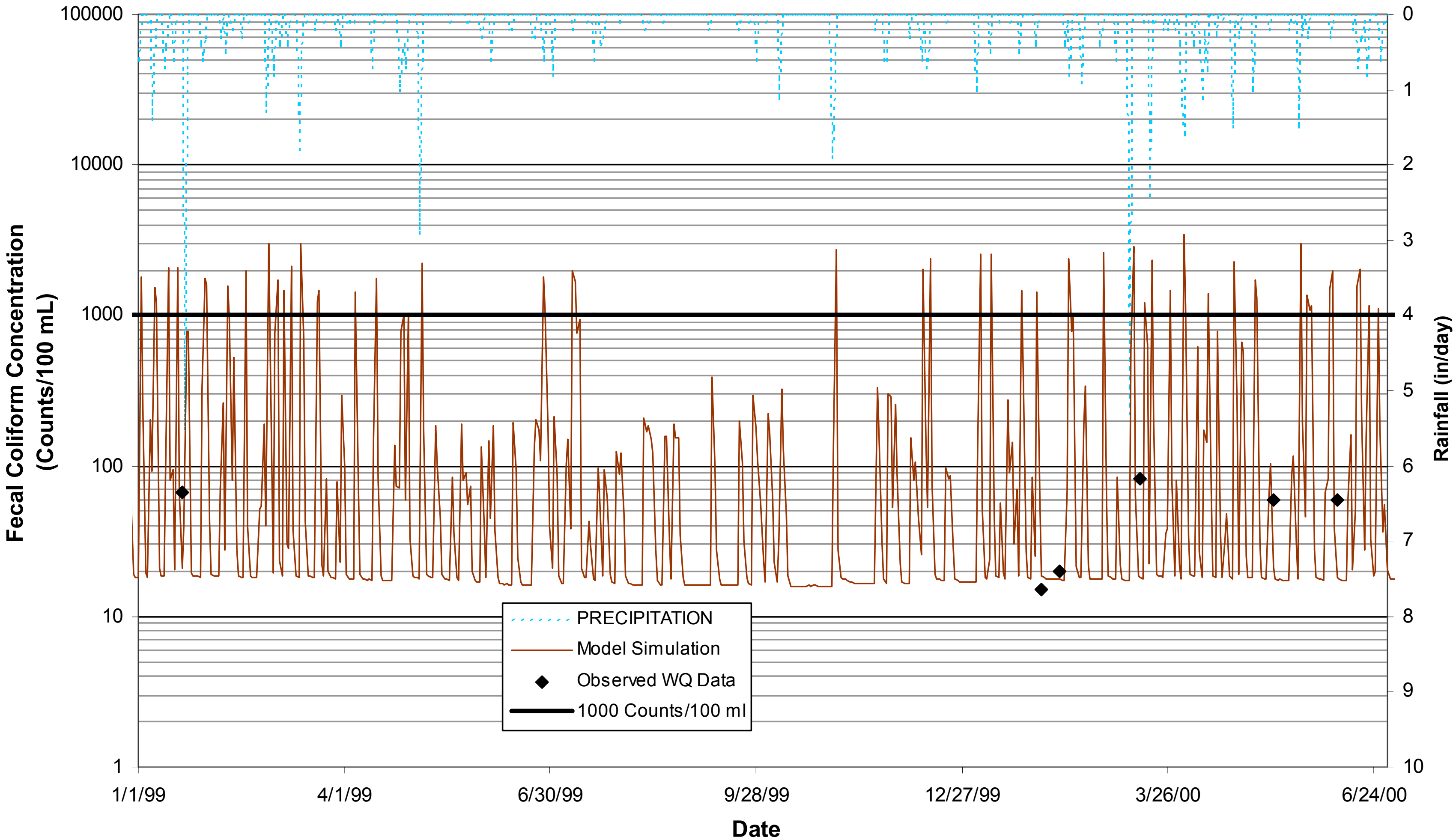


Figure C-24 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Subwatershed 0503 (Spring Creek, Lick Creek)

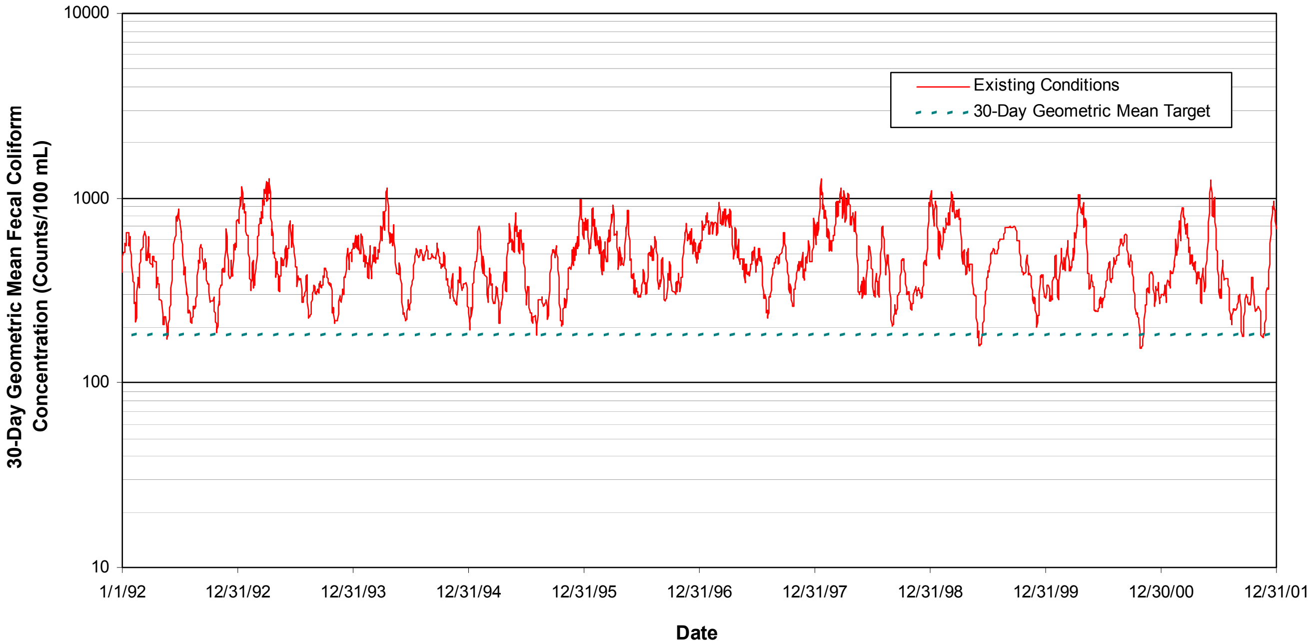


Figure C-25 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Subwatershed 0702 (Fountain Creek)

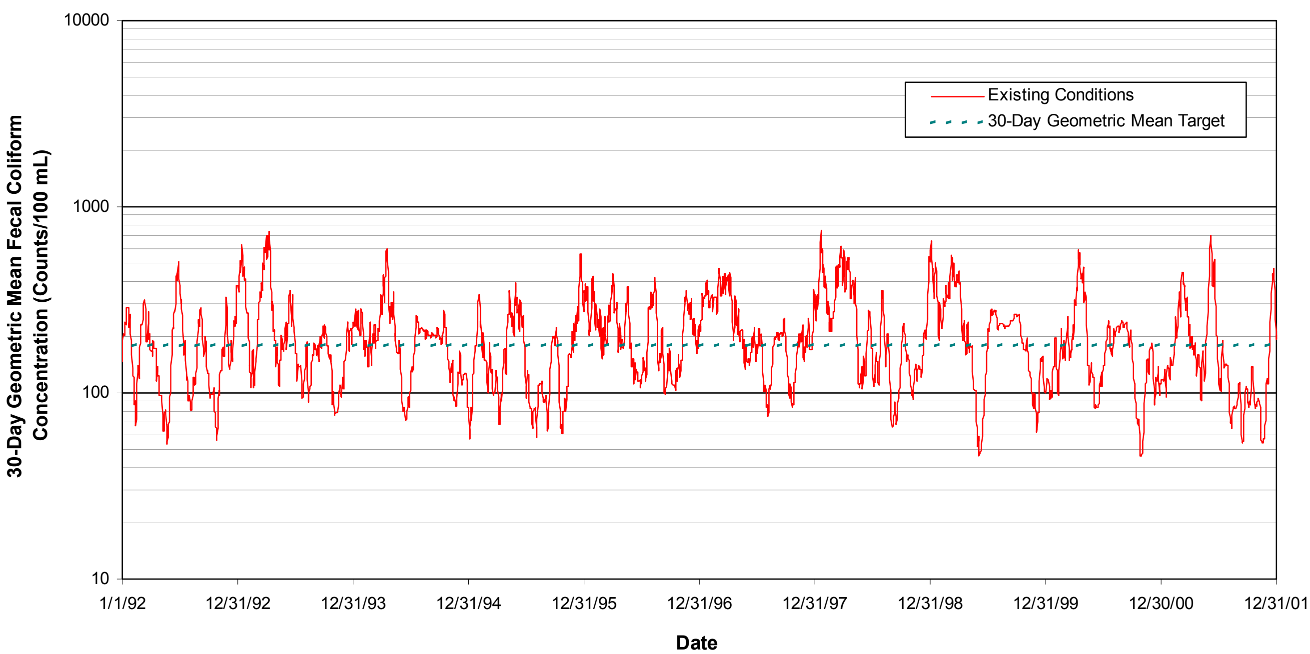


Figure C-26 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Wallace Branch

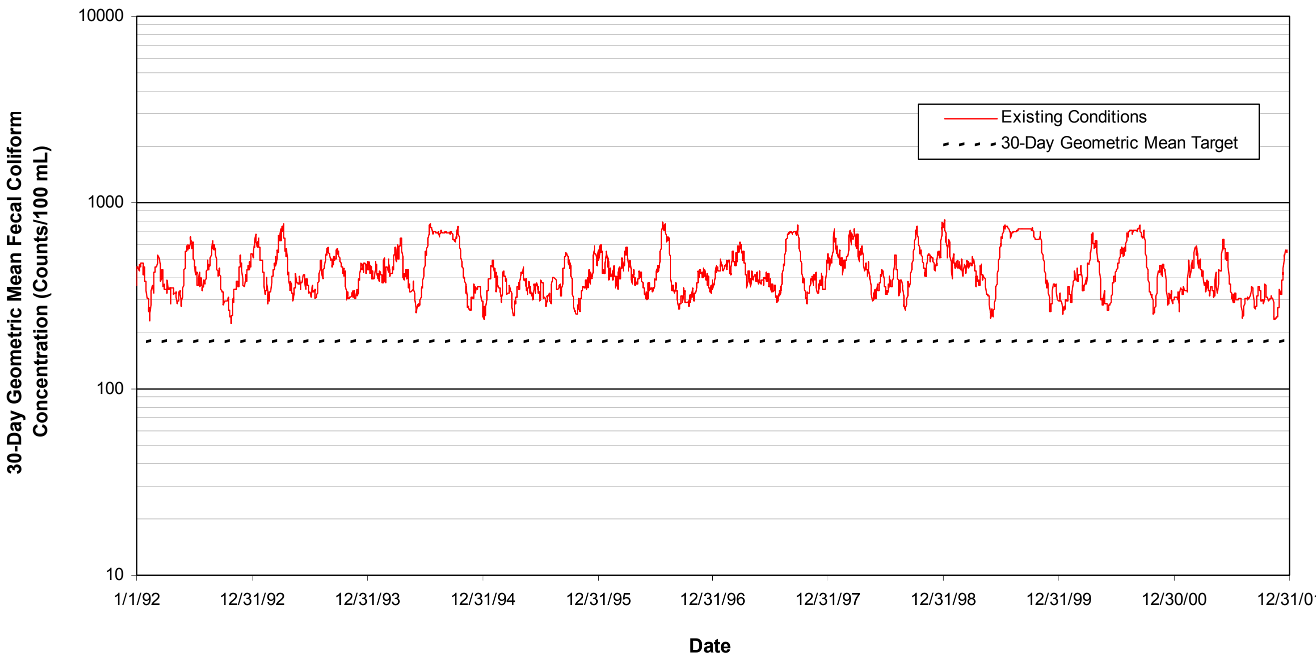


Figure C-27 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Thick Creek

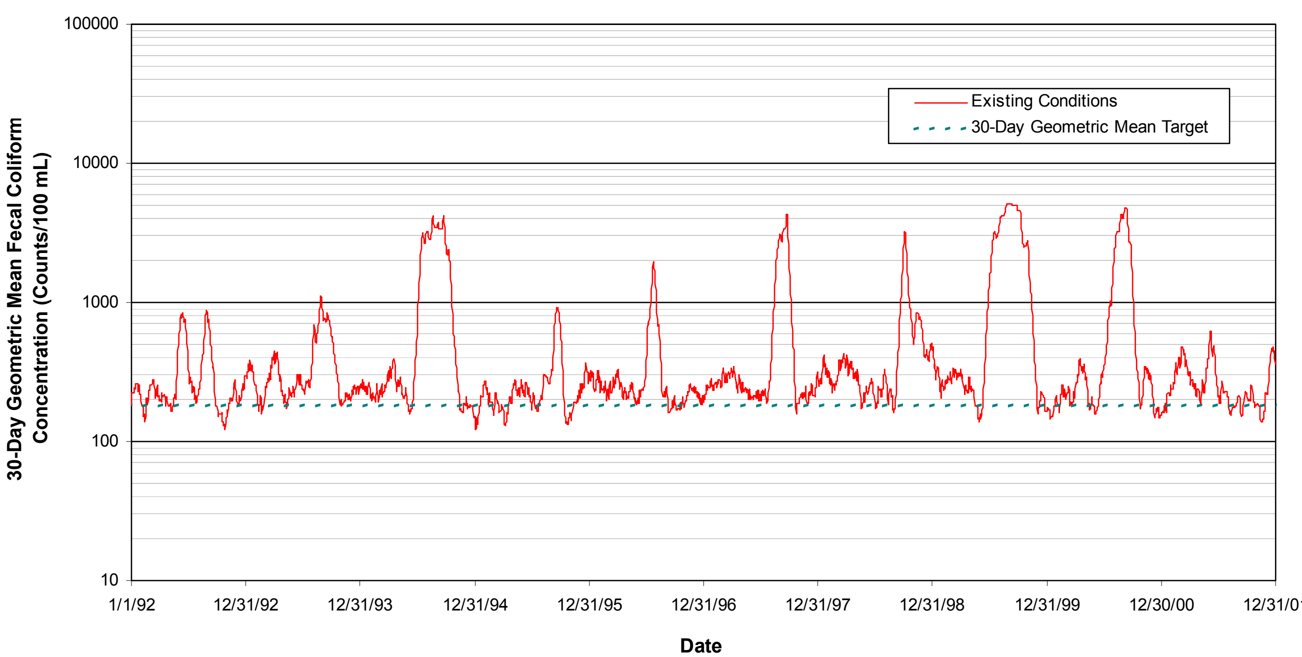


Figure C-28 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Subwatershed 0502 (Wilson Creek)

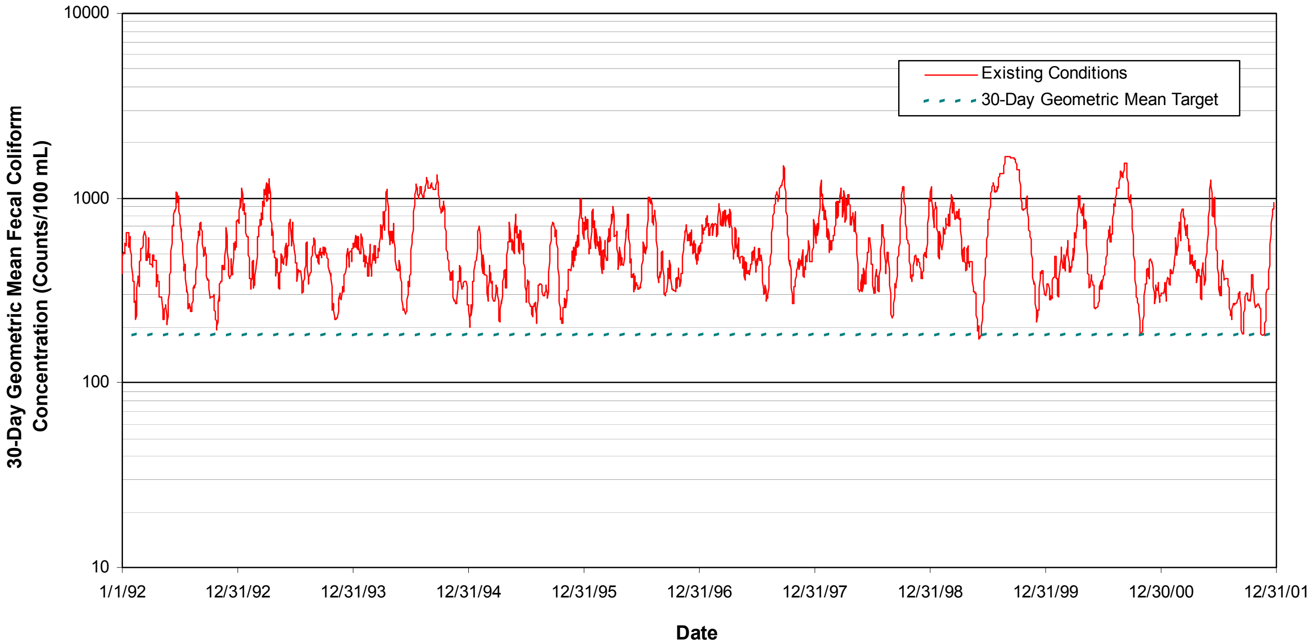


Figure C-29 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Subwatershed 0405 (Clem Creek)

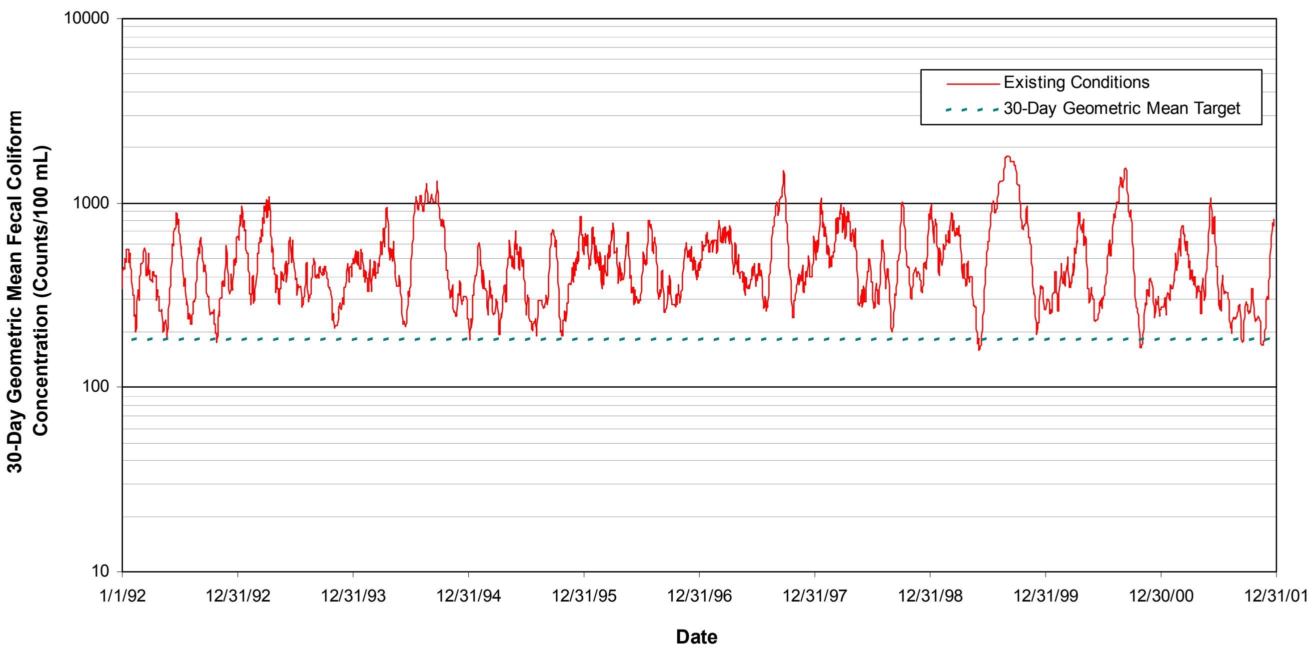


Figure C-30 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Subwatershed 0404 (Weakley Creek)

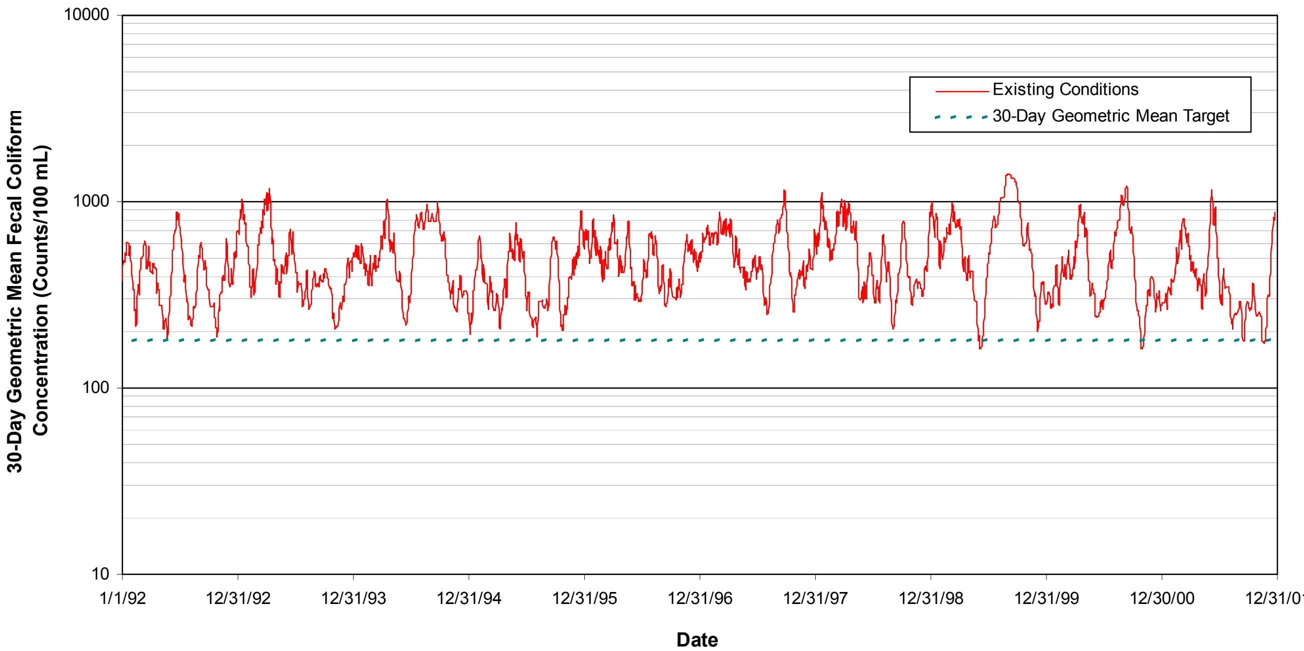


Figure C-31 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Subwatershed 0402 (Alexander Creek)

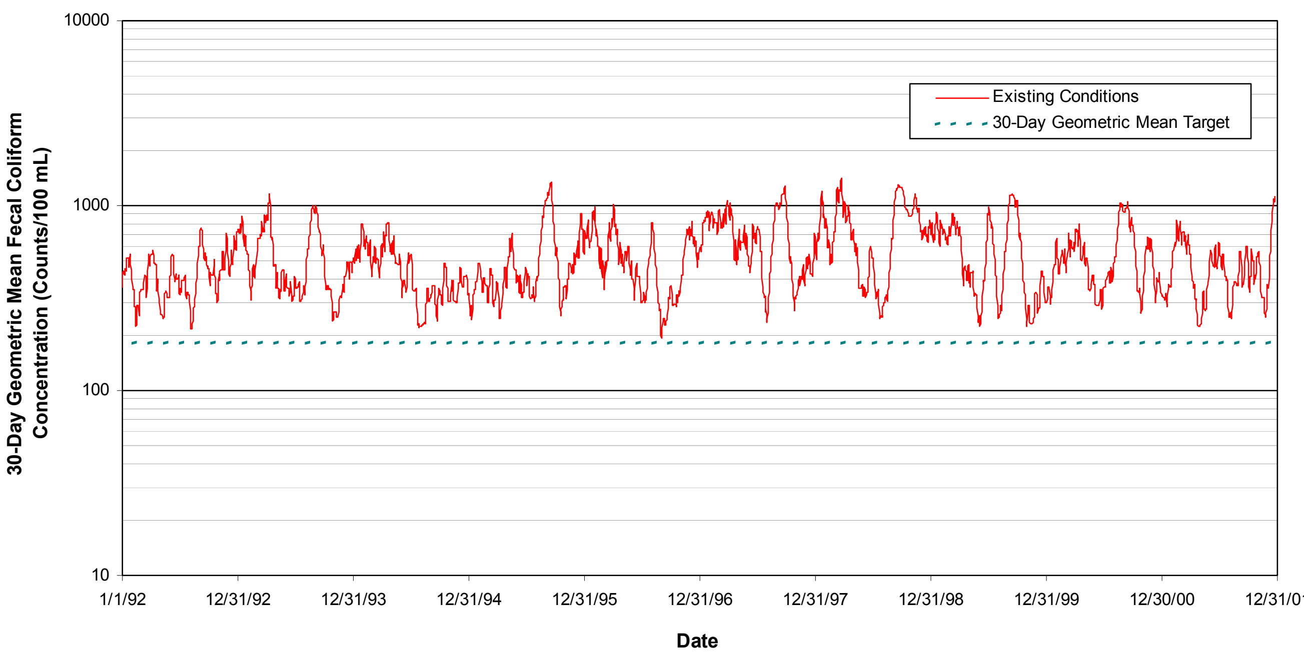


Figure C-32 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Subwatershed 0401 (North Fork Creek)

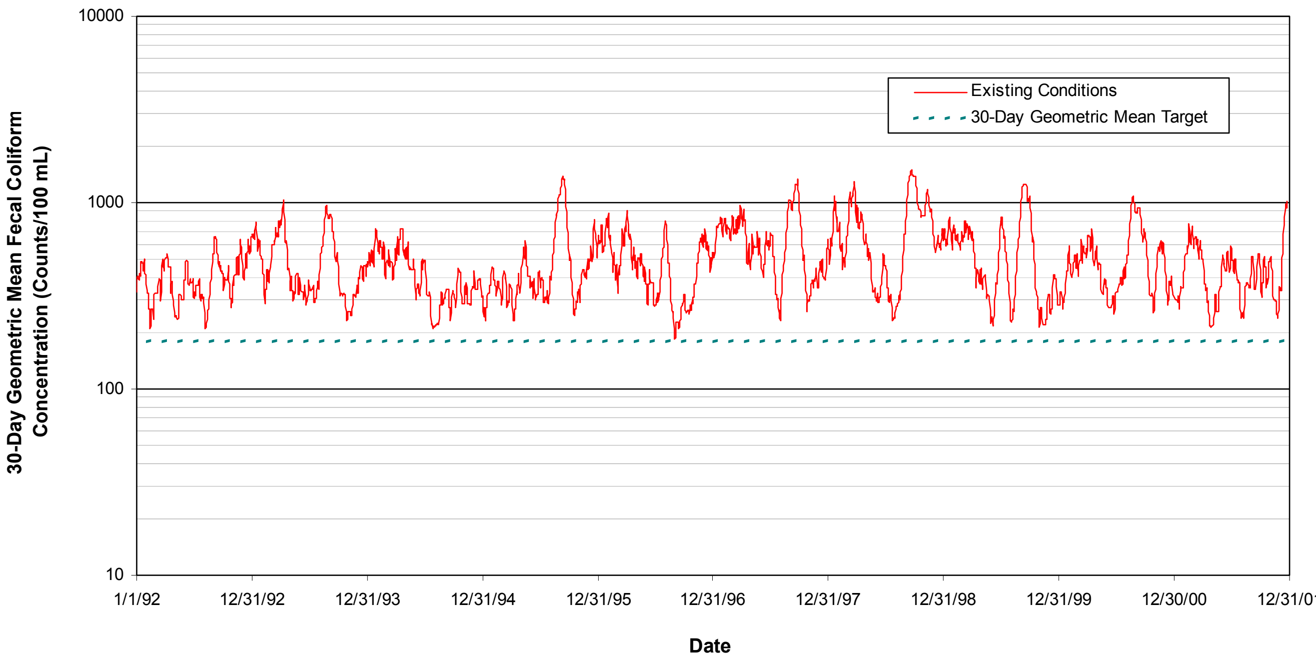


Figure C-33 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Subwatershed 0308 (Fall Creek, Hurricane Creek)

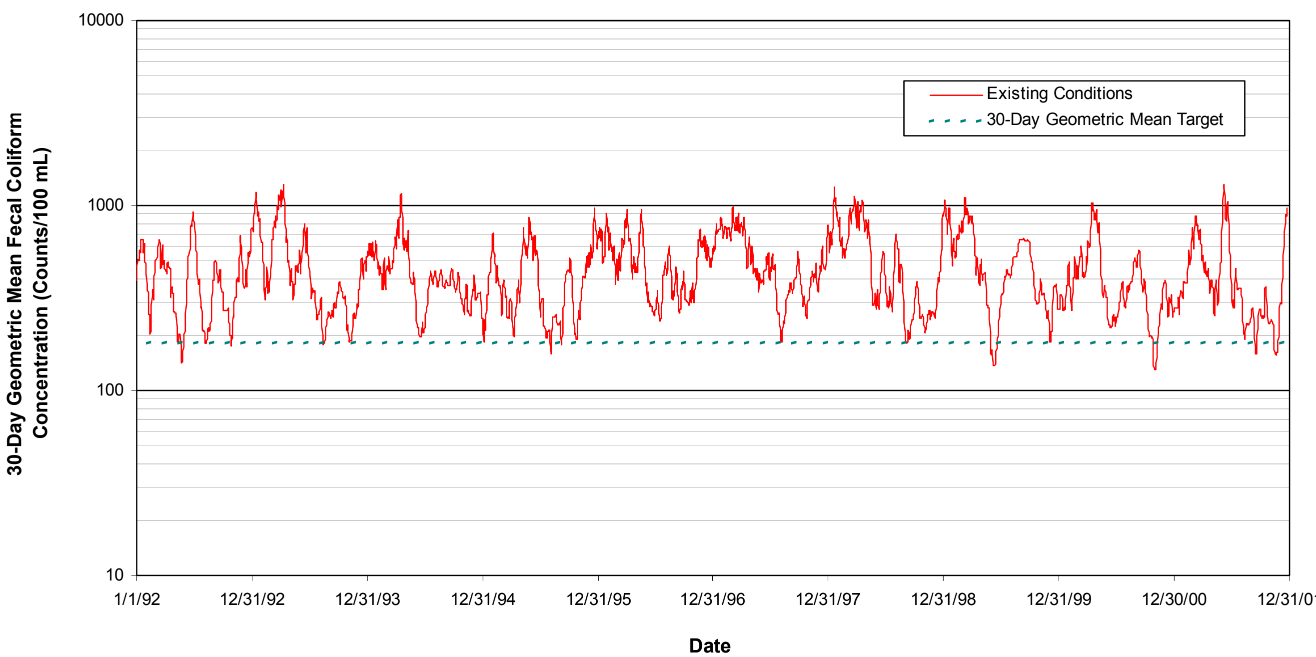


Figure C-34 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Bell Buckle Creek

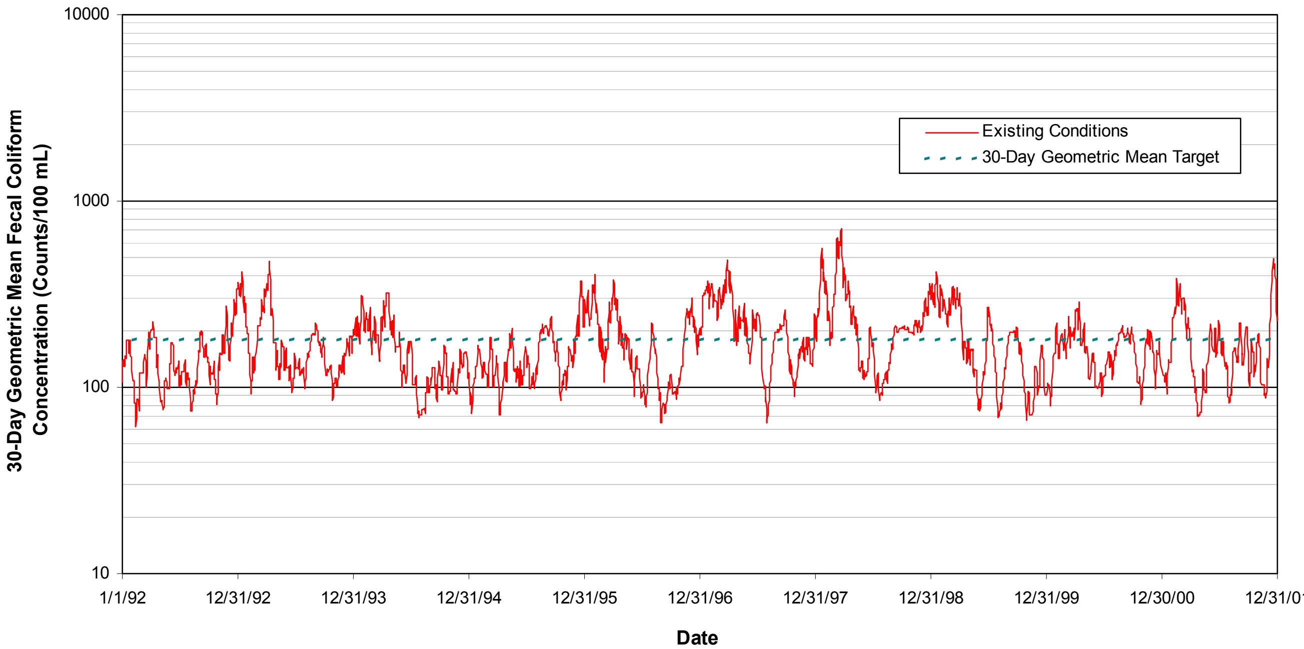


Figure C-35 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Subwatershed 0101 (Clear Branch, Duck River)

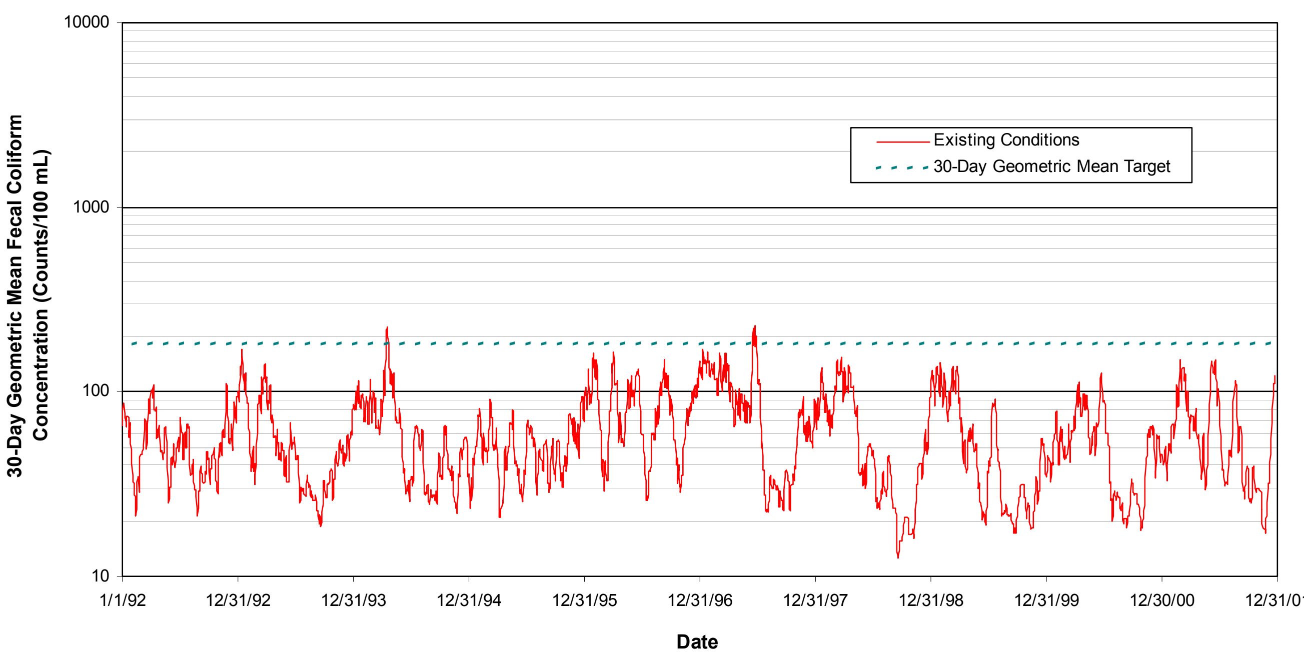


Figure C-36 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Clear Branch

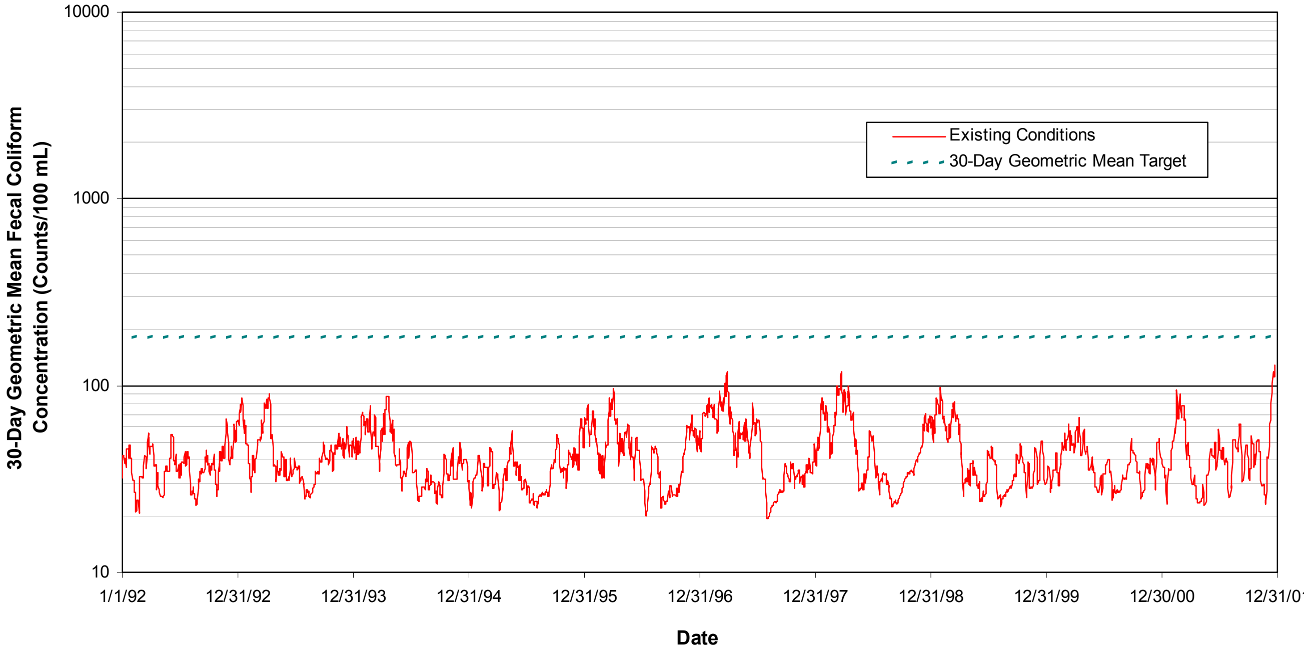
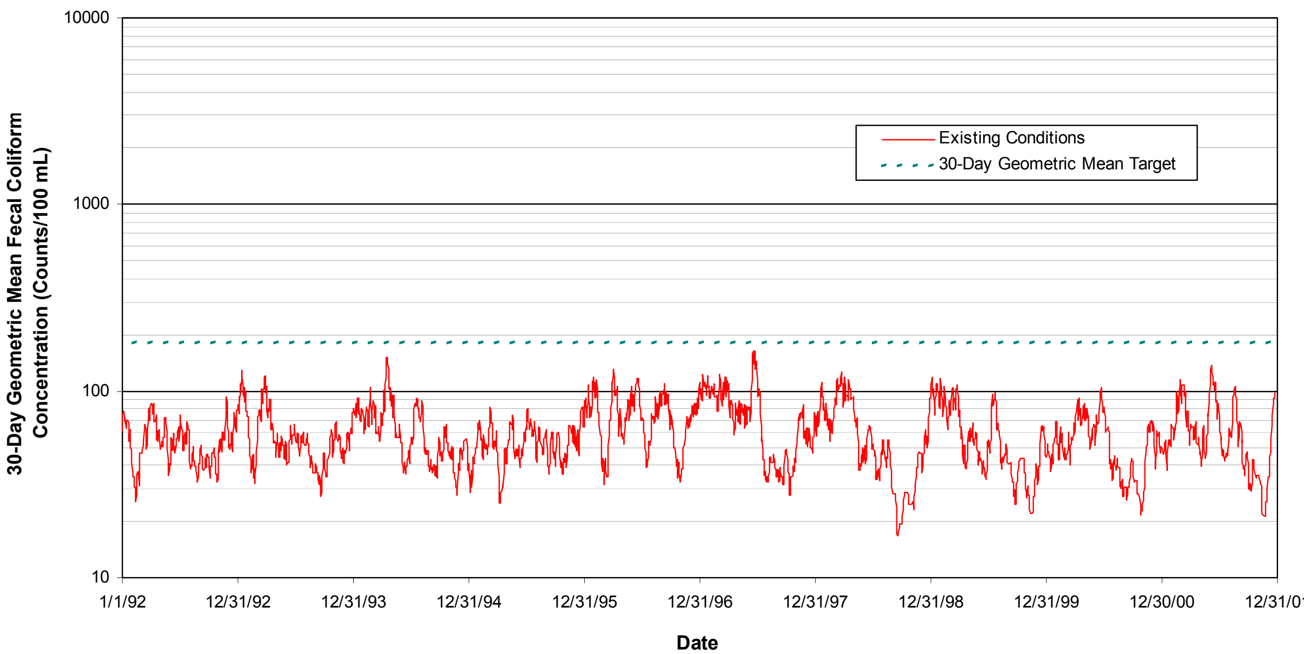


Figure C-37 Simulated 30-Day Geometric Mean Fecal Coliform Concentrations for Subwatershed 0102 (Little Duck River)



APPENDIX D

Load Duration Curve Methodology

LOAD DURATION CURVE METHOD

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 are useful for TMDL analysis:

- Load duration curves can serve as TMDL targets, thereby establishing allowable loading to waterbodies over the entire range of flow.

- Pollutant monitoring data, plotted on a load duration curve, provides a visual depiction of stream water quality with respect to allowable loads. The frequency and magnitude of exceedances are also illustrated.

- Load duration curves can be used to characterize the flow conditions under which exceedances occur. For example, exceedances that occur in the 0% to 10% area of the curve may be considered to represent extreme high flow problems that may be beyond feasible management solutions. Exceedances in the 99% to 100% area reflect extreme drought conditions.

- Different loading mechanisms can dominate at different flow regimes. Exceedances of the load duration curve during high flow conditions may indicate excessive nonpoint source loading associated with rain events, while exceedances at the lower flows can indicate point source problems.

D.1 Development of Flow Duration Curves

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 LSPC.

With one exception, flow duration curves for pathogen impaired waterbodies were derived from a flow duration curve developed at USGS Station No. 03597590, located on Wartrace Creek near Wartrace, Tennessee. The Wartrace Creek flow duration curve is shown in Figure D-1. Due to the large size of the drainage area, the flow duration curve for the Duck River at RM 216.2 was derived from a flow duration curve developed at USGS Station No. 03598000, located on the Duck River at Shelbyville, Tennessee. It should be noted that only data recorded after the construction of Normandy Dam (1976) was utilized for curve construction. The data used included the periods of record from 1/1/77 – 9/30/82 & 10/1/99 – 9/30/02. The Duck River flow duration curve is shown in Figure D-2. Flow duration curves for impaired waterbodies in the Upper Duck River watershed were constructed at stream locations corresponding to water quality monitoring stations using the drainage area extrapolation methodology.

D.2 Development of Load Duration Curves

Fecal coliform load duration curves were developed for impaired waterbodies from the flow duration curves developed in Section D.1 and available water quality monitoring data. Generally, these curves were constructed for each impaired HUC-12 subwatershed or drainage area at the location of the most downstream water quality monitoring station, located on an impaired stream segment, where adequate data was available.

Load duration curves were developed using the following procedure (Spring Creek is shown as an example, others are similar):

1. A load-duration curve was generated for Spring Creek by applying the fecal coliform target concentration of 900 cts./100 ml (1,000 cts./100ml - MOS) to each of the ranked flows used to generate the flow duration curve (ref.: Section D.1) and plotting the results. The fecal coliform target load corresponding to each ranked daily mean flow is:

   $(\text{Target Load})_{\text{Spring Ck}}$ = (900 cts./100 ml) x (Q) x (UCF)

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

2. Daily fecal coliform loads were calculated for each of the water quality samples collected at the SPRIN003.2ML monitoring station (ref.: Table B-1) by multiplying the sample concentration by the derived daily mean flow for the sampling date and the required unit conversion factor. On days where multiple samples were collected, the highest sample value was used.

   Note: 1) 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. One exception to this was in the case of the 10/6/99 data point for Spring Creek where the measured flow of 0.01 cfs was used in lieu of the derived daily mean flow of 0 cfs to calculate the sample load.

   2) Data from the NFORK007.7BE monitoring station was used to develop the load duration curve for the upper section of North Fork Creek in Subwatershed 0401.

3. Using the flow duration curve developed in Step 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 curve developed in Step 2 according to the PDFE. The resulting curve is shown in Figure D-3.

4. For cases where the existing load exceeded the target load, the reduction corresponding to each sample load was determined through comparison with the target load corresponding to the PDFE. The geometric mean of the calculated reductions of existing fecal coliform load required to meet the TMDL target was considered to be the required load reduction for the subwatershed (see Table D-1).

Load duration curves for other impaired waterbodies are shown in Figures D-4 through D-17. Required load reductions for these waterbodies are tabulated in Tables D-2 through D-15.

Figure D-1 Flow Duration Curve for Wartrace Creek at USGS Station 03597590

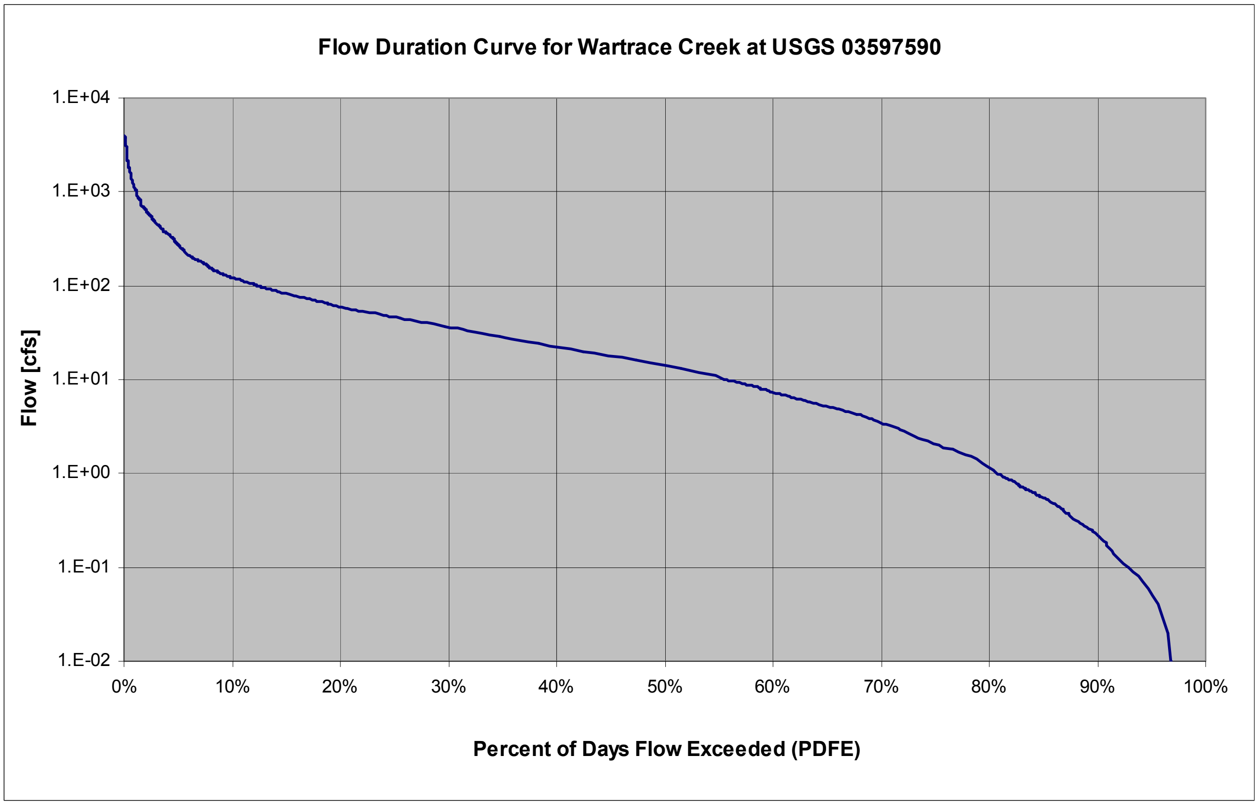


Figure D-2 Flow Duration Curve for Duck River at USGS Station 03598000

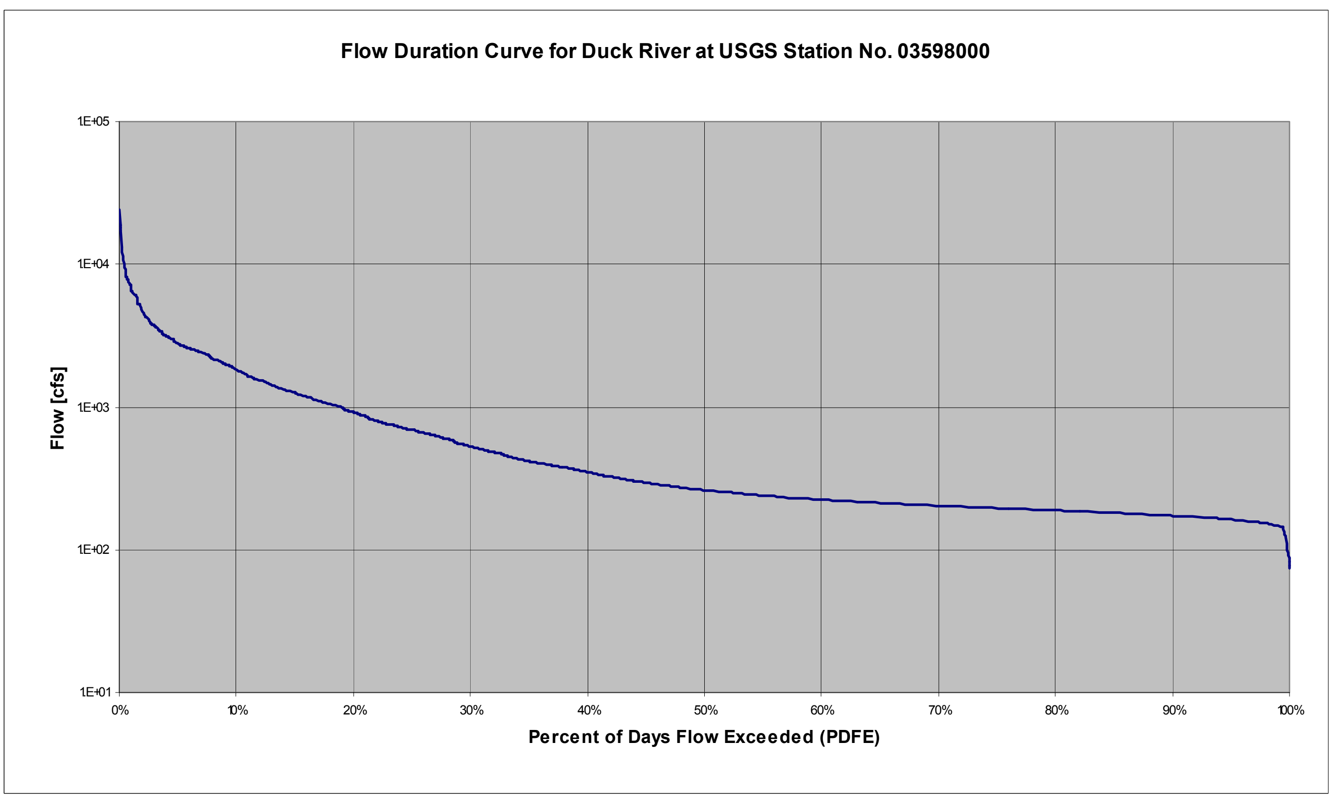


Figure D-3 Load Duration Curve for Spring Creek at SPRIN003.2ML

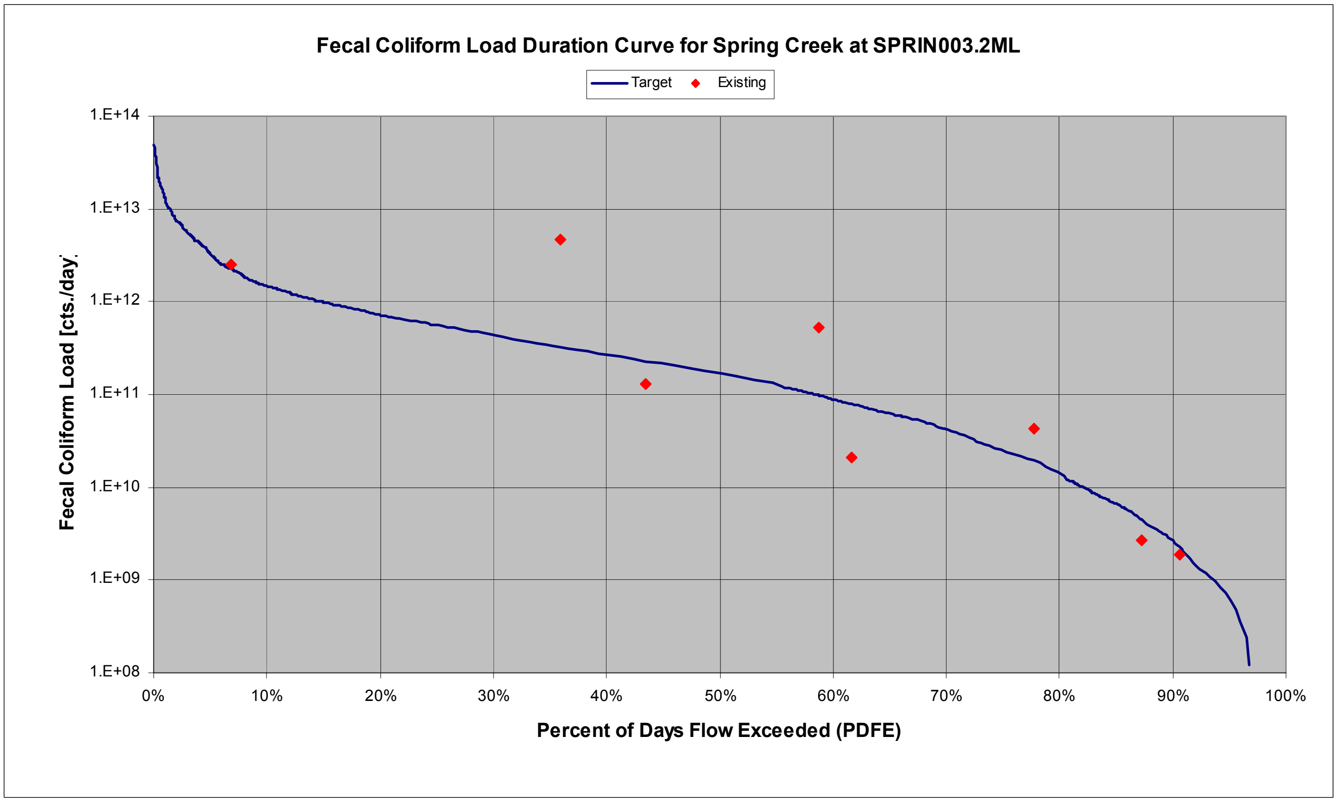


Table D-1 Determination of Required Load Reduction for Spring Creek

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
10/6/99	0.010	96.8%	1,300	3.181E+08	2.202E+08	30.8
11/9/99	0.104	90.6%	730	1.859E+09	2.292E+09	NR
12/2/99	0.203	87.3%	540	2.678E+09	4.464E+09	NR
1/6/00	4.438	58.8%	4,800	5.212E+11	9.773E+10	81.3
2/8/00	3.616	61.6%	240	2.123E+10	7.963E+10	NR
3/8/00	10.41	43.5%	510	1.299E+11	2.292E+11	NR
4/5/00	104.1	6.8%	1,000	2.547E+12	2.292E+12	10.0
5/4/00	14.79	35.9%	13,000	4.705E+12	3.258E+11	93.1
6/20/00	0.877	77.8%	2,000	4.290E+10	1.930E+10	55.0
					Geometric Mean	**41.8**

NR = Not Required

Figure D-4 Load Duration Curve for Fountain Creek at RM 14.5

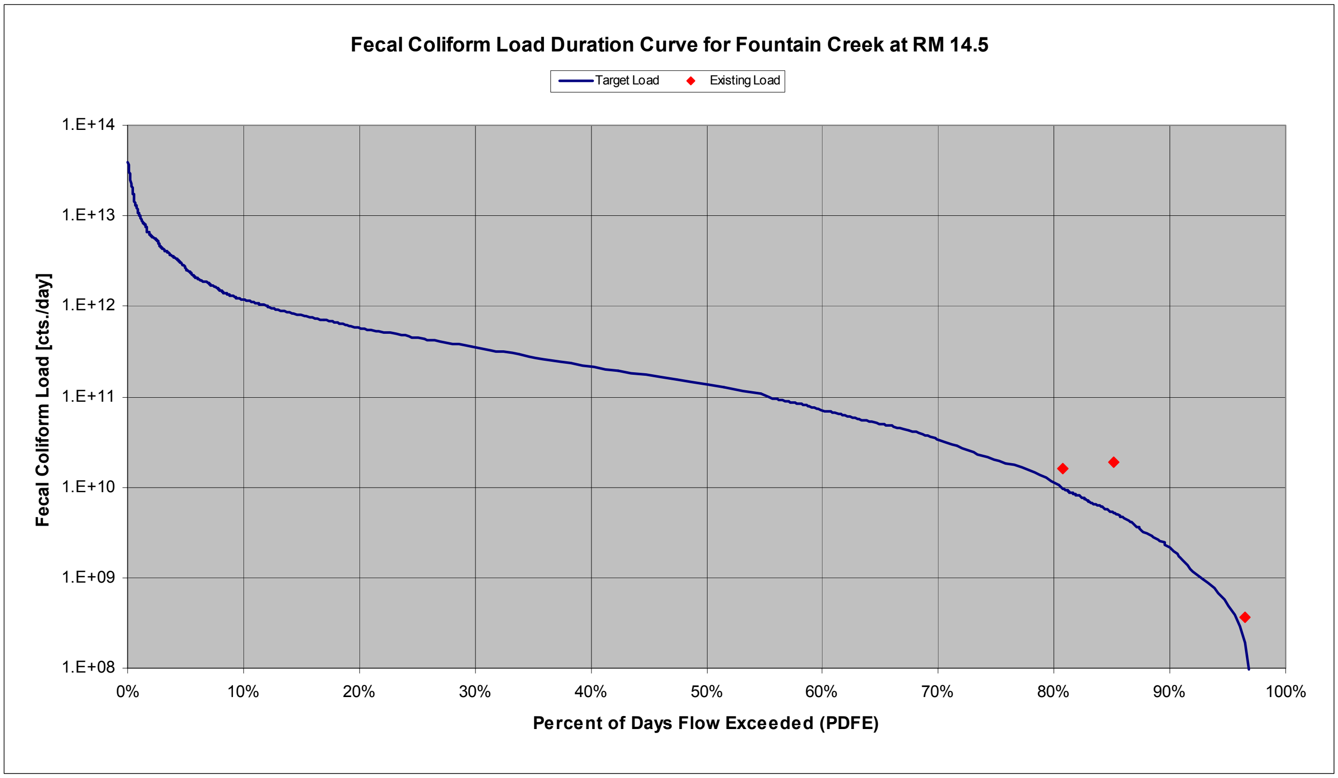


Table D-2 Determination of Required Load Reduction for Fountain Creek

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
8/26/98	0.436	80.8%	1,490	1.590E+10	9.604E+09	39.6
9/29/98	0.009	96.5%	1,690	3.643E+08	1.940E+08	46.7
10/20/98	0.057	91.8%	1	1.401E+06	1.261E+09	NR
11/17/98	0.238	85.2%	3,210	1.868E+10	5.239E+09	72.0
					Geometric Mean	**51.1**

NR = Not Required

Figure D-5 Load Duration Curve for Wallace Branch at STORET Station WALLA000.8WI

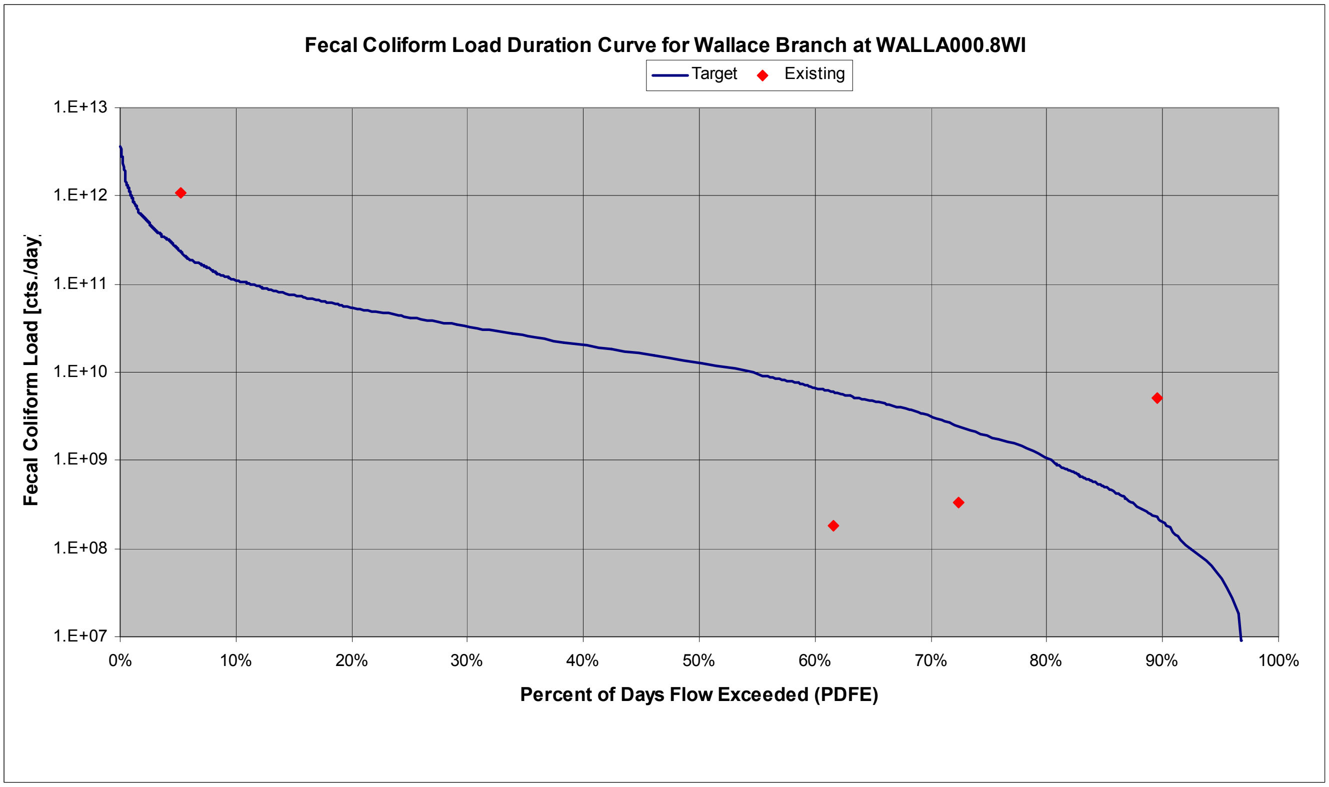


Table D-3 Determination of Required Load Reduction for Wallace Branch

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
2/8/00	0.272	61.6%	27	1.800E+08	5.999E+09	NR
4/12/00	10.61	5.2%	4,100	1.064E+12	2.336E+11	78.0
7/12/00	0.010	89.5%	20,000	5.049E+09	2.272E+08	95.5
5/30/00	0.111	72.4%	120	3.272E+08	2.454E+09	NR
					Geometric Mean	**86.3**

NR = Not Required

Figure D-6 Load Duration Curve for Thick Creek at STORET Station THICK002.0ML

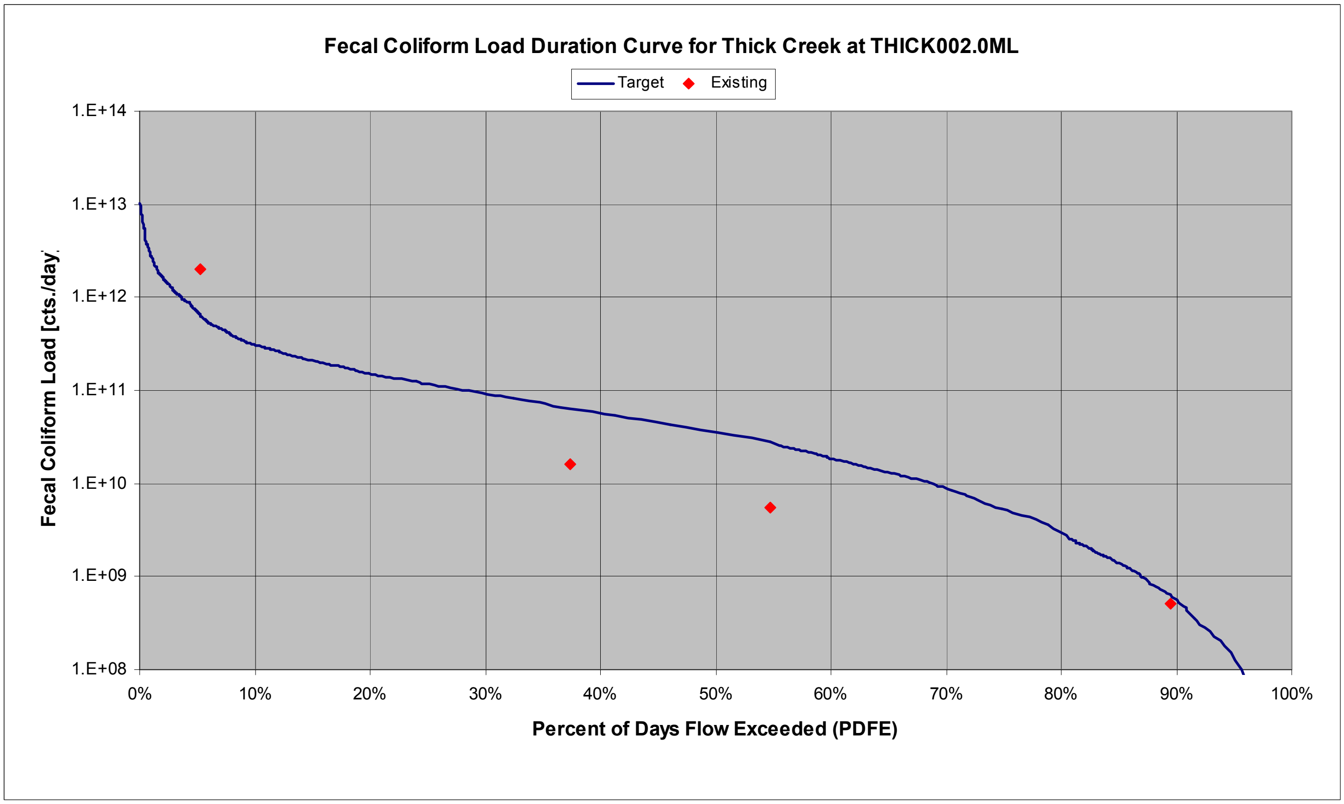


Table D-4 Determination of Required Load Reduction for Thick Creek

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
1/24/00	2.884	37.4%	230	1.623E+10	6.352E+10	NR
4/12/00	29.65	5.2%	2,800	2.031E+12	6.529E+11	67.9
7/12/00	0.03	89.5%	730	5.152E+08	6.352E+08	NR
10/30/00	0.045	87.0%	4	4.404E+06	9.909E+08	NR
5/29/01	1.269	54.7%	180	5.589E+09	2.795E+10	NR
					Geometric Mean	**67.9**

NR = Not Required

Figure D-7 Load Duration Curve for Wilson Creek at STORET Station WILSO000.7ML

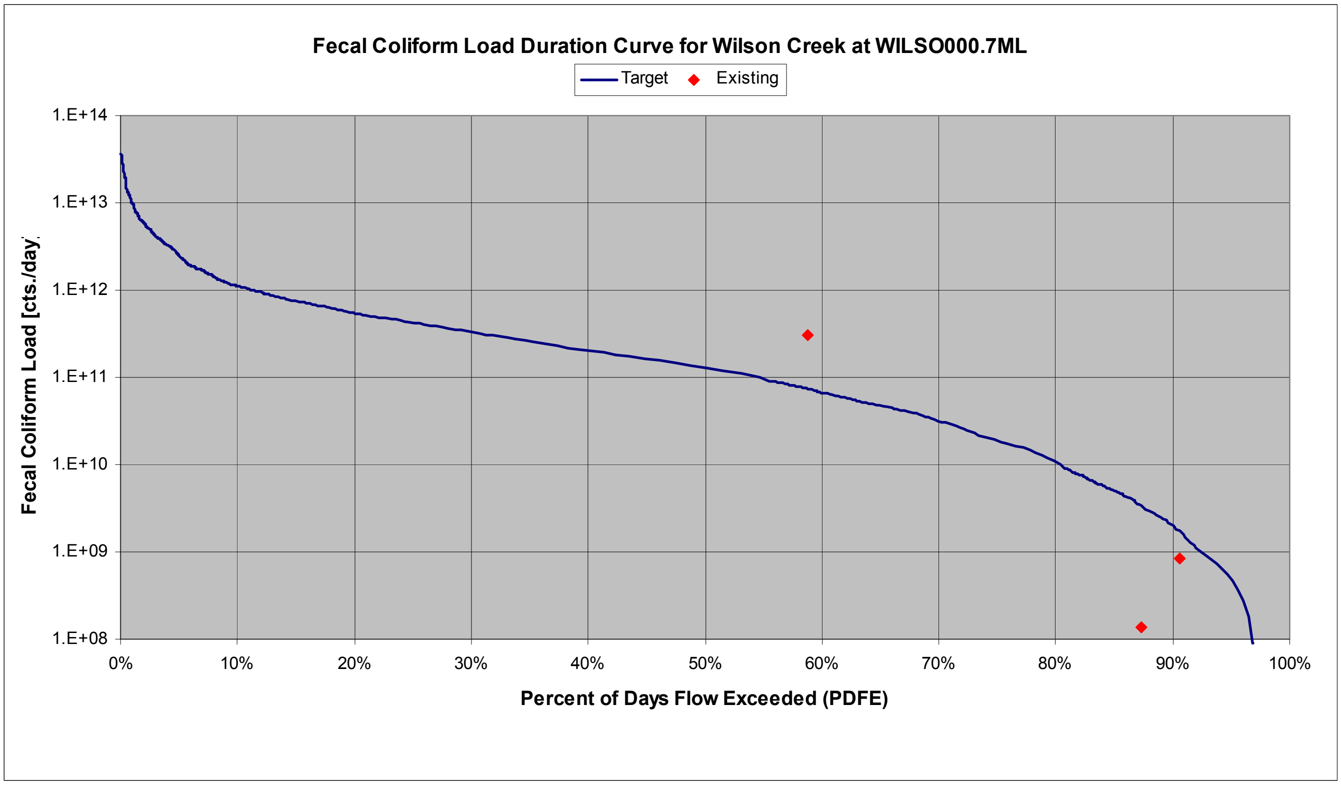


Table D-5 Determination of Required Load Reduction for Wilson Creek

Sample Date	Flow	PDFE	Fecal Coliform Sample Concen.			
			Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
11/9/99	0.079	90.6%	430	8.290E+08	1.735E+09	NR
12/2/99	0.153	87.3%	36	1.352E+08	3.379E+09	NR
1/6/00	3.359	58.8%	3,700	3.041E+11	7.397E+10	75.7
	NR = Not Required				**Geometric Mean**	**75.7**

Figure D-8 Load Duration Curve for Clem Creek at STORET Station CLEM000.4BE

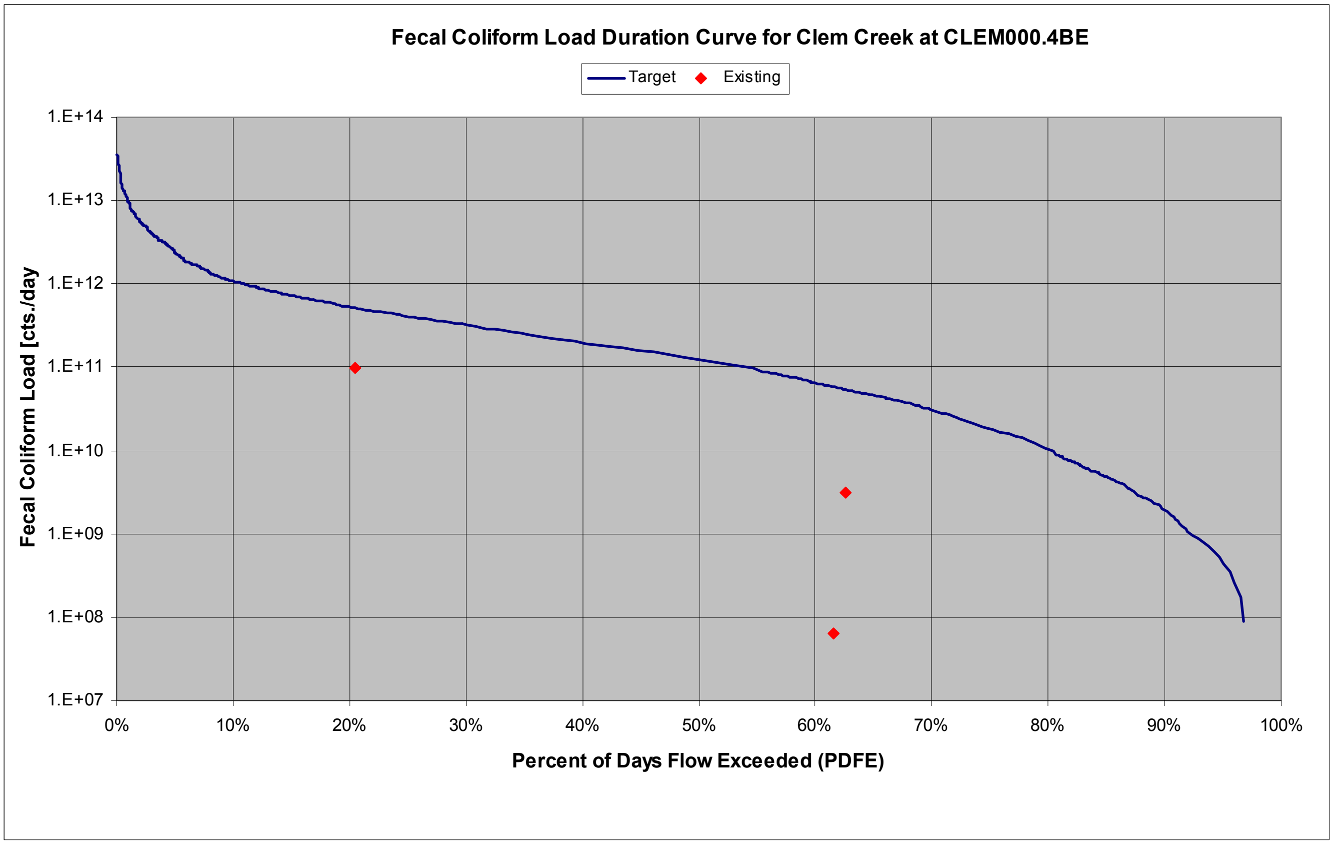


Table D-6 Determination of Required Load Reduction for Clem Creek

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
2/8/00	2.646	61.6%	1	6.474E+07	5.827E+10	NR
4/17/00	23.25	20.5%	170	9.672E+10	5.121E+11	NR
5/10/01	2.446	62.6%	52	3.112E+09	5.386E+10	NR
					Geometric Mean	**NR**

NR = Not Required

Figure D-9 Load Duration Curve for Weakley Creek at STORET Station WEAKL005.2BE

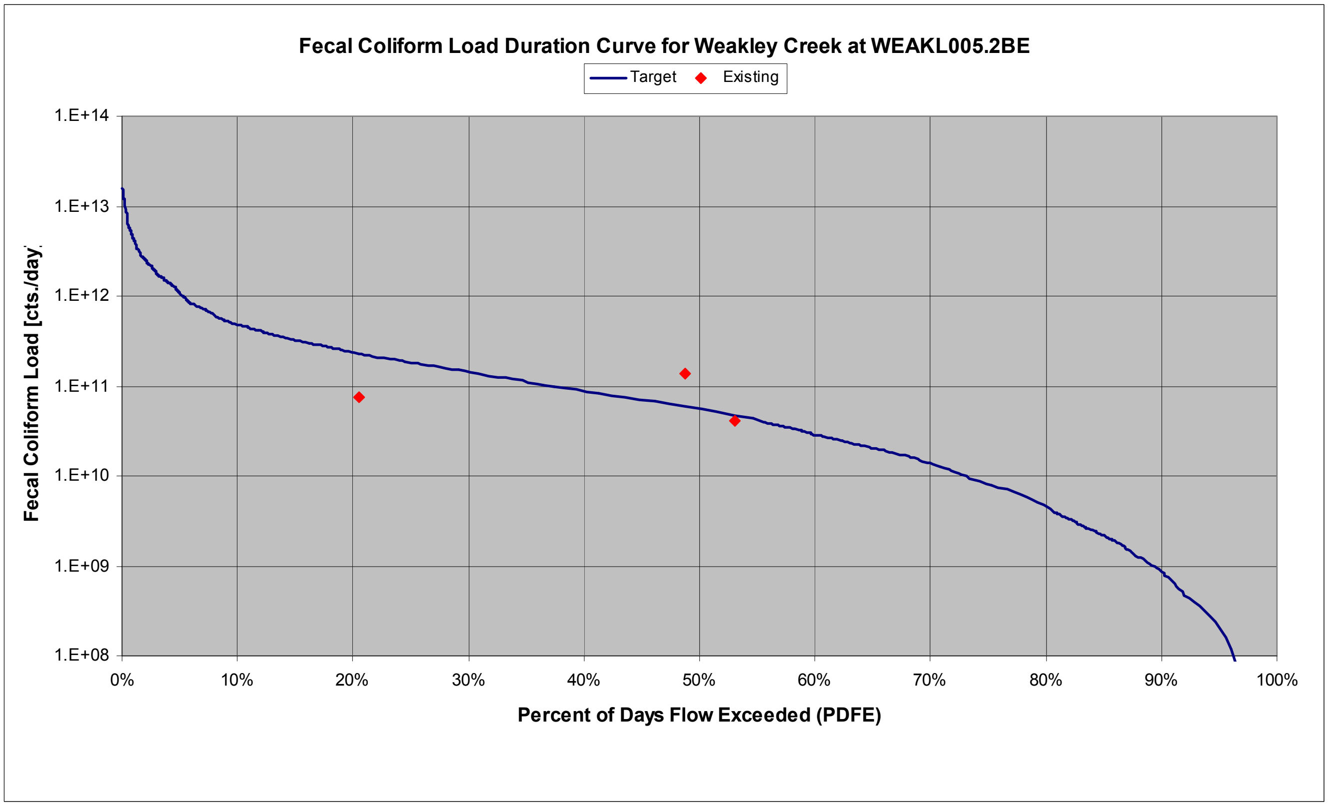


Table D-7 Determination of Required Load Reduction for Weakley Creek

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
1/10/00	2.689	48.7%	2,100	1.382E+11	5.922E+10	57.1
4/17/00	10.40	20.5%	300	7.633E+10	2.290E+11	NR
5/8/01	2.151	53.1%	770	4.053E+10	4.737E+10	NR
					Geometric Mean	**57.1**

NR = Not Required

Figure D-10 Load Duration Curve for Alexander Creek at STORET Station ALEXA004.0BE

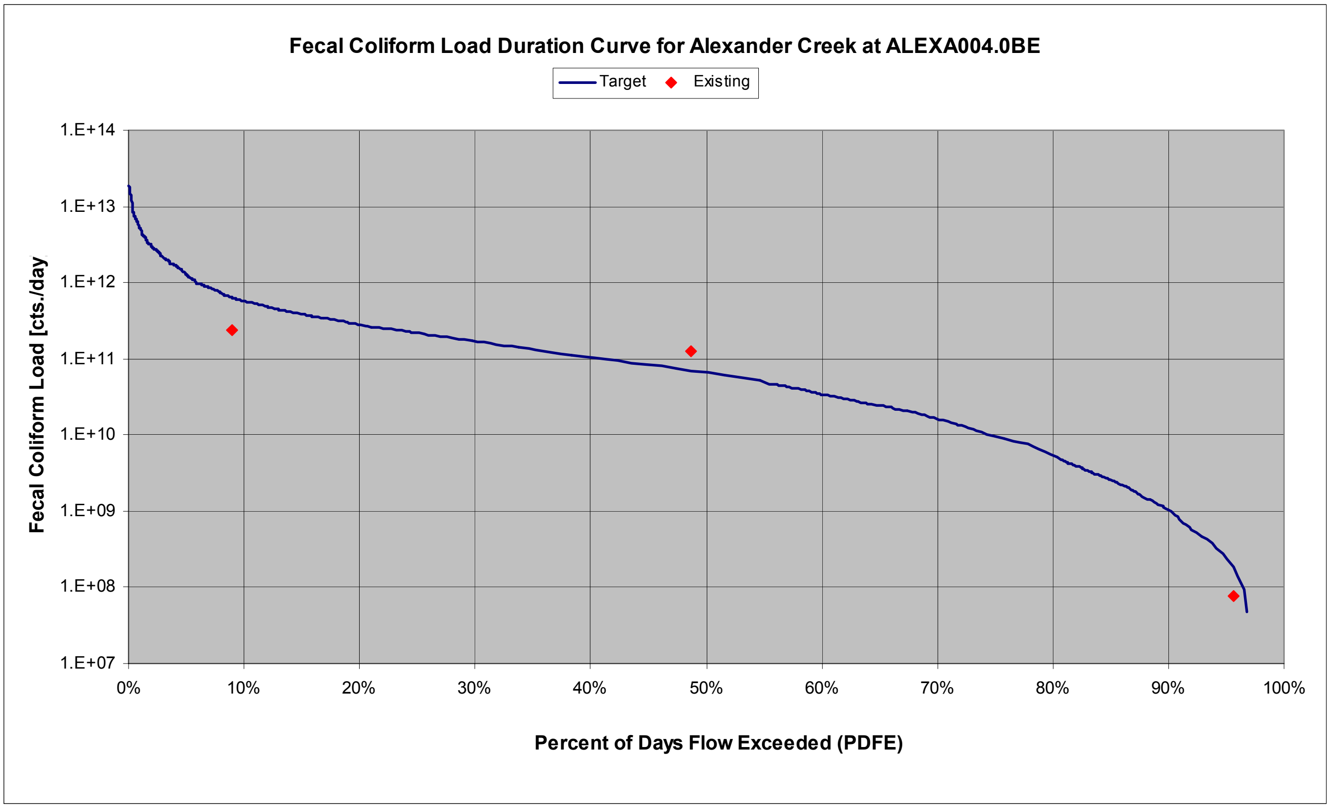


Table D-8 Determination of Required Load Reduction for Alexander Creek

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
1/10/00	3.194	48.7%	1,600	1.250E+11	7.034E+10	43.8
4/13/00	28.96	8.9%	340	2.409E+11	6.377E+11	NR
7/24/00	0.009	95.6%	370	7.711E+07	1.876E+08	NR
					Geometric Mean	**43.8**

NR = Not Required

Figure D-11 Load Duration Curve for North Fork Creek at STORET Station NFORK007.7BE

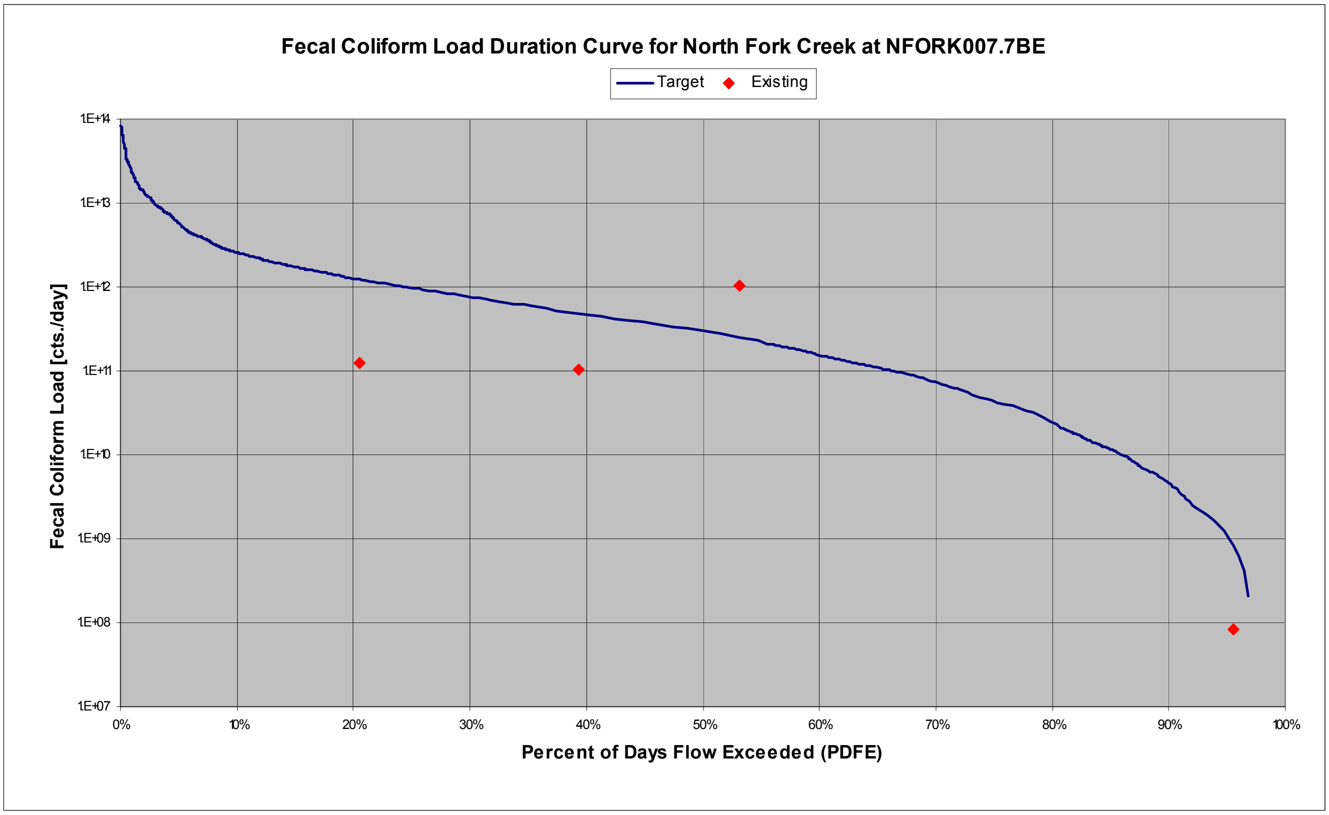


Table D-9 Determination of Required Load Reduction for North Fork Creek

Sample Date	Flow	PDFE	Fecal Coliform Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
2/1/00	22.03	39.3%	190	1.024E+11	4.852E+11	NR
4/17/00	55.57	20.5%	93	1.264E+11	1.224E+12	NR
7/24/00	0.04	95.6%	90	8.439E+07	8.439E+08	NR
5/8/01	11.50	53.1%	3,700	1.041E+12	2.532E+11	75.7
					Geometric Mean	**75.7**

NR = Not Required

Figure D-12 Load Duration Curve for Fall Creek at STORET Station FALL003.0BE

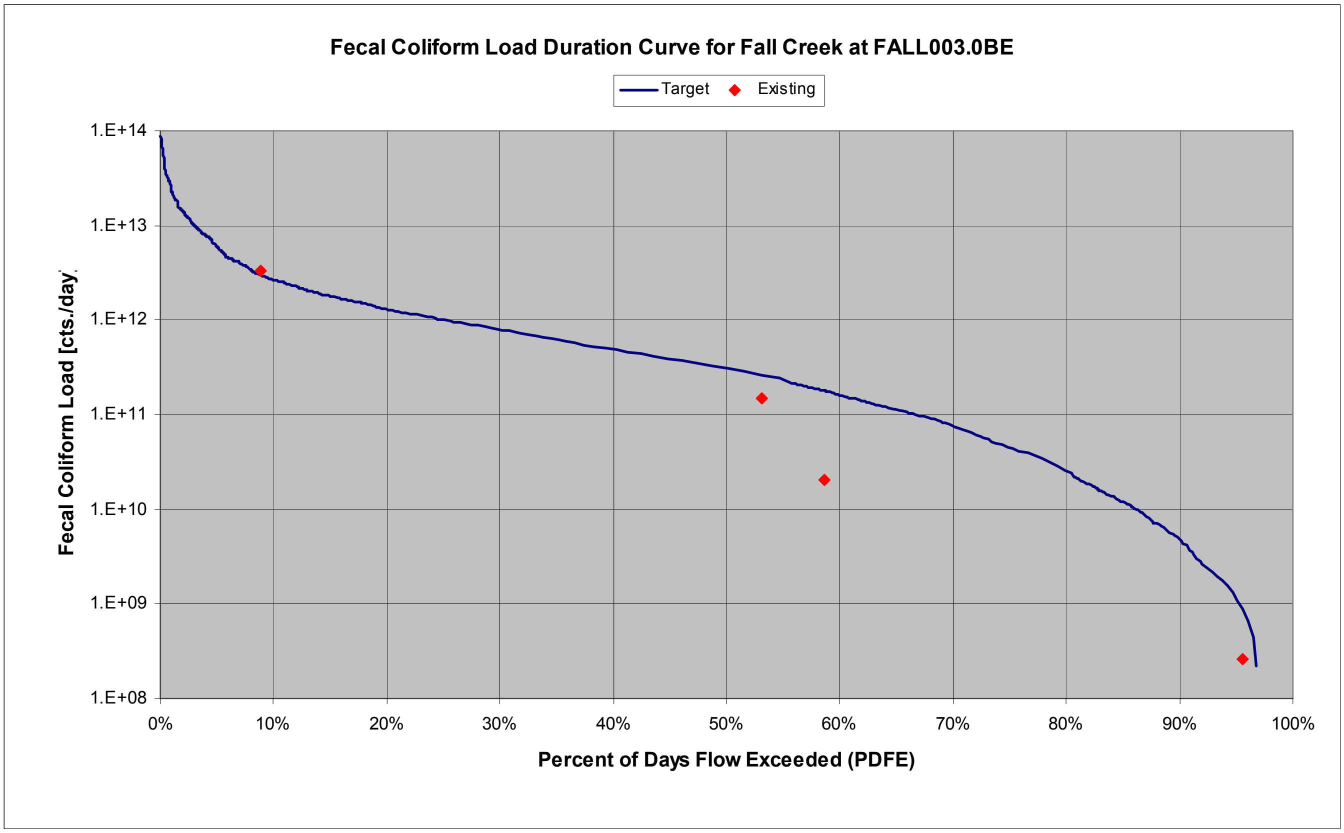


Table D-10 Determination of Required Load Reduction for Fall Creek

Sample Date	Flow	PDFE	Fecal Coliform Sample Concen.	Fecal Coliform Sample Load	Fecal Coliform Target Load	Fecal Coliform Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
1/12/00	8.235	58.6%	100	2.015E+10	1.813E+11	NR
4/13/00	134.9	8.9%	1,000	3.302E+12	2.971E+12	10.0
7/24/00	0.040	95.6%	270	2.622E+08	8.740E+08	NR
10/16/00	0.198	90.3%	5	2.428E+07	4.370E+09	NR
5/8/01	11.91	53.1%	510	1.486E+11	2.622E+11	NR
					Geometric Mean	**10.0**

NR = Not Required

Figure D-13 Load Duration Curve for Bell Buckle Creek at STORET Station BBUCK001.0BE

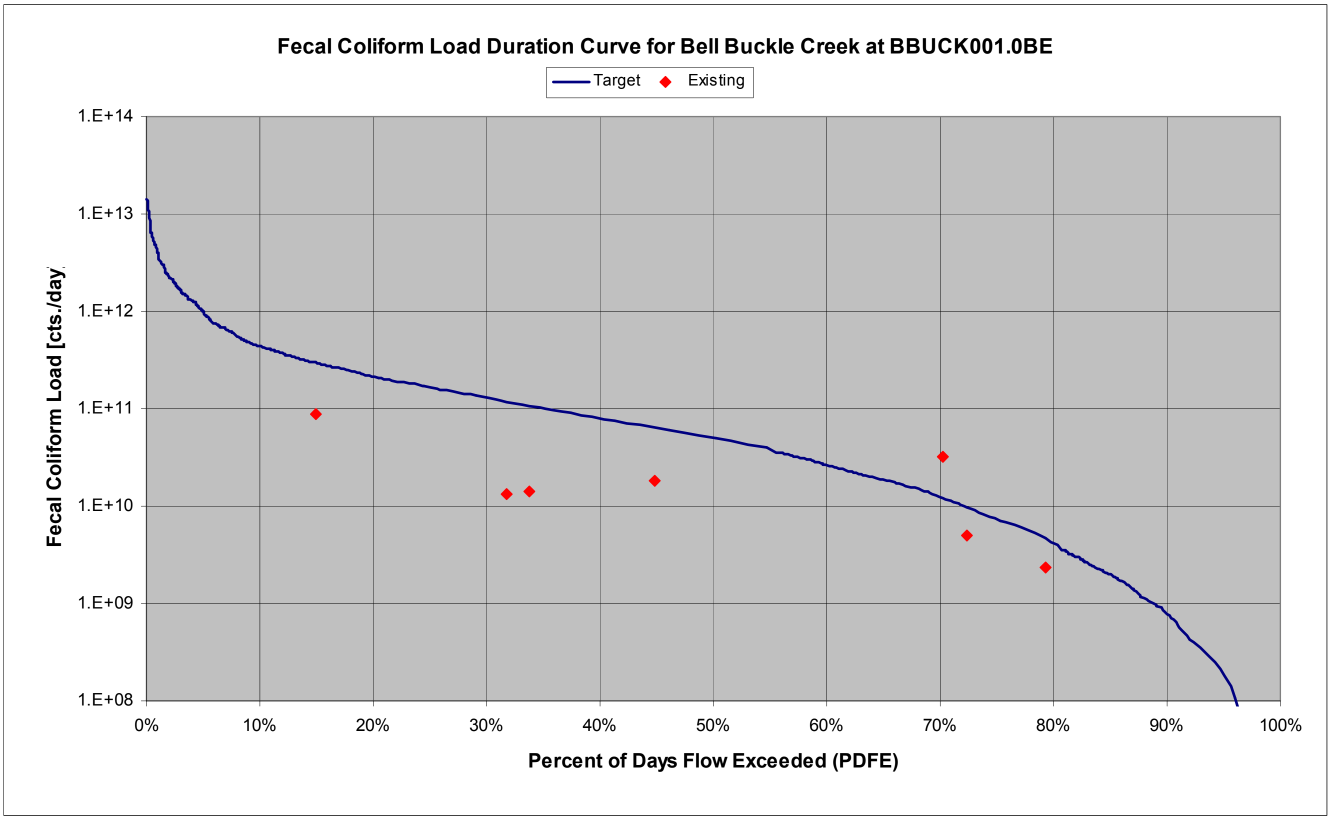


Table D-11 Determination of Required Load Reduction for Bell Buckle Creek

Sample Date	Flow	PDFE	Fecal Coliform Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
12/8/99	0.046	88.8%	46	5.131E+07	1.004E+09	NR
1/25/00	2.93	44.8%	250	1.793E+10	6.454E+10	NR
2/17/00	4.88	33.8%	120	1.434E+10	1.076E+11	NR
3/15/00	5.37	31.8%	100	1.315E+10	1.183E+11	NR
4/27/00	13.51	14.9%	270	8.928E+10	2.976E+11	NR
5/25/00	0.554	70.2%	2,400	3.251E+10	1.219E+10	62.5
6/21/00	0.212	79.3%	450	2.331E+09	4.661E+09	NR
8/6/01	0.440	72.4%	470	5.055E+09	9.681E+09	NR
					Geometric Mean	**62.5**

NR = Not Required

Figure D-14 Load Duration Curve for Clear Branch at STORET Station CLEAR001.1CE

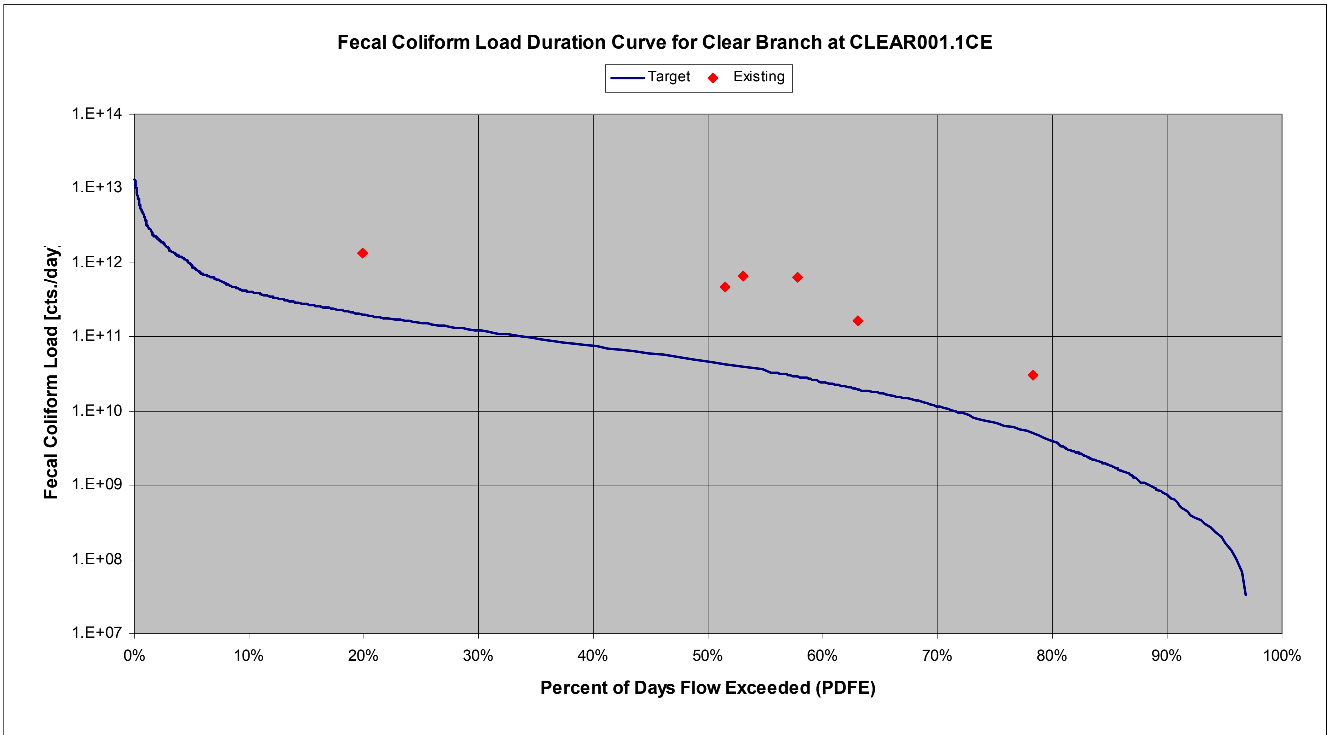


Table D-12 Determination of Required Load Reduction for Clear Branch

Sample Date	Flow	PDFE	Fecal Coliform Sample Concen.	Fecal Coliform Sample Load	Fecal Coliform Target Load	Fecal Coliform Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
12/16/99	1.82	53.1%	15,000	6.685E+11	4.011E+10	94.0
1/26/00	1.97	51.5%	9,700	4.683E+11	4.345E+10	90.7
2/9/00	0.90	63.0%	7,400	1.622E+11	1.972E+10	87.8
3/13/00	9.11	19.9%	6,000	1.337E+12	2.006E+11	85.0
5/11/00	1.32	57.8%	20,000	6.462E+11	2.908E+10	95.5
6/1/00	0.23	78.3%	5,400	3.008E+10	5.014E+09	83.3
					Geometric Mean	**89.3**

NR = Not Required

Figure D-15 Load Duration Curve for Little Duck River at STORET Station LDUCK001.3CE

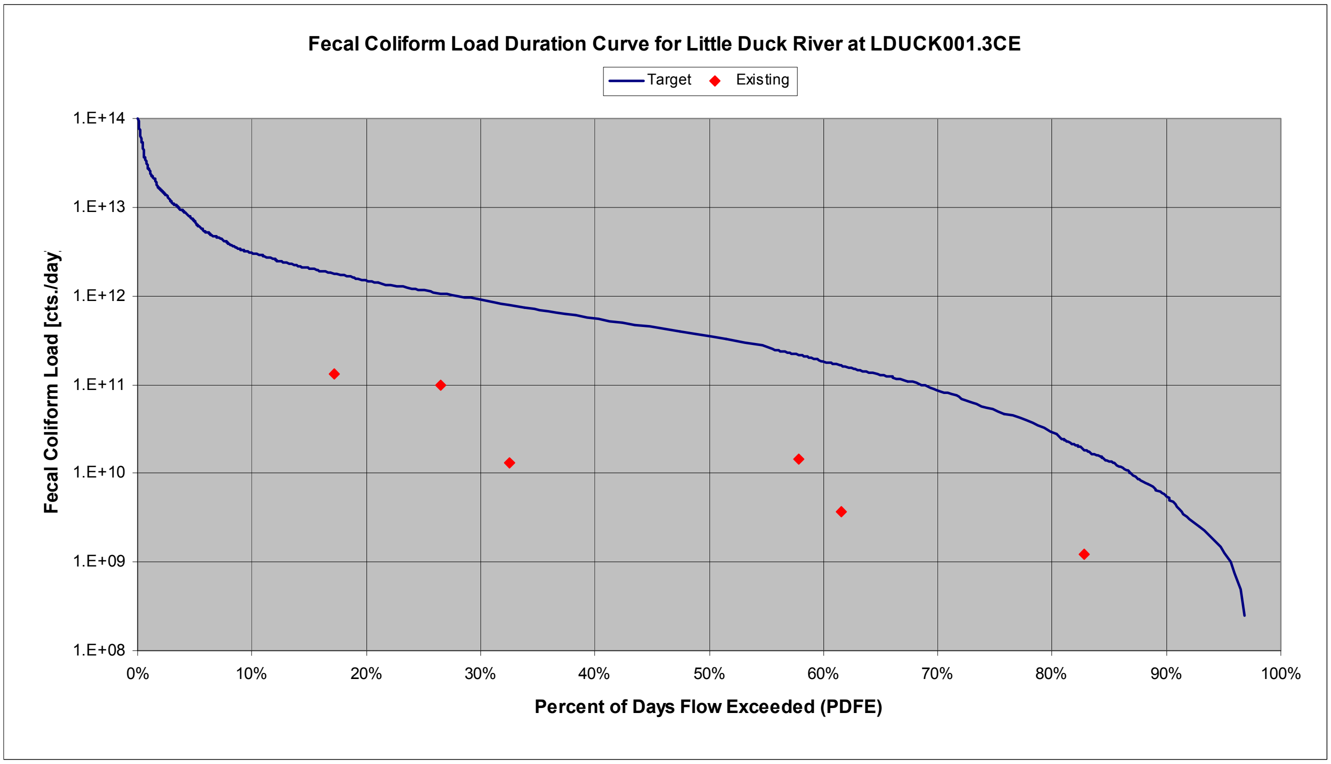


Table D-13 Determination of Required Load Reduction for Little Duck River

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
1/20/99	81.47	17.2%	67	1.336E+11	1.794E+12	NR
1/31/00	36.21	32.5%	15	1.329E+10	7.974E+11	NR
2/8/00	7.47	61.6%	20	3.655E+09	1.645E+11	NR
3/14/00	48.66	26.5%	83	9.881E+10	1.071E+12	NR
5/11/00	9.84	57.8%	60	1.445E+10	2.168E+11	NR
6/8/00	0.84	82.8%	60	1.229E+09	1.844E+10	NR
	NR = Not Required			**Geometric Mean**		**NR**

Figure D-16 Load Duration Curve for Duck River at STORET Station DUCK269.6CE

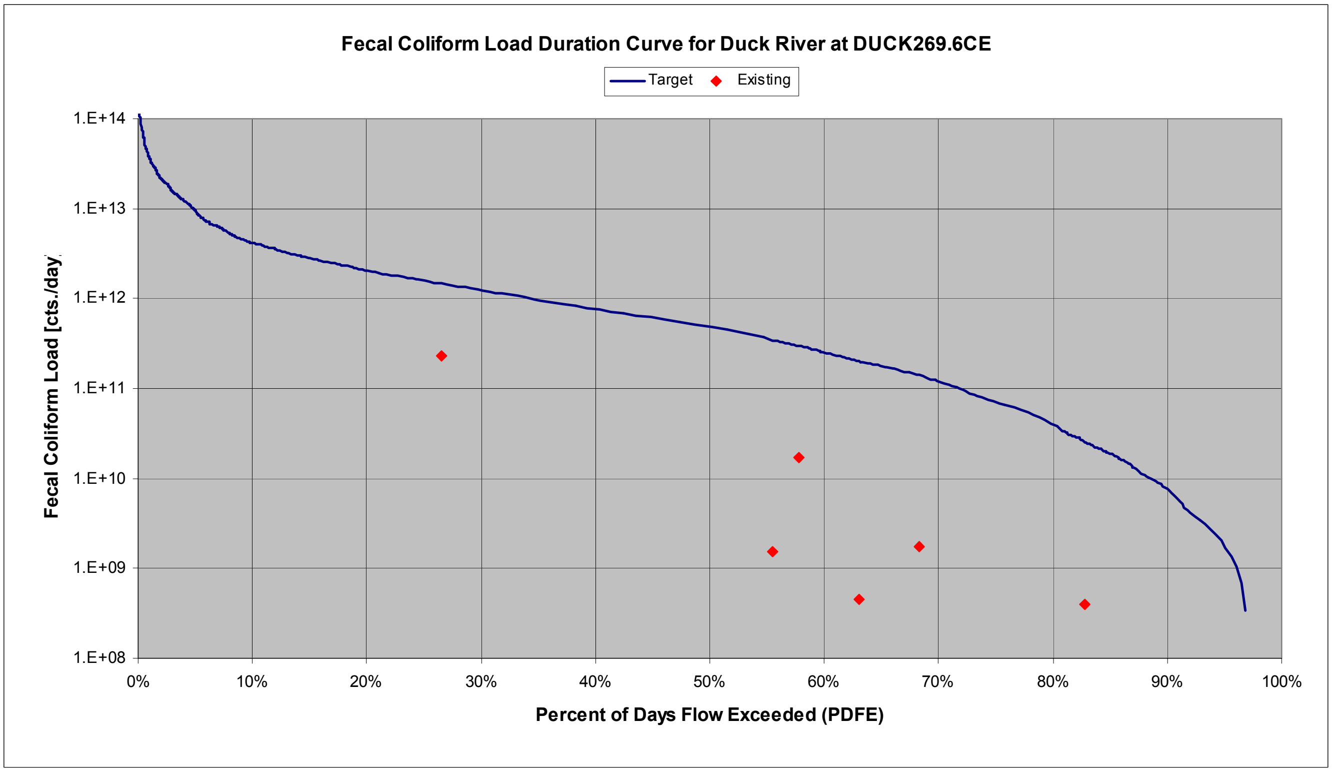


Table D-14 Determination of Required Load Reduction for Duck River at RM 269.6

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
12/20/99	6.38	68.3%	11	1.718E+09	1.406E+11	NR
1/27/00	15.57	55.5%	4	1.524E+09	3.429E+11	NR
2/9/00	9.19	63.0%	2	4.495E+08	2.023E+11	NR
3/14/00	66.95	26.5%	140	2.293E+11	1.474E+12	NR
5/11/00	13.55	57.8%	52	1.723E+10	2.983E+11	NR
6/8/00	1.15	82.8%	14	3.947E+08	2.537E+10	NR
					Geometric Mean	**NR**

NR = Not Required

Figure D-17 Load Duration Curve for Duck River at STORET Station DUCK216.2BE

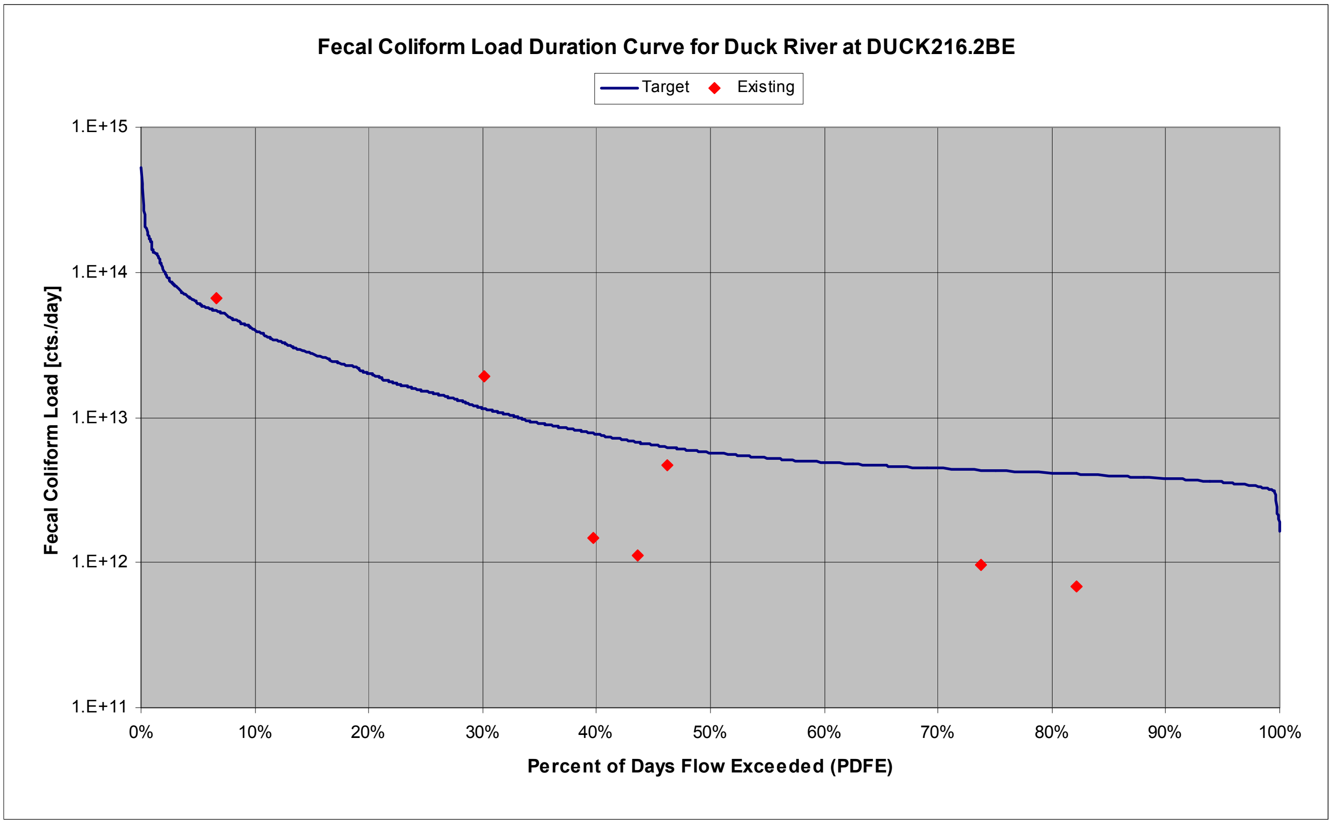


Table D-15 Determination of Required Load Reduction for Duck River at RM 216.2

Sample Date	Flow	PDFE	Fecal Coliform			
			Sample Concen.	Sample Load	Target Load	Required Load Reduction
	[cfs]	[%]	[cts/ 100 ml]	[cts/day]	[cts/day]	[%]
12/7/99	186.9	82.1%	150	6.861E+11	4.116E+12	NR
1/24/00	306.2	43.6%	150	1.124E+12	6.744E+12	NR
2/16/00	525.0	30.1%	1,500	1.927E+13	1.156E+13	40.0
3/15/00	354.0	39.7%	170	1.472E+12	7.795E+12	NR
4/26/00	2,475.7	6.6%	1,100	6.664E+13	5.452E+13	18.2
6/15/00	197.9	73.8%	200	9.683E+11	4.357E+12	NR
9/27/00	283.4	46.2%	670	4.646E+12	6.240E+12	NR
					Geometric Mean	**27.0**

NR = Not Required

APPENDIX E

Determination of 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) which 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 <u>other appropriate measure</u>.

For fecal coliform TMDLs in each impaired subwatershed, WLA terms include:

- $[\Sigma WLAs]_{WWTF}$ is the required load reduction associated with discharges of NPDES permitted WWTFs located in impaired subwatersheds. 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 permitted discharges are equal to the product of the permit limit, design flow, and required unit conversion factor.

- $[\Sigma WLAs]_{CAFO}$ is the load reduction required for all CAFOs in an impaired subwatershed. Since discharges from a CAFO liquid waste handling facility to waters of the state during a chronic or catastrophic rainfall event (in excess of a 25-year, 24-hour rainfall event), or as a result of an unpermitted discharge, upset, or bypass of the system, are not to cause or contribute to an exceedance of Tennessee water quality standards, a WLA = 0 is specified.

- $[\Sigma WLAs]_{MS4}$ is the required load reduction for discharges from MS4s. Fecal coliform loading from MS4s is the result of buildup/wash-off processes associated with storm events. The percent load reductions for MS4s are considered to be equal to the load reductions developed for TMDLs.

LA terms include:

- $[\Sigma LAs]_{DS}$ is the allowable fecal coliform load from “other direct sources”. These sources include leaking septic systems, leaking collection systems, illicit discharges, and animal access to streams. For all sources of this type, the LA = 0 (or to the maximum extent practicable).

- $[\Sigma LAs]_{SW}$ represents the required reduction in fecal coliform 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. The percent load reductions for precipitation-induced nonpoint sources are considered to be equal to the load reductions developed for TMDLs (and specified for MS4s).

Explicit MOS has already been incorporated into TMDL development as stated in Appendix C & Appendix D. TMDLs, WLAs, & LAs are applied to the entire HUC-12 subwatershed, except for Clear Branch, Bell Buckle Creek, Thick Creek, and Wallace Branch. TMDLs, WLAs, & LAs for these four waterbodies are applied to the drainage area of the impaired waterbody only (see Figure 10). WLAs & LAs for impaired waterbodies are summarized in Table E-1.

Table E-1 WLAs & LAs for Impaired Subwatersheds & Drainage Areas

Impaired Waterbody	HUC-12 Subwatershed (06040002____)	WLAs				LAs	
		WWTFs		CAFO	MS4s [a]	Precipitation Induced Nonpoint Sources	Other Direct Sources [b]
		Monthly Avg.	Daily Max.				
		[cts./day]	[cts./day]	[cts./day]	[% Red.]	[% Red.]	[cts./day]
Clear Branch	DA	NA	NA	NA	89.3	89.3	0
Duck River	0101	NA	NA	NA	20.4	20.4	0
Little Duck River	0102	2.572×10^{11}	1.286×10^{12}	NA	NR	NR	0
Bell Buckle Creek	DA	2.118×10^{10}	1.059×10^{11}	0	74.6	74.6	0
Duck River	0301	4.895×10^{11}	2.448×10^{12}	0	27.0	27.0	0
Duck River Tribs.	0303	NA	NA	NA	27.0	27.0	0
Fall Creek Hurricane Creek	0308	NA	NA	0	86.2	86.2	0
North Fork Creek	0401	NA	NA	0	87.9	87.9	0
Alexander Creek	0402	NA	NA	NA	87.3	87.3	0
Weakley Creek	0404	NA	NA	NA	87.1	87.1	0
Clem Creek	0405	NA	NA	NA	89.9	89.9	0
Wilson Creek	0502	NA	NA	NA	89.3	89.3	0
Spring Creek Lick Creek	0503	NA	NA	NA	85.9	85.9	0
Thick Creek	DA	NA	NA	NA	96.5	96.5	0
Wallace Branch	DA	NA	NA	NA	86.3	86.3	0
Fountain Creek	0702	NA	NA	NA	75.9	75.9	0

Note: NA = Not applicable; NR = No reduction required; TMDL = Percent load reduction specified for TMDL; DA = Drainage area.

a. Applies to any MS4 discharge loading in the HUC-12 subwatershed or drainage area.

b. The objective for all "other direct sources" is a load allocation of zero. It is recognized, however, that for leaking septic systems, a LA of 0 counts/day may not be practical. For these sources, the LA is interpreted to mean a reduction in fecal coliform loading to the maximum extent practicable, consistent with the requirement that these sources not contribute to a violation of the water quality standard for pathogens.

APPENDIX F

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 FECAL COLIFORM FOR WATERBODIES IMPAIRED BY PATHOGENS IN THE UPPER DUCK RIVER WATERSHED (HUC 06040002), TENNESSEE

Announcement is hereby given of the availability of Tennessee's proposed Total Maximum Daily Loads (TMDLs) for fecal coliform for several waterbodies in the Upper Duck River watershed located in middle 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 located in the Upper Duck River watershed are listed on Tennessee's final 1998 303(d) list or final 2002 303(d) list as not supporting designated use classifications due, in part, to pathogens associated with urban storm water runoff, storm sewer systems, municipal point sources, collection system failure, and agriculture. The TMDLs utilize Tennessee's general water quality criteria, USGS continuous record station flow data, in-stream water quality monitoring data, a calibrated dynamic water quality model, load duration curves, and an appropriate Margin of Safety (MOS) to establish reductions in fecal coliform loading which will result in lower in-stream concentrations and the attainment of water quality standards. The TMDLs require reductions in in-stream fecal coliform loading of approximately 20% to 96% in the listed waterbodies.

The proposed fecal coliform TMDLs may be downloaded from the Department of Environment and Conservation website:

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

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

Bruce R. Evans, P.E., Watershed Management Section
Telephone: 615-532-0668

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

Persons wishing to comment on the TMDLs are invited to submit their comments in writing no later than April 26, 2004 to:

Division of Water Pollution Control
Watershed Management Section
6th 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.